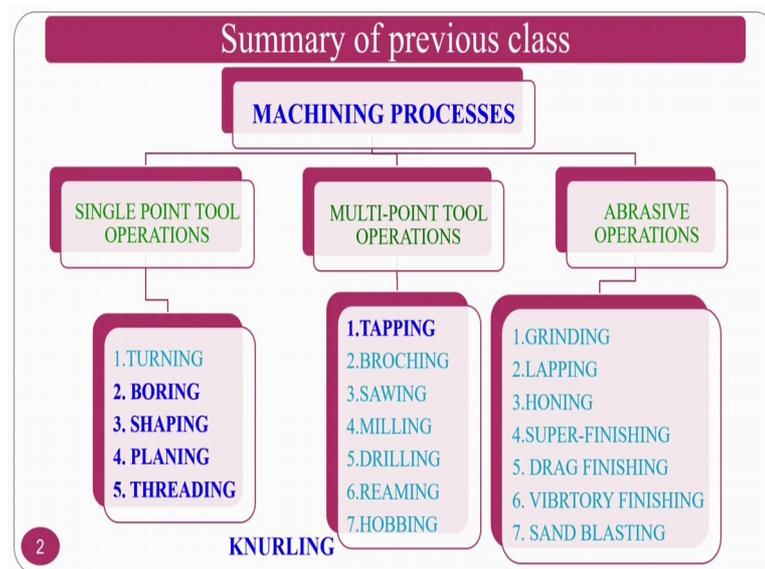


**Introduction to Machining and Machining Fluids**  
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**Indian Institute of Technology, Guwahati**

**Lecture - 22**  
**Practical Machining Processes – 2**

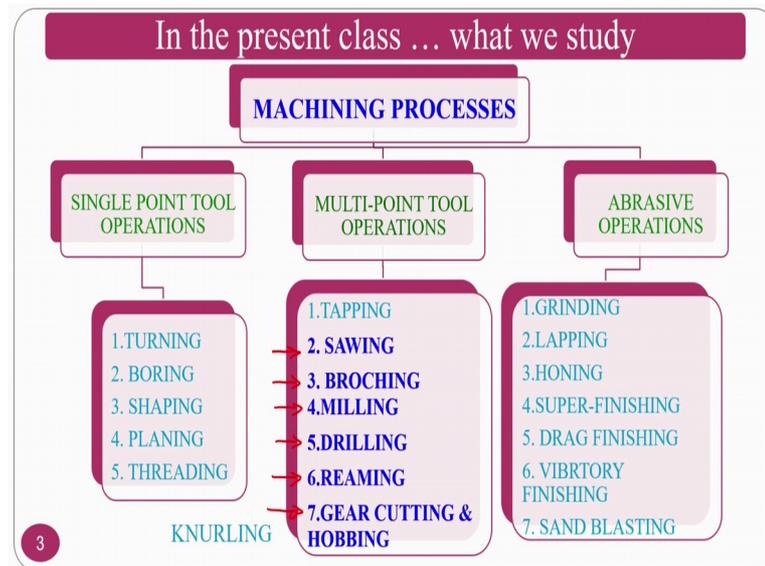
Today we are going to continue about the practical machining processes wherein till now we have studied about boring, shaping, planing, threading, turning, and tapping processes.

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Now we have already entered into the multipoint cutting tool processes and we see other processes in the multipoint cutting tool machining processes in this particular class ok.

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So, what we are going to see in this particular class is about sawing, broaching, and milling, drilling, as well as reaming then followed by gear cutting and gear hobbing. Just as a part it gives you only the introduction because many of you know about sawing especially milling, drilling, and all those things you know the mechanics.

And if at all you are interested in studying about the material removal mechanism, mechanical physics and all those things; you can take the course that I was repeating and again repeating there is a mechanics of machining course. So, you can take that is the advanced version of this particular course and some of the senior faculties will teach from the different IIT's ok.

From IIT Guwahati also one of the professor is going to teach you the mechanics of machining where you can study about the what is the mechanisms, what is the physics about of it and how the mathematical relations and all those things ok.

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In this particular course I just introduce about the course, I just introduce about the process only. Now we are moving to sawing process and the sawing this is for the fun sake just I kept do not take in a another way. So, this is about the sawing normally you might have seen the cutting of trees and all those things in a at the road sides and all places. So, the most important process in cutting of the trees and all those things is sawing process ok.

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### Introduction to Sawing

- Sawing is used to cut the correct sized workpiece from a large raw material stock.
- Chips are produced by a succession of small cutting edges.
- **Multiple** point cutting tool.
- Small teeth (cutting edge) produce chips progressively when passing through a workpiece.
- Chips are transported by the space between teeth : Gullets
- **Economical**: Material or energy wastage point
- Used to produce desired shape and size workpiece.



We see about the sawing process the introduction to sawing process sawing is used to cut the correct workpiece from the raw materials. So; that means, that if at all I want to cut the required shapes from a large or the bulk material normally you can go for the sawing process.

Chips are produced by the succession of small cutting; that means that there is a series of cutting edges will come and cut the particular component or particular bulk material. So, the chips are produced by each and every cutter individually ok.

So, multipoint cutting tool as you see from this particular process or from this particular process it is having a multipoint cutting ok. So, it will involve by cutting with a multiple points that are there on the cutter. The small teeth's which are nothing, but the cutting edges produces chips progressively when passing through; that means, that it will whenever it passes through the workpiece, it will generate particular chip. So, chips are transported by the space between teeth that is called Gullet.

I will come back to you in a example what is gullet and all those things. Gullet is nothing, but a space between two successive teeth's in a sawing process. So, it is economical because from the point of energy wastage and all those thing it will take less energy; even people will use for hang saw that is hacksaw so that you can remove that material, there is no additional power requirement and all those things used to produce desired shapes and sizes.

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Various types of hacksaws will be there are the sawing processes will be there one of the thing is the hacksaw that you can see here and the second is band saw. So, band saw normally will be there will be a machine where you just put the bend this blade and circular saws also will be there. So, it looks like a thin slitting milling cutter, but there are saws to cut the in the wooden industry and small small soft material industry also; this saw blades are used; this is about the blades configuration. These are the three 3 types of configurations.

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Then equipment if you see there is a horizontal band saw will be there and there will be a vertical band saw. Apart from the hand based hacksaw if at all you are going for the mechanical based or equipment based in that circumstances, you will have two types of band saw where the previous slide you have seen the blade just you mount the blade on either you vertical or horizontal band saw and you can use it.

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### Features of Saw Blades

<p><b>Material :</b></p> <ul style="list-style-type: none"><li>▪ <b>Small Blades:</b><ul style="list-style-type: none"><li>✓ High-speed steel (HSS)</li><li>✓ Carbon steel</li></ul></li><li>▪ <b>Longer Blades:</b><ul style="list-style-type: none"><li>✓ Combined strips of HSS strips</li></ul></li><li>▪ <b>Large size:</b><ul style="list-style-type: none"><li>✓ Carbide insertions</li></ul></li></ul> <p><b>Tooth Forms:</b></p> <ul style="list-style-type: none"><li>▪ Straight tooth</li><li>▪ Undercut tooth (clear tooth)</li><li>▪ Skip tooth (used for rough cutting)</li></ul> <p><b>Blade Thickness:</b></p> <ul style="list-style-type: none"><li>▪ Hand hacksaw blades : 0.64 mm</li><li>▪ Power hacksaw blade : 1.17 to 2.54 mm</li></ul>	<p><b>Tool Spacing:</b></p> <ul style="list-style-type: none"><li>▪ <b>Determines:</b><ul style="list-style-type: none"><li>✓ Size of the teeth</li><li>✓ Size of the gullet, the space for chips</li><li>✓ Strength of the tooth</li><li>✓ Number of teeth engaging with the workpiece</li></ul></li><li>▪ &lt; 1.5 mm : Hand saws (0.8 -1.8)</li><li>▪ &gt; 1.5 mm : Power hacksaws (1.4 -6.4)</li></ul> <p><b>Tooth Sets:</b></p> <ul style="list-style-type: none"><li>▪ Advantages for cutting: <b>Staggered</b></li><li>▪ Kerf is wider than the blade gage thickness</li></ul> <p><b>Length of Blade:</b></p> <ul style="list-style-type: none"><li>▪ Hand hacksaw : 10-12 in long ½ in wide</li><li>▪ Power hacksaw: 12-24 in long ½ to 2 in wide</li></ul>
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So, features of the blade if you see normally it will be decided by so many features. Now if you see the material and the tooth forms normally blade thickness should be as minimum as possible, but from the strength point of view and all point of view you have to choose optimally, and the tool spacing that is the how the teeth, what is the size of the teeth, what is the placement distance between teeth and teeth so that the gullet have sufficient space to occupy or give the (Refer Time: 05:53) for give space to the chip and tooth sets average and normally length of the blade.

So, if at all some people want to cut the very very big trees and do not cut the trees ok. First of all let me tell that do not cut the trees that is the from the humanitarian point of view, but if at all it is to be cut. So, normally these length of the blade plays a one of the major role because if you will have a more length number of teeth's will be more and how fast a 2 humans who are standing or placed on other both sides of the cutter are pulling it in terms of manual in terms of machine. So, it is always depend on the how speed you are cutting and all those things.

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### Sawing Terminology

1. **Blade Back:** Body of the blade not including tooth portion. 
2. **Thickness:** Dimension from side to side on the blade.
3. **Width:** Nominal dimension of a saw blade as measured from the tip of the tooth to the back of the band.
4. **Set:** Bending of teeth to right or left to allow clearance of the back of the blade through the cut.
5. **Kerf:** Amount of material removed by the cut of the blade. 
6. **Tooth Pitch:** Distance from the tip of one tooth to the tip of the next tooth.
7. **TPI:** Number of teeth per inch as measured from gullet to gullet.
8. **Gullet:** The curved area at the base of the tooth. The tooth tip to the bottom of the gullet is the gullet depth.
9. **Tooth Face:** The surface of the tooth on which the chip is formed.
10. **Tooth Rake Angle:** The angle of the tooth face measured with respect to a line perpendicular to the cutting direction of the saw.

So, the terminology because some of the people may not be well aware of this sawing terminology and all those things people may be aware about milling drilling and all those things whenever they come to the point of sawing process; this many terminologies are there so you may feel like that.

So, blade back body of the blade not including the tooth portion so if the cutter is like this though except this portion, the other portion is what your blade back. Thickness dimensions side to side; that means, if your blade thickness will be like this ok.

