Basics of Mechanical Engineering-2

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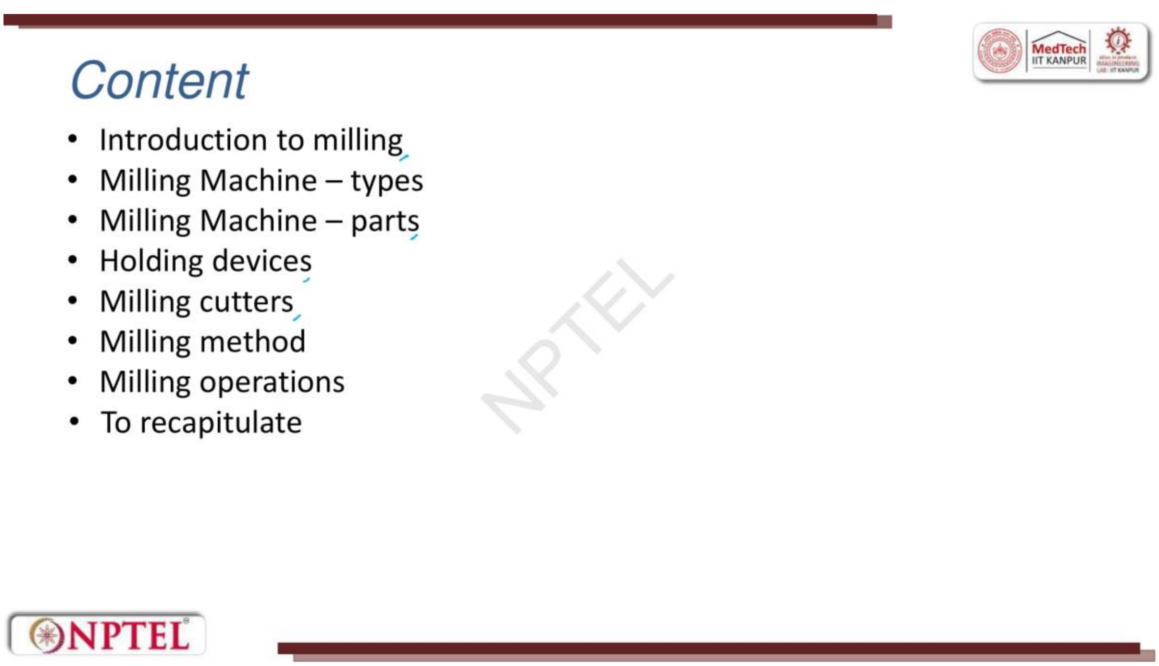
Week 10

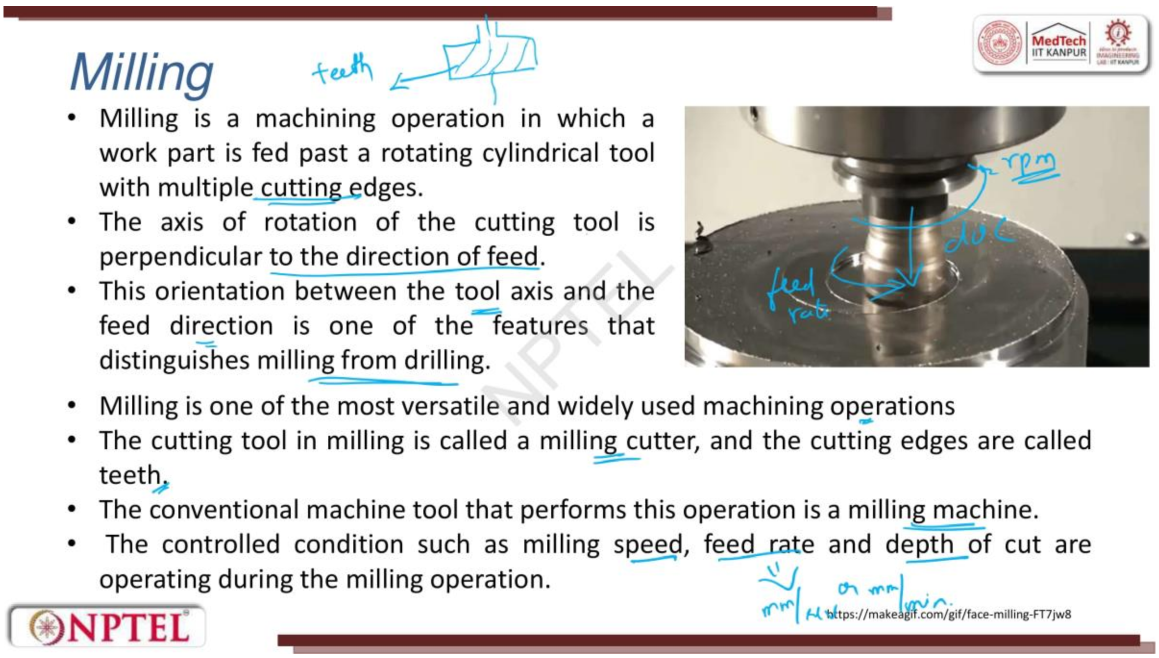
Lecture 39

Basics of Machining (Part 7 of 7)

Friends, welcome to the next lecture under the heading of Basics of Machining. In this lecture, we will try to cover milling, as we have already seen the fundamentals of a single-point cutting tool, the geometry involved in a single-point cutting tool, the types of chips produced by a single-point cutting tool, and a little bit of force analysis we also covered in the previous lectures. Now, we will move toward multipoint cutting. So, multipoint cutting, as we have already briefly discussed, involves multiple tools engaged in cutting. Milling is one common machining process that falls under multipoint cutting.



In this lecture, we will try to cover a brief introduction to milling, then types of milling machines, and then the parts involved in a milling machine. Some of them will be similar to those of a lathe, but in a milling machine, the workpiece is stationary, and the tool rotates. So, naturally, there will be different parts involved in a milling machine, then work-holding devices, different types of milling cutters, milling methods, and then we will try to see some of the operations commonly performed in milling. Finally, we will try to have a recap.



If you see this video, it clearly shows that the cutter is moving around a fixed workpiece. The cutter rotates at a very high speed. You are not able to clearly distinguish multiple cutting points. And here, if you see, there are chips being produced.

The majority of the chips produced are discontinuous, as compared to those in a lathe machine, where you had continuous chips while machining ductile material. Why is this phenomenon happening? Because the first cutter and the next cutter come in contact with the same place. So, you will have slightly longer but smaller chips.

And here, it is also interesting to see the milling cutter face trying to machine and create a slot on the workpiece. And here, it is trying to create a circular trajectory. It moves in a circular trajectory, and you are able to see it. Milling is a machining operation in which the workpiece is fed past a rotating cylindrical tool with multiple cutting edges. Suppose you try to have a cutter like this; here, you will have multiple cutting edges that come in contact with the workpiece.

The axis of rotation of the cutting tool is perpendicular to the direction of feed. This is very generic. Today, you have horizontal, vertical, and inclined options. This need not be true, but the majority of the time, it is true. The axis of rotation of the cutting tool is perpendicular to the direction of feed.

This orientation between the tool axis and the feed direction is one of the features that distinguishes milling from drilling. We saw a drilling operation using a lathe machine, wherein, in the tailstock, we mounted a drill and then rotated it against the workpiece. There, the RPM given was applied to the workpiece, and the rotation of the drill was done by hand. Here, it is given by the machine tool. Milling is one of the most versatile and widely used machining operations after the lathe machine.

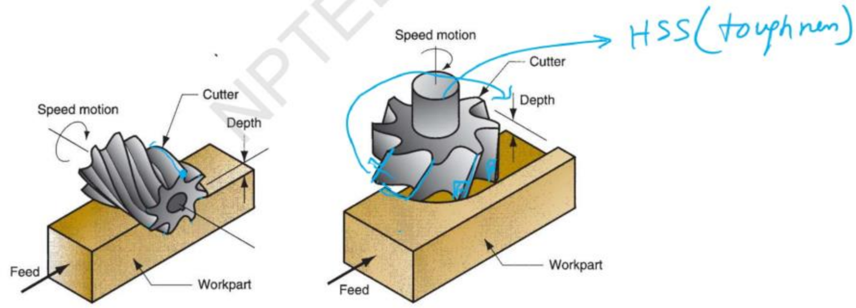
The cutting tool in the milling machine is called a milling cutter. So, this is called a cutter. Henceforth, the tool will be called a cutter, and the cutting edges are called teeth. This one is called a tooth. So, several teeth.

