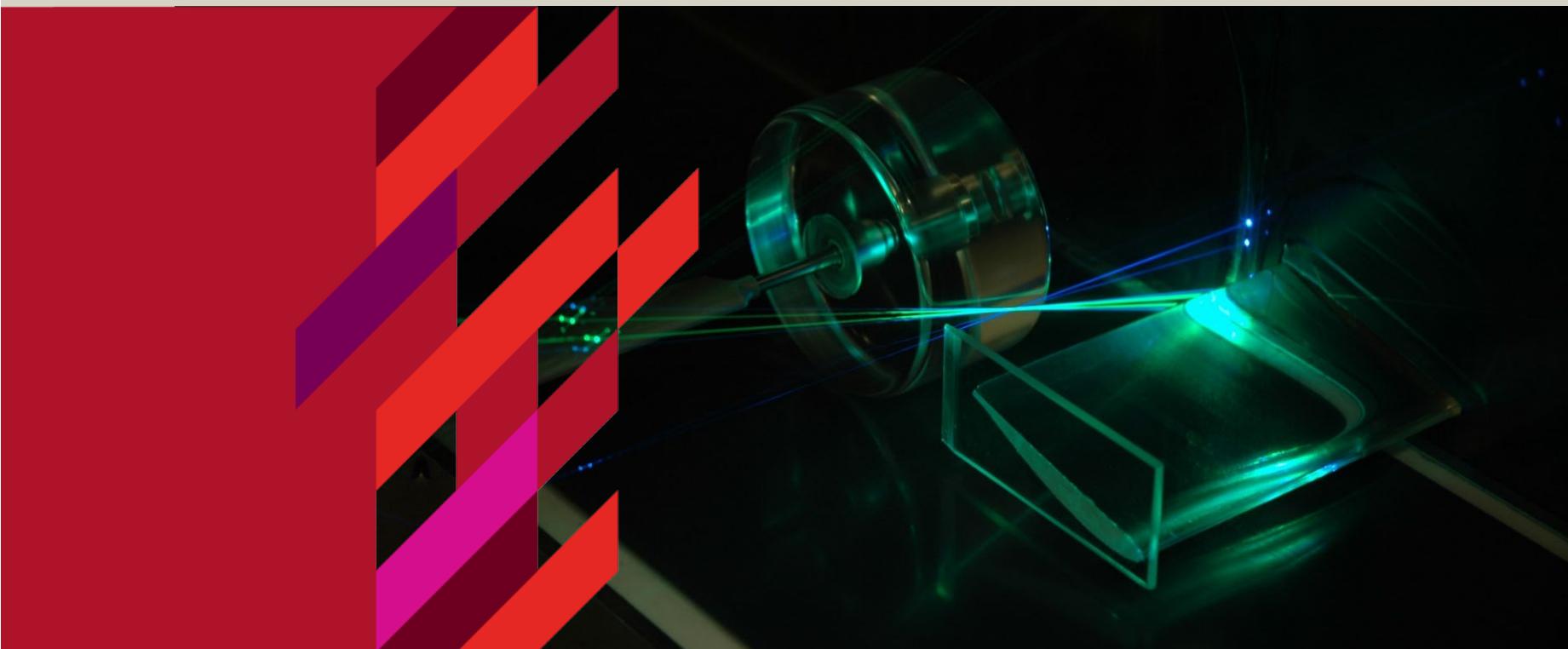




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# MECH2003, Mechanical Engineering Design Small Volume Manufacturing Techniques



# MECH2003: Mechanical Design

## Introduction to Small Volume Manufacture

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Who here has all ways wondered, I wish I could make something that could...

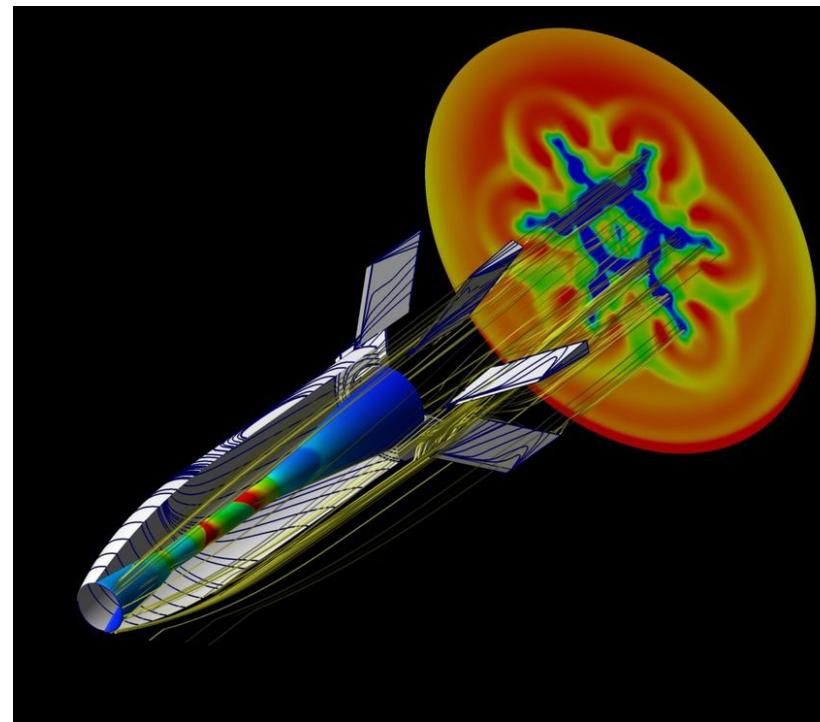


# MECH2003: Mechanical Design

## Introduction to Small Volume Manufacture

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Particularly in research and/or development, there is a requirement to be able to manufacture bespoke pieces of equipment in a cost effective manner.



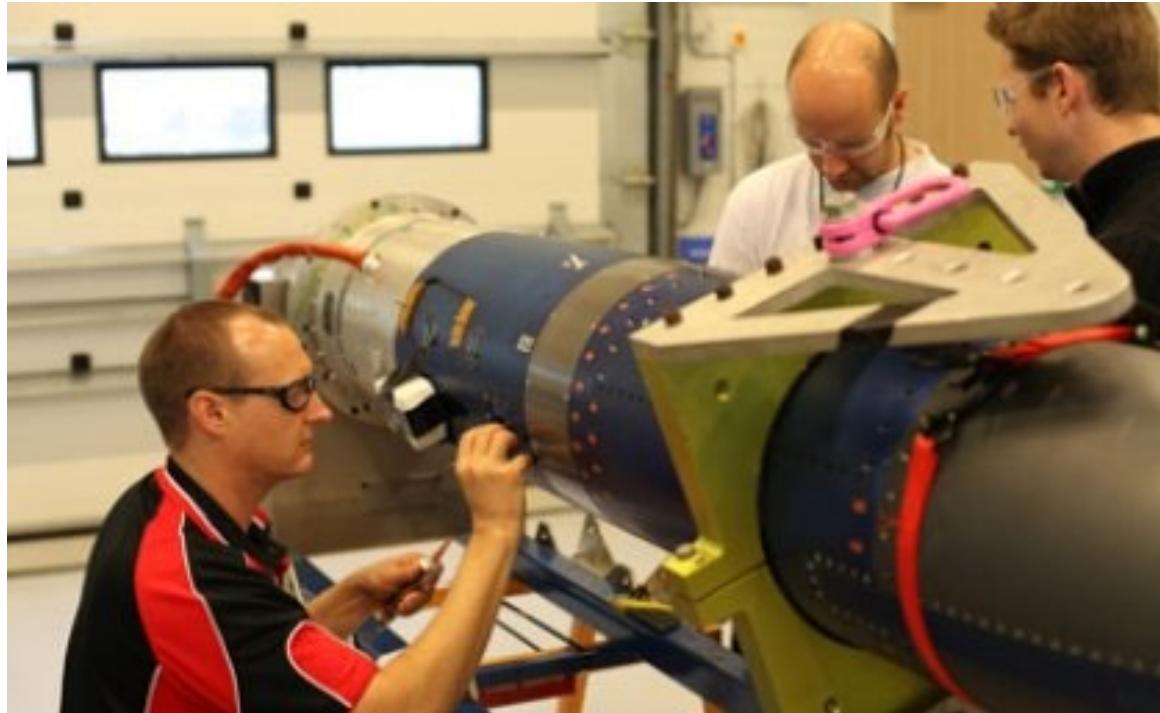
<http://hypersonics.mechmining.uq.edu.au/scramspace1>

# MECH2003: Mechanical Design

## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *Scramjets*



<http://hypersonics.mechmining.uq.edu.au/scramspace1>

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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *Scramjets*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *Human Powered Vehicle*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *Human Powered Vehicle*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *architectural prototyping*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *prototyping in manufacturing*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include – *product research and development*



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## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include - *custom bikes*



# MECH2003: Mechanical Design

## Introduction to Small Volume Manufacture

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Examples of bespoke equipment manufactured using small volume manufacturing techniques include - *custom cars*



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The objective of today's lecture is to:

1. Make you aware of what components and materials exist to manufacture bespoke mechanical systems.
2. Where these components can be obtained from.
3. Teach you what manufacturing techniques are available to you to produce mechanical systems in small quantities using material removal techniques.

# MECH2003: Mechanical Design

## Introduction to Small Volume Manufacture

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What components and materials exist to manufacture bespoke mechanical systems or components?



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What components and materials exist to manufacture bespoke mechanical systems or components?

- Bearings and Linear Bearings
- Pulleys and Belts, Chain Drives and Gears
- Flexible Couplings
- Fasteners
- Motors
- Piping and Ducting Sections
- Extrusions, billets, plate and sheet



## Available Components and Materials

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A large variety of **bearings** exist which are critical for systems that have rotating shafts.



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## Available Components and Materials

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The bridge of this CNC router requires to move back and forth effortlessly despite having a mass of 40kg, therefore the friction must be minimised.



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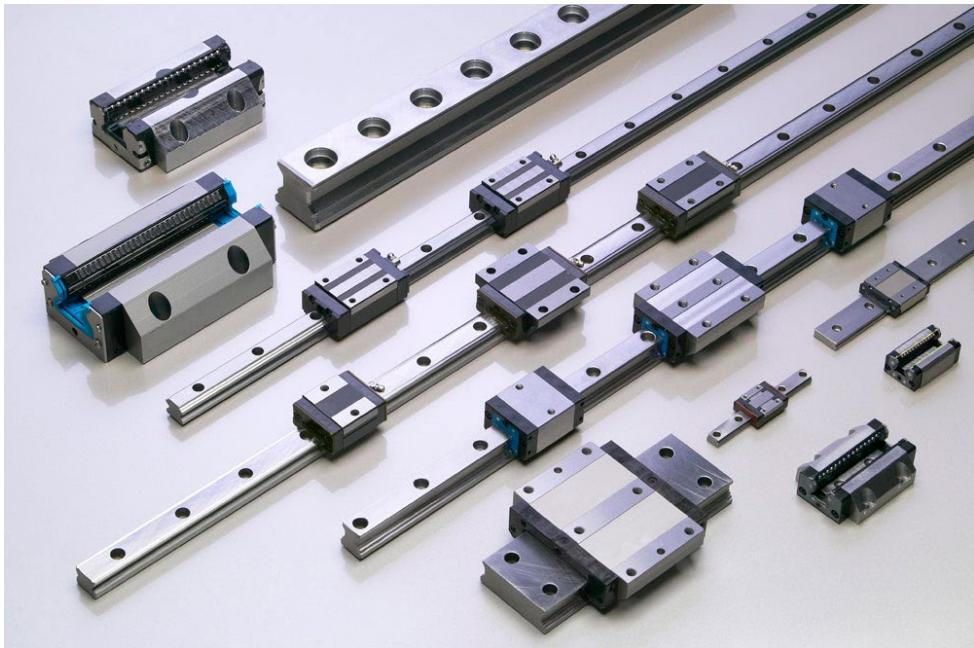


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## Available Components and Materials

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**Linear Bearings** minimise the friction between components that move along a straight path. Linear bearings have been used for the CNC router.