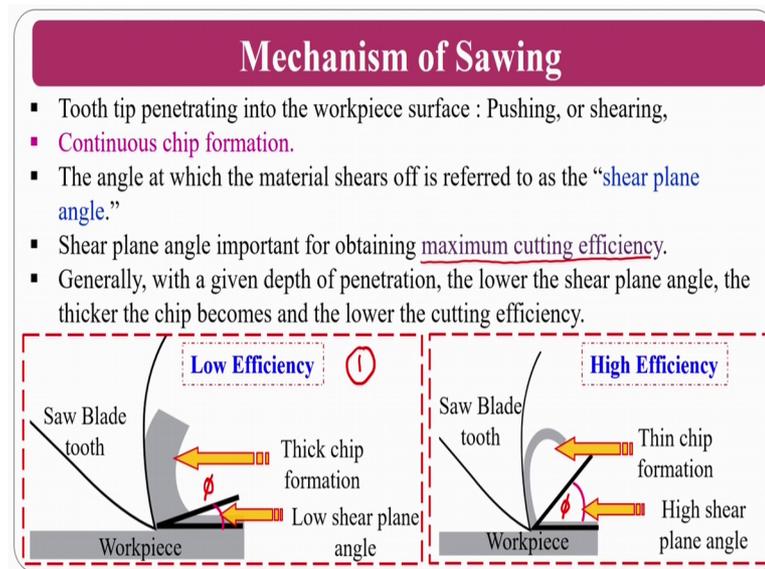
So, whatever the thickness, width normal dimensions of saw blade measured from the tip of the tooth to the back of the tip; that means, width is tip from the top tip to the back of the tip normally it will be called as a width. And the set bending of the teeth right to the left allow the clearance of the tip this is called the set of the tooth.

Kerf the amount of material removed by the cut of the blade; that means that if I have two things assume that this is a single entity if I am going to cut it. So, what is the width of my cut is nothing, but the kerf cut tooth pitch from one point of the crust of the one teeth to the crust of the another teeth.

TPI that is nothing but tooth per inch so how many number of tooth's are there per inch is nothing, but the tooth per inch. Gullet as I was talking to you about the gullet it is the curved area where the chip will be accommodated during the machining process ok. So,

tooth face the surface of the tooth on which the chip is formed; that means, that cutting edge and the cutting point and tooth rake angle. Normally rake angle of the tooth face is measured with respect to the line perpendicular to the cutting direction. Now this is about the rake angle.

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All these things you can see here. So, normally the tooth tip angle, shear plane and all those things; now I want to explain you about the shear plane rest all the things are common. So, if you see the shear plane angle important for obtaining maximum cutting efficiency.

If at all I want to get a particular operator want to get the cutting efficiency in a good way normally you have to check what is the shear plane angle ok. If the shear plane angle is too low if you see the case one that is the lower efficiency this is the shear plane angle, this is normally the shear plane angle represent by  $\phi$ . Here also if your shear plane angle is low normally what will happen? If you see generally depth of penetration; the lower the shear plane angle, the thicker the chip becomes and lower the cutting efficiency ok.

So, the chip thickness will increase and your efficiency will go down; that means, that you cannot pull if a manually some people are pulling it you cannot pull with that because the thickness is too high so it will be very difficult. So, you have to choose optimumly, what is the shearing angle that is so that if you can increase the shearing

angle up to optimum level. So, you can increase the efficiency. So, you can easily reciprocate it and improves the efficiency that is about the sawing process.

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### Mechanism of Sawing

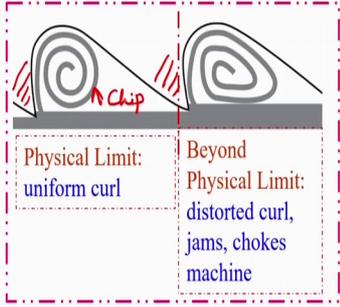
▪ **Shear plane angle is affected by:**

- ✓ Workpiece material
- ✓ Band speed
- ✓ Feed
- ✓ Lubrication and blade design

□ **Feed:**

- ✓ Feed refers to the depth of penetration of the tooth into the material being cut.
- ✓ Deeper feed results in a lower shear plane angle
- ✓ Light feed will increase the shear plane angle, but increase cost per cut.

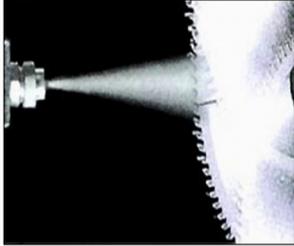
□ **Gullet Capacity:**

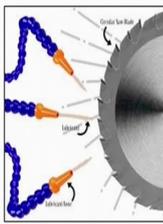
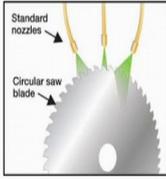


So, shear plane angle affect and feed affect and now we will see just a gullet. This particular portion is a teeth and this particular portion is the another teeth of particular sawing process. So, the this particular portion will accommodate this is the empty space where chip is accommodated ok. This particular portion is nothing, but the gullet ok.

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### Cutting fluids in Sawing





So, if you see the cutting fluids in the sawing process, the sawing process normally do not uses the cutting fluid whenever you are operating for the wood; however, whenever you want to chop it off from the very very big large size blanks to the small, small workpieces and all those things in the metallic region normally you should go for suitable cutting oils.

So, if temperature is high so you have to go for emulsions if the temperature is low you should go for lubricating dominating cutting fluids ok. Now, we move on to the broaching process.

(Refer Slide Time: 11:14)

### Introduction to Broaching

- Moves a multiple tooth cutting tool linearly relative to work in direction of tool axis
- Shape of the machined surface is determined by the contour of the cutting edges of the broach, particularly the shape of the final teeth.
- Machining operation completes in a single stroke.
- Teeth are at gradually increasing height.



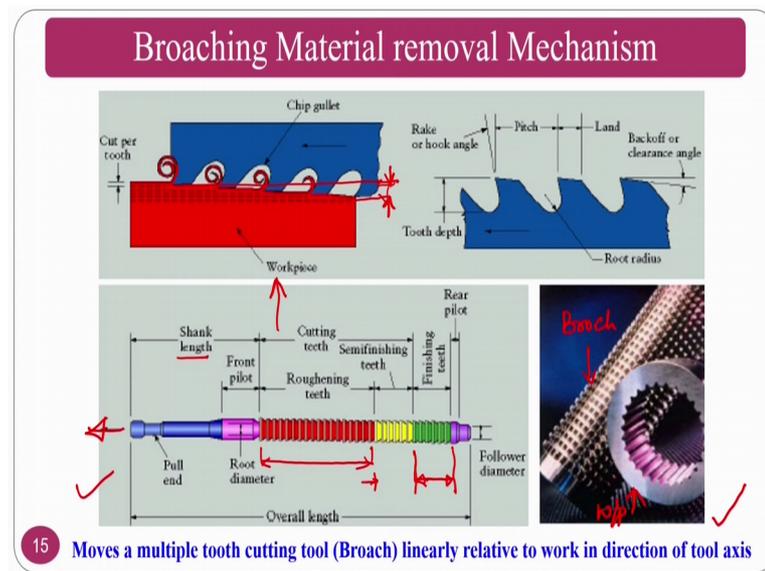
So, when the broaching process will be normally used in normally whenever you want very very big holes of different different shapes and all those things, where you cannot drill or you cannot do the other processes normally you can go for broaching operation. It moves a multiple tooth cutting tool linearly to workpiece, work in the direction of tool axis ok.

This is the broach normally and this is the axis of the broach and you will generate certain geometry that is conversely which is projected on the tool you normally just push it and you will get the output. The shape of the machine surface is determined by the contour of the cutting edges ok.

So, whatever the shape normally if you see here the gear is there on the gear you want to make a some slot for that purpose the broaching is used. So, whatever the surface that you are going to get here is nothing, but the contour decides the surface that you are going so I want a keyway path here on the gear. So, the broaching operation which is having the contour converse to the required shape is used here.

So, machining operation is complete in a single stroke; that means, that once if you pass on so whether horizontally or vertically, it will complete. The teeth are gradually increasing in height so that the final height will be decided by the last teeth of the broach ok.

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So the broaching material removal mechanism normally the broach is like this. So, where you will have a pull type of broach this one and you will pull from this end by putting into a existing hole. The prerequisite for the broaching operation is you should have a existing hole then only you can go for the broaching operations.

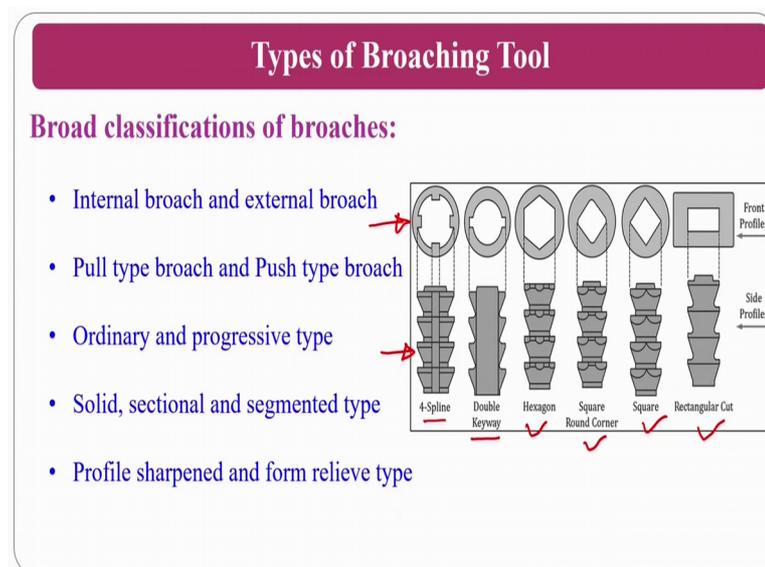
So, now this is the pull end and this is the shank length up to this one where the root diameter is there then roughening teeth's. Normally roughening teeth's this red one will have gradually increasing dimensions of the teeth so the cutting action will be gradually increases.

As you can see here so the thick the height of the each cutting edge is gradually increasing. If you see here, if you see here there is a gradually increasing height is there ok; that means, whatever the chip that is taking out by the broach which is nothing, but a tool is used in the broaching operation gradually takes a thin thin chips from each and every teeth of the broach ok.

So, next one is semi finishing teeth this yellow ones are semi finishing teeth's ok. So, this will gives us the semi finish; that means that it will not give me the final product then followed by the finishing teeth, this is green one is nothing, but your finishing teeth.

