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2019 Global Aerospace and Defence Industry Outlook

In 2018, the global aerospace and defence (A&D) industry recuperated and experienced a solid year as passenger travel demand strengthened and global military expenditure continued to rise.

The industry is expected to continue its growth trajectory in 2019, led by growing commercial aircraft production and strong defence spending. In the commercial aerospace sector, aircraft order backlog remains at an all-time high as demand for next-generation, fuel-efficient aircraft continues to surge with the rise in oil prices.

With the aircraft backlog at its peak, manufacturers are expected to ramp up production rates, hence, driving growth in the sector. However, manufacturers could experience supply chain interruptions as some suppliers may struggle to increase production to keep up with the growing backlog.

In the defence sector, heightened global tensions and geopolitical risks, recovery in the US defence budget, and higher defence spending by other major regional powers such as China, India, and Japan are expected to drive global defence sector growth in 2019 and beyond.

PRODUCTION RAMP UP

- Production ramp-up likely as commercial aircraft order backlog remains strong
- The commercial aircraft order backlog is at its peak of more than 14,000, with about 38,000 aircraft expected to be produced globally over the next 20 years.

DEFENCE INDUSTRY GROWTH

- Resurgence of global military spending as geopolitical risks increases worldwide.
- Geopolitical tensions are continuing to intensify and demand for military equipment is on the uptick, driving defence spending across the globe.

INTERNATIONAL TRADE LAWS

- Changes in the international trade agreements likely to disrupt the global supply chain and increase costs
- Free trade is important to the A&D industry as aircraft and arms exports drive revenue growth, especially for companies from the developed world.
- For instance, A&D is the leading net exporting industry in the United States, which generated a net trade surplus of US$86 billion in 2017. But there is a possibility that brewing transatlantic and transpacific trade tensions could affect this as duties being placed on steel and aluminium impact companies' bottom lines.
- Import tariffs on aluminium and steel—key raw materials imported by A&D manufacturers in the production of aircraft, missiles, rockets, tankers, etc.—will likely increase manufacturing costs and impact profitability.

MERGERS AND ACQUISITIONS

- Mergers & Acquisitions activity to remain strong as pressure continues on suppliers to reduce costs and increase production rates
- The A&D industry experienced significant mergers and acquisitions (M&A) activity over the last two years.

Industry Growth by Country

- US leads Aerospace and defence spend
- India and China will likely drive growth in both commercial aerospace and defence sectors, Japan is expected to be a key market primarily for the defence sector.
- Defence expenditure in France is also likely to expand as the United States encourages NATO countries to increase military spending to 2 percent of GDP.
- In the Middle East, defence spending is expected to recover as oil prices stabilize at much higher levels compared to the 2015–17 period.
- With respect to the United Kingdom, there is uncertainty around the impact of Brexit on the country's A&D industry.

CHINA

- Over the next 20 years, China could require 7,690 new commercial aircraft worth US$1.2 trillion.
- The country is the second-largest defence-spending nation after the United States; however, China's military expenditure to GDP percentage is much lower than that of the United States.
- China's 2018 defence budget grew 8.1 percent year over year to US$175 billion, which is the largest increase in the past three years.
- The country's defence expenditure is projected to grow in the range of 9–10 percent in the near future.

FRANCE

- France plans to boost its defence spending by 40 percent over the next six years as it aims to meet the NATO target of "2 percent of GDP" spent on defence by 2025.
- The defence ministry is targeting to increase defence spending of approximately US$2 billion per year between 2019–22 and US$3.5 billion each year during the 2023–25 period.
- The 2019 defence budget is expected to be around US$42.2 billion, up 5 percent year over year.
- Military spending in France is projected to increase by 5 percent per year until 2022.

INDIA

- By 2025, India is expected to become the "third largest" aviation market and supply about 478 million passengers transport by 2036.
- There could be a demand for more than 2,000 new aircraft in India over the next two decades, which would be dominated by single-aisle aircraft.
- The 2018–19 defence budget for the country stood at US$43.8 billion, a 7.7 percent increase from the 2017–18 budget.

JAPAN

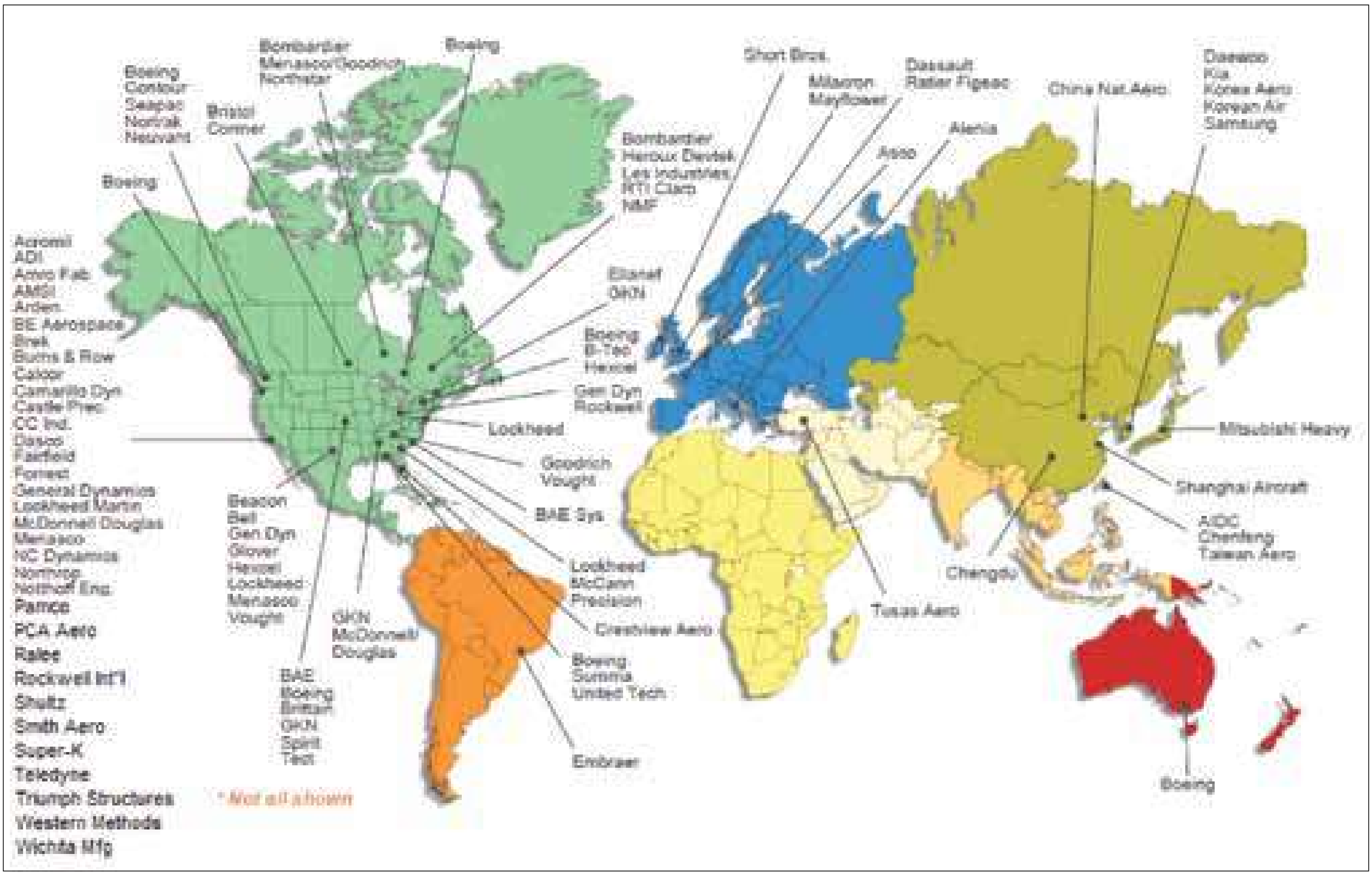
- Japan's passenger traffic growth over the next 20 years is expected to be sluggish at about 3.2 percent, much below the Asia Pacific passenger growth of 5.3 percent.
- The country's domestic market is dominated by two major Japanese airlines, but their market share has decreased over the past decade.
- However, the recent surge in low-cost carriers (LCCs) is likely to drive commercial aircraft demand in the future.
- Japanese airlines are primarily aiming to increase traffic from the high-growth Asia Pacific region by collaboration with other airlines.
- Japan's defence budget for 2018–19 was up by 2.1 percent to US$47.6 billion, marking an all-time high and the seventh straight annual increase; however, it remained below 1 percent of GDP.

MIDDLE EAST

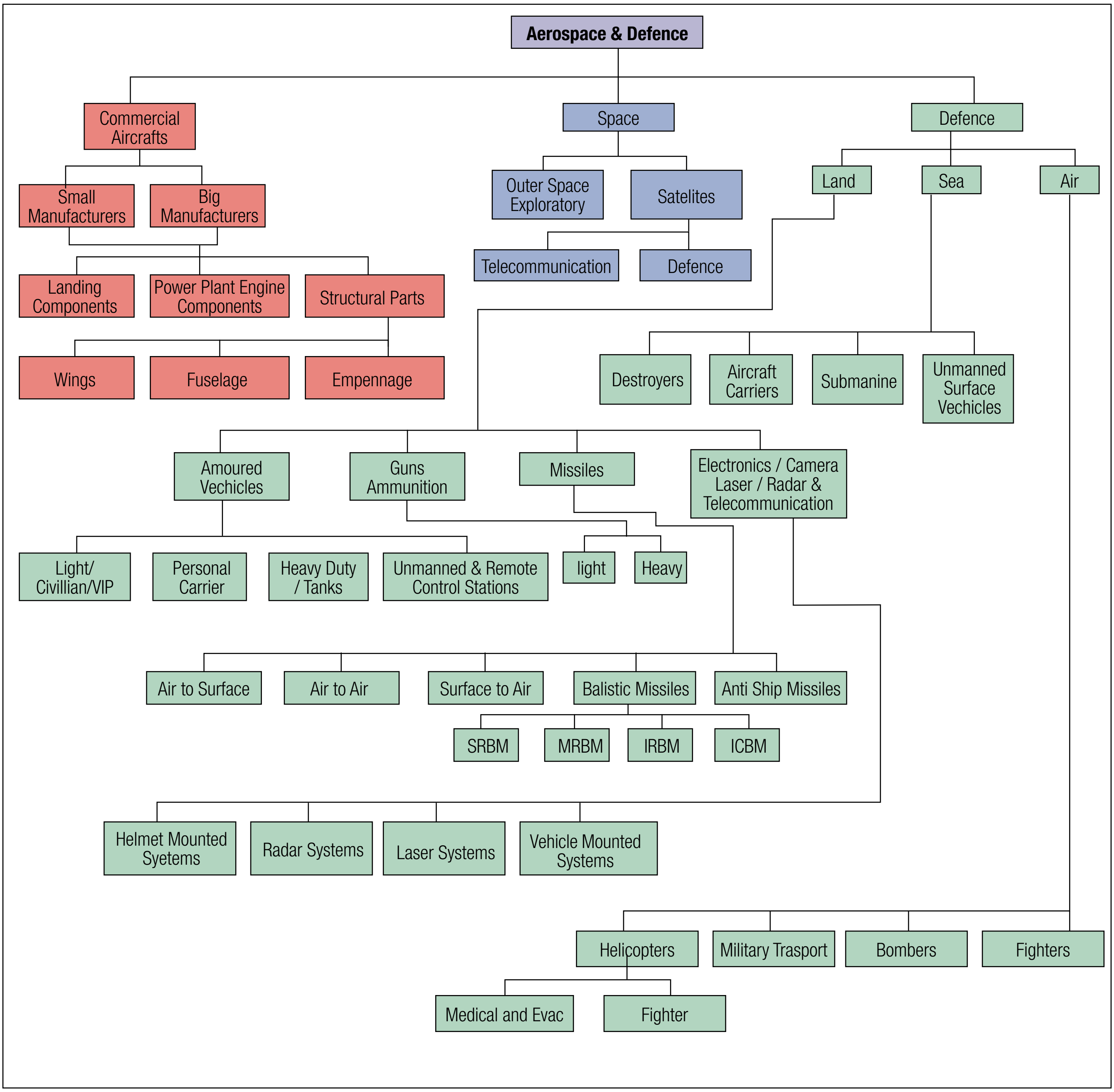
- Over the 2018–37 period, passenger traffic in the Middle East is forecast to grow at 5.2 percent, creating demand for 2,990 new aircraft valued at US$660 billion.
- In the Middle East, wide-body aircraft are likely to comprise more than 40 percent of the total aircraft demand over the next two decades, as the region primarily accounts for high-volume, ultra-long-haul flights.
- Seven out of the top ten countries with the highest military expenditure as a percentage of GDP are in the Middle East: Oman, Saudi Arabia, Kuwait, Jordan, Israel, Lebanon, and Bahrain.
- Though the pace of growth in defence spending by the two key countries in terms of defence expenditure in the region—the UAE and Saudi Arabia—has slowed, their defence expenditure is significant, and the region is expected to see mid-single-digit growth annually over the next decade.

UNITED KINGDOM

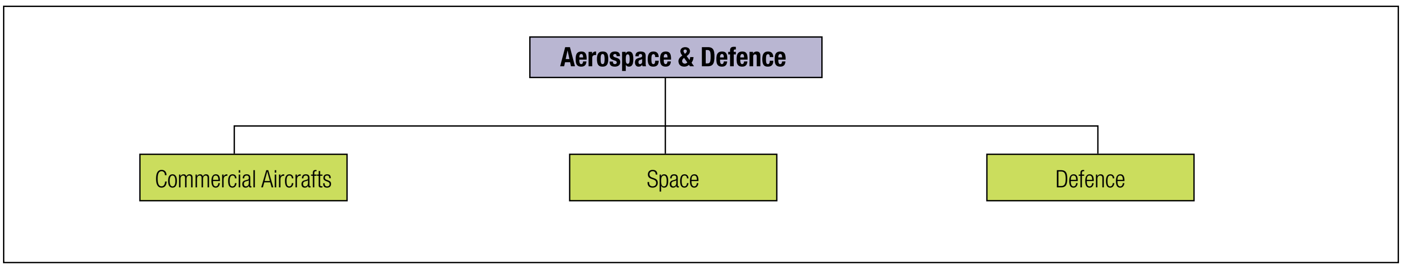
- The United Kingdom's defence budget of about US$52 billion (£40 billion) is near 2 percent of GDP.
- This budget could increase as a recent defence committee report recommended increasing the budget to 3 percent of GDP or US$78 billion (£60 billion) to strengthen the country's armed forces, including anti-submarine warfare to counter possible threats from Russia.
- As Brexit nears, there is uncertainty around its impact on the UK A&D industry—it may lead to disruption in supply chains and create new trade barriers as the country would renegotiate trade agreements with the European Union and other major trading nations.



Aerospace and Defence Business Classification



Aerospace and defence industry can be broadly classified into the below 3 verticals

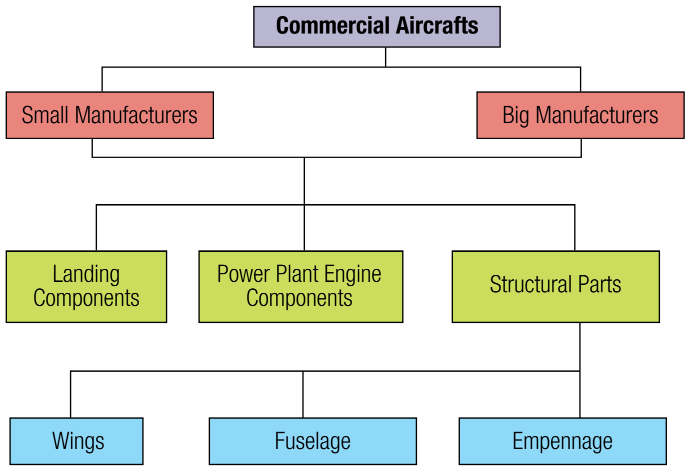


Commercial Aircrafts

Commercial Aircraft manufacturers can be broadly classified in terms of scale as Big and Small Manufacturers

A Commercial Aircraft can be broken down into 3 basic sections
- Landing Components
- Engine Components
- Structural Parts

Structural Parts can be further broken down into
- Wings
- Fuselage
- Empennage



ENGINE COMPONENTS POWER PLANT

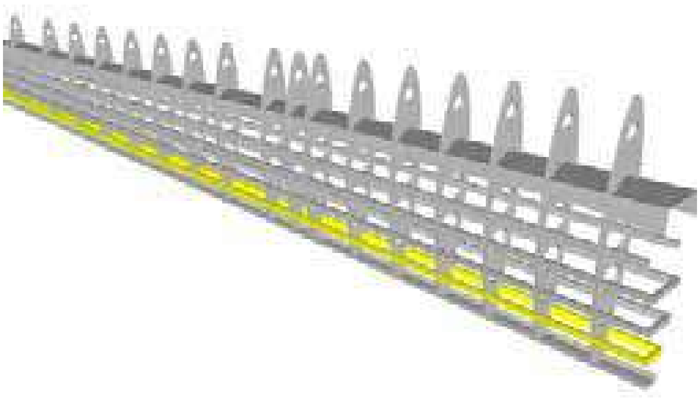
The power plant of an aircraft includes the engine and the propeller. The engine itself is a complicated system that is comprised of many smaller parts like cylinders, fans, and pistons. Together, these aircraft engine parts work to generate the power or thrust of an aircraft.

LANDING GEAR

You cannot have a safe plane without having a good landing gear. Not only are these parts imperative for landing, but the landing gear is also used to help an aircraft take off and taxi. The landing gear includes shock absorbers for a smooth landing and takeoff, as well as the wheels on the plane. These components are typically made of Titanium alloys. Located underneath the fuselage this is either fixed or retractable.

FUSELAGE

The fuselage is one of the major components on an aircraft. It is the long hollow tube that's also known as the body of the airplane, which holds the passengers, as well as the cargo. This area includes the cockpit, so the pilots are located in the front of the fuselage. Essentially, the fuselage connects all of the major parts of an airplane together. Titanium Fuselages are used majorly however Graphite epoxy, or carbon-fiber-reinforced polymer are under development.

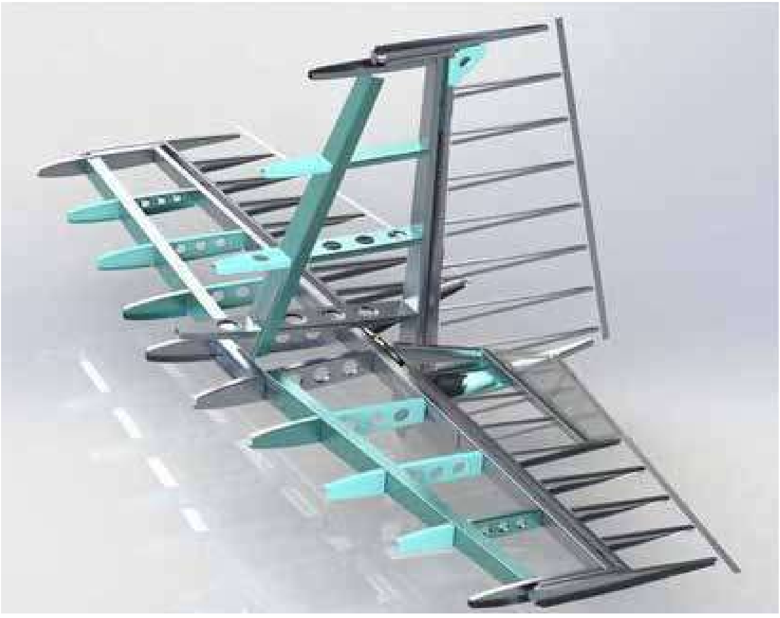


WINGS

The wings, also commonly known as foils, are aircraft parts that are imperative for flight. The airflow over the wings is what generates the majority of the lifting force necessary for flight.

The wings of a modern aircraft can be designed as a combination of different types of materials, depending on their specific structural function. The structure of the wing of an aircraft is comprised of several different elements, namely spars, skin and ribs, as well as control surfaces, such as ailerons and flaps.

Each of these components needs to support different loads and, thus, the right material needs to be selected. Titanium and aluminium alloys can be used in the manufacturing of ribs, whilst glass reinforced composite materials can be used in the design of the wing skin and the control surfaces.

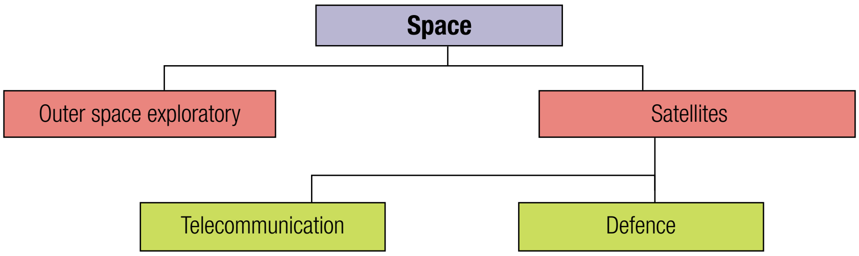


EMPENNAGE

The empennage is the tail end of the aircraft. It helps with the stability of the plane and has two main components called the rudder and the elevator. The rudder helps the aircraft steer from right to left, and the elevator helps with up and down movement.

Space

Space as a vertical in aerospace and defence can be classified under



Space can be classified in two types Outer space exploratory and Satellites

Satellites can be of two major types telecommunication and defence

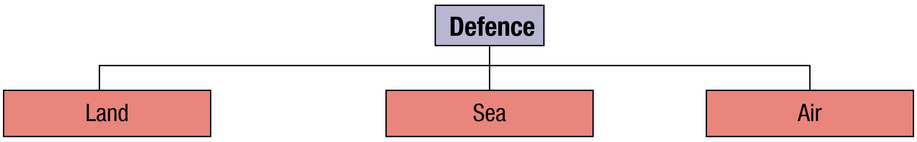
Various Materials used

- Pure Aluminum & Alumnium Alloys
- Brass
- Bronze
- Pure Copper
- Carbon Steel
- Cold Rolled Steel
- Hastelloy®
- Inconel®
- Monel®
- Delrin®
- Nylon
- Polyethylene
- Polytetrafluoroethylene (PTFE)
- Stainless Steel

Currently the option of 3D printing items in space holds many advantages over manufacturing situated on Earth. With 3D printing technologies, rather than exporting tools, parts and equipment from Earth into space, astronauts have the option to manufacture needed items directly. On-demand patterns of manufacturing make long-distance space travel more feasible and self-sufficient as space excursions require less cargo. Mission safety is also improved.

High Performance Cutting Tools

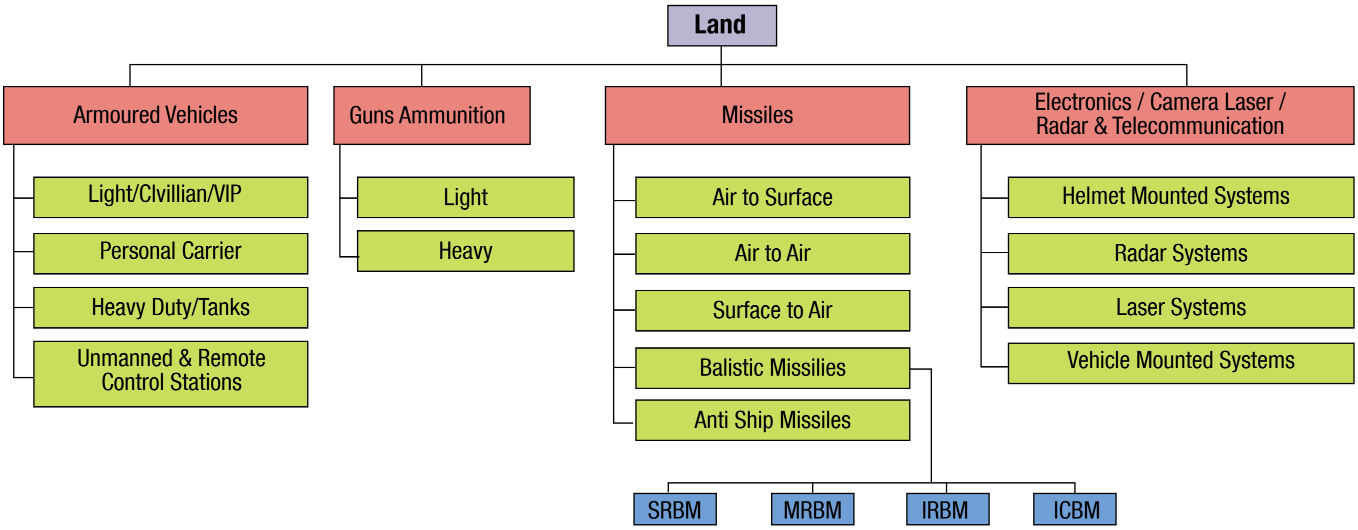
Defence



Defence is a very vast business under aerospace and defence and has three major businesses namely Land Defence Systems, Air Defence Systems and Sea Defence Systems.

Major spend happens in the Land and Air defence systems followed by the Sea Defence systems.

Land Defence Systems



Land defence systems can be classified as below

ARMOURED VEHICLES

Material used is Rolled homogeneous armour (RHA) which is a type of armour made of a single steel composition hot-rolled to improve its material characteristics, as opposed to layered or cemented armour.

GUNS AND AMMUNITION

Guns and Ammunition are one of the highest manufactured defence product in the world, Made up of multiple materials, including Steel, Aluminium and Plastics. They are primary categorized into light or heavy based on the calibre and Intensity

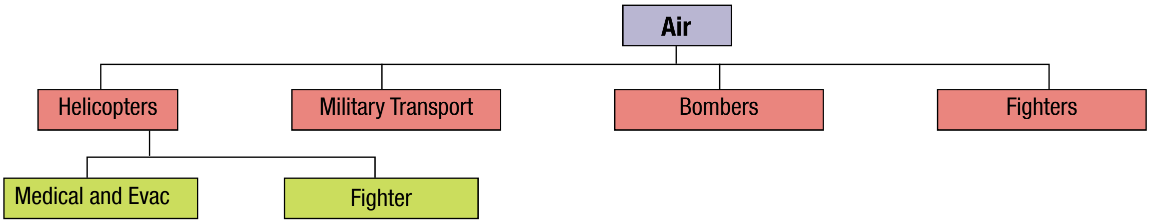
MISSILES

There are five types, air-to-air, air-to-surface, surface-to-air, anti ship/ tank & Ballistic missiles are most often categorized as short-range, medium-range, intermediate-range, and intercontinental ballistic missiles (SRBMs, MRBMs, IRBMs, and ICBMs)

ELECTRONICS/ CAMERA'S/ LASERS/ RADAR AND COMMUNICATION SYSTEMS

Navigation Systems, Servers, Camera's, Laser Guided Systems & Radar Systems, Defence Servers, Telecommunication modules use a lot of plastics and Aluminium.

Air Defence Systems



Air crafts have been in use in defence industry since 1783 when hydrogen balloons were used for air strikes. Now in the 21st century the air defence systems has reached the pinnacle of technology and is exploring unmanned and supersonic fighters for air strikes and defence.

HELICOPTERS

Due to the extreme maneuverability and short space requirement for landing and takeoff, they are used for medical evacuation and as a fighter chopper

MILITARY TRANSPORT

The number of aircrafts used in Military Transport for transporting personal, ammunition, food and health support in and out of war zones. The typical carriers are big aircrafts designed to transport as high as 100 tonnes over 6000 kilometres range.

FIGHTERS

The biggest fleet in any air force is the fighter aircraft is a military aircraft designed primarily for air-to-air combat against other aircraft. The hallmarks of a fighter are its speed, maneuverability, and small size relative to other combat aircraft. Although helicopters are sometimes used in similar roles, the term fighter is at present applied only to fixed-wing aircraft.

BOMBERS

Bombers is a combat aircraft designed to attack ground and naval targets by dropping air-to-ground weaponry (such as bombs), firing torpedoes and bullets, or deploying air-launched cruise missiles.

Sea Defence Systems

Sea

- Destroyers
- Aircraft Carriers
- Submanine
- Unmanned Surface Vechicles

SUBMARINE

A submarine (or sub) is a watercraft capable of independent operation underwater Submarines are referred to as "boats" rather than "ships" irrespective of their size. The development of submarine-launched ballistic missile and submarine-launched cruise missiles gave submarines a substantial and long-ranged ability to attack both land and sea targets with a variety of weapons ranging from cluster bombs to nuclear weapons.

DESTROYER

In naval terminology, a destroyer is a fast, maneuverable, long endurance warship intended to escort larger vessels in a fleet, convoy or battle group and defend them against powerful short range attackers.

UNMANNED SURFACE VEHICLES

(USV; also known as Unmanned Surface Vessels (USV) or (in some cases) Autonomous Surface Vehicles (ASV)) are boats that operate on the surface of the water without a crew. The new generation USVs can be operated remotely (by an operator on land or on a nearby vessel). These are used majorly for surveillance purposes

AIRCRAFT CARRIER

An aircraft carrier is a warship that serves as a seagoing airbase, equipped with a full-length flight deck and facilities for carrying, arming, deploying, and recovering aircraft. It is the capital ship of a fleet, as it allows a naval force to project air power without depending on local bases for staging aircraft operations.

Machinability of Aerospace & Defence Parts

THE INDUSTRY NEEDS

- Innovations in materials science and engineering has led to improved materials and solutions to technological, societal and environmental problems.
- The enhancement and refinement of new generation materials has led to better Machinability
- Materials science has advanced and Engineering is advancing biomaterials, ceramics, electronic materials, metals, polymers that effect all engineering areas.
- Alternate Materials to scarce metals and alloys
- New generation materials with higher strength to weight ratio
- Biodegradable materials

Example :- Exhaust Manifold – SG Iron to Teflon

Example :- Knuckle – Forged Steel to ADI

Example :- Aluminium – Aluminium Matrix Composites

MACHINABILITY

Machinability is the ease with which a metal can be cut permitting the removal with satisfactory finish and low cost

- Materials with good machinability require low power to cut, can be cut quickly, easily obtain a good finish, and do not wear the tool much; such materials are referred to free machining .
- The factors that typically improve a materials performance often degrade its machinability.
- When manufacturing components economically, engineers are challenged to find ways to improve machinability without harming performance.
- Machinability can be difficult to predict as there are so many variables in machining
- Two major factors that decide the machinability are the condition of the work material and the physical properties
- Other important factors are operating conditions, cutting tool material, geometry and machining process parameters
- There are many factors for Quantifying machinability; the ones commonly used are tool life, surface finish, cutting temperature, tool forces, power consumption
- The latest trend in the aerospace industry is moving to lighter materials and alternate materials which offer higher strength to weight ratio and structural integrity
- The aviation industry have moved a lot of parts to qualified vendors who currently are looking at tooling suppliers who can deliver
  A) Higher productivity
  B) Lighter Materials
  C) Structural Integrity
- The biggest challenge is productivity during machining.
- Condition of the work piece include eight factors -microstructure, grain size, heat treatment, chemical composition, fabrication, hardness, yield strength and tensile strength.
- Physical Properties are those of individual material groups such as Modulus of elasticity, thermal conductivity, thermal expansion and work hardening

MATERIALS THAT MATTER

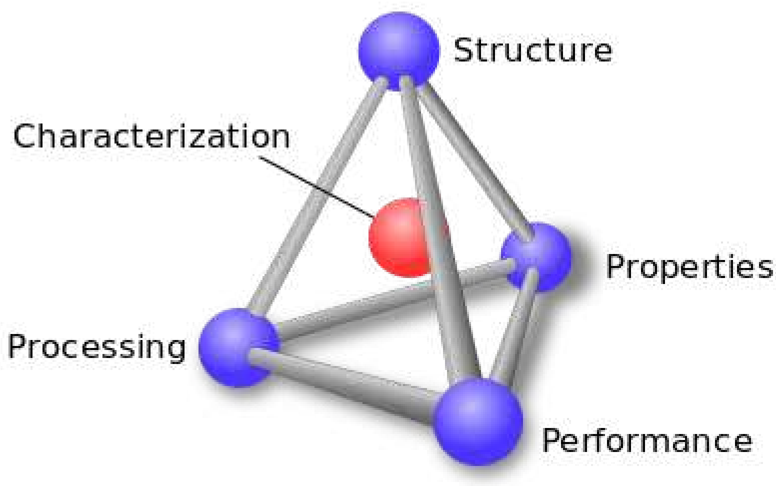
- Steel (P)
- Armour Steel (H)
- Cast Iron (K)
- Stainless Steel (M)
- Non Ferrous (N)
  - Aluminium
  - CFRP
  - GFRP
  - Polymers and Plastics
  - Composites
- Heat Resistant Super Alloys (S1-S3)
- Titanium (S4)

What is Materials science?

The interdisciplinary field of **materials science**, also commonly termed **materials science and engineering**, involves the discovery and design of new materials, with an emphasis on solids.

The origin of materials science stem from the enlightenment, when researchers began to use analytical thinking from **chemistry, physics,** and **engineering** to understand ancient, phenomenological observations in **metallurgy** and **mineralogy.**

Materials science is a syncretic discipline **hybridizing metallurgy, ceramics, solid-state physics, and chemistry.**



Structure – Materials science examines the structure of materials from the atomic scale, all the way up to the macro scale.

Properties – Materials exhibit various properties, which include the below.

- Mechanical & Physical properties -Strength of materials
- Chemical properties - Chemistry
- Electrical properties -Electricity
- Thermal properties- Thermodynamics
- Optical properties- Optics & Photonics
- Magnetic properties- Magnetism

Performance – Studying the relative performance for a particular application

Processing/ Synthesizing – This involves the creation of a material with the desired micro-nanostructure.

Characterization – Characterization is the way materials scientists examine the structure of a material. Various methods such as diffraction with X-rays, electrons, or neutrons, spectroscopy, Chemical analysis, thermal analysis, electron microscope analysis, etc.

Materials

STEEL

The carbon content in steel greatly effects its machinability. High carbon steels are difficult to machine because they are strong and because they contain carbides that abrade cutting tools.

- On the other hand if the carbon content is low they are soft and gummy and stick to the tool resulting in built up edge which reduces the tool life.
- Alloying elements such as chromium, Molybdenum are often added to improve the strength of steel. However these alloying elements decrease the machinability of steel. Addition of oxides abrade the cutting tools
- Steel has the best machinability when the Carbon percentage is about 0.20%- Tool and manufacturing engineers hand book (1989)
- Steel is an alloy of iron and carbon, and sometimes other elements. Because of its high tensile strength and low cost, it is one of the major materials used in an aircraft.
- Iron is able to take on two crystalline forms (allotropic forms), body centered cubic and face centered cubic, depending on its temperature.
- In the body-centered cubic arrangement, there is an iron atom in the center and eight atoms at the vertices of each cubic unit cell.
- In the face-centered cubic, there is one atom at the center of each of the six faces of the cubic unit cell and eight atoms at its vertices.
- It is the interaction of the allotropes of iron with the alloying elements, primarily carbon, that gives steel their range of unique properties.

In pure iron, the crystal structure has relatively little resistance to the iron atoms slipping past one another, and so pure iron is quite ductile, or soft and easily formed.

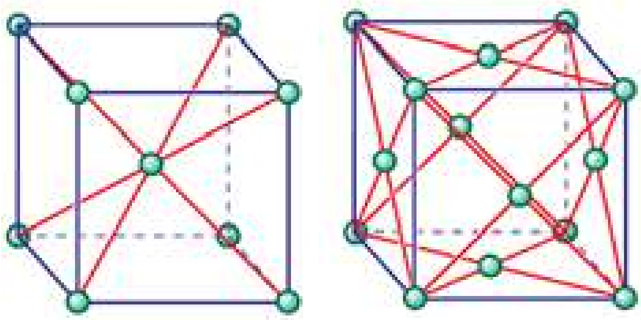
In steel, small amounts of carbon, other elements, and inclusions within the iron act as hardening agents that prevent the movement of dislocations.

The carbon in typical steel alloys may contribute up to 2.14% of its weight.

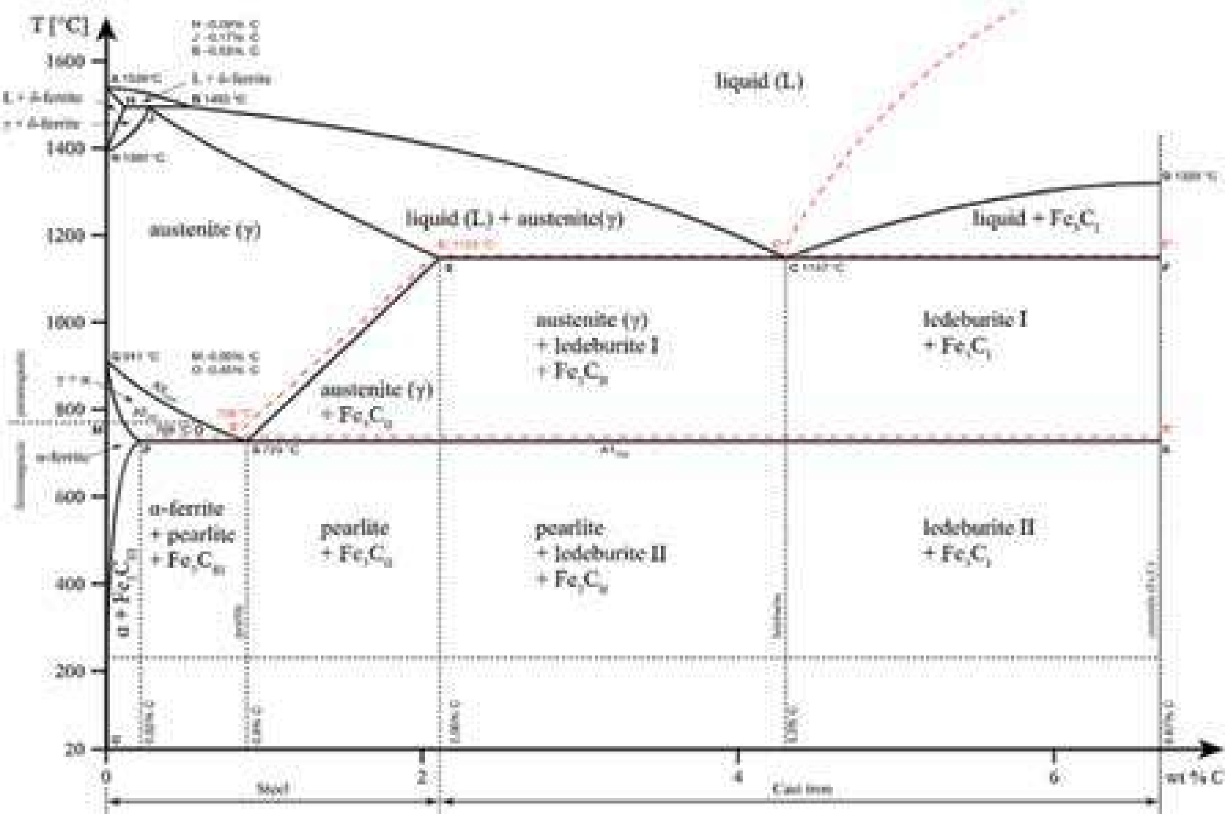
Varying the amount of carbon and many other alloying elements, as well as controlling their chemical and physical makeup in the final steel slows the movement of those dislocations that make pure iron ductile, and thus controls and enhances its qualities.

These qualities include the hardness, quenching behaviour, need for annealing, tempering behaviour, yield strength, and tensile strength of the resulting steel.

The increase in steel's strength compared to pure iron is possible only by reducing iron's ductility



body-centred cubic (bcc) face-centred cubic (fcc)



HARDENED STEEL

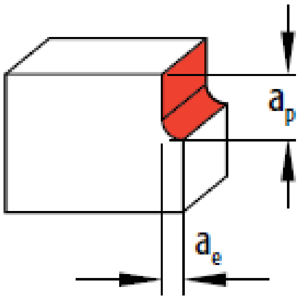
In general, hard milling involves cutting primarily tool steel or precipitation hardening stainless steel, such as 15-5 or 17-4, that has been hardened to at least 50 HRC. After a workpiece is roughed in the soft state, it is sent to the furnace for hardening and then finish machined with coated carbide, ceramic or PCBN tools. The amount of metal removal in the hardened state is minimal—perhaps just 0.010 " to 0.020 " per surface—making this process feasible for most hardened parts.

Depending on the workpiece configuration, production volume and amount of stock removal, however, it may be feasible to machine the workpiece entirely from a hardened state. Modern machine tools, advanced cutting tool materials and sophisticated CAM programs make what was once a highly improbable machining operation into one within the reach of many shops. The advantage of machining from a hardened state is having to cut it only once. Once you enter the cut ensure that you do not leave the cut.

Hardened Steel- Can be machined with two strategies HPM and HSM

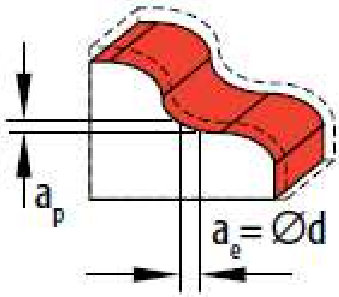
HPM

- High cutting speed (Vc)
- Large cutting depth (Ap)
- Small cutting width (Ae)
- Medium feed per tooth (Fz)/ table feed (Vf)



HSM

- High cutting speed (Vc)
- Small cutting depth (Ap)
- Small cutting width (Ae)
- High feed per tooth (Fz) / table feed (Vf)



CAST IRON

Cast Iron among the most common and least expensive of all the types, contains carbides in the form of lamellar graphite particles, which gives it excellent vibration damping properties and makes it ideal choice for engine components. It also has the highest level of machinability when compared to other types.

- **VERMICULAR CAST IRON**, also known as compacted graphite iron, offers greater strength and lower weight when compared to grey cast iron. Because vermicular cast iron is suitable for components subjected to both mechanical and thermal stress, automotive manufacturers are using it more in the production of cylinder heads and brake parts.
- **SILICON ALLOYED FERRITIC DUCTILE CAST IRON** is ideal for the production of wheel hubs and axles. Given its high degree of machinability and excellent mechanical properties, the material is becoming increasingly popular within the automotive industry.
- **NODULAR DUCTILE CAST IRON**, which consists of spheroid nodular graphite particles in ferrite and/or pearlite matrix, possesses high ductility, good fatigue strength, superior wear resistance and a high modulus of elasticity, and hence have been the choice of material for transmission housings and wheel suspension parts within the automotive and heavy equipment industries.

  **** Note Cast Iron does not have a significance use in Aerospace***
- **AUSTEMPERED DUCTILE IRON** offers high strength, high fatigue strength, good wear resistance and high values of elongation to fracture, making it a very competitive material in relation to many cast and forged steels. Because of great strength and elastic properties, Austempered ductile iron has the lowest level of machinability when compared to the other types of cast iron mentioned here.

THE SOLUTION

- The ideal cutting tool material for machining cast iron should have high strength and hardness in addition to high fracture toughness. Although this combination of properties is impossible to achieve in practice since high strength and low fracture toughness are synonymous, the selection of the proper cutting tool is important for machining various types of cast irons.

STAINLESS STEEL

Stainless steels have poor machinability compared to carbon steel because they are tougher and gummier and tend to work harden very rapidly

- Slightly hardening stainless steel reduces its gumminess and makes it easier to machine. AISI grades 304 and 416 are easier to machine because of the addition of sulphur and phosphorus
- It is essential to keep the cutting tools sharp when machining stainless steels.
- Careful grinding and honing of the tool faces to give accurate and sharp face angles is important. This helps optimise; tool life, finish, accuracy and tolerances productivity between regrinds and reduce tool breakages
- It is essential that cutting fluids are used when stainless steels are machined to overcome work hardening
- Design machining process with depth of cut below the work hardening zone.
- Stainless Steel :- Use adequate but not excess cutting speeds to avoid build up edge and quick wear.

PRESIPITATION HARDENED

Precipitation Hardening (PH) stainless steels are a family of corrosion resistant alloys some of which can be heat treated to provide tensile strengths of 850MPa to 1700MPa and yield strengths of 520MPA to over 1500MPa - some three or four times that of an austenitic stainless steel such as type 304 or type 316.

- Precipitation Hardening (PH) stainless steels are classified as Martensitic or semi-austenitic.
- They develop their high strength and hardness through a variety of heat treatments resulting in a very high strength-to-weight ratio.
- Semi-austenitic grades are 17-7 PH® and PH 15-7 Mo®. They are austenitic in the annealed state, and Martensitic in the hardened condition.
- Martensitic grades include 17-4 PH® and 15-5 PH®. The PH grades achieve high tensile properties in heat treated conditions.
- Applications for PH steels are high in aerospace components.
- Precipitation hardening is achieved by the addition of copper, molybdenum, aluminium and titanium either singly or in combination.

DIFFERENT TYPES OF PH MATERIALS USED IN THE AEROSPACE INDUSTRY.

- 13-8 Mo PH- 13% Cr-8% Ni-2.3% Mo
- 15-5 PH- 15% Cr-5% Ni
- 17-4 PH- 17% Cr-4% Ni
- 15-7 Mo PH- 15% Cr-7% Ni-2.5% Mo
- 17-7 PH- 17% Cr-7% Ni

TYPICAL CHALLENGES FACED MACHINING PH

- Thermal cracking due to corrosion
- Notch wear
- Lubricity, which is needed to reduce material build-up but can cause unwanted contamination in some instances
- Imbalanced cutting forces (it is necessary to maintain balance to avoid vibration, so in addition to stronger, more rigid cutting tools, good machine tools are a must).

SOLUTION FOR MACHINING PH

- Adequate Edge Prep
- Heat Resistant Raw Material
- Right Machining Strategy and tool path
- Chamfer or radius on edge to protect the edge

Alloy	UNS No.	Composition %								
		C	Mn	Si	Cr	Ni	Mo	Cu	Ti	Other
Martensitic										
PH 13-8 Mo	S13800	0.05	0.1	0.1	12.8	8	2.3			Al=1.1
15-5Ph	S15500	0.07	1	1	14.8	4.5	-	3.5		Nb=0.3
17-4PH	S17400	0.09	1	1	16.3	4	-	4		Nb=0.3
Custom 455	S45500	0.05	0.5	0.5	12	8.5	0.5	2	1.1	Nb=0.3
Semi-austentic										
PH15-7Mo	S15700	0.09	1	1	15	7.1	2.5	-	-	Al=1.1
17-7PH	S17700	0.08	0.9	0.5	16.5	7.5	-			Al=1.0
Austenitic										
A-286	S66286	0.08	2	1	15	25.5	1.25	-	-	Ti: 2.1
										Al: ≤0.35
										V: 0.3

ALUMINIUM

The primary tooling concerns when machining aluminium are:

- ♦ Minimizing the tendency of aluminium to stick to the tool cutting edges;
- ♦ Ensuring there is good chip evacuation from the cutting edge;
- ♦ Ensuring the core strength of the tool is sufficient to withstand the cutting forces without breaking.

- Materials, surface conditions and geometry are the three elements in tool design that interrelate to minimize these concerns.
- If these three elements do not work together, successful high-speed machining is not possible. It is imperative to understand all three of these elements in order to be successful in the high-speed machining of aluminium.
- The rule of thumb for high-speed aluminium machining tooling designs is to maximize space for chip evacuation. This is because aluminium is a very soft material, and the feed rate is usually increased which creates more and bigger chips.
- Aluminium DLC coatings provide the best CPC adding about 20 – 25 % to the total tool cost. This extends the tool life significantly as compared to an uncoated tool.
- Advent of PCD and MCD tools have shown great increase in productivity

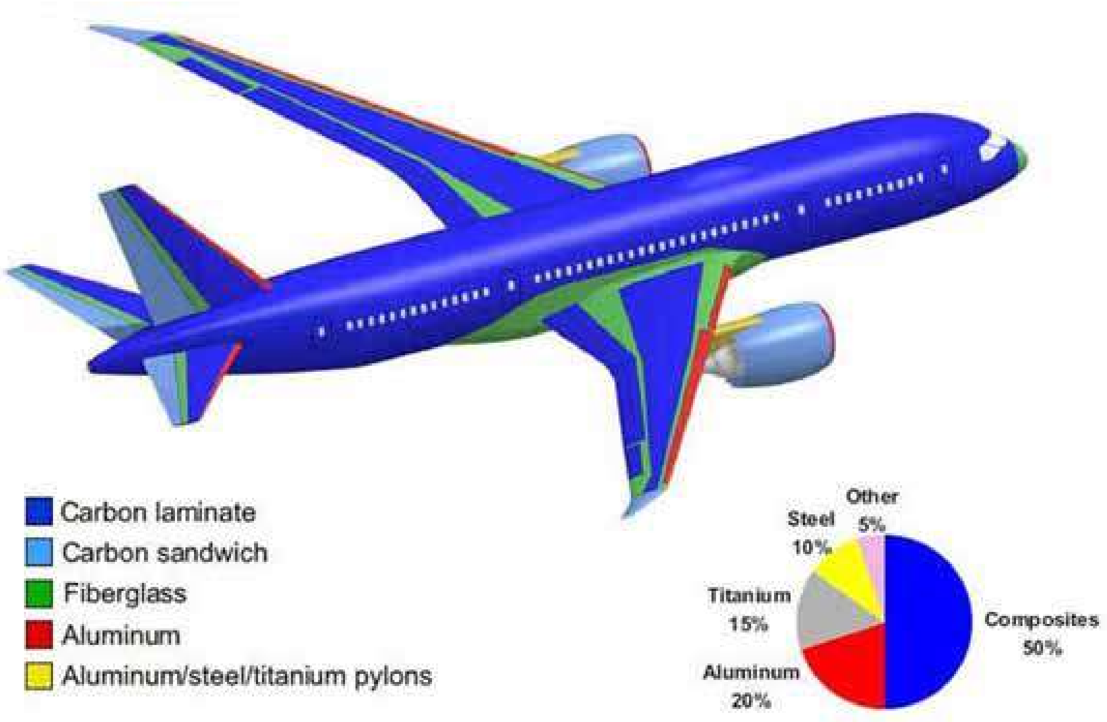
A BRIEF HISTORY

The Wright brothers chose aluminium for the cylinder block and other engine parts on their first manned flight in 1903. It was the first time an Al alloy had been heat-treated, a discovery that positioned aluminium's dominance in aerospace engineering.

Commonly used aluminium alloys

- **Grade 2014**- is a strong, tough metal suitable for arc and resistance welding*
- **Grade 2024**- high-grade alloy with excellent fatigue resistance, 2024 is used in sheet forms such as for the fuselage and wings due to its high tensile strength
- **Grade 5052**- non heat treatable, provides the highest strength and is highly ductility, so it can be formed into various shapes. It is also highly corrosion resistant.
- **Grade 6061(T6)**-is common to make aircrafts light. Easily welded and manipulated, 6061 is very light and fairly strong, making it ideal for fuselage and wings.
- **Grade 7050**- This alloy has high corrosion resistance and maintains strength in wide sections, making it more resistant to fractures. It's commonly used in wing skins and fuselage, especially in military aircraft.
- **Grade 7068**- the strongest alloys strength and low mass make it perfect for military aircraft.
- **Grade 7075**- With strength as steel due to its high levels of zinc, has excellent fatigue resistance. It can be machined easily.

COMPOSITES



Composites make up about 50% of the aircraft structure.
Above illustration is of a Boeing 787 body. * 777 model used 12% Composites and 50% Aluminium

- Benefits from composite materials are especially important where weight control is critical: Aerospace industry (main focus)
- New aeroplane models have >50% in weight from composites*

COMPOSITE MATERIALS DEPENDING ON APPLICATIONS

- Structural application
  High-Medium Temperature Epoxy
- Interiors
  Phenolics, HS carbon fibres, Glass fibres, Aramid (Kevlar)
- Non-structural applications
  Low cost resins - Polyester, Vinylesters

Definition: Engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure.

POLYMER MATRIX COMPOSITES (PMC's)

The most common. Also known as FRP - Fibre Reinforced Polymers - these materials use a polymer-based resin as the matrix, and a variety of fibres such as glass, carbon and Aramid as the reinforcement.

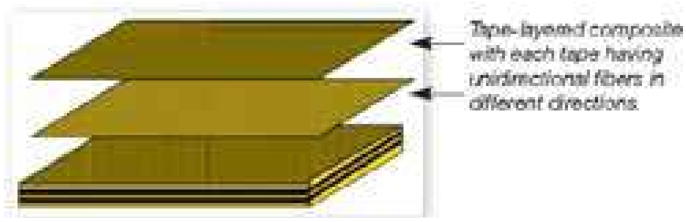
METAL MATRIX COMPOSITES (MMC's)

Increasingly found in the automotive industry, the matrix is a metal such as aluminium, the reinforcement fibres such as silicon carbide.

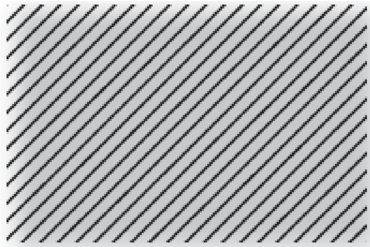
CERAMIC MATRIX COMPOSITES (CMC's)

Used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as silicon carbide and boron nitride.

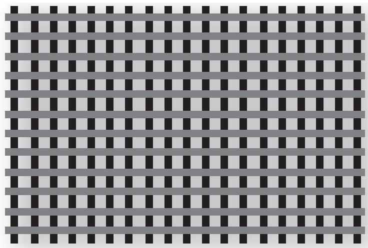
WHAT MAKES UP A COMPOSITE?



Resins
- Epoxy - The high-quality standard
- Phenolic - Fire resistant
- BMI, Cyanate - High temperature
- Polyester, Vinylester - Low cost
- Thermoplastic (PEEK, PEKK)
- High impact resistance


Unidirectional tape

Fiber Reinforcements
- Carbon fiber/Graphite fiber (high strength or high modulus)
- Glass fibers
- Ceramic fibers
- Polymer fibers (Kevlar, Polyethylene)
- Tungsten fibers


Fabric weave

Fiber Orientation and Structure
- Unidirectional reinforcement (UD)
- Planar reinforcement (PD)

Unidirectional reinforcement (UD)
Maximum strength and stiffness are obtained in the direction of the fiber

Properties
- Highest strength in direction of fiber orientation
- Bad handling features
- Critical machining due to high delamination risk

Planar reinforcement (PD)
Two dimensional woven fabric

Properties
- Uniform strength in all directions
- Better handling features
- Lower delamination risk

CFRP

Carbon-fiber reinforced polymers (particularly epoxy) have gained tremendous importance due to their high strength-to-weight ratio.

CFRPs are often used in stacks with aluminium or titanium
- Primary structural components
- Floor panels, for fastening

Laminates
- Fiber-resin "prepregs" (tape), with one laid on top of another (each tape laid in one or several directions) in one bag and vacuum molded to form a laminate.

Prepregs
Prepregs are composite materials in which a reinforcement fiber is pre-impregnated with a thermoplastic or thermoset resin matrix in a certain ratio.

CFRP vs GFRP

- The reason for using glassfiber on random coverings is simple: Electromagnetic transparency. Carbon fiber conducts electricity, so it will absorb much of what the antenna radiates away or "listens" for. Glassfibers are good insulators and transparent to radar waves.
- The reason for glassfiber on forward-facing surfaces is impact tolerance. Compared to carbon fiber, glassfibers have a higher elongation at fracture and are a homogenous material.

Why does elongation point matter?

- Energy absorption is integral under the stress-strain curve, and a higher elongation at fracture gives glassfiber better energy absorption qualities. The peak loads for carbon might be a bit higher, but carbon breaks at an elongation of less than 2% while glass stretches to 5% before rupture. Both, however, are inferior to most metals which have a phase of plastic deformation before rupture.
- The second point is based in the anisotropic nature of carbon fiber: When a carbon fiber is loaded in a direction away from its lengthwise axis, it will break easily. Glass, being an isotropic material, has the same strength in all directions, so a glassfiber composite is much better in taking arbitrary and impact loads.