Each tooth is a cutting edge. In conventional machine tools, the one that performs this operation is called a milling machine. The control conditions, such as milling speed, feed rate, and depth of cut, are operating parameters in milling operations. The same parameters we had in single-point cutting tools—speed, feed rate, depth of cut—are also present here. So, if you see that the tool is sunk inside.

So, this is called the depth of cut. The depth you set, the rate at which it rotates, is called the feed rate, and of course, you will have an RPM. Here, the feed rate will again be in mm/rev or mm/min.

Milling

- Milling is an interrupted cutting operation; the teeth of the milling cutter enter and exit the work during each revolution.
- This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation.
- The tool material and cutter geometry must be designed to withstand these conditions.



M.P. Groover, *Fundamental of modern manufacturing Materials, Processes and systems*, 4ed

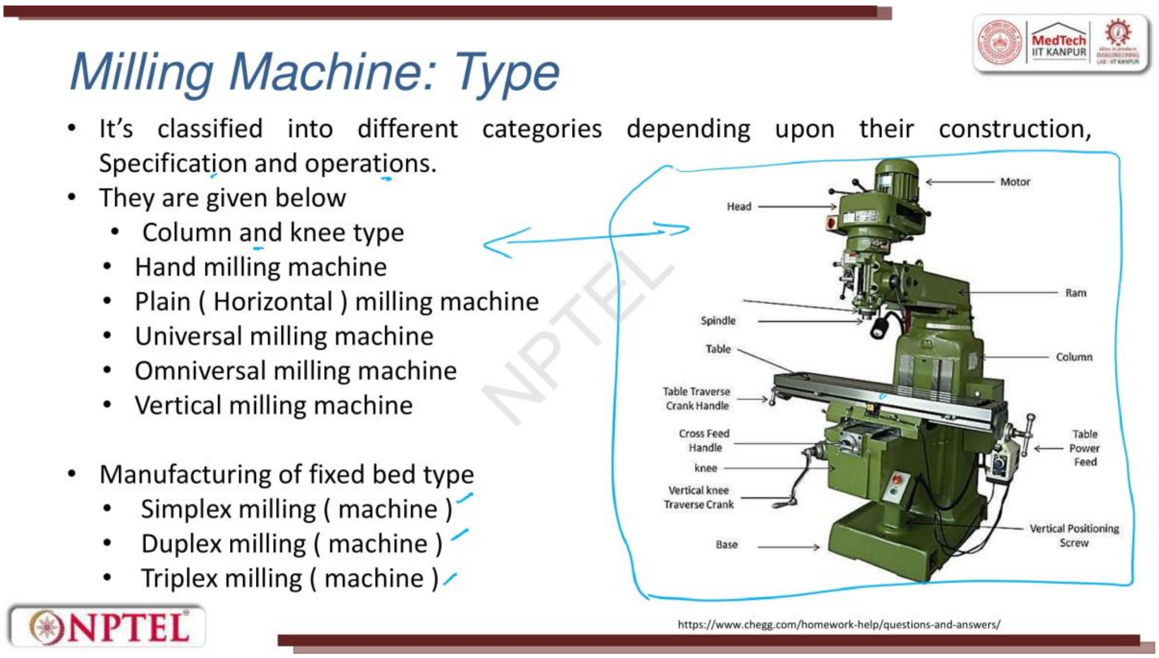
Milling is an interrupted cutting operation. So, if you see here very clearly, these are cutters, and each cutter has a cutting edge, which is called a tooth. So, a cutter is made out of multiple teeth, which is why it is called a multi-point cutting tool. In a lathe machine, you get continuous material removal, but here it is always interrupted cutting. So, interrupted cutting means that every time it cuts, then the next cut, and the next cut. So, there is always a phenomenon of vibration compared to that of a lathe machine. The teeth of a milling cutter enter and exit the workpiece during each revolution. So, what they are trying to say is that it enters when you keep moving.

So, if you see here, it enters for cutting. So, there is a chip that is removed. After the material is removed, the tooth exits. The interrupted cutting action subjects the teeth to a cyclic impact force and thermal shock on every rotation. Why is there thermal shock?

There is a friction phenomenon between the metal workpiece and the cutter. There is a friction phenomenon. In a single-point cutting tool, the tool edge was continuously in contact. Here, it is going to enter and then exit. So, there is going to be discontinuous contact.

The temperatures will be very high, but the teeth will also have time when they are in the idle cycle, so they will not come in contact with heat. So, they get cooled. So, basically because of this action, you will not have tool wear as fast as compared to that of a single-point cutting tool. The tool material and the geometry must be designed to withstand these conditions. So, the tool will generally be made out of HSS because that gives you the toughness property.

Today, we also have inserts. So, there are small inserts which are attached at the cutting edge, and they come in contact. These inserts are attached to a cutter wherein the rest of the portion will take care of the toughness property.



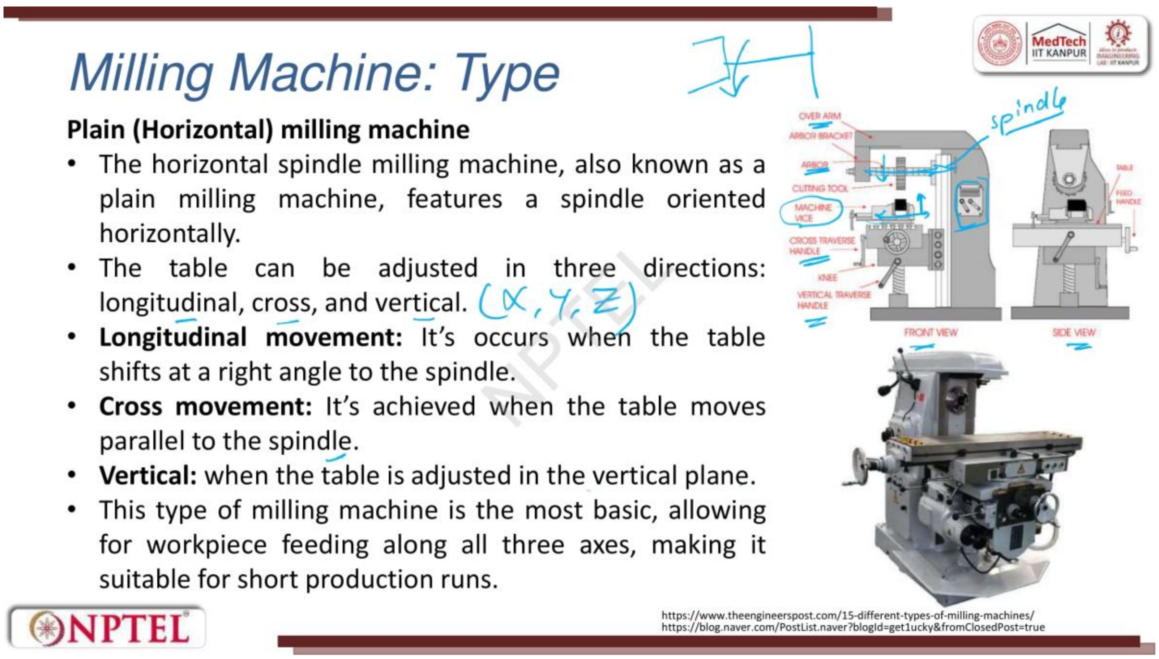
When we look at a typical milling machine, this is how it looks. In a lathe machine, we saw that it was horizontal. Here, I am trying to explain a vertical machine. So, it is classified into different categories depending on the construction, specification, and operation. So, the construction is a vertical axis. You can also have a horizontal axis. A horizontal milling machine is also possible.

But here we are trying to take the vertical axis. The moment you see the vertical axis, the next point is how do I specify the machine? In a lathe machine, we try to say the distance between the headstock and the tailstock and the swing diameter. That is the major thing. Here also, we will try to see what the specifications are.

And then, of course, we will try to see the operations. Here, you can see there is a column and knee type. A column, this is a vertical column, column and knee type. As though there is a knee here. Then, a hand milling machine.

Then, a plain milling machine, which is horizontal. Then, you have a universal milling machine. Then, an omniversal milling machine, which is universal, an omniversal milling machine. And, we have a vertical milling machine. So, these are the different types of milling machines.