So, finishing teeth will decide the final shape that I am going to get on this one; normally roughening teeth, semi finishing teeth and finishing teeth all will be of the same contour, but the final dimensions will be decided by the finishing teeth ok. You can see here a one of the examples how the broach; this is the broach, and this is the final workpiece that is received or it is a final component. So, this contour geometry is generated on the converse geometry generated on the final product. This is about the material removal mechanism in the broaching operation.

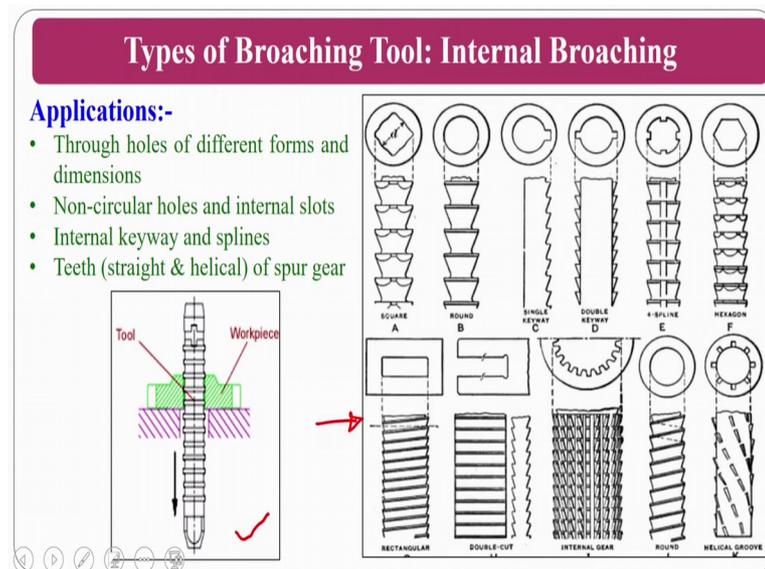
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Broaching normally classified into internal broaching, pull type broaching, and ordinary and progressive types solid, and sectional segmented type, and profile sharpened, and form relieve type. These are the varieties of the broach and if you can see here normally the different varieties; these are the tools and these are the shapes that is achieved during.

So, one is the spline force; spline is there double keyway is there where normally in order to fix the gears system and hexagonal system is there square, round contours, square is there, rectangle is there. These are the varieties of the contours that one can generate by using the broaching process.

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If you see this is the internal broaching normally whenever I want to make certain shapes in the internal geometry of the workpiece. Normally you can go for the broach previous slide also deals with internal broaching only.

Here again you can see how the broach you can utilize for the internal geometries of different, different shapes and how the function of the internal geometries can be explained in this schematic diagram ok. These are the examples how one can go about to fabricate the broaching operation these are the tools, and these are the geometries. So, external broaching also is there.

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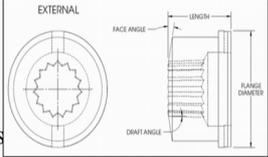
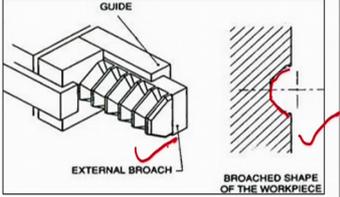
### Types of Broaching Tool : External Broaching

**External Broaching (pull and push)**

- Outperforms shaping, planing and milling w.r.t productivity, accuracy and surface finish.

**Applications:-**

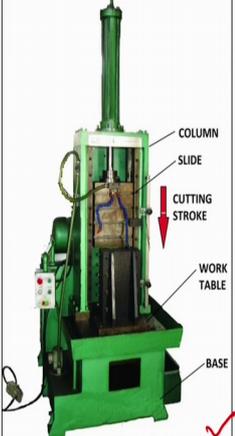
- Un-obstructed flat surfaces;
  - Flat
  - Peripheral
  - contour
- Grooves, slots, keyways etc..
- External splines
- Teeth of external spur gears and gear sectors



So, suppose somebody want to generate the external. So, normally you can go for some other process also, but you can also look at the broaching operation this is the external broaching operation if at all I want to generate this type of contour. So, that this type of external broach is used for this particular application.

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### Types of Broaching Machines



Horizontal Broaching Machine

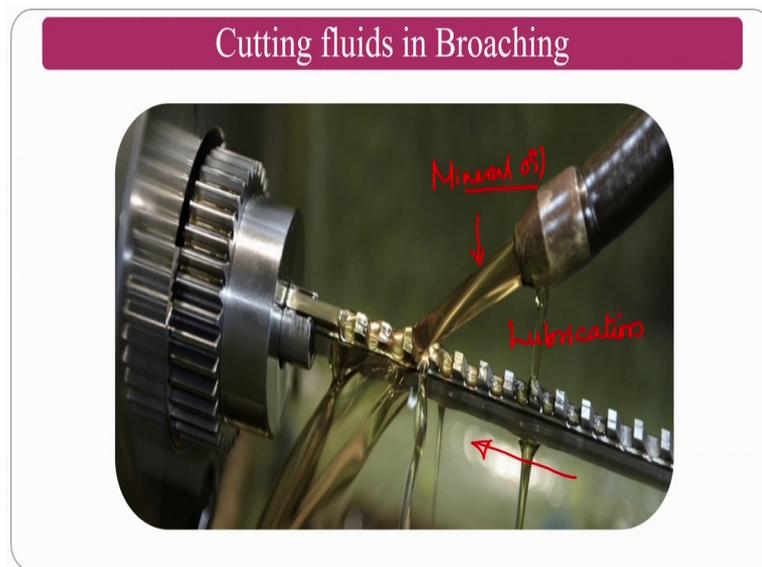
Vertical Broaching Machine

So, type of broaching machines there are two varieties of broaching machines are there, one is the vertical broaching machine, another one is the horizontal broaching machine.

If at all you are moving your broach vertically to the workpiece that is perpendicular to the workpiece that is called vertical.

If you are putting along the axis here also it will be axis here also so they have their own applications, they have their own from the point of energy utilization and all those things some places it is horizontal broaching is good some places vertical broaching is good. So, normally horizontal broaching can be used for big big workpieces.

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So, cutting fluid in the broaching since the broaching operation is very small velocity application where the broach gradually feed into the workpiece in that circumstances what is the thing is it will go very very slowly and the material removal will takes very very slowly. So, that dominating feature here is the friction not the temperature generation; for that purpose you will always go for mineral oil based cutting fluid.

You need lubricating character; you need lubrication type of characteristics rather than the cooling. So, that is why always or the most of the time people go for the mineral oil based pure cutting fluids without any water and all those things. Now, we move on to the milling; milling is a well known process and many of you who are listening to this one has a great knowledge about the milling process because it is the one of the primary process that one can learn in the B. Tech level. So, I am not going to touch much, but however, since is a part of the course just I will introduce about the milling process what are the varieties of milling and all those things.

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### Introduction

- Milling is the most common form of machining tool use in any work-shop.
- Milling is a very versatile process capable of producing simple two dimensional flat shapes to complex three dimensional interlaced surface configurations.
- **The milling process:**
  - ✓ Typically uses a multi-tooth cutter ✓
  - ✓ Cutting tools for this process are called milling cutters
  - ✓ Work is fed into the rotating cutter
  - ✓ Capable of high MRR
  - ✓ Well suited for mass production applications



Milling cutters

Milling is the most common form of machining to use in any work shop. This is a if you go to any type of work shop you will find the milling operation vertical milling, horizontal milling, universal milling and all; these they are varieties milling operations are there. So, at the same time the applications of the milling is too high; that it is a minimum requirement for a work shop ok. So, lathe and milling these are the two processes which a small industry also will have in their work shop.

Milling is a versatile process capable of producing simple two dimensional flat surfaces to the complex three dimensional surfaces ok. This can developed from the simple two dimension to the complex three dimensions the milling process typically uses the multipoint cutting tool cutting tools are called as the milling cutters basically.

And these are rotating cutters and capable of high MRR that is the material removal rate will be very high and the mass production applications is used. That means, that if at all I want to generate very high amount of a production rate normally one can go for milling process. You can see the milling cutters these are the milling cutters ok. These are the milling cutters that are used in various varieties of milling operation.

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## Principle of Milling

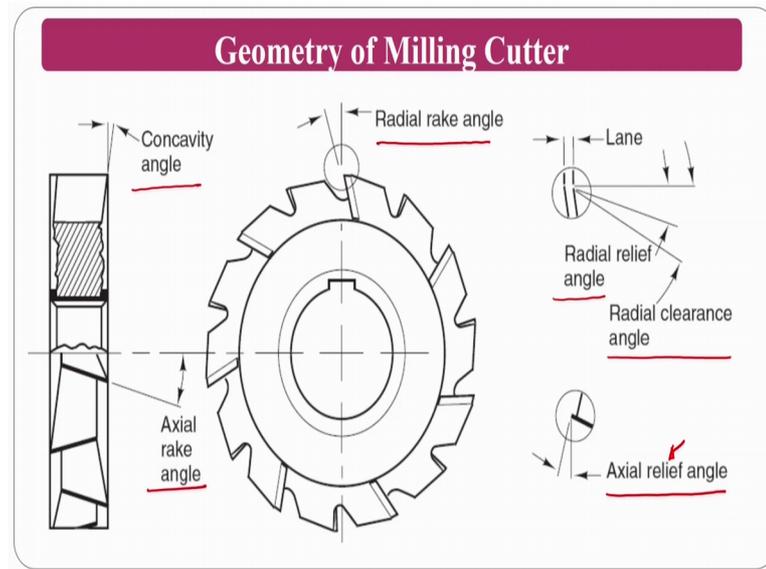
- Milling operations on the principle of rotary motion.
- A milling cutter is spun about an axis while a workpiece is advanced through it in such a way that the blades of the cutter are able to shave of material with each pass.
- Axis of the tool is perpendicular to the feed.
- Machined surface is formed in one or more passes of the work.

The principles of milling operation on rotary motion; rotary motion will be given to the cutter and workpiece material will be given some feed motion or table feed will be given. And there are different different varieties you can even give in a milling operation or horizontal milling operation you can even give the motion to the cutter also.

The milling cutter is spun about its own axis a while the workpiece is advanced through in such a way that blades of the cutter are able to shave the material; that means, that it can cut the workpiece material. Axis is perpendicular to the feeding and the machine surface is formed one or more passes; that means, that if at all I want very huge amount of material to be removed in that circumstances I have to go for multi passes, if at all I want to remove very less amount of material you can use in a single but make sure that you save the cutter ok.