MILLING

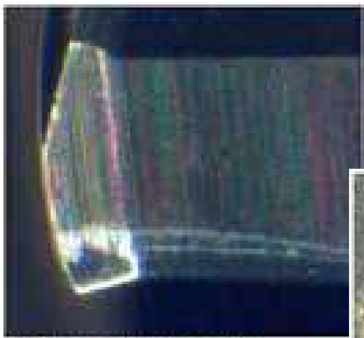
Machining of carbon fiber is generally done with a router; however, standard metal machining methods can be used. Machining carbon fiber requires higher spindle speeds than metals, but lower feed rates. The feed rates need to be adjusted to minimize the heat in the part while machining. Carbon fiber has a low thermal conductivity and the majority of the heat remains in the part since there are no chips to help dissipate the heat when machining. This heat from cutting can cause damage to the resin. Since coolant might not be permitted when machining carbon fiber, the tool path and tool must be used to control the heat in the part while machining. Additionally, fracturing of the fibers creates considerable abrasion on the cutting tool, so special tooling is required when machining carbon fiber.

DRILLING

- Drilling is a difficult machining procedure on carbon fiber. Carbon fiber is constructed of layers of material that could easily splinter or delaminate during machining. Drilling speed must be adjusted based on the size and depth of hole. Special drill bits designed specifically for carbon fiber help eliminate delamination during drilling.
- The dust from carbon fiber is conductive, and can migrate into electronics and short them out. Vacuum the dust frequently when machining to avoid damage to the machine.

Rapid Tool Wear

Very rapid flank wear due to the abrasive nature of composites.

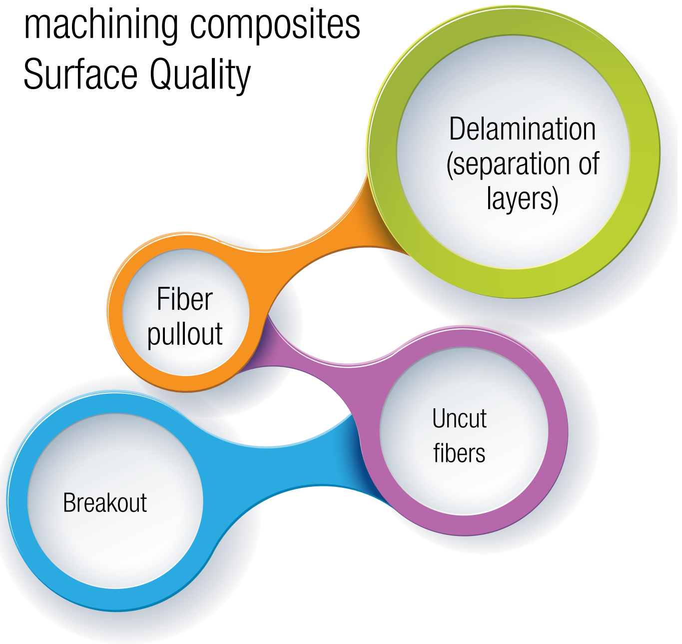


Tool wear on cutting edge

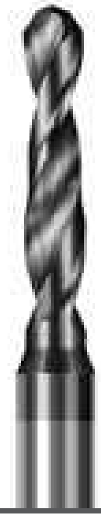
Delamination

Splintering/fraying

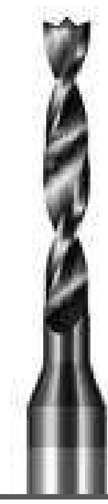
Challenges faced in machining composites Surface Quality



Double Angle Composite Drills help combat delamination and push-out in layered composite materials with specialized point geometry. The primary 130° point angle allows the drill to efficiently engage laminated composites without lifting the top layer of material. The shallower secondary 60° point angle reduces the amount of force required to move the drill through the material, further reducing the probability of delamination. The higher shear angle also aids in reducing push-out at the back of the workpiece by more gradually breaking through the part.



Brad Point Composite Drills are designed specifically for superior performance in fibrous composite materials. The trident-like brad point ensures that holes in fiber filled and reinforced materials come out clear and free of fraying. The outer points accurately score the outer diameter of drilled holes, eliminating uncut fibers, tear-out, and splintering. This avoids residual uncut fibres and fibre tear out.



POLYMERS

Polymers are lengthy chain compounds composed of monomers. A monomer is a molecule that can be bonded to other identical molecules. Polymers are basically enormous molecules made with a massive amount of smaller, identical molecules. Polymers have a different physical and chemical makeup than their monomers, and more uniquely, their properties can be tailored depending on their main purpose.

PLASTICS

Plastics are semi-organic materials that come from oil or petroleum. They are routinely labelled as polymers, as they are comprised of polymers. Plastics are produced by condensation and addition polymerization reactions. They are classified either as thermosetting polymers or thermoplastic polymers.

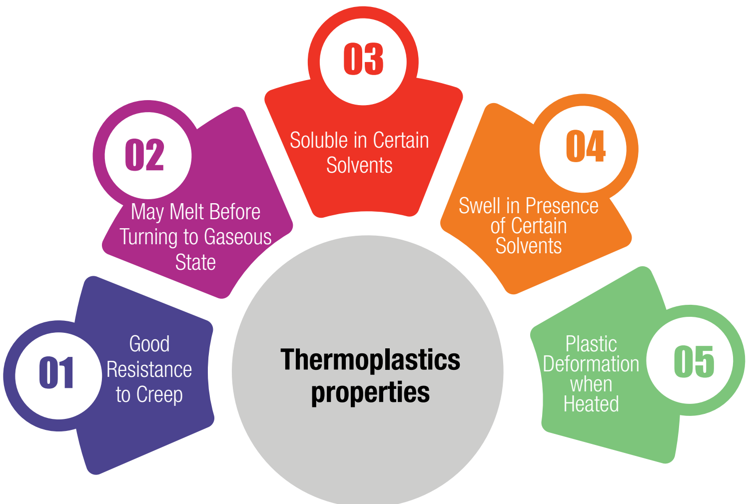
THERMOPLASTICS VS THERMOSETS

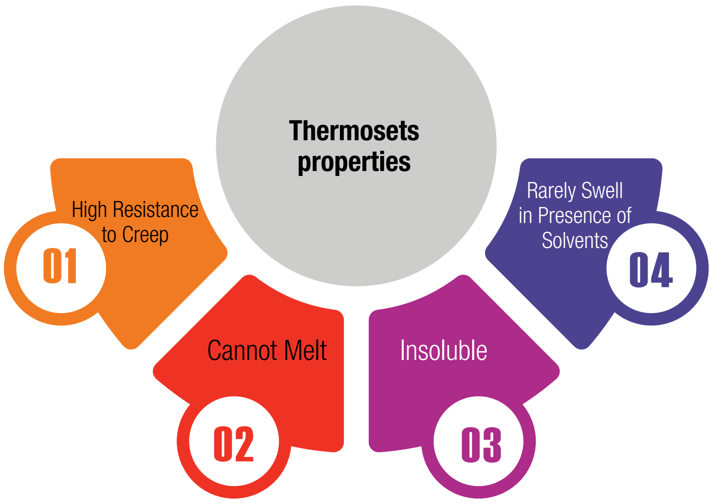
When it comes to polymers, you have two basic types: thermoplastics & thermosets.

It's crucial to know which one you're working with due to distinct differences between how those polymers react to heat and temperature.

Thermoplastics are capable of being repeatedly softened and pliable when temperature increases, meaning that when heat is applied, that results in a physical change for the polymer.

Thermosets, in contrast, turn into an infusible and insoluble material when cured by application of heat or chemical means, making for poor elasticity.





POLYMERS

HRSA materials fall into three groups:

- Nickel-based
- Iron-based
- Cobalt-based alloys

The physical properties and machining behaviour of each varies considerably, due both to the chemical nature of the alloy and the precise metallurgical processing it receives during manufacture.

Whether the metal is annealed or aged is particularly influential on the subsequent machining properties.

Nickel-based are the most widely used, and currently constitute over 50% of the weight of advanced aircraft engines. The trend is that this will increase in new engines in the future.

Common types include:

- Inconel 718, Waspaloy, Udimet 720 – precipitation hardened
- Inconel 625 – solution strengthened (not hardenable)

Iron-based have been developed from austenitic stainless steels. Some have very low thermal expansion coefficients (such as Incoloy 909) which make them especially suited for shafts, rings, and casings in aircrafts

They have the poorest hot strength properties of the three groups. Common types:

- Inconel 909,
- A286
- Greek Ascoloy

Cobalt-based display superior hot corrosion resistance at high temperatures compared to nickel-based alloys. They are more expensive and also more difficult to machine due to their great wear resistance.

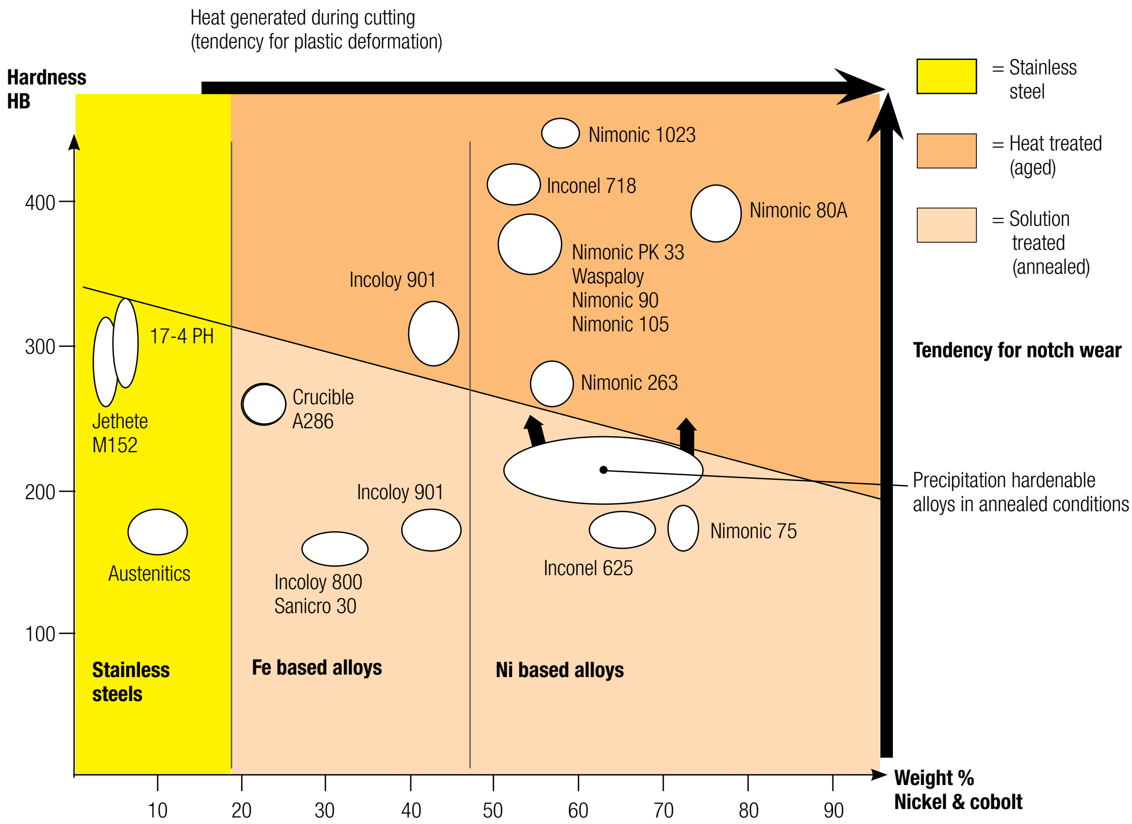
Their use in turbines is restricted to combustion parts in the hottest engine areas. Common types:

- CoCr
- Haynes 25
- Stellite 31

Alloy Group	Material	Hardness HB	
		Ann	Aged
Nickel	Inconell 718		425
	Inconell 706		285
	Inconell 625	200	
	Hastelloy S		
	Hastelloy X	160	
	Nimonic PK33		350
	Udimet 720		
	Waspaloy		
Iron	Greek Ascoloy		300
	A286		300
	Incoloy 909		
Cobalt	Haynes 25		
	Stellite 21	280	340
	Stellite 31		

Below table has the most common used heat resistant super alloys in the aerospace industry. With such a wide spread of materials under the generic heading of HRSA the machining behaviour can vary greatly even within the same alloy group.

In fact the same material can have numerous machining recommendations.

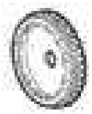
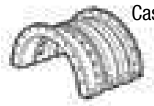
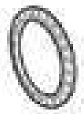
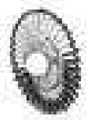
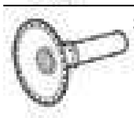


Machinability / Raw Material condition

Heat Treatment		
Annealing	Headting to controlled temperature then cooling at controlled rate	<30HRC
Solution Treatment	Heating followed by rapid cooling	<30HRC
Ageing	Slow cooling after solution treatment	up to 48HRC

- The state of heat treatment affects the hardness of the component and hence the wear mechanisms.
- The formation of the chip is a good indicator of the hardness – with hard materials it is easier to break the chip.
- Hardened materials have increased cutting temperatures and show a tendency to notching of the cutting edge at the depth of cut.
- The combination of a low entering angle and a hard substrate with a coating offering a heat barrier is required.
- Softer materials machine similarly to the stainless steel family.
- Carbide grades with greater toughness and reduced hot hardness – resistance to high temperatures – are required due to reduced cutting temperatures and increased chip hammering.
- Here, damage to areas outside the actual cutting edge is caused by the chips hitting against the tool.

AEROSPACE AND GAS TURBINE - NICKEL BASED

Component		Turning	Milling	Drilling	Others
	Discs	60%	10%	5%	25%
	Casings	45%	40%	15%	
	Rings	95%		5%	
	Blades Blisks Impellers	10%	50%		40%
	Shafts	70%	5%	25%	

By far the most common application for HRSA materials is the aircraft engine.

- The use of HRSA in the combustion part of the engine is increasing. This is typified by the fact that, whereas in 1950 only about 10% of the total weight of an aircraft gas turbine engine was made of super alloys, this has now risen to 50% in today's modern engines.
- Coolant should be applied in all operations excluding milling with ceramics. The volume and pressure should be high.

TITANIUM

- Milling makes up about ~90% of all the material removal (machining) processes in structural parts in aerospace machining.
- Titanium is one of the fastest growing materials used in aerospace applications. The prime rationale for designers to chose titanium in their designs is its relative low mass for a given strength level and its relative resistance to high temperature.
- Titanium sets complex machining demands. It has metallurgical characteristics and material properties that affect the cutting action more severely than other metals such as cast iron and stainless steel.
- However, by combining a well-planned process with dedicated application knowledge and tools/set-ups optimized for titanium, gains can be made to take advantage of the great properties that this material has to offer.

Titanium and its alloys are used extensively in the following areas:

- Aerospace engine, • Aerospace frame, • Aerospace landing gear
- Titanium components are machined in the forged condition and often require removal of up to 90% of the weight of the workpiece.
- The high-chemical reactivity of titanium alloys causes the chip to weld to the tool, leading to cratering and premature tool failure. The low thermal conductivity of these materials does not allow the heat generated during machining to dissipate from the tool edge. This causes high tool tip temperatures and excessive tool deformation and wear.
- Titanium alloys retain strength at high temperatures and exhibit low thermal conductivity. This distinctive property does not allow heat generated during machining to dissipate from the tool edge, causing high tool tip temperatures and excessive plastic deformation wear - leading to higher cutting forces.
- The high work-hardening tendency of titanium alloys can also contribute to the high cutting forces and temperatures that may lead to depth-of-cut notching.
  In addition, the Chip-Tool contact area is relatively small, resulting in large stress concentration due to these higher cutting forces and temperatures resulting in premature failure of the cutting tool
- Titanium alloys fall into three classes depending on the structures and alloying types present. These additions are reflected in the designation codes used to describe each alloy.
- Alpha alloys – additions of Al, O and/or N preferentially stabilise the phase.
- Beta alloys – additions of Mb, Fe, V Cr and/or Mn stabilise the phase.
- Mixed + alloys, in which a mixture of both classes is present. Mixed + alloys account for the majority of titanium alloys employed today.
- Ti-6Al-4V, first developed in 1954, remains the most common general purpose grade in use, not only for aerospace but also for general purpose applications. These chemical additions have a direct influence on the physical properties of the alloys, their chemical and thermal behaviour and their machinability.

- The Ti6Al4V Titanium alloys which feature both and phases and contain both and stabilizers is the most popular alloy in this group, which is primarily used in the aerospace industry. Alloys in this category are easily formable and exhibit high room-temperature strength and moderate high-temperature strength. The properties of these alloys can be altered through heat treatment.

Condition	Designation	Composition (approx %)							Tensile strength	Hardness	Specific cutting
		Al	Sn	Mo	V	Zr	Cr	Others	N mm-2	BHN	force kc/Mpa
α and near α alloys	Ti-5Al-2.5Sn	5	2.5					x.xx	790	300-400	1200
	Ti-5Al-2.5SNELI	5	2.5						690		
	Ti-8Al-1Mo-1V	8		1	1				900		
	Ti-6Al-2Sn-4Zr-2Mo	6	2	2		4			900		
	Ti-3Al-2.5V	3							620		
α and near β alloys	Ti-6Al-4V	6			4				900	310-350	1700
	Ti-6Al-6V-2Sn	6	2		6				1030		
	Ti-6Al-2Sn-4Zr-6Mo	6	2	6		4			1170		
	Ti-5Al-2Sn-4Mo-27r-4Cr (Ti-17)	5	2	4		2	4		1125		
	Ti-7Al-4Mo	7		4					1030		
	Ti-6Al-32Sn-27r-2Mo-2Cr-0,25Si	6	2	2		2	2	0.25	1280		
	Ti-8Mn							8	860		
	Ti-13V-11Cr-3Al	3			13		11		1170	275-400	2400
	Ti-11.5Mo-6Zr-4.5Sn (β III)		4.5	11.5		6			700		
	Ti-3Al-8V-6Cr-4Zr-4Mo (β C)	3		4	8	4	6		900		
	Ti-10V-2Fe-3Al	3			10			2	1170		
	Ti-15V-3Al-3Cr-3Sn	3	3		15		3		1000		
	Ti-5553	3		5	5		3	1.3	1160		

Machinability comparison of different titanium types is shown in the above table.

The cutting data in this guide focuses on speeds for **Ti6Al4V.** The same strategy and feeds should be used for other grades of titanium but the speed should be altered depending upon the level of machinability.

Ti-10V-2Fe-3Al is a non ferrous near Alloy of Titanium which has an excellent combination of strength, ductility, fracture toughness and high cycle fatigue strength. This grade is used extensively in landing gears.

Ti-8Al-1Mo-1V is most commonly used alloy. Special annealing cycles have been developed for this grade, which enhances its creep strength and fracture toughness while permitting it to maintain good strength levels.

ISSUES IN MACHINING TITANIUM

- Relatively poor tool life, even at low cutting speeds.
- High chemical reactivity causes chips to gall and weld to cutting edges.
- Low thermal conductivity increases cutting temperatures.
- Usually produces abrasive, tough, and stringy chips.
- Take precautionary measures when machining a reactive metal.
- Low elastic modulus easily causes deflection of workpiece.
- Easy work hardening

TITANIUM ALLOYS AND MACHINING CHALLENGES

Machining Properties	
Feature	**Influence on cutting tools**
Retains stength at relatively high temperatures	High forces and heat generation
Thin chip thickness, narrow contact area on rake face	Concentrated cutting forces, lower than average feed
Poor thermal conductivity	High hot hardness required Speed/feed sensitive
Cyclic chip formation - variable forces	Prone to vibration / chatter
Chemically reactive with cutting materials	Crater wear
High level of carbide content	Flank wear

Characteristics of alloying elements

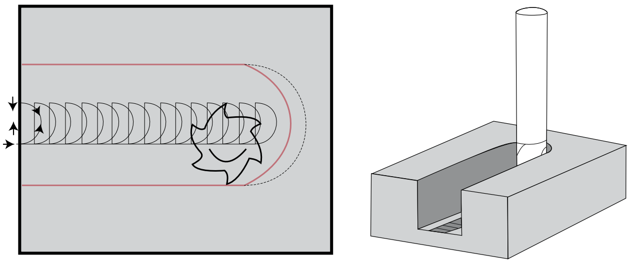
- **Manganese (Mn)** – improves hardenability, ductility and wear resistance. Mn eliminates formation of harmful iron sulfides, increasing strength at high temperatures.
- **Nickel (Ni)** – increases strength, impact strength and toughness, impart corrosion resistance in combination with other elements.
- **Chromium (Cr)** – improves hardenability, strength and wear resistance, sharply increases corrosion resistance at high concentrations (> 12%).
- **Tungsten (W)** – increases hardness particularly at elevated temperatures due to stable carbides, refines grain size.
- **Vanadium (V)** – increases strength, hardness, creep resistance and impact resistance due to formation of hard vanadium carbides, limits grain size.
- **Molybdenum (Mo)** – increases hardenability and strength particularly at high temperatures and under dynamic conditions.
- **Silicon (Si)** – improves strength, elasticity, acid resistance and promotes large grain sizes, which cause increasing magnetic permeability.
- **Lead (Pb)** – It is almost insoluble in liquid or solid steel. However, lead is sometimes added to carbon and alloy steels by means of mechanical dispersion during pouring to improve the machinability.
- **Titanium (Ti)** – improves strength and corrosion resistance, limits austenite grain size.
- **Cobalt (Co)** – improves strength at high temperatures and magnetic permeability.
- **Zirconium (Zr)** – increases strength and limits grain sizes.
- **Boron (B)** – highly effective hardenability agent, improves deformability and machinability.
- **Copper (Cu)** – improves corrosion resistance.
- **Aluminum (Al)** – deoxidizer, limits austenite grains growth.
- **Sulphur (S)** – Improves machinability in free-cutting steels, but without sufficient manganese it produces brittleness at red heat. It decreases weldability, impact toughness and ductility.
- **Tantalum (TA)** – Used as stabilizing elements in stainless steels. Each has a high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented.
- **Phosphorus (P)** – Increases strength and hardness and improves machinability. However, it adds marked brittleness or cold-shortness to steel.
- **Zirconium (Zr)** – It is added to killed high strength low alloy steels to achieve improvements in inclusion characteristics. Zirconium causes sulphide inclusions to be globular rather than elongated thus improving toughness and ductility in transverse bending.

Strategies of Machining - Trochoidal Milling

Trochoidal milling is a method of high material removal in which we create a slot wider than the cutting tool's cutting diameter. The circular cut is known as a trochoidal path.

Trochoidal milling is largely based on the concept of chip thinning. Conventional thinking suggests that cutting tools have an optimal chip load that determines the ideal width and size of the chips produced. The concept of combating chip thinning involves machining with a chip load that is larger than "optimal" in order to maintain a constant maximum chip thickness.

In contrast to a completely linear radial tool path in conventional machining, trochoidal milling takes advantage of a spiral tool path with a low radial depth of cut (Ae) to reduce load and wear on the tool (Figure 1).



Trochoidal milling methods were originally developed for roughing of difficult materials such as hard steels, ISO H, and HRSA-materials, but can also be used with other materials, especially in vibration sensitive applications. Trochoidal milling is primarily used for machining slots and roughing parts.

It is referred with multiple names (HVM- High Volume Machining) (HEM- High Efficiency Machining) . This technique has an improvement over traditional milling methods which have an advantage of using high speeds while maintaining a low radial depth of cut (Ae) and a high axial depth of cut (Ap).

For understanding these let me use the below terms to make it easy to understand this concept

fz is the feed per tooth of the tool

Z is the number of teeth in the tool

RPM (n) is the revolutions per minute of the tool

Vc is the cutting speed or surface speed of the tool which is got by the formula

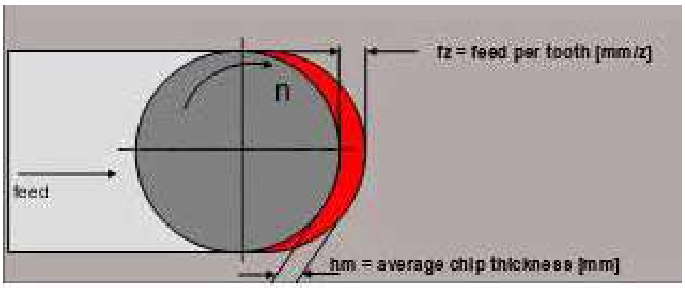
$$Vc = \pi \text{ X D X} \frac{\text{RPM}}{1000}$$

Vf is the table feed which is got by the formula

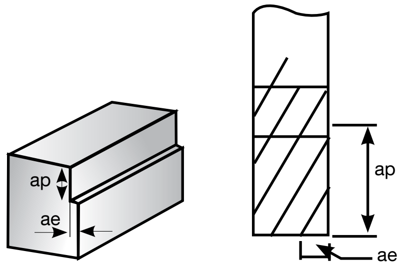
$$Vf = fz \text{ X Z X RPM}$$

(hm) is the average chip thickness

(ß) is the engagement angle of the tool

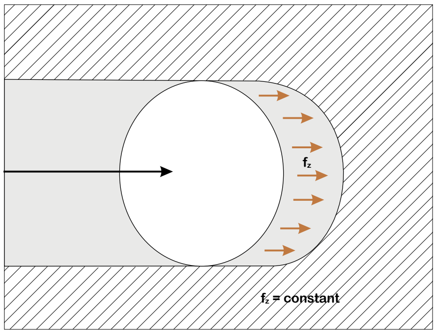


(Ae) is the radial depth of cut.
(Ap) is the axial depth of cut .

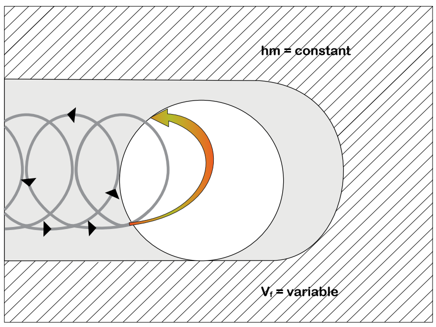


Let us now look at the differences betweenconventional and trochoidal milling

In Conventional milling the (fz) which is the feed per tooth is constant and unidirectional



In trochoidal milling machining happens along programmed trajectories at a constant (Vf) (which is the table feed) with different engagement angles (ß) based on the radial engagement of the tool (Ae)

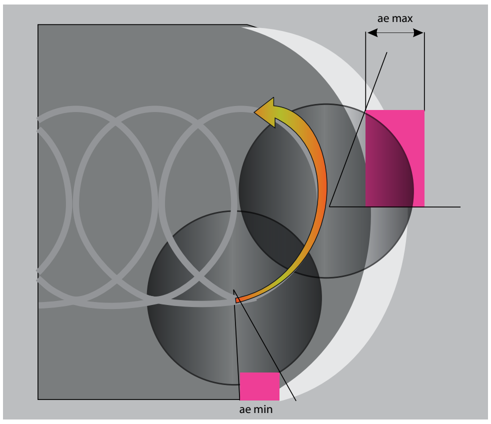


In Trochoidal you can have two strategies

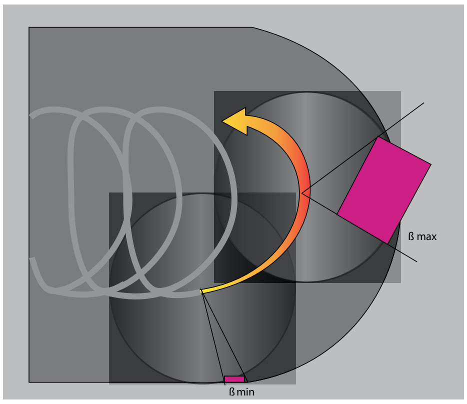
1 **Static** where the average chip thickness (hm) is maintained constant based on the material to be machined

2 **Dynamic** where the engagement angle and the average chip thickness (hm) is defined based on the profile to be machined and the material to be machined.

STATIC



DYNAMIC



In conventional Milling the Feed is calculated using the Formula

$$fz = hm\sqrt{(D/ae)}$$

In trochoidal milling the dynamic feed is calculated by keeping the average chip thickness constant based on the engagement with the part

$$hm = fz\sqrt{(ae/D)}$$

In conventional Milling we use a regular end mill with 3-4 Flutes for effective chip evacuation

In trochoidal milling we use a specific trochoidal end mill design with a bigger core diameter and more number of optimized 3-4-5-6-7 flutes

In conventional milling we use a regular end mill where we go with a low axial depth (Ap) and a higher radial depth (Ae), we cannot go higher as the heat generated would be high

In trochoidal milling we use a high axial depth (Ap) and a low radial depth (Ae) with less heat generated, resulting in longer tool life.

In conventional milling the tools are used on standard cnc center with normal Vc and fz

In trochoidal milling you will need to use a more dynamic cnc center with a high Vc and fz

In conventional milling the machining process is linear and standard

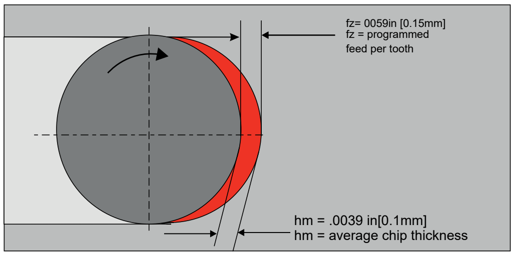
In trochoidal milling you will need to use a software which can help you generate this trochoidal program or can be manually programmed

In conventional milling the chip thickness (hm) is not constant and the cutting forces vary at entry of cut and exit of cut and are dependent on the work piece material.

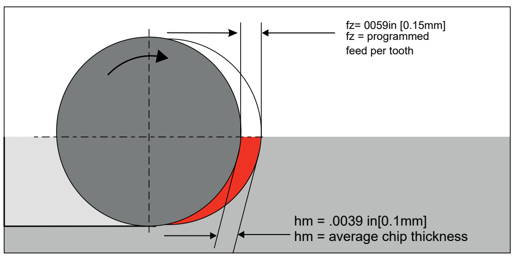
In trochoidal milling the chip thickness (hm) is programmed to be uniform and the milling process happens with a constant force and a constant engagement angle in static trochoidal milling and constant force with varying engagement angle in dynamic trochoidal milling hence ensuring least shock load and uniform heat dissipation

In conventional milling generally cutters are engaged between ½ of the cutter diameter to full engagement where the average chip thickness (hm) value remains more or less constant at the center line of the cutter so it does not impact the feed rate

100% Conventional



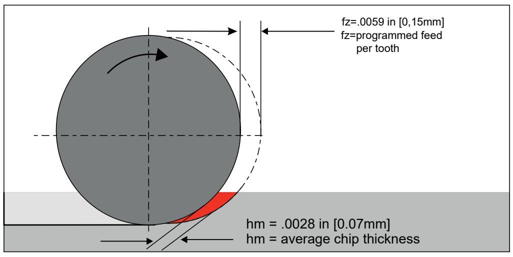
50% Conventional



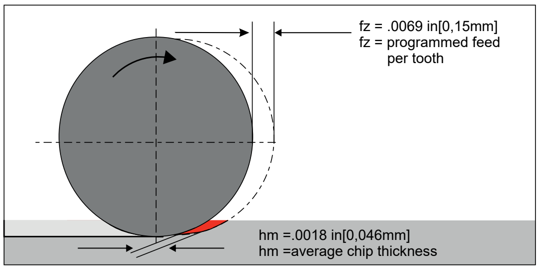
In trochoidal milling we work with the fundamental of keeping the average chip thickness (hm) constant with lower radial engagement (Ae)

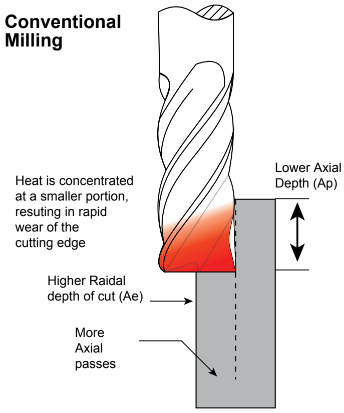
You will notice in the below image that as the radial engagement (Ae) reduced the average chip thickness (hm) value reduced. To compensate for this reduced hm value we must increase the feed sufficiently to ensure that the chip thickness remains constant

20% Trochoidal

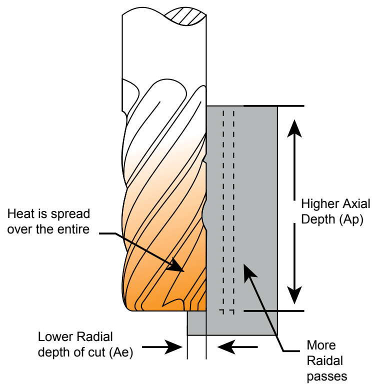


10% Trochoidal





Trochoidal Milling



Advantages of Trochoidal Milling

- **Decreased cutting forces**
  Trochoidal milling works on the concept of keeping the average chip thickness constant throughout the cut and a reduced axial engagement during the cut. This reduces the overall cutting forces. This method combined with the right entry and exit strategies is used to ensure the least shock load on the tool.

- **Reduced heat**
  In trochoidal milling we work with the basic understanding that we operate with a higher (Ap) when compared to a low Depth (Ap) in conventional milling this ensures higher spread over the cutting edge and complete engagement of the edge. The reduced heat and wear, combined with their uniform spread on the cutting edge, result in significantly improved tool life over conventional slotting methods.

- **Greater machining accuracy**
  The End mills designed for trochoidal milling are designed with chip gullets which are designed not to take more than 25-30% of Ae, which basically leads to a bigger core diameter which is generally almost 25-30% higher than the conventional end mills. The strategy of using lower radial engagements ensure lower deflection and better stability which in turn results in higher accuracy

- **Improved tool life**
  Due to the high cutting speed, lower cutting forces the tool life is significantly better than conventional machining

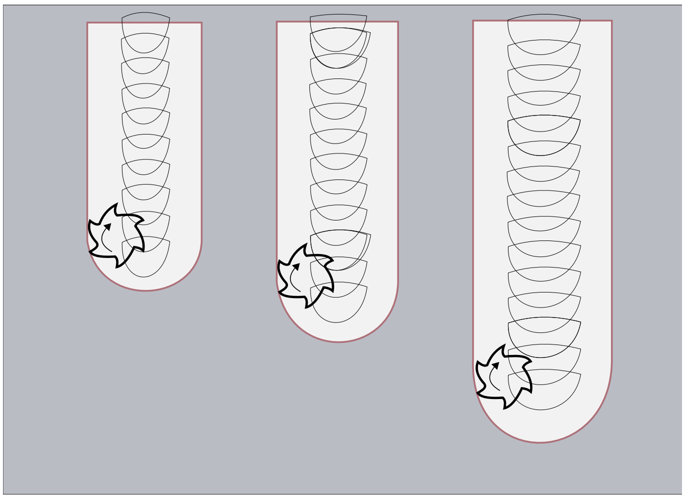
- **Faster cycle times**
  Trochoidal end milling tools are designed with a stronger core design and higher number of flutes. This feature combined with the capability to machine higher Ap ensures a drastic reduction in cycle time. With the reduced radial engagement the stability increases which allows us to run at higher cutting speeds which also contributes to reduction in cycle times

- **Improved Finish**
  Even though we consider slotting a roughing operation, the reduced radial engagement and decreased cutting forces from trochoidal milling often result in an improved finish over a conventional slotting tool path. We however, recommend a finishing pass along the walls of the work piece to finish the walls which may be required to remove any material left from the spiral motion of the cutting tool

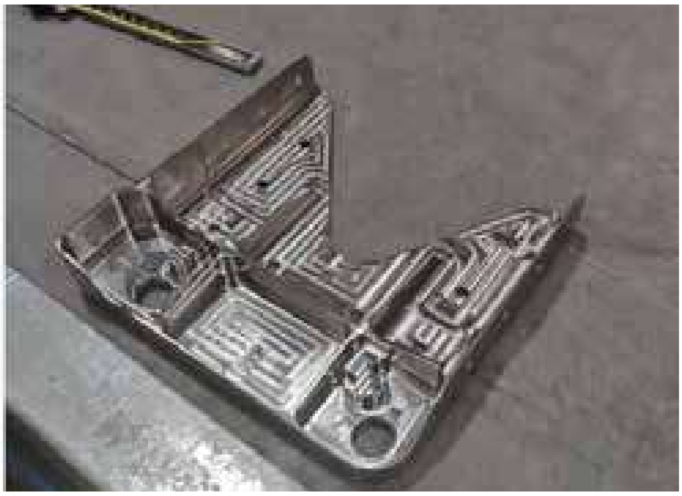
- **Structural integrity**
  In conventional milling, when machining thin walls and surfaces with ribs there is a general challenge of maintaining the structural integrity of the part. Conventional milling has repeated entry and exits which causes stress on the part, possible breakouts and possible field failure of part. Trochoidal milling has a reduced radial engagement which ensures that the radial forces are minimal and due to which there is lower stress on the part

Understand that we need heat to shear and that would mean the Cutting speeds need to be increased accordingly. Knowledge of the specific cutting force (kc) is very important to optimize parameters

- **One tool for multiple slot sizes**
  Trochoidal milling as a process is recommended when you have high volumetric removal. Since trochoidal milling uses a tool to machine a slot wider than its cutting diameter, the same tool can be used to create slots of varying sizes, rather than just one. The advantage you get here is you can use a single tool and do multiple profiles.



Series	Number of teeth	Helix	Primary workpiece	Secondary workpiece
Razorcut - CBC	3	30	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut NCBCH	3	40	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut CBCH	3	40	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut 3FWFCR	3	38	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut 3FWFXL	3	38	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut 3F	3	38	Aluminium 6000/7000 series	Wrought Aluminium
Razorcut 3FWF	3	38	Aluminium 6000/7000 series	Wrought Aluminium
F193CB	4	45	Titanium	Stainless Steel
NF193CB / NF193CBL	4	45	PH	Stainless Steel
F193CB (16/20/25)	6	45	Titanium	Stainless Steel
NF193CB / NF193CBL (16/20/25)	6	45	PH	Stainless Steel
F194CB	4	45	Titanium	Stainless Steel
F194CB (16/20/25)	6	45	Titanium	Stainless Steel
5VR	5	38	Titanium	PH Steel
6VR	6	45	Titanium	PH Steel
F180TR	7	38	Titanium	Stainless Steel
NF180TR	7	38	Titanium	Stainless Steel
F177TR	4	38	PH	Stainless Steel
NF177TR	4	38	PH	Stainless Steel
F178TR (GOLD)	5	38	Stainless Steel	Steel
F178TR (BLACK)	5	38	Titanium	Super Alloys
Proton Plus	4	50	Hardened Steel H1	Hardened Steel H2



Trochoidal Milling 16mm End Mill for a vendor of Boeing	
Challenge	Reduction in CPC
Component	Structural Part for Boeing
Competiton	Hanita 57N8
Solution	EM 16.00MMX34X48X100SH16 5FLT CR1 ALT
Cutting data	Machine : Makino- HMC, Shrinkfit- Totem , Coolant – Soluble Oil RPM = 1550-1620 I Feed = 850-920 I Ap = 22mm, Ae = 1.6mm Existing Tool Life – 220 minutes I Achieved Tool Life – 300 minutes
Result	36% improvement in Tool life
Benefit	Reduction in Tool Change

Trochoidal Milling 16mm End Mill for a vendor of Boeing	
Challenge	Reduction in CPC
Component	Boeing Floor to Frame Fitting
Competiton	Hanita 57N8
Solution	EM 16.00MMX34X48X100SH16 6F CR3 5FLTALT
Cutting data	Machine : Mitsubishi DH80 HMC Holder BT50 Side-lock Totem, Coolant – Soluble Oil RPM = 1200 I Feed = 420 I Ap = 30mm, Ae = 4mm Existing Tool Life – 240 minutes I Achieved Tool Life – 344 minutes
Result	43% improvement in Tool life
Benefit	Reduction in Tool Change

Based on our experience and study of usage of trochoidal milling tools on various materials we have come up with a quick reference guide for starting parameters for Dynamic Trochoidal machining.We have arrived at Ae/D Ratio max and min limiters as well as the engagement angle of these tools when tackling flat surfaces (ß max) and corners (ß min)

Use these above conditions to get optimum results while machining.

Material Group	Ae/D Ratio		Engagement Angles	
Series	Ae Max	Ae Min	ß Max	ß Min
Steel P1, P2	20.00%	10.00%	53.1	10
High Alloy Steel P3, P4, P5 & PH	15.00%	10.00%	53.1	10
Tool Steels 45 HRc, P6, PH upto 48 HRc	16.00%	0.80%	47.2	10
Stainlees Steel M1, M2	15.00%	7.00%	53.1	10
Stainless M3, Duplex and Super Duplex	10.00%	7.00%	53.1	10
Cast Iron K1	25.00%	20.00%	53.1	10
S G Iron K2, K3	20.00%	15.00%	53.1	10
Alumminium	30.00%	20.00%	66.4	10
Titanium S4	12.00%	8.00%	40.54	10
Inconel S3	10.00%	6.00%	43.2	10
Super Alloys S1, S2	10.00%	5.00%	40.54	10
Hardened Steel H1 (44-48) HRc	12.00%	0.80%	40.54	10
Hardened Steel H2 (49-55) HRc	4.70%	0.80%	25	10
Hardened Steel H3 (56-60) HRc	2.20%	0.80%	17	10
Hardened Steel H4 >60 HRc	1.10%	0.80%	12	10

Parameter Calculation for Trochoidal Milling

Step 1:- Based on the work piece material to be machined select the right tool make a of note the number of flutes / overhang length/ cutting length / helix angle and input this into the CAM software

Step 2 :- Select the Ae/D Ratio limits and engagement angle limits from the above chart based on the material to be machined and enter this the CAM software

Step 3:- From the below chart based on the Ae/D ratio calculate the correct feed rate by multiplying the catalogue recommended feed the feed multiplication factor to get the correct chip load and enter this into the CAM software.

Step 4:- From the below chart based on the Ae/D ratio calculate the correct Vc by multiplying the catalogue recommended Vc with the cutting speed multiplication factor to achieve the right specific cutting force for the material group and enter the revised cutting speed into the CAM software.

Ae/D Ratio	Radial depth of cut (ae) based on diameter mm						Engagement Angle ß	Feed Multiplication Factor	Cutting Speed Multiplication Factor
Series	6	8	10	12	16	20			
0.10%	0.006	0.008	0.010	0.012	0.016	0.020	3.620	15.819	2.250
0.50%	0.030	0.040	0.050	0.060	0.080	0.100	8.110	7.089	2.200
1.00%	0.060	0.080	0.100	0.120	0.160	0.200	11.480	5.025	2.100
2.00%	0.120	0.160	0.200	0.240	0.320	0.400	16.260	3.571	2.000
3.00%	0.180	0.240	0.300	0.360	0.480	0.600	19.950	2.931	1.800
4.00%	0.240	0.320	0.400	0.480	0.640	0.800	23.070	2.552	1.750
5.00%	0.300	0.400	0.500	0.600	0.800	1.000	25.840	2.294	1.650
6.00%	0.360	0.480	0.600	0.720	0.960	1.200	28.360	2.105	1.600
8.00%	0.480	0.640	0.800	0.960	1.280	1.600	32.860	1.843	1.550
10.00%	0.600	0.800	1.000	1.200	1.600	2.000	36.870	1.667	1.500
12.00%	0.720	0.960	1.200	1.440	1.920	2.400	40.540	1.539	1.450
15.00%	0.900	1.200	1.500	1.800	2.400	3.000	45.570	1.400	1.400
20.00%	1.200	1.600	2.000	2.400	3.200	4.000	53.130	1.250	1.350
25.00%	1.500	2.000	2.500	3.000	4.000	5.000	60.000	1.155	1.330
30.00%	1.800	2.400	3.000	3.600	4.800	6.000	66.420	1.091	1.300
40.00%	2.400	3.200	4.000	4.800	6.400	8.000	78.460	1.021	1.270
50.00%	3.000	4.000	5.000	6.000	8.000	10.000	90.000	1.000	1.250
60.00%	3.600	4.800	6.000	7.200	9.600	12.000	101.540	0.950	1.150
75.00%	4.500	6.000	7.500	9.000	12.000	15.000	120.000	0.900	1.100
100.00%	6.000	8.000	10.000	12.000	16.000	20.000	180.000	0.800	1.000

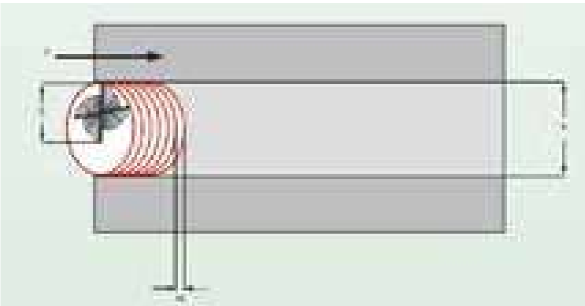
Requirements

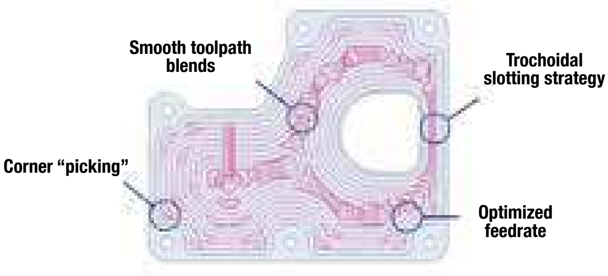
STATIC TROCHOIDAL MILLING
- Dynamic machine.
- CNC-Program.
- Modern tool.
- Cutting data for trochoidal machining.

DYNAMIC TROCHOIDAL MILLING
- Dynamic CNC-machine.
- CAD/CAM Solutions like iMachining from SolidCAM.
- Modern tool.
- Cutting data for trochoidal machining.

Static Trochoidal Milling for a Full Slot

- Use a tool in which D<b
- Program circles in the CNC program (as a cycle)
- After one circle, repeat the same with an offset.
- Optimise by shortening the lane "in the air" to a form like a "D"





For Dynamic Trochoidal Milling

- Transfer the basic idea control of chip thickness to dynamic processes.
- Dynamic adaption of feed in relation to ae and engagement angles through an intelligent CAM Software.

Let me illustrate with an example how to calculate the parameters for machining a structural part of titanium using static trochoidal milling

Material :- Ti6AL4V (Grade 5)

Stock to be removed :- Ap 25mm Ae 2mm on the wall

In the interest of optimizing structural integrity and surface finish, let us select a roughing and finishing tool.

Stock for Roughing Ae 1.8mm/Ap 25mm

Stock for Finish Ae 0.2mm/ Ap 25mm

For the roughing cycle

Based on the tool selector let us select a roughing tool F194CB FBK0510346

Series	FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Chamfer	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)
F194CB	FBK0510346	16	32	92	16			0.35		6	45	Titanium	1.92	0.02

Update the above dimensions in the CAM Program

Based on the stock the Ae/D ratio can be calculated as below (1.8/16) = 11%

From the Chart above this condition is well within our limit for machining of 12%

From the catalogue the reference Vc is 55m/min and fz is 0.035mm/tooth

Multiply the corresponding chip load factor and the Vc correction factor and you will get the revised Vc as 77m/min and fz as 0.055mm/tooth

The corresponding RPM 1531 and Vf 506mm/min are calculated

From the Calculator provided calculate the corresponding engagement angle which is 39.19°

Note all these values and update it in the CAM software

For the finish cycle

Based on the tool selector let us go with a finishing tool 6VR FBK0508793

Series	FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Chamfer	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)
6VR	FBK0508793	16	32	92	16					6	45	Titanium	1.92	0.022

Based on the stock the Ae/D ratio can be calculated as below (0.2/16) = 1.25%

From the Chart above this condition is well within our limit for machining of 12%

From the catalogue the reference Vc is 55m/min and fz is 0.064mm/tooth

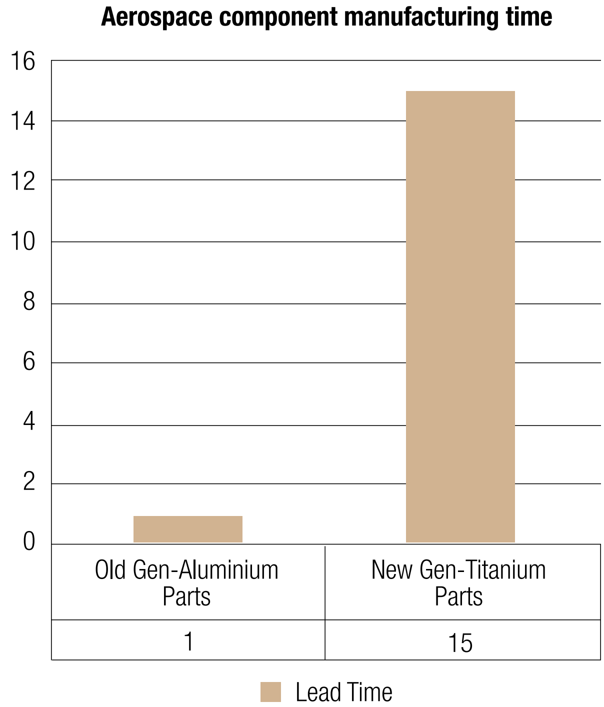
Multiply the corresponding chip load factor and the Vc correction factor and you will get the revised Vc as 110m/min and fz as 0.288mm/tooth

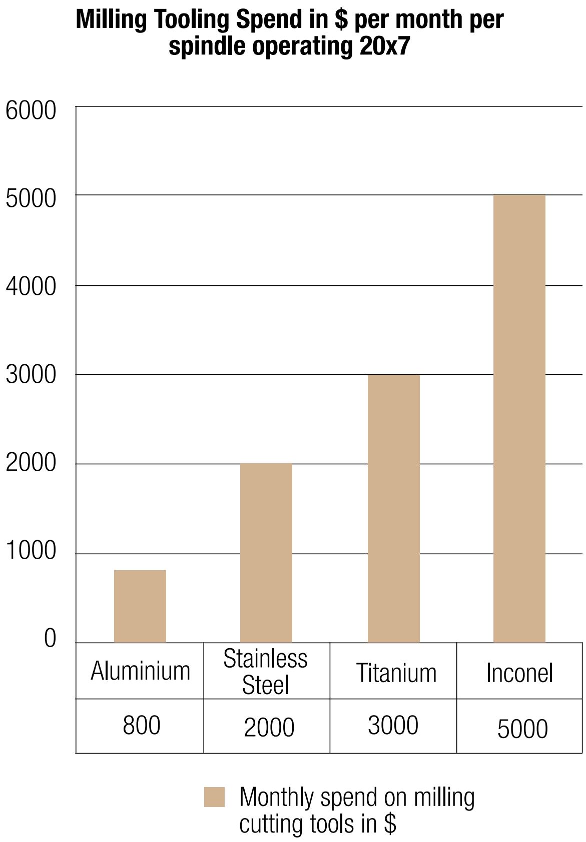
The corresponding RPM 2188 and Vf 3780mm/min are calculated

From the calculator provided calculate the corresponding engagement angle which is 12.84°

Note all these values and update it in the CAM software

Lead time and spend on end mills in aerospace industry





Specific Cutting Force

- For power, torque and cutting force calculations, the specific cutting force, or kc1, is used. It can be explained as the force, Fc, in the cutting direction **(Image 1)**, needed to cut a chip area of 1 mm² that has a thickness of 1 mm. The kc value is different for the six material groups,
- Note that the Specific cutting Force can vary based on the feed rate and the material hardness within the material group. This can be determined experimentally by conducting actual cutting tests
- Using the Specific Cutting Force for the application, You can calculate the Power in kW at the cutting edge and the motor. Using this data you can calculate the Torque needed by the spindle to cut.
- This will help you understand before cutting whether the spindle is capable of taking the load and whether the parameters calculated for cutting are suitable for that machine.

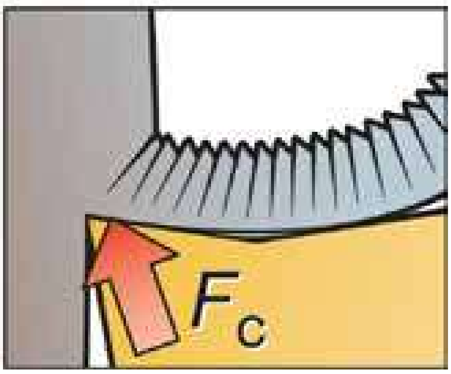


Image 1

Material Grop	Specific Cutting Force Kc (N/mm²)
P	1400-3200
M	1700-2800
K	780-1650
N	350-1350
S	1300-3300
H	3090-4750

$$P_c = \frac{a_p \times a_e \times v_f \times k_c}{60 \times 10^6}$$

Understanding the Quality requirements in Aerospace

AS9100 is the international Quality Management System standard for the Aviation, Space and Defence (AS&D) industry, created by the IAQG, and AS9100 Rev D (2016) is the most recent version.

The standard **provides suppliers with requirements for creating and maintaining a comprehensive quality system for providing safe and reliable products to the AS&D industry,** as well as civil & military aviation requirements. **"AS9100 Certified" means an organization has met the requirements of AS9100D.**

There are three ASD Standards, typically mutually exclusive:
AS9100 – Design, Develop or Manufacture
AS9110 – Aircraft Maintenance Organizations
AS9120 – ASD Distributors of components like electronics and hardware
AS9100 mentions several other guidance standards that you should understand.

These additional standards don't require certification, they provide guidance.
- It does **NOT** matter what size your organization is: 1 person or 1 million people
- It is **NOT** a product standard that defines product quality. AS9100 asks you to control your processes, so your end product meets customer requirements.
- It is **NOT** a personal Standard – a person cannot get certified to AS9100.

AS9100 Includes all of ISO 9001 quality management system requirements and specifies additional requirements for a quality management system for the aerospace industry.

Important aspects for a tool manufacturer to be covered in understanding the quality requirements
Stress induced by tool on the part.
Thermal stress induced due to machining.
Accuracy and tolerance of the part.
Functionality of the part.
Warpage of thin wall components.

Optimized Production Planning Process

Optimising the above is of course necessary, however, to achieve an optimised process these must be combined with process and application 'know how' to achieve secure productive machining. This information considers in which order to build an optimised process for HRSA milling and discusses important 'success factors' for each stage.

Typical components - aerospace

Analysis of the Features

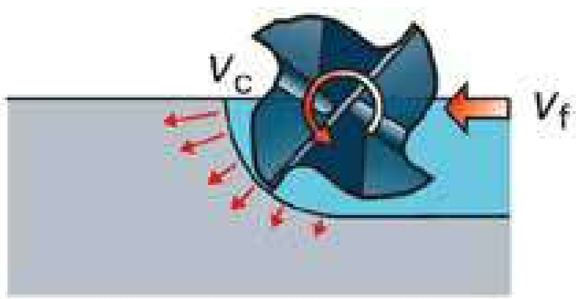
Most HRSA components are critical parts of the aircraft engine with complex features to be machined. Careful planning and application of modern cutting tool materials can dramatically reduce cycle time. Planning the order of operations in order to reduce part distortion is also an important factor when planning the machining strategy.

Machining Strategies

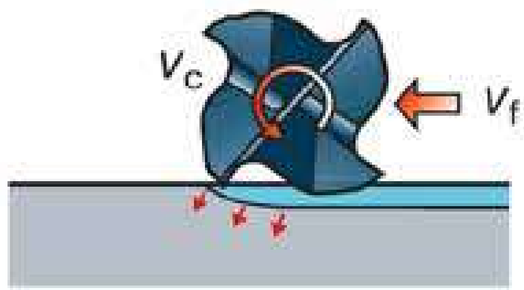
Machining Strategy, Machine Requirements:- Horizontal/ Vertical, Configuration – 3/4/5-axis, Spindle Speed, table feed, Power Torque requirements, Spindle coupling, Coolant Requirements, Fixturing and Stability of the Machine

Due to the high hot hardness and toughness of HRSA, they are one of the most difficult to machine materials placing great demands on the tool. The outcome is traditionally, low cutting speeds and hence lower productivity/higher machining costs.

High speed machining (HSM) techniques offer an effective way to increase productivity and to mill intricate and thin-walled components. The high feed rates do not allow as much heat to get transferred into the component, due to the short contact time, compared to conventional milling techniques. However low radial cuts are required to keep the chip thickness small and allow for the higher feed rate.



Traditional milling, time for heat propagation.

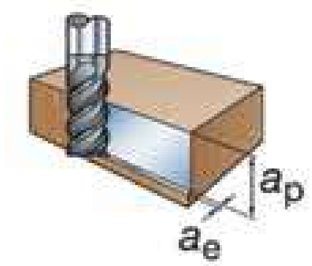


Feed faster than heat propagation.