In a lathe machine, we saw an engine lathe and a tabletop lathe. So, like that, here also we see all these things. Manufacturing of a fixed bed type includes simplex, duplex, and triplex types of milling machines. Manufacturing of a fixed bed type. So, the bed is this. This is the base, and this is the bed.



So, a plain milling machine or a horizontal milling machine. In a horizontal milling machine, this is the front view, and this is the side view. You can see the cutter is mounted horizontally, and here this is the machine vise where the work is held rigidly. So, now the table can go up, or the cutter can come down, and then it will come in contact with the workpiece to remove material.

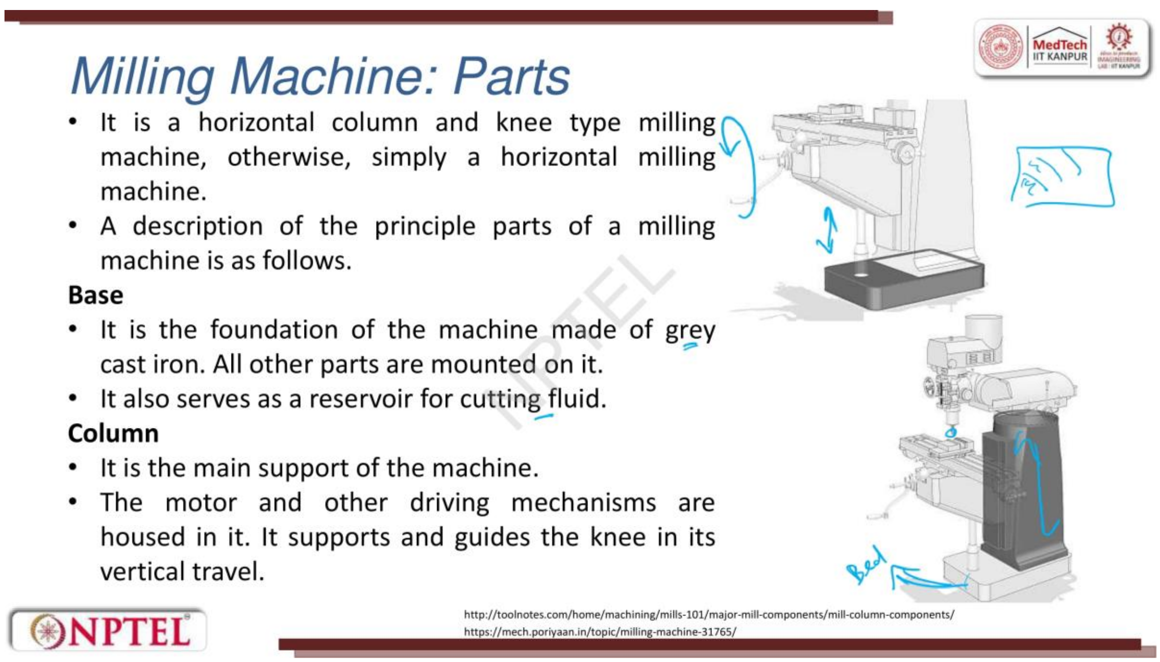
Depending upon the angle you place the vice, you can try to have a taper or you can try to have a straight slot possible. The height of the table can be adjusted by a vertical transverse handle. And if you want to have this motion, that can be done by a cross transverse handle. So, one is depth height-wise, and the other one is in one direction you can traverse. It can be x or y. It can be in this direction.

So, that is also given here. So, you have a same freedom like that in lathe machine. Here also you have this cross slide. So, cross traverse handle is there. So, you try to rotate it.

So, then this portion moves. The cutter is held in a arbor. The arbor is used to hold and this arbor is attached to a spindle, wherein which the RPM, the motor is attached to it and here are that gearbox levers, you can try to get multiple combinations. The arbor has to be held on the other side, otherwise it will be like a cantilever type, the deflection can happen, so you are holding it. So, that holding is done by a over arm.

This is a typical horizontal milling machine or a plain milling machine. The table can be adjusted in three directions, longitudinal, cross and vertical. So, you try to get X, Y and Z movement. You can try to have any two movements. Depending upon the two movements, you will try to get a taper.

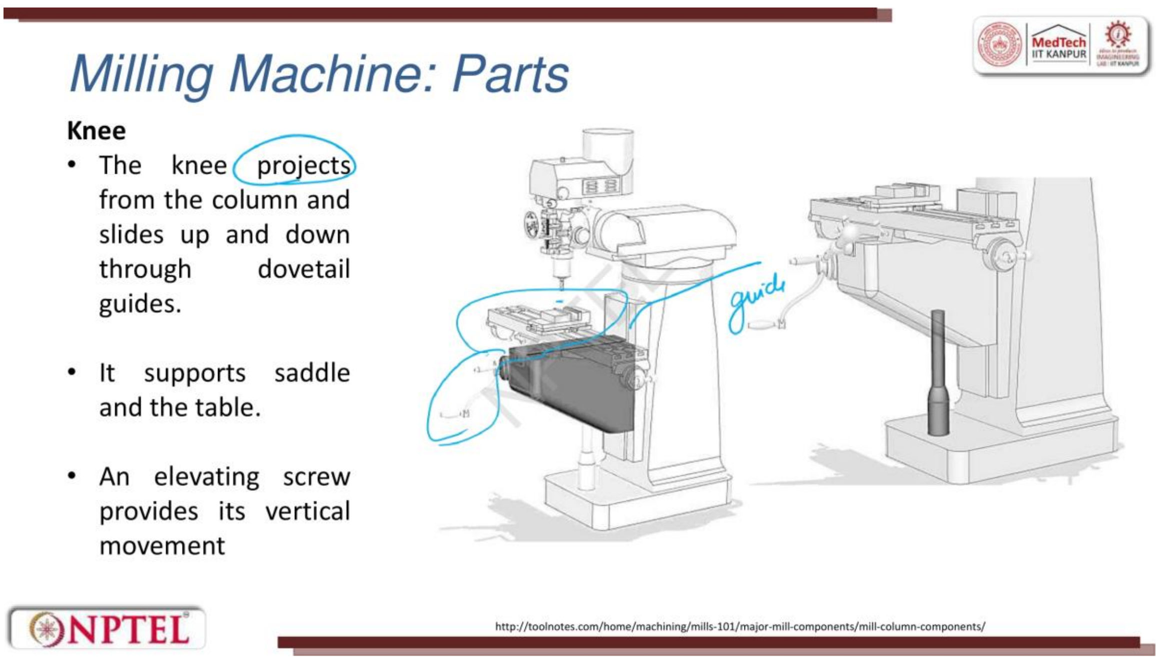
The longitudinal movement occurs when the table shifts at a right angle to the spindle. The cross movement is achieved when the table moves parallel to the spindle. The vertical adjustment is made in the vertical plane when the table moves against the cutter.



In the horizontal column and knee-type milling machine, or simply a horizontal milling machine, you see the following description. For example, you have this vertical motion going up, with this handle rotating.

So, this is the bed—the base or the bed—and this bed is mounted on a column. So, this is a column, and this column then houses the cutter. This is a cutter, along with all the adjustments. The foundation base, or the bed, is the foundation of the machine, made out of gray cast iron. Gray cast iron is used predominantly because it provides toughness and is very hard.

It also has lubricating properties. If you examine the microstructure, you can see graphite present along with the material. So, this graphite also provides lubrication. It also serves as a reservoir for cutting fluid. So, here you can also use it as a tank. The column is the main support. This is the column. This is the main support of the machine, and the motor and other drive mechanisms are mounted on it.

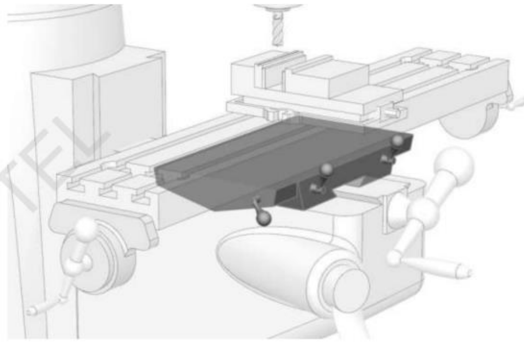


The knee is like a human sitting. So, this is the knee. The knee projects from the column and slides up and down vertically. So, there is a guide. Like in a lathe machine, you also have a guide here. This is the guide. This guide restricts it and moves it up and down. It supports the saddle. It supports the saddle part, and then it is able to move up and down, left and right.