So, otherwise cutters are assume that if you are going for a very thin thin cutters are there. Peoples nowadays talk about micro milling cutters where the RPM goes more than 10000 to 15000 RPM; even some of the cutters go around 30000 RPM so and the thickness of cutters is very small. So, you should be very careful whenever the people who are taking up the milling so there is a micro milling, high speed micro milling is one of the good areas to take up if at all you are a masters or PhD students. And you can work with the different different types of cutting fluids that I have specified on advanced materials, but make sure that your tool also will be a one of the advanced material ok.

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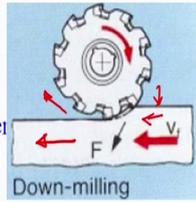
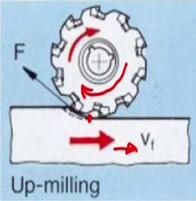
So, geometry of the cutter normally it is a multipoint cutting tool where if you see the single point cutting tool type of tool bits or embedded on it ok. So, concavity angle will be there, angle rake angle will be there, and radial rake angle will be there. There are different different angles are there these are all given on the textbooks some of the basic textbooks also will be there.

As I said there is a relief angle is there relief angle also called as clearance angle or it is also called as flank angle radian radial clearance angle and radial relief angle ok. These are the different different angles are there in the milling cutter.

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### UP-Milling and Down Milling

- ❖ **Conventional milling (up milling)**
  - Most common method of feed
  - Feed work against the rotation of the cutter
  - Maximum chip thickness at end of cut ✓ *Min-Max*
- ❖ **Climb milling (Down milling)**
  - Maximum chip thickness at beginning of cut
  - Suited for machining of thin and hard to hold parts
  - 20% less  $H_p$  than conventional milling
  - Machine must be very rigid to safely
- ✓ Easy chip disposal
  - Exert down force, so fixture design is simple and less expensive
  - Reduces work hardening
- 25 Preferred for heat treated alloys and Stainless steel



Conventional milling there are two varieties of milling that is called up milling and down milling. So, many of you come across this as a basic the conventional is a up milling process the most common fed method there. If at all you see the cutter direction and the workpiece motion are opposite in the direction if you take at that particular tangent at that particular point. So, if you are workpiece fed against the rotational motion of your cutter normally at that particular contact point both motions are in opposite direction that is called up milling.

In the down milling if you see it is in the same direction maximum chip thickness at end of the cut you will get ok. So, minimum to maximum is the one thing and this is the good about this particular material. Normally there is a down milling operation also, where you can see that the cutter moves in the same direction of the workpiece moves the maximum chip thickness at the beginning of cut to the minimum thickness.

So, this is the one of the disadvantage from the point of machining because anybody whenever you want to go and play certain game you need a warm up. So, gradually you have to increase the temperature then only you have to play the game. You cannot directly go and play the weight lifting or basketball or something, you need to go for warm up then raise the temperature of the body, then get the flexibility of the body then you play the game.

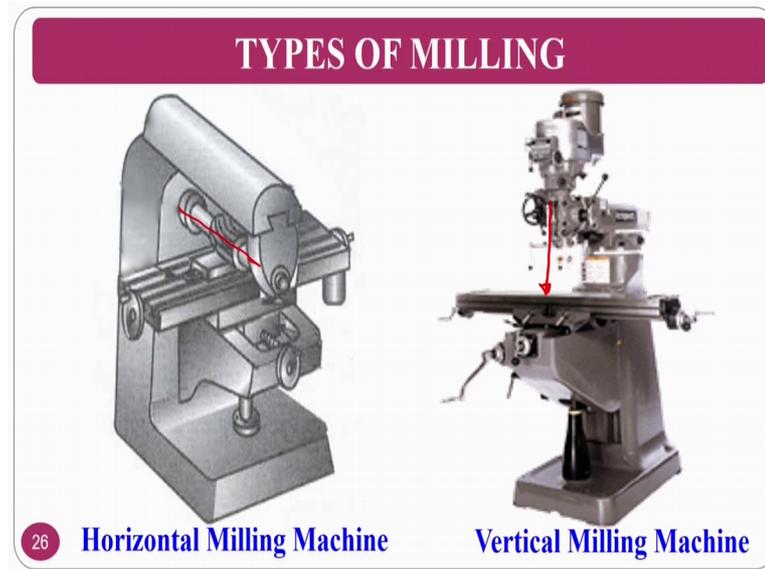
So, from the point of the up milling it is good because gradually chip thickness will vary from minimum to maximum that is warm up for the cutter I am just correlating not exactly just I mean to say is that you start with the minimum and go to the maximum that will be always better rather than going from the maximum and going to the minimum; it is not like first play the weight lifting then go for just warming up that is not good ok. So, up milling from that particular point of view is good.

So, suited for machining of the thin and hard to hold parts and normally the advantage of this particular process is you may not require a very good fixturing that is the biggest advantage of the down milling process. Because even though the fixture is not properly held what will happen since it is cutting downwards there is no problem of lifting up the workpiece.

One of the biggest advantage at the other advantage if you see; the other advantage what you can see is easy chip disposal because the chip is coming like this ok. So, the chip is coming like this means because there is no upper side on this one because you are workpiece feeding is in this direction. So, upper side is here so lower side is this one. So, there is no problem of chip disposal and all those things and reduces the work hardening and preferred for heat treated alloy and stainless steel this is variety one of the varieties of the workpiece material.

This is about the up milling and down milling many books will give you many differences just go through it, but only biggest advantage of the down milling is you need not go for a very very sophisticated fixturing for holding the workpiece. But for the machining point of view one should always try to prefer the up milling because it goes minimum to maximum.

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There are two varieties of milling processes are there horizontal, vertical milling machines means your arbor axis. This is the arbor axis will be parallel to your workpiece in the other case it is perpendicular to your the arbor axis. Arbor is nothing, but where you mount the cutter normally cutter is a independent body compared to the machine, there is a difference between machine tool and a cutting tool.

So, machine tool is nothing, but complete machine itself is a machine tool and the cutter only is a cutting tool. So, cutting tool is a sub set of machine tool if at all you have already plays the cutting tool on the machine so that is why whenever the definition comes vertical and horizontal careful about writing arbor axis rather than the cutting tool axis also.

People may understand that you have a knowledge; but the terminology that you use whenever the examination is there or whenever you go for the interviews normally because cutter is a independent body normally milling process. So, you talk about arbor arbor is a one of the integral part of the milling machine that is why normally arbor axis is deciding factor for horizontal or vertical milling machines

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### TYPES OF MILLING

- **Universal Milling Machine :**
  - ✓ Horizontal type milling machine
  - ✓ This machine can produce spur, spiral, bevel gears, twist drills, reamers, milling cutters etc.
  - ✓ Table has four type of movement
  - ✓ Fed at an angle to milling cutter
  - ✓ Use for helical milling.

**MRR =  $Wd f_m$  ;  $d$  = depth of cut;**  
 **$W$  = Width of W/P;  $f_m$  = Feed per min**



**Universal milling machine**

So, there is another one machine that is called universal milling machine. This is normally horizontal type milling machine only, but this machine can produce spur, spiral, bevel gears, and twist drills, and reamers.

And the table has four types of movements basically so that is why it is called as a universal milling machine fed at an angle of the milling cutter used for helical milling and all those things ok. It is not only this will have multiple types of movements that is why it is called as universal milling machine when it is invented.

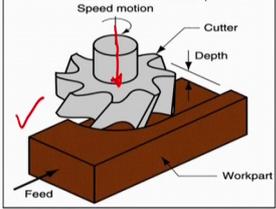
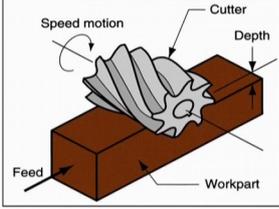
The MRR normally the mechanics I am not going to teach, but; however, just to give you what is the material removal rate in a milling process. Because why I am giving is some people may be appearing for the GATE examination or some of the interviews. So, milling is one of the common process people may ask you that is what is MRR is nothing, but  $W d f_m$ ; where  $d$  is a depth of cut and  $w$  is the width of cut and  $f_m$  is the feed per the minute.

So, you can if you get the 3 values now you can solve MRR because why I am telling MRR only is this is the machining process, where you talk about material removal rate it is not a finishing process like abrasive processes, or super finishing processes where you worry about the final roughness. That is why always machining processes means you talk about the material removal rate per unit time and if it is a finishing process you talk about the final finish that you got per unit time or some other factor.

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### Classification

- **Peripheral (side) Milling Operation:**
  - ✓ Generally in a plane parallel to the axis of the cutter
  - ✓ Cross section of the milled surface corresponds to the contour of the cutter
- **Face Milling Operation:**
  - ✓ Generally at right angles to the axis of rotation of the cutter
  - ✓ Milled surface is flat and has no relationship to the contour of the cutter
  - ✓ Combined cutting action of the side and face of the milling cutter ✓



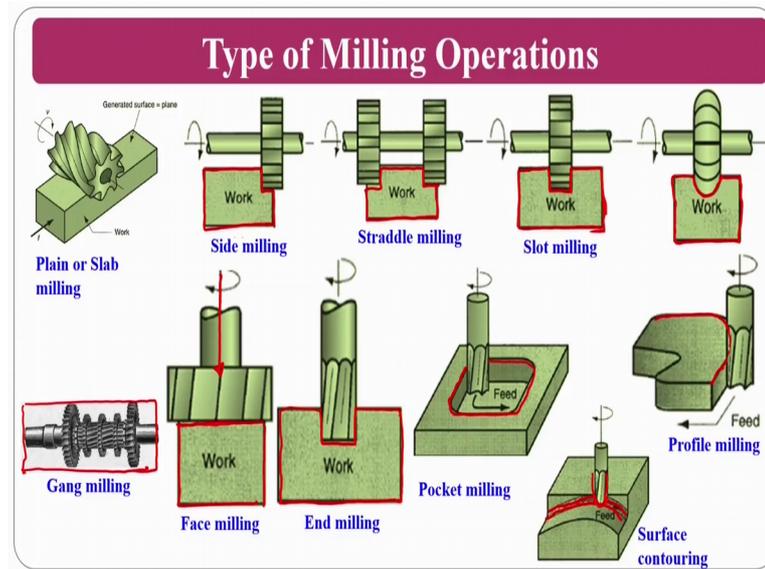
The diagram for Peripheral (side) Milling shows a cutter rotating around its axis, which is parallel to the workpart's surface. The workpart is moving forward (Feed) and the cutter is moving along its length (Speed motion). The depth of cut is indicated. The milled surface has a contour that matches the shape of the cutter's teeth.