HSM uses high RPM and axial cut (ap) with a small radial engagement (ae) and feed per tooth (fz). This is possible due to

FACTOR	EFFECT	BENEFIT
Thin chip thickness Small arc of engagement	Lower cutting force / deflection Reduced temperature at cutting zone	Deeper axial cuts Higher speeds

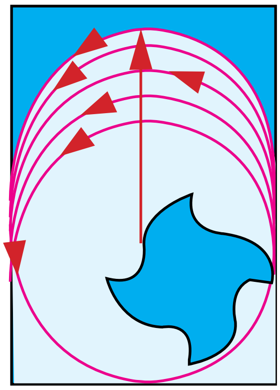
This method requires a machine with high spindle speed and high feed dynamics putting no extra load and demand on the rigidity of the machine



PROCESSES USING HSM TECHNIQUES

Trochoidal Milling

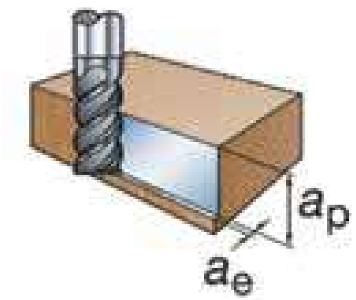
- A roughing/high material removal method used when in a confined space or slot.
- A continuous spiraling path feeding in the radial direction to form a groove or a profile.
- It requires specialised programming and machine capabilities.



Peel Milling

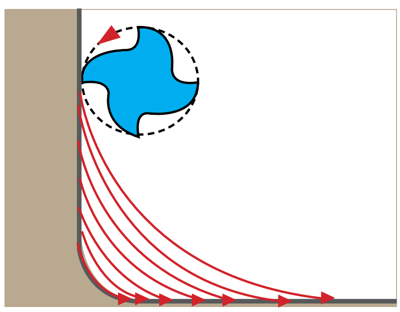
It is very similar to the Trochoidal Path. It uses

- Small radial cutting depth
- Deep cutting depth
- High cutting speed
- Spiral Cutter
- Roughing method which normally eliminates semi-finishing



Slicing

A semi-roughing technique used to produce a profile. Multiple passes to reduce the radial immersion. It requires a machine with high spindle speed and dynamic capability.



Plunge Milling

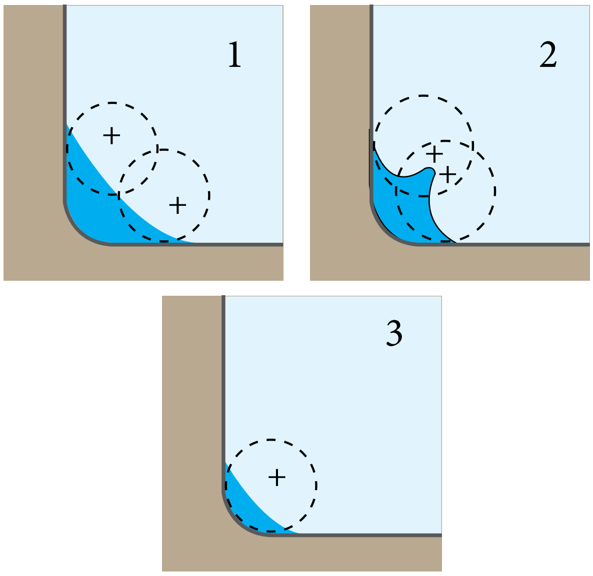
Here, the end of the cutter (axial cutting edge) is used instead of the side (radial cutting edge). This method offers an ideal solution for difficult materials like titanium.

Application

- Demanding conditions such as instability, long tool length
- In tool overhangs over 4 × Dc
- For semi-finishing of corners
- When machine power/torque is limited
- Horizontal machines facilitate chip evacuation

Advantages

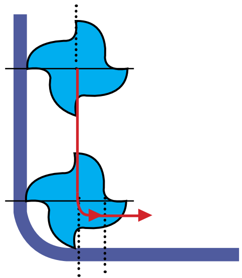
- Low power consumption/noise



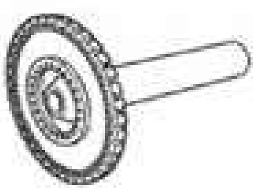
Top View

Profiling

A finishing technique used to produce a finished profile e.g. flank milling which reduces the number of axial passes. This requires a machine with high spindle speed and specialised programming techniques for simultaneous 5 axis for blisk/impellor machining.

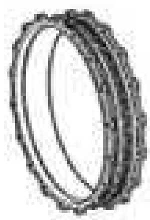


Some of the typical components that can be machined using HSM techniques for example are blisks, impellers, turbines (LPT and HPT) and exhaust casings.



Slots - shafts

Blisk/impeller



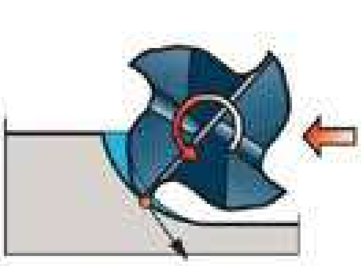
Scallops - casings

APPLICATION RECOMMENDATIONS

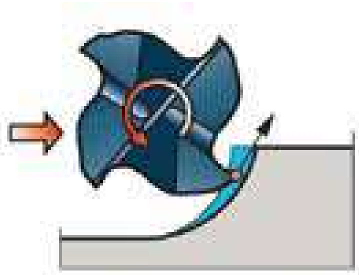
Down milling

It is almost always more favourable to apply down milling rather than up milling. When the cutting edge goes into contact in down milling, the chip thickness has its maximum value, in up milling the chip thickness is zero.

The tool life is generally shorter in up milling due to the fact that there is considerably more heat generated due to the rubbing action that takes place on entry. The radial forces are also considerably higher in up milling.



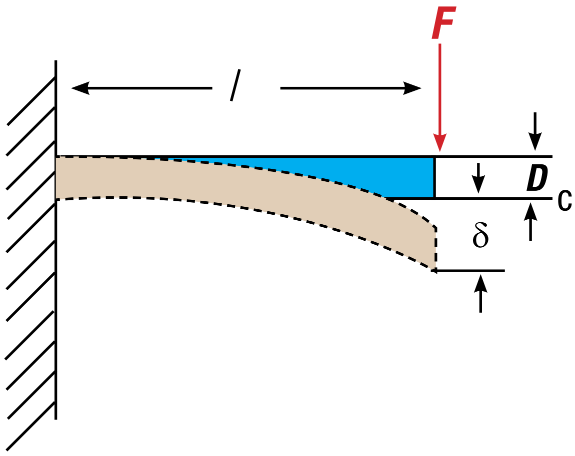
Down milling (climb milling)



Up milling (conventional milling)

Avoid excessive deflection

Shallow radial cuts (ae) should be applied to avoid excessive deflection of the cutting tool and to keep a high tolerance level and geometrical accuracies on the machined component. It is important to use a tool with a maximum core diameter (higher bending stiffness).



l = overhang
Dc = tool diameter
F = radial force
δ = deflection
E = modulus of rigidity of the tool
δ = F x l3/ E x (π x Dc4)

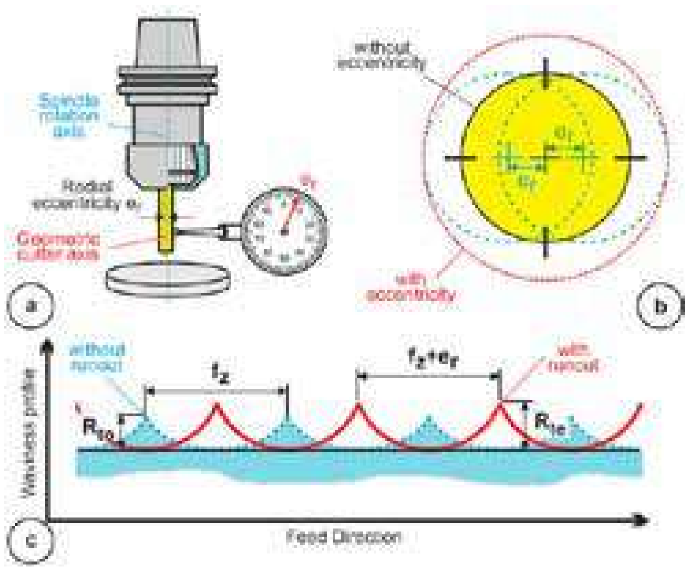
20% overhang reduction reduces tool deflection by 50%.20% increased Dc (10 to 12mm) reduces tool deflection by 50%.

Run Out Control

One of the main criteria when deciding both the tool and holding device is to have as **small a run out as possible.**

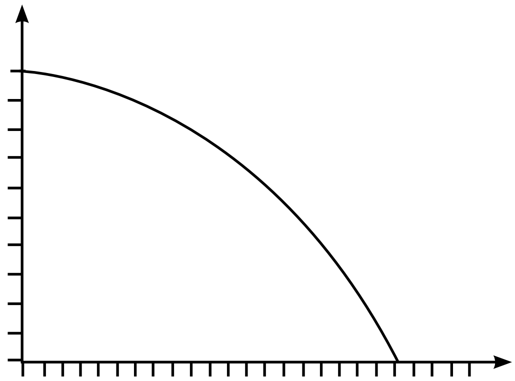
This keeps a **uniform chip thickness** on each cutting edge and hence has an **even load distribution.**

The total indicator run out (TIR) should not be more than 10 microns. A good rule of thumb is that 'For every 10 microns in added run out the tool life reduces by 50%'!



Use Shrink fits to get

Minimised run out	-	increased tool life.
Stability	-	reduced vibrations allowing higher depths of cut.
Reduced Clamping forces	-	resists pull out with high helix cutters



Machining Strategies for Titanium/ HRSA- Difficult to machine super alloys need various strategies to be implemented while manufacturing the tool and when machining

- Keep Radial Engagement Low
- Increase Flute Quantity
- Make a Thick-to-Thin Chip- Climb Milling
- Arc In- Trochoidal Method
- End on a Chamfer
- Rely on Secondary Relief
- Alter the Axial Depth
- Limit the Axial Depth Around Slender Features (8:1)(15:1)(30:1)
- Choose a Tool Much Smaller than the Pocket
- Take a Cue from Tool Steel (HSM strategy)

Machine requirement

Horizontal/Vertical

For larger components such as engine casings where there are many different features and where access is an issue it is best to use a horizontal machine. This also makes it easier to evacuate the chips, preventing re-cutting of the chips, giving a more secure tool life. For some ring components and mounting brackets vertical machine tools can create improved stability.

Configuration – 3/4/5-axis

It is common to have a fourth/fifth axis on horizontal machines to give good accessibility e.g. for casings and closed faces.
For complex parts (3D profiles, blisks) 5-axis rigid machines are used, with fully simultaneous five access control.

Spindle speed

Three cutting strategies dictate the spindle speed requirements:

a) Solid carbide tools – (low torque) – the cutting speed (Vc) is between 30 to 100 m/min. For cutter diameters 8 to 16 mm this will give an rpm requirement between 4000 to 600 rpm
b) Carbide inserts – (high torque) - the cutting speed (vc) is normally limited to a maximum of 40 m/min, for cutter diameters 25 mm to 80 mm this will give an rpm requirement of 500 rpm to 159 rpm.
c) Ceramic inserts – (high power and torque) – typically cutting speeds (vc) can be as high as 1000 m/min, for cutter diameters 50 mm this will give an rpm of 6365.

Table feed

a) For roughing, using carbide inserts, the table feed is naturally relatively low, putting demands on stability rather than speed.
b) For roughing, with ceramics, the table feed can be up to around 2.5 m/min. Whilst this is not an extreme table feed, care must be taken that the control system can cope with direction change at this feed to avoid undercutting/shortcuts etc.

Power/torque requirement

a) Basically, the power requirement varies with the amount of metal to be removed, average chip thickness, cutter geometry and speed. The greater the metal removal rate (Q cm3/min) the higher the power requirement.
b) With spindle speeds for roughing much lower than for less exotic materials, it puts great importance on ensuring that power and torque are available at low rpms (a machine with insufficient torque and power will give fluctuating chip thickness in turn giving unstable performance).

Spindle coupling

a) Most HRSA alloys work-harden during machining and have higher strength and 'gumminess' not typical in other materials.
b) Heavy duty machining equipment and an ISO 50 taper (or equivalent) spindle is recommended to minimise chatter and work-hardening of the alloy ahead of the cutting.

Coolant

a) Unlike milling in most other materials, coolant is always recommended to assist in chip removal, control heat at the cutting edge and prevent re-cutting of the chips. High pressure coolant (70 bars) applied through the spindle/tools and externally has been seen to give good benefits compared to low pressure.

Fixturing

a) The shape and fixturing of the component is of great importance. Aerospace engine components are often thin-walled and have a lot of complex features which easily create distortion and vibration.
b) This is often the reason why engine casings have complex fixtures to reduce vibration and support the workpiece in relation to the direction of the cutting forces. Light cutting tools with positive geometries can help to ensure a safe, distortion-free machining operation.
c) Use of Dampening elements **(Example :- Aluminium light weight fixtures for Titanium parts)**

Stability

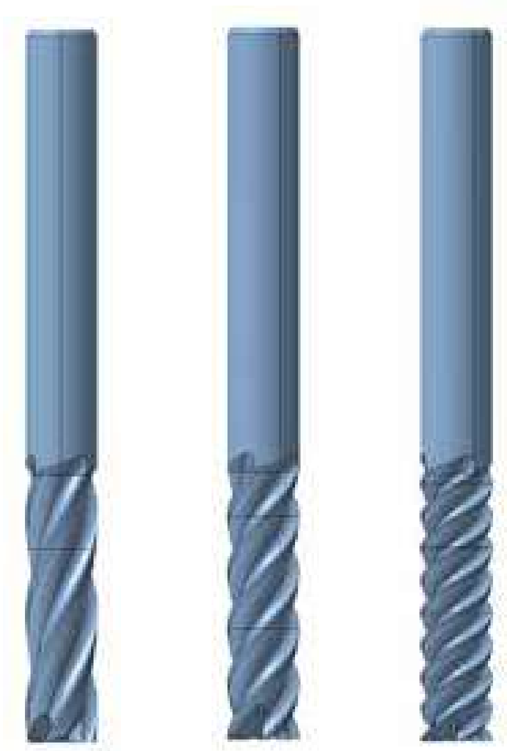
a) The condition and stability of the machine has an effect on the quality of the surface and can impair tool life. Excessive wear of the spindle bearings or feed mechanism can result in a poor surface structure.
b) As well as ensuring a stable machine tool, other factors such as tool overhang, tuned adaptors etc should be considered.

Wear

Typical wear observed on an end mill in the case of Inconel is micro chipping rather than flank wear.

The edge line starts frittering before it leads to total cutting edge failure. The transition from micro chipping to failure is exponential, hence once this wear is observed the tool should be immediately indexed. This can be monitored with the power/load gauge or by sound.

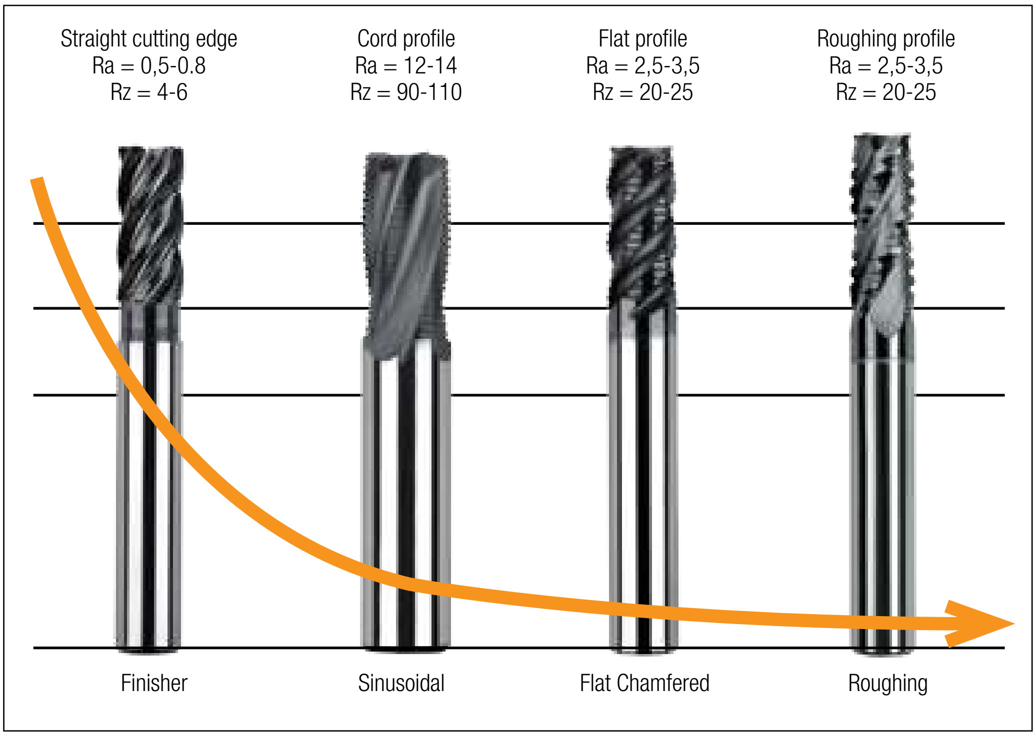
In Titanium micro chipping occurs at a much later stage when compared to Inconel



30^0 45^0 60^0

Optimized Number of Flutes

- Optimised cutter design & cutting parameters and selection of No of flutes (zn) are critical to machine super alloys
- Inconel is a sticky material which can cause problems with clogging of the chip flutes. Therefore even though with HSM, employing low radial engagement with thin chips, extra close multi-fluted end mills (as used in hardened steel) are not recommended.
- The thin chip produced can prove catastrophic if it sticks to the cutting edge and can lead to tool breakage.
- A Thumb rule used when selecting an end mill for roughing and finishing of Inconel is as below
  4 flutes - 8-12mm
  5 flutes - 12.5-20mm
  6 flutes - 20-25mm
  7 flutes – 25mm and above
- However a balance should thus be struck between productivity (multi-flute) and security (lesser no of flutes).



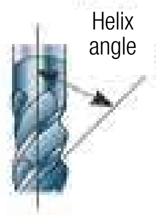
Power Consumption

Helix angle

An end mill's helix angle is defined as the angle of the cutting edge relative to the centreline of the tool. The helix influences tool performance mainly by affecting chip flow and cutting forces by determining the length of engagement of the cutting edge for a given depth of cut.

The greater the helix angle, the longer the cutting edge length allowing longer tool life and also giving a more gradual entry and exit into and from the workpiece. This lowers the radial forces that want to push the end mill and workpiece away from each other.

The result is a smoother machining action with less deflection. In most cases, high helix is recommended for finishing operations and a low helix in roughing because of the added strength.



A 40-50 degree helix is optimally suited for milling in Inconel when radial cuts (ae) are less than 20% of the cutter diameter Dc, for example trochoidal, slicing and finishing.

One general rule of thumb is that as the helix angle increases, the length of engagement along the cutting edge will decrease. That said, there are many benefits and drawbacks to slow and high helix angles that can impact any machining operation.

Low helix (Below 40 dgrees)

Benefits

- Enhanced Strength – A larger core creates a strong tool that can resist deflection, or the force that will bend a tool under pressure.
- Reduced Lifting – A slow helix will decrease a part from lifting off of the worktable in settings that are less secure.
- Larger Chip Evacuation – The slow helix allows the tool to create a large chip, great for hogging out material.

Drawbacks

- Rough Finish – A slow helix end mill takes a large chip, but can sometimes struggle to evacuate the chip. This inefficiency can result in a sub-par part finish.
- Slower Feed Rate – The increased radial force of a slow helix end mill requires running the end mill at a slower feed rate.

High helix (above 40 degrees)

Benefits

- Lower Radial Force – The tool will run quieter and smoother due to better shearing action, and allow for less deflection and more stability in thin wall applications.
- Efficient Chip Evacuation – As the helix angle increases, the length of cutting edge engagement will decrease, and the axial force will increase. This lifts chips out and away, resulting in efficient chip evacuation.
- Improved Part Finish – With lower radial forces, high helix tools are able to cut through material much more easily with a better shearing action, leaving an improved surface finish.

Drawbacks

- Weaker Cutting Teeth – With a higher helix, the teeth of a tool will be thinner, and therefore weaker.
- Deflection Risk – The smaller teeth of the high helix tool will increase the risk of deflection, or the force that will bend a tool under pressure. This limits how fast you can push high helix tools.
- Increased Risk of Tool Failure – If deflection isn't properly managed, this can result in a poor finish quality and tool failure.

In my years of experience I have come to understand that the Helix angle on an End Mill is one of the most neglected features of the End Mill, due to the lack of information on this feature
Let us now look at the influence of helix on the length of the cutting edge in contact while machining

Basic Terms used during the discussion below
ap Axial depth of cut
ae Radial depth of cut
Helix angle hx
Φ =(90o-hx)
LCE= Length of the cutting edge
Z= number of teeth
LCEz= Length of the cutting edge per teeth

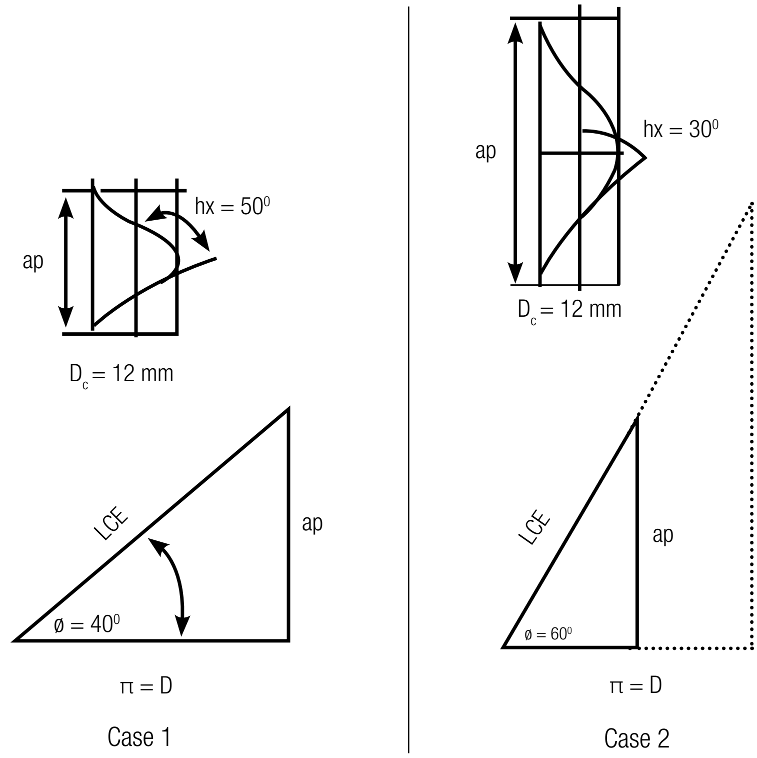
Simulation to show the Increase in cutting edge length as the helix angle increases
The diagram shows increased length of cutting edge (LCE) as the helix angle (hx) increases.

CASE 1

Dia (Dc) = 12mm
Helix Angle (hx) = 50°
ø = 40°
ap = tan(40) * π * 12
ap = 31.64mm
LCE = ap/sin(40)
LCE = 31.64mm/sin(40)
LCE = 49.22mm

CASE 2

Dia (Dc) = 12mm
Helix Angle (hx) = 30°
ø = 60°
ap = tan(60) * π * 12
ap = 65.32mm
LCE = ap/sin(60)
LCE = 65.32mm/sin(60)
LCE =75.42mm



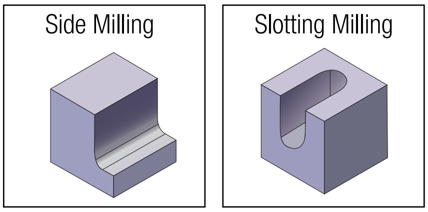
This basically indicates that at a lower helix, the length of the cutting edge increases
Let us now assume that in Case 2, we need to take the same ap as in Case 1 which is 31.64mm.

LCE= ap/sin(60)   LCE= 31.64mm/sin(60)   LCE= 36.53mm

This gives us an insight that at a similar ap the LCE reduces as the Helix reduces

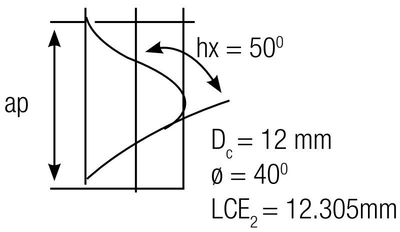
Now that we have understood that the helix has a relationship to the cutting edge length.

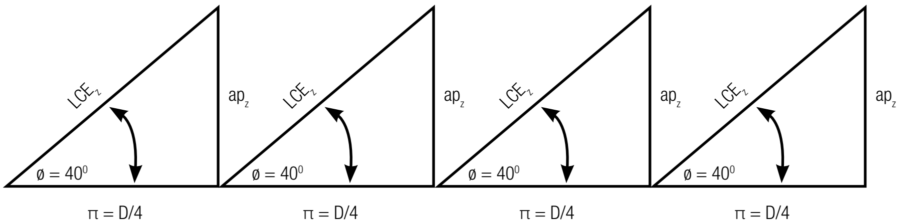
Let us now understand the relevance in 2 scenarios (Slotting and Side Milling)



Now let us assume you are slotting a part with a diameter of 12mm and you need to make a slot of 12mm with a 4 flute end mill (Let us consider Case 1 that the tool has a 50 degree Helix and the LCE is 49.22mm.

Let us consider that the max ap based on each flute before the second flute starts to cut is apz and the max length of cutting edge is LCEz





Now using simple trigonometry we can achieve

CASE 3

Dia (Dc) = 12mm

Helix Angle (hx) = 50°

ø = 40°

$\mathbf{ap_z}$ = tan (40) * π * 12/4

$\mathbf{ap_z}$ = 7.91mm

$\mathbf{LCE_z}$ = ap_z/sin (40)

$\mathbf{LCE_z}$ = 7.91mm/sin (40)

$\mathbf{LCE_z}$ = 12.305mm

This is a case where there is no teeth overlapping, which causes zero or no micro vibrations

This Case is where the flutes overlap while cutting. This causes micro vibrations.

To resolve this, you can either modify the helix angle (hx) or the Diameter of the tool

Dia (Dc)= 12mm, ap_z = 12mm   Helix Angle (hx) = 50o   ø =40°

From Case 3

We know ap_z for no overlap is 7.91mm with hx 50°

For apz = 12mm with no overlap with 12mm Dia, we will recalculate the hx

tan(ø) = apz/(ϖ X D/4)

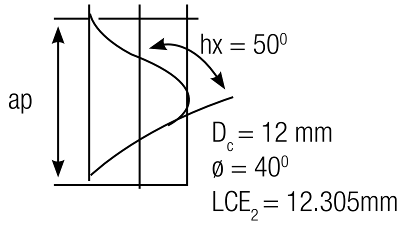
tan(ø) = 12/(ϖ X 12/4)

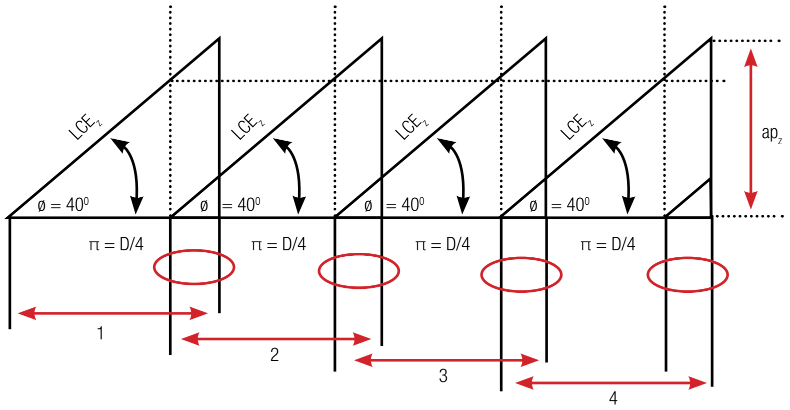
tan(ø) = 1.2727

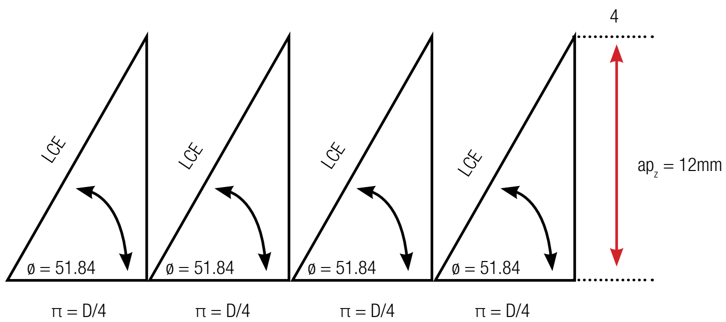
ø = tan-1(1.2727)

ø = 51.84°

hx = 38.16°







CASE 4

For ap_z = 12mm with no overlap with 12mm Dia, we will recalculate the hx

tan(ø) = ap_z/(π X D/4)

tan(ø) = 12/(ϖ X 12/4)

tan(ø) = 1.2727

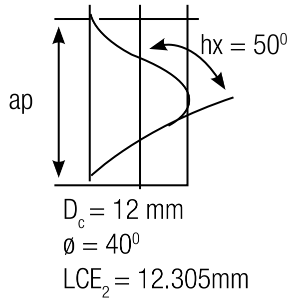
ø = tan-1(1.2727)

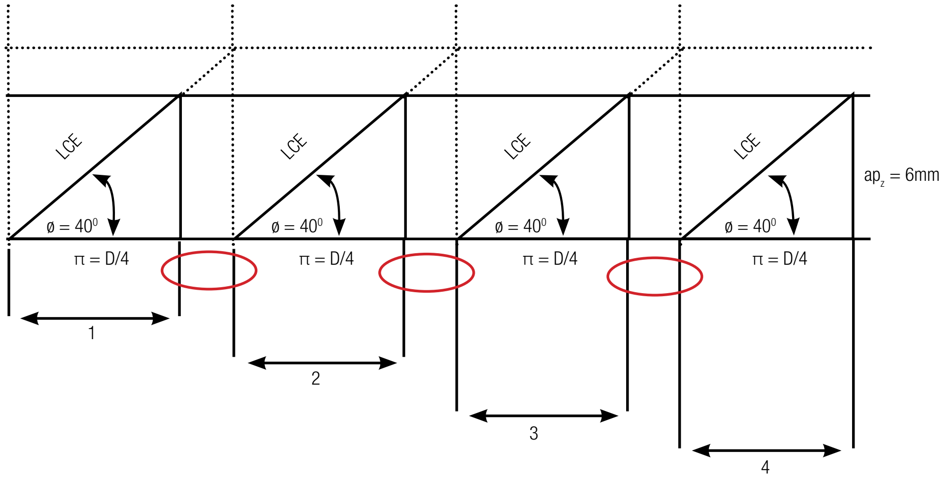
ø = 51.84°

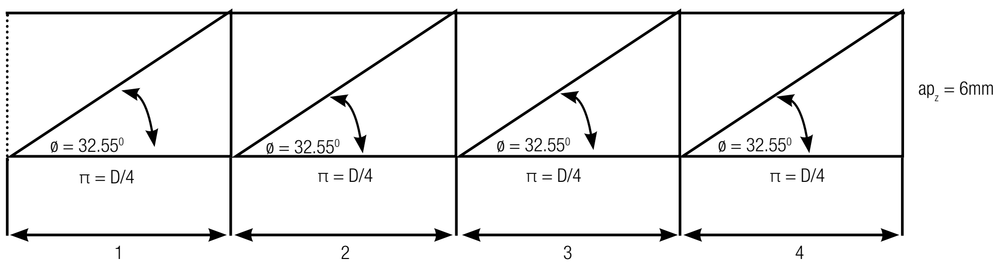
hx = 38.16°

This Case is where the flutes do not overlap while cutting. Causing micro vibration.
To resolve this, you can either modify the helix angle (hx) or the Diameter of the tool

This Case is where the flutes do not overlap while cutting. Causing micro vibration.
To resolve this, you can either modify the helix angle (hx) or the Diameter of the tool







CASE 5

Dia (Dc) = 12mm

ap_z = 6mm

Helix Angle (hx) = 50°

ø =40°

From Case 3

We know ap_z for no overlap is 7.91mm with hx 50°

For ap_z = 6mm with no overlap with 12mm Dia, we will recalculate the hx

tan (ø) = ap_z/(π X D/4)

tan (ø) = 6/(π X 12/4)

tan (ø) = 1.2727

ø = tan^{-1}(0.67364)

ø = 32.55°

hx = 57.55°

This in essence tells you that if you want to slot the part at 1XD you will need to optimize your helix angle at 38.16 degrees to ensure that you have no Micro vibrations due to teeth overlapping

Please see below table which indicates the maximum dept you can machine without teeth overlap with various number of flute options with Standard Helix angles offered by various suppliers

	3 Flute							
Helix	**30**	**35**	**38**	**40**	**42**	**45**	**50**	**60**
Dc	Max Axial Depth (ap) in mm							
4	7.26	5.98	5.36	4.99	4.65	4.19	3.52	2.42
6	10.89	8.98	8.05	7.49	6.98	6.29	5.27	3.63
8	14.52	11.97	10.73	9.99	9.31	8.38	7.03	4.84
10	18.15	14.96	13.41	12.49	11.63	10.48	8.79	6.05
12	21.77	17.95	16.09	14.98	13.96	12.57	10.55	7.26
16	29.03	23.94	21.45	19.98	18.62	16.76	14.06	9.68
20	36.29	29.92	26.82	24.97	23.27	20.95	17.58	12.10

	4 Flute							
Helix	**30**	**35**	**38**	**40**	**42**	**45**	**50**	**60**
Dc	Max Axial Depth (ap) in mm							
4	5.44	4.49	4.02	3.75	3.49	3.14	2.64	1.81
6	8.17	6.73	6.03	5.62	5.24	4.71	3.96	2.72
8	10.89	8.98	8.05	7.49	6.98	6.29	5.27	3.63
10	13.61	11.22	10.06	9.36	8.73	7.86	6.59	4.54
12	16.33	13.47	12.07	11.24	10.47	9.43	7.91	5.44
16	21.77	17.95	16.09	14.98	13.96	12.57	10.55	7.26
20	27.22	22.44	20.11	18.73	17.45	15.71	13.19	9.07

	5 Flute							
Helix	**30**	**35**	**38**	**40**	**42**	**45**	**50**	**60**
Dc	Max Axial Depth (ap) in mm							
4	4.35	3.59	3.22	3.00	2.79	2.51	2.11	1.45
6	6.53	5.39	4.83	4.49	4.19	3.77	3.16	2.18
8	8.71	7.18	6.44	5.99	5.58	5.03	4.22	2.90
10	10.89	8.98	8.05	7.49	6.98	6.29	5.27	3.63
12	13.06	10.77	9.65	8.99	8.38	7.54	6.33	4.35
16	17.42	14.36	12.87	11.99	11.17	10.06	8.44	5.81
20	21.77	17.95	16.09	14.98	13.96	12.57	10.55	7.26

	6 Flute							
Helix	**30**	**35**	**38**	**40**	**42**	**45**	**50**	**60**
Dc	Max Axial Depth (ap) in mm							
4	3.63	2.99	2.68	2.50	2.33	2.10	1.76	1.21
6	5.44	4.49	4.02	3.75	3.49	3.14	2.64	1.81
8	7.26	5.98	5.36	4.99	4.65	4.19	3.52	2.42
10	9.07	7.48	6.70	6.24	5.82	5.24	4.40	3.02
12	10.89	8.98	8.05	7.49	6.98	6.29	5.27	3.63
16	14.52	11.97	10.73	9.99	9.31	8.38	7.03	4.84
20	18.15	14.96	13.41	12.49	11.63	10.48	8.79	6.05

	7 Flute							
Helix	**30**	**35**	**38**	**40**	**42**	**45**	**50**	**60**
Dc	Max Axial Depth (ap) in mm							
4	3.11	2.56	2.30	2.14	1.99	1.80	1.51	1.04
6	4.67	3.85	3.45	3.21	2.99	2.69	2.26	1.56
8	6.22	5.13	4.60	4.28	3.99	3.59	3.01	2.07
10	7.78	6.41	5.75	5.35	4.99	4.49	3.77	2.59
12	9.33	7.69	6.90	6.42	5.98	5.39	4.52	3.11
16	12.44	10.26	9.19	8.56	7.98	7.18	6.03	4.15
20	15.55	12.82	11.49	10.70	9.97	8.98	7.53	5.18

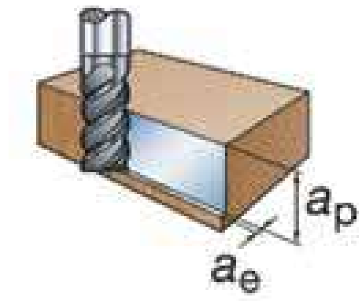
You can further improve your productivity by

1) Using a variable index to reduce vibrations caused due to harmonics caused due to the constant sound of Impact.
2) You can add a edge rounding value to strengthen your cutting edge
3) You can dampen the vibrations further by working in the Safe zones after calculating the FRF of the machine.

Now let's look at side milling as a Topic and understand the relevance of using the entire edge for Peel Milling and Slicing without tooth overlaps which cause micro vibrations with high axial cuts

It is very similar to the Trochoidal Path. It uses

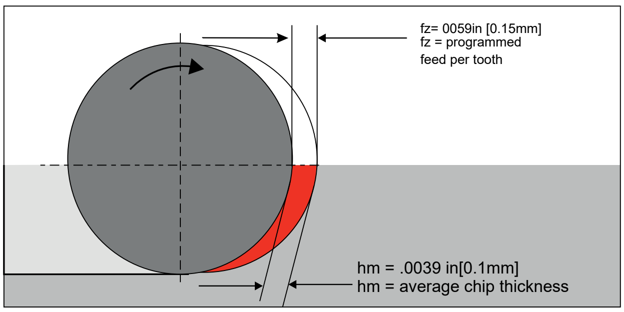
- Small radial cutting depth
- Deep cutting depth
- High cutting speed
- Spiral Cutter
- Roughing method which normally eliminates semi-finishing



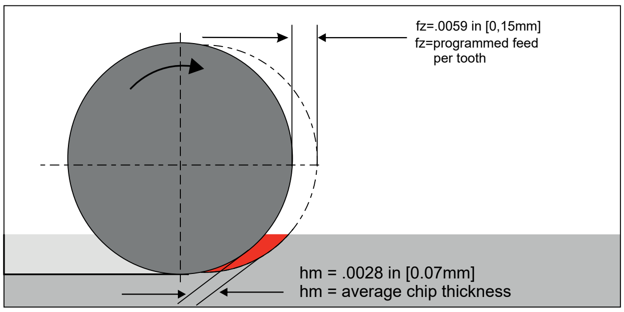
By using a smaller ae% we can use ensure we have a very small engagement angle Beta (ß). This will allow us to use the max LCE while milling without shocking the spindle. This is now dependant on the Workpiece material and the pitch of the tool

In the below 3 images you can see that as the radial engagement (ae/D) Ratio goes from 50% to 10% the Engagement angle reduces

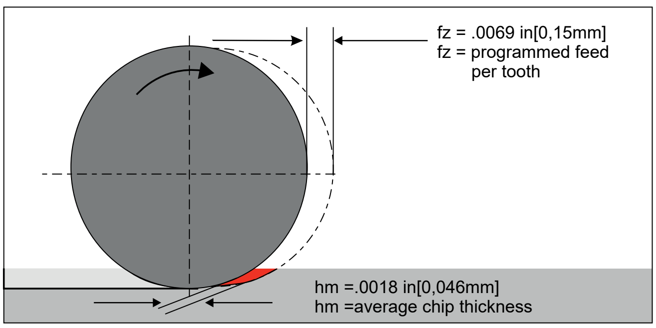
50% Conventional



20% Trochoidal



10% Trochoidal



In the below Chart we have indicated the safe (ae/D) limits to work with while machining various material groups

Material Group	ae/D Max	ae/D Min	Beta Max
Steel P1, P2	20%	10%	53.1
High Alloy Steel P3, P4, P5 & PH	15%	10%	53.1
Tool Steels 45 HRc, P6, PH upto 48 HRc	16%	1%	47.2
Stainlees Steel M1, M2	15%	7%	53.1
Stainless M3, Duplex and Super Duplex	10%	7%	53.1
Cast Iron K1	25%	20%	53.1
S G Iron K2, K3	20%	15%	53.1
Aluminium	30%	20%	66.4
Titanium S4	12%	8%	40.54
Inconel S3	10%	6%	43.2
Super Alloys S1, S2	10%	5%	40.54
Hardened Steel H1 (44-48) HRc	12%	1%	40.54
Hardened Steel H2 (49-55) HRc	5%	1%	25
Hardened Steel H3 (56-60) HRc	2%	1%	17
Hardened Steel H4 >60 HRc	1%	1%	12

Further advanced method is to reduce the load on the spindle and calculate hoe many teeth are in cut based on the pitch and the number of teeth

Please Table shows the number of teeth in contact and the engagement angle range for various options of 4/5/6/7 flute end mills based on the pitch.

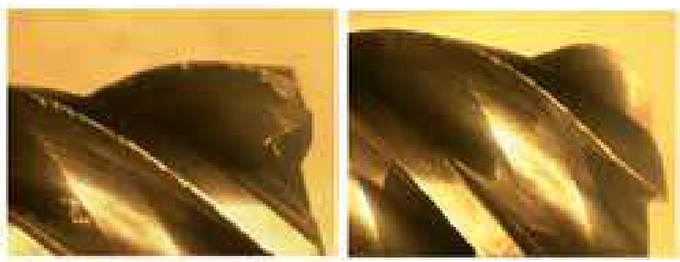
By having this information you can tweak your ae/D ratio to ensure 1 teeth is in contact and the spindle load is the least.

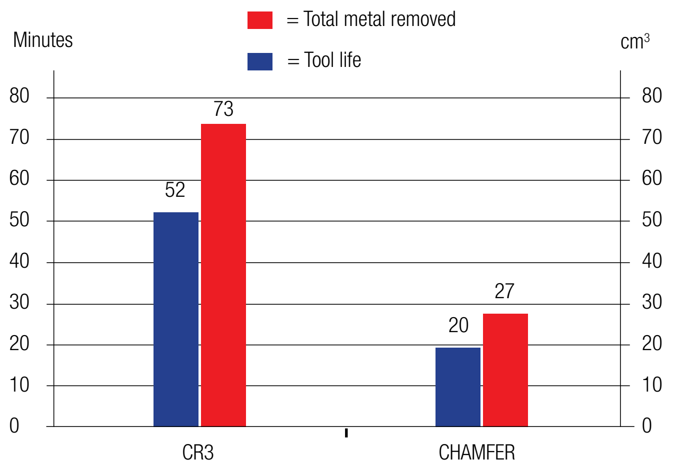
Pitch	Teeth	Angle min	Angle max	Teeth in contact
90.00	4	0	90	1
90.00	4	90	180	2
72.00	5	0	72	1
72.00	5	72	144	2
60.00	6	0	60	1
60.00	6	60	120	2
60.00	6	120	180	3
51.43	7	0	51.43	1
51.43	7	51.43	102.86	2
51.43	7	102.86	154.29	3
120.00	3	0	120	1
120.00	3	120	240	2

Corner geometry

The main wear observed in the case of HSM in Inconel is micro chipping at the cutting edge. A radius end mill, due to increased strength is always better compared to a chamfer or sharp corner.

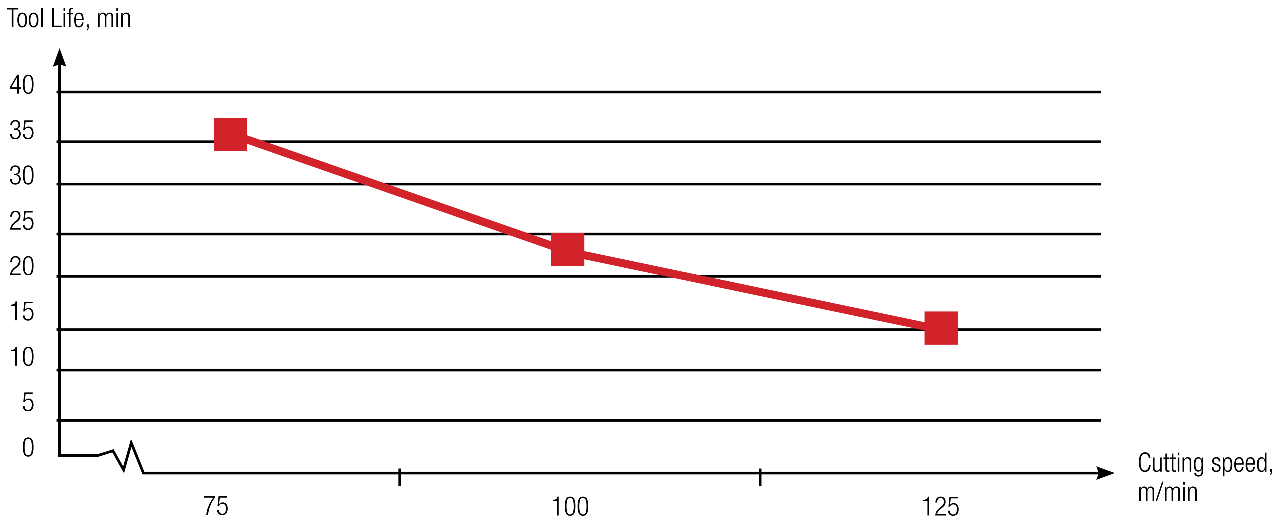
Comparison between chamfer and radius end mill
Vc 100 m/min, ap 10 mm, hex 0.02 mm, ae 0.5 mm,
fz 0.05 mm/tooth Material: Inconel 718





Cutting speed (Vc)

Because of the relatively low radial engagements in HSM one can make use of higher than normal cutting speed (Vc), 75 to 100 m/min gives the best balance between productivity and tool life. The chart shows the difference in performance relative to cutting speed.

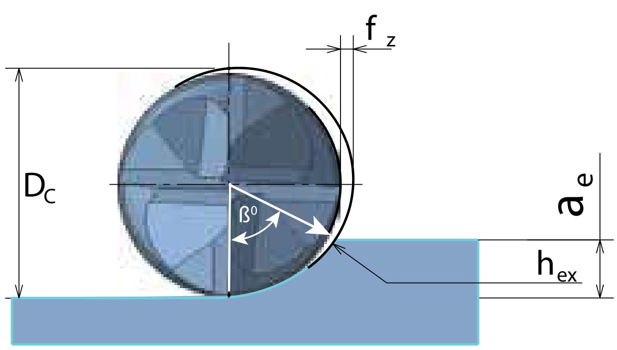


Chip thickness (hex)

The low radial engagement reduces the chip thickness compared to the feed/tooth. Using the optimised chip thickness is pivotal in optimisation of finishing, slicing or trochoidal milling.

Ae/D %		Cutting Speed Multiplication Factor
Lower Limit	Upper Limit	
0.10%	0.50%	2.20
0.50%	1.00%	2.10
1.01%	1.99%	2.00
2.00%	2.99%	1.80
3.00%	3.99%	1.75
4.00%	4.99%	1.65
5.00%	5.99%	1.60
6.00%	10.00%	1.50
10.01%	15.00%	1.40
15.01%	20.00%	1.35
20.01%	25.00%	1.33
25.01%	30.00%	1.30
30.01%	40.00%	1.25
40.01%	50.00%	1.25
50.01%	60.00%	1.15
60.01%	75.00%	1.10
75.01%	100.00%	1.00

% (Ae/D) Enagagement	Chip Load Factor
0.10%	**15.819**
0.50%	**7.089**
1.00%	5.025
2.00%	3.571
3.00%	2.931
4.00%	2.552
5.00%	2.294
6.00%	2.105
8.00%	1.843
10.00%	1.667
12.00%	1.539
15.00%	1.400
20.00%	1.250
25.00%	1.155
30.00%	1.091
40.00%	1.021
50.00%	1.000
60.00%	1.000
75.00%	1.000
100.00%	1.000



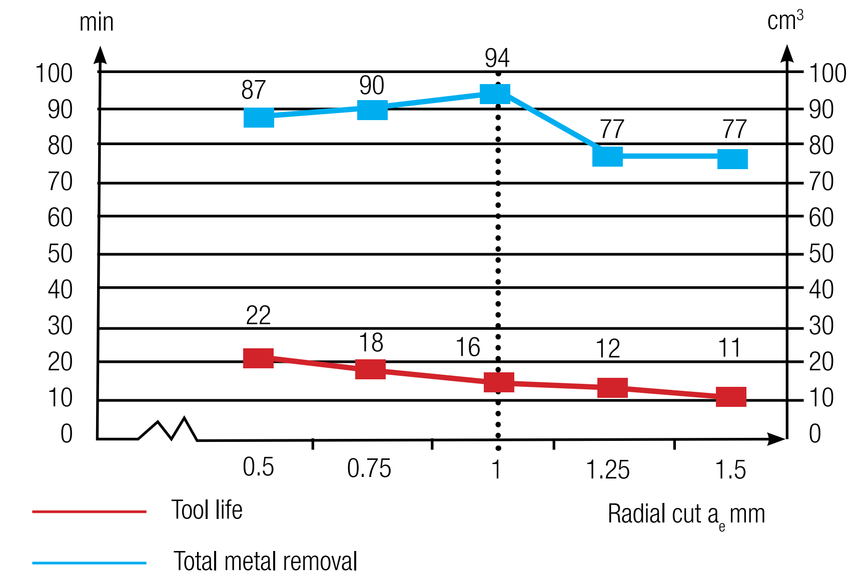
Radial cut (ae)

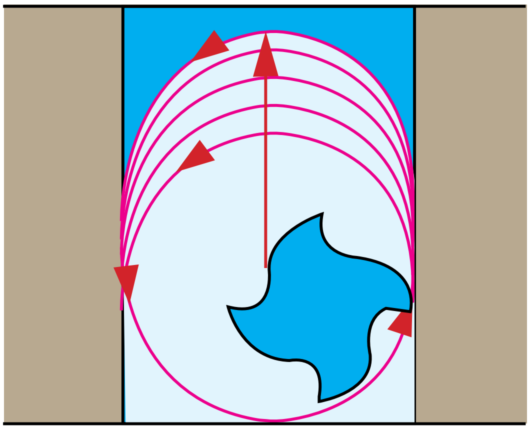
For roughing applications it can be seen in the diagram that the maximum total material removed, when running with a constant speed and chip thickness, can be achieved with ae = 1.0 mm. (for a 12mm tool)

Total metal removed and tool life vs radial cut vc 75 m/min, ap 10 mm, hex 0.04 mm Material: Inconel 718

Test conducted with a 4 Flute (50 degree helix tool)

This equates to 8% ae/Dc and should be used as a base when roughing operations are required.

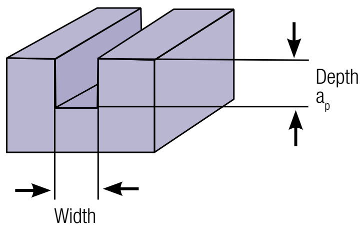




Trochoidal milling

This is an established process in hardened steels and aluminium. Now it is being extensively used in HSRA and Titanium

The process puts low demands on stability and can be an extremely productive and secure method. This is advantageous especially where the components are large and costly calling for a secure productive solution.



Parameter selection

As can be seen, during trochoidal milling, the maximum width of cut – ae max is not equal to the programmed step over-‘w’. The maximum radial cut (ae) max should not exceed 20% of the cutter diameter.

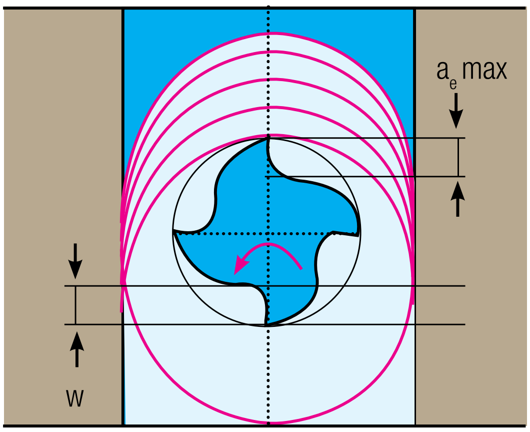
Start recommendations for trochoidal milling:

Cutter diameter, mm Dc = 65% slot width

Step over, mm w = 8% Dc,

ap = 1 to 1.5 x Dc, Cutting speed vc = 75m/min

Feed/tooth fz = 0.05mm/tooth



ae/D Ratio	Radial depth of cut (ae) based on diameter mm						Enagagement Angle ß	Feed Factor	Cutting Speed Factor
	6	8	10	12	16	20			
0.10%	0.006	0.008	0.010	0.012	0.016	0.020	3.62	15.819	2.25
0.50%	0.030	0.040	0.050	0.060	0.080	0.100	8.11	7.089	2.20
1.00%	0.060	0.080	0.100	0.120	0.160	0.200	11.48	5.025	2.10
2.00%	0.120	0.160	0.200	0.240	0.320	0.400	16.26	3.571	2.00
3.00%	0.180	0.240	0.300	0.360	0.480	0.600	19.95	2.931	1.80
4.00%	0.240	0.320	0.400	0.480	0.640	0.800	23.07	2.552	1.75
5.00%	0.300	0.400	0.500	0.600	0.800	1.000	25.84	2.294	1.65
6.00%	0.360	0.480	0.600	0.720	0.960	1.200	28.36	2.105	1.60
8.00%	0.480	0.640	0.800	0.960	1.280	1.600	32.86	1.843	1.55
10.00%	0.600	0.800	1.000	1.200	1.600	2.000	36.87	1.667	1.50
12.00%	0.720	0.960	1.200	1.440	1.920	2.400	40.54	1.539	1.45
15.00%	0.900	1.200	1.500	1.800	2.400	3.000	45.57	1.400	1.40
20.00%	1.200	1.600	2.000	2.400	3.200	4.000	53.13	1.250	1.35
25.00%	1.500	2.000	2.500	3.000	4.000	5.000	60.00	1.155	1.33
30.00%	1.800	2.400	3.000	3.600	4.800	6.000	66.42	1.091	1.30
40.00%	2.400	3.200	4.000	4.800	6.400	8.000	78.46	1.021	1.27
50.00%	3.000	4.000	5.000	6.000	8.000	10.000	90.00	1.000	1.25
60.00%	3.600	4.800	6.000	7.200	9.600	12.000	101.54	1.000	1.15
75.00%	4.500	6.000	7.500	9.000	12.000	15.000	120.00	1.000	1.10
100.00%	6.000	8.000	10.000	12.000	16.000	20.000	180.00	1.000	1.00

Program CAM

CAD/CAM stands for computer-aided design & computer-aided manufacturing. CAD/CAM software is used to design and manufacture prototypes, finished products and production runs.

In order to generate the actual model, CAM works alongside CAD—using CAD designs, CAM uses numerical coding to run the machine that creates the product. A CAD/CAM package allows companies to develop and save their own product designs, and program machines to create the actual component.

THIN WALL MACHINING GUIDE- ESSENTIALS

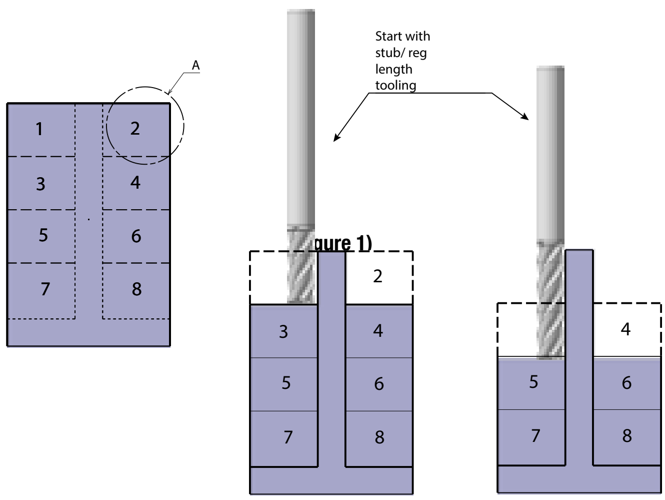
Thin Wall Machining is a new norm in Aerospace Parts, especially structural parts where the use of High strength to weight ratio materials are used like Ti6Al4V and Al6061. To understand the application let us understand BTF ratio. BTF Ratio is the weight of the raw material divided by the weight of the final component. For conventional metal manufacturing like milling, the BTF ratio is often higher than 10, which means that less than 10% of the raw material remains in the final part. Now that we understand BTF ratio, Let's take the example for a floor to frame fitting in an aircraft which at a Raw material stage is 20 Kgs of Ti6Al4V and the finish weight is shy of a kilogram. Some of the Engine parts in an aircraft which have a somplex profile with strategies of thin wall are IBR (Integral Blisk Rotors), Aerofoils and Impellers which will need advanced CAM programming techniques to ensure a smooth profile on a 5 Axis machine.