Milling Machine: Parts

Saddle

- The saddle enables the side to side (X-axis) as well as the in and out (Y-axis) motion of the milling machine.
- It is the intermediate component between the table and the knee.
- The saddle supports and it carries the table.



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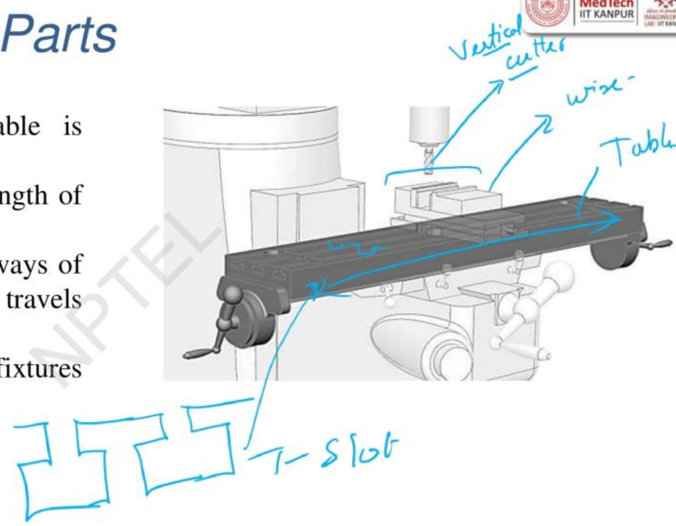
Milling Machine: Parts

Table

- The top surface of the table is accurately machined.
- There are T-slots along the length of the table for holding the work.
- The table rests on the guide ways of the saddle and longitudinally travels in a horizontal plane.
- It supports the workpiece, fixtures etc.



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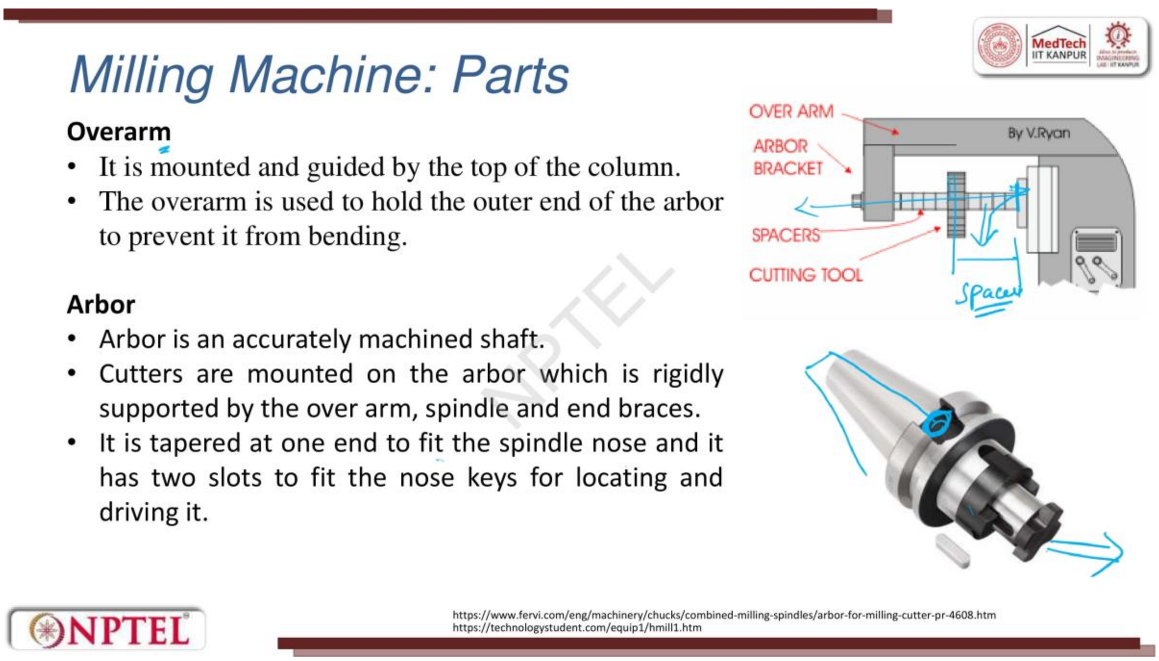
This is the saddle. The saddle enables side-to-side as well as in-and-out motion of the milling cutter. It is the intermediate component between the table and the knee.

The saddle supports, it carries the table. Now you can see the table part, this is a table, and this is vice to hold and this is the cutter and here it is called as vertical cutter, vertical axis cutter or a face milling. There are T-slots in the table, these T-slots, T-slots will be something like this. This will be here. These are the T-slots which are here and these T-slots are used to hold the vice.

There are T-slots along the length of the table. Why is that T-slots along the length of the table? It gives you infinite locating positions. If it is a hole, if there are holes done, then there are fixed discrete points. When you have a long lengthy T-slot, there is infinite locking positions.

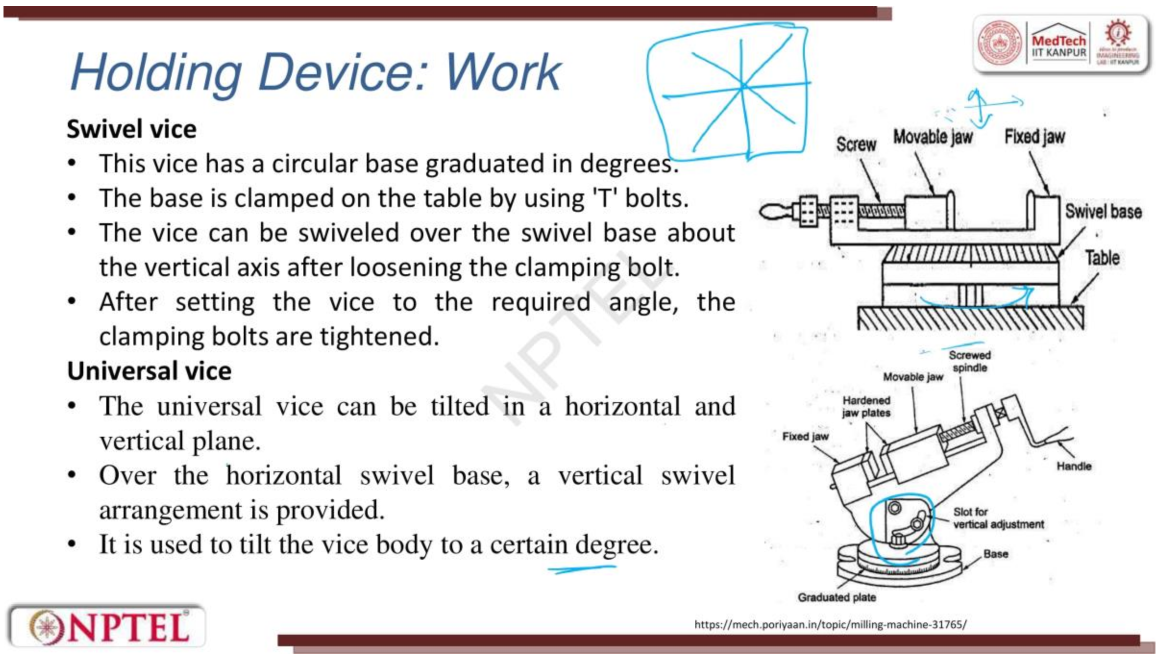
They are T-slots along the length of the table for holding the workpiece. The table rests on the guide and the saddle and the longitudinal travel in the horizontal plane. It supports the workpiece fixture etc. Workpiece is on the top. The workpiece is held in a fixture. That is a vice.



The overarm, as I have already told. So, if you see in the arbor, you are placing the cutter. Now, from the end to the cutter, whatever the cutter location, here you will have spacers. These spacers are used to move the cutter along this axis and locate it at a point where you want to machine exactly.

The other way around, here also what will happen is the cutter should not wobble or deflect, so we protect it again by putting a spacer. So, these spacers try to locate the cutter with respect to the workpiece. The arbor is an accurately machined shaft. This is the accurately machined shaft. The cutters are mounted on the arbor, which is rigidly supported by an overarm.