The diagram for Face Milling shows a cutter rotating around its axis, which is perpendicular to the workpart's surface. The workpart is moving forward (Feed) and the cutter is moving along its length (Speed motion). The depth of cut is indicated. The milled surface is flat, and the cutter's teeth are shown cutting both the side and the face of the workpart.

Classification of milling you can say that it is a peripheral milling and on this face milling. Generally in the peripheral milling the plane is parallel to the cutter axis at the same time cross sectional milled surface corresponding to the contour of the cutter normal. So, the cross section of the milled surface corresponding; that means, that in one go you can cut it. In the face milling operation it is a vertical milling operation because your axis is perpendicular at the same time mill surface is flat has no relationship with the contour of the cutter ok.

So, in the peripheral milling you have affect on the contour here there is no affect on the contour. Combined cutting action of the side and face of the milling cutter will be used both things will be used while you cut the workpiece in the face milling operation.

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So, type of milling operations there are variety of milling operations you may come across. The first one is slab milling or the plain milling where you have seen in the previous slide also. So, another one is side milling assume that I want to cut a particular portion of my workpiece that is on a particular side that is called side milling operation.

Then comes the straddle milling that is instead of cutting one side if at all I am going for cutting a two steps on the two sides of this one it is called a straddle milling and if at all I want to make a slot on a workpiece now normally the slot cutting, milling machines the cutter will be very very thin this type of slots you can cut for the keyways and all those things.

If you see the form milling form is the different different types of forms you can generate so that is depend on the contour that you are going to fabricate on your cutter. We will decide what this type of contour that you want on the final product. The face milling face milling is like a rare, it is a vertical milling type because your axis is perpendicular. So, whatever the thing that you want to do like facing operation in a lathe; you can do here also in a face milling operation.

You can see the end milling in it is also similar to the face milling operation, but if the cutter is smaller than your workpiece you can make the pockets of your own dimensions that is nothing, but your cutter dimension in that way it will be. So, the pocket milling end milling is a same process you can extend to the pocket.

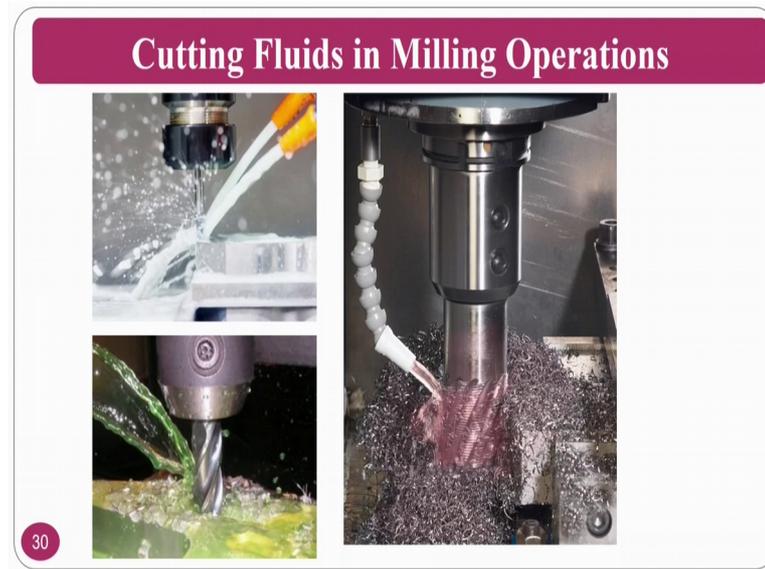
So, you can generate the pocket on the, but only by giving the CNC control tool you can generate the CNC control. So, that the end milling cutter itself can make the pocket milling another one is profile milling end milling as this capability that if at all you have any profile to be machined you can also machine this type of profiles or any type of contour profiles are some profiles you can cut this is about the profile milling.

There is another one is gang milling gang milling is nothing, but how in a single go all the cutters will take part as a gang where you know much better than me about what is the gang and all those things children you will have your own friend circle I am not saying that gang in a negative sense, but I am positive sense you have your friend circle where you just go for eating breakfast lunch in hostel and all those things. So, everybody will take part in the milling process that is about the gang milling.

These are the varieties of milling process and at last we will have a surface contour. Normally here it also look like a end milling process, but you will have a ball type of nose that is a spherical type of nose will be there that will help in cutting the contours ok. If at all I want to generate certain contours; I can generate the beautiful contours and like assume that I want somebody want to generate the Neem plant or hipping plants for the biomedical applications you need contour type of milling operations these are the varieties or the types of milling operations that one can do.

So, it has a variety of applications in the industry that is why every small small work shop also always will have this type of milling operations. If they have a milling machine of horizontal and vertical milling machine they can do a n number of jobs for their customers. So, cutting fluids in the milling operation normally milling operation will be done at very high speed so; obviously, the temperature will be goes high that is why you go always with the emulsion type of cutting fluids.

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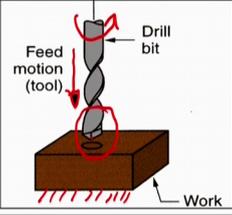
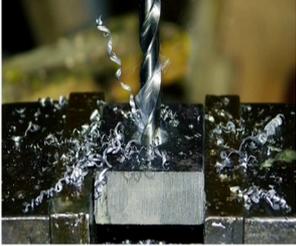
At the same time you some time if your speed is low and if at all you want to go for lubrication purpose; then you can go for normal mineral oil at the same time if at all I want to go for very very high speeds. So, you can go for high amount of water in the cutting fluid applications that is about the milling operation and their corresponding cutting fluids that one can use in the milling operation.

Now, we move on to the drilling operation. So, drilling operation is the primary operation normally one want to generate any type of hole ok. If somebody want to do the threading operation you need a hole, if at all somebody want to do the broaching operation; you need a hole, if at all somebody want to do the reaming operation you need a hole ok. Reaming operation I will come after this particular process. So, the initial process to develop the hole is nothing, but the drilling operation.

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### Introduction to Drilling

- A drilling machine was **primarily designed to originate a hole.**
- **Low cost** operation & Fast
- The hole is generated by the **rotating edge** of a **cutting tool.**
- **Cutting motion** is provided by **rotating the drill** and **feeding** is done by **giving rectilinear motion to the drill in the axial direction.**
- The **rotating edge** of the drill exerts a **large force** on the workpiece and the **hole is generated.**
- The removal of **metal in a drilling operation is by shearing and extrusion.**



So, drilling machine was the primarily designed to originate a hole that means, that start it is a starting step to make any type of internal features it is a low cost, and it is a fast process. The hole is generated by the rotating edge of the cutting tool that is called drill bit. So, the cutting motion is provided by the rotating drill and the feeding is done by rectilinear motion to the drill are the axial direction.

So, normally what is I want to say is the feed motion is given at the same time there will be a rotating motion also will be there and the workpiece is completely stationary. In this way the drilling operation will takes, the rotating edge of the drill exerts large force on the workpiece and the hole is generated it will the edge which is there here will exert lot of force on the workpiece and exerts the lot of forces and generates the hole.

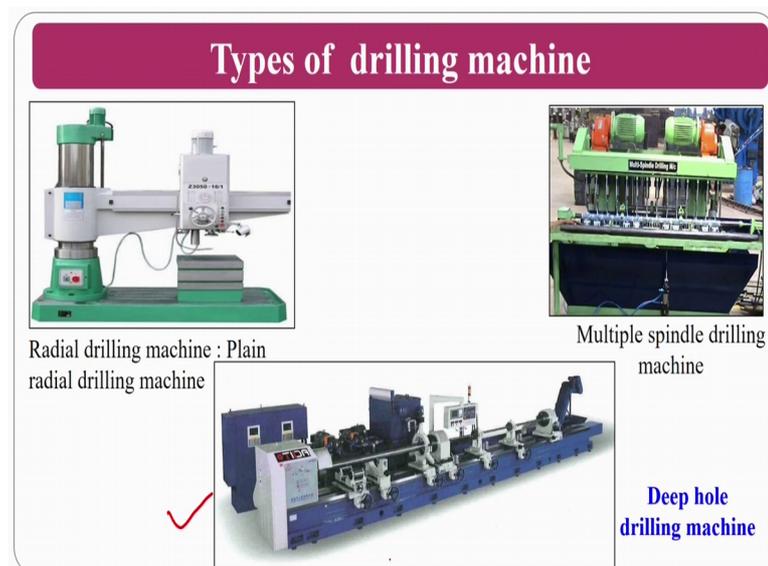
So, the material removal normally will be done by the shearing and extrusion because it is the material removal in the drilling operation is done by the shearing operation as well as extrusion operation. Because extrusion means I am just pushing it into the workpiece at the same time it is shearing means it is rotating by in the stationary workpiece. So, the material removal mechanism will be extrusion followed by the shearing operation.

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Types of drills if you see portable drilling machines is there, sensitive drilling machines are there, gang drilling is there; that means, that as just now I was telling about some gang. So, where you can have multiple operations can be done in a single go that is upright drilling with a round column is there, at the same time you have a rectangular box column also will be there these are the varieties of the drilling machines are available in the market.

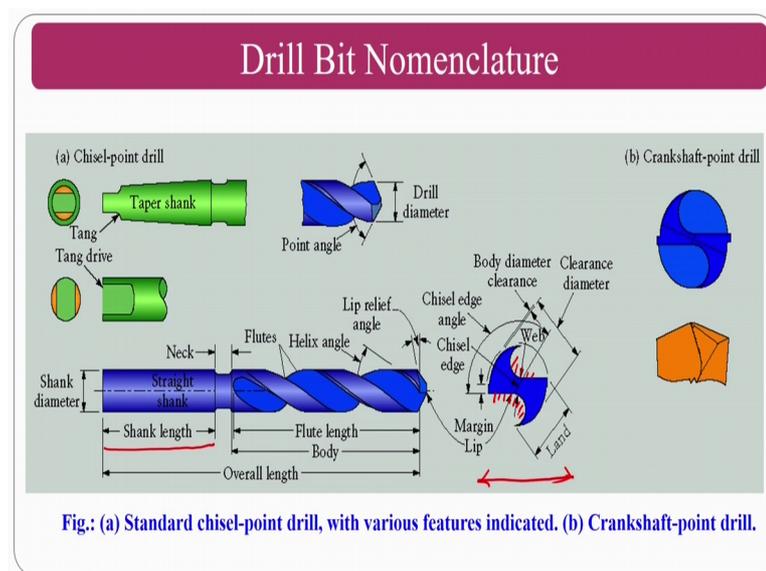
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So, radial drilling machine and multiple spindle drilling machine and deep hole. This is the one of the varieties most of the people may not have seen this is called deep hole drilling machine. So, whenever if at all some people want to do the drilling operation normally through drilling if at all somebody want to do basically you may choose the very very small workpieces. Because if the drill fails or the brokes then it will be a problem neither the workpiece is useful for us or at the same time tool also is a big loss that is why there is specialized tools if at all somebody want to do the deep hole drilling.