PROPER TOOLING

Imagine that you need to machine a part where the wall thickness to the height Ratio is above 15. A long length tool, combined with a long length of cut, cannot be used due to deflection, chatter and breakage. It is essential to keep the tool as stable as possible while maintaining the ability to reach to the desired depth. It is essential to look at necked-down tooling when reaching depths more than 3 times the diameter.

UNDERSTANDING AXIAL DEPTH OF CUT (ADOC)

Keeping a wide cross-section behind the wall for support on the way down is vital. Below, we recommend producing a "stepped down" approach dividing the total wall height to manageable depths while working each side of the wall. In the below image the mangebale depth has been indicated with numbers between 1 to 8. Each block height indicating the depth that can be machined in one pass. The ADOC dimension can/will vary depending on the material (and its hardness) being cut.

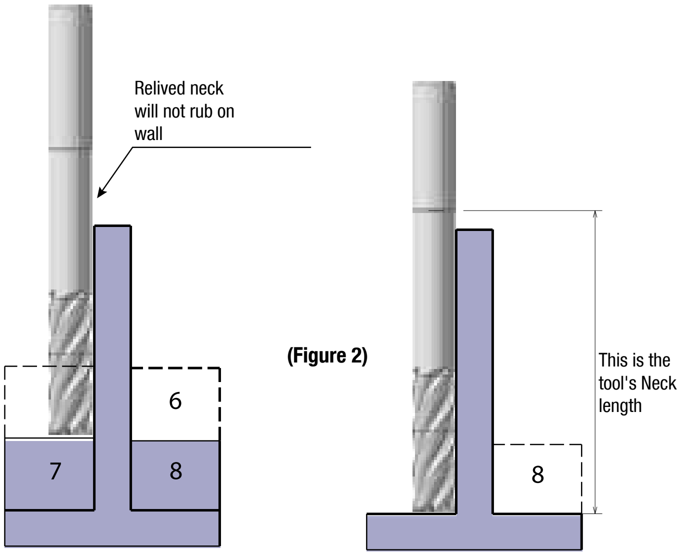


UNDERSTANDING RADIAL DEPTH OF CUT (DOC)

A progressive radial depth of cut (RDOC) strategy is of equal importance as wall height is being established. Reducing tool pressure while support stock is disappearing is equally important to keep wall stable.

OTHER IDEAS

- Climb milling will help to keep tool pressure to a minimum.
- Vibration dampening/wall stabilization can be achieved in "hard to fixture thin wall situations" by using thermoplastic compounds or wax - which can be removed (Ideal when machining parts which have a high thermal stability like Super Alloys and Titanium)   (thermally).
- The use of ultra-high performance tool paths can optimize tool performance, work with lighter depths of cut and offer less tool cutting pressure.



(Figure 2)

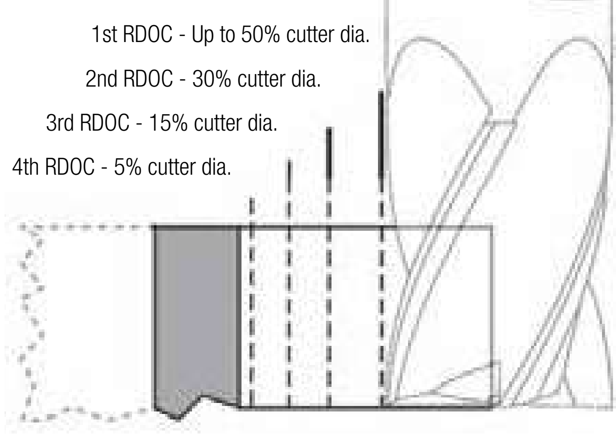
THIN WALL MACHINING CAN BE CATEGORISED INTO 3 TYPES BASED ON THE HEIGHT TO THICKNESS RATIO (H:T)

Ratio H:T of 15:1	Ratio H:T between 15:1- 30:1	Ratio H:T >30:1

STRATEGY

4:1 for Non Ferrous	8:1 for Steel/ Stainless Steel/ Super alloys

Detail A

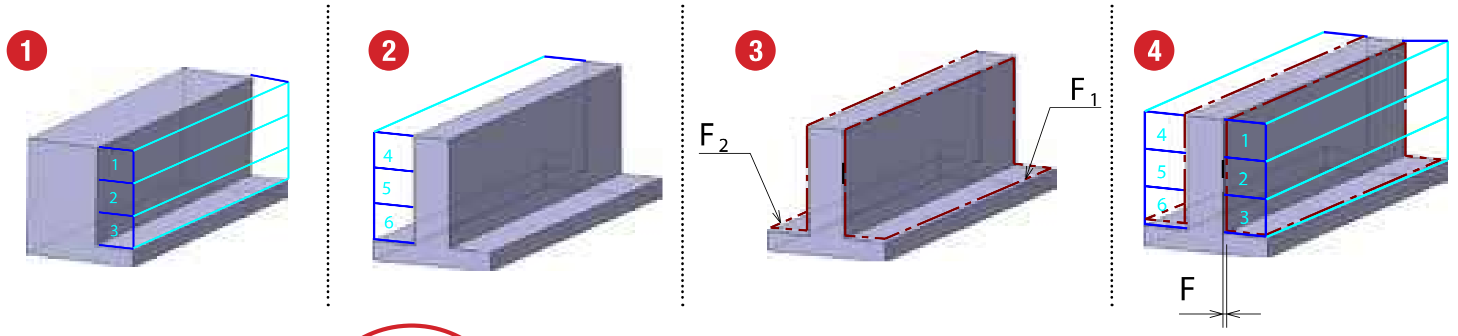


Detail A represents a 5-step progressive radial approach. The number of passes will depend upon your particular application, material/hardness & final wall thickness/height.

Note:
Thin walls deflect under pressure so separate machining passes are required to minimize friction and vibration.

Milling part features with thin wall characteristics while maintaining dimensional accuracy and straightness can be difficult at best. Although multiple factors contribute, some key components are discussed below and can help turn these types of applications around.

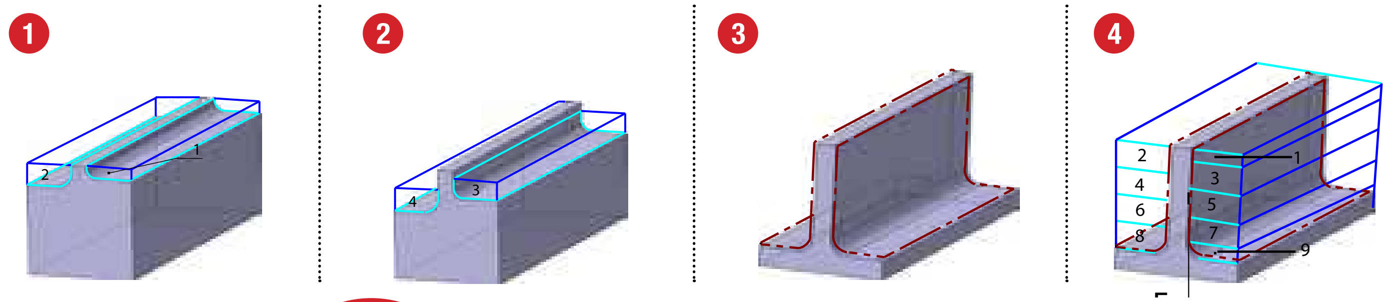
RATIO H:T OF 15:1



STABILITY
RELATIVELY STABLE

- Machine each side of the wall in overlapping passes
- Leave clearance on the faces for finishing passes
- When machining 15:1 and lower please ensure that you follow the above flow of steps

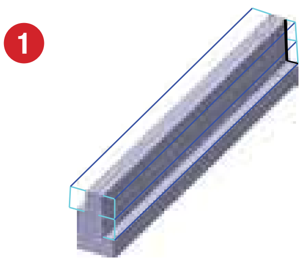
RATIO H:T OF 30:1

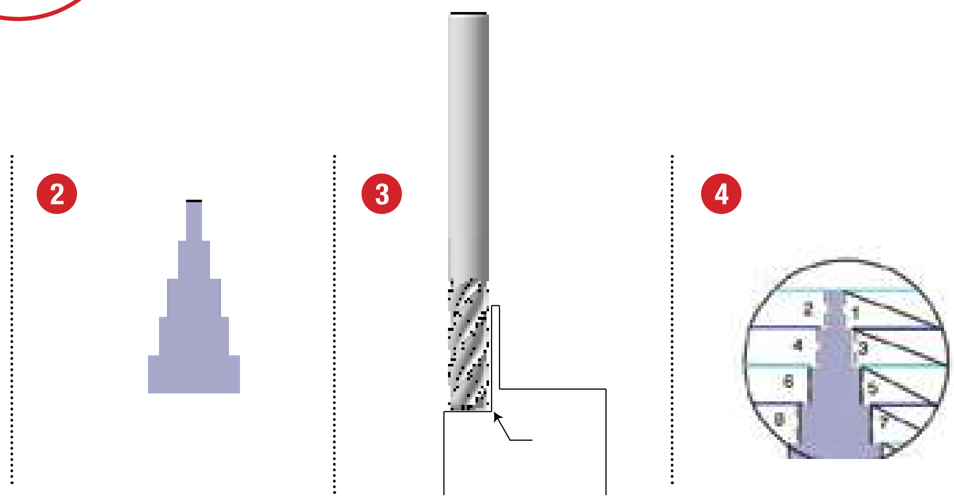


STABILITY
LESS STABLE AND PRONE TO DEFLECTION

- Choose step-support milling, with passes on alternate sides of the wall
- Overlapping passes provide material support to add stability
- Less than 30:1 for Non ferrous structures ensure that the last machining pass takes out 80% of the material and For high strength materials like super alloys keep 0.2mm as a finish stock. For ferrous materials you can keep stock between 0.2mm-1mm

RATIO H:T >30:1





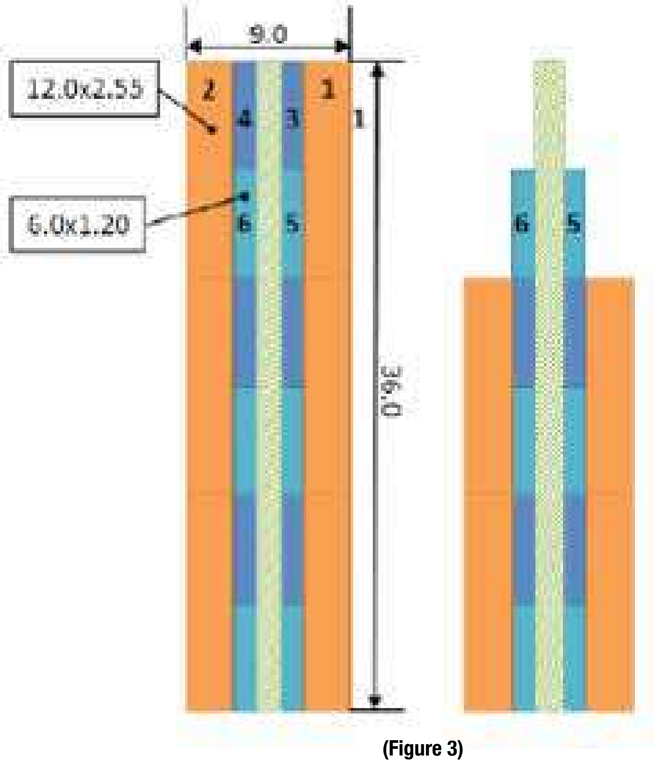
STABILITY
VERY UNSTABLE

- Machine passes on alternating sides of the wall
- Approach the wall thickness in stages
- The material support of thicker sections is crucial as thinner sections are being machined
- Move passes down the wall in a step formation moving outwards

STRATEGY 4:1 FOR ALUMINIUM

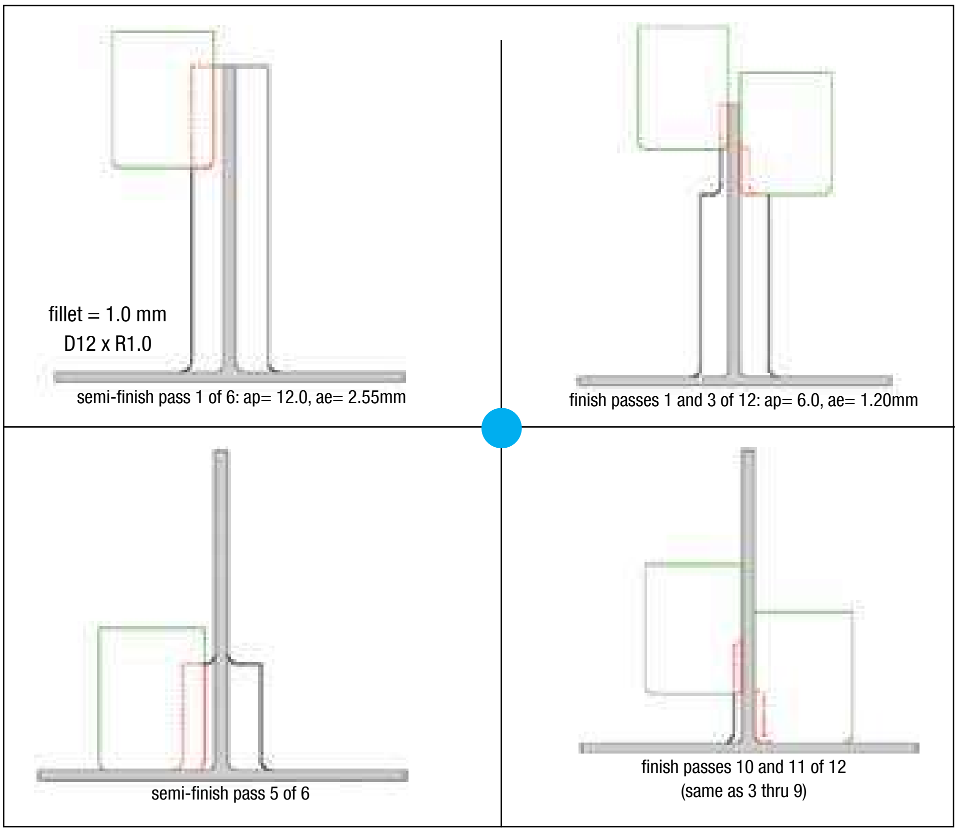
- 4:1 rule – ratio of wall height to wall thickness
- In our case the wall is 36 mm tall, hence in roughing we reduced the wall to 9 mm thick
- During finishing too the axial DOC cannot be larger than 4 x wall thickness
- In our case finished wall thickness is 1.5 mm, hence max. axial DOC is 6 mm
- Finishing is typically done in 2 radial passes, with the last pass removing ~80% of final wall thickness, i.e. a radial DOC of
  1.2 mm
- Hence wall is 3.9 mm thick before final finishing, i.e. a pre-finish will remove 5.1 mm.
- Apply the 4:1 rule again, i.e. 4 x 3.9 = 15.6 mm axial DOC for pre-finish cut. (Practically take as 12 mm)
- Applying the 4:1 rule results in 18 passes to finish each wall.
- Wall is divided into three levels, each level requiring 2 pre-finish cuts and four finish cuts.

Waterfall Technique



(Figure 3)

(Figure 4)



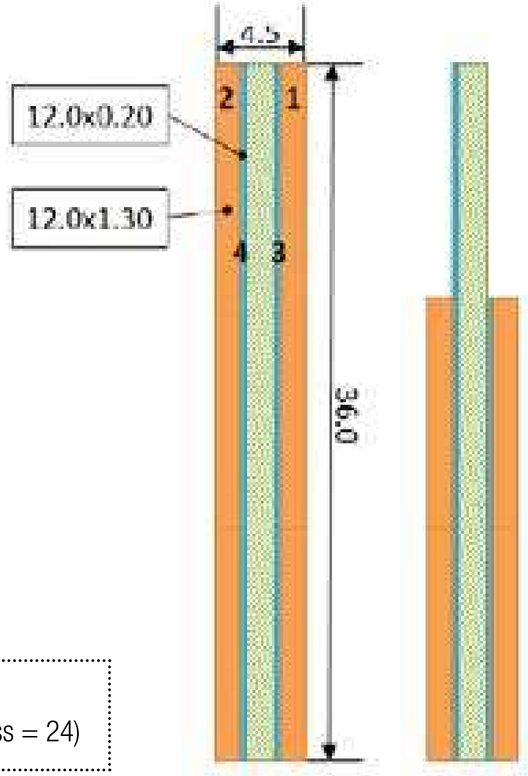
(Figure 5)

THIN WALL MACHINING - TITANIUM

In order to machine thin pocket walls in titanium without vibration problems, the eight-to-one rule (8:1) can be used to devise the machining plan. This approach, ensures the part is always stiff enough to machine, avoiding part vibrations.

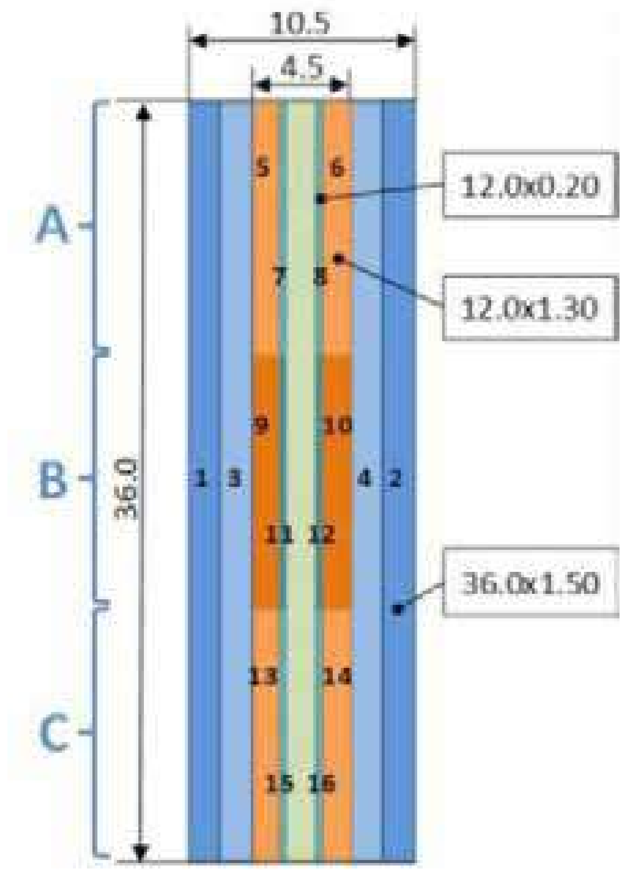
Aircraft structural parts have complex shapes, hence work piece chatter is difficult to eliminate as natural frequencies change constantly during machining.

Using the 8:1 rule makes the titanium part "rigid", allowing you to focus on only optimizing your cutters to be able to achieve the cuts resulting from the method (smaller cuts can be taken but will slow down machining). Hence, titanium behaves as a stiffer material than aluminum where the ratio is 4:1.



(Figure 6)

The application of the rule is done in reverse order (Figure):
Example :- thin wall 36.0mm high, 1.5mm thick (ratio of height to thickness = 24)



(Figure 7)

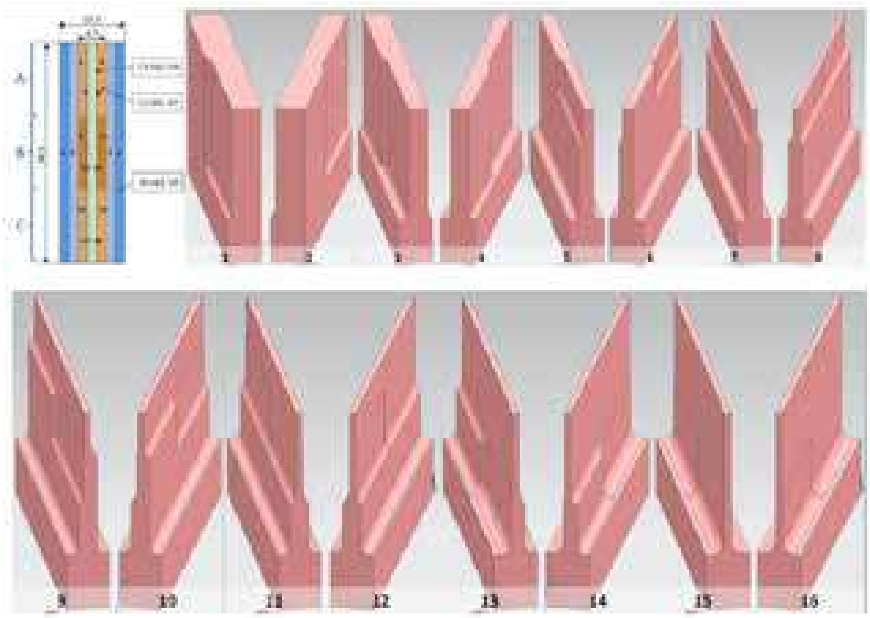
The result of roughing and semi finishing needs to result in a ratio of wall height and wall thickness of 8:1 (no more); Example: for a 36.0mm wall, the thickness after roughing and semi-finishing should be 4.5mm or more.

When taking the final finishing pass, the axial depth of cut cannot be larger than 8 times the finished wall thickness; Example: for a 1.50mm thick wall, the maximum cutting depth is 12.0mm

Finishing is typically done in two radial passes (depending on wall height), the last one removing 0.20mm; this wall will measure 1.50+2x0.20=1.9mm thick before final finishing.

As the wall measures 4.5mm thick after rough/semi-finish, there is 1.30mm to remove before final finishing to obtain a 1.9mm thick wall, which is done by a pre-finish cut.

Repeated application of the 8:1 rule allows to take us 8x1.9=15.2mm axial depth of cut. In this case it's practical to use 12.0mm depth, which will then be followed by finishing at the same depth.

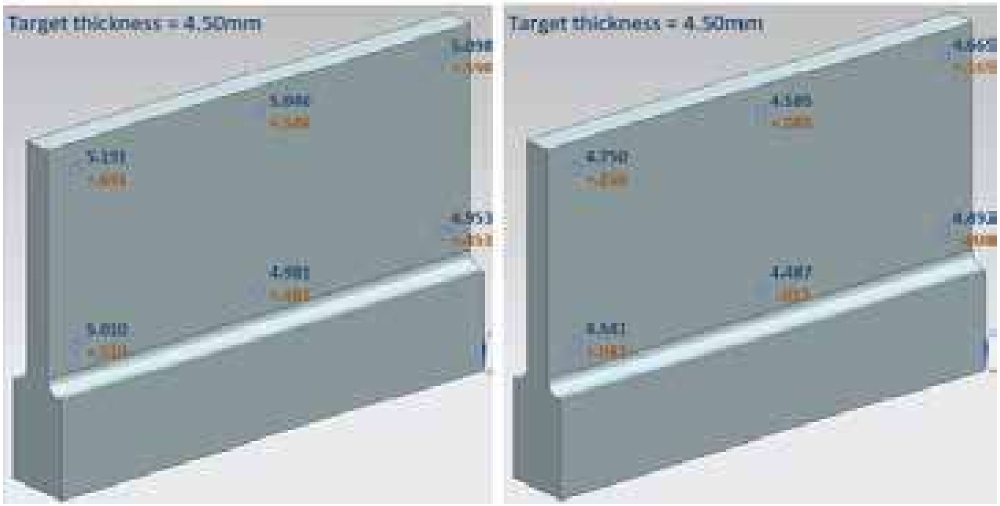


(Figure 8)

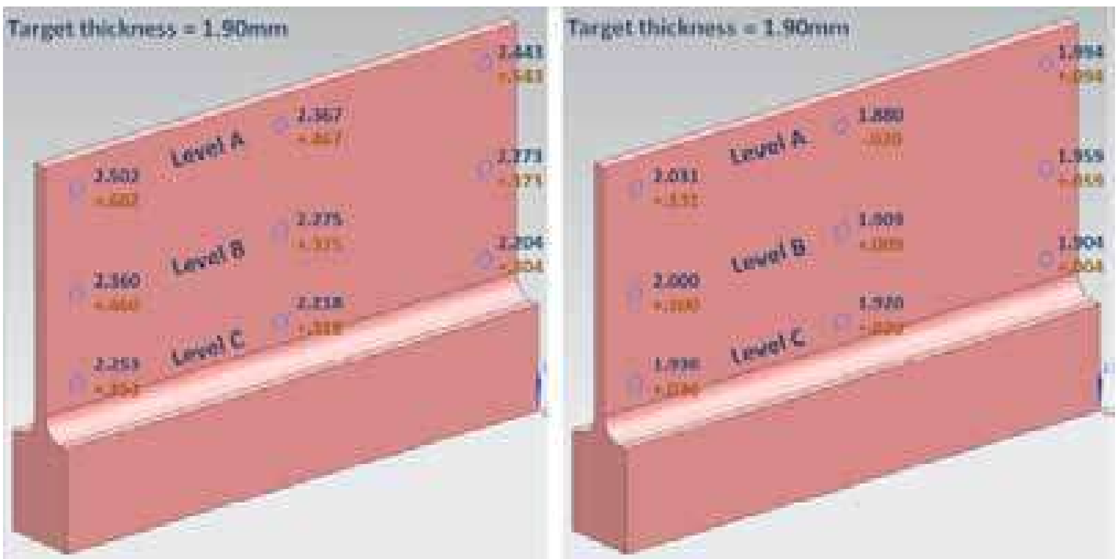
Figure 8 Titanium plate machining steps; 1-4 roughing; 5-6 semi-finish, 7,8 finish; Images of the partially machined work pieces were generated using Unigraphics NX7.5

First Stage

Roughing Wall thickness readings



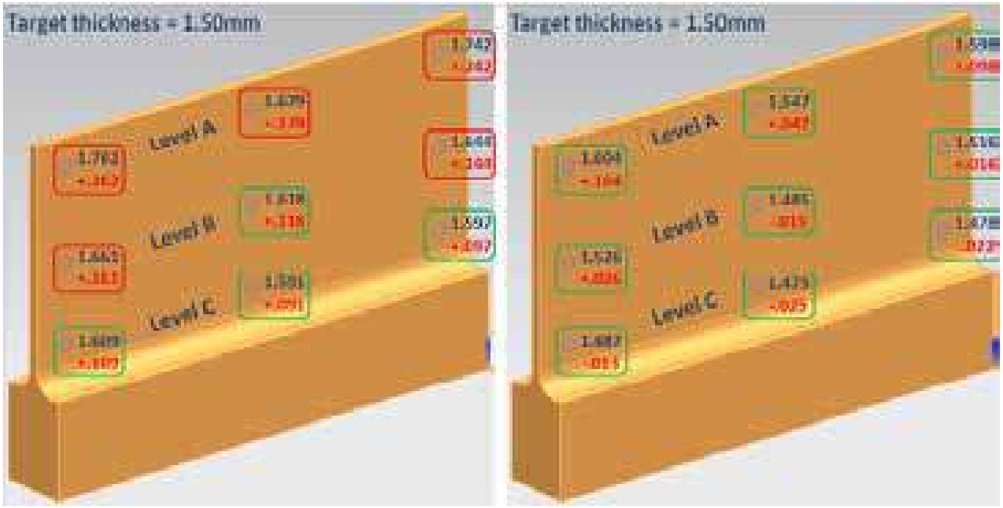
(Figure 9)



(Figure 10)

Second Stage

Semi Finish wall thickness readings



Third Stage

Finish Wall thickness Readings

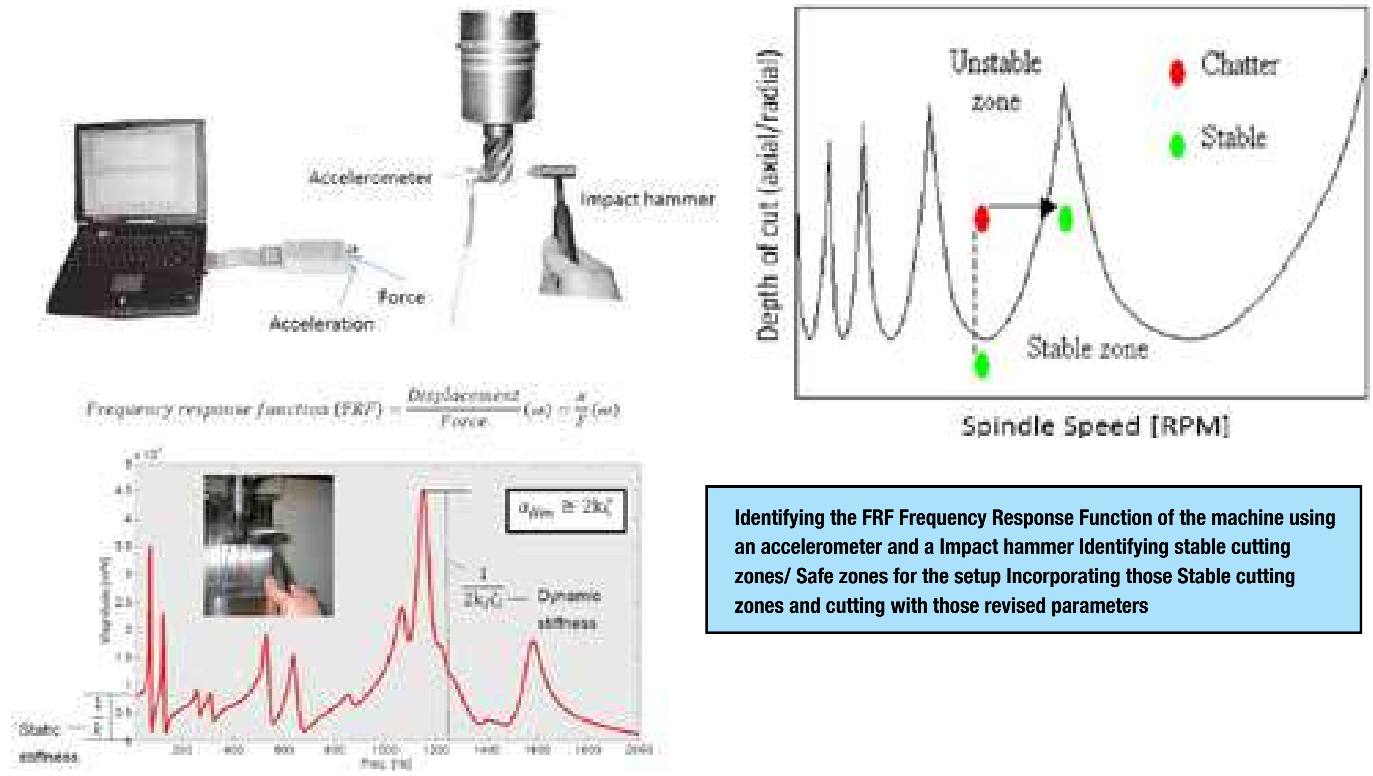
(Figure 11)

THIN WALL MACHINING GUIDE- TITANIUM 8:1 (ACTUAL READING)

Machining Step	Location	Part deflection (µm)	Tool deflection (µm)	Total deflection (µm)	NC program Compensation (µm)
Step 1 Roughing	Top	42	130	172	250
Step 2 Roughing	Top	52	130	182	250
Step 3 Roughing	Top	69	130	199	250
Step 4 Roughing	Top	114	130	244	250
Step 5 Semi-finishing	Top	108	117	225	250
Step 6 Semi-finishing	Top	131	117	248	250
Step 7 Finishing	Top	37	28	65	50
Step 8 Finishing	Top	41	28	69	50
Step 9 Semi-finishing	Middle	44	117	161	180
Step 10 Semi-finishing	Middle	60	117	177	180
Step 11 Finishing	Middle	20	28	48	50
Step 12 Finishing	Middle	23	28	51	50
Step 13 Semi-finishing	Bottom	12	117	129	140
Step 14 Semi-finishing	Bottom	25	117	142	140
Step 15 Finishing	Bottom	14	28	42	50
Step 16 Finishing	Bottom	15	28	43	50

The below readings were further dealt with using an accelerometer and the vibrations were resolved. (Figure 12)

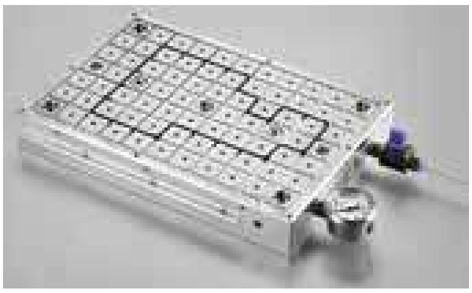
THIN WALL MACHINING GUIDE- TITANIUM 8:1 (FRF)



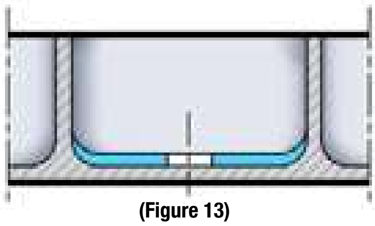
Identifying the FRF Frequency Response Function of the machine using an accelerometer and a Impact hammer Identifying stable cutting zones/ Safe zones for the setup Incorporating those Stable cutting zones and cutting with those revised parameters

(Figure 12)

THIN POCKET FLOOR MACHINING

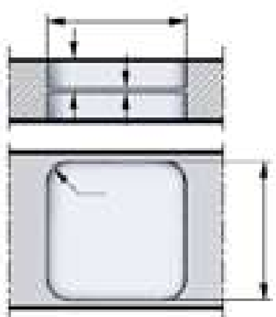


If a thin pocket floor is fully supported by fixturing one sided web, see (Figure 13), radial step-over and feed are adjusted to obtain the required surface finish, by pocketing from the center to the walls. You start by opening it from the center and then going outward towards the walls.



(Figure 13)

If you have a two-sided web that is not supported (Figure 14) when the second side is being finished, you have to leave a thicker floor on the last side to finish. The first side can be finished as if it was supported. The last side is stepped down in small axial passes until the finished floor before you step out radially (“down and over” technique). This method will take longer to machine but has the advantage of simple and cheap fixturing. For very large production runs, vacuum tooling maybe more cost-effective.



(Figure 14)

Note :- When machining the final pass of first side keep Ae 30% of D. This will ensure that the Surface does not attract too much of Axial force but more radial force. When machining the final pass of the second side ensure that the Ae is 60% of D. It may not give you the best surface finish but will ensure least vibrations and warpage

Industry Solutions

Tooling solutions that Takes productivity to next level.

Aerospace industry is one of the most technically advanced industries in the world. Continuous improvement in material science, high level precision involved and cost pressure add to the list of challenges.

Totem's wide range of high performance tooling solution gives best performance in class performance which meets all the stringent tolerance requirements of the aerospace industry.

Through the focused application of Technology in Cutting, Totem is your ideal productivity partner.

AEROENGINE

Manufacturing components of Aero engine requires an in-depth knowledge in the field the complex difficult to machine materials, their properties and best tools to do the job.

Totem offers range of high performance tooling solutions that can help you manufacture most of the aero engine component.

Our highly experienced team of application engineers bring in years of experience in aero-engine solutions, which ensure high tool life and required cost for component.

CASINGS

Casing are manufactured from nickel and exotic alloys, these large and highly complex components present a host of machining challenges for cost effective manufacture.

Totem has number of proven case studies for the machining of combustion casings, including scallops, bosses and all scanned surfaces.

BLISK

Blisks are manufactured from both Titanium and Nickel, these are considered as difficult to machine materials, these critical components are becoming more common due to the advantages of weight, efficiency and through-life servicing.

Totem has developed range of tooling solutions for the roughing, semi-finish and finish machining of various bladed rotors.

FAN DISC

Manufactured from titanium this highly complex component has numerous critical features.

Through an extensive programme of research & development, Totem has developed market leading fan disc tooling and application strategies for the production of multiple features, including:

- Bulb slot milling
- Hook milling
- Scallop milling
- Flange milling

FAN BLADES

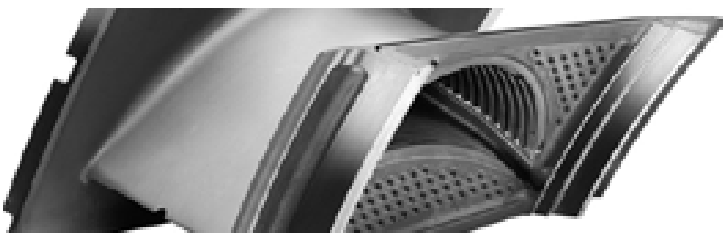
Traditionally manufactured from titanium, Totem has a wide range of tools specially developed for machining of complete components including; aerofoil surfaces, platforms and roots.

Recent market developments have introduced carbon fibre fan blade technology with the subsequent need for highly complex titanium shrouds or leading edges. Totem has optimised tooling range which are apt for the production of these difficult to machine components.

AEROFOILS

Aerofoils are manufactured from titanium, nickel and other HRSA's, Totem has wide range of tooling solution specially developed machining aerofoil and application strategies for the machining of complete components including; aerofoil surfaces, leading & trailing edges, platforms and roots.

Carbon fibre fan blade technology has being developed with the subsequent need for highly complex titanium shrouds or leading edges. Totem has been pioneer in this component evolution and has developed optimised tooling solutions for the production of these critical parts.



NGV

Nozzle Guide Vanes are advance form of airfoils which are made of composite materials as it has to bear extreme temperatures inside the Turbine

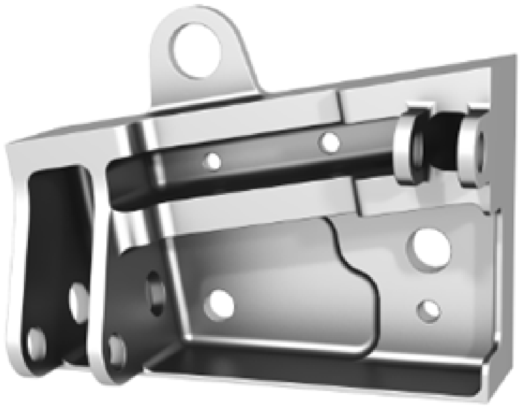
Totem has years of experience in the machining of Nozzle Guide Vanes using carbide end mills, ball nose cutters, drills and reamers.

Tight tolerance is maintained to allow complex NGV shapes to be machined with very high accuracy as well as being suitable for adaptive machining / auto-correction.

IP / HP DISC

IP/HP Discs are manufactured from nickel and exotic alloys, Totem has developed range of specially designed tooling solutions for the manufacturing of high pressure disc component with below features.

- V-Slot Rough Milling
- Fir-Tree Milling



AEROSTRUCTURE

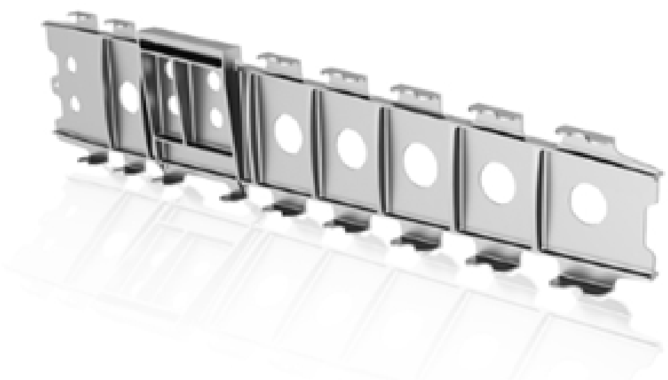
Totem has special solutions developed keeping in mind the complex aerospace structural components requirements which have advanced applications with reduced cycle time.

Our tooling solutions comprises of tool material and geometry optimisation, tool holder specification, defined application parameter provision and programming methodology support to ensure the delivery of absolute component quality with maximised cost effectiveness.

TITANIUM STRUCTURES

Totem's innovative titanium machining tools has numerou applications including:

- Pylon Brackets
- Engine Mounts
- Landing Gear Structures
- Floor to frame fittings



ALUMINIUM STRUCTURES

Totem's solutions for aluminium machining solutions are designed for several aerospace applications including:

- Ribs
- Spars
- Skins

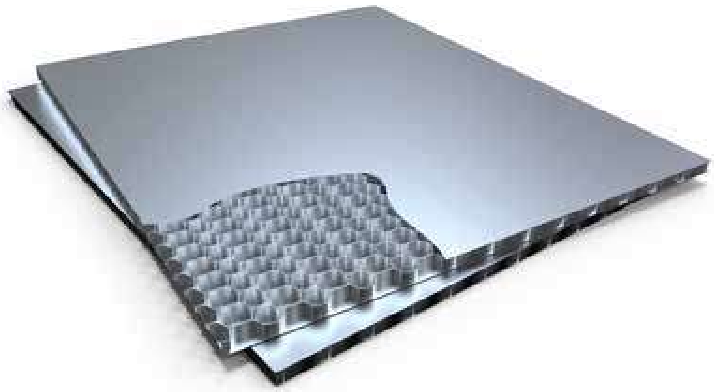
Our Razorcut series are specially designed to provide high performance machining for all aerospace alloy grades keeping in mind the machining challenges of the components such as the thin walls and bases of Ribs etc.

Totem's aluminium tooling ranges are balanced by design to precisely control the consistency of the cutting edge at high speed rotations enabling high efficiency and stable machining with repeatable accuracy.

AIRFRAME

Totem offers unique drilling and machining solutions for a wide range of airframe applications across fuselage, wing, leading edge, trailing edge and tail structures.

Many different types of materials are used in airframe manufacture, including aluminium, composites and titanium, Totem manufactures many different tooling solutions in carbide, diamond coated and polycrystalline diamond (PCD) for Hole Production, Edging, Trimming and Surface Generation applications.



COMPOSITES

Composite structures demand unique tooling solutions. Totem's composite tooling excellent production performance with reduced cost per component.

The combination of stacked composite structures, commonly layered with aluminium and titanium alloys, generate additional manufacturing challenges and increase the need for optimised tooling designs.

Totem's range of composite tooling is developed to overcome the inherent challenges of these demanding material combinations.

HOLE PRODUCTION

Our drill geometries produce high quality holes by actively reducing delamination and splintering, while effectively controlling chip evacuation.

Totem supplies complete process tooling solutions for all composite applications including, drills, reamers, countersinks in both carbide and diamond coated options

EDGING, TRIMMING & SURFACE GENERATION

Our composite machining solutions, both diamond coated carbide, reduce fibre splintering and generate improved MRR's, with the ability to reduce or eliminate secondary operations through significantly improved surface finish.

CONTENT

High Performance Cutting Tools

RAZORCUT CBC/CBCH/NCBCH

80

WORK PIECE MATERIALS

PRIMARY
(Aluminium 6000/7000 series)

SECONDARY
(Wrought Aluminium 6061 & Cast Aluminum 6061)

FEATURES
- 3 Flutes
- Center Cutting
- Coarse Pitch (CBC)/Chamfered Pitch (CBCH/NCBCH)
- Roughing for Aluminium
- Uncoated

FUNCTION
- High MRR
- Excellent for Roughing of Alumnium

BENEFITS
Superior Tool Life

FOR TROCHOIDAL MILLING

Note:- Ask for the TiCN Coated Program to machine Cast Aluminium Skin

RAZORCUT 1F

81

WORK PIECE MATERIALS

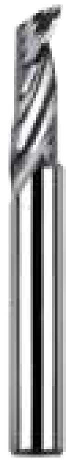
PRIMARY
(Aluminium & Plastics)

SECONDARY
(Delerine, PEEK, Organic Materials)

FEATURES
- 1 Flute
- 30 Degree Helix
- Unique flute design for excellent wall finish
- Uncoated & Polished
- Sharp Cutting Edge

FUNCTION
- High MRR
- Excellent for machining Plastics, Delerine and Organic materials

BENEFITS
- Superior Tool Life
- Excellent floor finish



Note:- Ask for the Hard Carbon coated for superior productivity

RAZORCUT 2FWF

81

WORK PIECE MATERIALS

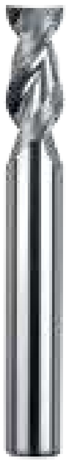
PRIMARY
(Aluminium 6000/7000 series)

SECONDARY
(Wrought Aluminium 6061 & Cast Aluminum 6061)

FEATURES
- 2 Flutes
- 45 Degree Helix
- Center Cutting
- Wiper Design for Excellent floor finish
- Uncoated

FUNCTION
- High MRR
- Excellent for finishing of Alumnium

BENEFITS
- Superior Tool Life
- Excellent floor finish



RAZORCUT 3FWF/3FWFCR/3FWFXL

81

WORK PIECE MATERIALS

PRIMARY
(Aluminium 6000/7000 series)

SECONDARY
(Wrought Aluminium 6061 & Cast Aluminum 6061)

FEATURES
- 3 Flutes
- Unequal flute Design
- Center Cutting
- Wiper Design for Excellent floor finish
- Uncoated

FUNCTION
- High MRR
- Excellent for finishing of Alumnium

BENEFITS
- Superior Tool Life
- Excellent floor finish

FOR TROCHOIDAL MILLING

Note:- Ask for the TiCN Coated Program to machine Cast Aluminium Skin

RAZORCUT 3F

82

WORK PIECE MATERIALS

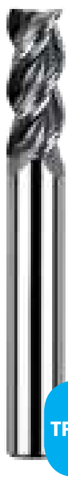
PRIMARY
(Aluminium 6000/7000 series)

SECONDARY
(Wrought Aluminium 6061 & Cast Aluminum 6061)

FEATURES
- 3 Flutes
- Unequal flute Design
- Center Cutting
- Uncoated

FUNCTION
- High MRR
- Excellent for semifinishing of Alumnium

BENEFITS
- Superior Tool Life
- Excellent floor finish



FOR TROCHOIDAL MILLING

HEX3 & HEX3L

83

WORK PIECE MATERIALS

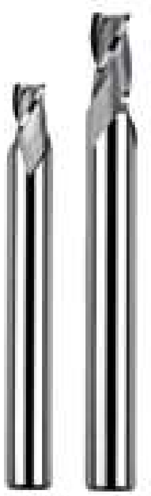
PRIMARY
(Aluminium 6000/7000 series)

SECONDARY
(Wrought Aluminium 6061 & Cast Aluminum 6061)

FEATURES
- 3 Flutes
- Robust Core for General Milling of non ferrous materials
- Center Cutting
- Uncoated

FUNCTION
- High MRR
- Excellent for semifinishing

BENEFITS
- Superior Tool Life
- Excellent floor finish



CONTENT

F192CB / F192 CBL
83

WORK PIECE MATERIALS

PRIMARY: (Steel)

SECONDARY: (Cast Iron)

FEATURES
- 3-4 Flutes
- Center Cutting
- Sinosoidal Pitch
- Superior Coating

FUNCTION
- High MRR
- Stable cutting at high cutting speeds

BENEFITS

Superior Tool Life

F193CB/NF193CB/NF193CBL
84

WORK PIECE MATERIALS

PRIMARY: (Titanium & PH Steel)

SECONDARY: (Stainless Steel)

FEATURES
- 4-6 Flutes
- Center Cutting
- 45 degree Helix for faster chip evacuation
- Flat pitch
- Superior Coating

FUNCTION
- High MRR
- Excellent for machining Plastics, Delerine and Organic materials

BENEFITS
- Superior Tool Life
- Excellent floor finish

FOR TROCHOIDAL MILLING

NANO
85

WORK PIECE MATERIALS

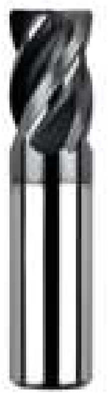
PRIMARY: (Steel & Stainless Steel)

SECONDARY: (Cast Iron)

FEATURES
- 4 Flutes
- Center Cutting
- Short Length

FUNCTION
- High MRR
- Stable cutting at high cutting speeds

BENEFITS
- Superior Tool Life
- One tool for roughing and finishing operations.
- Milling at a value price when re-grinding is not justified.
- Stable, low-vibration solution with soft cut for mill-turn machines.



TURBO ROUGHER-TR (F177TR / NF177TR)
85

WORK PIECE MATERIALS

PRIMARY: (PH Steel)

SECONDARY: (Stainless Steel)

FEATURES
- Variable pitch and Variable helix
- Stable core geometry
- Optimized centre cutting geometry
- New generation coating
- Available in 4 Flutes
- Available with Neck options

FUNCTION
- High MRR
- Ability to work at high Parameters due to the reinforced core.

BENEFITS
- Higher productivity
- Superior Tool Life.
- Excellent Surface Finish.