This we have already seen. So, now here in this arbor, you will also have the other end here, you will have a taper spindle locating point. So, here they will have a cutter or the arbor which is located. So, it is a taper at one end to fit the spindle nose, and it has two slots to fit the nose keys. These are the slots. You will have the opposite side, the nose keys for locating the driving edge.

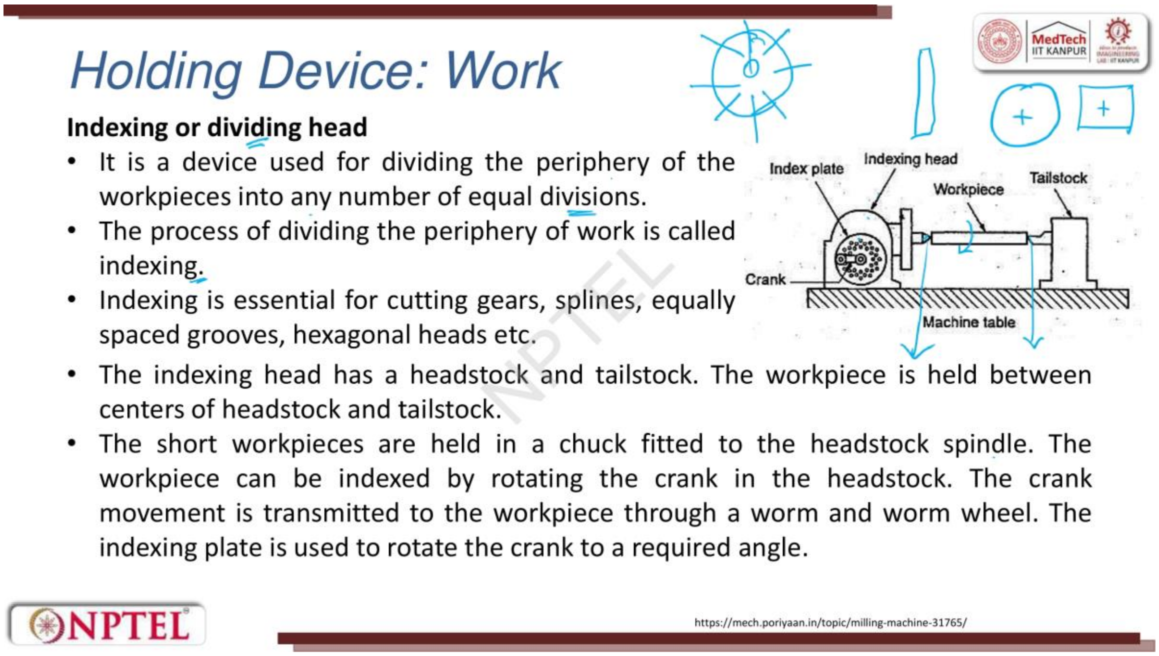


This is the vice. The vice can have only up-down movement or left-right movement. If you have a proper setting and gear meshing, you can also have a swinging motion. That means it can move up and down, left and right. This is easy. But now, if you want to orient at an angle, then we have a wheel—a handle wheel—which rotates, and the vise gets meshed onto a gear. It tries to rotate, and you can fix it at an angle.

So, what is the freedom? It tries to—suppose you want to make slots like this—it is possible. You want to make slots like this; this is also possible. All these things are happening in one plane. In one plane, you cut.

But now, there is also a possibility you can tilt it. You can tilt it like this. You can tilt it like this. That is called the universal vice. Here, you see that this option is also given to the vice, such that you can get the taper also.

Swivel vice and universal vice. Let us understand universal vice. Universal vice can be tilted in horizontal and vertical plane. Over the horizontal swivel base, the vertical swivel arrangement is provided. It is used to tilt the vice body to a certain degree. So, this one as well as this one is possible.



There is also an indexing head. This is used to make a taper in one axis or two axis. Swivel is around a single plane you rotate. When we try to look into indexing or dividing head, so where do we use it?

We use this when we want to make a gear or if you want to make slots. you want to make slots, you will try to have an indexing mechanism. So, what is the function of the indexing mechanism is? You will try to rotate, the workpiece rotates to a fixed angle, and then you hold the workpiece. Now you rotate, you still, you rotate, you still. Now when you rotate and still what happens at that plane you can try to do operation.

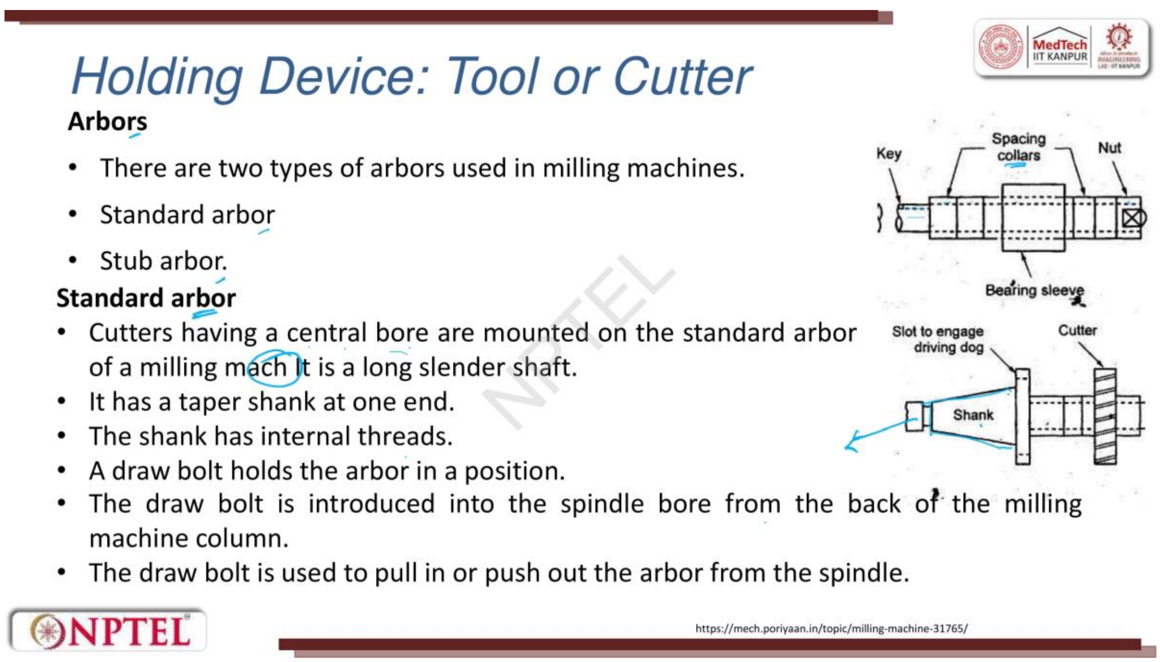
Suppose there is a cutter which is supposed to make a straight groove. Now I index. So, a cylindrical part can be made into a square by using this indexing mechanism. A gear can be cut by using this indexing mechanism. In the index, there is also an indexing plate.

In the indexing plate, there are multiple holes, and then you have a crank to locate it, rotate it, and lock it. So, this indexing head plate will transfer the data to the indexing head, from the head it will transfer the data to the workpiece, and the workpiece rotates.

Here, the workpiece is held between two centers; these two centers are called the tailstock and headstock. So, the tailstock is a dead center where there is no RPM applied. Again, this portion is also a dead stock; you rotate it and then stop it.

So, it is a device for dividing the periphery of the workpiece into any number of equal divisions. This has to be uniform. For example, the angle between these two can be 30 degrees, and it has to be uniform all around. The process of dividing the periphery is called indexing. This is very much required.

If you want to have a hexagonal bolt or convert a cylinder to a square, this indexing mechanism is required. If you want to cut a gear, it is required. The indexing head has a headstock and a tailstock. The workpiece is held between the headstock and the tailstock. This is the headstock, and this is the tailstock. The short workpiece is held in a chuck fitted to the headstock spindle. The longer one is held between the headstock and the tailstock.