---

**Linear Bearings** achieve this in a very similar way to regular bearings, balls roll between two raceways where the load is transferred, and then return along a return channel.

## Available Components and Materials

---

We also spoke last week about coupling methods between shafts such as **Pulleys and Belts**, **Gears** and **Chain Drives**.



## Available Components and Materials

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There are also means to directly couple two shafts which are close to being aligned. Flexible couplings and CV joints allow for this to be achieved.



Flexible coupling

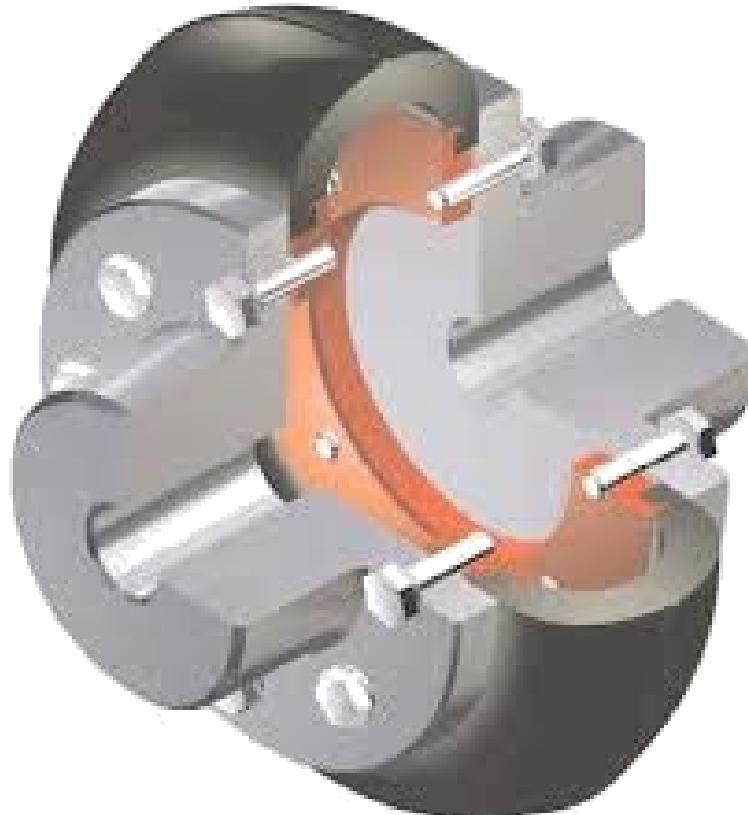


CV joint

## Available Components and Materials

---

Flexible couplings attach between two non aligned shafts and allow power to be transmitted through a flexible center.





## Available Components and Materials

---

**CV joints** also attach and transmit power between two non aligned shafts. They comprise of balls or a pair of internal perpendicular shafts to accommodate misalignments.



## Available Components and Materials

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**CV joints** are more commonly found with rubber boots surrounding them which allow grease to be kept inside the assembly and sand or dirt out.



## Available Components and Materials

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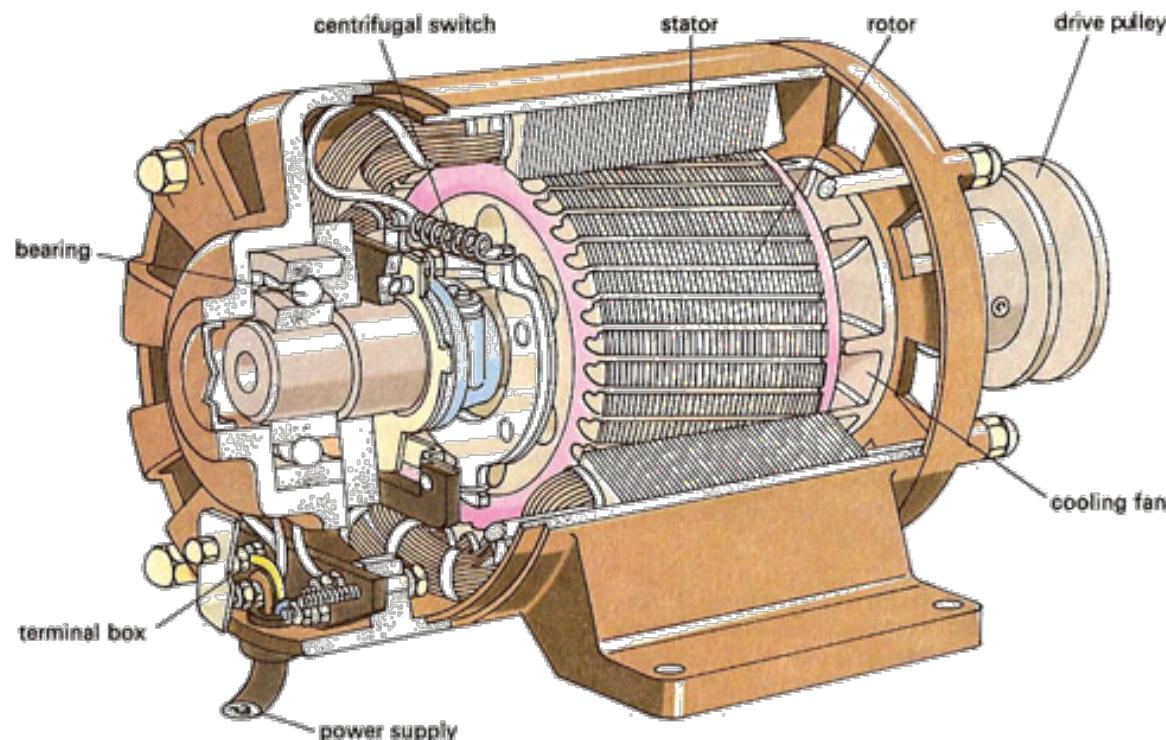
Fasteners allow components to be non-permanently or permanently joined together. We will be discussing these components in great detail next week...



## Available Components and Materials

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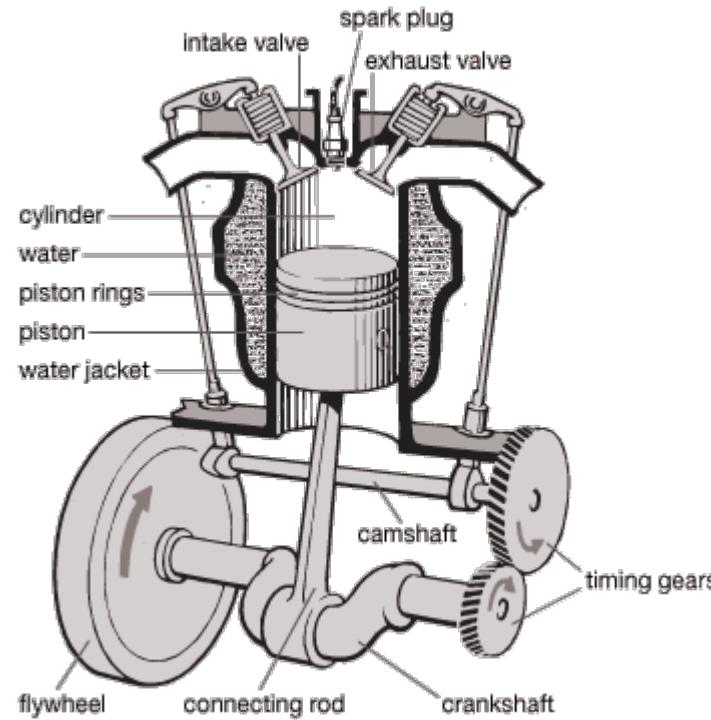
**Electric Motors** allow mechanical power to be generated wherever there is a suitable electrical supply. More will be discussed about the selection of Electric Motors in a fortnight.



## Available Components and Materials

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Internal Combustion (IC) Engines allow mechanical power to be generated using fuel. The operation and variants of IC engines will be discussed in a fortnight.



## Available Components and Materials

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There is often a requirement to transport fluids in mechanical systems. To accommodate this, a series of piping, fittings, hoses and ducts are available.

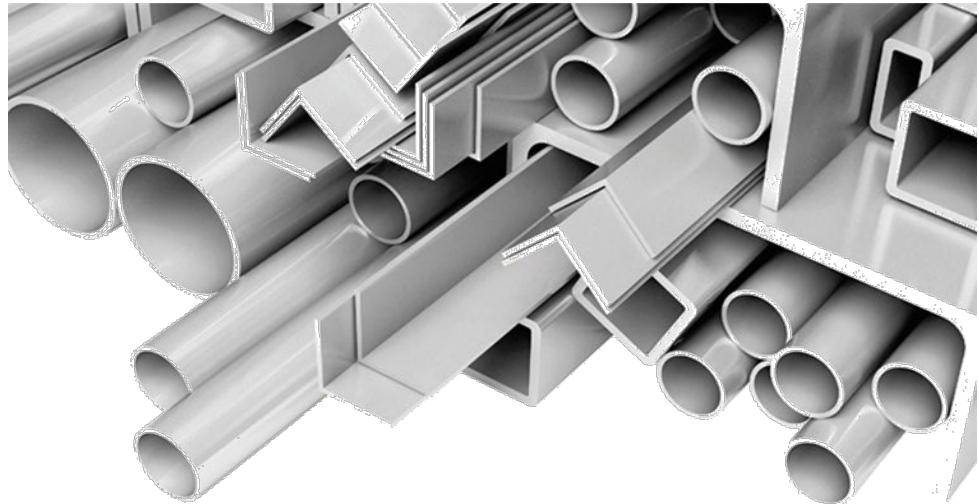


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## Available Components and Materials

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Despite all the available components, it is still required to manufacture some items. A large array of raw materials can be sourced that are available as either extrusions, billets or sheet to assist with this.