FOR TROCHOIDAL MILLING

F194CB
85

WORK PIECE MATERIALS

PRIMARY: (Titanium)

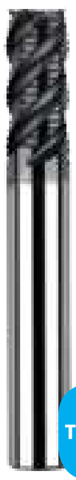
SECONDARY: (Stainless Steel)

FEATURES
- 4-6 Flutes
- Center Cutting
- 45 degree Helix for faster chip evacuation
- Flat pitch
- Superior Coating

FUNCTION
- High MRR
- Stable cutting at high cutting speeds

BENEFITS

Superior Tool Life



FOR TROCHOIDAL MILLING

TURBO ROUGHER-TR (F179TR / F179TRL)
86

WORK PIECE MATERIALS

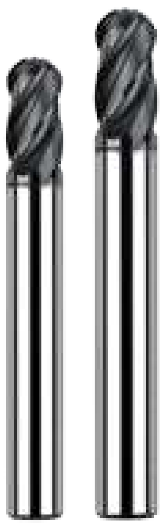
PRIMARY: (PH Steel)

SECONDARY: (Heat Resistant Super Alloys)

FEATURES
- Variable pitch and Variable helix
- Stable core geometry
- Optimized centre cutting geometry ball profile
- New generation coating
- Avaiable in 4 flutes

FUNCTION
- Ability to work at high Parameters due to the reinforced core.
- High MRR
- Higher productivity

BENEFITS
- Superior Tool Life.
- Excellent wall surface finish.
- High MRR



CONTENT

TURBO ROUGHER-TR (F178TR- BLACK) — 87

WORK PIECE MATERIALS

PRIMARY: (Titanium)

SECONDARY: (Heat Resistant Super Alloys)

FEATURES

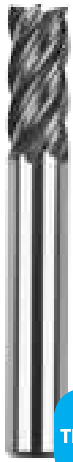
- Variable pitch and Variable helix
- Stable core geometry
- Optimized centre cutting geometry with 3 degree ramping capability
- New generation coating
- Avaiable in 5 Flutes

FUNCTION

- Ability to work at high Parameters due to the reinforced core.
- High MRR
- Higher productivity

BENEFITS

- Superior Tool Life.
- Excellent wall surface finish.
- High MRR



FOR TROCHOIDAL MILLING

TURBO ROUGHER-TR (F178TR- GOLD) — 87

WORK PIECE MATERIALS

PRIMARY: (Stainless Steel)

SECONDARY: (Steel)

FEATURES

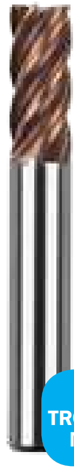
- Variable pitch and Variable helix
- Stable core geometry
- Optimized centre cutting geometry with 3 degree ramping capability
- New generation coating
- Avaiable in 5 Flutes

FUNCTION

- Ability to work at high Parameters due to the reinforced core.
- High MRR
- Higher productivity

BENEFITS

- Superior Tool Life.
- Excellent wall surface finish.
- High MRR



FOR TROCHOIDAL MILLING

5VR — 88

WORK PIECE MATERIALS

PRIMARY: (Titanium)

SECONDARY: (PH Steel)

FEATURES

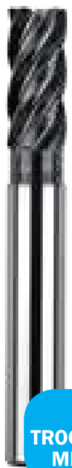
- Robust Core Design
- 5 flutes for High Productivity
- Optimized centre cutting geometry with 3 degree Rmping capability

FUNCTION

- Operates at high cutting speeds
- Geometry programmed to suit adequate material removal at various enagemnet angles

BENEFITS

- Highest dynamic speed rates
- Highest material removal rate
- Least cutting forces
- Prolonged tool life due to reduced shock
- High savings in cycle time when compared to the conventional milling strategy



FOR TROCHOIDAL MILLING

6VR — 88

WORK PIECE MATERIALS

PRIMARY: (Titanium)

SECONDARY: (Stainless Steel)

FEATURES

- Robust Core Design
- 6 flutes for High Productivity

FUNCTION

- Operates at high cutting speeds
- Geometry programmed to suit adequate material removal at various enagemnet angles

BENEFITS

- Highest dynamic speed rates
- Highest material removal rate
- Least cutting forces
- Prolonged tool life due to reduced shock
- High savings in cycle time when compared to the conventional milling strategy

FOR TROCHOIDAL MILLING

TURBO ROUGHER-TR (F180TR/NF180TR/F180TRL) — 89

WORK PIECE MATERIALS

PRIMARY: (Titanium)

SECONDARY: (Stainless Steel)

FEATURES

- Variable pitch and Variable helix
- Stable core geometry
- Optimized centre cutting geometry
- New generation coating
- Avaiable in 7 Flutes
- Avaiable with Neck options

FUNCTION

- Ability to work at high Parameters due to the reinforced core.
- High MRR
- Higher productivity

BENEFITS

- Superior Tool Life.
- Excellent wall surface finish.
- High MRR

FOR TROCHOIDAL MILLING

PROTON PLUS — 89

WORK PIECE MATERIALS

PRIMARY: (Hardened Steel H1)

SECONDARY: (Hardened Steel H2)

FEATURES

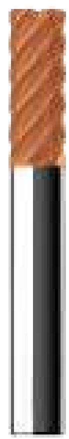
- Superior nano grain structure raw material
- Wear resistant grade
- Ideal Chip flow geometry
- Close tolerance end mills for finishing for higher accuracy

FUNCTION

- Operates at high cutting speeds on hardened materials
- Polishing for hardened dies can be minimized
- No need of multiple setups, Job can be finished with single clamping and it is much easy yto achieve high accuracy

BENEFITS

- Superior Tool Life
- Excellent floor finish



HSM

91

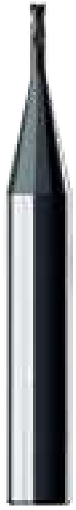
WORK PIECE MATERIALS

PRIMARY: (Steel)

FEATURES
- Superior micro grain structure raw material
- Wear resistant grade
- Same tool for Roughing and Finishing for Mould Machining
- Ideal to machine upto 42 HRc

FUNCTIONS
- Operates at high cutting speeds on Moulds

BENEFITS
- Higher Tool Life and consistency



CHAMFER

92

60 DEGREE COUNTERSINK TOOLS WITH 4 FLUTES

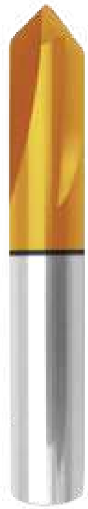
RANGE

3mm to 16mm

90 DEGREE COUNTERSINK TOOLS WITH 4 FLUTES

RANGE

3mm to 16mm



SPOTTING

92

60 DEGREE SPOTTING DRILLS,
Right-hand helix, standard length Cut Shank Dia. = h6 tolerance range; point angle tolerance +0°/-1°

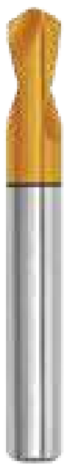
RANGE: 2mm to 16mm

90 DEGREE SPOTTING DRILLS,
Right-hand helix, standard length Cut / Shank Dia. = h6 tolerance range; point angle tolerance +0°/-1°

RANGE: 2mm to 16mm

120 DEGREE SPOTTING DRILLS,
Right-hand helix, standard length Cut / Shank Dia. = h6 tolerance range; point angle tolerance +0°/-1°

RANGE: 2mm to 16mm

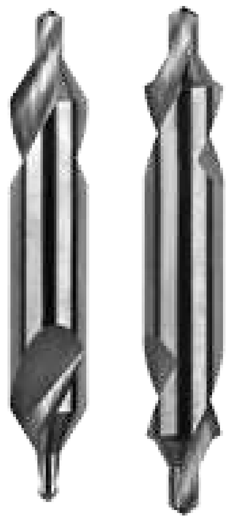


CARBIDE CENTER DRILL

93

Center Drill available in DIN 333 Standard in LH/RH with both Form A & Form B

RANGE: 1mm to 8mm



SPIRAL POINT PM TAPS

94

WORK PIECE MATERIALS

PRIMARY: (Stainless Steel, Titanium & Inconel)

FEATURES
- Superior grade HSSE / HSSE PM steel
- Special angular geometry ensures chips are pushed downwards
- Edge polishing for better thread finish and higher tool life

FUNCTION
- Better coolant flow since the chips are pushed downwards

BENEFITS
- Increased productivity through high speed cutting and long tool life

SPIRAL FLUTE PM TAPS

95

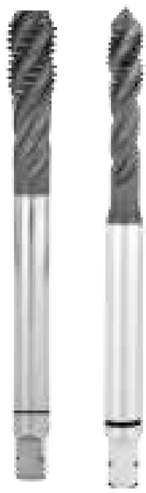
WORK PIECE MATERIALS

PRIMARY: (Stainless Steel)

FEATURES
- Special flute geometry for excellent chip evacuation
- New chamfer geometry and reduced helix (15deg) for short broken chips
- Stress relieving and edge polishing done for cutting edges to avoid chipping off

FUNCTION
- For deep hole tapping – 2.5 D

BENEFITS
- Better thread finish

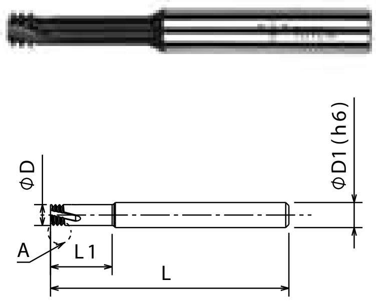


CONTENT

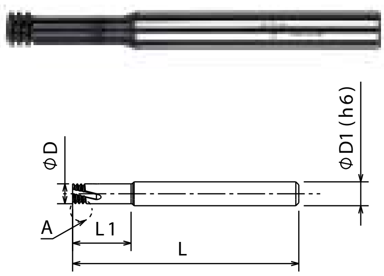
CONTENT

TOTEM
High Performance Cutting Tools

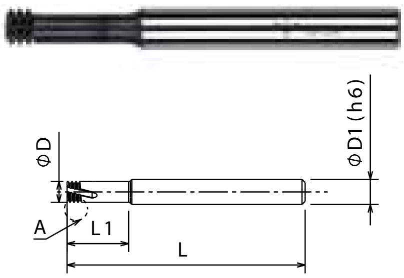
INTERNAL THREADING UPTO 3D FOR (MJ) ISO THREAD



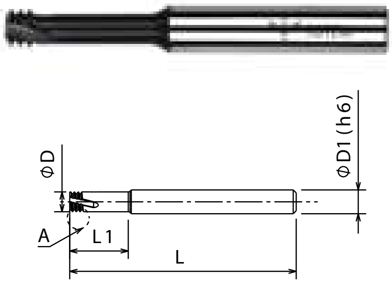
INTERNAL THREADING FOR HARD MATERIALS UPTO 2D FOR ISO METRIC THREAD



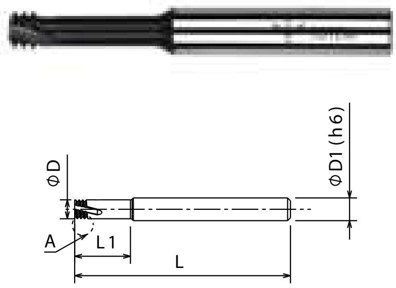
INTERNAL THREADING FOR HARD MATERIALS UPTO 3D FOR ISO METRIC THREAD



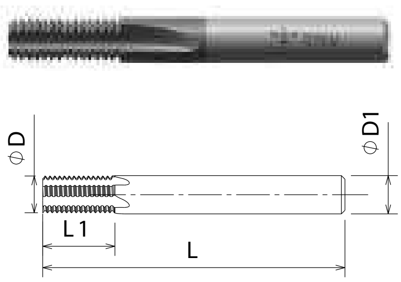
INTERNAL THREADING FOR HARD MATE-RIALS UPTO 2D FOR (UN, UNF) UNIFIED THREAD



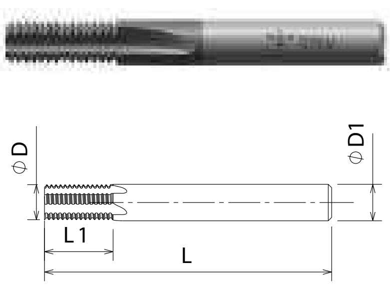
INTERNAL THREADING FOR HARD MATERIALS UPTO 3D FOR (UN, UNF) UNIFIED THREAD



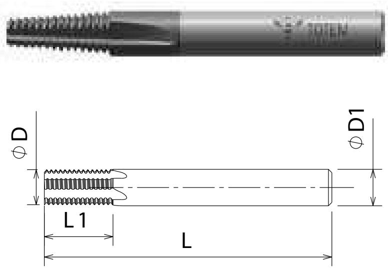
INTERNAL THREADING FOR ISO METRIC THREAD



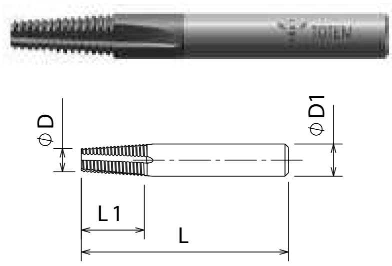
INTERNAL THREADING FOR (UNC, UNF, UNEF) UNIFIED THREAD



INTERNAL/EXTERNAL THREADING FOR NPT

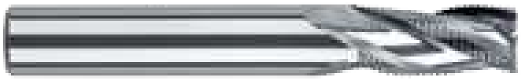


INTERNAL/EXTERNAL THREADING FOR NPTF



CONTENT

RAZORCUT CBC FOR ROUGHING OF ALUMINIUM



Carbide | REG | 30° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Chamfer	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	CH	Z			30%			20%	
FBK0508672	6.00	13.00	57.00	6.00	0.50	3	30	Al 6000/7000	1.80	0.036	Wrought Alumnium	1.20	0.036
FBK0508673	8.00	16.00	63.00	8.00	1.00	3	30	Al 6000/7000	2.40	0.048	Wrought Alumnium	1.60	0.048
FBK0508674	10.00	22.00	72.00	10.00	1.00	3	30	Al 6000/7000	3.00	0.060	Wrought Alumnium	2.00	0.06
FBK0508675	12.00	26.00	83.00	12.00	1.00	3	30	Al 6000/7000	3.60	0.072	Wrought Alumnium	2.40	0.072
FBK0508676	16.00	32.00	92.00	16.00	1.00	3	30	Al 6000/7000	4.80	0.096	Wrought Alumnium	3.20	0.096
FBK0508677	20.00	38.00	104.00	20.00	1.00	3	30	Al 6000/7000	6.00	0.120	Wrought Alumnium	4.00	0.12
FBK0508678	25.00	45.00	121.00	25.00	1.00	3	30	Al 6000/7000	7.50	0.151	Wrought Alumnium	5.00	0.151

RAZORCUT CBCH FOR ROUGHING OF ALUMINIUM

Carbide | REG | 40° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Chamfer	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	CH	Z			30%			20%	
FBK0508701	6.00	13.00	57.00	6.00	0.250	3	40	Al 6000/7000	1.80	0.039	Wrought Alumnium	1.20	0.039
FBK0508702	8.00	16.00	63.00	8.00	0.250	3	40	Al 6000/7000	2.40	0.053	Wrought Alumnium	1.60	0.053
FBK0508703	10.00	22.00	72.00	10.00	0.500	3	40	Al 6000/7000	3.00	0.066	Wrought Alumnium	2.00	0.066
FBK0508704	12.00	26.00	83.00	12.00	0.500	3	40	Al 6000/7000	3.60	0.079	Wrought Alumnium	2.40	0.079
FBK0508705	16.00	32.00	92.00	16.00	1.000	3	40	Al 6000/7000	4.80	0.105	Wrought Alumnium	3.20	0.105
FBK0508706	20.00	38.00	104.00	20.00	1.000	3	40	Al 6000/7000	6.00	0.131	Wrought Alumnium	4.00	0.131
FBK0508707	25.00	45.00	121.00	25.00	1.500	3	40	Al 6000/7000	7.50	0.142	Wrought Alumnium	5.00	0.142

RAZORCUT NCBCH FOR ROUGHING OF ALUMINIUM

REG | 40° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0509069	6.00	8.00	57.00	6.00	5.00	18.00	0.25	3	40	Al 6000/7000	1.80	0.039	Wrought Alumnium	1.20	0.039
FBK0509070	8.00	10.00	63.00	8.00	7.00	24.00	0.25	3	40	Al 6000/7000	2.40	0.053	Wrought Alumnium	1.60	0.053
FBK0509071	10.00	12.00	76.00	10.00	9.00	30.00	0.50	3	40	Al 6000/7000	3.00	0.066	Wrought Alumnium	2.00	0.066
FBK0509072	12.00	15.00	83.00	12.00	11.00	36.00	0.50	3	40	Al 6000/7000	3.60	0.079	Wrought Alumnium	2.40	0.079
FBK0509073	16.00	20.00	92.00	16.00	15.00	48.00	1.00	3	40	Al 6000/7000	4.80	0.105	Wrought Alumnium	3.20	0.105
FBK0509074	20.00	24.00	104.00	20.00	19.00	104.00	1.00	3	40	Al 6000/7000	6.00	0.131	Wrought Alumnium	4.00	0.131

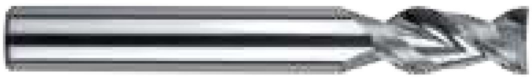
High Performance Cutting Tools

RAZOR CUT 1F FOR MACHINING ALUMINIUM AND PLASTICS

Carbide | REG | 30° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0509238	3.00	12.00	50.00	3.00	1	30
FBK0509239	4.00	15.00	60.00	4.00	1	30
FBK0509240	5.00	17.00	60.00	5.00	1	30
FBK0509241	6.00	20.00	65.00	6.00	1	30
FBK0509242	8.00	25.00	65.00	8.00	1	30
FBK0509243	10.00	25.00	75.00	10.00	1	30

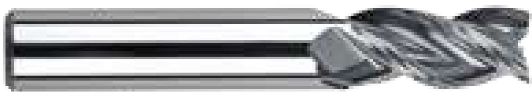
RAZORCUT 2FWF FOR FINISHING OF ALUMNIUM



Carbide | REG | 45° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0508795	1.50	6.00	38.00	3.00	2	45
FBK0508796	2.00	8.00	38.00	3.00	2	45
FBK0508797	2.50	9.00	38.00	3.00	2	45
FBK0508798	3.00	12.00	38.00	3.00	2	45
FBK0508799	4.00	12.00	50.00	4.00	2	45
FBK0508800	5.00	14.00	50.00	5.00	2	45
FBK0508801	5.00	14.00	50.00	6.00	2	45
FBK0508802	6.00	16.00	50.00	6.00	2	45
FBK0508803	8.00	20.00	63.00	8.00	2	45
FBK0508804	10.00	22.00	76.00	10.00	2	45
FBK0508805	12.00	25.00	76.00	12.00	2	45
FBK0508806	16.00	32.00	89.00	16.00	2	45
FBK0508807	20.00	38.00	104.00	20.00	2	45

RAZORCUT 3FWF FOR FINISHING OF ALUMNIUM



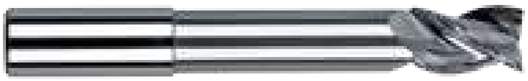
Carbide | REG | 38° | 6535 HA | BF

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			30%			20%	
FBK0508708	3.00	12.00	38.00	3.00	3	38	Al 6000/7000	0.90	0.02	Wrought Alumnium	0.60	0.02
FBK0508709	4.00	12.00	51.00	4.00	3	38	Al 6000/7000	1.20	0.02	Wrought Alumnium	0.80	0.02
FBK0508710	5.00	14.00	51.00	5.00	3	38	Al 6000/7000	1.50	0.02	Wrought Alumnium	1.00	0.02
FBK0508711	6.00	16.00	50.00	6.00	3	38	Al 6000/7000	1.80	0.03	Wrought Alumnium	1.20	0.03
FBK0508712	8.00	20.00	63.00	8.00	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.60	0.04
FBK0508713	10.00	22.00	76.00	10.00	3	38	Al 6000/7000	3.00	0.04	Wrought Alumnium	2.00	0.04
FBK0508714	12.00	25.00	76.00	12.00	3	38	Al 6000/7000	3.60	0.05	Wrought Alumnium	2.40	0.05
FBK0508715	16.00	32.00	89.00	16.00	3	38	Al 6000/7000	4.80	0.06	Wrought Alumnium	3.20	0.06
FBK0508716	20.00	38.00	104.00	20.00	3	38	Al 6000/7000	6.00	0.06	Wrought Alumnium	4.00	0.06

RAZORCUT 3FWFCR FOR SEMIFINISHING AND FINISHING ALUMINIUM

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0508685	6.00	9.00	63.00	6.00	5.40	18.00	0.20	3	38	Al 6000/7000	1.80	0.03	Wrought Alumnium	1.20	0.03
FBK0508686	6.00	9.00	63.00	6.00	5.40	18.00	0.50	3	38	Al 6000/7000	1.80	0.03	Wrought Alumnium	1.20	0.03
FBK0508687	6.00	9.00	63.00	6.00	5.40	18.00	1.00	3	38	Al 6000/7000	1.80	0.03	Wrought Alumnium	1.20	0.03
FBK0508688	8.00	12.00	76.00	8.00	7.20	24.00	0.20	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.60	0.04
FBK0508689	8.00	12.00	76.00	8.00	7.20	24.00	0.50	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.60	0.04
FBK0508690	8.00	12.00	76.00	8.00	7.20	24.00	1.00	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.60	0.04
FBK0508691	10.00	15.00	89.00	10.00	9.00	30.00	0.20	3	38	Al 6000/7000	3.00	0.06	Wrought Alumnium	2.00	0.06
FBK0508692	10.00	15.00	89.00	10.00	9.00	30.00	0.50	3	38	Al 6000/7000	3.00	0.06	Wrought Alumnium	2.00	0.06
FBK0508693	10.00	15.00	89.00	10.00	9.00	30.00	1.00	3	38	Al 6000/7000	3.00	0.06	Wrought Alumnium	2.00	0.06
FBK0508694	12.00	18.00	100.00	12.00	10.80	36.00	0.20	3	38	Al 6000/7000	3.60	0.07	Wrought Alumnium	2.40	0.07
FBK0508695	12.00	18.00	100.00	12.00	10.80	36.00	0.50	3	38	Al 6000/7000	3.60	0.07	Wrought Alumnium	2.40	0.07
FBK0508696	12.00	18.00	100.00	12.00	10.80	36.00	1.00	3	38	Al 6000/7000	3.60	0.07	Wrought Alumnium	2.40	0.07
FBK0508697	16.00	24.00	110.00	16.00	14.40	48.00	0.20	3	38	Al 6000/7000	4.80	0.09	Wrought Alumnium	3.20	0.09
FBK0508698	16.00	24.00	110.00	16.00	14.40	48.00	0.50	3	38	Al 6000/7000	4.80	0.09	Wrought Alumnium	3.20	0.09
FBK0508699	16.00	24.00	110.00	16.00	14.40	48.00	1.00	3	38	Al 6000/7000	4.80	0.09	Wrought Alumnium	3.20	0.09
FBK0508700	16.00	24.00	110.00	16.00	14.40	48.00	2.00	3	38	Al 6000/7000	4.80	0.09	Wrought Alumnium	3.20	0.09

RAZORCUT 3FWFXL LONG REACH TOOL FOR SEMIFINISHING AND FINISHING ALUMINIUM

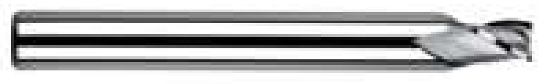


FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0508679	6.00	10.00	100.00	6.00	5.50	42.00	0.20	3	38	Al 6000/7000	1.20	0.02	Wrought Alumnium	0.90	0.021
FBK0508680	8.00	13.00	100.00	8.00	7.30	48.00	0.20	3	38	Al 6000/7000	1.60	0.03	Wrought Alumnium	1.20	0.029
FBK0508681	10.00	16.00	125.00	10.00	9.10	60.00	0.20	3	38	Al 6000/7000	2.00	0.04	Wrought Alumnium	1.50	0.036
FBK0508682	12.00	20.00	125.00	12.00	11.00	73.00	0.20	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.80	0.043
FBK0508683	16.00	26.00	150.00	16.00	14.56	100.00	0.20	3	38	Al 6000/7000	3.20	0.06	Wrought Alumnium	2.40	0.057
FBK0508684	20.00	32.00	150.00	20.00	18.20	100.00	0.20	3	38	Al 6000/7000	4.00	0.07	Wrought Alumnium	3.00	0.072

RAZORCUT 3F FOR GENERAL MACHINING OF NON FERROUS MATERIALS

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			30%			20%	
FBK0509996	3.00	12.00	38.00	3.00	3	38	Al 6000/7000	0.90	0.02	Wrought Alumnium	0.60	0.02
FBK0509997	4.00	12.00	50.00	4.00	3	38	Al 6000/7000	1.20	0.02	Wrought Alumnium	0.80	0.02
FBK0509998	5.00	14.00	50.00	5.00	3	38	Al 6000/7000	1.50	0.02	Wrought Alumnium	1.00	0.02
FBK0509999	6.00	16.00	50.00	6.00	3	38	Al 6000/7000	1.80	0.03	Wrought Alumnium	1.20	0.03
FBK0510000	8.00	20.00	63.00	8.00	3	38	Al 6000/7000	2.40	0.04	Wrought Alumnium	1.60	0.04
FBK0510001	10.00	22.00	76.00	10.00	3	38	Al 6000/7000	3.00	0.04	Wrought Alumnium	2.00	0.04
FBK0510002	12.00	25.00	76.00	12.00	3	38	Al 6000/7000	3.60	0.05	Wrought Alumnium	2.40	0.05
FBK0510003	16.00	32.00	89.00	16.00	3	38	Al 6000/7000	4.80	0.06	Wrought Alumnium	3.20	0.06
FBK0510004	20.00	38.00	104.00	20.00	3	38	Al 6000/7000	6.00	0.06	Wrought Alumnium	4.00	0.06

HEX3 FOR GENERAL MACHINING OF NON FERROUS MATERIALS

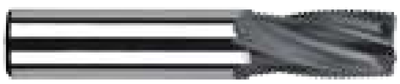


FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0508823	2.00	3.00	50.00	6.00	3	30
FBK0508824	2.50	3.00	50.00	6.00	3	30
FBK0508825	3.00	4.00	50.00	6.00	3	30
FBK0508826	3.50	4.00	50.00	6.00	3	30
FBK0508827	4.00	5.00	54.00	6.00	3	30
FBK0508828	4.50	5.00	54.00	6.00	3	30
FBK0508829	5.00	6.00	54.00	6.00	3	30

HEX3L FOR GENERAL MACHINING OF NON FERROUS MATERIALS

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0508844	2.00	6.00	53.00	6.00	3	30
FBK0508845	2.50	6.00	53.00	6.00	3	30
FBK0508846	3.00	7.00	57.00	6.00	3	30
FBK0508847	3.50	7.00	57.00	6.00	3	30
FBK0508848	4.00	8.00	57.00	6.00	3	30
FBK0508849	4.50	8.00	57.00	6.00	3	30
FBK0508850	5.00	10.00	57.00	6.00	3	30

F192CB - SINUSOIDAL CHIP BREAKER ROUGHER FOR MACHINING STEEL, STAINLESS STEEL AND CAST IRON



FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0508669	6	13	57	6	3	20
FBK0504029	8	16	64	8	3	20
FBK0504089	10	20	70	10	4	20
FBK0508670	12	26	83	12	4	20
FBK0508671	16	32	89	16	4	20
FBK0504094	20	38	102	20	4	20

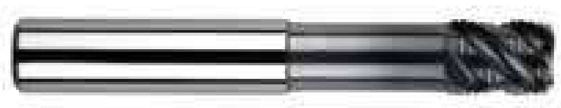
F192CBL- SINUSOIDAL CHIP BREAKER ROUGHER FOR MACHINING STEEL, STAINLESS STEEL AND CAST IRON

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0509830	6	40	100	6	3	20
FBK0509831	8	40	100	8	3	20
FBK0509833	10	45	100	10	4	20
FBK0509835	12	50	100	12	4	20

F193CB CHIP BREAKER ROUGHER FOR MACHINING TITANIUM AND STAINLESS STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Cr	Z			30%			20%	
FBK0510347	6.00	8.00	57.00	6.00	0.75	4	45	Titanium	0.72	0.008	Stainless Steel	0.90	0.010
FBK0510348	8.00	10.00	63.00	8.00	0.75	4	45	Titanium	0.96	0.011	Stainless Steel	1.20	0.013
FBK0510349	10.00	12.00	72.00	10.00	0.75	4	45	Titanium	1.20	0.013	Stainless Steel	1.50	0.016
FBK0510350	12.00	16.00	83.00	12.00	1.00	4	45	Titanium	1.44	0.016	Stainless Steel	1.80	0.020
FBK0510351	16.00	18.00	92.00	16.00	1.00	6	45	Titanium	1.92	0.020	Stainless Steel	2.40	0.024

NF193CB CHIP BREAKER ROUGHER FOR MACHINING PH STEEL AND STAINLESS STEEL



FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0510352	6.00	8.00	57.00	6.00	5.50	21.00	0.75	4	45	PH	0.90	0.011	Stainless Steel	0.90	0.010
FBK0510353	8.00	10.00	63.00	8.00	7.30	28.00	0.75	4	45	PH	1.20	0.014	Stainless Steel	1.20	0.013
FBK0510354	10.00	12.00	72.00	10.00	9.10	35.00	0.75	4	45	PH	1.50	0.017	Stainless Steel	1.50	0.016
FBK0510355	12.00	14.00	83.00	12.00	11.00	42.00	1.00	4	45	PH	1.80	0.022	Stainless Steel	1.80	0.020
FBK0510356	16.00	18.00	92.00	16.00	14.56	56.00	1.00	6	45	PH	2.40	0.027	Stainless Steel	2.40	0.024

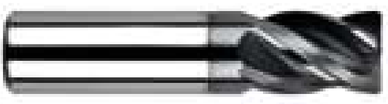
NF193CBL CHIP BREAKER ROUGHER FOR MACHINING PH STEEL AND STAINLESS STEEL

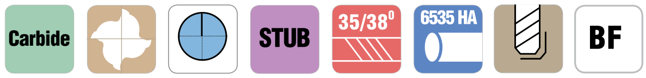
FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0510555	6.00	8.00	100.00	6.00	5.50	42.00	0.75	4	45	PH	0.90	0.010	Stainless Steel	0.90	0.010
FBK0510556	8.00	10.00	100.00	8.00	7.30	42.00	0.75	4	45	PH	1.20	0.013	Stainless Steel	1.20	0.013
FBK0510557	10.00	12.00	100.00	10.00	9.10	42.00	0.75	4	45	PH	1.50	0.016	Stainless Steel	1.50	0.016
FBK0510558	12.00	14.00	125.00	12.00	11.00	42.00	1.00	4	45	PH	1.80	0.020	Stainless Steel	1.80	0.020
FBK0510559	16.00	18.00	125.00	16.00	14.56	56.00	1.00	6	45	PH	2.40	0.024	Stainless Steel	2.40	0.024

F194CB CHIP BREAKER ROUGHER FOR MACHINING TITANIUM AND STAINLESS STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Chamfer	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	CH	Z			30%			20%	
FBK0510342	6.00	13.00	57.00	6.00	0.25	4	45	Titanium	0.72	0.008	Stainless Steel	0.90	0.010
FBK0510343	8.00	16.00	63.00	8.00	0.25	4	45	Titanium	0.96	0.011	Stainless Steel	1.20	0.013
FBK0510344	10.00	22.00	72.00	10.00	0.25	4	45	Titanium	1.20	0.013	Stainless Steel	1.50	0.016
FBK0510345	12.00	26.00	83.00	12.00	0.35	6	45	Titanium	1.44	0.016	Stainless Steel	1.80	0.020
FBK0510346	16.00	32.00	92.00	16.00	0.35	6	45	Titanium	1.92	0.020	Stainless Steel	2.40	0.024

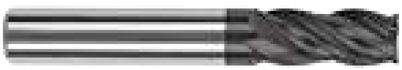
NANO - STUB LENGTH TOOL FOR ECONOMIC MILLING OF STEEL/ STAINLESS STEEL AND CAST IRON





FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Chamfer	Number of teeth	Helix
	ØD1	L1	L	ØD2	CH	Z	
FBK0508782	4.00	7.00	38.00	6.00	0.40	4	35/38
FBK0508783	5.00	7.00	38.00	6.00	0.40	4	35/38
FBK0508784	6.00	8.00	38.00	6.00	0.40	4	35/38
FBK0508785	8.00	11.00	43.00	8.00	0.40	4	35/38
FBK0508786	10.00	13.00	50.00	10.00	0.50	4	35/38
FBK0508787	12.00	15.00	55.00	12.00	0.50	4	35/38
FBK0508788	16.00	15.00	66.00	16.00	CR0.50	6	35/38

F177TR 4 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING PH STEEL AND STAINLESS STEEL

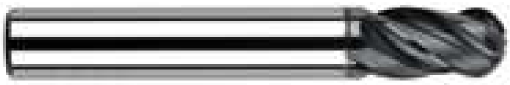


FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Chamfer	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	CH	Z			30%			20%	
FBK0508921	4.0	11.0	55.0	6.0	0.4	4	38	PH	0.60	0.008	Stainless Steel	0.60	0.008
FBK0508922	6.0	13.0	57.0	6.0	0.4	4	38	PH	0.90	0.012	Stainless Steel	0.90	0.012
FBK0508923	8.0	19.0	63.0	8.0	0.4	4	38	PH	1.20	0.017	Stainless Steel	1.20	0.017
FBK0508924	10.0	22.0	72.0	10.0	0.5	4	38	PH	1.50	0.020	Stainless Steel	1.50	0.020
FBK0508925	12.0	26.0	83.0	12.0	0.5	4	38	PH	1.80	0.024	Stainless Steel	1.80	0.024
FBK0508926	16.0	32.0	92.0	16.0	0.5	4	38	PH	2.40	0.030	Stainless Steel	2.40	0.030
FBK0508927	20.0	38.0	104.0	20.0	0.5	4	38	PH	3.00	0.034	Stainless Steel	3.00	0.034

NF177TR 4 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING PH STEEL AND STAINLESS STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			30%			20%	
FBK0508731	6.00	12.00	100.00	6.00	5.50	42.00	0.40	4	38	PH	0.90	0.012	Stainless Steel	0.90	0.012
FBK0508732	8.00	16.00	100.00	8.00	7.30	62.00	0.40	4	38	PH	1.20	0.017	Stainless Steel	1.20	0.017
FBK0508733	10.00	20.00	100.00	10.00	9.10	60.00	0.50	4	38	PH	1.50	0.020	Stainless Steel	1.50	0.020
FBK0508734	12.00	24.00	125.00	12.00	11.00	73.00	0.50	4	38	PH	1.80	0.024	Stainless Steel	1.80	0.024
FBK0508735	16.00	32.00	150.00	16.00	14.56	100.00	0.50	4	38	PH	2.40	0.030	Stainless Steel	2.40	0.030
FBK0508736	20.00	40.00	175.00	20.00	18.20	100.00	0.50	4	38	PH	3.00	0.034	Stainless Steel	3.00	0.034

F179TR BALL NOSE 4 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING PH STEEL & STAINLESS STEEL



FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix
	ØD1	L1	L	ØD2	Z	
FBK0510279	6.00	13.00	57.00	6.00	4	38
FBK0510280	8.00	19.00	63.00	8.00	4	38
FBK0510281	10.00	22.00	72.00	10.00	4	38
FBK0510282	12.00	26.00	83.00	12.00	4	38
FBK0510283	16.00	32.00	92.00	16.00	4	38

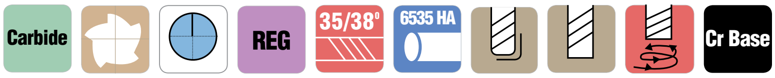
F179TRL BALL NOSE 4 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING PH STEEL AND STAINLESS STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Number of teeth	Helix
	ØD1	L1	L	ØD2	ØD3	NL	Z	
FBK0510487	6	9	101	6	5.8	32	4	38
FBK0510625	8	12	101	8	7.6	42	4	38
FBK0510626	10	15	127	10	9.6	52	4	38
FBK0510627	12	18	152	12	11.4	62	4	38
FBK0510628	16	24	152	16	15.2	82	4	38

TOTEM®

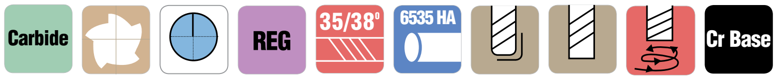
High Performance Cutting Tools

F178TR BLACK 5 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING TITANIUM & SUPER ALLOYS)



FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
BLACK	ØD1	L1	L	ØD2	Cr	Z			12%			10%	
FBK0508717	4.00	11.00	55.00	6.00	0.25	5	38	Titanium	0.48	0.006	Super Alloys	0.40	0.004
FBK0508718	4.00	11.00	55.00	6.00		5	38	Titanium	0.48	0.006	Super Alloys	0.40	0.004
FBK0508719	6.00	13.00	57.00	6.00	0.40	5	38	Titanium	0.72	0.009	Super Alloys	0.60	0.006
FBK0508720	6.00	13.00	57.00	6.00		5	38	Titanium	0.72	0.009	Super Alloys	0.60	0.006
FBK0508721	8.00	19.00	63.00	8.00	0.50	5	38	Titanium	0.96	0.013	Super Alloys	0.80	0.008
FBK0508722	8.00	19.00	63.00	8.00		5	38	Titanium	0.96	0.013	Super Alloys	0.80	0.008
FBK0508723	10.00	22.00	72.00	10.00	0.50	5	38	Titanium	1.20	0.016	Super Alloys	1.00	0.01
FBK0508724	10.00	22.00	72.00	10.00		5	38	Titanium	1.20	0.016	Super Alloys	1.00	0.01
FBK0508725	12.00	26.00	83.00	12.00	0.75	5	38	Titanium	1.44	0.018	Super Alloys	1.20	0.012
FBK0508726	12.00	26.00	83.00	12.00		5	38	Titanium	1.44	0.018	Super Alloys	1.20	0.012
FBK0508727	16.00	32.00	92.00	16.00	0.75	5	38	Titanium	1.92	0.022	Super Alloys	1.60	0.015
FBK0508728	16.00	32.00	92.00	16.00		5	38	Titanium	1.92	0.022	Super Alloys	1.60	0.015
FBK0508729	20.00	38.00	104.00	20.00	0.75	5	38	Titanium	2.40	0.026	Super Alloys	2.00	0.017
FBK0508730	20.00	38.00	104.00	20.00		5	38	Titanium	2.40	0.026	Super Alloys	2.00	0.017

F178TR GOLD (5 FLUTE VARIBLE HELIX VARIABLE PITCH TOOL FOR MACHINING STAINLESS STEEL AND STEEL)

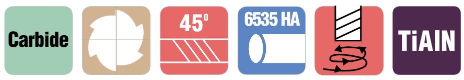


FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
GOLD	ØD1	L1	L	ØD2	Cr	Z			12%			10%	
FBK0510616	4.00	11.00	55.00	6.00	0.25	5	38	Stainless Steel	0.60	0.007	Steel	0.60	0.013
FBK0510617	4.00	11.00	55.00	6.00		5	38	Stainless Steel	0.60	0.007	Steel	0.60	0.013
FBK0510414	6.00	13.00	57.00	6.00	0.40	5	38	Stainless Steel	0.90	0.011	Steel	0.90	0.02
FBK0510618	6.00	13.00	57.00	6.00		5	38	Stainless Steel	0.90	0.011	Steel	0.90	0.02
FBK0510338	8.00	19.00	63.00	8.00	0.50	5	38	Stainless Steel	1.20	0.015	Steel	1.20	0.027
FBK0510619	8.00	19.00	63.00	8.00		5	38	Stainless Steel	1.20	0.015	Steel	1.20	0.027
FBK0510339	10.00	22.00	72.00	10.00	0.50	5	38	Stainless Steel	1.50	0.019	Steel	1.50	0.032
FBK0510620	10.00	22.00	72.00	10.00		5	38	Stainless Steel	1.50	0.019	Steel	1.50	0.032
FBK0510340	12.00	26.00	83.00	12.00	0.75	5	38	Stainless Steel	1.80	0.022	Steel	1.80	0.037
FBK0510621	12.00	26.00	83.00	12.00		5	38	Stainless Steel	1.80	0.022	Steel	1.80	0.037
FBK0510341	16.00	32.00	92.00	16.00	0.75	5	38	Stainless Steel	2.40	0.027	Steel	2.40	0.045
FBK0510622	16.00	32.00	92.00	16.00		5	38	Stainless Steel	2.40	0.027	Steel	2.40	0.045
FBK0510623	20.00	38.00	104.00	20.00	0.75	5	38	Stainless Steel	3.00	0.031	Steel	3.00	0.051
FBK0510624	20.00	38.00	104.00	20.00		5	38	Stainless Steel	3.00	0.031	Steel	3.00	0.051

5VR VARIABLE HELIX AND VARIABLE PITCH TOOL FOR MACHINING TITANIUM AND PH STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			12%			15%	
FBK0508649	6.00	13.00	64.00	6.00	5.64	18.00	0.50	5	38	Titanium	0.72	0.009	PH	0.90	0.012
FBK0508650	6.00	13.00	64.00	6.00	5.64	18.00	1.00	5	38	Titanium	0.72	0.009	PH	0.90	0.012
FBK0508651	6.00	13.00	64.00	6.00	5.64	18.00	1.50	5	38	Titanium	0.72	0.009	PH	0.90	0.012
FBK0508652	6.00	14.00	64.00	6.00	5.64	18.00		5	38	Titanium	0.72	0.009	PH	0.90	0.012
FBK0508653	8.00	19.00	76.00	8.00	7.52	24.00	0.50	5	38	Titanium	0.96	0.013	PH	1.20	0.017
FBK0508654	8.00	19.00	76.00	8.00	7.52	24.00	1.00	5	38	Titanium	0.96	0.013	PH	1.20	0.017
FBK0508655	8.00	18.00	76.00	8.00	7.52	24.00		5	38	Titanium	0.96	0.013	PH	1.20	0.017
FBK0508656	10.00	22.00	76.00	10.00	9.40	30.00	0.50	5	38	Titanium	1.20	0.016	PH	1.50	0.020
FBK0508657	10.00	22.00	76.00	10.00	9.40	30.00	1.00	5	38	Titanium	1.20	0.016	PH	1.50	0.020
FBK0508658	10.00	22.00	76.00	10.00	9.40	30.00	2.00	5	38	Titanium	1.20	0.016	PH	1.50	0.020
FBK0510260	10.00	22.00	76.00	10.00	9.40	30.00	3.00	5	38	Titanium	1.20	0.016	PH	1.50	0.020
FBK0508659	10.00	22.00	76.00	10.00	9.40	30.00		5	38	Titanium	1.20	0.016	PH	1.50	0.020
FBK0508660	12.00	26.00	84.00	12.00	11.28	36.00	0.50	5	38	Titanium	1.44	0.018	PH	1.80	0.024
FBK0510270	12.00	26.00	84.00	12.00	11.28	36.00	1.00	5	38	Titanium	1.44	0.018	PH	1.80	0.024
FBK0510271	12.00	26.00	84.00	12.00	11.28	36.00	2.00	5	38	Titanium	1.44	0.018	PH	1.80	0.024
FBK0510259	12.00	26.00	84.00	12.00	11.28	36.00	3.00	5	38	Titanium	1.44	0.018	PH	1.80	0.024
FBK0508663	12.00	26.00	84.00	12.00	11.28	36.00		5	38	Titanium	1.44	0.018	PH	1.80	0.024
FBK0508664	16.00	32.00	100.00	16.00	15.04	48.00	0.50	5	38	Titanium	1.92	0.022	PH	2.40	0.030
FBK0508665	16.00	32.00	100.00	16.00	15.04	48.00	1.00	5	38	Titanium	1.92	0.022	PH	2.40	0.030
FBK0508666	16.00	32.00	100.00	16.00	15.04	48.00	2.00	5	38	Titanium	1.92	0.022	PH	2.40	0.030
FBK0510261	16.00	32.00	100.00	16.00	15.04	48.00	3.00	5	38	Titanium	1.92	0.022	PH	2.40	0.030
FBK0510269	16.00	32.00	100.00	16.00	15.04	48.00	5.00	5	38	Titanium	1.92	0.022	PH	2.40	0.030
FBK0508668	16.00	32.00	100.00	16.00	15.04	48.00		5	38	Titanium	1.92	0.022	PH	2.40	0.030

6VR 6 FLUTE TOOL FOR FINISH MACHINING OF TITANIUM AND PH STEEL



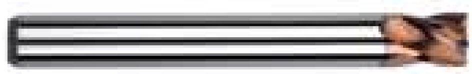
FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			12%			15%	
FBK0508789	6.00	13.00	57.00	6.00	6	45	Titanium	0.72	0.009	PH	0.90	0.012
FBK0508790	8.00	19.00	63.00	8.00	6	45	Titanium	0.96	0.013	PH	1.20	0.017
FBK0508791	10.00	22.00	72.00	10.00	6	45	Titanium	1.20	0.016	PH	1.50	0.020
FBK0508792	12.00	26.00	83.00	12.00	6	45	Titanium	1.44	0.018	PH	1.80	0.024
FBK0508793	16.00	32.00	92.00	16.00	6	45	Titanium	1.92	0.022	PH	2.40	0.027
FBK0508794	20.00	38.00	104.00	20.00	6	45	Titanium	2.40	0.026	PH	3.00	0.03

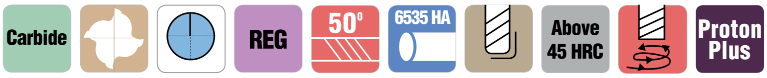
TOTEM®
High Performance Cutting Tools

F180TR/NF180TR/F180TRL 7 FLUTE TOOL FOR FINISH MACHINING OF TITANIUM AND STAINLESS STEEL

FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Neck Diameter	Neck Length	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	ØD3	NL	Cr	Z			12%			12%	
FBK0508808	10.00	30.00	76.00	10.00			0.50	7	38	Titanium	1.20	0.018	Stainless Steel	1.50	0.022
FBK0508809	12.00	36.00	100.00	12.00			0.50	7	38	Titanium	1.44	0.021	Stainless Steel	1.80	0.026
FBK0508810	16.00	48.00	110.00	16.00			0.50	7	38	Titanium	1.92	0.027	Stainless Steel	2.40	0.033
FBK0508811	10.00	30.00	76.00	10.00	9.40	22.00	0.50	7	38	Titanium	1.20	0.018	Stainless Steel	1.50	0.022
FBK0508812	12.00	36.00	100.00	12.00	11.28	26.00	0.50	7	38	Titanium	1.44	0.021	Stainless Steel	1.80	0.026
FBK0508813	16.00	48.00	110.00	16.00	15.04	32.00	0.50	7	38	Titanium	1.92	0.027	Stainless Steel	2.40	0.033
FBK0511263	10	50	100	10			0.5	7	38	Titanium	1.20	0.018	Stainless Steel	1.50	0.022
FBK0511264	12	60	125	12			0.5	7	38	Titanium	1.44	0.021	Stainless Steel	1.80	0.026
FBK0511265	16	80	141	16			0.5	7	38	Titanium	1.92	0.027	Stainless Steel	2.40	0.033

PROTON PLUS END MILLS TO MACHINE HARDENED STEEL BETWEEN 42-58 HRC WITH CORNER RADIUS



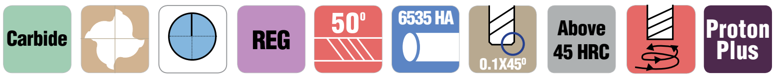


FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Corner Radius	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Cr	Z			12%			4.7%	
FBK0508851	3.00	4.50	50.00	6.00	0.25	4	50	Hardened Steel H1	0.36	0.017	Hardened Steel H2	0.14	0.012
FBK0508852	3.00	4.50	50.00	6.00	0.50	4	50	Hardened Steel H1	0.36	0.017	Hardened Steel H2	0.14	0.012
FBK0508853	4.00	6.00	50.00	6.00	0.25	4	50	Hardened Steel H1	0.48	0.026	Hardened Steel H2	0.19	0.016
FBK0508854	4.00	6.00	50.00	6.00	0.50	4	50	Hardened Steel H1	0.48	0.026	Hardened Steel H2	0.19	0.016
FBK0508855	5.00	8.00	50.00	6.00	0.25	4	50	Hardened Steel H1	0.60	0.028	Hardened Steel H2	0.24	0.018
FBK0508856	5.00	8.00	50.00	6.00	0.50	4	50	Hardened Steel H1	0.60	0.028	Hardened Steel H2	0.24	0.018
FBK0508857	6.00	6.00	50.00	6.00	0.25	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508858	6.00	6.00	50.00	6.00	0.50	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508859	6.00	6.00	50.00	6.00	0.75	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508860	6.00	6.00	50.00	6.00	1.00	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508861	8.00	12.00	63.00	8.00	0.50	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508862	8.00	12.00	63.00	8.00	0.75	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508863	8.00	12.00	63.00	8.00	1.00	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508864	8.00	12.00	63.00	8.00	1.50	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508865	10.00	15.00	76.00	10.00	0.50	4	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508866	10.00	15.00	76.00	10.00	1.00	4	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508867	10.00	15.00	76.00	10.00	1.50	4	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508868	10.00	15.00	76.00	10.00	2.00	4	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508869	12.00	18.00	76.00	12.00	0.50	4	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508870	12.00	18.00	76.00	12.00	1.00	4	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508871	12.00	18.00	76.00	12.00	1.50	4	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508872	12.00	18.00	76.00	12.00	2.00	4	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508873	16.00	24.00	89.00	16.00	0.50	4	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0508874	16.00	24.00	89.00	16.00	1.50	4	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0508875	16.00	24.00	89.00	16.00	2.00	4	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0508876	20.00	30.00	104.00	20.00	0.50	4	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062
FBK0508877	20.00	30.00	104.00	20.00	1.00	4	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062
FBK0508878	20.00	30.00	104.00	20.00	2.00	4	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062

PROTON PLUS END MILLS TO MACHINE HARDENED STEEL BETWEEN 42-58 HRC

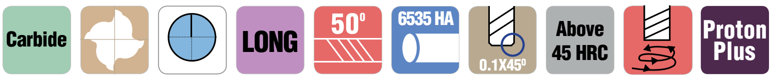
FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			12%			4.70%	
FBK0509820	6.00	15.00	76.00	6.00	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0509821	8.00	20.00	100.00	8.00	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0509822	10.00	25.00	100.00	10.00	5	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0509823	12.00	30.00	125.00	12.00	6	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0509824	16.00	40.00	125.00	16.00	6	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0509825	20.00	50.00	150.00	20.00	6	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062
FBK0509826	25.00	63.00	150.00	25.00	6	50	Hardened Steel H1	3.00	0.121	Hardened Steel H2	1.18	0.067

PROTON PLUS END MILLS TO MACHINE HARDENED STEEL BETWEEN 42-58 HRC



FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			12%			4.70%	
FBK0508765	3.00	5.00	50.00	6.00	4	50	Hardened Steel H1	0.36	0.017	Hardened Steel H2	0.14	0.012
FBK0508766	4.00	6.00	50.00	6.00	4	50	Hardened Steel H1	0.48	0.026	Hardened Steel H2	0.19	0.016
FBK0508767	5.00	8.00	50.00	6.00	4	50	Hardened Steel H1	0.60	0.028	Hardened Steel H2	0.24	0.018
FBK0508768	6.00	9.00	50.00	6.00	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508769	8.00	12.00	63.00	8.00	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508770	10.00	15.00	76.00	10.00	4	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508771	12.00	18.00	76.00	12.00	4	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508772	16.00	24.00	89.00	16.00	4	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0508773	20.00	30.00	104.00	20.00	4	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062
FBK0508774	25.00	38.00	121.00	25.00	5	50	Hardened Steel H1	3.00	0.121	Hardened Steel H2	1.18	0.067

PROTON PLUS END MILLS TO MACHINE HARDENED STEEL BETWEEN 42-58 HRC



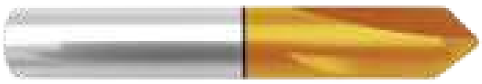
FG Code	Cutting Dia	Flute Length	OAL	Shank Dia	Number of teeth	Helix	Primary W/P	Ae (max)	hm (Max)	Secondary W/P	Ae (max)	hm (max)
	ØD1	L1	L	ØD2	Z			12%			4.70%	
FBK0508775	6.00	21.00	76.00	6.00	4	50	Hardened Steel H1	0.72	0.037	Hardened Steel H2	0.28	0.023
FBK0508776	8.00	28.00	100.00	8.00	4	50	Hardened Steel H1	0.96	0.047	Hardened Steel H2	0.38	0.029
FBK0508777	10.00	35.00	100.00	10.00	5	50	Hardened Steel H1	1.20	0.056	Hardened Steel H2	0.47	0.035
FBK0508778	12.00	42.00	125.00	12.00	6	50	Hardened Steel H1	1.44	0.075	Hardened Steel H2	0.56	0.047
FBK0508779	16.00	56.00	125.00	16.00	6	50	Hardened Steel H1	1.92	0.086	Hardened Steel H2	0.75	0.054
FBK0508780	20.00	70.00	150.00	20.00	6	50	Hardened Steel H1	2.40	0.099	Hardened Steel H2	0.94	0.062
FBK0508781	25.00	88.00	150.00	25.00	6	50	Hardened Steel H1	3.00	0.121	Hardened Steel H2	1.18	0.067

HSM END MILL FOR RIB MILLING OF MULTIPLE MATERIALS

Carbide | 30° | 6535 HA | TiAlN

FG Code	Cutting Dia	Shank Dia	Flute Length	Neck Length	Neck Diameter	OAL	Number of teeth	Helix
	ØD1	ØD2	L1	NL	ØD3	L	Z	
FBK0508963	1	4	1.5	4	0.97	50	2	30
FBK0508964	1	4	1.5	6	0.97	50	2	30
FBK0508965	1	4	1.5	8	0.95	50	2	30
FBK0508966	1	4	1.5	10	0.95	50	2	30
FBK0508967	1	4	1.5	12	0.93	50	2	30
FBK0508968	1.2	4	1.5	6	1.17	50	2	30
FBK0508969	1.2	4	1.8	8	1.15	50	2	30
FBK0508970	1.2	4	1.8	10	1.15	50	2	30
FBK0508971	1.2	4	1.8	12	1.13	50	2	30
FBK0508972	1.2	4	1.8	16	1.13	50	2	30
FBK0508973	1.4	4	2.1	6	1.37	50	2	30
FBK0508974	1.4	4	2.1	8	1.35	50	2	30
FBK0508975	1.4	4	2.1	10	1.35	50	2	30
FBK0508976	1.4	4	2.1	12	1.33	50	2	30
FBK0508977	1.4	4	2.1	16	1.31	50	2	30
FBK0508978	1.4	4	2.1	18	1.31	50	2	30
FBK0508979	1.4	4	2.1	20	1.31	50	2	30
FBK0508980	1.5	4	2.3	6	1.47	50	2	30
FBK0508981	1.5	4	2.3	8	1.47	50	2	30
FBK0508982	1.5	4	2.3	10	1.45	50	2	30
FBK0508983	1.5	4	2.3	12	1.43	50	2	30
FBK0508984	1.5	4	2.3	16	1.41	50	2	30
FBK0508985	1.5	4	2.3	18	1.41	63	2	30
FBK0508986	1.5	4	2.3	20	1.39	63	2	30
FBK0508987	1.8	4	2.7	6	1.77	50	2	30
FBK0508988	1.8	4	2.7	12	1.73	50	2	30
FBK0508989	2	4	3	6	1.97	50	2	30
FBK0508990	2	4	3	8	1.97	50	2	30
FBK0508991	2	4	3	10	1.95	50	2	30
FBK0508992	2	4	3	12	1.95	50	2	30
FBK0508993	2	4	3	16	1.91	50	2	30
FBK0508994	2	4	3	20	1.89	63	2	30
FBK0508995	2	4	3	30	1.89	75	2	30
FBK0508996	2.5	4	3.7	8	2.4	50	2	30
FBK0508997	2.5	4	3.7	10	2.4	50	2	30
FBK0508998	2.5	4	3.7	12	2.4	50	2	30
FBK0508999	2.5	4	3.7	14	2.4	50	2	30
FBK0509000	2.5	4	3.7	16	2.4	63	2	30
FBK0509001	2.5	4	3.7	20	2.4	63	2	30
FBK0509002	2.5	4	3.7	25	2.4	63	2	30
FBK0509003	2.5	4	3.7	30	2.4	80	2	30
FBK0509004	3	6	4.5	8	2.85	50	2	30
FBK0509005	3	6	4.5	10	2.85	50	2	30
FBK0509006	3	6	4.5	12	2.85	50	2	30
FBK0509007	3	6	4.5	16	2.85	63	2	30
FBK0509008	3	6	4.5	20	2.85	63	2	30
FBK0509009	3	6	4.5	30	2.85	80	2	30

CHAMFER TOOL (60°/90°)



Carbide | 30° | TiN

FG Code 60°	FG Code 90°	Cutting Dia	Flute Length	Shank Dia	OAL	Number of teeth	Helix
		ØD1	L1	ØD2	L	Z	
FBJ0505363	FBJ0505410	3.00	20.00	3.00	50.00	4	30
FBJ0505364	FBJ0505411	4.00	20.00	4.00	50.00	4	30
FBJ0505365	FBJ0505357	5.00	20.00	5.00	50.00	4	30
FBJ0505366	FBJ0505358	6.00	20.00	6.00	50.00	4	30
FBJ0505367	FBJ0505359	8.00	25.00	8.00	60.00	4	30
FBJ0505368	FBJ0505360	10.00	30.00	10.00	75.00	4	30
FBJ0505369	FBJ0505361	12.00	30.00	12.00	75.00	4	30
FBJ0505370	FBJ0505362	16.00	30.00	16.00	100.00	4	30

SPOTING DRILL (60°/90°/120°)

Carbide | 30° | TiN

60°

90°

120°

FG Code 60°	FG Code 90°	FG Code 120°	Cutting Dia	Flute Length	Shank Dia	OAL	Number of teeth	Helix
			ØD1	L1	ØD2	L	Z	
FBJ0505371	FBJ0505380	FBJ0505389	2.00	6.00	2.00	50.00	2	30
FBJ0505372	FBJ0505381	FBJ0505390	3.00	8.00	3.00	50.00	2	30
FBJ0505373	FBJ0505382	FBJ0505391	4.00	11.00	4.00	50.00	2	30
FBJ0505374	FBJ0505383	FBJ0505392	5.00	13.00	5.00	50.00	2	30
FBJ0505375	FBJ0505384	FBJ0505393	6.00	15.00	6.00	50.00	2	30
FBJ0505376	FBJ0505385	FBJ0505394	8.00	20.00	8.00	60.00	2	30
FBJ0505377	FBJ0505386	FBJ0505395	10.00	25.00	10.00	75.00	2	30
FBJ0505378	FBJ0505387	FBJ0505396	12.00	30.00	12.00	75.00	2	30
FBJ0505379	FBJ0505388	FBJ0505397	16.00	45.00	16.00	100.00	2	30

High Performance Cutting Tools

CARBIDE CENTER DRILL

Carbide | DIN 333 | FORM A | 118° | BF

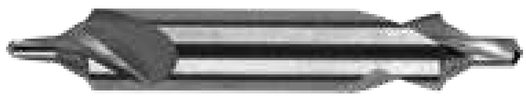
FORM A RH

Descrption	EDP
CENTER DRILL 1 X3.15 TYPE A RH DIN333	FBJ0505428
CENTER DRILL 1.25 X3.15 TYPE A RH DIN333	FBJ0505429
CENTER DRILL 1 X4 TYPE A RH DIN333	FBJ0505430
CENTER DRILL 1.6 X4 TYPE A RH DIN333	FBJ0505431
CENTER DRILL 2 X5 TYPE A RH DIN333	FBJ0505432
CENTER DRILL 2.5 X6.3 TYPE A RH DIN333	FBJ0505433
CENTER DRILL 3 X8 TYPE A RH DIN333	FBJ0505434
CENTER DRILL 3.15 X8 TYPE A RH DIN333	FBJ0505461

FORM A LH

Descrption	EDP
CENTER DRILL 1 X3.15 TYPE A LH DIN333	FBJ0505442
CENTER DRILL 1.25 X3.15 TYPE A LH DIN333	FBJ0505443
CENTER DRILL 1 X4 TYPE A LH DIN333	FBJ0505444
CENTER DRILL 1.6 X4 TYPE A LH DIN333	FBJ0505445
CENTER DRILL 2 X5 TYPE A LH DIN333	FBJ0505446
CENTER DRILL 2.5 X6.3 TYPE A LH DIN333	FBJ0505447
CENTER DRILL 3 X8 TYPE A LH DIN333	FBJ0505448
CENTER DRILL 3.15 X8 TYPE A LH DIN333	FBJ0505460

Carbide | DIN 333 | FORM B | 118° | BF



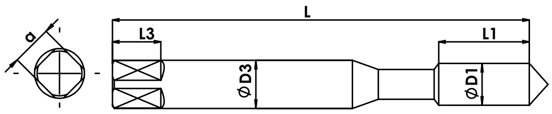
FORM B RH

Descrption	EDP
CENTER DRILL 1 X3.15 TYPE B RH DIN333	FBJ0505435
CENTER DRILL 1.25 X3.15 TYPE B RH DIN333	FBJ0505436
CENTER DRILL 1 X4 TYPE B RH DIN333	FBJ0505437
CENTER DRILL 1.6 X4 TYPE B RH DIN333	FBJ0505438
CENTER DRILL 2 X5 TYPE B RH DIN333	FBJ0505439
CENTER DRILL 2.5 X6.3 TYPE B RH DIN333	FBJ0505440
CENTER DRILL 3 X8 TYPE B RH DIN333	FBJ0505441
CENTER DRILL 3.15 X8 TYPE B RH DIN333	FBJ0505459

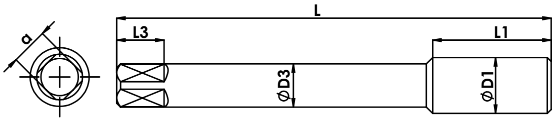
FORM B LH

Descrption	EDP
CENTER DRILL 1 X3.15 TYPE B LH DIN333	FBJ0505449
CENTER DRILL 1.25 X3.15 TYPE B LH DIN333	FBJ0505450
CENTER DRILL 1 X4 TYPE B LH DIN333	FBJ0505451
CENTER DRILL 1.6 X4 TYPE B LH DIN333	FBJ0505452
CENTER DRILL 2 X5 TYPE B LH DIN333	FBJ0505453
CENTER DRILL 2.5 X6.3 TYPE B LH DIN333	FBJ0505454
CENTER DRILL 3 X8 TYPE B LH DIN333	FBJ0505455
CENTER DRILL 3.15 X8 TYPE B LH DIN333	FBJ0505458

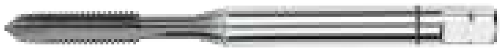
HSS-E PM | DIN 371/376 | 6HX | C/2-3P



Reinforced Shank DIN371 (1/4" - 3/8")



Reduced Shank DIN376 (7/16" - 1")



SPIRAL POINT PM TAPS FOR STAINLESS STEEL M& MF

Size	FG Code	Description
M3X0.5	FAB0207083	HPT 3X.5 SAS5 PM DIN 371
M4X0.7	FAB0207084	HPT 4X.7 SAS5 PM DIN 371
M5X0.8	FAB0207085	HPT 5X.8 SAS5 PM DIN 371
M6X1	FAB0207086	HPT 6X1 SAS5 PM DIN 371
M8X1		HPT 8X1 SAS5 PM DIN 374
M8X1.25	FAB0207087	HPT 8X1.25 SAS5 PM DIN 371
M10X1		HPT 10X1 SAS5 PM DIN 374
M10X1.25		HPT 10X1.25 SAS5 PM DIN 374
M10X1.5	FAB0207088	HPT 10X1.5 SAS5 PM DIN 371
M12X1.25		HPT 12X1.25 SAS5 PM DIN 374
M12X1.5		HPT 12X1.5 SAS5 PM DIN 374
M12X1.75	FAB0207089	HPT 12X1.75 SAS5 PM DIN 376