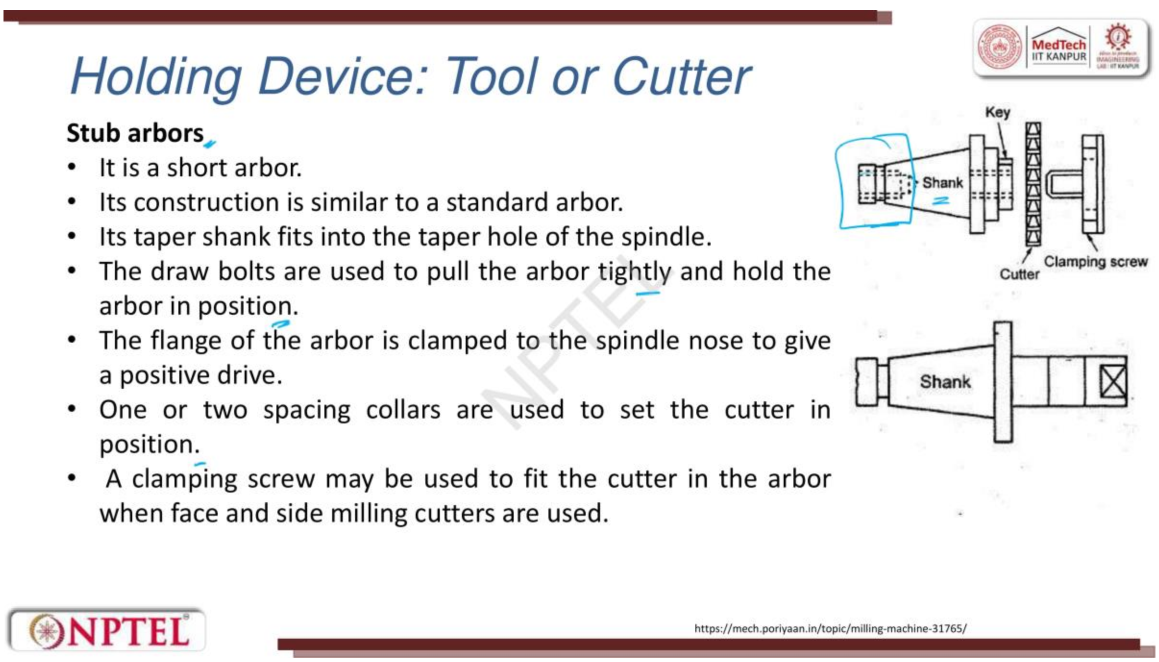


There are several types of arbors. The major ones are the standard arbor and the stub arbor. This is the standard arbor. You will have a key that locks because when you have a spacer, it is cylindrical. When you have a shaft, it is also cylindrical.

Now, these two cylinders—the hollow cylinder—must be secured when resting on top of a shaft. So, here, what we do between the two is place a key. The key ensures positive locking between the spacer and the shaft.

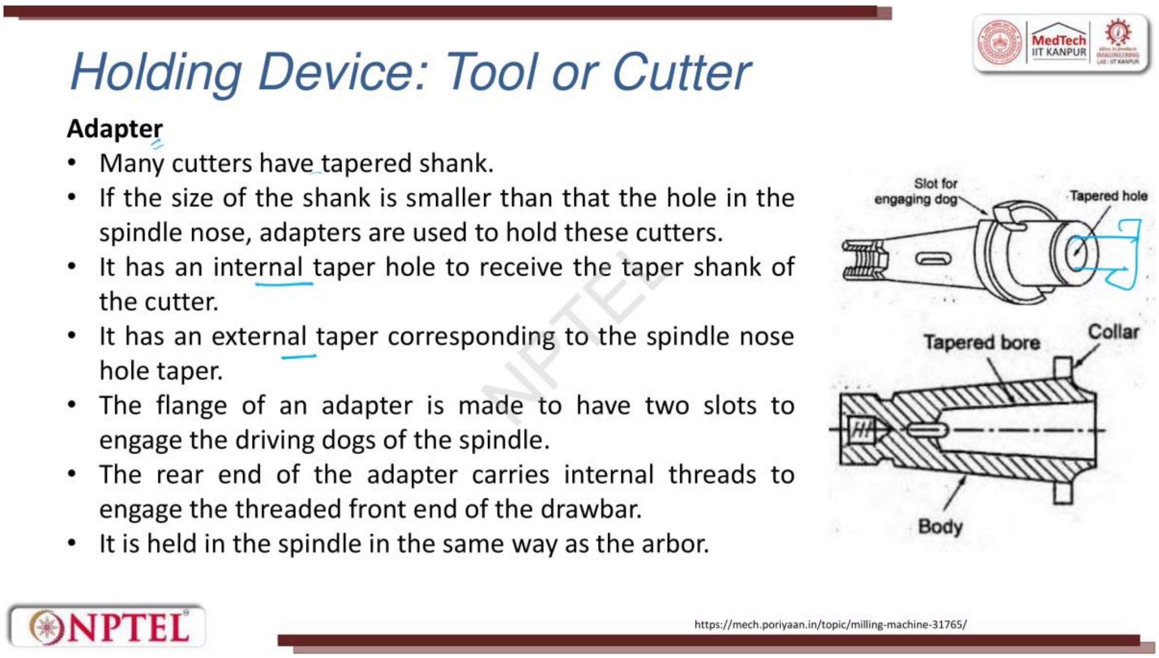
So, that is what the spacing collar is, and then you have a nut. So, standard arbor. A standard arbor having a center bore is mounted on a standard arbor of a milling machine. The arbor has a shank, which is always tapered. This is called a Morse taper.

And here, what will happen is? You will have a self-locking mechanism, a self-locking mechanism, which is why the shanks are tapered. The top end of the shank will be attached with a nut and bolt so that it gets properly fastened to the machine tool. A shank has an internal thread. The draw bolt holds the arbor in position. The draw bolt is introduced into the spindle bore—this is the draw bolt—from the back of the milling machine column. The draw bolt is used to pull in and push out the arbor from the spindle so that you have a positive locking.



Stub arbors—these are small arbors, stub, short arbors. Their construction is very similar to that of a standard arbor. So, a shank—there you had a draw bolt. So, here you have a small one, very similar to that of a draw bolt. So, that is used to hold the shank to the machine tool. The tapered shank fits into the tapered hole of the spindle.

The draw bolt is used to pull the arbor tightly and hold the workpiece. So, this is the draw bolt, this portion. The flange of the arbor is clamped to the spindle nose to give a positive drive. One or two spacing collars are used to set the cutter in position. The clamping screws may be used to fit the cutter on the arbor.



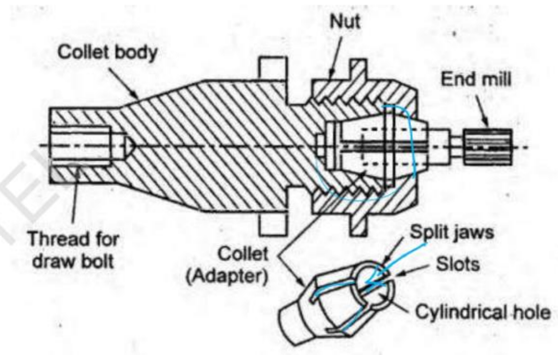
Then we have an adapter. These are all arbors. Then we have an adapter. Many cutters have taper shanks. This is an adapter. So, they have a taper hole. The shank also has a taper hole. This also has a taper hole. So, to mount this adapter to the machine tool, we will always have a slot to engage the dog so that you have a positive drive. So, this is used.

So, many cutters have a tapered shank. It has an internal tapered hole to receive the tapered shank of the cutter. Then it has an external taper; the internal taper is also there, and the external taper is also there to hold it in the machine tool. So, basically, the cutter comes here.

Holding Device: Tool or Cutter

Spring collet

- Milling cutters which carry straight shanks held in a collet chuck carrying a spring collet.
- The collet chuck has a taper shank to fit into the milling machine spindle.
- It has internal threads for tightening it with the spindle by means of a draw bolt.



- It has an externally threaded body. The body has a tapered hole to receive the collet.
- The tapered portion of the spring collet is split into three equally spaced slots.
- The collet has a cylindrical hole to receive the straight shank of the cutter.