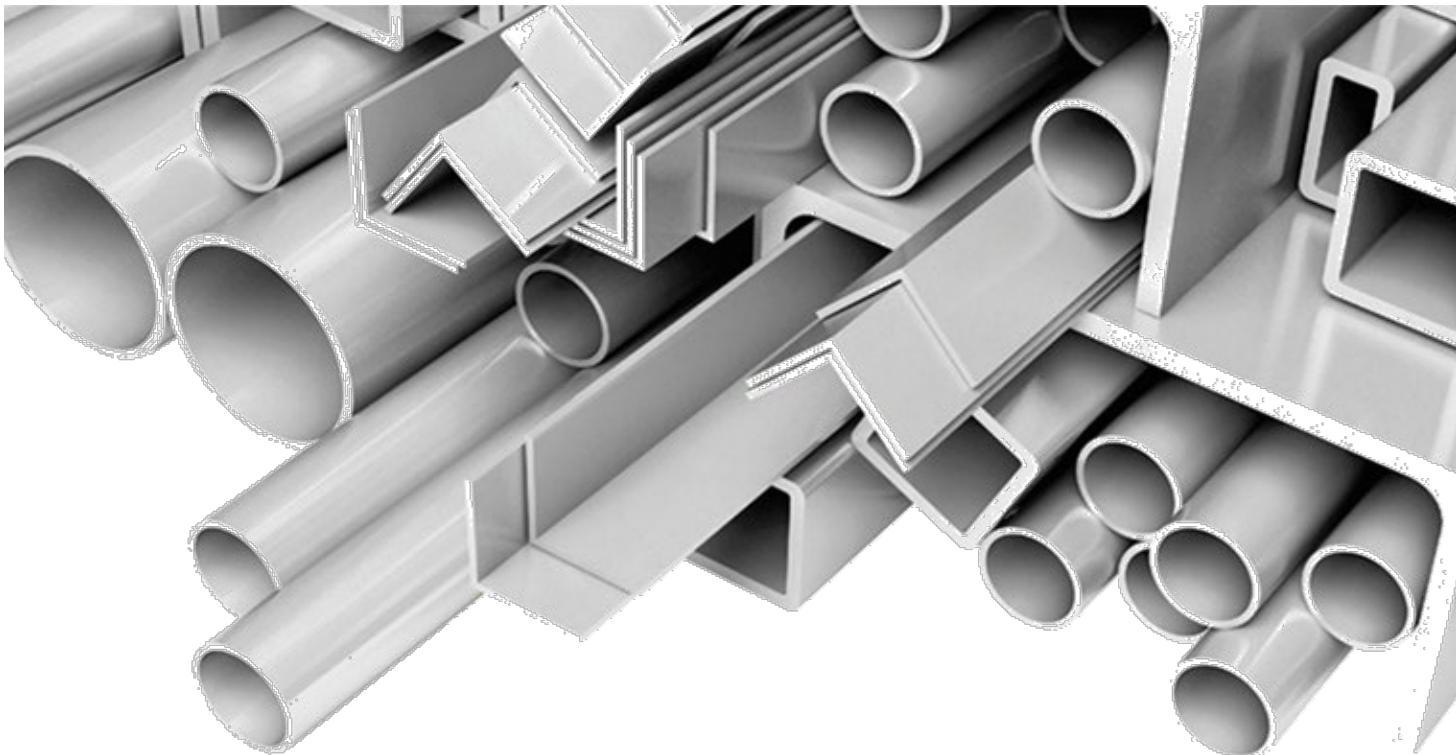




## Available Components and Materials

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Extrusions, are lengths of material that have a constant cross sectional shape. They come in a large variety of shapes and materials.



## Available Components and Materials

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Some extrusions shapes are deliberately designed to facilitate easy assembly with the use of brackets and or fasteners making the assembly process easy.



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## Available Components and Materials

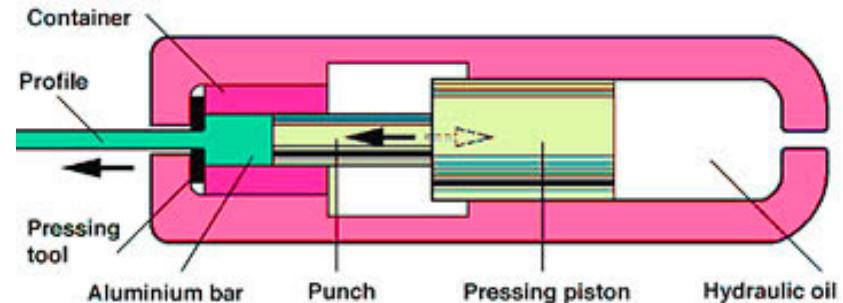
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Such extrusions were used to manufacture the CNC router that the MQ HPRT would use for example.



## Available Components and Materials

Extrusions are created by pushing heated material through a form called a dye.



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## Available Components and Materials

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Each cross sectional shape requires its own specific die to be manufactured, hollow sections require more complex dies.



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Material is heated before extruding, but never melted.

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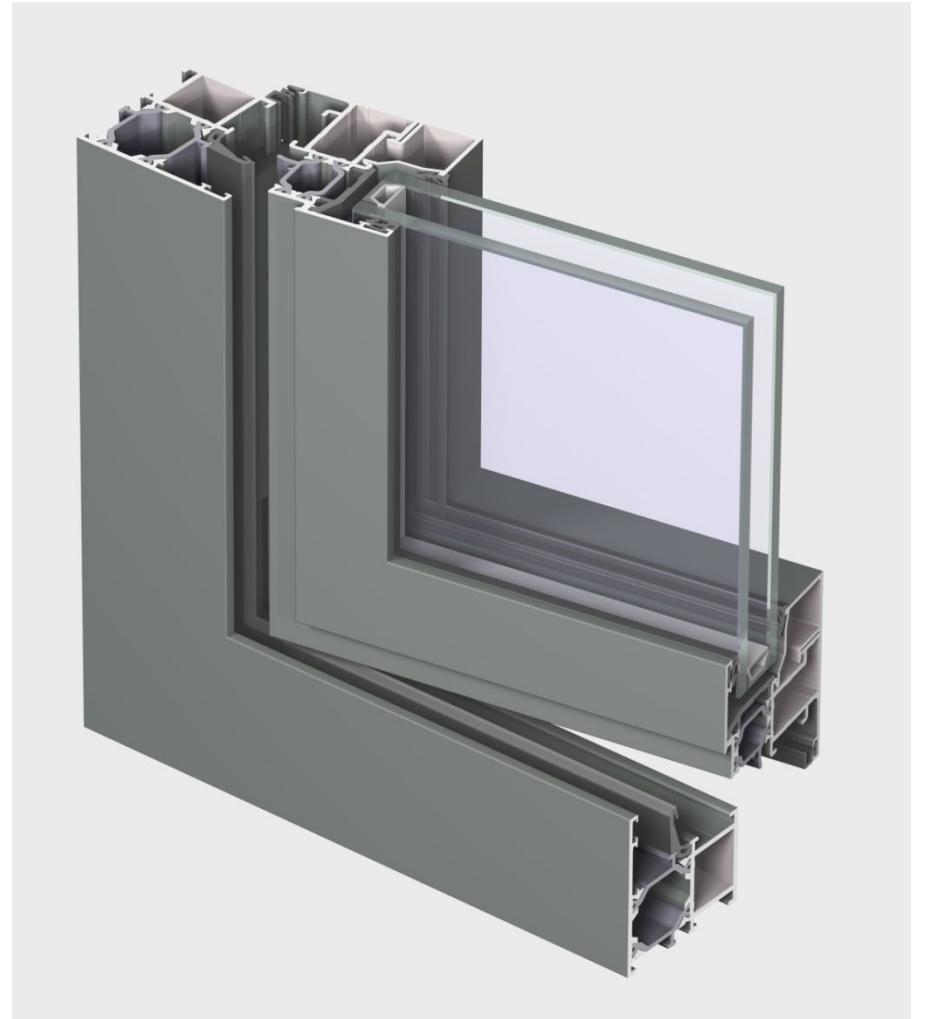


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## Available Components and Materials

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Extrusions come in many alternative shapes, some are designed to manufacture window frames after being cut appropriately and assembled using brackets.

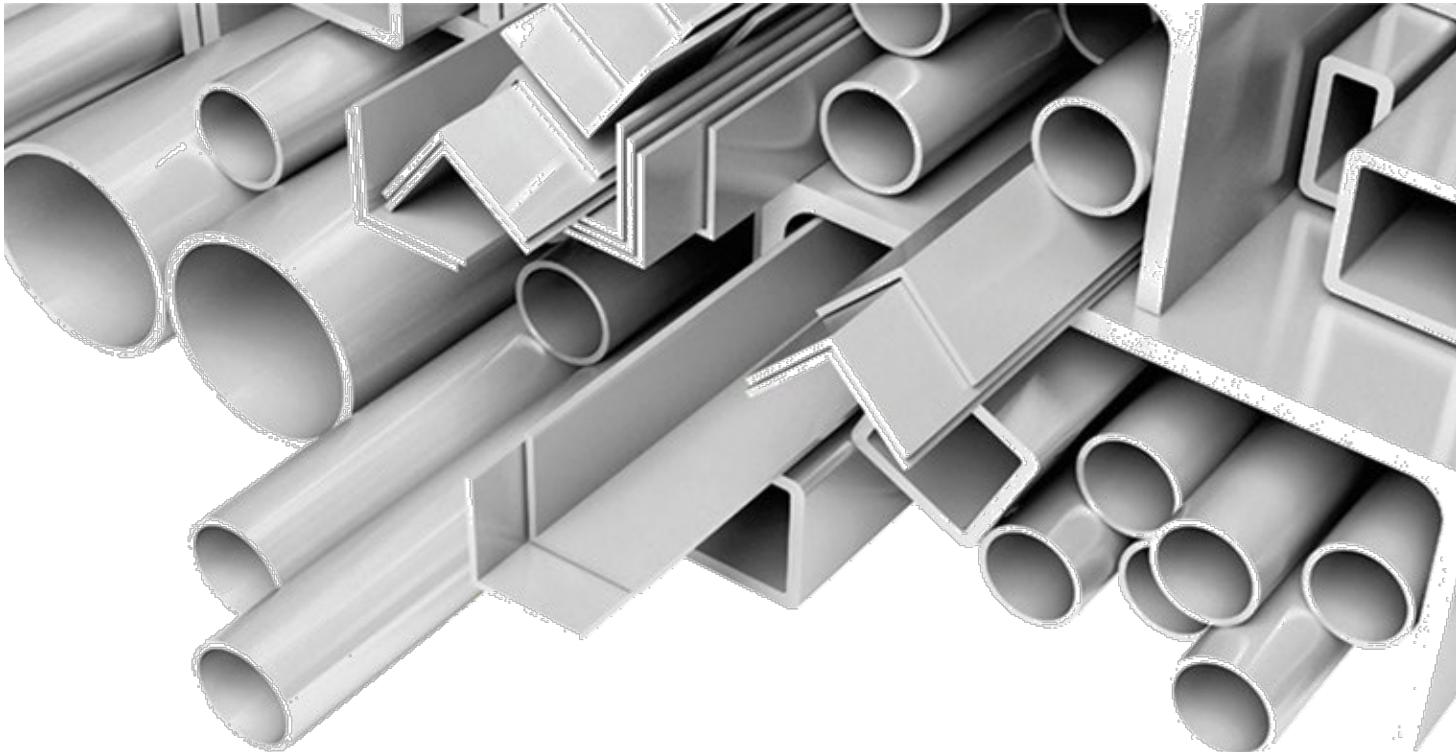


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## Available Components and Materials

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The large number of Extrusions available can assist the manufacture of bespoke mechanical components by reducing the work required to create a component.





## Available Components and Materials

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When suitable extrusions do not exist, billets of material can be used. These are large blocks of material that can be cut and or machined to a desired shape.



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## Available Components and Materials

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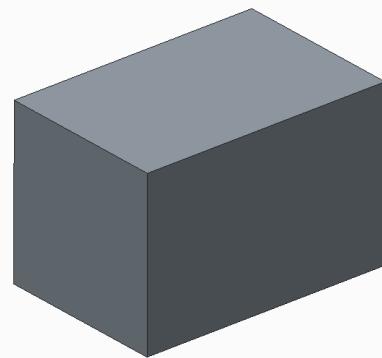
Billets are used when dimensions of the components are critical and the material properties must be very well understood.





## Available Components and Materials

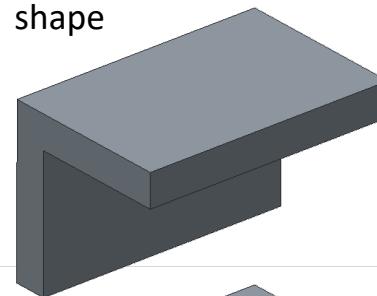
Significant machining is required to achieve the desired component when starting from a billet in comparison to modifying an extrusion. The machining processes will be discussed shortly.