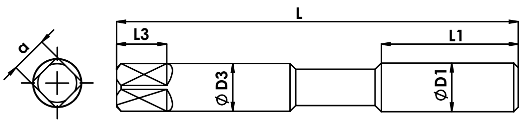
SPIRAL POINT PM TAPS FOR STAINLESS STEEL UNC

Size	FG Code	Description
4 UNC	FAB0207151	HPT 4 UNC SAS5 PM DIN 371
6 UNC	FAB0207152	HPT 6 UNC SAS5 PM DIN 371
8 UNC	FAB0207153	HPT 8 UNC SAS5 PM DIN 371
10 UNC	FAB0207154	HPT 10 UNC SAS5 PM DIN 371
1/4 UNC	FAB0207155	HPT 1/4 UNC SAS5 PM DIN 371
5/16 UNC	FAB0207156	HPT 5/16 UNC SAS5 PM DIN 371
3/8 UNC	FAB0207157	HPT 3/8 UNC SAS5 PM DIN 371

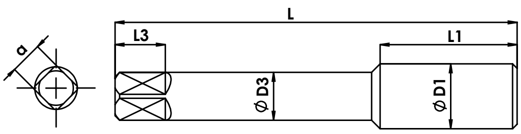
SPIRAL POINT PM TAPS FOR STAINLESS STEEL UNF

Size	FG Code	Description
4 UNF	FAB0207171	HPT 4 UNF SAS5 PM DIN 371
6 UNF	FAB0207172	HPT 6 UNF SAS5 PM DIN 371
8 UNF	FAB0207173	HPT 8 UNF SAS5 PM DIN 371
10 UNF	FAB0207174	HPT 10 UNF SAS5 PM DIN 371
1/4 UNF	FAB0207175	HPT 1/4 UNF SAS5 PM DIN 371
5/16 UNF	FAB0207176	HPT 5/16 UNF SAS5 PM DIN 371
3/8 UNF	FAB0207177	HPT 3/8 UNF SAS5 PM DIN 371

HSS-E PM | DIN 371/376 | 6HX | B/4-4.5P



Reinforced Shank (M3 - M10)
Male Centre upto M5



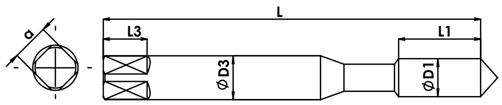
Reduced Shank (M12 - M16)

SPIRAL POINT PM TAPS FOR TITANIUM AND INCONEL

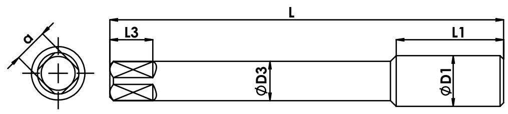
Size	FG Code	Description
M3X0.5	FAB0204694	HPT 3X.5 SAI6 PM DIN 371
M4X0.7	FAB0204695	HPT 4X.7 SAI6 PM DIN 371
M5X0.8	FAB0204696	HPT 5X.8 SAI6 PM DIN 371
M6X1	FAB0204697	HPT 6X1 SAI6 PM DIN 371
M8X1	FAB0204810	HPT 8X1 SAI6 PM DIN 374
M8X1.25	FAB0204698	HPT 8X1.25 SAI6 PM DIN 371

Size	FG Code	Description
M10X1	FAB0204812	HPT 10X1 SAI6 PM DIN 374
M10X1.25	FAB0204811	HPT 10X1.25 SAI6 PM DIN 374
M10X1.5	FAB0204699	HPT 10X1.5 SAI6 PM DIN 371
M12X1.25	FAB0204815	HPT 12X1.25 SAI6 PM DIN 374
M12X1.5	FAB0204816	HPT 12X1.5 SAI6 PM DIN 374
M12X1.75	FAB0204700	HPT 12X1.75 SAI6 PM DIN 376

HSS-E PM | DIN 371/376 | 6HX | C/2-3P | 45°



Reinforced Shank DIN371 (M3 - M10)



Reduced Shank DIN376 (M12 - M20)

SPIRAL FLUTE PM TAPS FOR STAINLESS STEEL M AND MF

Size	FG Code	Description
M3X0.5	FAB0205539	HPT 3X.5 SBS5 PM DIN 371
M4X0.7	FAB0205540	HPT 4X.7 SBS5 PM DIN 371
M5X0.8	FAB0205541	HPT 5X.8 SBS5 PM DIN 371
M6X1	FAB0205542	HPT 6X1 SBS5 PM DIN 371
M8X1	FAB0206392	HPT 8X1 SBS5 PM DIN 374
M8X1.25	FAB0205543	HPT 8X1.25 SBS5 PM DIN 371
M10X1		HPT 10X1 SBS5 PM DIN 374
M10X1.25		HPT 10X1.25 SBS5 PM DIN 374
M10X1.5	FAB0205544	HPT 10X1.5 SBS5 PM DIN 371
M12X1.25		HPT 12X1.25 SBS5 PM DIN 374
M12X1.5		HPT 12X1.5 SBS5 PM DIN 374
M12X1.75	FAB0205545	HPT 12X1.75 SBS5 PM DIN 376

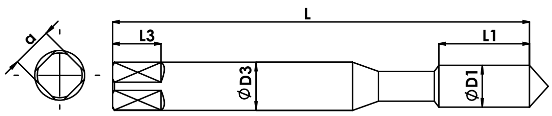
SPIRAL FLUTE PM TAPS FOR STAINLESS STEEL UNC

Size	FG Code	Description
4 UNC	FAB0207158	HPT 4 UNC SBS5 PM DIN 371
6 UNC	FAB0207159	HPT 6 UNC SBS5 PM DIN 371
8 UNC	FAB0207160	HPT 8 UNC SBS5 PM DIN 371
10 UNC	FAB0207161	HPT 10 UNC SBS5 PM DIN 371
1/4 UNC	FAB0205558	HPT 1/4 UNC SBS5 PM DIN 371
5/16 UNC	FAB0205559	HPT 5/16 UNC SBS5 PM DIN 371
3/8 UNC	FAB0205560	HPT 3/8 UNC SBS5 PM DIN 371

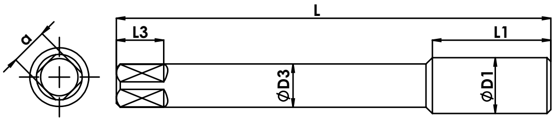
SPIRAL FLUTE PM TAPS FOR STAINLESS STEEL UNF

Size	FG Code	Description
4 UNF	FAB0207178	HPT 4 UNF SBS5 PM DIN 371
6 UNF	FAB0207179	HPT 6 UNF SBS5 PM DIN 371
8 UNF	FAB0207180	HPT 8 UNF SBS5 PM DIN 371
10 UNF	FAB0207181	HPT 10 UNF SBS5 PM DIN 371
1/4 UNF	FAB0207182	HPT 1/4 UNF SBS5 PM DIN 371
5/16 UNF	FAB0207183	HPT 5/16 UNF SBS5 PM DIN 371
3/8 UNF	FAB0207184	HPT 3/8 UNF SBS5 PM DIN 371

HSS-E PM | DIN 371/376 | 6HX | C/2-3P | 18°



Reinforced Shank DIN371 (M3 - M10)

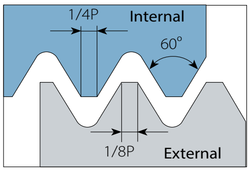


Reduced Shank DIN376 (M12 - M16)

SPIRAL FLUTE PM TAPS FOR STAINLESS STEEL

Size	FG Code	Description
M3X0.5	FAB0204703	HPT 3X.5 SBI6 PM DIN 371
M4X0.7	FAB0204704	HPT 4X.7 SBI6 PM DIN 371
M5X0.8	FAB0204705	HPT 5X.8 SBI6 PM DIN 371
M6X1	FAB0204706	HPT 6X1 SBI6 PM DIN 371
M8X1	FAB0204738	HPT 8X1 SBI6 PM DIN 374
M8X1.25	FAB0204707	HPT 8X1.25 SBI6 PM DIN 371

Size	FG Code	Description
M10X1	FAB0204814	HPT 10X1 SBI6 PM DIN 374
M10X1.25	FAB0204813	HPT 10X1.25 SBI6 PM DIN 374
M10X1.5	FAB0204708	HPT 10X1.5 SBI6 PM DIN 371
M12X1.25	FAB0204739	HPT 12X1.25 SBI6 PM DIN 374
M12X1.5	FAB0204898	HPT 12X1.5 SBI6 PM DIN 374
M12X1.75	FAB0204709	HPT 12X1.75 SBI6 PM DIN 376

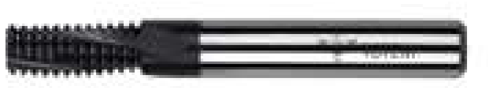


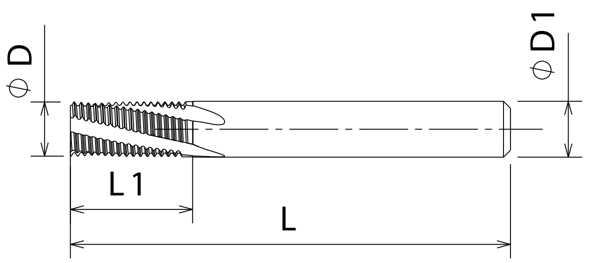
Multi Flute

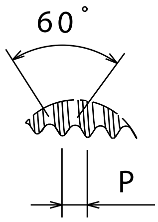
ISO metric thread

Internal threading

TM | RHS | M | MF | IT | ISO | TiAlN







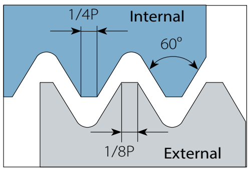
Thread Size		Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	M5	0.5	TMRHS-0.5ISO-3.8MMX10.3X57 SH6 3FL TA	3.8	10.3	57	6	3	FBV0503000
	M7	0.5	TMRHS-0.5ISO-5.9MMX10.2X57 SH6 3FL TA	5.9	10.2	57	6	3	FBV0503001
M4.5	M5	0.75	TMRHS-0.75ISO-3.6MMX10.1X57 SH6 3FL TA	3.6	10.1	57	6	3	FBV0503002
	M8	0.75	TMRHS-0.75ISO-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503003
	M10	0.75	TMRHS-0.75ISO-7.9MMX15.3X63 SH8 4FL TA	7.9	15.3	63	8	4	FBV0503004
M5		0.8	TMRHS-0.8ISO-3.9MMX10X57 SH6 3FL TA	3.9	10	57	6	3	FBV0503005
M6	M7	1	TMRHS-1.0ISO-4.8MMX11.5X57 SH6 3FL TA	4.8	11.5	57	6	3	FBV0503006
M6	M7	1	TMRHS-1.0ISO-4.8MMX14.5X57 SH6 3FL TA	4.8	14.5	57	6	3	FBV0503007
	M8	1	TMRHS-1.0ISO-5.9MMX12.5X57 SH6 3FL TA	5.9	12.5	57	6	3	FBV0503008
	M10	1	TMRHS-1.0ISO-7.9MMX17.5X63 SH8 4FL TA	7.9	17.5	63	8	4	FBV0503009
	M12	1	TMRHS-1.0ISO-9.9MMX20.5X73 SH10 4FL TA	9.9	20.5	73	10	4	FBV0503010
M8	M9	1.25	TMRHS-1.25ISO-5.9MMX14.4X57 SH6 3FL TA	5.9	14.4	57	6	3	FBV0503011
M8	M9	1.25	TMRHS-1.25ISO-5.9MMX19.5X57 SH6 3FL TA	5.9	19.5	57	6	3	FBV0503012
M10	M11	1.5	TMRHS-1.5ISO-7.9MMX18.5X63 SH8 3FL TA	7.9	18.5	63	8	3	FBV0503013
	M13	1.5	TMRHS-1.5ISO-9.9MMX21.8X73 SH10 4FL TA	9.9	21.8	73	10	4	FBV0503014
	M15	1.5	TMRHS-1.5ISO-11.9MMX26.3X84 SH12 4FL TA	11.9	26.3	84	12	4	FBV0503015
	M20	1.5	TMRHS-1.5ISO-15.9MMX35.2X105 SH16 6FL TA	15.9	35.2	105	16	6	FBV0503016
M12		1.75	TMRHS-1.75ISO-9.2MMX21.8X73 SH10 3FL TA	9.2	21.8	73	10	3	FBV0503017
M14		2	TMRHS-2.0ISO-9.9MMX25X73 SH10 3FL TA	9.9	25	73	10	3	FBV0503018
M16		2	TMRHS-2.0ISO-11.9MMX27X84 SH12 4FL TA	11.9	27	84	12	4	FBV0503019
	M20	2	TMRHS-2.0ISO-15.9MMX37X105 SH16 5FL TA	15.9	37	105	16	5	FBV0503020
M20		2.5	TMRHS-2.5ISO-15.9MMX36.3X105 SH16 5FL TA	15.9	36.3	105	16	5	FBV0503021
M24	M27	3	TMRHS-3.0ISO-15.9MMX40.5X105 SH16 3FL TA	15.9	40.5	105	16	3	FBV0503022
M27		3	TMRHS-3.0ISO-19.9MMX43X105 SH20 4FL TA	19.9	43	105	20	4	FBV0503023

High Performance Cutting Tools

Defined by: R262 (DIN 13) I Tolerance class: 6H

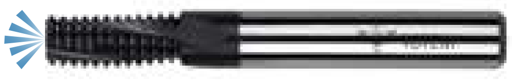
Multi Flute

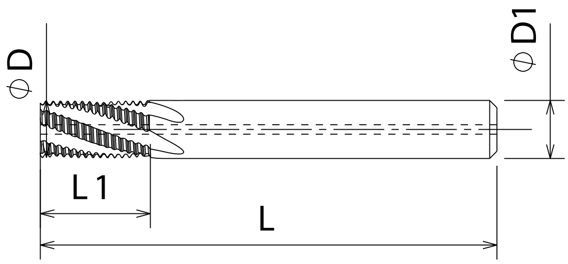
ISO metric thread
Internal threading

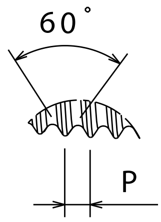


TM | RHC | M | MF | IT | ISO | TiAlN

with coolant hole







Detail View A

Thread Size		Pitch Mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	M5	0.5	TMRHC-0.5ISO-3.8MMX10.3X57 SH6 3FL TA	3.8	10.3	57	6	3	FBV0503024
	M7	0.5	TMRHC-0.5ISO-5.9MMX10.2X57 SH6 3FL TA	5.9	10.2	57	6	3	FBV0503025
M4.5	M5	0.75	TMRHC-0.75ISO-3.6MMX10.1X57 SH6 3FL TA	3.6	10.1	57	6	3	FBV0503026
	M8	0.75	TMRHC-0.75ISO-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503027
	M10	0.75	TMRHC-0.75ISO-7.9MMX15.3X63 SH8 4FL TA	7.9	15.3	63	8	4	FBV0503028
M5		0.8	TMRHC-0.8ISO-3.9MMX10X57 SH6 3FL TA	3.9	10	57	6	3	FBV0503029
M6	M7	1	TMRHC-1.0ISO-4.8MMX11.5X57 SH6 3FL TA	4.8	11.5	57	6	3	FBV0503030
M6	M7	1	TMRHC-1.0ISO-4.8MMX14.5X57 SH6 3FL TA	4.8	14.5	57	6	3	FBV0503031
	M8	1	TMRHC-1.0ISO-5.9MMX12.5X57 SH6 3FL TA	5.9	12.5	57	6	3	FBV0503032
	M10	1	TMRHC-1.0ISO-7.9MMX17.5X63 SH8 4FL TA	7.9	17.5	63	8	4	FBV0503033
	M12	1	TMRHC-1.0ISO-9.9MMX20.5X73 SH10 4FL TA	9.9	20.5	73	10	4	FBV0503034
M8	M9	1.25	TMRHC-1.25ISO-5.9MMX14.4X57 SH6 3FL TA	5.9	14.4	57	6	3	FBV0503035
M8	M9	1.25	TMRHC-1.25ISO-5.9MMX19.5X57 SH6 3FL TA	5.9	19.5	57	6	3	FBV0503036
M10	M11	1.5	TMRHC-1.5ISO-7.9MMX18.5X63 SH8 3FL TA	7.9	18.5	63	8	3	FBV0503037
	M13	1.5	TMRHC-1.5ISO-9.9MMX21.8X73 SH10 4FL TA	9.9	21.8	73	10	4	FBV0503038
	M15	1.5	TMRHC-1.5ISO-11.9MMX26.3X84 SH12 4FL TA	11.9	26.3	84	12	4	FBV0503039
	M20	1.5	TMRHC-1.5ISO-15.9MMX35.2X105 SH16 6FL TA	15.9	35.2	105	16	6	FBV0503040
M12		1.75	TMRHC-1.75ISO-9.2MMX21.8X73 SH10 3FL TA	9.2	21.8	73	10	3	FBV0503041
M14		2	TMRHC-2.0ISO-9.9MMX25X73 SH10 3FL TA	9.9	25	73	10	3	FBV0503042
M16		2	TMRHC-2.0ISO-11.9MMX27X84 SH12 4FL TA	11.9	27	84	12	4	FBV0503043
	M20	2	TMRHC-2.0ISO-15.9MMX37X105 SH16 5FL TA	15.9	37	105	16	5	FBV0503044
M20		2.5	TMRHC-2.5ISO-15.9MMX36.3X105 SH16 5FL TA	15.9	36.3	105	16	5	FBV0503045
M24	M27	3	TMRHC-3.0ISO-15.9MMX40.5X105 SH16 3FL TA	15.9	40.5	105	16	3	FBV0503046
M27		3	TMRHC-3.0ISO-19.9MMX43X105 SH20 4FL TA	19.9	43	105	20	4	FBV0503047

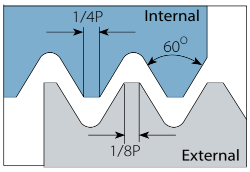
High Performance Cutting Tools

Defined by: ANSI B1.1:74 I Tolerance class: 2B

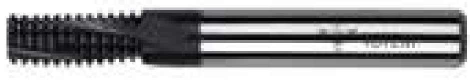
Multi Flute

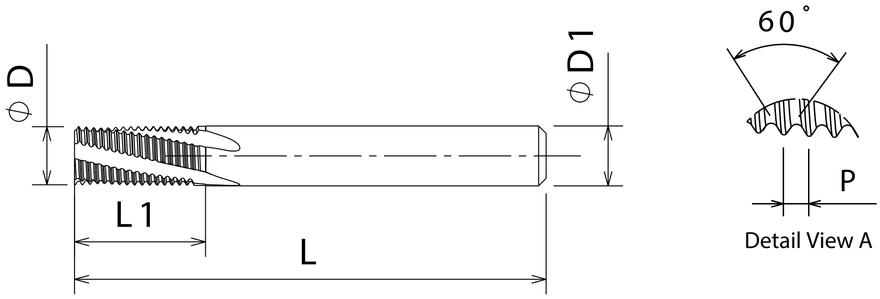
(UNC, UNF, UNEF) unified thread

Internal threading



TM RHS UNC UNF UNEF IT UNIFIED TiAIN

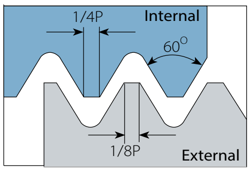




Thread Size			Pitch Mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse UNC	Fine UNF	Extra Fine UNEF			mm	mm	mm	mm		
		5/16"	32	TMRHS-32UN-5.9MMX14X57 SH6 3FL TA	5.9	14	57	6	3	FBV0503048
		3/8"	32	TMRHS-32UN-7.9MMX18X63 SH8 3FL TA	7.9	18	63	8	3	FBV0503049
	1/4"		28	TMRHS-28UN-5.1MMX12.2X57 SH6 3FL TA	5.1	12.2	57	6	3	FBV0503050
		7/16"-1/2"	28	TMRHS-28UN-7.9MMX15.8X63 SH8 4FL TA	7.9	15.8	63	8	4	FBV0503051
	5/16"		24	TMRHS-24UN-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503052
	3/8"		24	TMRHS-24UN-7.9MMX15.3X63 SH8 4FL TA	7.9	15.3	63	8	4	FBV0503053
	9/16" ,5/8"		24	TMRHS-24UN-11.9MMX22.7X84 SH12 4FL TA	11.9	22.7	84	12	4	FBV0503054
1/4"			20	TMRHS-20UN-4.8MMX12X57 SH6 3FL TA	4.8	12	57	6	3	FBV0503055
	7/16"		20	TMRHS-20UN-7.9MMX19.7X63 SH8 3FL TA	7.9	19.7	63	8	3	FBV0503056
	1/2"		20	TMRHS-20UN-9.9MMX22.5X73 SH10 4FL TA	9.9	22.5	73	10	4	FBV0503057
		3/4"-1"	20	TMRHS-20UN-11.9MMX26X84 SH12 4FL TA	11.9	26	84	12	4	FBV0503058
5/16"			18	TMRHS-18UN-5.7MMX16X57 SH6 3FL TA	5.7	16	57	6	3	FBV0503059
	9/16" ,5/8"		18	TMRHS-18UN-9.9MMX23.5X73 SH10 4FL TA	9.9	23.5	73	10	4	FBV0503060
3/8"			16	TMRHS-16UN-6.8MMX18.2X63 SH8 3FL TA	6.8	18.2	63	8	3	FBV0503061
	3/4"		16	TMRHS-16UN-11.9MMX26.2X84 SH12 4FL TA	11.9	26.2	84	12	4	FBV0503062
7/16"			14	TMRHS-14UN-7.8MMX20.8X63 SH8 3FL TA	7.8	20.8	63	8	3	FBV0503063
	7/8"		14	TMRHS-14UN-11.9MMX24.5X84 SH12 4FL TA	11.9	24.5	84	12	4	FBV0503064
1/2"			13	TMRHS-13UN-9.3MMX24.4X73 SH10 3FL TA	9.3	24.4	73	10	3	FBV0503065
9/16"			12	TMRHS-12UN-10.6MMX26.4X84 SH12 4FL TA	10.6	26.4	84	12	4	FBV0503066
	1"		12	TMRHS-12UN-15.9MMX39.1X105 SH16 5FL TA	15.9	39.1	105	16	5	FBV0503067
5/8"			11	TMRHS-11UN-11.5MMX31.1X84 SH12 3FL TA	11.5	31.1	84	12	3	FBV0503068
3/4"			10	TMRHS-10UN-14.3MMX36.8X105 SH16 4FL TA	14.3	36.8	105	16	4	FBV0503069
7/8"			9	TMRHS-9UN-15.9MMX40.9X105 SH16 4FL TA	15.9	40.9	105	16	4	FBV0503070
1"			8	TMRHS-8UN-19.7MMX42.8X105 SH20 4FL TA	19.7	42.8	105	20	4	FBV0503071

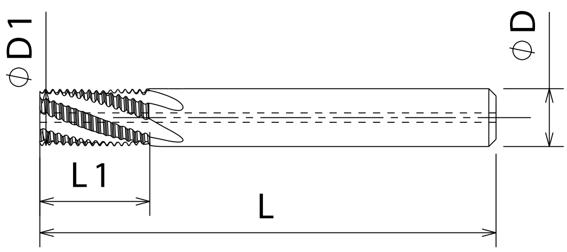
Multi Flute

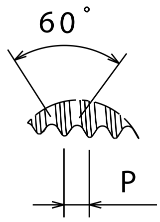
(UNC, UNF, UNEF) Unified Thread
Internal Threading



TM | RHC | UNC | UNF | UNEF | IT | UNIFIED | TiAIN

with coolant hole





Detail View A

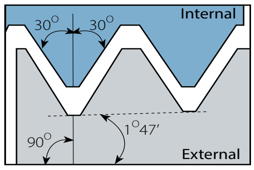
Thread Size			Pitch Mm	Description	D1	L1	L	D	Flutes	EDP No
Coarse UNC	Fine UNF	Extra Fine UNEF			mm	mm	mm	mm		
		5/16"	32	TMRHC-32UN-5.9MMX14X57 SH6 3FL TA	5.9	14	57	6	3	FBV0503072
		3/8"	32	TMRHC-32UN-7.9MMX18X63 SH8 3FL TA	7.9	18	63	8	3	FBV0503073
	1/4"		28	TMRHC-28UN-5.1MMX12.2X57 SH6 3FL TA	5.1	12.2	57	6	3	FBV0503074
		7/16"-1/2"	28	TMRHC-28UN-7.9MMX15.8X63 SH8 4FL TA	7.9	15.8	63	8	4	FBV0503075
	5/16"		24	TMRHC-24UN-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503076
	3/8"		24	TMRHC-24UN-7.9MMX15.3X63 SH8 4FL TA	7.9	15.3	63	8	4	FBV0503077
	9/16", 5/8"		24	TMRHC-24UN-11.9MMX22.7X84 SH12 4FL TA	11.9	22.7	84	12	4	FBV0503078
1/4"			20	TMRHC-20UN-4.8MMX12X57 SH6 3FL TA	4.8	12	57	6	3	FBV0503079
	7/16"		20	TMRHC-20UN-7.9MMX19.7X63 SH8 3FL TA	7.9	19.7	63	8	3	FBV0503080
	1/2"		20	TMRHC-20UN-9.9MMX22.5X73 SH10 4FL TA	9.9	22.5	73	10	4	FBV0503081
		3/4"-1"	20	TMRHC-20UN-11.9MMX26X84 SH12 4FL TA	11.9	26	84	12	4	FBV0503082
5/16"			18	TMRHC-18UN-5.7MMX16X57 SH6 3FL TA	5.7	16	57	6	3	FBV0503083
	9/16", 5/8"		18	TMRHC-18UN-9.9MMX23.5X73 SH10 4FL TA	9.9	23.5	73	10	4	FBV0503084
3/8"			16	TMRHC-16UN-6.8MMX18.2X63 SH8 3FL TA	6.8	18.2	63	8	3	FBV0503085
	3/4"		16	TMRHC-16UN-11.9MMX26.2X84 SH12 4FL TA	11.9	26.2	84	12	4	FBV0503086
7/16"			14	TMRHC-14UN-7.8MMX20.8X63 SH8 3FL TA	7.8	20.8	63	8	3	FBV0503087
	7/8"		14	TMRHC-14UN-11.9MMX24.5X84 SH12 4FL TA	11.9	24.5	84	12	4	FBV0503088
1/2"			13	TMRHC-13UN-9.3MMX24.4X73 SH10 3FL TA	9.3	24.4	73	10	3	FBV0503089
9/16"			12	TMRHC-12UN-10.6MMX26.4X84 SH12 4FL TA	10.6	26.4	84	12	4	FBV0503090
	1"		12	TMRHC-12UN-15.9MMX39.1X105 SH16 5FL TA	15.9	39.1	105	16	5	FBV0503091
5/8"			11	TMRHC-11UN-11.5MMX31.1X84 SH12 3FL TA	11.5	31.1	84	12	3	FBV0503092
3/4"			10	TMRHC-10UN-14.3MMX36.8X105 SH16 4FL TA	14.3	36.8	105	16	4	FBV0503093
7/8"			9	TMRHC-9UN-15.9MMX40.9X105 SH16 4FL TA	15.9	40.9	105	16	4	FBV0503094
1"			8	TMRHC-8UN-19.7MMX42.8X105 SH20 4FL TA	19.7	42.8	105	20	4	FBV0503095

High Performance Cutting Tools

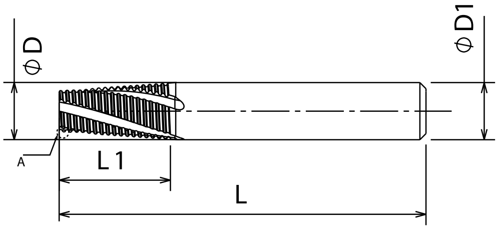
Defined by: USAS B2.1:1968
Tolerance class: Standard NPT

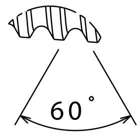
Multi Flute

NPT
Internal/external threading



TM | RHTS | NPT | ET | IT | NPT | TiAlN





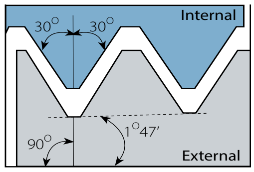
Detail view A

Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	27	TMRHTS-27NPT-5.9MMX9.8X57 SH6 3FL TA	5.9	9.8	57	6	3	FBV0503096
1/8"	27	TMRHTS-27NPT-7.7MMX10.9X63 SH8 3FL TA	7.7	10.9	63	8	3	FBV0503097
1/4"-3/8"	18	TMRHTS-18NPT-9.9MMX16.4X73 SH10 4FL TA	9.9	16.4	73	10	4	FBV0503098
1/2"	14	TMRHTS-14NPT-11.9MMX20.8X84 SH12 4FL TA	11.9	20.8	84	12	4	FBV0503099
1/2"	14	TMRHTS-14NPT-15.9MMX20.8X93 SH16 4FL TA	15.9	20.8	93	16	4	FBV0503100
1"-2"	11.5	TMRHTS-11.5NPT-19.9X29.7X105 SH20 4F TA	19.9	29.7	105	20	4	FBV0503101
2 1/2"-6"	8	TMRHTS-8NPT-19.9MMX38.1X105 SH20 4FL TA	19.9	38.1	105	20	4	FBV0503102

Defined by: USAS B2.1:1968 I Tolerance class: Standard NPT

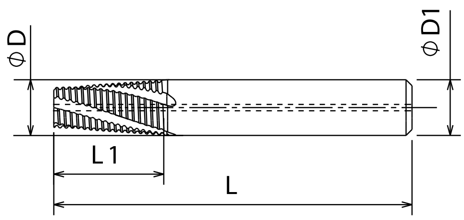
Multi Flute

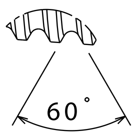
NPT
Internal/external threading



TM | RHTC | NPT | ET | IT | NPT | TiAlN

with coolant hole





Detail view A

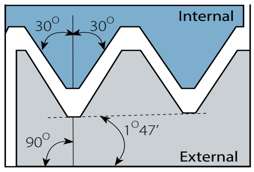
Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	27	TMRHTC-27NPT-5.9MMX9.8X57 SH6 3FL TA	5.9	9.8	57	6	3	FBV0503103
1/8"	27	TMRHTC-27NPT-7.7MMX10.9X63 SH8 3FL TA	7.7	10.9	63	8	3	FBV0503104
1/4"-3/8"	18	TMRHTC-18NPT-9.9MMX16.4X73 SH10 4FL TA	9.9	16.4	73	10	4	FBV0503105
1/2"	14	TMRHTC-14NPT-11.9MMX20.8X84 SH12 4FL TA	11.9	20.8	84	12	4	FBV0503106
1/2"	14	TMRHTC-14NPT-15.9MMX20.8X93 SH16 4FL TA	15.9	20.8	93	16	4	FBV0503107
1"-2"	11.5	TMRHTC-11.5NPT-19.9X29.7X105 SH20 4F TA	19.9	29.7	105	20	4	FBV0503108
2 1/2"-6"	8	TMRHTC-8NPT-19.9MMX38.1X105 SH20 4FL TA	19.9	38.1	105	20	4	FBV0503109

High Performance Cutting Tools

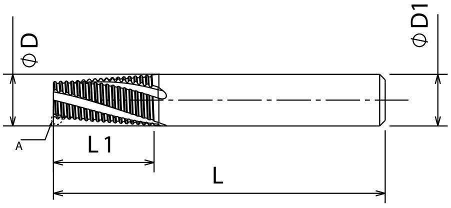
Defined by: ANSI 1.20.3-1976
Tolerance class: Standard NPTF

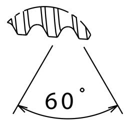
Multi Flute

NPTF
Internal/external threading



TM | RHTS | NPTF | IT | ET | NPT | TiAlN





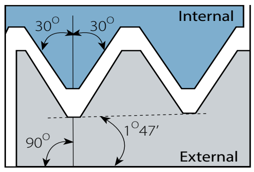
Detail view A

Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	27	TMRHTS-27NPTF-5.9MMX9.9X57 SH6 3FL TA	5.9	9.9	57	6	3	FBV0503110
1/8"	27	TMRHTS-27NPTF-7.7MMX10.8X63 SH8 3FL TA	7.7	10.8	63	8	3	FBV0503111
1/4"-3/8"	18	TMRHTS-18NPTF-9.9MMX16.2X73 SH10 4FL TA	9.9	16.2	73	10	4	FBV0503112
1/2"	14	TMRHTS-14NPTF-11.9MMX20.8X84 SH12 4F TA	11.9	20.8	84	12	4	FBV0503113
1"-2"	11.5	TMRHTS-11.5NPTF-19.9MMX29.7X105SH204FTA	19.9	29.7	105	20	4	FBV0503114
2 1/2"-6"	8	TMRHTS-8NPTF-19.9MMX38.1X105 SH20 4F TA	19.9	38.1	105	20	4	FBV0503115

Defined by: ANSI 1.20.3-1976 I Tolerance class: Standard NPTF

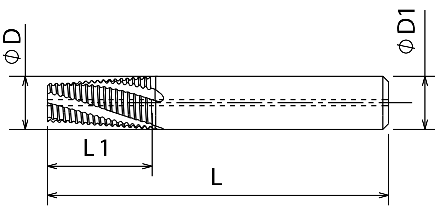
Multi Flute

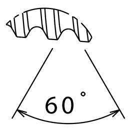
NPTF
Internal/External Threading



TM | RHTC | NPTF | IT | ET | NPTF | TiAlN

with coolant hole





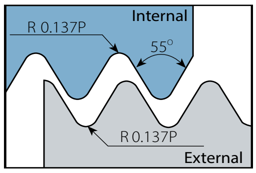
Detail view A

Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	27	TMRHTC-27NPTF-5.9MMX9.9X57 SH6 3FL TA	5.9	9.9	57	6	3	FBV0503116
1/8"	27	TMRHTC-27NPTF-7.7MMX10.8X63 SH8 3FL TA	7.7	10.8	63	8	3	FBV0503117
1/4"-3/8"	18	TMRHTC-18NPTF-9.9MMX16.2X73 SH10 4FL TA	9.9	16.2	73	10	4	FBV0503118
1/2"	14	TMRHTC-14NPTF-11.9MMX20.8X84 SH12 4F TA	11.9	20.8	84	12	4	FBV0503119
1"-2"	11.5	TMRHTC-11.5NPTF-19.9MMX29.7X105SH204FTA	19.9	29.7	105	20	4	FBV0503120
2 1/2"-6"	8	TMRHTC-8NPTF-19.9MMX38.1X105 SH20 4F TA	19.9	38.1	105	20	4	FBV0503121

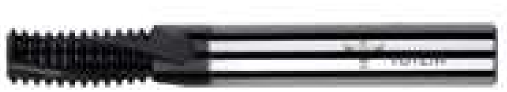
Defined by: B.S.2779:1956
Tolerance class: Medium class

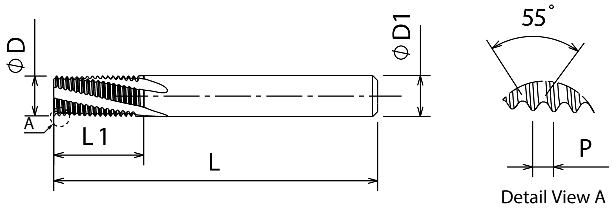
Multi Flute

BSP (G)
Internal/external threading



TM | RHS | BSP | IT | ET | BS | TiAlN



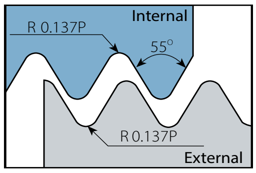


Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	28	TMRHS-28BSP-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503122
1/8"	28	TMRHS-28BSP-7.9MMX14X63 SH8 3FL TA	7.9	14.0	63	8	3	FBV0503123
1/4"-3/8"	19	TMRHS-19BSP-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503124
1/2"-7/8"	14	TMRHS-14BSP-11.9MMX22.7X84 SH12 4FL TA	11.9	22.7	84	12	4	FBV0503125
1"-2"	11	TMRHS-11BSP-15.9MMX32.1X105 SH16 4F TA	15.9	32.1	105	16	4	FBV0503126
1"-6"	11	TMRHS-11BSP-19.9MMX40.4X105 SH20 5F TA	19.9	40.4	105	20	5	FBV0503127

Defined by: B.S.2779:1956 I Tolerance class: Medium class

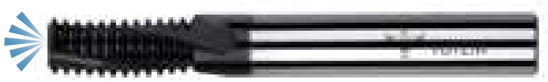
Multi Flute

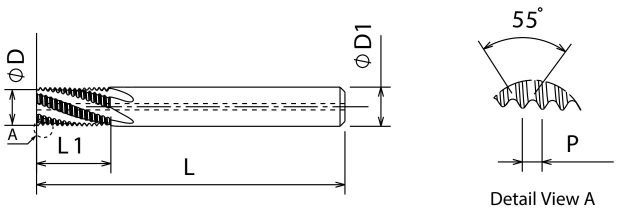
BSP (G)
Internal/external threading



TM | RHC | BSP | IT | ET | BS | TiAlN

with coolant hole





Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	28	TMRHC-28BSP-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503128
1/8"	28	TMRHC-28BSP-7.9MMX14X63 SH8 3FL TA	7.9	14.0	63	8	3	FBV0503129
1/4"-3/8"	19	TMRHC-19BSP-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503130
1/2"-7/8"	14	TMRHC-14BSP-11.9MMX22.7X84 SH12 4FL TA	11.9	22.7	84	12	4	FBV0503131
1"-2"	11	TMRHC-11BSP-15.9MMX32.1X105 SH16 4F TA	15.9	32.1	105	16	4	FBV0503132
1"-6"	11	TMRHC-11BSP-19.9MMX40.4X105 SH20 5F TA	19.9	40.4	105	20	5	FBV0503133

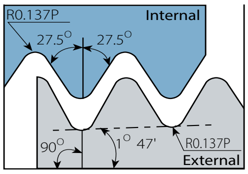
High Performance Cutting Tools

Defined by: B.S.21:1985 I Tolerance class: Tolerance class: Standard BSPT

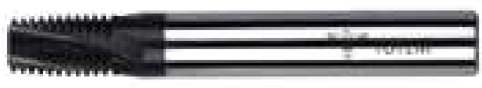
Multi Flute

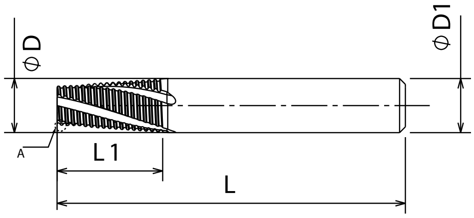
BSPT (Rc)

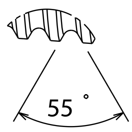
Internal/external threading



TM | RHTS | BSPT | IT | ET | BS | TiAIN







Detail view A

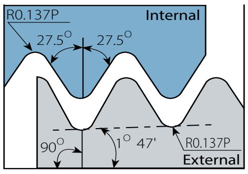
Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	28	TMRHTS-28BSPT-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503134
1/8"	28	TMRHTS-28BSPT-7.9MMX14X63 SH8 3FL TA	7.9	14.0	63	8	3	FBV0503135
1/4"-3/8"	19	TMRHTS-19BSPT-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503136
1/2"-7/8"	14	TMRHTS-14BSPT-11.9MMX22.7X84SH12 4FL TA	11.9	22.7	84	12	4	FBV0503137
1"-2"	11	TMRHTS-11BSPT-15.9MMX32.1X105SH16 4F TA	15.9	32.1	105	16	4	FBV0503138
1"-6"	11	TMRHTS-11BSPT-19.9MMX40.4X105SH20 5F TA	19.9	40.4	105	20	5	FBV0503139

Defined by: B.S.21:1985 I Tolerance class: Tolerance class: Standard BSPT

Multi Flute

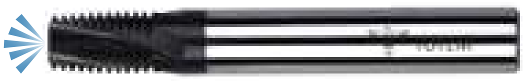
BSPT (Rc)

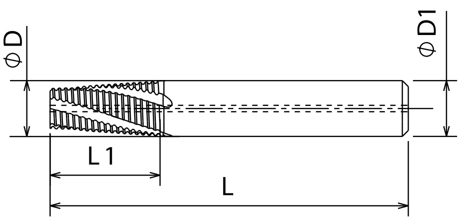
Internal/external threading

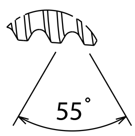


TM | RHTC | BSPT | IT | ET | BS | TiAIN

with coolant hole







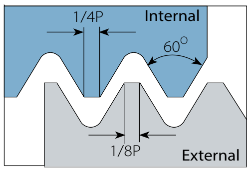
Detail view A

Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"	28	TMRHTC-28BSPT-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503140
1/8"	28	TMRHTC-28BSPT-7.9MMX14X63 SH8 3FL TA	7.9	14.0	63	8	3	FBV0503141
1/4"-3/8"	19	TMRHTC-19BSPT-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503142
1/2"-7/8"	14	TMRHTC-14BSPT-11.9MMX22.7X84SH12 4FL TA	11.9	22.7	84	12	4	FBV0503143
1"-2"	11	TMRHTC-11BSPT-15.9MMX32.1X105SH16 4F TA	15.9	32.1	105	16	4	FBV0503144
1"-6"	11	TMRHTC-11BSPT-19.9MMX40.4X105SH20 5F TA	19.9	40.4	105	20	5	FBV0503145

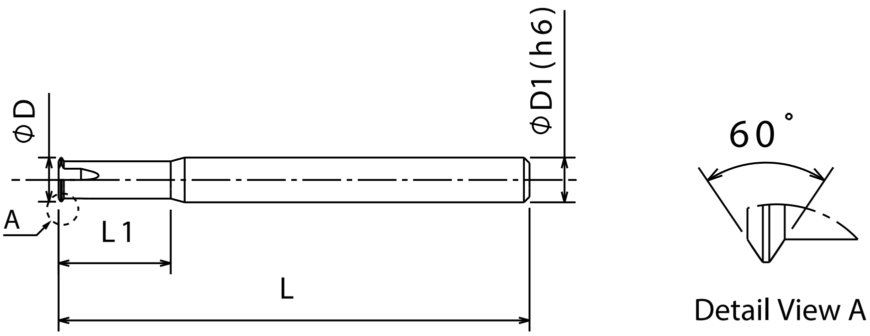
Defined by: ANSI B1.1:74 I Tolerance class: 2B

Multi Flute

Partial profile 60⁰
Internal/external threading



TM | STP 60 | UNC | UNF | M | MF | IT | ET | ISO | UNIFIED | TiAIN



Detail View A

Pitch Range		Description	D	L1	L	D1	Flutes	Minimum Hole Dia	EDP No
mm	TPI		mm	mm	mm	mm			
0.35-0.6	72-40	TMST-P60 1.95MMX6X39 SH3 3FL TA	1.95	6	39	3	3	2.0	FBV0503146
0.5-0.8	48-32	TMST-P60 2.45MMX7.7X39 SH3 3FL TA	2.45	7.7	39	3	3	2.6	FBV0503147
0.5-0.8	48-32	TMST-P60 3.15MMX10X51 SH4 3FL TA	3.15	10	51	4	3	3.3	FBV0503148
0.5-1.0	48-24	TMST-P60 4.00MMX12X51 SH4 3FL TA	4.0	12	51	4	3	4.2	FBV0503149
0.5-1.25	48-20	TMST-P60 4.70MMX15X57 SH6 3FL TA	4.7	15	57	6	3	4.9	FBV0503150
0.5-1.25	48-20	TMST-P60 6.00MMX18X57 SH6 3FL TA	6.0	18	57	6	3	6.3	FBV0503151
0.75-1.5	32-16	TMST-P60 8.00MMX24X63 SH8 3FL TA	8.0	24	63	8	3	8.3	FBV0503152
1.0-2.5	24-10	TMST-P60 10.00MMX30X73 SH10 4FL TA	10.0	30	73	10	4	10.4	FBV0503153
1.0-2.5	24-10	TMST-P60 12.00MMX36X84 SH12 4FL TA	12.0	36	84	12	4	12.5	FBV0503154

TOTEM

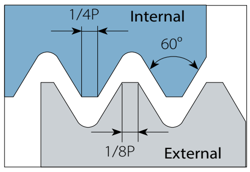
High Performance Cutting Tools

Defined by: R262 (DIN 13) I Tolerance class: 6H

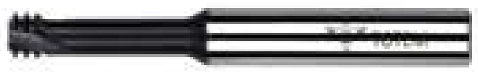
Multi Flute

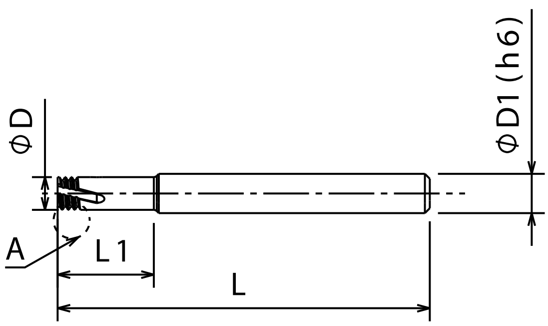
ISO metric thread

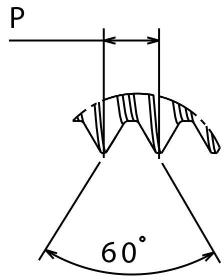
Internal threading upto 2D



TM | MT 2D | M | IT | ISO | TiAIN







Detail view A

Thread Size	Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
M1.6	0.35	TMMT2D-0.35-ISO-1.2MMX3.3X39 SH3 3FL TA	1.2	3.3	39	3	3	FBV0503155
M1.6	0.35	TMMT2D-0.35-ISO-1.2MMX3.3X57 SH6 3FL TA	1.2	3.3	57	6	3	FBV0503156
M2	0.4	TMMT2D-0.4-ISO-1.54MMX4.4X39 SH3 3FL TA	1.54	4.4	39	3	3	FBV0503157
M2	0.4	TMMT2D-0.4-ISO-1.54MMX4.4X57 SH6 3FL TA	1.54	4.4	57	6	3	FBV0503158
M2.2	0.45	TMMT2D-0.45-ISO-1.63MMX4.8X39 SH3 3FL TA	1.63	4.8	39	3	3	FBV0503159
M2.5	0.45	TMMT2D-0.45-ISO-1.96MMX5.3X57 SH6 3FL TA	1.96	5.3	57	6	3	FBV0503160
M3	0.5	TMMT2D-0.5-ISO-2.4MMX6.4X57 SH6 3FL TA	2.4	6.4	57	6	3	FBV0503161
M3.5	0.6	TMMT2D-0.6-ISO-2.75MMX7.4X57 SH6 3FL TA	2.75	7.4	57	6	3	FBV0503162
M4	0.7	TMMT2D-0.7-ISO-3.15MMX8.6X57 SH6 3FL TA	3.15	8.6	57	6	3	FBV0503163
M5	0.8	TMMT2D-0.8-ISO-4MMX12D57 SH6 3FL TA	4	12	57	6	3	FBV0503164
M6	1	TMMT2D-1.0-ISO-4.75MMX13X57 SH6 3FL TA	4.75	13	57	6	3	FBV0503165
M8	1.25	TMMT2D-1.25-ISO-5.95MMX17.3X57 SH6 3F TA	5.95	17.3	57	6	3	FBV0503166
M10	1.5	TMMT2D-1.5-ISO-7.90MMX22D63 SH8 3FL TA	7.9	22	63	8	3	FBV0503167
M12	1.75	TMMT2D-1.75-ISO-9.40MMX25.5X73 SH10 3FTA	9.4	25.5	73	10	3	FBV0503168
M14	2	TMMT2D-2.0-ISO-9.95MMX29X73 SH10 3FL TA	9.95	29	73	10	3	FBV0503169
M16	2	TMMT2D-2.0-ISO-11.95MMX33X84 SH12 4FL TA	11.95	33	84	12	4	FBV0503170
M20	2.5	TMMT2D-2.5-ISO-15.90MMX42D105 SH16 5F TA	15.9	42	105	16	5	FBV0503171

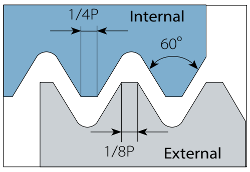
TOTEM
High Performance Cutting Tools

Defined by: R262 (DIN 13) I Tolerance class: 6H

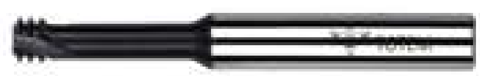
Multi Flute

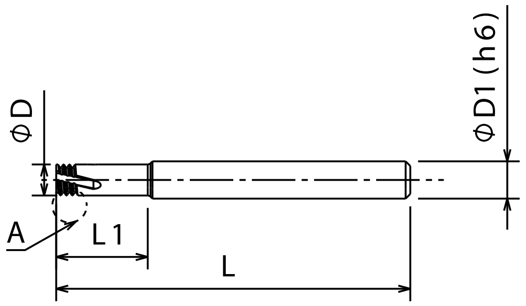
ISO metric thread

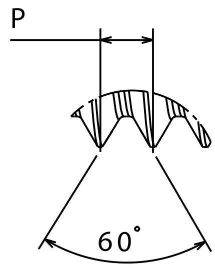
Internal threading upto 3D/4D



TM | MT 3D | MT 4D | M | IT | ISO | TiAIN







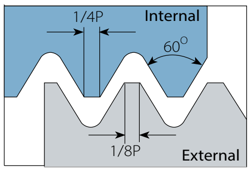
Detail view A

Thread Size	Pitch mm	Description	D mm	L1 mm	L mm	D1 mm	Flutes	EDP No
M0.8	0.20	TMMT3D-0.2-ISO-0.6MMX1.8X39 SH3 3FL TA	0.6	1.8	39	3	3	FBV0503172
M1	0.25	TMMT3D-0.25-ISO-0.72MMX2.9X39 SH3 3FL TA	0.72	2.9	39	3	3	FBV0503173
M1.2	0.25	TMMT3D-0.25-ISO-0.9MMX3X39 SH3 3FL TA	0.9	3	39	3	3	FBV0503174
M1.4	0.30	TMMT3D-0.3-ISO-1.06MMX3.9X39 SH3 3FL TA	1.06	3.9	39	3	3	FBV0503175
M1.6	0.35	TMMT3D-0.35-ISO-1.2MMX5.1X39 SH3 3FL TA	1.2	5.1	39	3	3	FBV0503176
M1.6	0.35	TMMT3D-0.35-ISO-1.2MMX5.1X57 SH6 3FL TA	1.2	5.1	57	6	3	FBV0503177
M2	0.40	TMMT3D-0.4-ISO-1.54MMX6.1X39 SH3 3FL TA	1.54	6.1	39	3	3	FBV0503178
M2	0.40	TMMT3D-0.4-ISO-1.54MMX10X39 SH3 3FL TA	1.54	10	39	3	3	FBV0503179
M2	0.40	TMMT3D-0.4-ISO-1.54MMX6.1X57 SH6 3FL TA	1.54	6.1	57	6	3	FBV0503180
M2	0.40	TMMT4D-0.4-ISO-1.54MMX6.1X100 SH6 3FL TA	1.54	6.1	100	6	3	FBV0503181
M2.5	0.45	TMMT3D-0.45-ISO-1.96MMX7.6X39 SH6 3FL TA	1.96	7.6	39	6	3	FBV0503182
M2.5	0.45	TMMT3D-0.45-ISO-1.96MMX7.6X100 SH6 3F TA	1.96	7.6	100	6	3	FBV0503183
M3	0.50	TMMT3D-0.5-ISO-2.4MMX9.3X57 SH6 3FL TA	2.4	9.3	57	6	3	FBV0503184
M3	0.50	TMMT4D-0.5-ISO-2.4MMX9.3X100 SH6 3FL TA	2.4	9.3	100	6	3	FBV0503185
M3.5	0.60	TMMT3D-0.6-ISO-2.75MMX10.6X57 SH6 3FL TA	2.75	10.6	57	6	3	FBV0503186
M4	0.70	TMMT3D-0.7-ISO-3.15MMX12.4X57 SH6 3FL TA	3.15	12.4	57	6	3	FBV0503187
M4	0.70	TMMT3D-0.7-ISO-3.15MMX16X57 SH6 3FL TA	3.15	16	57	6	3	FBV0503188
M4	0.70	TMMT4D-0.7-ISO-3.15MMX12.4X100 SH6 3F TA	3.15	12.4	100	6	3	FBV0503189
M5	0.80	TMMT3D-0.8-ISO-4MMX15.6X57 SH6 3FL TA	4	15.6	57	6	3	FBV0503190
M5	0.80	TMMT3D-0.8-ISO-4MMX21X57 SH6 3FL TA	4	21	57	6	3	FBV0503191
M5	0.80	TMMT4D-0.8-ISO-4MMX15.6X100 SH6 3FL TA	4	15.6	100	6	3	FBV0503192
M6	1.00	TMMT3D-1.0-ISO-4.75MMX19X57 SH6 3FL TA	4.75	19	57	6	3	FBV0503193
M6	1.00	TMMT4D-1.0-ISO-4.75MMX19X100 SH6 3FL TA	4.75	19	100	6	3	FBV0503194
M6	1.00	TMMT3D-1.0-ISO-4.75MMX24D57 SH6 3FL TA	4.75	24	57	6	3	FBV0503195
M8	1.25	TMMT3D-1.25-ISO-5.95MMX24.3X57 SH6 3F TA	5.95	24.3	57	6	3	FBV0503196
M8	1.25	TMMT4D-1.25-ISO-5.95MMX24.3X100 SH6 3FTA	5.95	24.3	100	6	3	FBV0503197
M10	1.50	TMMT3D-1.5-ISO-7.9MMX31X63 SH8 3FL TA	7.9	31	63	8	3	FBV0503198
M10	1.50	TMMT4D-1.5-ISO-7.90MMX31X100 SH8 3FL TA	7.9	31	100	8	3	FBV0503199
M12	1.75	TMMT3D-1.75-ISO-9.4MMX36X73 SH10 3FL TA	9.4	36	73	10	3	FBV0503200
M16	2.00	TMMT4D-2.0-ISO-11.95MMX48X100 SH12 4F TA	11.95	48	100	12	4	FBV0503201