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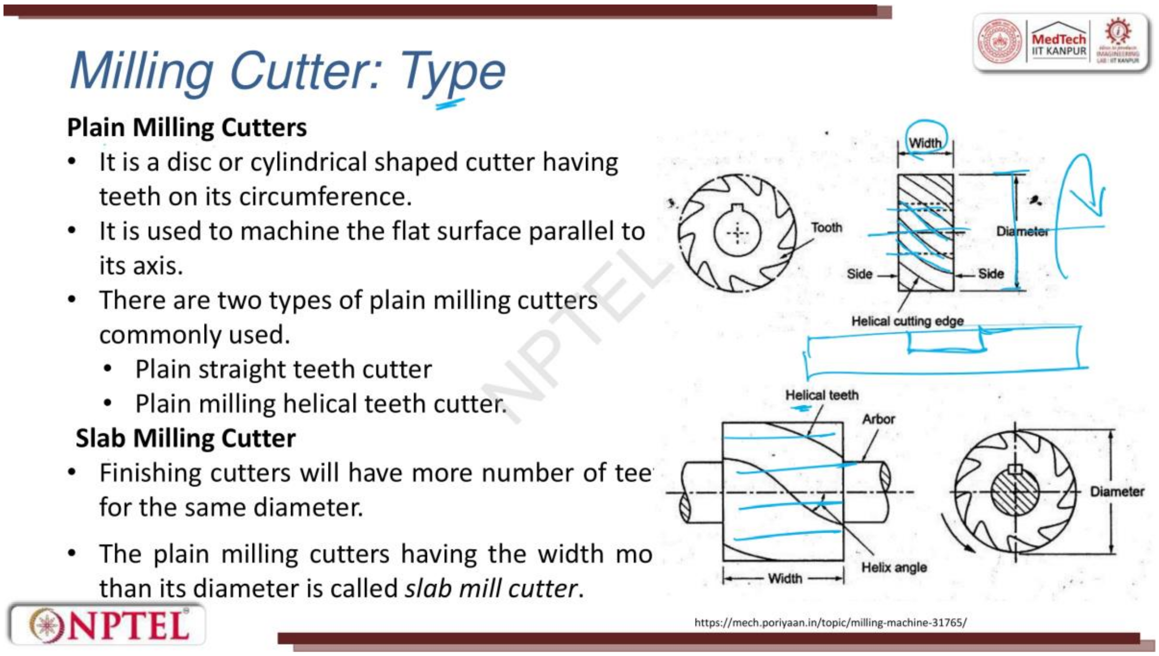
You also have spring collets. These are all mechanical, hard, solid collets. Spring collets are a little fragile. So, what happens is, here you have cut grooves on a cylindrical part where the material will have a lot of elastic limits. It will have a little bit of expanding and contracting. So, now you push the tool inside.

The tool is pushed inside. The split jaws expand and then lock. Those things are called spring collets. Spring collets are also used. When do we use spring collets?

When the diameter of the cutter is very small, we go for spring collets. Otherwise, we go for adapters and arbors.

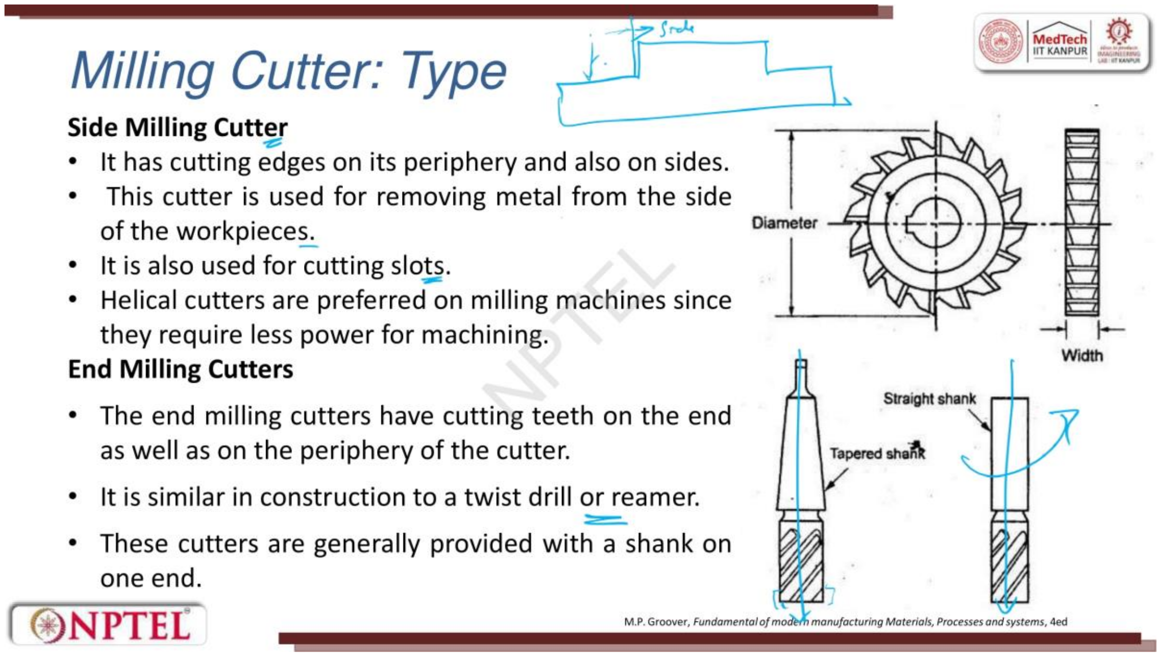


There are different types of milling cutters, we will see them. One is called as the plain milling cutter. So, in plain milling cutter, this is the cutter. So, you have a width of the cutter. Then you have the diameter of the cutter which is important and then you will have a center portion of the cutter which is used to locate himself with the arbor or goes inside the arbor. Then you will have these are all tooths. These are all tooths. So, now what you do is you try to hold the cutter and then rotate it.

You try to get a flat or a slot output when we have a slab milling cutter the slot size the groove whatever is getting done here it can be small when you want to make only a flat plain surface, then we go for a slab cutter wherein which the width is slightly wider. And here you see there are helical teeth.

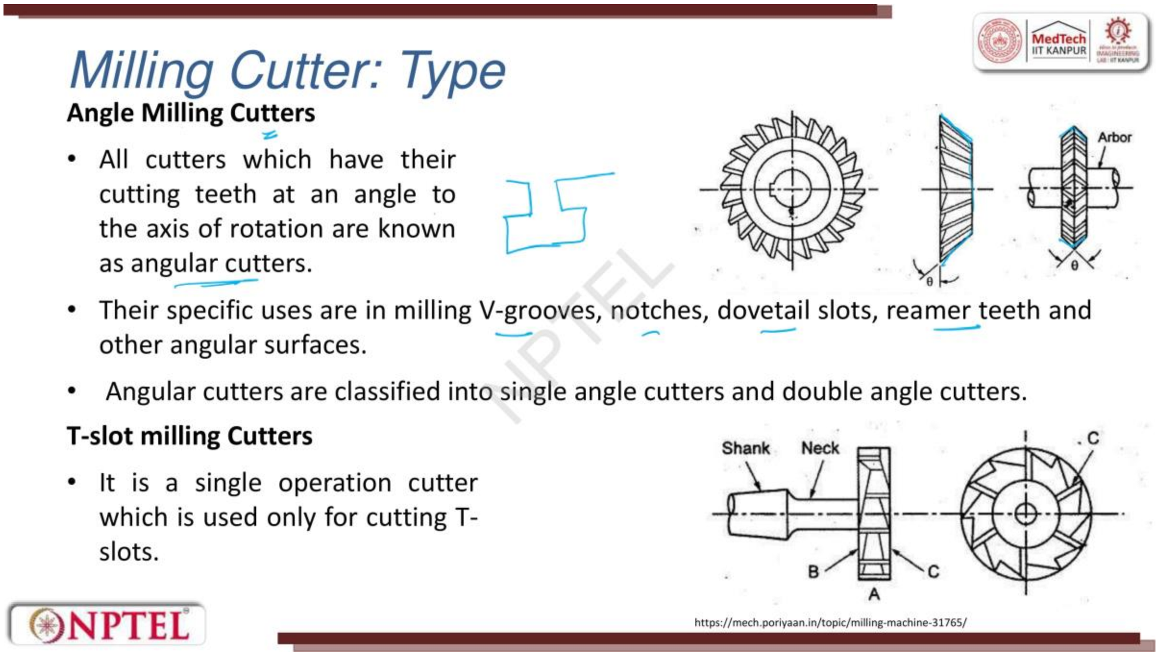
You can also have parallel teeth and helical teeth. These helical teeth will give you a effect of smooth coming inside and going outside. The straight cutting tools will have an impact at regular intervals of time.

You can have plain teeth or helical teeth. In a slab, the thickness is larger. The finishing cutter, which has more teeth for the same diameter, and the plain milling cutter, having a width greater than the diameter, is called the slab milling cutter.