Cut billet too required length



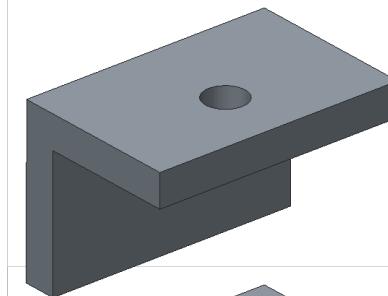
Machine to achieve desired shape



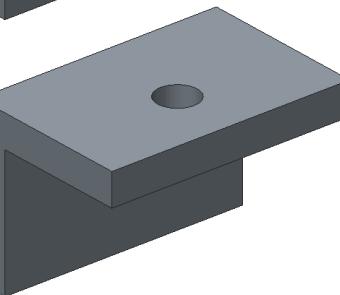
Cut extrusion too required length



Drill desired hole



Drill desired hole



## Available Components and Materials

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If the component that is required to be manufactured should have very thin walls, then sheet material can be folded to produce the desired component.



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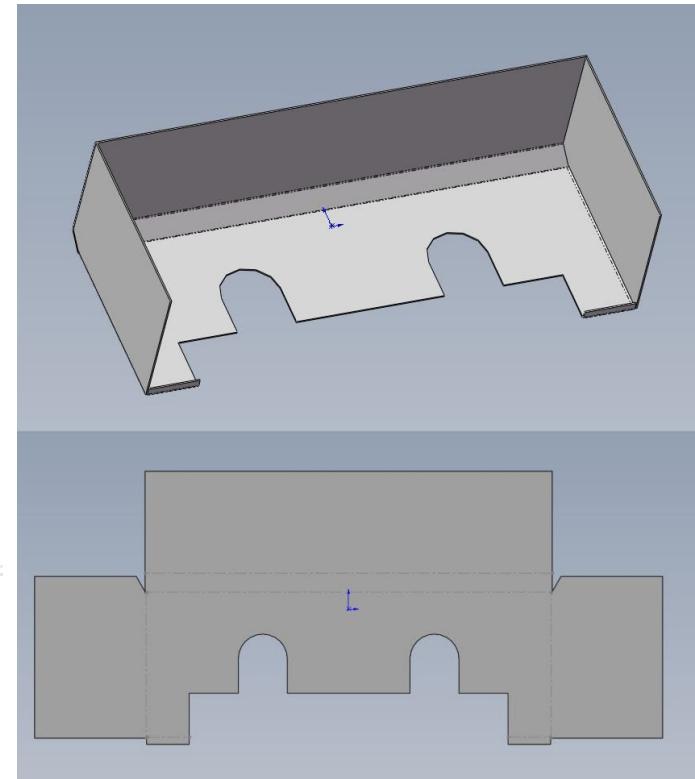
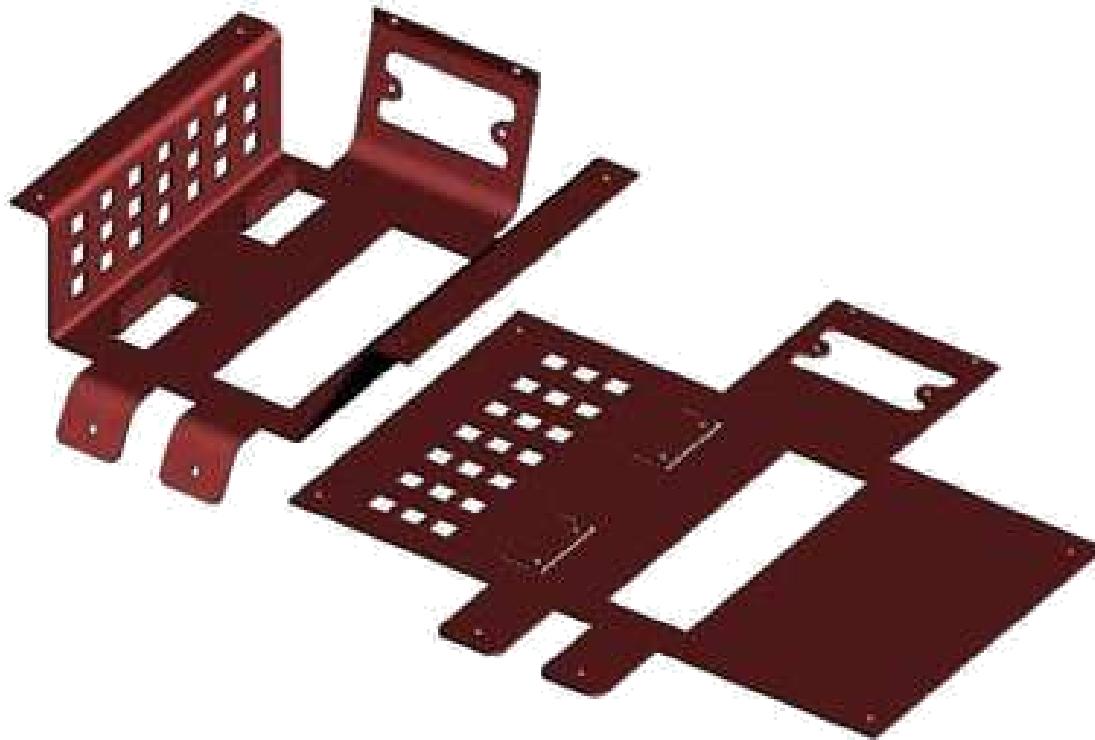


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## Available Components and Materials

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Assuming that a minimum bend radius for the material is known, to fold a component from sheet requires an unfolded shape to be determined and then cut out...



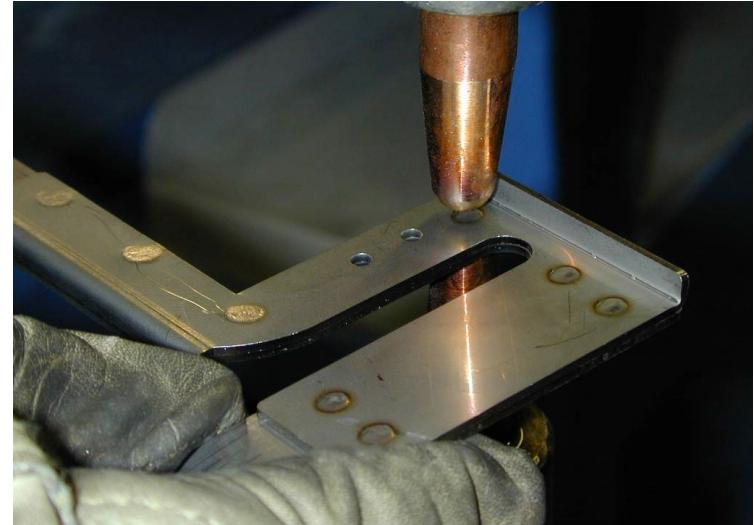
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## Available Components and Materials

Once cut, the shape is folded from the sheet material, the sides are joined using either rivets or different welding techniques.



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Numerous suppliers exist for all the components discussed thus far and many more. They include:

- **Blackwoods** – large variety of items ([www.blackwoods.com.au](http://www.blackwoods.com.au))
- **RS** – large variety of items (<http://au.rs-online.com/web>)
- **SKF** – ball bearing suppliers (<http://www.skf.com/au>)
- etc...

*Google and the Yellow Pages are also a great way to find suppliers!*

## Available Components and Materials

---

### Example 1:

A project requires the supply of 200 M6 countersunk screws that are 30mm long. Find a suitable supplier for these items and provide the part number for them.



## Available Components and Materials

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### Example 2:

A project requires the supply of deep groove ball bearings with steel shields that has an inner diameter of 30mm. What is the thickness and outer diameters available for this inner diameter and what are the part numbers for these components. Can you download a CAD model for them?



## Available Components and Materials

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### Example 3:

A 50mm x 50mm Aluminum L section is required to manufacture some brackets. Find a suitable supplier and determine what thickness this material is available in.



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When manufacturing mechanical components in small quantities, the techniques utilised to achieve this can be classified into two broad categories:

- Material Removal Techniques
- Additive Material Techniques

---

When manufacturing mechanical components in small quantities, the techniques utilised to achieve this can be classified into two broad categories:

- Material Removal Techniques – *Starting with a piece of greater volume than that required and then removing material until the desired component geometry is achieved.*
- Additive Material Techniques

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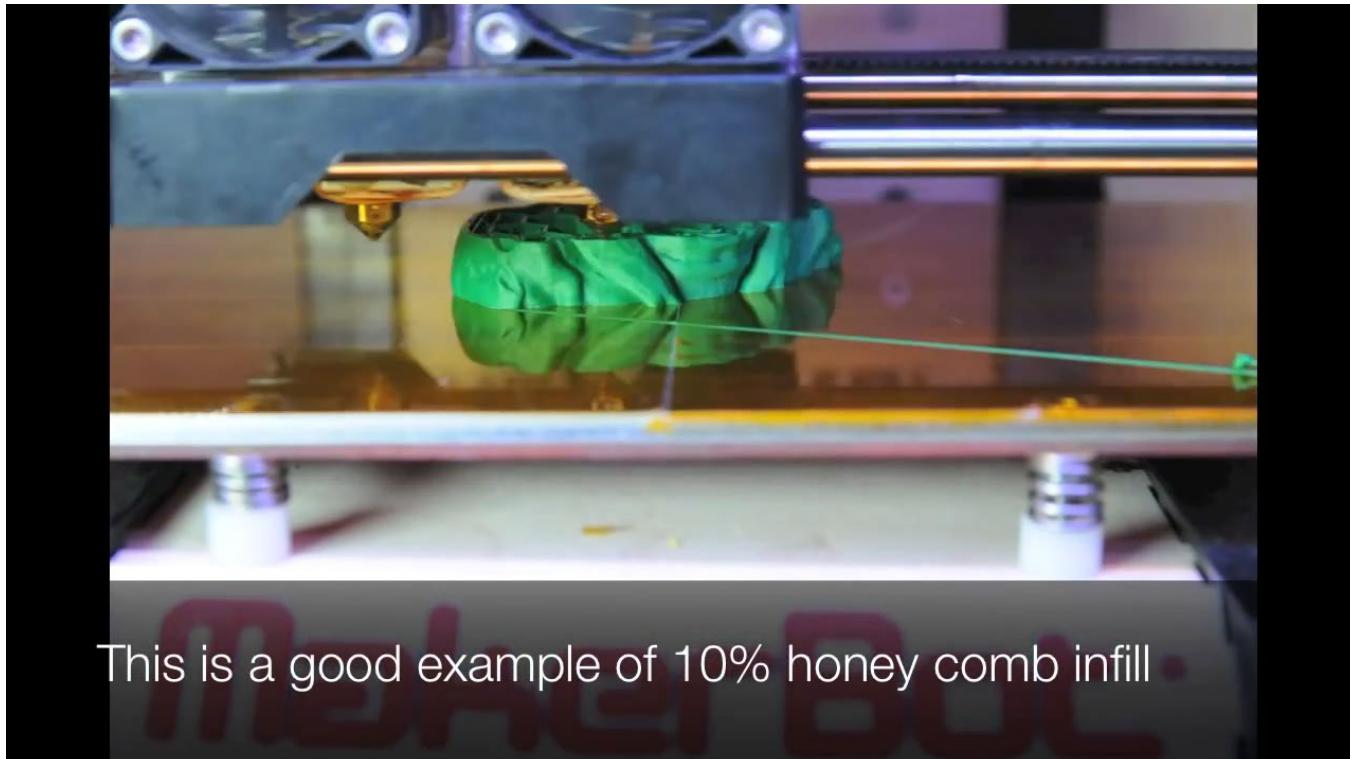
When manufacturing mechanical components in small quantities, the techniques utilised to achieve this can be classified into two broad categories:

- Material Removal Techniques – *Starting with a piece of greater volume than that required and then removing material until the desired component geometry is achieved.*
- Additive Material Techniques – *Laying material such that the final component's volume is very similar to the volume of material used.*

## Material Additive Techniques

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The most common additive material technique currently used is 3D printing. This relies on melting a plastic and then laying it onto a board to cool.