So, deep hole drilling normally used for those applications where you want to go for the broaching in the next go. If at all some big workpieces are there from one side drilling will be done 50 percent. And rotate the workpiece then and just do the other side also ok, then you go for the boring operation also you can go because you can enlarge the existing hole then you can go for the broaching operation.

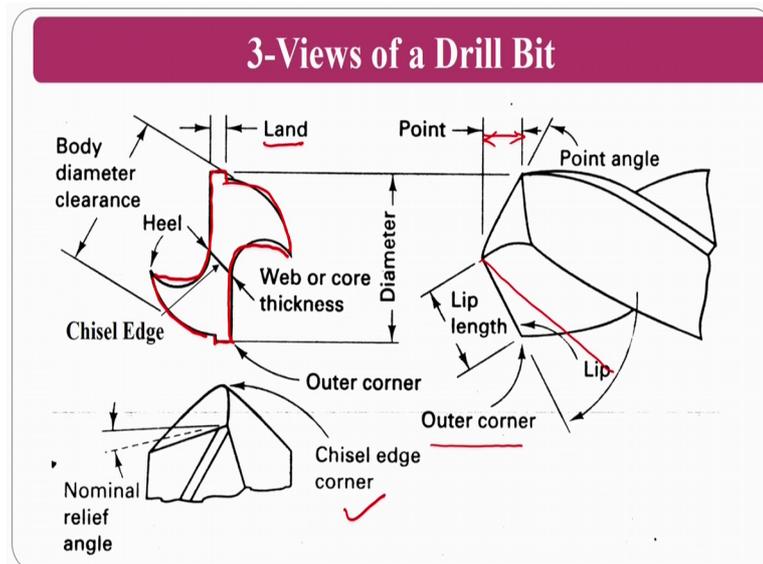
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So, drill bits normally drill bits have a variety of geometry the geometry is chisel point drill normally taper shank will be there this is called mores taper. Normally you might have seen or you might know what is mores taper and all those things just you push it into the shank fixture where it has to be held just you it will have its own fixing because of the taper that is provided that is called mores taper and this is called the shank length.

Let me talk about this particular tool normally this is shank length where this is no role in the machining process the machining process will be done by the complete body of the drill bit where the flutes are normally provided. If you see this particular image where the flutes are even flute this is the one flute another flute is this one. So, always the drill bits will have even flutes because to evacuate chips from the both sides so that there would not be any vibrations and all those things ok.

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So, regarding the three dimensional views you will come in this one. So, you can see the three views of the drill bit where if you take any particular side. If you come it is very easy to draw so if at all somebody want to practice you can practice with writing a J here and another one J here then you just add ok.

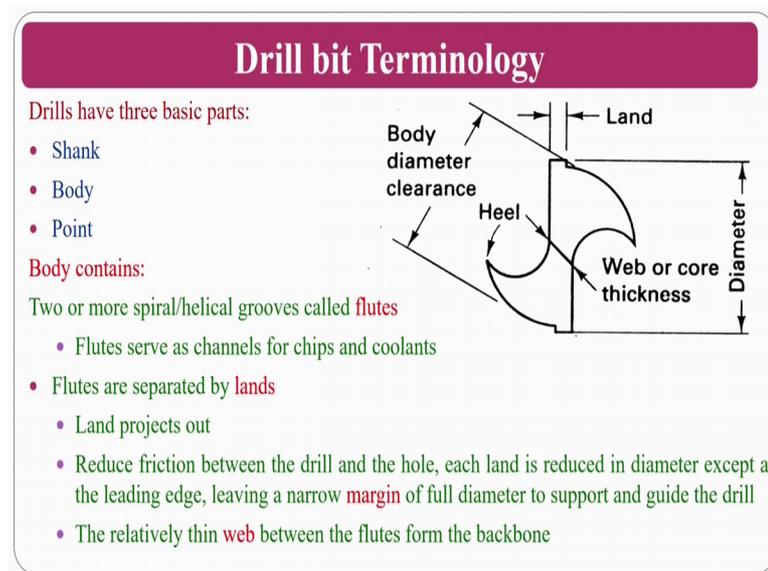
Then you take up the other sides and you can take the lengths of other side and you can draw easily ok. So, this say how you can draw and if you see this is the land basically land is the cutting edge which is provided so that the complete drill bit will not touch with the workpiece otherwise the friction of the cutting will goes enormously high that is why normally land will be provided, this point will be there you can see in this one this is called the point.

So, this point always is a initial step to make a hole that is I told you know that say called extrusion followed by the shearing. So, extrusion part will be done by this point. So, lip angle will play a major role so lip angle as minimum as possible if you have lip angle

like this it will have move extrusion into the workpiece will be better that is about the lip angle.

And the normal relief angle also will be provided here chisel edge angle also will be provided the corners and these are the some of the terminologies that one can use in the drilling process. So, the mechanism if at all I want to perform properly then extrusion followed by the shearing you should always choose your proper dimensions of the geometries here.

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The drill bit terminologies as I explained in the previous slide. This is about the various terminologies what is the function of the land? What is the function of the heal? What is the web or core thickness this core thickness is the one that we will try to extrude the initial step ok.

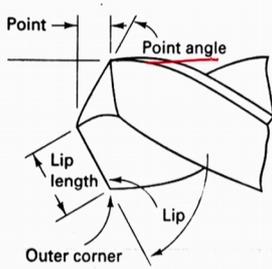
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### Drill bit Terminology

- Some drills have internal longitudinal holes through which cutting fluids are forced. Improves lubrication, cooling and washing away of chips.

**Point**

- Cone-shaped point contains the cutting edge and the various clearance angles
- Cone (point) angle affects the direction of the flow of chips across the tool face and into the flute.
  - 118° cone angle is normally used.
  - 90 – 118 degree used for drilling brittle material
  - 118 – 135 degrees used for more ductile material



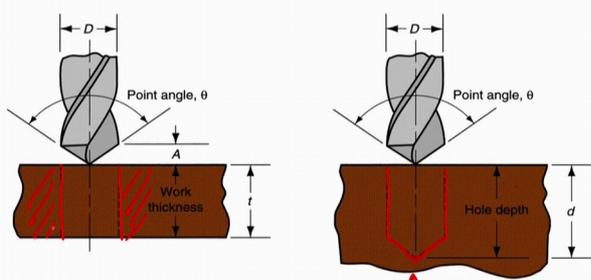
The diagram illustrates the geometry of a drill bit's point. It shows a 3D perspective of the point with several labeled features: 'Point' at the tip, 'Point angle' as the angle between the two cutting edges, 'Lip length' as the distance from the point to the start of the flutes, 'Lip' as the edge of the flute, and 'Outer corner' as the rounded edge of the lip.

So the flutes are also provided, if you see the flutes and the flutes are provided to evacuate the chip, and at the same time drill, if you see the cutting fluid has to go into the machining region for that purpose also the flutes will help. These are other terminologies where the point? What is the point? What is the lip length? What is the lip angle and all those things and what is the point how the point angle will vary if at all I want to the extrusion or if I want more about the shearing then you have play with this type of terminologies.

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### Drilling Operation

- Through-holes** - drill exits opposite side of work.
- Blind-holes** - does not exit work opposite side.



The diagram illustrates two types of drilling operations. (a) Through-hole: A drill bit with diameter  $D$  and point angle  $\theta$  is shown drilling through a workpiece of thickness  $t$ . The hole depth is labeled as  $A$ . (b) Blind hole: A drill bit with diameter  $D$  and point angle  $\theta$  is shown drilling into a workpiece of thickness  $t$ . The hole depth is labeled as  $d$ . A red arrow points to the bottom of the hole in (b).

Fig.: Two hole types: (a) through-hole, and (b) blind hole.

There are two types of holes one is the blind hole another one is the through hole. Through hole means I will across the workpiece cross section the hole will be made. Here if it is a blind hole means you do not go to the other side of the workpiece; that means, that you will end here itself so; that means, you from other side if you see here it looks blind that is nothing is there like that you will observe so, that is the difference between a through hole as well as the blind hole.

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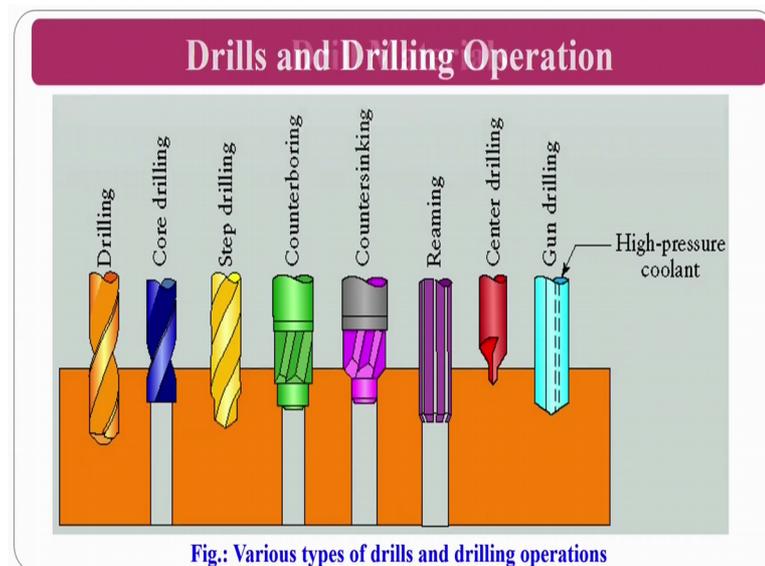


Fig.: Various types of drills and drilling operations

So, drills and drilling operations there are varieties of drilling operations are there. So, the first one is drilling normal drilling, the second one is core drilling where you can generate these extending type of hole you can generate. The other one is a step drilling where you can generate this type of geometry where you will have a extension at the step different steps will be there.

So, counter boring the geometry normally you will you are going to get is a step type of geometry you will get and the counter sinking. So, in normally the laptop or some other places to safe guard from the accidents of the scratches and all those things the screws are held in the counter sinking regions and counter boring regions. So, counter sinking will have a taper one and you will have a this type of hole.