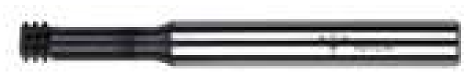
Multi Flute

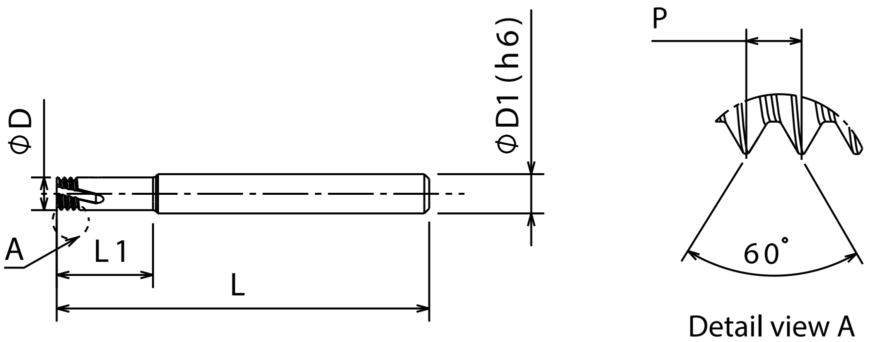
(UNC, UNF) unified thread

Internal threading upto 2D



TM | MT 2D | UNC | UNF | IT | UNIFIED | TiAlN





Thread Size		Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	1	72	TMMT2D-72-UN-1.44MMX3.8X39 SH3 3FL TA	1.44	3.8	39	3	3	FBV0503202
1	2	64	TMMT2D-64-UN-1.4MMX3.9X39 SH3 3FL TA	1.40	3.9	39	3	3	FBV0503203
2	3	56	TMMT2D-56-UN-1.66MMX4.6X39 SH3 3FL TA	1.66	4.6	39	3	3	FBV0503204
2	3	56	TMMT2D-56-UN-1.66MMX4.6X57 SH6 3FL TA	1.66	4.6	57	6	3	FBV0503205
3	4	48	TMMT2D-48-UN-1.88MMX5.4X57 SH6 3FL TA	1.88	5.4	57	6	3	FBV0503206
4		40	TMMT2D-40-UN-2.12MMX6.2X57 SH6 3FL TA	2.12	6.2	57	6	3	FBV0503207
5	6	40	TMMT2D-40-UN-2.46MMX7.1X57 SH6 3FL TA	2.46	7.1	57	6	3	FBV0503208
	8	36	TMMT2D-36-UN-3.31MMX8.8X57 SH6 3FL TA	3.31	8.8	57	6	3	FBV0503209
6		32	TMMT2D-32-UN-2.57MMX7.3X57 SH6 3FL TA	2.57	7.3	57	6	3	FBV0503210
8		32	TMMT2D-32-UN-3.22MMX10.1X57 SH6 3FL TA	3.22	10.1	57	6	3	FBV0503211
	10	32	TMMT2D-32-UN-3.7MMX10.5X57 SH6 3FL TA	3.70	10.5	57	6	3	FBV0503212
	12	28	TMMT2D-28-UN-4.2MMX10.9X57 SH6 3FL TA	4.20	10.9	57	6	3	FBV0503213
	1/4"	28	TMMT2D-28-UN-5.2MMX14X57 SH6 3FL TA	5.20	14.0	57	6	3	FBV0503214
10		24	TMMT2D-24-UN-3.55MMX10.4X57 SH6 3FL TA	3.55	10.4	57	6	3	FBV0503215
	5/16"	24	TMMT2D-24-UN-6.65MMX16.7X63 SH8 3FL TA	6.65	16.7	63	8	3	FBV0503216
1/4"	7/16"	20	TMMT2D-20-UN-4.85MMX13.7X57 SH6 3FL TA	4.85	13.7	57	6	3	FBV0503217
	7/16"	20	TMMT2D-20-UN-7.95MMX24X63 SH8 3FL TA	7.95	24.0	63	8	3	FBV0503218
5/16"		18	TMMT2D-18-UN-5.95MMX16.5X57 SH6 3FL TA	5.95	16.5	57	6	3	FBV0503219
	5/8"	18	TMMT2D-18-UN-11.9MMX34X84 SH12 4FL TA	11.90	34.0	84	12	4	FBV0503220
3/8"		16	TMMT2D-16-UN-6.9MMX21X63 SH8 3FL TA	6.90	21.0	63	8	3	FBV0503221
7/16"		14	TMMT2D-14-UN-7.95MMX23.5X63 SH8 3FL TA	7.95	23.5	63	8	3	FBV0503222
1/2"		13	TMMT2D-13-UN-9.3MMX27X73 SH10 3FL TA	9.30	27.0	73	10	3	FBV0503223
9/16"		12	TMMT2D-12-UN-9.95MMX29X63 SH10 3FL TA	9.95	29.0	63	10	3	FBV0503224
5/8"		11	TMMT2D-11-UN-11.5MMX33X84 SH12 3FL TA	11.50	33.0	84	12	3	FBV0503225

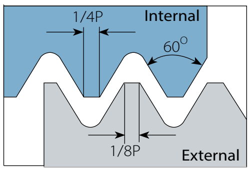
High Performance Cutting Tools

Defined by: ANSI B1.1:74 I Tolerance class: 2B

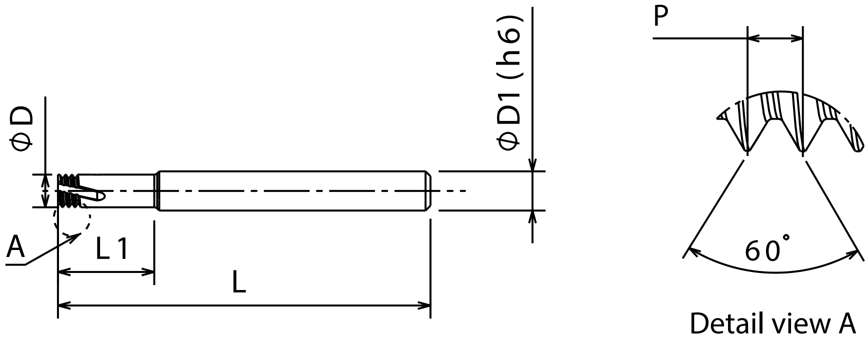
3 Flute

(UNC, UNF) unified thread

Internal threading upto 3D/4D



TM | MT 3D | MT 4D | UNC | UNF | IT | UNIFIED | TiAlN



Thread Size		Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	0	80	TMMT3D-80-UN-1.18MMX3.9X39 SH3 3FL TA	1.18	3.9	39	3	3	FBV0503226
	1	72	TMMT3D-72-UN-1.44MMX5.8X39 SH3 3FL TA	1.44	5.8	39	3	3	FBV0503227
	1	72	TMMT3D-72-UN-1.44MMX5.8X57 SH6 3FL TA	1.44	5.8	57	6	3	FBV0503228
2	3	56	TMMT3D-56-UN-1.66MMX6.8X39 SH3 3FL TA	1.66	6.8	39	3	3	FBV0503229
2	3	56	TMMT4D-56-UN-1.66MMX6.8X57 SH6 3FL TA	1.66	6.8	57	6	3	FBV0503230
2	3	56	TMMT3D-56-UN-1.66MMX6.8X100 SH6 3FL TA	1.66	6.8	100	6	3	FBV0503231
4		40	TMMT4D-40-UN-2.12MMX8.1X57 SH6 3FL TA	2.12	8.1	57	6	3	FBV0503232
4		40	TMMT3D-40-UN-2.12MMX8.1X100 SH6 3FL TA	2.12	8.1	100	6	3	FBV0503233
5		40	TMMT3D-40-UN-2.46MMX9.8X57 SH6 3FL TA	2.46	9.8	57	6	3	FBV0503234
6	6	32	TMMT3D-32-UN-2.57MMX10.7X57 SH6 3FL TA	2.57	10.7	57	6	3	FBV0503235
6		32	TMMT4D-32-UN-2.57MMX10.7X100 SH6 3FL TA	2.57	10.7	100	6	3	FBV0503236
8		32	TMMT3D-32-UN-3.22MMX12.7X57 SH6 3FL TA	3.22	12.7	57	6	3	FBV0503237
	10	32	TMMT3D-32-UN-3.7MMX15.5X57 SH6 3FL TA	3.70	15.5	57	6	3	FBV0503238
	10	32	TMMT4D-32-UN-3.7MMX15.5X100 SH6 3FL TA	3.70	15.5	100	6	3	FBV0503239
	12	28	TMMT3D-28-UN-4.2MMX16X57 SH6 3FL TA	4.20	16.0	57	6	3	FBV0503240
	1/4"	28	TMMT3D-28-UN-5.2MMX19.3X57 SH6 3FL TA	5.20	19.3	57	6	3	FBV0503241
	1/4"	28	TMMT4D-28-UN-5.2MMX19.3X100 SH6 3FL TA	5.20	19.3	100	6	3	FBV0503242
	5/16"	24	TMMT3D-24-UN-6.65MMX24.2X63 SH8 3FL TA	6.65	24.2	63	8	3	FBV0503243
1/4"	7/16"	20	TMMT3D-20-UN-4.85MMX19.4X57 SH6 3FL TA	4.85	19.4	57	6	3	FBV0503244
1/4"	7/16"	20	TMMT4D-20-UN-4.85MMX19.4X100 SH6 3FL TA	4.85	19.4	100	6	3	FBV0503245
5/16"		18	TMMT3D-18-UN-5.9MMX23X57 SH6 3FL TA	5.90	23.0	57	6	3	FBV0503246
3/8"		16	TMMT3D-16-UN-6.9MMX28.5X63 SH8 3FL TA	6.90	28.5	63	8	3	FBV0503247

TOTEM

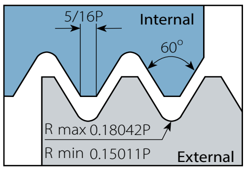
High Performance Cutting Tools

Defined by: MIL-S-8879C I Tolerance class: 3B

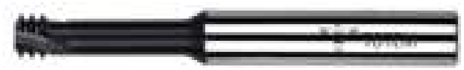
3 Flute

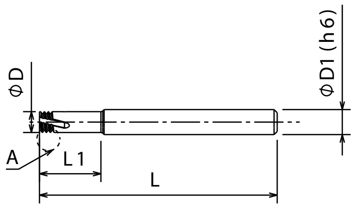
(UNJ) unified thread

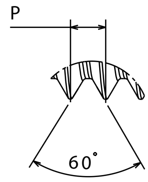
Internal threading upto 3D



TM | MT 3D | UNJ | UNJF | IT | UNIFIED | TiAlN







Detail view A

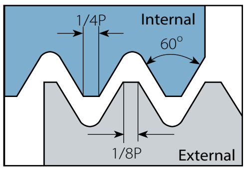
Thread Size		Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
4	6	40	TMMT3D-40-UNJ-2.1MMX8X57 SH6 3FL TA	2.1	8	57	6	3	FBV0503248
8	10	32	TMMT3D-32-UNJ-3.3MMX13X57 SH6 3FL TA	3.3	12	57	6	3	FBV0503249
	1/4"	28	TMMT3D-28-UNJ-5.4MMX19X57 SH6 3FL TA	5.4	19	57	6	3	FBV0503250
	5/16" , 3/8"	24	TMMT3D-24-UNJ-6.7MMX24X63 SH8 3FL TA	6.7	24	63	8	3	FBV0503251
1/4"		20	TMMT3D-20-UNJ-5MMX19X63 SH6 3FL TA	5	19	63	6	3	FBV0503252
	7/16"	20	TMMT3D-20-UNJ-7.9MMX28X63 SH8 3FL TA	7.9	28	63	8	3	FBV0503253
5/16"		18	TMMT3D-18-UNJ-6.4MMX24X63 SH8 3FL TA	6.4	24	63	8	3	FBV0503254
3/8"		16	TMMT3D-16-UNJ-6.9MMX24X63 SH8 3FL TA	6.9	24	63	8	3	FBV0503255
7/16"		14	TMMT3D-14-UNJ-7.9MMX26X63 SH8 3FL TA	7.9	26	63	8	3	FBV0503256
1/2"		13	TMMT3D-13-UNJ-9.9MMX28X73 SH10 3FL TA	9.9	28	73	10	3	FBV0503257

Defined by: ISO 5855 I Tolerance class: 4h/6h-4H/5H

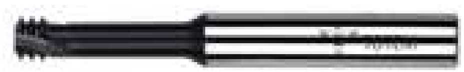
Multi Flute

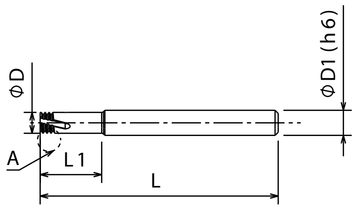
(MJ) ISO Thread

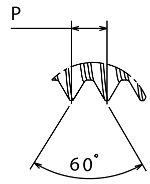
Internal Threading upto 3D



TM | MT 3D | MJ | IT | MJ | TiAlN







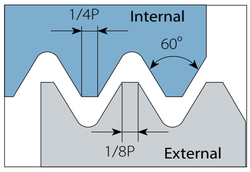
Detail view A

Thread Size	Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
MJ4.0	0.70	TMMT3D-0.7-MJ-3.2MMX13X57 SH6 3FL TA	3.2	12	57	6	3	FBV0503258
MJ5.0	0.80	TMMT3D-0.8-MJ-4MMX15X57 SH6 3FL TA	4	15	57	6	3	FBV0503259
MJ6.0	1.00	TMMT3D-1.0-MJ-4.8MMX18X57 SH6 3FL TA	4.8	18	57	6	3	FBV0503260
MJ8.0	1.25	TMMT3D-1.25-MJ-6.5MMX24X63 SH8 3FL TA	6.5	24	63	8	3	FBV0503261
MJ10.0	1.50	TMMT3D-1.5-MJ-7.9MMX31X63 SH8 3FL TA	7.9	31	63	8	3	FBV0503262
MJ12.0	1.75	TMMT3D-1.75-MJ-9.4MMX31X73 SH10 3FL TA	9.4	31	73	10	3	FBV0503263
MJ14.0 , MJ16.0	2.00	TMMT3D-2.0-MJ-9.9MMX36X73 SH10 3FL TA	9.9	36	73	10	3	FBV0503264

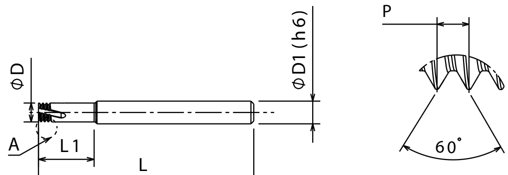
Defined by: R262 (DIN 13) I Tolerance class: 6H

3 Flute

ISO metric thread
Internal threading for hard materials upto 2D



TM | MTH 2D | 62 HrC | M | IT | ISO | TiAlN



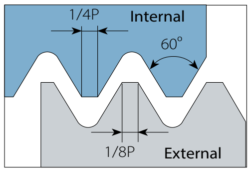
Detail view A

Thread Size	Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
M1.6	0.35	TMMTH2D-0.35-ISO-1.2MMX3.3X57 SH6 3FL TA	1.2	3.3	57	6	3	FBV0503265
M2	0.40	TMMTH2D-0.4-ISO-1.54MMX4.4X57 SH6 3FL TA	1.54	4.4	57	6	3	FBV0503266
M2.2	0.45	TMMTH2D-0.45-ISO-1.63MMX4.8X57 SH6 3FL TA	1.63	4.8	57	6	3	FBV0503267
M2.5	0.45	TMMTH2D-0.45-ISO-1.96MMX5.3X57 SH6 3FL TA	1.96	5.3	57	6	3	FBV0503268
M3	0.50	TMMTH2D-0.5-ISO-2.4MMX6.4X57 SH6 3FL TA	2.4	6.4	57	6	3	FBV0503269
M3.5	0.60	TMMTH2D-0.6-ISO-2.75MMX7.4X57 SH6 3FL TA	2.75	7.4	57	6	3	FBV0503270
M4	0.70	TMMTH2D-0.7-ISO-3.15MMX8.6X57 SH6 3FL TA	3.15	8.6	57	6	3	FBV0503271
M5	0.80	TMMTH2D-0.8-ISO-4MMX12X57 SH6 3FL TA	4	12	57	6	3	FBV0503272
M6	1.00	TMMTH2D-1-ISO-4.75MMX13X57 SH6 3FL TA	4.75	13	57	6	3	FBV0503273
M8	1.25	TMMTH2D-1.25-ISO-5.95MMX17.3X57 SH6 3FL TA	5.95	17.3	57	6	3	FBV0503274
M10	1.50	TMMTH2D-1.5-ISO-7.9MMX22X63 SH8 3FL TA	7.9	22	63	8	3	FBV0503275

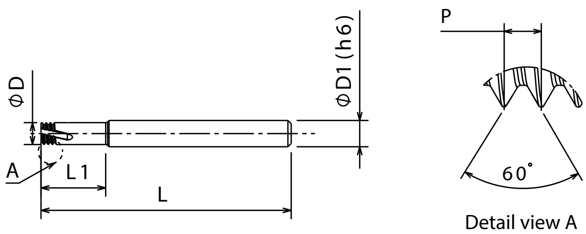
Defined by: R262 (DIN 13) I Tolerance class: 6H

Multi Flute

ISO metric thread
Internal threading for hard materials upto 3D



TM | MTH 3D | 62 HrC | M | IT | ISO | TiAlN



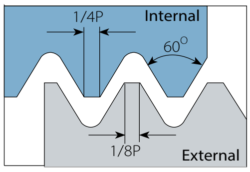
Detail view A

Thread Size	Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
M1.6	0.35	TMMTH3D-0.35-ISO-1.2MMX5.1X57 SH6 3FL TA	1.2	5.1	57	6	3	FBV0503276
M2	0.4	TMMTH3D-0.4-ISO-1.54MMX6.1X57 SH6 3FL TA	1.54	6.1	57	6	3	FBV0503277
M2.2	0.45	TMMTH3D-0.45-ISO-1.96MMX7.6X57 SH6 3FL TA	1.96	7.6	57	6	3	FBV0503278
M3	0.5	TMMTH3D-0.5-ISO-2.4MMX9.3X57 SH6 3FL TA	2.4	9.3	57	6	3	FBV0503279
M4	0.7	TMMTH3D-0.7-ISO-3.15MMX12.4X57 SH6 3FL TA	3.15	12.4	57	6	3	FBV0503280
M5	0.8	TMMTH3D-0.8-ISO-4MMX15.6X57 SH6 3FL TA	4	15.6	57	6	3	FBV0503281
M6	1	TMMTH3D-1-ISO-4.75MMX19X57 SH6 3FL TA	4.75	19	57	6	3	FBV0503282
M8	1.25	TMMTH3D-1.25-ISO-5.95MMX24.3X57 SH6 3FL TA	5.95	24.3	57	6	3	FBV0503283

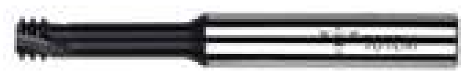
Defined by: ANSI B1.1:74 I Tolerance class: 2B

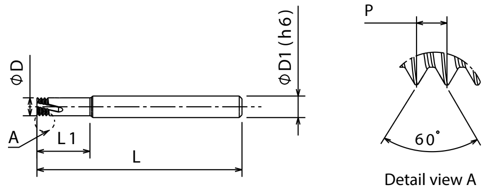
3 Flute

(UN, UNF) unified thread
Internal threading for hard materials upto 2d



TM | MTH 2D | UNC | UNF | 62 HrC | IT | UNIFIED | TiAlN



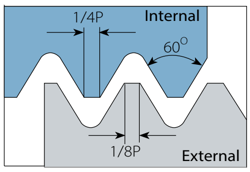


Thread Size		Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	1	72	TMMTH2D-72-UN-1.44MMX3.8X57 SH6 3FL TA	1.44	3.8	57	6	3	FBV0503284
1	2	64	TMMTH2D-64-UN-1.4MMX3.9X57 SH6 3FL TA	1.4	3.9	57	6	3	FBV0503285
2	3	56	TMMTH2D-56-UN-1.66MMX4.6X57 SH6 3FL TA	1.66	4.6	57	6	3	FBV0503286
3	4	48	TMMTH2D-48-UN-1.88MMX5.4X57 SH6 3FL TA	1.88	5.4	57	6	3	FBV0503287
4		40	TMMTH2D-40-UN-2.12MMX6.2X57 SH6 3FL TA	2.12	6.2	57	6	3	FBV0503288
5	6	40	TMMTH2D-40-UN-2.46MMX7.1X57 SH6 3FL TA	2.46	7.1	57	6	3	FBV0503289
	8	36	TMMTH2D-36-UN-3.31MMX8.8X57 SH6 3FL TA	3.31	8.8	57	6	3	FBV0503290
6		32	TMMTH2D-32-UN-2.57MMX7.8X57 SH6 3FL TA	2.57	7.8	57	6	3	FBV0503291
8	10	32	TMMTH2D-32-UN-3.22MMX10.3X57 SH6 3FL TA	3.22	10.3	57	6	3	FBV0503292
	1/4"	28	TMMTH2D-28-UN-5.2MMX14X57 SH6 3FL TA	5.2	14	57	6	3	FBV0503293
10		24	TMMTH2D-24-UN-3.55MMX10.4X57 SH6 3FL TA	3.55	10.4	57	6	3	FBV0503294
	5/16"	24	TMMTH2D-24-UN-6.65MMX16.7X64 SH8 3FL TA	6.65	16.7	64	8	3	FBV0503295
1/4"	7/16"	20	TMMTH2D-20-UN-4.85MMX13.7X57 SH6 3FL TA	4.85	13.7	57	6	3	FBV0503296
	7/16"	20	TMMTH2D-20-UN-7.95MMX24X64 SH8 3FL TA	7.95	24	64	8	3	FBV0503297
5/16"		18	TMMTH2D-18-UN-5.95MMX16.5X57 SH6 3FL TA	5.95	16.5	57	6	3	FBV0503298
3/8"		16	TMMTH2D-16-UN-6.9MMX20X63 SH8 3FL TA	6.9	20	63	8	3	FBV0503299
7/16"		14	TMMTH2D-14-UN-7.95MMX23.5X63 SH8 3FL TA	7.95	23.5	63	8	3	FBV0503300

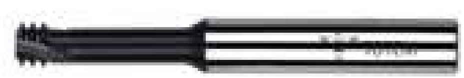
Defined by: ANSI B1.1:74 I Tolerance class: 2B

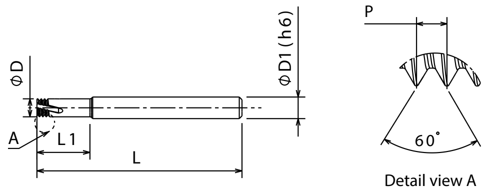
3 Flute

(UN, UNF) Unified Thread
Internal Threading For Hard Materials upto 3D



TM | MTH 3D | UNC | UNF | 62 HrC | IT | UNIFIED | TiAlN





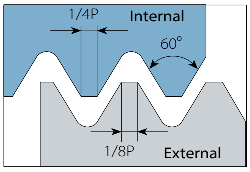
Thread Size		Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	1	72	TMMTH3D-72-UN-1.44MMX5.8X57 SH6 3FL TA	1.44	5.8	57	6	3	FBV0503301
5	6	40	TMMTH3D-40-UN-2.46MMX9.8X57 SH6 3FL TA	2.46	9.8	57	6	3	FBV0503302
8	10	32	TMMTH3D-32-UN-3.22MMX12.7X57 SH6 3FL TA	3.22	12.7	57	6	3	FBV0503303
	1/4"	28	TMMTH3D-28-UN-5.2MMX19.3X57 SH6 3FL TA	5.2	19.3	57	6	3	FBV0503304
	5/16"	24	TMMTH3D-24-UN-6.65MMX24.2X63 SH8 3FL TA	6.65	24.2	63	8	3	FBV0503305
1/4"	7/16"	20	TMMTH3D-20-UN-4.85MMX19.4X57 SH6 3FL TA	4.85	19.4	57	6	3	FBV0503306

Defined by: R262 (DIN 13) I Tolerance class: 6H

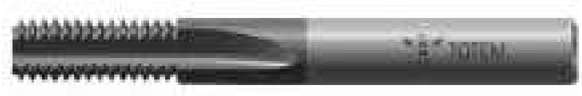
High Performance Cutting Tools

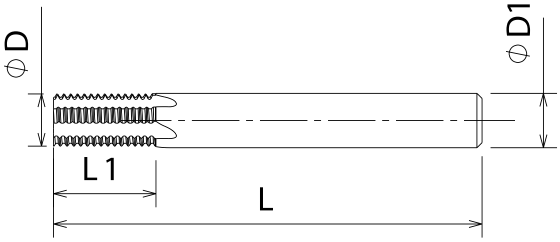
Multi Flute

ISO metric thread
Internal threading



TM | RSS | M | MF | IT | ISO | TiAIN





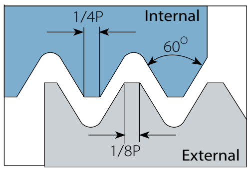
Thread Size		Pitch mm	Description	D	L1	L	D1	Flutes	EDP No
Coarse	Fine			mm	mm	mm	mm		
	M8	0.75	TMRSS-0.75-ISO-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503307
M5		0.80	TMRSS-0.8-ISO-3.9MMX10X57 SH6 3FL TA	3.9	10	57	6	3	FBV0503308
M6	M7	1.00	TMRSS-1-ISO-4.8MMX11.5X57 SH6 3FL TA	4.8	11.5	57	6	3	FBV0503309
	M10	1.00	TMRSS-1-ISO-7.9MMX17.5X63 SH8 4FL TA	7.9	17.5	63	8	4	FBV0503310
	M12	1.00	TMRSS-1-ISO-9.9MMX20.5X73 SH10 4FL TA	9.9	20.5	73	10	4	FBV0503311
M8	M9	1.25	TMRSS-1.25-ISO-5.9MMX14.4X57 SH6 3FL TA	5.9	14.4	57	6	3	FBV0503312
M10	M11	1.50	TMRSS-1.5-ISO-7.9MMX18.5X63 SH8 3FL TA	7.9	18.5	63	8	3	FBV0503313
	M13	1.50	TMRSS-1.5-ISO-9.9MMX21.8X73 SH10 4FL TA	9.9	21.8	73	10	4	FBV0503314
	M15	1.50	TMRSS-1.5-ISO-11.9MMX26.3X84 SH12 4FL TA	11.9	26.3	84	12	4	FBV0503315
M12		1.75	TMRSS-1.75-ISO-7.9MMX18X64 SH8 3FL TA	7.9	18	64	8	3	FBV0503316
M14		2.00	TMRSS-2-ISO-9.9MMX25X73 SH10 3FL TA	9.9	25	73	10	3	FBV0503317
M16		2.00	TMRSS-2-ISO-11.9MMX27X84 SH12 4FL TA	11.9	27	84	12	4	FBV0503318
M20		2.50	TMRSS-2.5-ISO-11.9MMX30X84 SH12 4FL TA	11.9	30	84	12	4	FBV0503319
M24	M27	3.00	TMRSS-3-ISO-11.5MMX40.5X105 SH16 4FL TA	11.5	40.5	105	16	4	FBV0503320

High Performance Cutting Tools

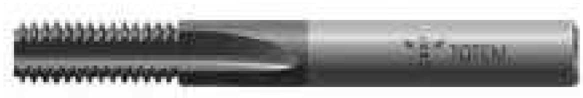
Defined by: ANSI B1.1:74 I Tolerance class: 2B

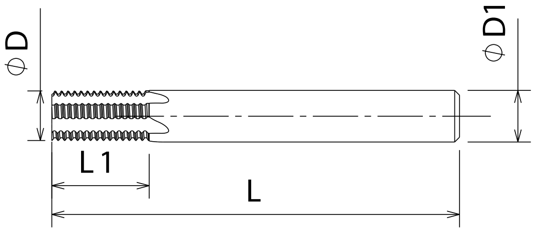
Multi Flute

(UNC, UNF, UNEF) unified thread
Internal threading



TM | RSS | UNC | UNF | UNEF | IT | UNIFIED | TiAlN



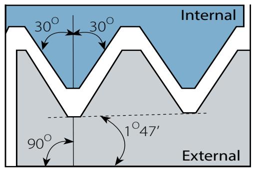


Thread Size			Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
Coarse UNC	Fine UNF	Extra Fine UNEF			mm	mm	mm	mm		
		5/16"	32	TMRSS-32-UN-5.9MMX14X57 SH6 3FL TA	5.9	14	57	6	3	FBV0503321
	1/4"		28	TMRSS-28-UN-5.1MMX12.2X57 SH6 3FL TA	5.1	12.2	57	6	3	FBV0503322
		7/16"-1/2"	28	TMRSS-28-UN-7.9MMX15.8X63 SH8 4FL TA	7.9	15.8	63	8	4	FBV0503323
	5/16"		24	TMRSS-24-UN-5.9MMX10.8X57 SH6 3FL TA	5.9	10.8	57	6	3	FBV0503324
1/4"			20	TMRSS-20-UN-4.8MMX12X57 SH6 3FL TA	4.8	12	57	6	3	FBV0503325
	7/16"		20	TMRSS-20-UN-7.9MMX19.7X63 SH8 3FL TA	7.9	19.7	63	8	3	FBV0503326
	1/2"		20	TMRSS-20-UN-9.9MMX17.5X73 SH10 4FL TA	9.9	17.5	73	10	4	FBV0503327
5/16"			18	TMRSS-18-UN-5.7MMX16X57 SH6 3FL TA	5.7	16	57	6	3	FBV0503328
	9/16"-5/8"		18	TMRSS-18-UN-7.9MMX18.5X63 SH8 3FL TA	7.9	18.5	63	8	3	FBV0503329
3/8"			16	TMRSS-16-UN-6.8MMX18.2X63 SH8 3FL TA	6.8	18.2	63	8	3	FBV0503330
	3/4"		16	TMRSS-16-UN-11.9MMX26.2X84 SH12 4FL TA	11.9	26.2	84	12	4	FBV0503331
7/16"			14	TMRSS-14-UN-7.8MMX20.8X63 SH8 3FL TA	7.8	20.8	63	8	3	FBV0503332
	7/8"		14	TMRSS-14-UN-11.9MMX24.5X84 SH12 4FL TA	11.9	24.5	84	12	4	FBV0503333
1/2"			13	TMRSS-13-UN-9.3MMX24.4X73 SH10 3FL TA	9.3	24.4	73	10	3	FBV0503334
9/16"			12	TMRSS-12-UN-10.6MMX26.4X84 SH12 4FL TA	10.6	26.4	84	12	4	FBV0503335
	1”		12	TMRSS-12-UN-15.9MMX39.1X105 SH16 5FL TA	15.9	39.1	105	16	5	FBV0503336
5/8"			11	TMRSS-11-UN-11.5MMX31.1X84 SH12 4FL TA	11.5	31.1	84	12	4	FBV0503337
3/4"			10	TMRSS-10-UN-14.3MMX36.8X105 SH16 4FL TA	14.3	36.8	105	16	4	FBV0503338
7/8"			9	TMRSS-9-UN-15.9MMX40.9X105 SH16 4FL TA	15.9	40.9	105	16	4	FBV0503339
1”			8	TMRSS-8-UN-19.7MMX39.7X105 SH20 4FL TA	19.7	39.7	105	20	4	FBV0503340

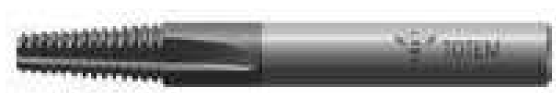
Defined by: USAS B2.1:1968
Tolerance class: Standard NPT

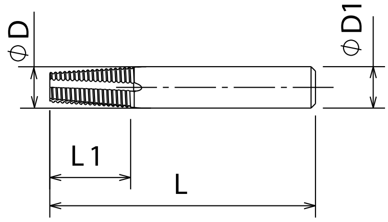
Multi Flute

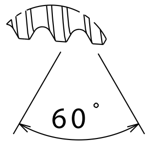
NPT
Internal/external threading



TM | RSTS | NPT | IT | ET | NPT | TiAlN







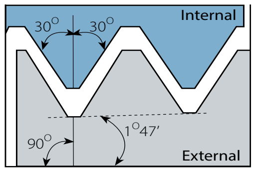
Detail view A

Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"-1/8"	27	TMRSTS-27-NPT-5.9MMX9.8X57 SH6 3FL TA	5.9	9.8	57	6	3	FBV0503341
1/4"-3/8"	18	TMRSTS-18-NPT-9.9MMX16.2X73 SH10 4FL TA	9.9	16.2	73	10	4	FBV0503342
1/2"	14	TMRSTS-14-NPT-11.9MMX20.8X83 SH12 4FL TA	11.9	20.8	83	12	4	FBV0503343
1"-2"	11.5	TMRSTS-11.5-NPT-19.9MMX29.7X105 SH20 4FL TA	19.9	29.7	105	20	4	FBV0503344
2 1/2"-6"	8	TMRSTS-8-NPT-19.9MMX38.1X105 SH20 4FL TA	19.9	38.1	105	20	4	FBV0503345

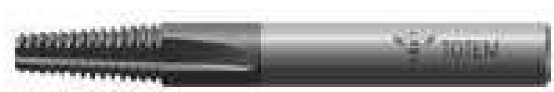
Defined by: USAS B2.1:1968 I Tolerance class: Standard NPT

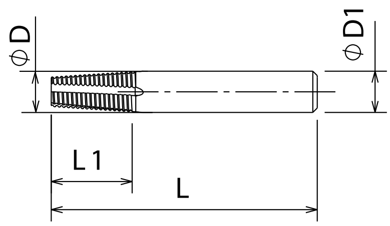
Multi Flute

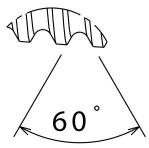
NPTF
Internal/external threading



TM | RSTS | NPTF | IT | ET | NPTF | TiAlN







Detail view A

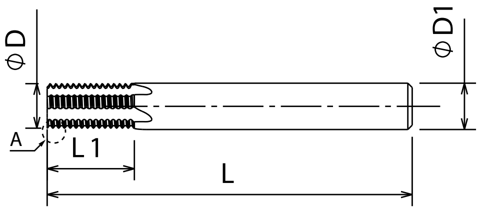
Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"-1/8"	27	TMRSTS-27-NPTF-5.9MMX9.9X57 SH6 3FL TA	5.9	9.9	57	6	3	FBV0503346
1/4"-3/8"	18	TMRSTS-18-NPTF-9.9MMX16.2X73 SH10 4FL TA	9.9	16.2	73	10	4	FBV0503347
1/2"	14	TMRSTS-14-NPTF-11.9MMX20.8X83 SH12 4FL TA	11.9	20.8	83	12	4	FBV0503348
1"-2"	11.5	TMRSTS-11.5-NPTF-19.9MMX29.7X105SH20 4FTA	19.9	29.7	105	20	4	FBV0503349
2 1/2"-6"	8	TMRSTS-8-NPTF-19.9MMX38.1X105 SH20 4FL TA	19.9	38.1	105	20	4	FBV0503350

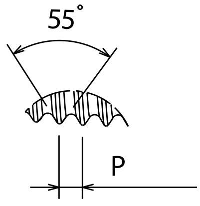
Multi Flute

BSP (G)

Internal/external threading

TM | RSS | BSP | ET | IT | BS | TiAlN





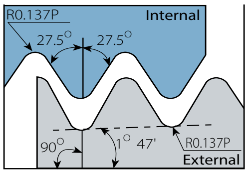
Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"-1/8"	28	TMRSS-28-BSP-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503351
1/4"-3/8"	19	TMRSS-19-BSP-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503352
1/2"-7/8"	14	TMRSS-14-BSP-11.9MMX22.7X83 SH12 4FL TA	11.9	22.7	83	12	4	FBV0503353
1"-2"	11	TMRSS-11-BSP-15.9MMX32.1X105 SH16 4FL TA	15.9	32.1	105	16	4	FBV0503354

Defined by: B.S.21:1985 I Tolerance class: Tolerance class: Standard BSPT

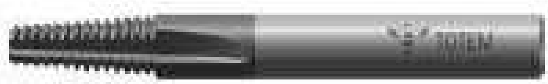
Multi Flute

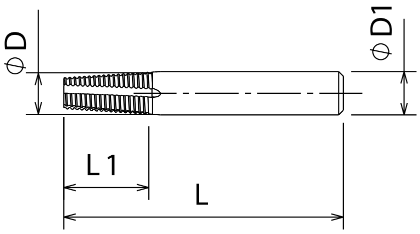
BSPT (Rc)

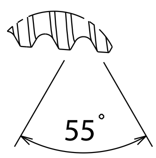
Internal/external threading



TM | RSTS | BSP | ET | IT | BS | TiAlN





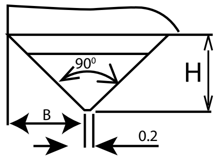


Thread Size	Pitch TPI	Description	D	L1	L	D1	Flutes	EDP No
			mm	mm	mm	mm		
1/16"-1/8"	28	TMRSTS-28-BSPT-5.9MMX11.3X57 SH6 3FL TA	5.9	11.3	57	6	3	FBV0503355
1/4"-3/8"	19	TMRSTS-19-BSPT-9.9MMX16.6X73 SH10 4FL TA	9.9	16.6	73	10	4	FBV0503356
1/2"-7/8"	14	TMRSTS-14-BSPT-11.9MMX22.7X83 SH12 4FL TA	11.9	22.7	83	12	4	FBV0503357
1"-2"	11	TMRSTS-11-BSPT-15.9MMX32.1X105 SH16 4FL TA	15.9	32.1	105	16	4	FBV0503358

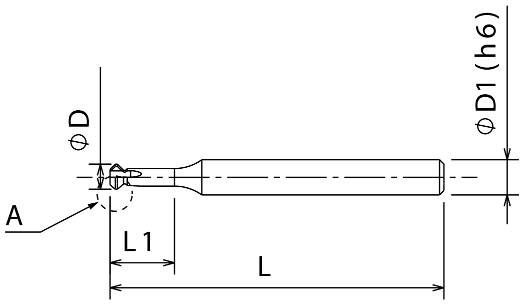
High Performance Cutting Tools

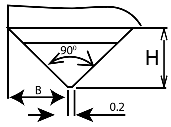
3 Flute

Chamfer tools
Internal chamfering- short



CT | A90S | SHORT | IC | IT | TiAlN



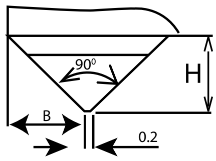


Detail View A

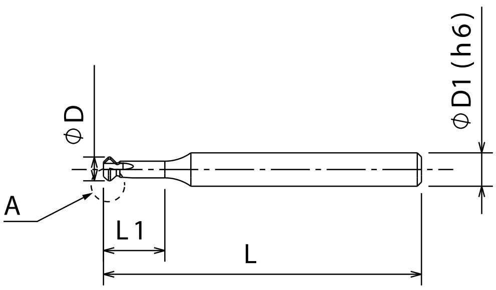
Description	D	L1	L	D1	H	B	Angle	No. Of Flutes	EDP No
	mm	mm	mm	mm	mm	mm	a		
CT-A90S-1.5MMX4X39 SH3 3FL TA	1.50	4	39	3	0.3	0.4	90	3	FBV0503359
CT-A90S-2MMX5X39 SH3 3FL TA	2.00	5	39	3	0.4	0.5	90	3	FBV0503360
CT-A90S-2.5MMX6X39 SH3 3FL TA	2.50	6	39	3	0.5	0.6	90	3	FBV0503361
CT-A90S-3.1MMX8X51 SH4 3FL TA	3.10	8	51	4	0.6	0.6	90	3	FBV0503362
CT-A90S-3.9MMX10X51 SH4 3FL TA	3.90	10	51	4	0.8	0.9	90	3	FBV0503363
CT-A90S-4.5MMX11X58 SH6 3FL TA	4.50	11	58	6	1.1	1.2	90	3	FBV0503364
CT-A90S-4.9MMX12X58 SH6 3FL TA	4.90	12	58	6	1.1	1.2	90	3	FBV0503365
CT-A90S-5.9MMX14X58 SH6 3FL TA	5.90	14	58	6	1.5	1.6	90	3	FBV0503366
CT-A90S-7.9MMX20X64 SH6 3FL TA	7.90	20	64	8	1.6	1.7	90	3	FBV0503367

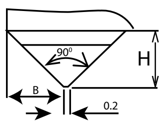
3 Flute

Chamfer tools
Internal chamfering- long



CT | A90L | LONG | IC | IT | TiAlN





Detail View A

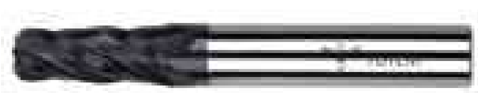
Description	D	L1	L	D1	H	B	Angle	No. Of Flutes	EDP No
	mm	mm	mm	mm	mm	mm	a		
CT-A90L-3.1MMX12X51 SH4 3FL TA	3.1	12	51	4	0.6	0.6	90	3	FBV0503368
CT-A90L-3.9MMX16X51 SH4 3FL TA	3.9	16	51	4	0.8	0.9	90	3	FBV0503369
CT-A90L-4.9MMX20X58 SH6 3FL TA	4.9	20	58	6	1.1	1.2	90	3	FBV0503370
CT-A90L-5.9MMX24X58 SH4 3FL TA	5.9	24	58	6	1.5	1.6	90	3	FBV0503371
CT-A90L-7.9MMX30X64 SH8 3FL TA	7.9	30	64	8	1.6	1.7	90	3	FBV0503372

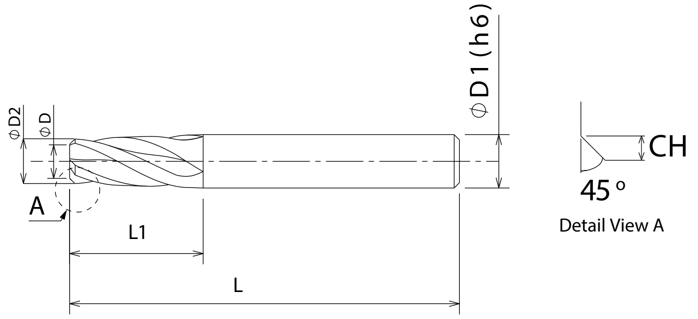
4 Flute

Taper end mills for conic preperation for taper threads (NPT, NPTF, BSPT) 45 degree chamfer preperation tool

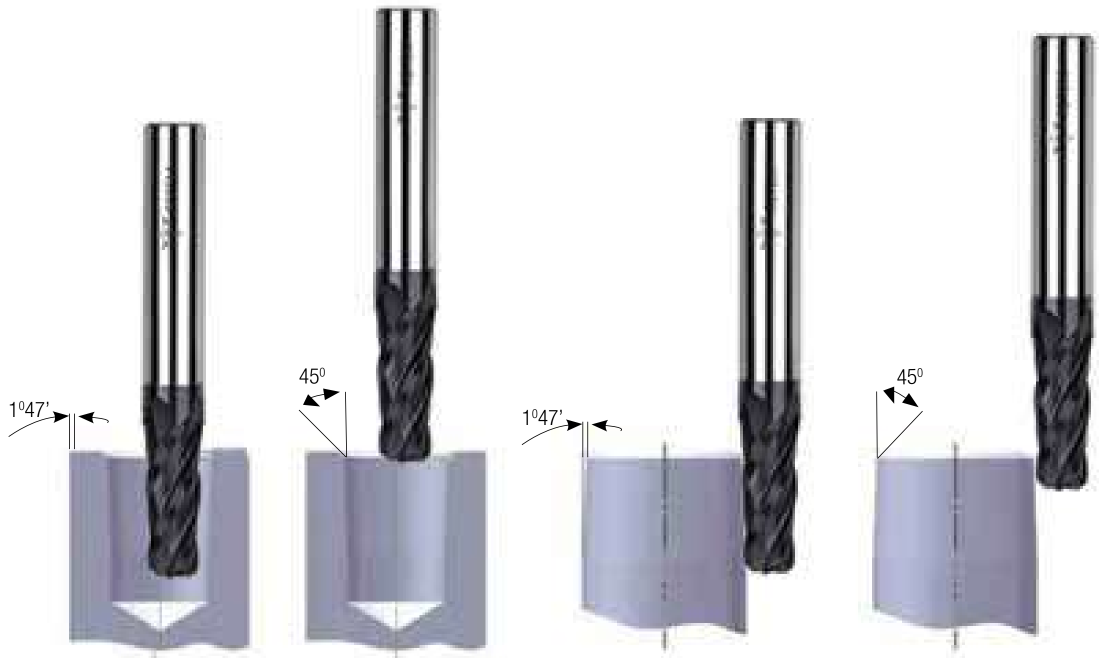
Internal chamfering- short

TP | IC | EC | ICP | ECP | TiAlN





Description	D	L1	L	D1	D2	TPR Angle	CH	No. Of Flutes	EDP No
	mm	mm	mm	mm	mm	a	mm		
EM 3.00MMX15X58 SH6 CH1 TPR1.47 4FL TA	3	15	58	6	5	1.47	1	4	FBV0503373
EM 5.60MMX25X73 SH10 CH1.4 TPR1.47 4F TA	5.6	25	73	10	8.4	1.47	1.4	4	FBV0503374
EM 6.30MMX33X84 SH12 CH1.8 TPR1.47 4FTA	6.3	33	84	12	9.9	1.47	1.8	4	FBV0503375

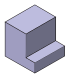
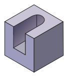


INTERNAL TAPER PREPARATION | INTERNAL CHAMFERING | EXTERNAL TAPER PREPARATION | EXTERNAL CHAMFERING

Cutting parameters

RAZORCUT- CBC

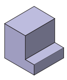
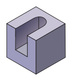
Centre cutting high performance 3 flute chip breaker end mill for roughing of aluminium with corner chamfer - Razorcut CBC - 6.0 mm to 25.0 mm

Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
																												
			5	2.3	1.6	1.4	1.2	1.1	1						Multiply fz by this multiplication factor based on ae. For excellant floor finish, use the standard fz per chart below. Only add chip thinning multiplication factor when roughing or semi-finishing.													
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	Diameter in mm													
															6.0		8.0		10.0		12.0		16.0		20.0		25.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	0.75XD	1xD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.053	0.066	0.070	0.088	0.088	0.110	0.106	0.132	0.141	0.176	0.176	0.220	0.220	0.275
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.047	0.059	0.063	0.079	0.079	0.099	0.095	0.119	0.126	0.158	0.158	0.198	0.198	0.248

If you are using Trochoidal Strategy with the Razorcut CBC. Program the helix as 30 degrees, use the starting hm value as given in the catalogue section, Use an engagement angle starting value of 53.13 degrees to get good results.

RAZORCUT- CBCH/NCBCH

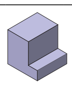
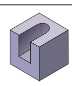
Centre cutting high performance 3 flute chip breaker end mill for roughing of aluminium with corner radius - Razorcut CBCH/NCBCH - 6.0 mm to 25.0 mm

Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
																												
			5	2.3	1.6	1.4	1.2	1.1	1						Multiply fz by this multiplication factor based on ae. For excellant floor finish, use the standard fz per chart below. Only add chip thinning multiplication factor when roughing or semi-finishing.													
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	Diameter in mm													
															6.0		8.0		10.0		12.0		16.0		20.0		25.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	0.75XD	1xD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.058	0.072	0.077	0.096	0.096	0.120	0.115	0.144	0.154	0.192	0.192	0.240	0.208	0.260
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.052	0.065	0.069	0.086	0.086	0.108	0.104	0.130	0.138	0.173	0.173	0.216	0.192	0.240
		3	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.040	0.050	0.054	0.067	0.067	0.084	0.081	0.101	0.107	0.134	0.134	0.168	0.144	0.180
		4	840	660	600	560	540	520	500	460	575	400	750	fz	0.046	0.058	0.062	0.077	0.077	0.096	0.092	0.115	0.123	0.154	0.154	0.192	0.164	0.205
		5	525	413	375	350	338	325	313	500	625	250	1000	fz	0.052	0.065	0.069	0.086	0.086	0.108	0.104	0.130	0.138	0.173	0.173	0.216	0.187	0.234

If you are using Trochoidal Strategy with the Razorcut CBCH/NCBCH. Program the helix as 40 degrees, use the starting hm value as given in the catalogue section, Use an engagement angle starting value of 53.13 degrees to get good results.

RAZORCUT 1F

Razor Cut 1F for machining alumnium and plastics - 3.0 mm to 10.0 mm

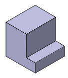
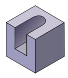
Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling		Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%														
															Diameter in mm											
			ap Max	ap Max	ap 1.2D	ap 1.2D	ap 1.1D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	3.0		4.0		5.0		6.0		8.0		10.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	1XD	0.5XD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.017	0.021	0.022	0.028	0.028	0.035	0.034	0.042	0.045	0.056	0.056	0.070
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.014	0.017	0.018	0.022	0.022	0.028	0.027	0.034	0.036	0.045	0.045	0.056

For better finish reduce the feed rate.

Cutting parameters

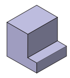
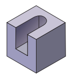
RAZORCUT 2FWF

Centre cutting high performance end mill for non ferrous materials with wiper technology - Razorcut 2FWF - 1.5 mm to 20.0 mm

Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%																	
																																
			5	2.3	1.6	1.4	1.2	1.1	1	←					Multiply fz by this multiplication factor based on ae. For excellant floor finish, use the standard fz per chart below. Only add chip thinning multiplication factor when roughing or semi-finishing.																	
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	Diameter in mm																	
															1.5		2.0		4.0		6.0		8.0		10.0		12.0		16.0		20.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	1XD	0.5XD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.011	0.014	0.014	0.018	0.029	0.036	0.043	0.054	0.058	0.072	0.072	0.090	0.086	0.108	0.115	0.144	0.144	0.180
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.010	0.012	0.013	0.016	0.026	0.032	0.039	0.049	0.052	0.065	0.065	0.081	0.078	0.097	0.104	0.130	0.130	0.162

RAZORCUT- 3FWF/ 3F

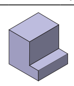
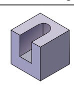
Centre cutting high performance 3 flute end mill for non ferrous materials with wiper technology - Razorcut 3FWF/3F - 3.0 mm to 20.0 mm

Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
																												
			5	2.3	1.6	1.4	1.2	1.1	1	←					Multiply fz by this multiplication factor based on ae. For excellant floor finish, use the standard fz per chart below. Only add chip thinning multiplication factor when roughing or semi-finishing.													
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	Diameter in mm													
															3.0		6.0		8.0		10.0		12.0		16.0		20.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	0.75XD	1xD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.022	0.027	0.043	0.054	0.058	0.072	0.072	0.090	0.086	0.108	0.115	0.144	0.144	0.180
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.019	0.024	0.039	0.049	0.052	0.065	0.065	0.081	0.078	0.097	0.104	0.130	0.130	0.162

If you are using Trochoidal Strategy with the Razorcut 3FWF. Program the helix as 38 degrees, use the starting hm value as given in the catalogue section, Use an engagement angle starting value of 53.13 degrees to get good results.

RAZORCUT- 3FWFXL/RAZOR CUT 3FWFCR

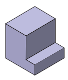
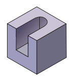
Centre cutting high performance 3 flute end mill for non ferrous materials with wiper technology - Razorcut 3FWFXL/3FWFCR - 6.0 mm to 20.0 mm

Material			Cutting speed (Vc) for Shoulder Milling (rough and semi finish). If high power spindle is available, you can increase Vc upto 2 times							Cutting speed (Vc) for slot milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%											
																										
			5	2.3	1.6	1.4	1.2	1.1	1	←					Multiply fz by this multiplication factor based on ae. For excellant floor finish, use the standard fz per chart below. Only add chip thinning multiplication factor when roughing or semi-finishing.											
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap	ap	Cutting Speed Vc		mm	Diameter in mm											
															6.0		8.0		10.0		12.0		16.0		20.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	0.75XD	1xD	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1050	825	750	700	675	650	625	1000	1250	500	2000	fz	0.048	0.060	0.064	0.080	0.080	0.100	0.096	0.120	0.128	0.160	0.160	0.200
		2	1050	825	750	700	675	650	625	800	1000	500	1500	fz	0.043	0.054	0.058	0.072	0.072	0.090	0.086	0.108	0.115	0.144	0.144	0.180

If you are using Trochoidal Strategy with the Razorcut 3FWFCR. Program the helix as 38 degrees, use the starting hm value as given in the catalogue section, Use an engagement angle starting value of 66.42 degrees to get good results.

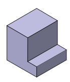
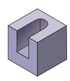
Cutting parameters

HEX3/HEX3L

Material			Side Milling							Slot Milling						Recommended Feed/Tooth (fz) For Side Milling & For Slotting, Reduced fz by 20%.																	
																																	
			5	2.3	1.6	1.4	1.2	1.1	1	1	1	**1**	←			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.																	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	0.25xD	0.5xD	1xD	Cutting Speed Vc		mm	Diameter in mm																	
																1.0		1.5		2.0		2.5		3.0		3.5		4.0		4.5		5.0	
													min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Non Ferrous	N	1	1000	786	714	667	643	619	595	571	524	571	476	1000	Fz	0.003	0.004	0.005	0.006	0.006	0.008	0.008	0.010	0.010	0.012	0.011	0.014	0.013	0.016	0.014	0.018	0.016	0.020
		2	750	589	536	500	482	464	446	429	393	429	357	750	Fz	0.003	0.004	0.005	0.006	0.006	0.008	0.008	0.010	0.010	0.012	0.011	0.014	0.013	0.016	0.014	0.018	0.016	0.020
		3	750	589	536	500	482	464	446	429	393	429	357	750	Fz	0.003	0.004	0.005	0.006	0.006	0.008	0.008	0.010	0.010	0.012	0.011	0.014	0.013	0.016	0.014	0.018	0.016	0.020

NANO

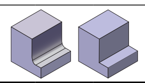
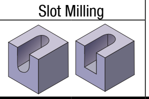
Centre cutting stub length high performance end mill - NANO - 4.0 mm to 12.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling / Rough and Semi Finish							Cutting Speed (Vc) for Slot Milling			Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%						
																			
			5	2.3	1.6	1.4	1.2	1.1	1	←			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.						
			ap Max	ap Max	ap 1.5D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc)		mm	Diameter in mm					
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	ae/D 30%	ae/D 50%	ae/D 100%	min	max	Range	4.0	6.0	8.0	10.0	12.0	12.0
Steel	P	1	378	297	270	252	243	234	225	200	180	378	fz	0.030	0.050	0.060	0.070	0.075	0.080
		2	336	264	240	224	216	208	200	180	160	336	fz	0.030	0.050	0.060	0.070	0.075	0.080
		3	336	264	240	224	216	208	200	170	160	336	fz	0.025	0.040	0.050	0.060	0.070	0.075
		4	294	231	210	196	189	182	175	150	140	294	fz	0.023	0.036	0.045	0.054	0.063	0.070
Stain-less Steel	M	1	189	149	135	126	122	117	113	103	90	189	fz	0.025	0.040	0.050	0.060	0.065	0.070
		2	126	99	90	84	81	78	75	70	60	126	fz	0.020	0.030	0.040	0.050	0.060	0.070
Cast Iron	K	1	252	198	180	168	162	156	150	135	120	252	fz	0.030	0.050	0.060	0.070	0.080	0.090
		2	231	182	165	154	149	143	138	120	110	231	fz	0.025	0.040	0.050	0.060	0.070	0.080
		3	210	165	150	140	135	130	125	115	100	210	fz	0.020	0.030	0.040	0.050	0.060	0.070

Cutting parameters

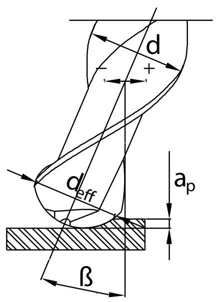
F177TR/NF177TR/F179TR/F179TRL

Centre cutting high performance end mill / ball nose for roughing & finishing - F177 TR/ NF177 TR / F179 TR / F179 TRL - 4.0 mm to 20.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling							Cutting Speed (Vc) for Slot Milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
																												
			5	2.3	1.6	1.4	1.2	1.1	1	1		←			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.													
			CT NCT	CT NCT	CT NCT	CT NCT	CT NCT	CT	CT	CT		Cutting Speed (Vc)			Diameter in mm													
			ap max	ap max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc) for Slot Milling			mm	4.0		6.0		8.0		10.0		12.0		16.0		20.0	
			ae 1%	ae 5%	ae 10%	ae 15%	ae 20%	ae 30%	ae 50%	ae/D 100%		min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	1	315	248	225	210	203	195	188	1XD	175	150	315	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	294	231	210	196	189	182	175	1XD	165	140	294	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		3	252	198	180	168	162	156	150	1XD	140	120	252	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		4	189	149	135	126	122	117	113	0.75XD	120	90	189	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088
		5	126	99	90	84	81	78	75	1XD	80	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		6	105	83	75	70	68	65	63	0.75XD	62.5	50	105	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Stainless Steel	M	1	189	149	135	126	122	117	113	1XD	102.5	90	189	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	126	99	90	84	81	78	75	1XD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		3	126	99	90	84	81	78	75	1XD	65	60	126	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Cast Iron	K	1	252	198	180	168	162	156	150	1XD	135	120	252	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	231	182	165	154	149	143	138	1XD	120	110	231	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		3	210	165	150	140	135	130	125	1XD	115	100	210	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
Super Alloys	S	1	105	83	75	70	68	65		0.3XD	70	50	105	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	53	41	38	35	34	33		0.3XD	32.5	25	53	fz	0.010	0.013	0.015	0.019	0.021	0.026	0.026	0.032	0.030	0.037	0.037	0.046	0.043	0.054
		3	126	99	90	84	81	78	75	1XD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		4	105	83	75	70	68	65	63	1XD	55	50	105	fz	0.013	0.016	0.021	0.026	0.030	0.037	0.036	0.045	0.042	0.052	0.051	0.064	0.059	0.074
Hard Materials	H	1	168	132	120	112	108	104	100	0.75XD	110	80	168	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088

		4 Flute	4 Flute	4 Flute
		Flat	Flat/ Neck	Ball
CT	Standard	F177TR	NF177TR	F179TR
NCT	Long	NF179TR		

CT- indicates that when using these end mills – use the Chip load multiplication factor
NCT- Indicates that when using these end mills- do not use the chip load multiplication factor



* For ball nose end mills - If axial depth (ap) is less than the ball diameter, the speed is figured using the effective cutting diameter (D_{eff}) Formula 1
* For ball nose end mills - If axial depth (ap) is less than the ball diameter, and tool is tilted by an angle β, the speed is figured using the effective cutting diameter (D_{eff}) Formula 2

Formula 1

$$D_{eff} = 2 \times \sqrt{ADOC \times (D-ADOC)}$$

Formula 2

$$D_{eff} = D \times \text{sine} \left[\beta + \arccos \left(\frac{D-2 \times ADOC}{D} \right) \right]$$

Disclaimer
* Technical data provided should be considered advisory only as variations may be necessary depending on the particular application.