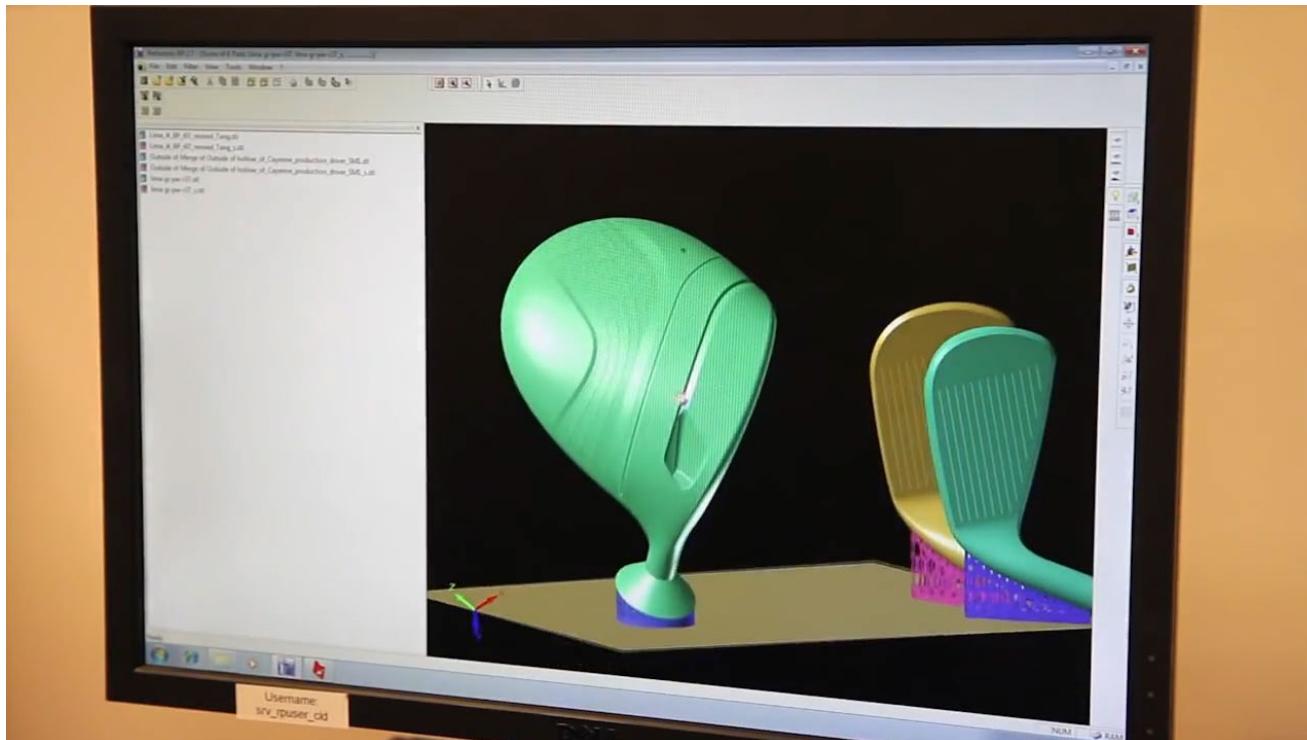




## Material Additive Techniques

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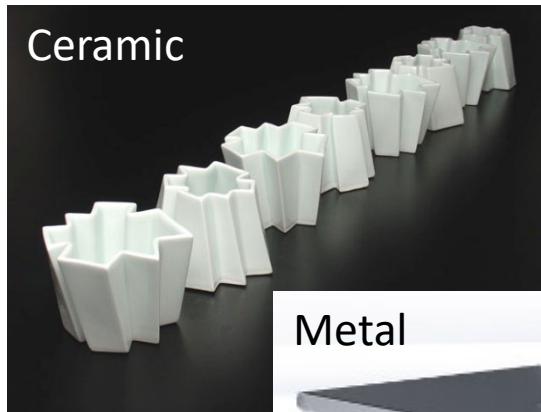
Rapid prototyping has proceeded 3D printing, this process is different in that a laser is used to solidify a powder or liquid to build the component layer by layer.



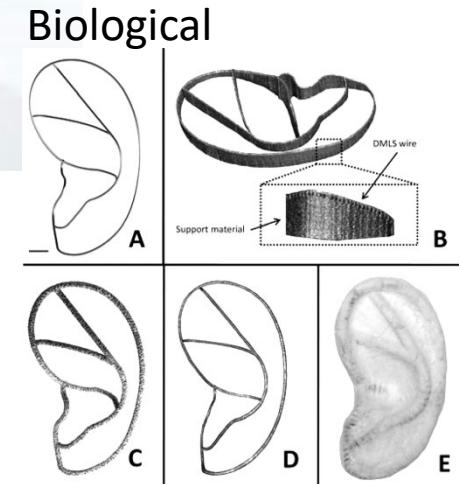


## Material Additive Techniques

This process can be used to manufacture components from a variety of materials include ceramic, metals, rubbers and even biological materials.



Metal



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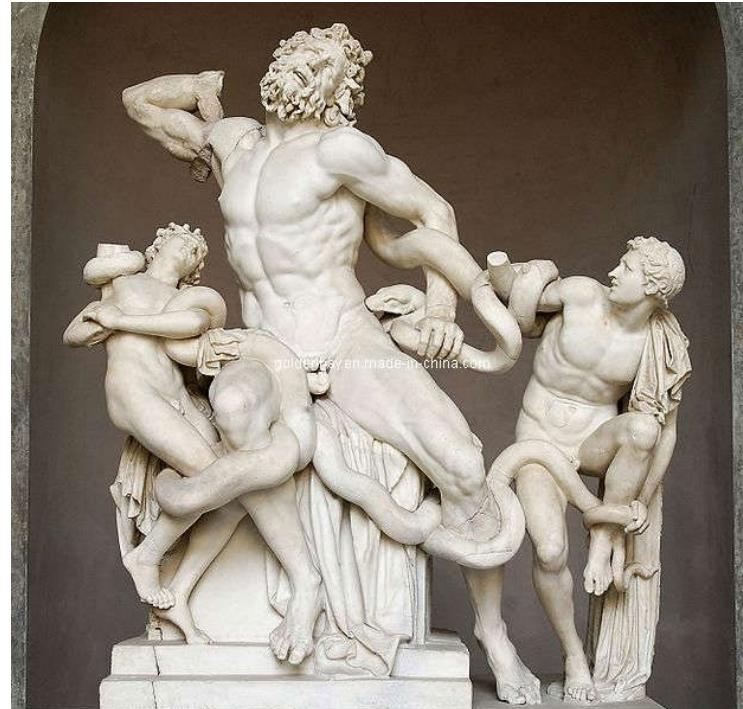
One of the oldest additive material techniques used are composite constructions. These are very labour intensive as sheets of material are laid one at a time by hand.



## Material Removal Techniques

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Additive material techniques are relatively new, historically components have been manufactured by carving the desired geometry from a larger volume of material.



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## Material Removal Techniques

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Even ancient monuments and statues have been carved by utilising these techniques.



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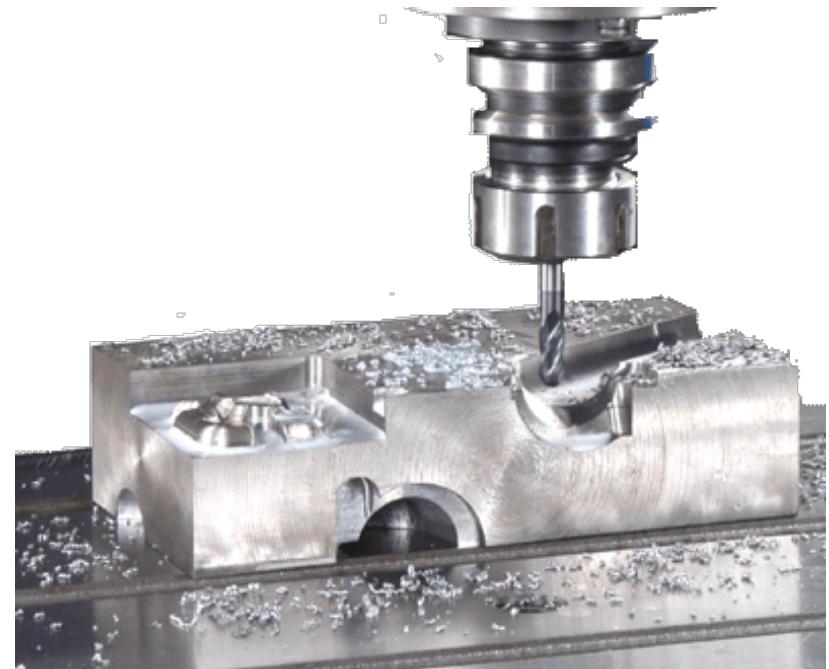


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## Material Removal Techniques

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Material Removal Techniques currently being used to machine components don't use a chisel, but rely on cutting or chipping material away until the desired geometry is achieved.

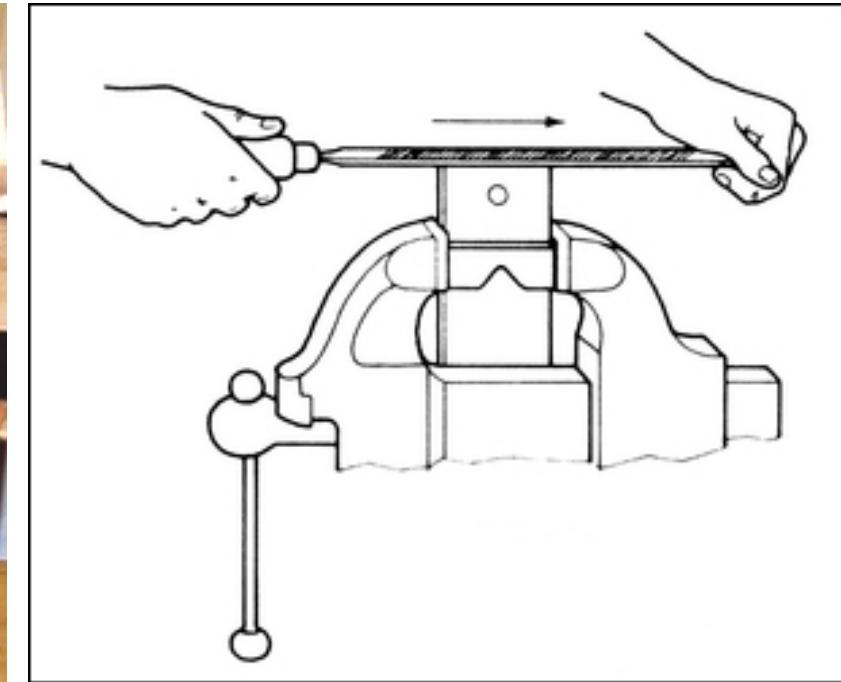




## Material Removal Techniques

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Hand tools such as saws and files are used to cut or shape material and they have several common features



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Both saws and files are intended to remove material in only one direction. This is because they have teeth that are inclined in order to assist with the cutting action.