So, reaming; reaming we are going to study normally reamings are used to enlarge the existing hole and to finish the existing holes. Center drilling center drilling is a process normally one can see in the lathe operation to hold the workpiece between the centers.

So, on the other side of the machine that is near the tiles stock to put the dead center normally center drilling will be done.

And the gun drilling normally gun drilling will have a cooling applications normally whenever some people want to make very very large holes or I mean to say lengthy holes. So, you need to send the cutting fluid very frequently that is about the gun drilling process these are the varieties of drilling operations are there ok.

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### Drill Materials

- Carbon Steels
- High Speed Tool Steels
- Solid Carbides such as Tungsten Carbide
- Coated Tool Steels such as TiN High Speed Grades
- Carbide or Ceramic Inserts



So, we move on to the drilling materials where are the materials that are used here is the carbon steels, high speed cutting tools, solid carbides, coated steels and ceramic inserts also be used for that drill bit materials I am just talking about.

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### Drills Fluids

- Cooling
- Lubrication
- Chip evacuation

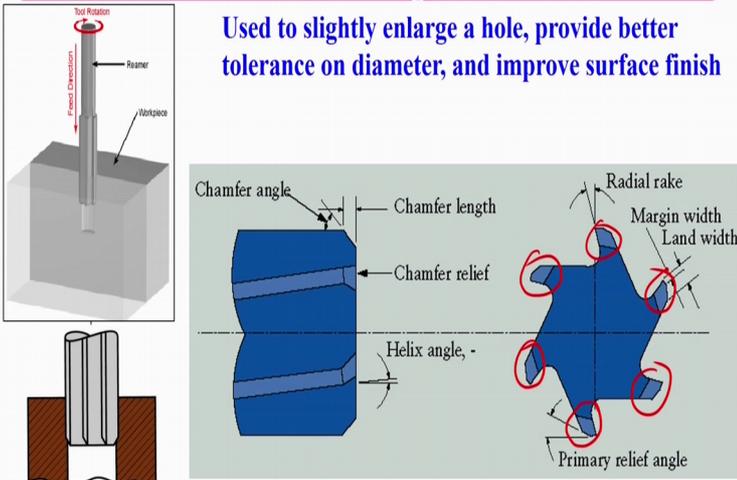


Fluids if you see the applications of fluids you will have a cooling, lubrication. The other main important in the drilling operation is chip evacuation cutting fluid has to go through the flute these are the flutes, it has to go through the flute and it will help the chip to evacuate from the location at the same time some people also uses the spray. So, there are apart from the cutting fluids you can also use the spray so that sticking nature will be minimum or you can use both the fluids. Move on to the reaming process the reaming process.

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### Reaming

**Used to slightly enlarge a hole, provide better tolerance on diameter, and improve surface finish**

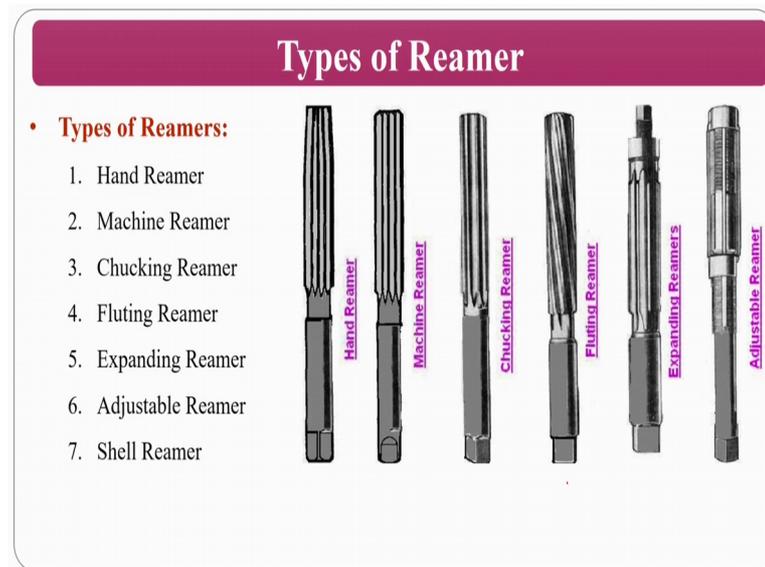


The reaming is a process where to enlarge the existing hole and to clean the bars; that means, that it will also helps in the finishing of the hole. So; that means, that if at all I want to finish a hole by enlarging it normally one person can go for reaming process so you can generate a good surface on the product also.

If at all I want m ten hole I am seeing that 10 mm hole normally people go for 9.8 drill, and then 10 mm reaming you can go and you can generate the finished hole ok. I mean to say not nano finished you can get a good amount of surface finish because you have a multiple teeth's here rather than 2 cutting edges in the drilling process.

Here you can see there are multiple cutters 1, 2, 3, 4, 5, 6 cutters are there in the drilling operation will have 2. So, the number of cutters are more then obviously, the load distribution will be proper and finishing of the hole as well as enlarging will be easy.

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These are the different types of reamers reamer is nothing, but the tool that will be used in a reaming process that is called hand reamer will be there, the machine reamer, chucking reamer, fluting reamer, expanding reamer, adjustable reamer, and the shell reamer. These are the reamers that are used in various applications of the reaming process. So, this is about the reaming process move on to the gear cutting process and gear hobbing process.

Gear hobbing process is the process of gear cutting only so that is why these two are there at the same time gear can be cut by milling operation also since you people have already seen at the early stages of this particular lecture of you can use the milling process appropriately for cutting your teeth's, you can use normal milling process, you can use the form milling process to generate however, we can see the gear cutting here also the gears are used to transmit the power or motion basically both one shaft to another shaft.

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### Introduction

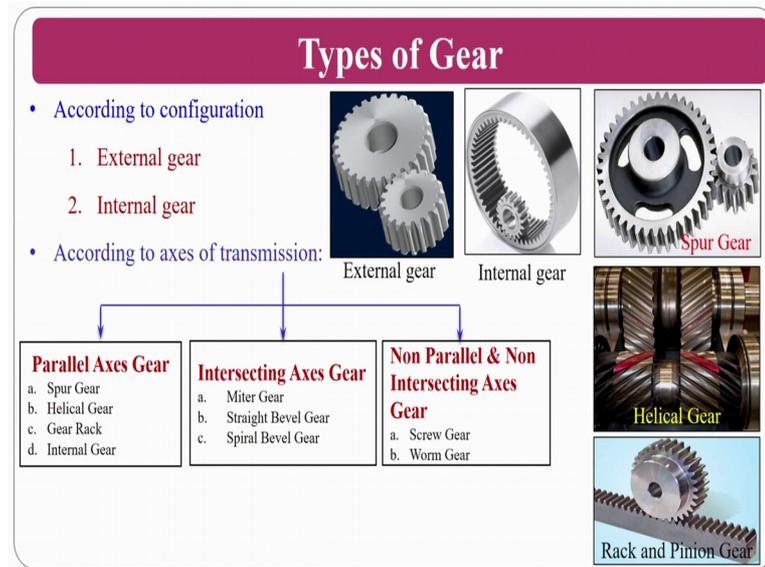
- **Gear** are used to transmission of power or motion or both from one shaft to another shaft.
- **Gear cutting** is any machining process for creating a gear.
- Common gear-cutting processes : hobbing, broaching, milling, and grinding. Such cutting operations may occur either after or instead of forming processes such as forging, extruding, investment casting, or sand casting.
- **General Applications Of Gears:**
  - (i)Machineries for mining, tea processing etc.
  - (ii)Precision equipments, clocks and watches
  - (iii)Industrial robots and toys.
  - (iv)Gear boxes of automobiles
  - (v)Speed gear box, feed gear box and some other kinematic units of machine tools
  - (vi)Speed and / or feed drives of several metal forming machines



The gear cutting is any machining process for creating a gear; that means, that any process if you use which is a subtractive process normally you can call it as a gear cutting process. The common gear cutting processes are nothing, but hobbing that is called gear hobbing broaching also one can use mostly important process that one can use is milling process and for getting good surface finish one can go for grinding also.

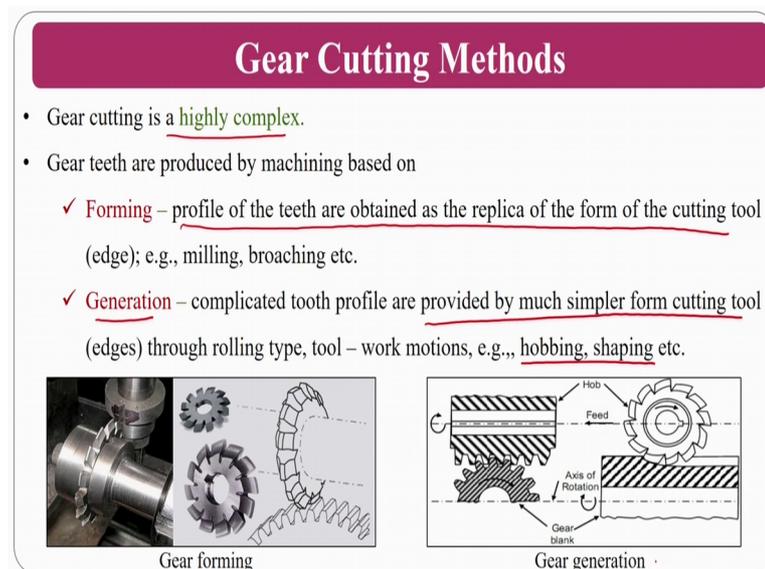
So, general applications normally these are the applications one can use which are machineries for mining, processing, robots, and toys. Mostly nowadays are using you can see many motions is required for robots to move hand and or fingers motion if at all somebody want to control using mechanical means you have to go for gears at the same time electronic means also will be there you can control especially gear boxes and speeds varying people many of you might have driven your bikes and cars and these are all then mostly on gear systems.

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So, there are varieties of gears that is external gears and internal gears. If you see the according to the access of transmission these are the varieties are there we are not into the gears just we see about how the gears cutting will be done or the gears manufacturing will be done.

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So, gear cutting methods gear cutting is highly complex that is because the tool are fabricated converse of the shape so that you can generate the required shape. So, one is the forming profile teeth obtained in the replica of the cutter normally and another one is

generation complicated tooth profile provided much simpler form of the cutting tool that is called hobbing and shaping process. So, gear forming process if you can see here how one can cut here at the same time gear generation that is also is possible the shaping, planing and slotting.