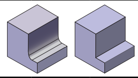
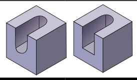
Note
When maximum speed of the machine spindle less than value of recommended milling conditions, adjust conditions by calculation as follows.
(Maximum Spindle Speed of Spindle)/(Spindle Speed of Recommended Milling Condition)= Conversion Rate(α)

Feed of Recommended Milling Condition(Vf mm/min) X α = Corrected Vf (mm/min)

Cutting parameters

F178TR BLACK/ GOLD

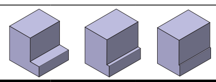
Centre cutting high performance 5 flute end mill for roughing & finishing - F178 TR Black/Gold - 4.0 mm to 20.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling for Rough and Semi Finish							Cutting Speed (Vc) for Slot Milling					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
																												
			5	2.3	1.6	1.4	1.2	1.1	1	←					Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.													
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc) for Slot Milling	Cutting Speed (Vc)		mm	Diameter in mm 4.0		6.0		8.0		10.0		12.0		16.0		20.0	
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	ae/D 30%	ae/D 50%	ae/D 100%		min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	1	315	248	225	210	203	195	188	1xD	175	150	315	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	294	231	210	196	189	182	175	1xD	165	140	294	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		3	252	198	180	168	162	156	150	1xD	140	120	252	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		4	189	149	135	126	122	117	113	0.75XD	120	90	189	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088
		5	126	99	90	84	81	78	75	1xD	80	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		6	105	83	75	70	68	65	63	0.75XD	62.5	50	105	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Stainless Steel	M	1	189	149	135	126	122	117	113	1xD	102.5	90	189	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	126	99	90	84	81	78	75	1xD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		3	126	99	90	84	81	78	75	1xD	65	60	126	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Cast Iron	K	1	252	198	180	168	162	156	150	1xD	135	120	252	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	231	182	165	154	149	143	138	1xD	120	110	231	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		3	210	165	150	140	135	130	125	1xD	115	100	210	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
Super Alloys	S	1	105	83	75	70	68	65		0.3XD	70	50	105	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	53	41	38	35	34	33		0.3XD	32.5	25	53	fz	0.010	0.013	0.015	0.019	0.021	0.026	0.026	0.032	0.030	0.037	0.037	0.046	0.043	0.054
		3	126	99	90	84	81	78	75	1xD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		4	105	83	75	70	68	65	63	1xD	55	50	105	fz	0.013	0.016	0.021	0.026	0.030	0.037	0.036	0.045	0.042	0.052	0.051	0.064	0.059	0.074
Hard Materials	H	1	168	132	120	112	108	104	100	0.75XD	110	80	168	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088

F178TR Gold to be used on Stainless Steel and Steel as first preferance/ SuperAlloys, Cast Iron and Hard Steel as a second preferance
F178TR Black to be used on Titanium and Super Alloys as a frist preferance/ Stainless Steel/ Steel/ Cast Iron and Hard Steel as the second preferance

F180TR / NF180TR / F180TRL SEMI FINISHING

Centre cutting high performance 7 flute end mill for roughing & finishing - F180TR/NF 180TR Semi Finishing - 10.0 mm to 16.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling								Recommended Feed/Tooth (fz)					
																
			5	2.3	1.6	1.4	1.2	←			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.					
			ap Max	ap 2.5D	ap 2.5D	ap 2D	ap 2D	Cutting Speed (Vc)		mm	Diameter in mm 10.0		12.0		16.0	
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	min	max	Range	min	max	min	max	min	max
Steel	P	1	500	393	750	333	298	238	500	fz	0.048	0.060	0.052	0.065	0.064	0.080
		2	240	189	360	160	143	115	240	fz	0.048	0.060	0.052	0.065	0.064	0.080
		3	150	118	225	100	89	72	150	fz	0.043	0.054	0.050	0.062	0.062	0.077
		4	150	118	225	100	89	72	150	fz	0.043	0.054	0.050	0.062	0.062	0.077
		5	100	78	150	67	59	48	100	fz	0.038	0.048	0.045	0.056	0.056	0.070
Stainless Steel	M	1	115	90	173	77	69	55	115	fz	0.049	0.061	0.056	0.070	0.070	0.087
		2	80	63	120	53	48	38	80	fz	0.038	0.048	0.045	0.056	0.056	0.070
		3	70	55	105	47	42	34	70	fz	0.032	0.040	0.038	0.047	0.046	0.057
Super Alloys	S	1	90	71	135	60	54	43	90	fz	0.049	0.061	0.056	0.070	0.070	0.087
		2	40	31	60	27	24	19	40	fz	0.026	0.032	0.030	0.037	0.037	0.046
		3	80	63	120	53	48	38	80	fz	0.038	0.048	0.045	0.056	0.056	0.070
		4	60	47	90	40	36	29	60	fz	0.036	0.045	0.042	0.052	0.051	0.064
Hard Materials	H	1	140	110	210	93	83	67	140	fz	0.043	0.054	0.050	0.062	0.062	0.077
		2	120	94	180	80	71	57	120	fz	0.032	0.040	0.038	0.047	0.046	0.057

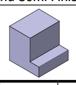
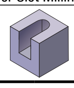
TOTEM

High Performance Cutting Tools

Cutting parameters

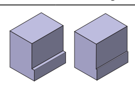
5VR

Centre cutting 5 flute end mill for finishing steel and super alloys for Trochoidal milling - 5VR- 4.0 mm to 20.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling for Rough and Semi Finish 							Cutting Speed (Vc) for Slot Milling 					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
			5	2.3	1.6	1.4	1.2	1.1	1	←					Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.													
															Diameter in mm													
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc) for Slot Milling	Cutting Speed (Vc)		mm	4.0		6.0		8.0		10.0		12.0		16.0		20.0	
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	ae/D 30%	ae/D 50%	ae/D 100%		min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	1	315	248	225	210	203	195	188	1xD	175	150	315	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	294	231	210	196	189	182	175	1xD	165	140	294	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		3	252	198	180	168	162	156	150	1xD	140	120	252	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		4	189	149	135	126	122	117	113	0.75XD	120	90	189	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088
		5	126	99	90	84	81	78	75	1xD	80	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		6	105	83	75	70	68	65	63	0.75XD	62.5	50	105	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Stainless Steel	M	1	189	149	135	126	122	117	113	1xD	102.5	90	189	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	126	99	90	84	81	78	75	1xD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		3	126	99	90	84	81	78	75	1xD	65	60	126	fz	0.013	0.016	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Cast Iron	K	1	252	198	180	168	162	156	150	1xD	135	120	252	fz	0.022	0.028	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	231	182	165	154	149	143	138	1xD	120	110	231	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		3	210	165	150	140	135	130	125	1xD	115	100	210	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
Super Alloys	S	1	105	83	75	70	68	65		0.3XD	70	50	105	fz	0.018	0.023	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	53	41	38	35	34	33		0.3XD	32.5	25	53	fz	0.010	0.013	0.015	0.019	0.021	0.026	0.026	0.032	0.030	0.037	0.037	0.046	0.043	0.054
		3	126	99	90	84	81	78	75	1xD	70	60	126	fz	0.015	0.019	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		4	105	83	75	70	68	65	63	1xD	55	50	105	fz	0.013	0.016	0.021	0.026	0.030	0.037	0.036	0.045	0.042	0.052	0.051	0.064	0.059	0.074
Hard Materials	H	1	168	132	120	112	108	104	100	0.75XD	110	80	168	fz	0.017	0.021	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088

6VR

Centre cutting high performance 6 flute end mill for Trochoidal milling - 6VR - 6.0 mm to 20.0 mm

Material			Cutting Speed (Vc) for Shoulder Milling 					Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%											
			5	2.3	←			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finish											
								Diameter in mm											
			ap max	ap 1.5D	Cutting Speed (Vc)		mm	6.0		8.0		10.0		12.0		16.0		20.0	
			ae/D 1%	ae/D 5%	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	1	315	248	150	315	fz	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	294	231	140	294	fz	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		3	252	198	120	252	fz	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		4	189	149	90	189	fz	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088
		5	126	99	60	126	fz	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		6	105	83	50	105	fz	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Stain-less Steel	M	1	168	132	80	168	fz	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	126	99	60	126	fz	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		3	126	99	60	126	fz	0.020	0.025	0.027	0.034	0.032	0.040	0.038	0.047	0.046	0.057	0.052	0.065
Cast Iron	K	1	252	198	120	252	fz	0.035	0.044	0.048	0.060	0.058	0.072	0.066	0.083	0.081	0.101	0.091	0.114
		2	231	182	110	231	fz	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		3	210	165	100	210	fz	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
Special Alloys	S	1	105	83	50	105	fz	0.029	0.036	0.040	0.050	0.049	0.061	0.056	0.070	0.070	0.087	0.081	0.101
		2	42	33	20	42	fz	0.015	0.019	0.021	0.026	0.026	0.032	0.030	0.037	0.037	0.046	0.043	0.054
		3	105	83	50	105	fz	0.023	0.029	0.032	0.040	0.038	0.048	0.045	0.056	0.056	0.070	0.065	0.081
		4	95	74	45	95	fz	0.021	0.026	0.030	0.037	0.036	0.045	0.042	0.052	0.051	0.064	0.059	0.074
Hard-ened Steel	H	1	168	132	80	168	fz	0.026	0.033	0.036	0.045	0.043	0.054	0.050	0.062	0.062	0.077	0.070	0.088

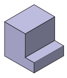
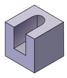
High Performance Cutting Tools

Cutting parameters

F192CB/ F192CBL METRIC

Sinusoidal regular length 3/4 flute chip breaker end mill - F192CB/NF192CB/F192CBL - 6.0 mm to 25.0 mm

Sinusoidal regular length 3/4 flute chip breaker end mill - F192CB/NF192CB/F192CBL - 6.0 mm to 25.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling / Rough and Semi Finish							Cutting Speed (Vc) for Slot Milling				
														
			5	2.3	1.6	1.4	1.2	1.1	1	1	1	←		
			CT NCT	CT NCT	CT NCT	CT NCT	CT NCT	CT	CT	CT	CT			
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc) for Slot Milling	Cutting Speed (Vc)		mm
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	ae/D 30%	ae/D 50%	ae/D 100%	ae/D 100%	min	max	Range
Steel	P	1	315	248	225	210	203	195	188	1 x D	175	150	315	fz
Steel	P	2	294	231	210	196	189	182	175	1 x D	165	140	294	fz
Steel	P	3	252	198	180	168	162	156		0.75 D	140	120	252	fz
Steel	P	4	189	149	135	126	122	117		0.5 x D	120	90	189	fz
Steel	P	5	126	99	90	84	81	78		0.75 XD	80	60	126	fz
Stainless Steel	M	1	168	132	120	112	108	104		0.75 x D	90	80	168	fz
Stainless Steel	M	2	126	99	90	84	81	78		0.75 x D	70	60	126	fz
Stainless Steel	M	3	126	99	90	84	81	78		0.75 x D	70	60	126	fz
Cast Iron	K	1	252	198	180	168	162	156	150	1 x D	140	120	252	fz
Cast Iron	K	2	231	182	165	154	149	143		1 x D	125	110	231	fz
Cast Iron	K	3	210	165	150	140	135	130		1 x D	115	100	210	fz
Super Alloys	S	1	105	83	75	70	68	65		0.75 xD	70	50	105	fz
Super Alloys	S	3	105	83	75	70	68	65		0.75 xD	65	50	105	fz
Hard Materials	H	1	168	132	120	112	108	104		0.75 xD	110	80	168	fz

Material Group			Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.													
			Diameter in mm													
			6.0		8.0		10.0		12.0		16.0		20.0		25.0	
			min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	1	0.033	0.041	0.039	0.049	0.047	0.059	0.058	0.072	0.070	0.087	0.074	0.093	0.078	0.098
Steel	P	2	0.033	0.041	0.039	0.049	0.047	0.059	0.058	0.072	0.070	0.087	0.074	0.093	0.078	0.098
Steel	P	3	0.026	0.033	0.033	0.041	0.039	0.049	0.049	0.061	0.060	0.075	0.066	0.082	0.070	0.087
Steel	P	4	0.023	0.029	0.030	0.037	0.035	0.044	0.043	0.054	0.053	0.066	0.058	0.072	0.061	0.076
Steel	P	5	0.020	0.025	0.026	0.033	0.031	0.039	0.039	0.049	0.048	0.06	0.052	0.065	0.056	0.07
Stainless Steel	M	1	0.026	0.033	0.033	0.041	0.039	0.049	0.049	0.061	0.060	0.075	0.066	0.082	0.070	0.087
Stainless Steel	M	2	0.020	0.025	0.026	0.033	0.031	0.039	0.039	0.049	0.048	0.06	0.052	0.065	0.056	0.07
Stainless Steel	M	3	0.014	0.018	0.021	0.026	0.026	0.032	0.031	0.039	0.038	0.048	0.042	0.052	0.045	0.056
Cast Iron	K	1	0.033	0.041	0.039	0.049	0.047	0.059	0.058	0.072	0.070	0.087	0.074	0.093	0.078	0.098
Cast Iron	K	2	0.026	0.033	0.033	0.041	0.039	0.049	0.049	0.061	0.060	0.075	0.066	0.082	0.070	0.087
Cast Iron	K	3	0.020	0.025	0.026	0.033	0.031	0.039	0.039	0.049	0.048	0.06	0.052	0.065	0.056	0.07
Super Alloys	S	1	0.026	0.033	0.033	0.041	0.039	0.049	0.049	0.061	0.060	0.075	0.066	0.082	0.070	0.087
Super Alloys	S	3	0.020	0.025	0.026	0.033	0.031	0.039	0.039	0.049	0.048	0.06	0.052	0.065	0.056	0.07
Hard Materials	H	1	0.023	0.029	0.030	0.037	0.035	0.044	0.043	0.054	0.053	0.066	0.058	0.072	0.061	0.076

		3 Flute 4 Flute
CT	Stub	**F192CBS**
CT	Standard	**F192CB**
NCT	Long	**F192CBL**

CT- indicates that when using these end mills – use the Chip load multiplication factor
NCT- Indicates that when using these end mills- do not use the chip load multiplication factor

Disclaimer
* Technical data provided should be considered advisory only as variations may be necessary depending on the particular application.

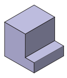
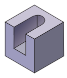
Note
When maximum speed of the machine spindle less than value of recommended milling conditions, adjust conditions by calculation as follows.
(Maximum Spindle Speed of Spindle)/(Spindle Speed of Recommended Milling Condition)= Conversion Rate(α)

Feed of Recommended Milling Condition(Vf mm/min) X α = Corrected Vf (mm/min)

Cutting parameters

F193CB/ NF193CB/ NF193CBL METRIC

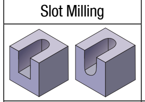
Flat pitch regular length 4/6 flute chip breaker end mill with corner radius - F193CB/NF 193CB/F193CBL - 6.0 mm to 25.0 mm

Material Group			Cutting Speed (Vc) for Shoulder Milling / Rough and Semi Finish 							Cutting Speed (Vc) for Slot Milling 				
			5	2.3	1.6	1.4	1.2	1.1	1	1	1	←		
			CT NCT	CT NCT	CT NCT	CT NCT	CT NCT	CT	CT	CT	CT			
			ap Max	ap Max	ap 2D	ap 1.5D	ap 1.25D	ap 1D	ap 1D	ap 1D	Cutting Speed (Vc) for Slot Milling	Cutting Speed (Vc)		mm
			ae/D 1%	ae/D 5%	ae/D 10%	ae/D 15%	ae/D 20%	ae/D 30%	ae/D 50%	ae/D 100%		min	max	Range
Steel	P	3	252	198	180	168	162	156	150	0.75xD	140	120	252	fz
		4	189	149	135	126	122	117		0.5xD	120	90	189	fz
		5	126	99	90	84	81	78	75	0.75xD	80	60	126	fz
		6	105	83	75	70	68	65		0.5xD	63	50	105	fz
Stainless Steel	M	1	168	132	120	112	108	104	100	0.75xD	90	80	168	fz
		2	126	99	90	84	81	78		0.75xD	70	60	126	fz
		3	126	99	90	84	81	78		0.75xD	70	60	126	fz
Cast Iron	K	1	252	198	180	168	162	156	150	0.75xD	140	120	252	fz
		2	231	182	165	154	149	143	138	0.75xD	125	110	231	fz
		3	210	165	150	140	135	130		0.75xD	115	100	210	fz
Super Alloys	S	1	105	83	75	70	68	65		0.75xD	70	50	105	fz
		2	42	33	30	28	27	26		0.3xD	30	20	42	fz
		3	105	83	75	70	68	65		0.75xD	65	50	105	fz
		4	95	74	68	63	61	59		0.5xD	55	45	95	fz
Hard Materials	H	1	168	132	120	112	108	104	100	0.5xD	110	80	168	fz
		2	147	116	105	98	95			0.3xD	95	70	147	fz
		3	126	99	90	84	81			0.2xD	75	60	126	fz

Material Group			Recommended Feed/Tooth (fz=mm/th) for shoulder milling/slot milling, reduce fz by 20%													
			Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below. Only add chip thinning when roughing or semi-finishing.													
			Diameter in mm													
			6.0		8.0		10.0		12.0		16.0		20.0		25.0	
			min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	3	0.025	0.031	0.034	0.043	0.041	0.051	0.050	0.063	0.062	0.078	0.081	0.101	0.091	0.114
		4	0.022	0.028	0.030	0.038	0.037	0.046	0.045	0.056	0.055	0.069	0.070	0.088	0.078	0.098
		5	0.020	0.025	0.027	0.034	0.033	0.041	0.041	0.051	0.050	0.063	0.065	0.081	0.073	0.091
		6	0.017	0.021	0.023	0.029	0.027	0.034	0.034	0.042	0.041	0.051	0.052	0.065	0.057	0.071
Stainless Steel	M	1	0.025	0.031	0.034	0.043	0.041	0.051	0.050	0.063	0.062	0.078	0.081	0.101	0.091	0.114
		2	0.020	0.025	0.027	0.034	0.033	0.041	0.041	0.051	0.050	0.063	0.065	0.081	0.073	0.091
		3	0.017	0.021	0.023	0.029	0.027	0.034	0.034	0.042	0.041	0.051	0.052	0.065	0.057	0.071
Cast Iron	K	1	0.030	0.037	0.041	0.051	0.049	0.061	0.060	0.075	0.073	0.091	0.091	0.114	0.099	0.124
		2	0.025	0.031	0.034	0.043	0.041	0.051	0.050	0.063	0.062	0.078	0.081	0.101	0.091	0.114
		3	0.020	0.025	0.027	0.034	0.033	0.041	0.041	0.051	0.050	0.063	0.065	0.081	0.073	0.091
Super Alloys	S	1	0.025	0.031	0.034	0.043	0.041	0.051	0.050	0.063	0.062	0.078	0.081	0.101	0.091	0.114
		2	0.014	0.017	0.018	0.022	0.022	0.027	0.026	0.033	0.034	0.042	0.043	0.054	0.049	0.061
		3	0.020	0.025	0.027	0.034	0.033	0.041	0.041	0.051	0.050	0.063	0.065	0.081	0.073	0.091
		4	0.018	0.022	0.025	0.031	0.030	0.038	0.037	0.046	0.046	0.058	0.059	0.074	0.067	0.084
Hard Materials	H	1	0.022	0.028	0.030	0.038	0.037	0.046	0.045	0.056	0.055	0.069	0.070	0.088	0.078	0.098
		2	0.017	0.021	0.023	0.029	0.027	0.034	0.034	0.042	0.041	0.051	0.052	0.065	0.057	0.071
		3	0.014	0.017	0.018	0.023	0.022	0.027	0.027	0.034	0.033	0.041	0.042	0.052	0.046	0.057

Note: For endmills with 6 flutes use ap 60% of table values

HSM- 2 FLUTE FLAT

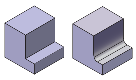
Material Group			Cutting Speed (Vc) for Slot Milling 	Cutting Speed (Vc)		Recommended Feed/Tooth (fz)																										
						Diameter in mm																										
						mm	1.0		1.5		2.0		3.0		4.0		5.0		6.0		8.0		10.0		12.0		14.0		16.0		20.0	
			ap 0.5D ae/D 100%	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	3	45	45	72	fz	0.004	0.005	0.006	0.008	0.008	0.010	0.012	0.015	0.016	0.020	0.020	0.025	0.029	0.036	0.038	0.048	0.048	0.060	0.058	0.072	0.067	0.084	0.077	0.096	0.096	0.120
		4	40	40	68	fz	0.003	0.004	0.005	0.006	0.006	0.008	0.010	0.012	0.013	0.016	0.016	0.020	0.024	0.030	0.032	0.040	0.040	0.050	0.048	0.060	0.056	0.070	0.064	0.080	0.080	0.100
Stainless Steel	M	1	27	27	45	fz	0.002	0.003	0.004	0.005	0.005	0.006	0.007	0.009	0.010	0.012	0.012	0.015	0.019	0.024	0.026	0.032	0.032	0.040	0.038	0.048	0.045	0.056	0.051	0.064	0.064	0.080

Dia 1-3mm- Slot with 0.2XD

High Performance Cutting Tools

Cutting parameters

HSM- 4 FLUTE FLAT/ 4 FLUTE BALL

Material Group			Cutting Speed (Vc) for Shoulder Milling 	Cutting Speed (Vc)			Recommended Feed/Tooth (fz) – Diameter in mm																									
						mm	1.0		1.5		2.0		3.0		4.0		5.0		6.0		8.0		10.0		12.0		14.0		16.0		20.0	
			ap 1D ae/D 10%	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	3	90	90	120	fz	0.004	0.005	0.006	0.008	0.008	0.010	0.012	0.015	0.016	0.020	0.020	0.025	0.029	0.036	0.038	0.048	0.048	0.060	0.058	0.072	0.067	0.084	0.077	0.096	0.096	0.120
		4	75	75	90	fz	0.003	0.004	0.005	0.006	0.006	0.008	0.010	0.012	0.013	0.016	0.016	0.020	0.024	0.030	0.032	0.040	0.040	0.050	0.048	0.060	0.056	0.070	0.064	0.080	0.080	0.100
Stainless Steel	M	1	60	60	75	fz	0.002	0.003	0.004	0.005	0.005	0.006	0.007	0.009	0.010	0.012	0.012	0.015	0.019	0.024	0.026	0.032	0.032	0.040	0.038	0.048	0.045	0.056	0.051	0.064	0.064	0.080

#RPM = Vc x 318.057/Tool Dia. #mm/min = RPM x number of teeth x mm/tooth
L1 max = maximum length of cutting as per catalog

Disclaimer
* Technical data provided should be considered advisory only as variations may be necessary depending on the particular application.
* For ball nose end mills - If axial depth (ap) is less than the ball diameter, the speed is figured using the effective cutting diameter (Deff) Formula 1
* For ball nose end mills - If axial depth (ap) is less than the ball diameter, and tool is tilted by an angle ß, the speed is figured using the effective cutting diameter (Deff) Formula 2

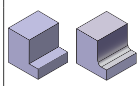
Formula 1

$$D_{eff} = 2 \times \sqrt{ADOC \times (D-ADOC)}$$

Formula 2

$$D_{eff} = D \times \text{sine}\left[\beta + \arccos\left(\frac{D-2 \times ADOC}{D}\right)\right]$$

HSM- 2 FLUTE BALL

Material Group			Cutting Speed (Vc) for Shoulder Milling 	Cutting Speed (Vc)			Recommended Feed/Tooth (fz) – Diameter in mm																									
						mm	1.0		1.5		2.0		3.0		4.0		5.0		6.0		8.0		10.0		12.0		14.0		16.0		20.0	
			ap 0.2D ae/D 30%	min	max	Range	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	P	3	90	90	120	fz	0.009	0.011	0.013	0.017	0.018	0.022	0.026	0.033	0.035	0.044	0.044	0.055	0.058	0.072	0.077	0.096	0.096	0.120	0.115	0.144	0.134	0.168	0.154	0.192	0.192	0.240
		4	75	75	90	fz	0.007	0.009	0.011	0.014	0.014	0.018	0.022	0.027	0.029	0.036	0.036	0.045	0.048	0.060	0.064	0.080	0.080	0.100	0.096	0.120	0.112	0.140	0.128	0.160	0.160	0.200
Hardened Steel	M	1	60	60	75	fz	0.007	0.009	0.011	0.014	0.014	0.018	0.022	0.027	0.029	0.036	0.036	0.045	0.048	0.060	0.064	0.080	0.080	0.100	0.096	0.120	0.112	0.140	0.128	0.160	0.160	0.200

Dia 1-3mm- Profile(Ae) with 0.2XD

Cutting parameters

PROTON - 2 FLUTE BALL

Material			Profile Milling	Recommended Feed/Tooth (fz) For profile milling																				
				Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below																				
			Ap 2%D	Paraemeters	1.0		1.5		2.0		3.0		4.0		5.0		6.0		8.0		10.0		12.0	
				min	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	p	5	5%	fz	0.011	0.013	0.012	0.015	0.013	0.016	0.020	0.025	0.026	0.033	0.034	0.043	0.038	0.048	0.042	0.052	0.044	0.055	0.047	0.059
				Vc	157		236		312		312		313		292		262		279		292		262	
		6	5%	fz	0.009	0.012	0.011	0.013	0.011	0.014	0.019	0.023	0.025	0.031	0.031	0.039	0.034	0.043	0.037	0.046	0.039	0.049	0.042	0.052
				Vc	157		226		300		300		300		280		253		269		280		252	
Hardened Steel	H	1	5%	fz	0.009	0.012	0.010	0.013	0.011	0.014	0.017	0.021	0.022	0.028	0.028	0.035	0.032	0.039	0.034	0.042	0.036	0.045	0.038	0.048
				Vc	141		203		251		250		251		236		207		226		236		211	
		2	5%	fz	0.008	0.011	0.009	0.012	0.010	0.013	0.015	0.019	0.020	0.025	0.025	0.032	0.028	0.035	0.030	0.038	0.032	0.040	0.035	0.043
				Vc	126		174		220		222		220		212		189		201		207		189	
		3	5%	fz	0.008	0.010	0.009	0.011	0.010	0.012	0.015	0.019	0.020	0.025	0.025	0.031	0.027	0.034	0.030	0.037	0.032	0.040	0.032	0.040
				Vc	110		156		201		198		201		181		166		176		182		166	
		4	5%	fz	0.007	0.009	0.009	0.011	0.009	0.011	0.014	0.017	0.018	0.022	0.022	0.028	0.025	0.031	0.027	0.033	0.029	0.036	0.029	0.037
				Vc	110		140		179		179		182		165		151		163		167		151	

#RPM = Vc x 318.057/Tool Dia. #mm/min = RPM x number of teeth x mm/tooth

Disclaimer
* Technical data provided should be considered advisory only as variations may be necessary depending on the particular application.
* For ball nose end mills - If axial depth (ap) is less than the ball diameter, the speed is figured using the effective cutting diameter (Deff) Formula 1
* For ball nose end mills - If axial depth (ap) is less than the ball diameter, and tool is tilted by an angle ß, the speed is figured using the effective cutting diameter (Deff) Formula 2

Formula 1

$$D_{eff} = 2 \times \sqrt{ADOC \times (D-ADOC)}$$

Formula 2

$$D_{eff} = D \times \text{sine}\left[\beta + \arccos\left(\frac{D-2 \times ADOC}{D}\right)\right]$$

When maximum speed of the machine spindle less than value of recommended milling conditions, adjust conditions by calculation as follows.

(Maximum Spindle Speed of Spindle)/(Spindle Speed of Recommended Milling Condition)= Convertion Rate(α)
Feed of Recommeded Milling Condition(Vf mm/min) X α = Corrected Vf (mm/min)

PROTON- 4 FLUTE FLAT AND CORNER RADIUS

Material			Profile Milling	Recommended Feed/Tooth (fz) For profile milling																								
				Multiply fz by this X Factor based on ae. When finishing, use the standard fz per chart below																								
			Ap 1XD	Paraemeters	1.0		1.5		2.0		3.0		4.0		5.0		6.0		8.0		10.0		12.0		10.0		12.0	
				min	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Steel	p	5	5%	fz	0.003	0.003	0.004	0.005	0.005	0.006	0.007	0.009	0.009	0.012	0.011	0.014	0.013	0.016	0.017	0.021	0.020	0.024	0.023	0.029	0.027	0.033	0.029	0.036
				Vc	151		180		209		206		210		247		247		248		245		251		246		245	
		6	5%	fz	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.008	0.009	0.011	0.010	0.013	0.012	0.015	0.015	0.019	0.018	0.022	0.021	0.026	0.025	0.031	0.027	0.034
				Vc	119		141		163		163		166		196		195		196		193		198		196		195	
Hardened Steel	H	1	5%	fz	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.008	0.009	0.011	0.010	0.013	0.012	0.015	0.015	0.019	0.018	0.022	0.021	0.026	0.024	0.031	0.028	0.034
				Vc	80		95		110		108		111		130		130		131		129		132		131		129	
		2	5%	fz	0.002	0.002	0.002	0.003	0.003	0.004	0.005	0.006	0.007	0.008	0.008	0.010	0.009	0.011	0.011	0.014	0.013	0.016	0.016	0.020	0.018	0.023	0.021	0.026
				Vc	64		78		91		90		91		101		100		101		101		100		101		101	
		3	5%	fz	0.001	0.002	0.002	0.002	0.003	0.003	0.004	0.005	0.005	0.007	0.006	0.008	0.007	0.009	0.009	0.011	0.011	0.013	0.012	0.016	0.015	0.018	0.017	0.021
				Vc	50		60		69		71		70		80		79		80		80		79		80		82	
		4	5%	fz	0.001	0.002	0.002	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.007	0.006	0.008	0.007	0.009	0.009	0.011	0.010	0.013	0.012	0.016	0.014	0.018
				Vc	39		50		60		60		60		70		70		70		69		70		70		69	

(Maximum Spindle Speed of Spindle)/(Spindle Speed of Recommended Milling Condition)= Convertion Rate(α)
Feed of Recommeded Milling Condition(Vf mm/min) X α = Corrected Vf (mm/min)

Cutting parameters

SPOTTING DRILLS

Workpiece Material Group			Cutting Speed (Vc)	Feed mm/rev								
				Diameter in mm								
				2	3	4	5	6	8	10	12	16
Steel	P	1	70-80	0.0635	0.0991	0.1245	0.1499	0.1753	0.2007	0.2261	0.2515	0.2769
		2	60-70	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
		3	50-60	0.0508	0.0787	0.0940	0.1143	0.1346	0.1549	0.1753	0.1956	0.2159
		4	40-50	0.0406	0.0635	0.0754	0.0872	0.0991	0.1109	0.1228	0.1347	0.1465
		5	20-25	0.0508	0.0787	0.0940	0.1143	0.1346	0.1549	0.1753	0.1956	0.2159
Stainless Steel	M	1	20-25	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
		2	15-20	0.0508	0.0787	0.0940	0.1143	0.1346	0.1549	0.1753	0.1956	0.2159
		3	12-15	0.0508	0.0787	0.0940	0.1143	0.1346	0.1549	0.1753	0.1956	0.2159
Cast Iron	K	1	80-90	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
		2	70-80	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
		3	60-70	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
Super Alloys	S	1	15-20	0.0406	0.0635	0.0754	0.0872	0.0991	0.1109	0.1228	0.1347	0.1465
		4	10-15	0.0406	0.0635	0.0754	0.0872	0.0991	0.1109	0.1228	0.1347	0.1465
Cast Iron	K	1	150-200	0.1245	0.2007	0.2388	0.2769	0.3150	0.3531	0.3912	0.4293	0.4674
		2	120-150	0.0991	0.1600	0.1897	0.2193	0.2489	0.2786	0.3082	0.3379	0.3675
		3	100-120	0.0991	0.1600	0.1897	0.2193	0.2489	0.2786	0.3082	0.3379	0.3675
Non Ferrous	N	1	160-180	0.0787	0.1245	0.1499	0.1753	0.2007	0.2261	0.2515	0.2769	0.3023
		2	160-180	0.0787	0.1245	0.1499	0.1753	0.2007	0.2261	0.2515	0.2769	0.3023
		3	120-130	0.0787	0.1245	0.1499	0.1753	0.2007	0.2261	0.2515	0.2769	0.3023
		4	20-30	0.0635	0.0991	0.1194	0.1397	0.1600	0.1803	0.2007	0.2210	0.2413
		5	40-50	0.0508	0.0787	0.0940	0.1143	0.1346	0.1549	0.1753	0.1956	0.2159

CHAMFER TOOL

Workpiece Material Group			Cutting Speed (Vc)	Feed mm/rev						
				Diameter in mm						
				3	6	8	10	12	16	20
Steel	P	1	150-160	0.010	0.013	0.015	0.025	0.033	0.043	0.048
		2	130-140	0.008	0.010	0.013	0.015	0.025	0.033	0.043
		3	100-110	0.008	0.010	0.013	0.015	0.025	0.033	0.043
		4	80-90	0.008	0.010	0.013	0.015	0.025	0.033	0.043
		5	60-70	0.008	0.010	0.013	0.015	0.025	0.033	0.043
Stain-less Steel	M	1	60-70	0.008	0.010	0.013	0.015	0.025	0.033	0.043
		2	40-50	0.008	0.010	0.013	0.015	0.025	0.033	0.043
Super Alloys	S	1	65-70	0.008	0.010	0.013	0.015	0.025	0.033	0.043
		2	40-45	0.008	0.010	0.013	0.015	0.025	0.033	0.043
Cast Iron	K	1	140-150	0.010	0.013	0.015	0.025	0.033	0.043	0.048
		2	120-130	0.008	0.010	0.013	0.015	0.025	0.033	0.043
Non Ferrous	N	1	165-175	0.127	0.018	0.025	0.033	0.043	0.048	0.064

Cutting parameters

HIGH PERFORMANCE TAPS

Series	Material Group			Cutting Speed (Vc)
SAS5 PM	Stainless Steel	M	1	
			2	
			3	

Series	Material Group			Cutting Speed (Vc)
SBS5 PM	Stainless Steel	M	1	10-12
			2	8-10
			3	6-8

Series	Material Group			Cutting Speed (Vc)
SAI6 PM	Super Alloys	S	1	10-15
			2	6-12
			3	8-12
			4	4-6

Series	Material Group			Cutting Speed (Vc)
SBI6 PM	Super Alloys	S	1	6-10
			2	5-8
			3	6-8
			4	3-5

CENTER DRILLS

Workpiece Material Group			Cutting Speed (Vc)	Feed mm/rev											
				Diameter in mm											
				0.5	1	1.25	1.6	2	2.5	3	3.15	4	5	6.3	8
Steel	P	1	60-70	0.008	0.015	0.028	0.028	0.037	0.051	0.059	0.064	0.079	0.079	0.099	0.124
		2	45-50	0.008	0.015	0.028	0.028	0.037	0.051	0.059	0.064	0.079	0.079	0.099	0.124
		3	35-45	0.008	0.013	0.024	0.023	0.031	0.041	0.049	0.051	0.064	0.064	0.079	0.099
		4	20-35	0.008	0.015	0.028	0.028	0.037	0.051	0.059	0.064	0.079	0.079	0.099	0.124
		5	15-20	0.005	0.008	0.015	0.017	0.023	0.033	0.039	0.041	0.051	0.051	0.064	0.079
Stainless Steel	M	1	30-20	0.008	0.013	0.024	0.023	0.031	0.041	0.049	0.051	0.064	0.064	0.079	0.099
		2	20-15	0.008	0.013	0.024	0.023	0.031	0.041	0.049	0.051	0.064	0.064	0.079	0.099
		3	15-Oct	0.008	0.013	0.024	0.023	0.031	0.041	0.049	0.051	0.064	0.064	0.079	0.099
Cast Iron	K	1	50-60	0.013	0.018	0.036	0.041	0.056	0.079	0.094	0.099	0.124	0.124	0.16	0.201
		2	60-70	0.013	0.018	0.036	0.041	0.056	0.079	0.094	0.099	0.124	0.124	0.16	0.201
		3	50-60	0.01	0.015	0.03	0.033	0.045	0.064	0.076	0.079	0.099	0.099	0.124	0.16
Super Alloys	S	1	Oct-15	0.005	0.005	0.011	0.013	0.018	0.025	0.031	0.033	0.041	0.041	0.051	0.064
		4	Oct-15	0.005	0.008	0.015	0.017	0.023	0.033	0.039	0.041	0.051	0.051	0.064	0.079
Non Ferrous	N	1	150-160	0.015	0.02	0.043	0.05	0.07	0.099	0.119	0.124	0.16	0.16	0.201	0.249
		2	100-120	0.013	0.018	0.036	0.041	0.056	0.079	0.094	0.099	0.124	0.124	0.16	0.201
		3	140-150	0.013	0.018	0.036	0.041	0.056	0.079	0.094	0.099	0.124	0.124	0.16	0.201
		4	120-130	0.01	0.015	0.03	0.033	0.045	0.064	0.076	0.079	0.099	0.099	0.124	0.16
		5	90-100	0.01	0.015	0.03	0.033	0.045	0.064	0.076	0.079	0.099	0.099	0.124	0.16

High Performance Cutting Tools

THREAD MILL

CARBIDE GRADE : K40UF

AN ADVANCED PVD TiALN COATED GRADE OVER A TOUGH WEAR-RESISTANT SUBMICRON SUBSTRATE FOR GENERAL PURPOSE MACHINING OF STEEL, STAINLESS STEEL, SUPERALLOYS.

Workpiece Material Group			Hardness HB	Cutting Speed m/min (Vc)	Feed (fz) mm/tooth Cutting Diameters						
					1.5-3	3-5	5-7	7-9	9-11	11-14	14-20
Steel	P	1	130	70-130	0.03	0.04	0.06	0.07	0.09	0.09	0.12
		2	200	60-120	0.02	0.04	0.05	0.06	0.08	0.08	0.1
		3	240	60-110	0.02	0.03	0.04	0.05	0.05	0.05	0.08
		4	270	60-100	0.02	0.03	0.04	0.05	0.05	0.05	0.06
		5	400	50-80	0.01	0.02	0.03	0.03	0.04	0.04	0.05
Stainless Steel	M	1	200	70-100	0.02	0.02	0.03	0.04	0.05	0.05	0.07
		2	240	70-90	0.02	0.02	0.03	0.04	0.04	0.04	0.06
		3	400	60-80	0.015	0.02	0.02	0.03	0.03	0.03	0.04
Cast Iron K	K	1	190	60-110	0.02	0.03	0.06	0.07	0.08	0.09	0.11
		2	180	60-90	0.02	0.03	0.05	0.06	0.08	0.09	0.12
		3	240	60-90	0.02	0.02	0.03	0.05	0.07	0.08	0.11
Non Ferrous	N	1	80	80-300	0.03	0.04	0.06	0.07	0.10	0.13	0.15
		2	90	100-300	0.03	0.04	0.06	0.07	0.11	0.13	0.16
		3	100	60-250	0.03	0.04	0.06	0.07	0.11	0.13	0.16
		4		100-400	0.05	0.06	0.08	0.09	0.13	0.15	0.18
Super Alloys	N	1	270	25-50	0.01	0.01	0.01	0.02	0.02	0.03	0.03
		2	350	20-40	0.01	0.01	0.01	0.02	0.02	0.03	0.03
		3	300	20-40	0.01	0.01	0.01	0.02	0.02	0.03	0.03
		4		40-80 30-60 20-50 20-50	0.02 0.02 0.02 0.02	0.02 0.02 0.02 0.02	0.02 0.02 0.02 0.02	0.03 0.03 0.03 0.02	0.04 0.03 0.03 0.03	0.04 0.04 0.03 0.03	0.05 0.05 0.04 0.04
Hardened Steel	H	2	50 HRc	25-40	0.01	0.01	0.02	0.02	0.02	0.03	0.03
		3	56 HRc	25-50	0.01	0.01	0.02	0.02	0.02	0.03	0.03

THREAD MILL ADDITIONAL INFORMATION

INFEED METHOD

TANGENTIAL APPROACH

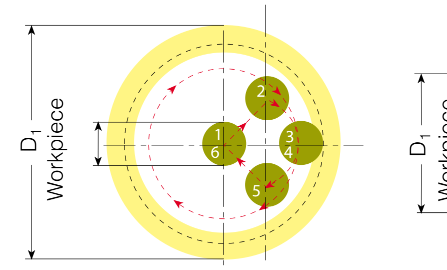
Thread milling cutter strategy of Machining and how to enter and exit the work piece. The Tangential arc approach is considered as the best method.

With this method, the tool enters and exits the work piece smoothly. No marks are left on the work piece and there is no vibration, even with harder materials.

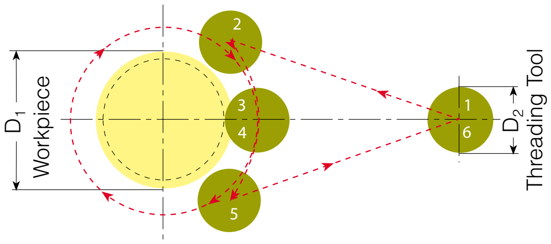
Although it requires slightly more complex programming than the radial approach (see below), this is the method recommended for machining the highest quality threads.

1-2: Rapid approach
2-3: Tool entry along tangential arc, with simultaneous feed along z-axis (@ 30% of the programming Feed)
3-4: Helical movement during one full orbit (360 degrees in cut at full programmed Feed)
4-5: Tool exit along tangential arc, with continuing feed along z-axis
5-6: Rapid return

Internal Thread



External Thread



RADIAL APPROACH

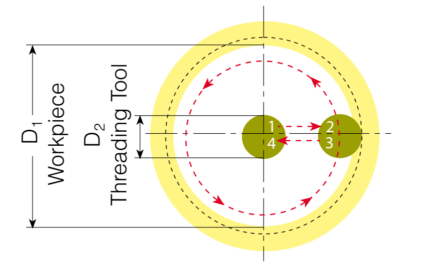
This is the simplest method.

There are two characteristics worth noting about the radial approach:

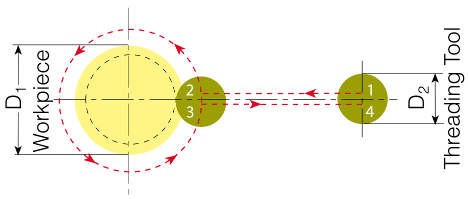
- a small vertical mark may be left at the entry (and exit) point. This is of no significance to the thread itself.
- when using this method with very hard materials, the tool may have a tendency to vibrate as it approaches the full cutting depth.

Note: Radial feed during entry to the full profile depth should only be 1/3 of the subsequent circular feed.

Internal Thread



External Thread

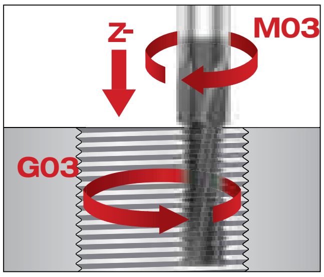


1-2: Radial entry
2-3: Helical movement during one full orbit (360 degrees in cut at full programmed Feed)
3-4: Radial exit

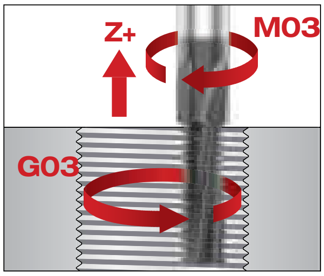
THREAD MILLING METHODS

INTERNAL THREADING

Climb Milling

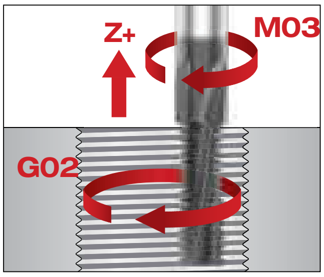


Internal left hand thread

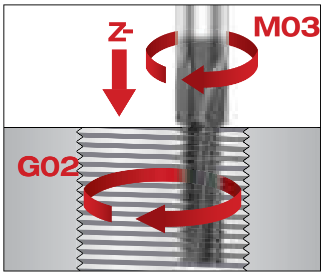


Internal right hand thread

Conventional Milling



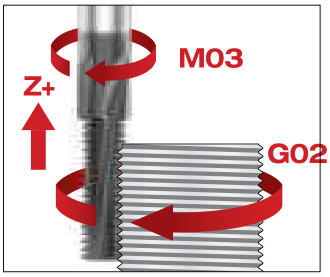
Internal left hand thread



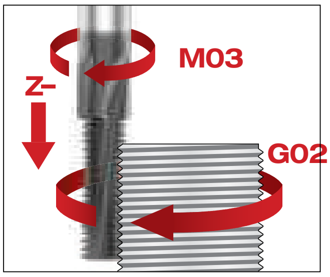
Internal right hand thread

EXTERNAL THREADING

Climb Milling

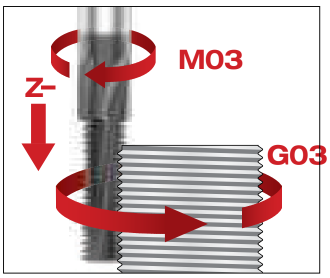


External left hand thread

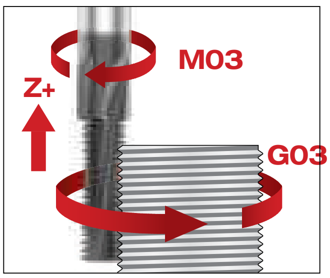


External right hand thread

Conventional Milling



External left hand thread



External right hand thread

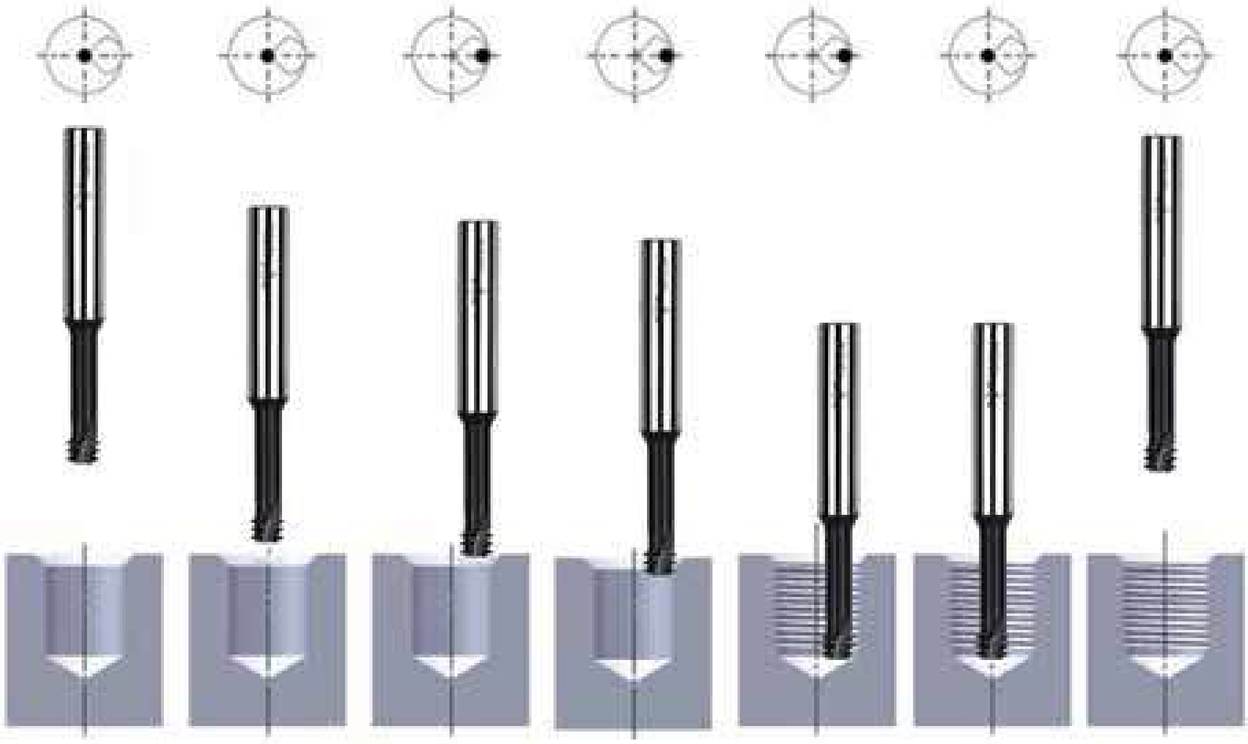
G CODES

G00	Send to position with rapid feed
G01	Send to position with linear movement and control by feed
G02	Clockwise circular interpolation
G03	Counter-clockwise circular interpolation
G40	Cutter compensation cancel
G41	Turn on left hand cutter compensation
G42	Turn on right hand cutter compensation
G54-59	Available workpiece coordinate settings
G90	Absolute positioning
G91	Incremental positioning

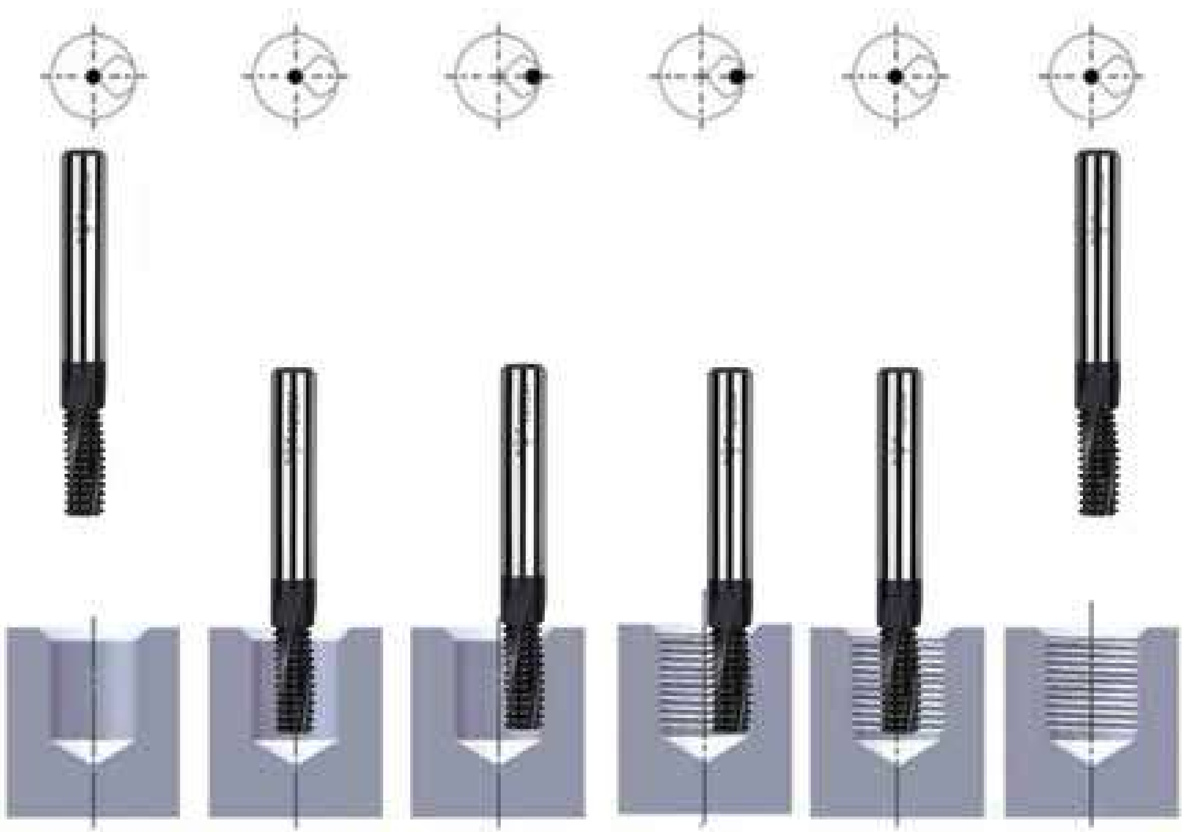
M CODES

M00	Program stop
M01	Program optional stop
M03	Turn on spindle clockwise direction
M04	Turn on spindle counter-clockwise direction
M05	Turn off spindle rotation
M06	Tool change
M08	Coolant on
M09	Coolant off
M30	Program end and reset to start of program

THREADMILL CYCLE FOR MT2D/MT3D/MT4D



THREADMILL CYCLE FOR RHTS/RHTC/RHS/RHC/RSS/RSTS



ICONGALLERY

TOOL TYPE

CT	Chamfer Tool
TP	Taper Preperation
TM	Thread Mill

DESIGN TYPE

STP 60	Single Tooth Partial Profile
MT 2D	Multi Tooth 2D
MT 3D	Multi Tooth 3D
MT 4D	Multi Tooth 4D
MTH 2D	Multi Tooth 2D For Hard Part
MTH 3D	Multi Tooth 3D For Hard Part
RHS	Regular Helical Flute Solid
RHTS	Regular Helical Flute Taper Solid
RHC	Regular Helical Flute Coolant
RHTC	Regular Helical Flute Taper Coolant
RSS	Regular Straight Flute Solid
RSTS	Regular Straight Flute Taper Solid
A90S	Angle 90 Short Tool
A90L	Angle 90 Long Tool

OPERATAION TYPE

ICP	Internal Conic Prep
ECP	External Conic Prep
IT	Internal Threading
ET	External Threading
EC	External Chamfer
IC	Internal Chamfer

THREAD FORM

ISO	ISO
UNIFIED	Unified
NPT	National Pipe Thread Pipe Thread
BS	British Standard

FEATURE

	Solid
	Coolant Feed

LENGTH

SHORT	Short
LONG	Long

COATING

TiAIN	Titanium Aluminium Nitride Coating

THREAD FORM DETAIL

M	Metric Screw Thread Series
MF	Metric Fine Screw Thread Series
UNC	Unified Coarse Thread Series
UNEF	Unified Extra Fine Thread Series
UNF	Unified Fine Thread Series
NPT	American National Standard Taper Pipe Thread
NPTF	Dryseal American National Standard Taper Pipe Thread
BSPT	British Standard Taper Pipe Thread
BSF	British Standard Fine Thread Series
BSP	British Standard Pipe
BSW	British Standard Whitworth Coarse Thread Series

CUTTING DIRECTION

LH	Left Hand
RH	Right Hand

FLUTE STYLE

H	Helical
S	Straight

APPLICATION

62 HrC	For materials Upto 62 HrC
	For arospace application

ICONGALLERY

TOOL SUBSTRATE

- Carbide — Carbide
- HSS — High Speed Steel M2 Grade
- HSS-E PM — High Speed Steel Powder Metallurgy

HELIX ANGLE

End Mills/ Taps/ Reamers

18° 20° 30° 35° 35/38° 38° 45° VARI

POINT ANGLE

- 118° — 118 Degree
- 60° — 60 Degree
- 90° — 90 Degree
- 120° — 120 Degree

NUMBER OF FLUTES

- 2 Flutes
- 6 Flutes
- 3 Flutes
- 4-6 — 4 to 6 Flutes
- 4 Flutes
- 7 — 7 Flutes
- 5 Flutes

CUTTING TYPE

- Center Cutting

END MILLS LENGTH

- REG — Regular / Standard Length
- LONG — Long Length
- EXTRA LONG — Extra Long Length
- LONG REACH — Long Reach Length

WORKPIECE HARDNESS

- Above 45 HRC — Hardness above 45 HRc

SHANK TYPE

- 6535 HA — Round Shank
- 6535 HB — Weldon Shank
- Universal Shank

SURFACE TREATMENT

- BF — Bright Finish
- TiN — Titanium Nitride Coating
- TiAlN — Titanium Aluminium Nitride Coating
- Cr Base — Chromium Based Coating
- Proton Plus — Proton Plus Coating

CORNER STYLE

- Square End
- Ball Nose
- Corner Chamfer
- 0.1X45° — Corner Reinforcement
- Corner Radius

STRATEGY

- Trochoidal Milling

STANDARD

- DIN 333 — DIN333
- DIN 371 — DIN371
- DIN 376 — DIN376

DRILL FORMS

- FORM A — Form A
- FORM B — Form B

CLASS OF THREAD

- 6HX — 6HX

CHAMFER

- C/2-3P — 2 to 3 Chamfer
- B/4-4.5P — 4 to 4.5 Chamfer

High Performance Cutting Tools

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