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## Material Removal Techniques

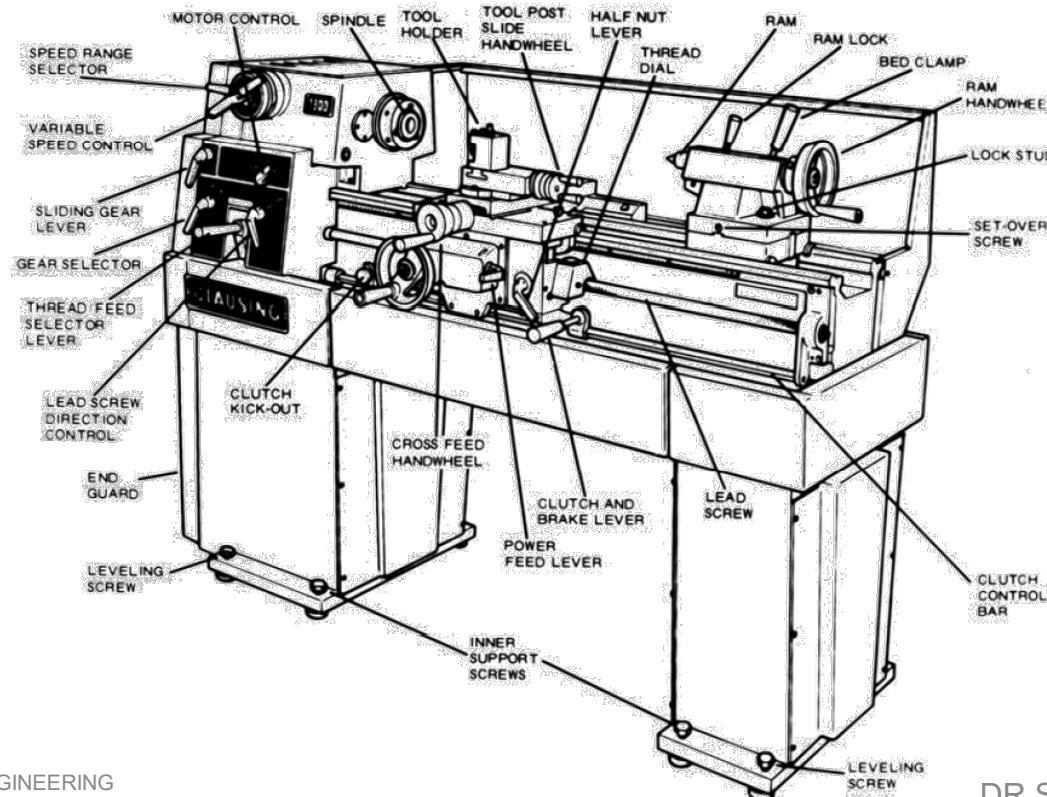
The size of the teeth on either should be matched with the material that is being worked with. Large coarse teeth are for soft materials like wood, fine teeth for steel.





## Material Removal Techniques

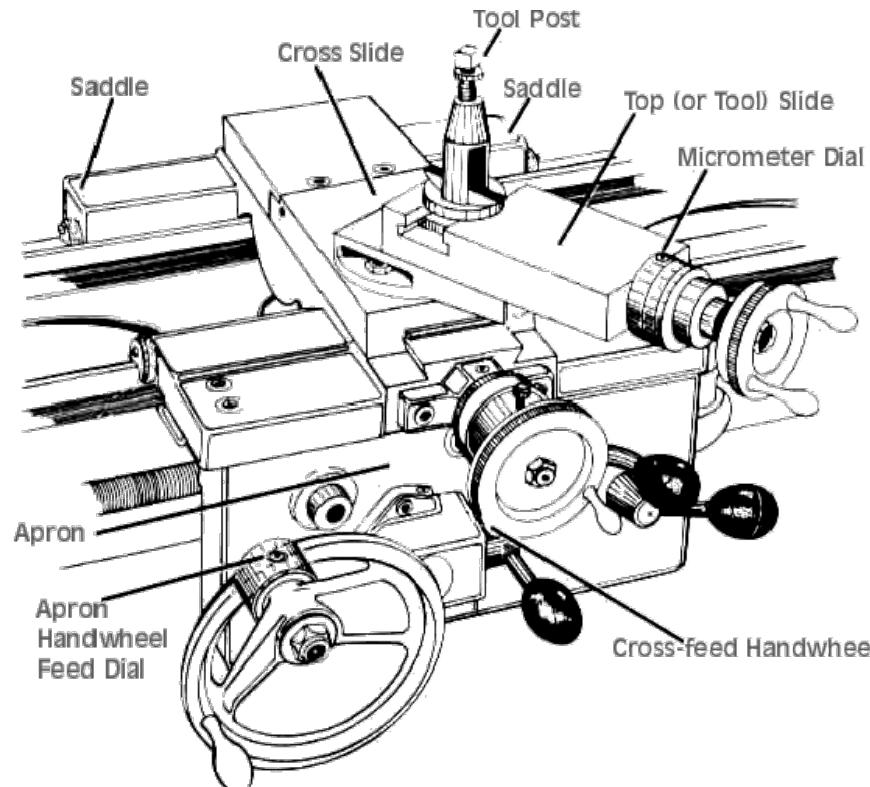
Lathes are commonly used to manufacture components with mostly cylindrical sections. They rotate the component while the cut is made by the “bit”.



## Material Removal Techniques

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The bit is supported by the toolholder which is located on the cross feed that allows the bit to be moved towards and away from the axis of rotation.



## Material Removal Techniques

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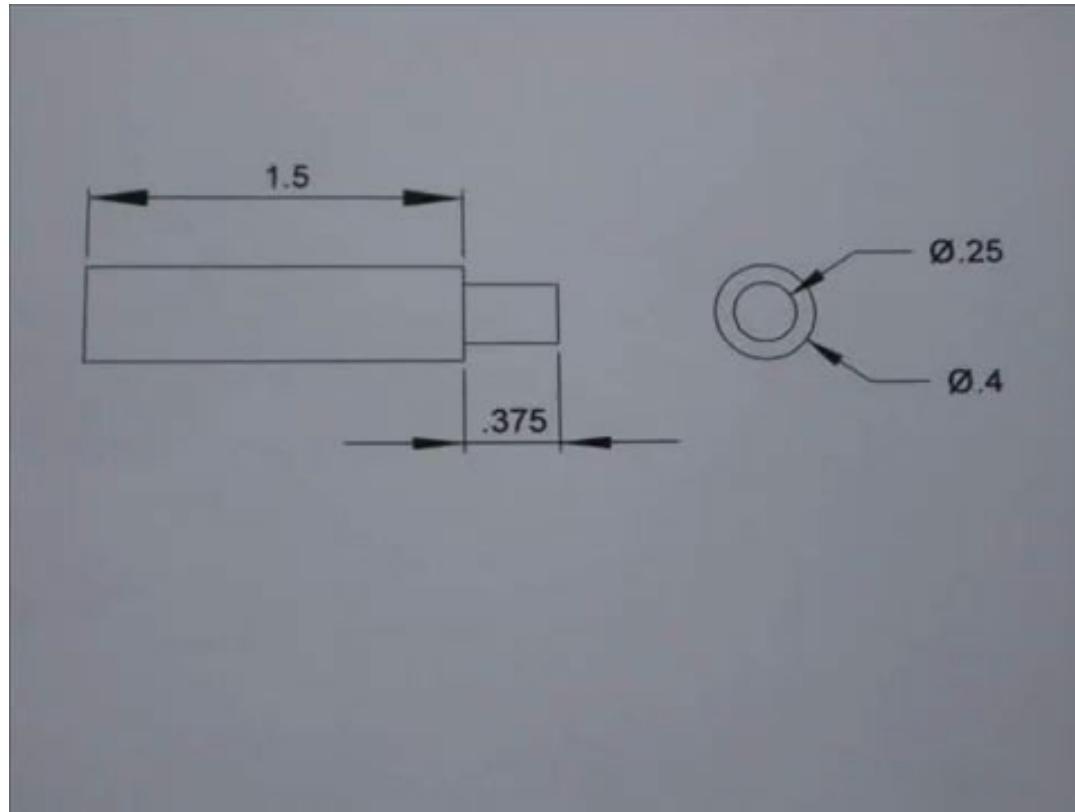
A bit is a component made of much harder material than that which is being cut, possibly hardened steel or tungsten carbide and they come in a variety of shapes.



## Material Removal Techniques

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In this video you can see the bit being forced into the material changing its diameter.

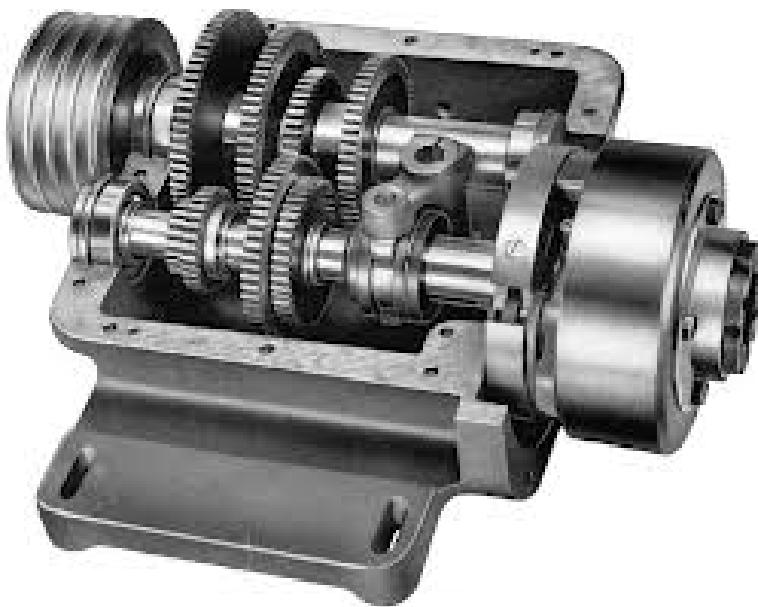


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## Material Removal Techniques

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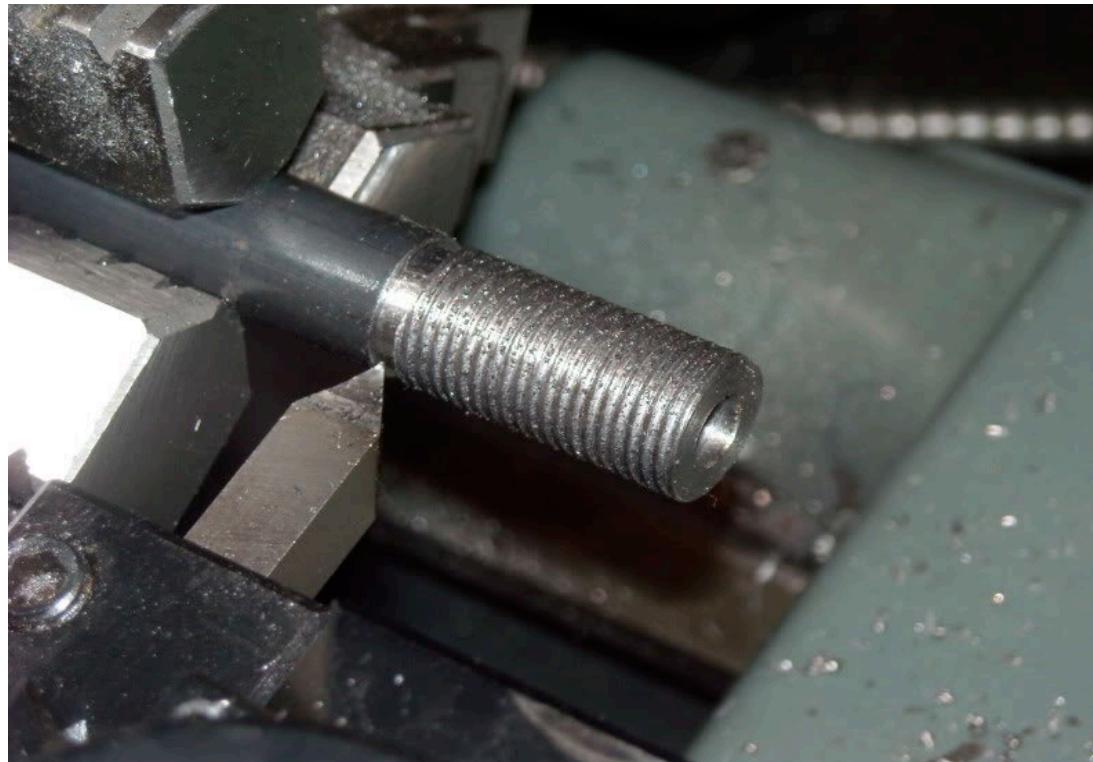
Lathes have gearboxes that allow the spindle to be turned at different angular velocities which is dictated by the diameter and the material that requires to be cut.