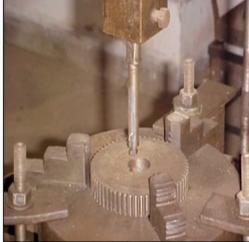
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### Gear Cutting Methods

- **Shaping, Planing and Slotting :**
  - ✓ **Low** productivity and quality
  - ✓ Used for making **one or few** teeth on one or two pieces of gears basically for **repair** and **maintenance** purpose.
  - ✓ Planing machine : for making teeth of large gears
  - ✓ Slotting machine : for internal gears.
  - ✓ Shaping machine : straight toothed spur gear can be produce



Planing



Cutting of gear by slotting



Cutting of gear by shaping

So, if you can also use the planing operation gear cutting by the slotting operation also is possible at the same time gear cutting by the shaping process also you can use it.

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### Gear Cutting Methods

- **Milling :**
  - ✓ Gear teeth can be produced by both disc and end mill type form milling cutter.
- Production of gear teeth by form milling are characterized by :
  - ✓ Use of **HSS** form milling cutters ✓
  - ✓ Use of **ordinary milling machines** ✓
  - ✓ **Low** production rate for
    - Slow speed and feed
    - Need of indexing after machining each tooth gap
  - ✓ **Low accuracy** and surface finish
  - ✓ **Inventory problem** – due to need of a set of eight cutters for each module – pressure angle combination.



Cutting of gear by milling

- End mill type cutters are used for teeth of large gears and / or module.

The most important thing are the versatile process to generate the gear teeth on a blank is by milling process. Normally gear teeth can be produced by a disc using a end milling type or horizontal milling or vertical milling depend on your application you can go the production of teeth in a form milling characterized by the use of HSS milling cutters ordinary milling machines and all those things.

So, what I want to say here because many of you already know about the milling process. So, if your module is known, gear blank size is known, you can calculate the number of teeth's the standard equations are there, universal indexing method is there, many methods are there you can do this and you might have already done in your laboratory courses for gear cutting. Even though if you are from a small small colleges; also this milling machines will be there and gear cutting will be one of the simple processes that normally people will teach ok.

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### Gear Cutting : Disadvantages

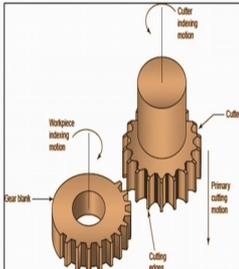
- **Gear milling:**
  - ✓ Slow process for gear generation as compared to other methods.
- Gear is generated by cutting one-by-one tooth.
- Not suitable for larger batch size.
- The other methods required very high capital cost and setup cost as compared to gear milling so these are not economical for smaller batch size, only gear cutting by milling operation is recommended for smaller batch size

Gear milling which is a slow process basically and normally the disadvantage is one teeth by another teeth it will cut the large batch size is not suitable because if at all I want to cut 500 gears per day normally this is not a right choice. So, another one is milling operation is recommended for small and batch size assume that I want to generate 5 or 6 per day you can go for the gear cutting operation using milling operation.

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### Gear Cutting Methods : Generation

- Generation method is characterised by **automatic indexing** and **ability** of a single cutter to cover the entire range of number of teeth for a given combination of module and pressure angle.
- High productivity
- Economical
- Gear generation methods are:
  - ✓ 1. Gear Shaping (Pinion cutter)
  - ✓ 2. Gear Planing (Rack cutter)
  - ✓ 3. Gear Hobbing



**1. Gear Shaping (Pinion Cutter):**

- Pinion shaped cutter is used, which is mounted with its **axis vertical** and is reciprocate up and down.
- Commonly use process.
- Cutter and the gear blank both are **rotated slowly** about their own axis.

If at all I want to generate in a great number that is mass production normally one can go for the gear shaping, planing, or hobbing process. These are the three processes one can go.

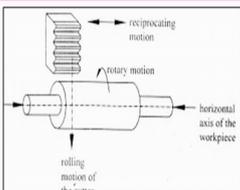
What is the gear shaping is? So, pinion cutter will be there so there will be a pinion cutter just you use pinion shaped cutter is used which mounted on the axis vertically reciprocate up and down so that you can generate the teeth.

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### Gear Cutting Methods : Generation

**2. Gear Planing (Rack Cutter):**

- Performed by a rack cutter with **3–6 straight teeth**.
- Cutters **reciprocate parallel** to the work axis when cutting spur gears, and parallel to the helix angle when cutting helical gears.
- **Reciprocating action** of the cutter, there is **synchronized rotation** of the gear blank with each stroke of the cutter, with a corresponding advance of the cutter in a feed movement.



Gear planing

So, second one is the gear planing. So, here also you will have a reciprocating motion planing will be there and you just reciprocate parallelly normally; and you will get the teeth's on the blank that is mounted. So, the that you will get the gear teeth.

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### Gear Hobbing : Introduction

- ✓ Hobbing is a machining process for gear cutting, cutting splines, and cutting sprockets on a hobbing machine.
- ✓ The HSS or carbide cutter having teeth like gear milling



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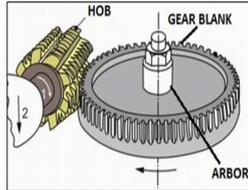
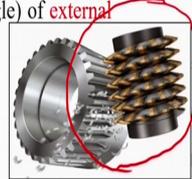
The most important is gear hobbing which is the commonly used process whenever somebody want to generate.

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### Gear Cutting Methods : Generation

**Gear Hobbing :**

- HSS or carbide cutter tool is used
- Hob (cutter) : Behave like a single or multiple start worm.
- Having lesser number (only three) of tool – work motions, hobbing machines are much more rigid, strong and productive than gear shaping machine.
- Used for cutting straight or helical teeth (single) of external spur gears and worm wheels.
- Less accuracy and finish


These are the varieties of things that will be used less accuracy and finish is there. The same time you can see here how the gear hobbing takes place? How the cutter is cutting in a single go.

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**Process Characteristics**

- Is a gear generating process that uses a hob cutter
- Cutters and blanks rotate in a timed relationship
- Maintains a proportional feed rate between the gear blank and the hob
- Cuts several teeth on a progressive basis used for high production runs

The process characteristics it is a gear generating process which use the hob cutter. Cutters and blanks rotate timely in a synchronization relationship maintains the proportional feed rate between gear blank and the hob and cuts several teeth progressive basis for high production; that means, that you can go for high production rates.

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**Advantages and Disadvantages**

- **Advantages**
  - ✓ Can generate spur, helical, worm and worm wheels.
  - ✓ Continuous process
  - ✓ Rapid
  - ✓ Economical
  - ✓ Highly productive
  - ✓ Produces accurate gears
  - ✓ Suitable for medium and large batch production.
  - ✓ Cutter is universal, because it can cut all gears of same module, irrespective of number of teeth on the gear.
- **Disadvantages**
  - ✓ Cannot generate internal gears and bevel gears.
  - ✓ Enough space has to be there in component configuration for hob approach.
  - ✓ cannot be used for cutting herring bong gears

So, advantages are like this just there are many many advantages just go through this slide. At the same time there are some of the disadvantages also there for the this particular hobbing process.

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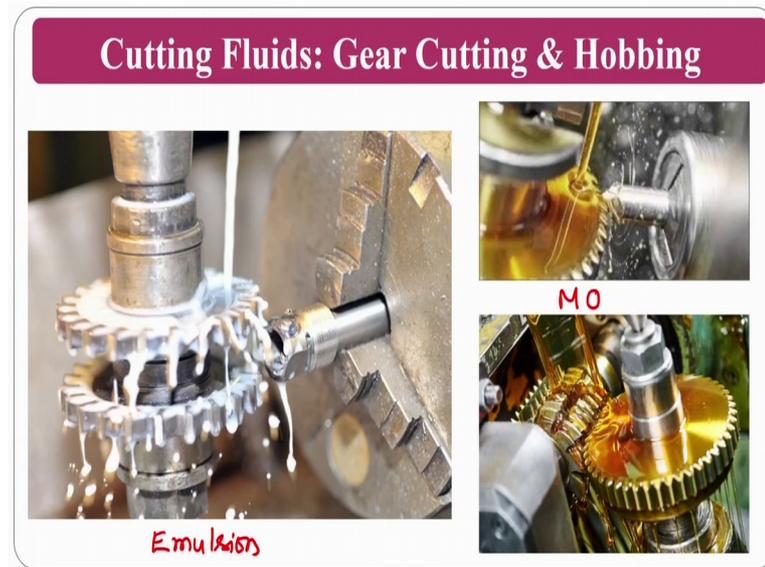
### Applications of Gear Hobbing

- ✓ The gears produced by gear hobbing are used in automobiles, machine tools, various instruments, clocks and other equipment.
- ✓ The two shafts (Hob spindle and work piece spindle) are rotated at a proportional ratio
- ✓ This determines the number of teeth on the blank; for example, if the gear ratio is 40:1 the hob rotates 40 times to each turn of the blank, which produces 40 teeth in the blank.



And so applications you have tremendous applications of gear hobbing; as I said milling is one of the common process if the milling itself is a common process milling is a main cutting process for the gears. So, the applications of gear cutting as well as gear hobbing will be tremendous. So these are the applications produced by the gear hobbing are used in various industries like machine tool industry to automobile industry. Nowadays people are using in medical industry also and the; it determines what are the number of teeth that you want to produce and all those things.

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Coming to the cutting fluids in gear cutting and hobbing basically gear cutting process will be at temperature high temperature process because your milling cutter will rotate at very high speeds for that purpose you always go for emulsions, type of cutting fluid. If at all gear hobbing process the gear hobbing process is a reciprocating process a slowly cutting process that is why you will go for mineral oil based cutting fluids.

So, there is a variety if the cutting temperatures are very high because of the cutter rotation is very fast in that circumstances you can go for emulsions; if at all people want to go for slow and for the hobbing purpose normally you can go. So, you can differentiate from this slide itself the mineral oil looks like a golden color as well as emulsions look like a milky color ok. This is about the today's class and we will see the summary what we have we have studied particular class.

We have studied about the sawing process, broaching process, milling process, drilling process, reaming gear cutting, and gear hobbing process we have seen in this particular class. And now we move on to the next class to the abrasive processes one of the most of and well known abrasive process is grinding.

So, we deal mostly about the grinding then we followed by the some of the grinding process like lapping, honing, and some other process. And we also see what about the grinding fluids and all those things as this particular course is about machining and machining fluids.

Thank you for this particular class.