## Material Removal Techniques

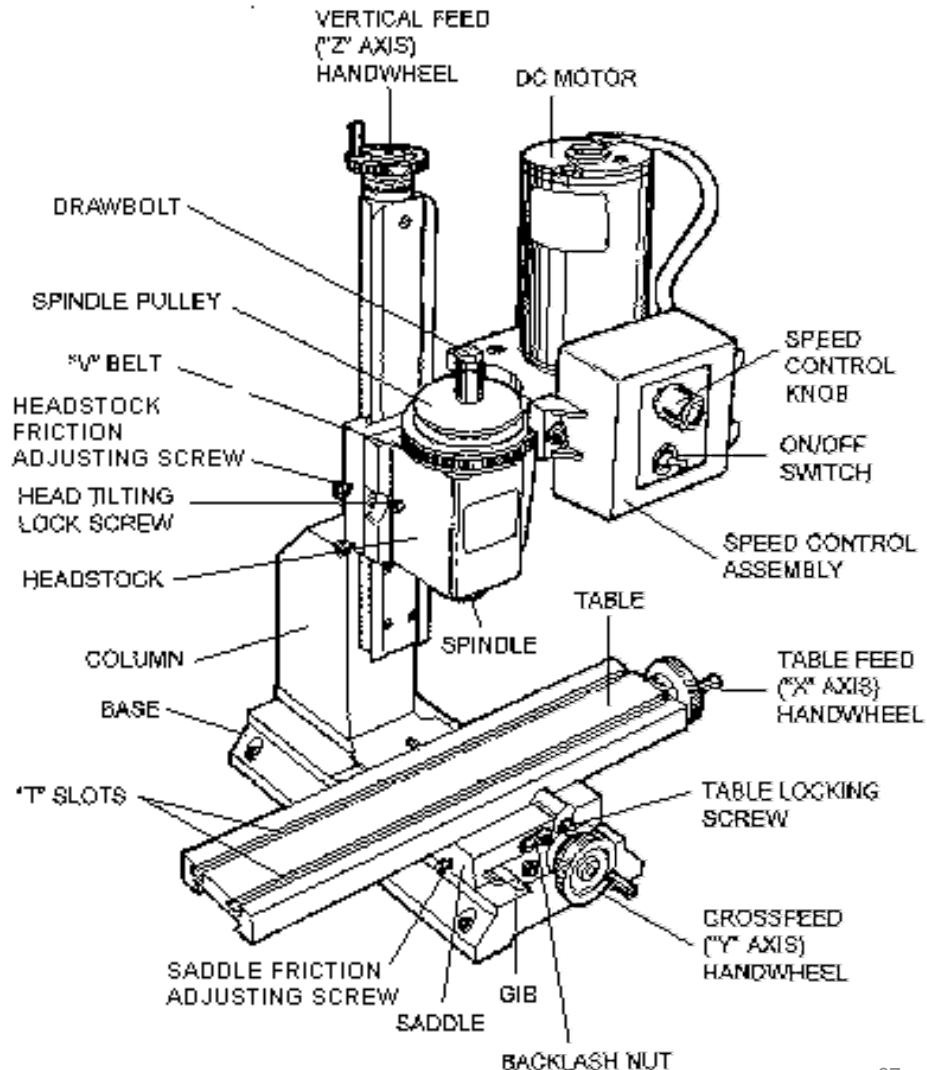
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Lathes can be used to also cut screw threads. To accommodate this feature, the stock can be traversed automatically to achieve the desired pitch for the thread.



## Material Removal Techniques

For components that are more rectangular in shape, mills are better suited. Mills keep the material stationary while an endmill is turned by the spindle.

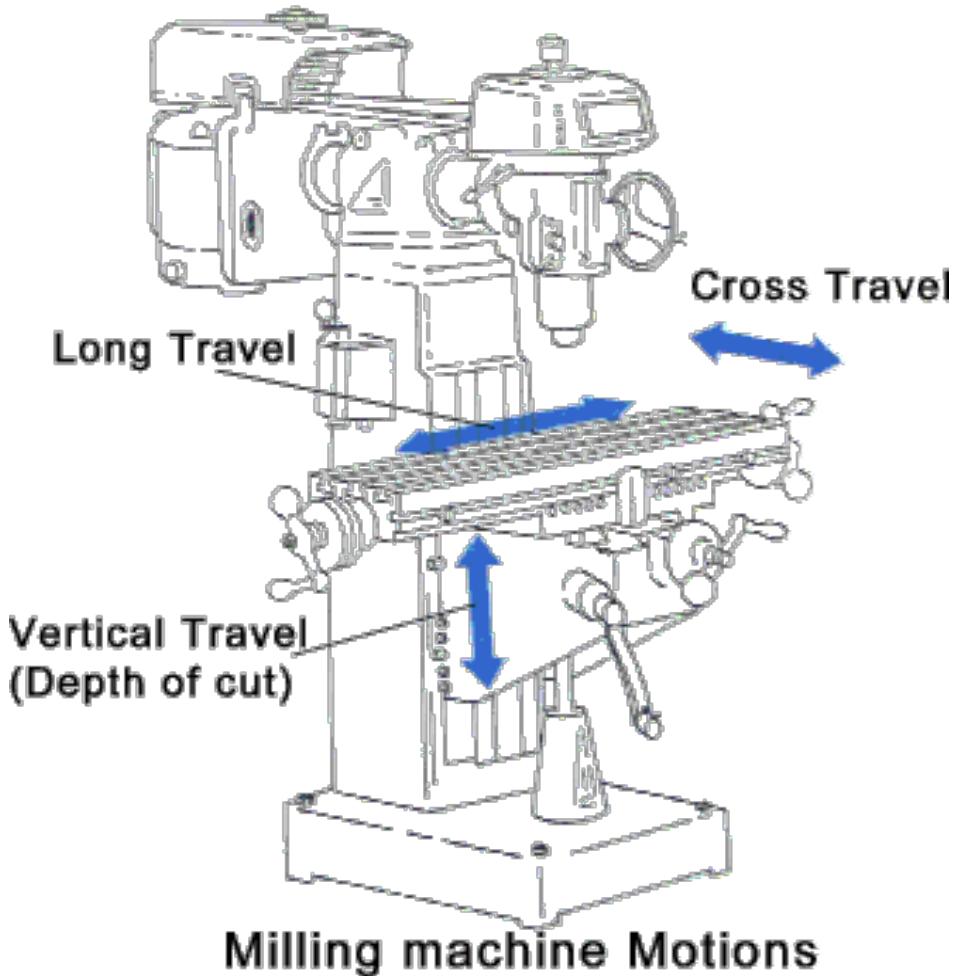




## Material Removal Techniques

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The piece can be moved left and right, forward and back as well as up and down into the endmill to machine slots or the outer shape of a component using the three travels.



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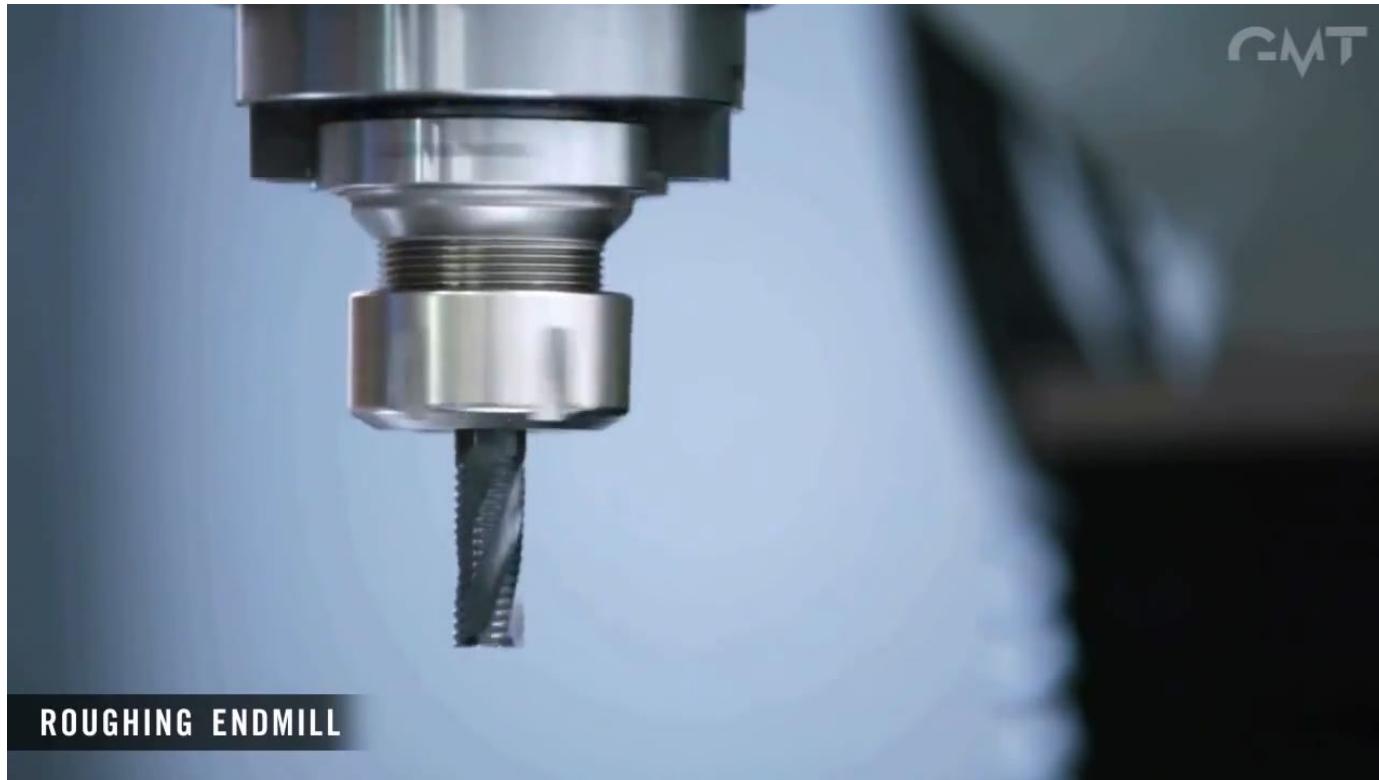


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## Material Removal Techniques

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Many different end mills can be used to machine different features into a work piece and accelerate the process.



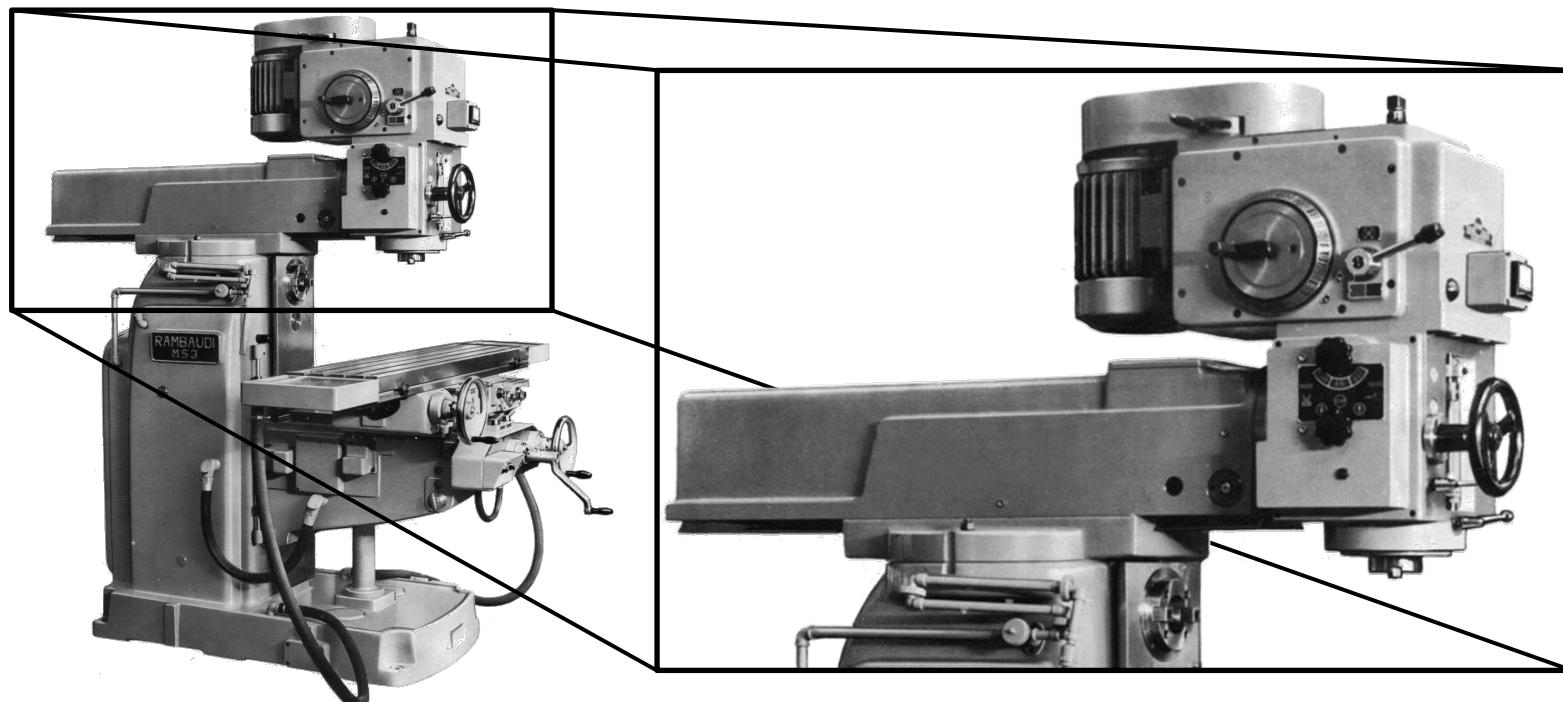
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## Material Removal Techniques

The cutting speed can also be varied on a mill to suit the material and the diameter tool that is being used by adjusting the gearbox above the spindle.



## Material Removal Techniques

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Both the lathes and the mills presented thus far have been manually operated. To ensure that the necessary accuracy is achieved, more modern mills are fitted with digital displays measuring the x, y and z axis translation.



## Material Removal Techniques

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Often desired components are too complex for a machinist to manufacture manually and the complexity dictates additional axis of motion are required.

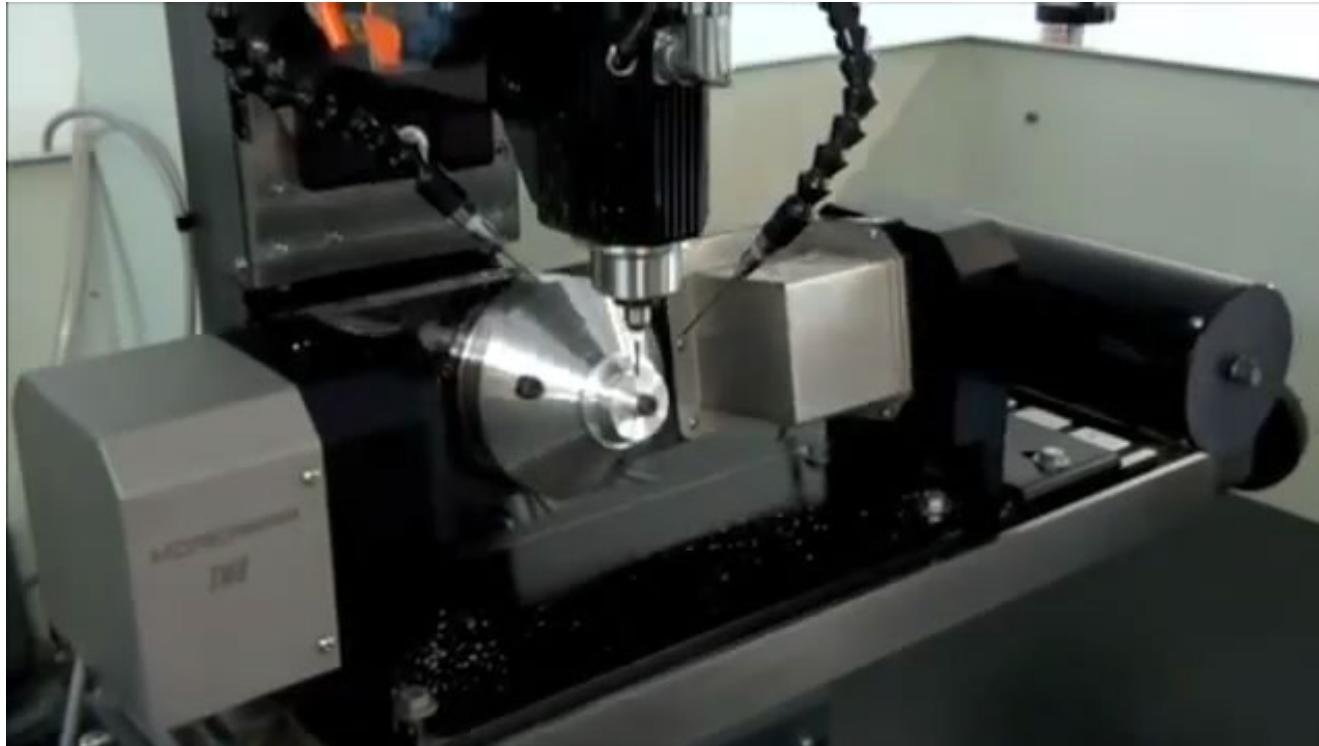


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## Material Removal Techniques

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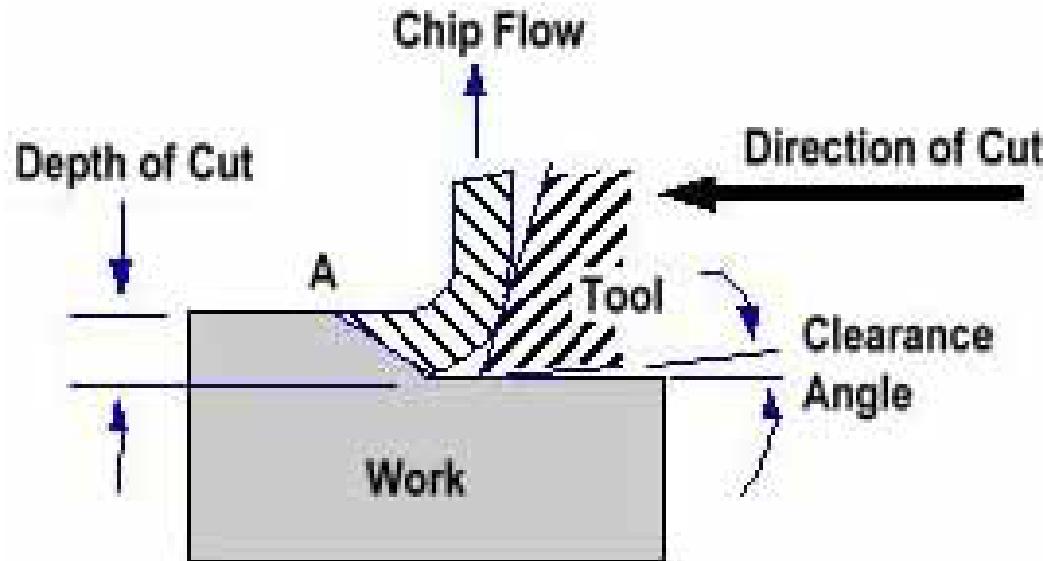
For such occurrences, 5 axis Computer Numerically Controlled mills are required.



## Material Removal Techniques

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A variety of different machines and hand tools exist, but they all must respect theory that outlines how much material can be removed at once.



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## Material Removal Techniques

This is controlled by the speed (or RPM) of the spindle. The following equation can assist with determining the correct rpm after selecting the appropriate material cutting speed from this table.

$$RPM = \frac{300 \times \text{Cutting Speed}}{\text{Diameter}}$$

Material	Cutting tool material	Rough cut	Finishing cut
		m/min	m/min
Free Cutting Steel	HSS	35	90
	Cast Alloy	75	145
	Carbide	125	205
Low Carbon Steel	HSS	31	80
	Cast Alloy	65	130
	Carbide	106	190
Medium Carbon Steel	HSS	30	69
	Cast Alloy	58	107
	Carbide	92	152
High Carbon Steel	HSS	24	61
	Cast Alloy	53	91
	Carbide	76	137
Cast Iron Grey	HSS	24	41
	Cast alloy	43	76
	Carbide	69	125
Brass / Bronze Free Cutting	HSS	53	110
	Cast Alloy	105	170
	Carbide	175	275
Aluminium	HSS	40	90
	Cast Alloy	55	115
	Carbide	75	185
Plastics	HSS	30	75
	Cast Alloy	45	115
	Carbide	60	150



## Material Removal Techniques

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Not following the suggested cutting speeds by the theory may result in broken end mills, drill bits or lathe tips.



## Material Removal Techniques

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Another consequence would be overheating the component being machined. The ideal cutting speed ensures the heat is concentrated on the chips being removed. For this reason lubrication can also assist.



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In conclusion, there are many available components that can be purchased to create mechanical systems.

When the desired components can not be purchased, small volume manufacturing techniques can be used to achieve the desired design.

The manufacturing process will usually either rely on adding or removing material to achieve the desired component.