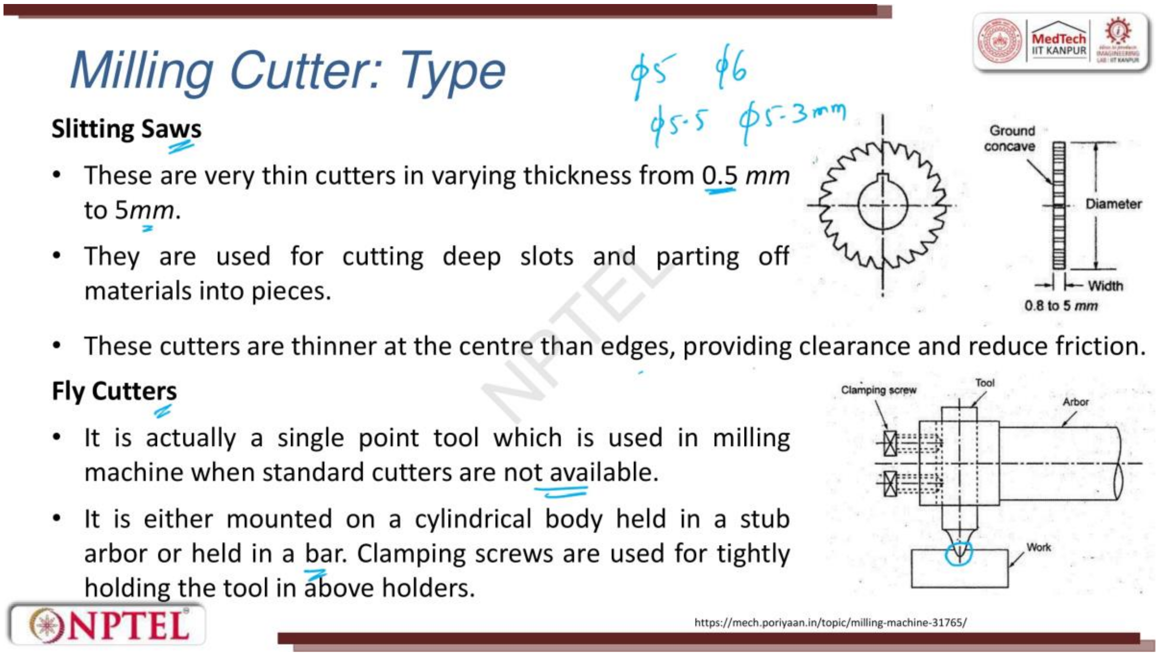
There are also side milling cutters, which are used to mill the sides. This is the workpiece. So, you are trying to cut. So, the side—this is a side portion—the side of the workpiece is removed. It has a cutting edge on the periphery and also on the side. So, it can cut in this direction as well as this direction. This cutter is used to remove material from the side of the workpiece.

It is also used for cutting slots. Next comes the end milling cutter. All three things are for horizontal; this is for vertical. End milling cutters are for vertical; you can rotate them, and here the flat end portion will come in contact with the workpiece to remove material, and also the side is used for cutting. The end milling cutters have cutting teeth on the end as well as on the periphery of the cutter. It is similar in construction to a twist drill or a reamer. These cutters are generally provided with a shank on one side.



You have angle milling cutters. So, all cutters which have their cutting teeth at an angle to the axis of rotation are called angle cutters. So, this is an angle cutter. Some angle is there. So, this is used to cut V-grooves, notches, dovetail slots, reamer teeth, etc. So, here there is an angle on the base of the cutter itself. That is what we call an angle milling cutter. We also have T-slot cutters.

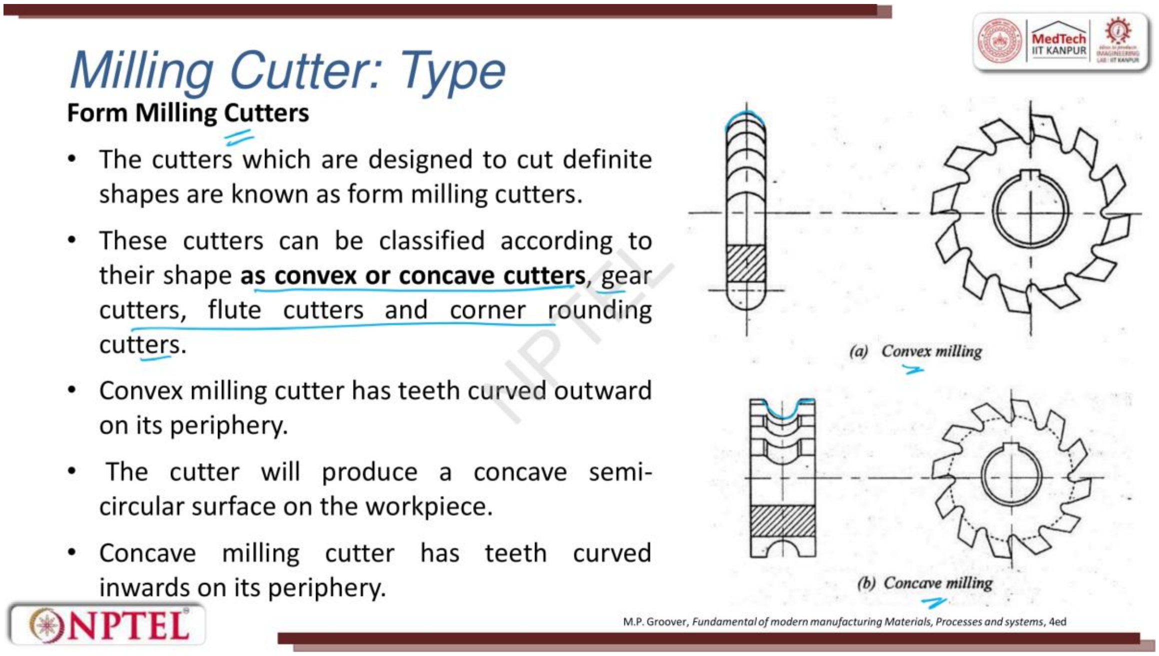
T-slot cutters are basically used for generating such profiles. So, you cut from the side and go all along. So, they are called T-slot cutters. They are also very efficiently used. So, we saw plane, then slab; plane is small, slab is large width, then we have side, then we have end, then angle, then T-slot. These are some of the types of milling cutters.



When the milling cutter becomes very small, it is called as the slit. So, the saw is used to cut the piece or it is used for parting the piece. Splitting it. So, the thickness can vary from 0.5 millimeter to 5 millimeter, that is the thickness.

So, basically wood and all we do sawing operation. They are used for cutting deep slots and parting of operations. These cutters are thin at the center than edges providing clearance and reduce to friction. So, we are talking about here the teeth will be sharp and then the teeth when it cuts when it cuts it also has friction. So, we will try to reduce it, we will make it thin so that lot of the other portion apart from the teeth does not come in contact with the work piece.

Fly cutter is also an interesting thing where we make a single point cutting, it rotates and it goes around, it rotates about its axis and also it rotates about the other axis, about the tool axis itself. It is actually a single point tool which is used in milling machines when standard cutters are not available. If you non-standard, for example, you might have dia 5, you might have dia 6, but if you want to have dia 5.5 or dia 5.3 millimeter, then we use fly cutters. It is either mounted on a cylindrical body held in the stub arbor or held in a bar. The clamping screws are used to tightly hold the tool in the above holders.



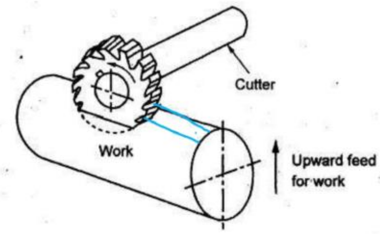
There are also form cutters, like what we saw in single-point cutting tool form tools. Here, you can also grind the milling cutter to the shape you want to replicate. These cutters are classified according to their shape as convex or concave cutters, gear cutters, flute cutters, or corner radius cutters. Depending on your requirements, you can choose. You can have a convex or a concave cutter.

Now, if you want to create a bump on the workpiece, you go for a concave cutter. If you want to create a groove, then you go for convex milling cutters. They all fall under the category of form milling cutters.

Milling Cutter: Type

Woodruff Key Slot Milling Cutter

- It is a small type of end milling cutter which is similar to plain and side mills.
- The cutter may have straight or staggered teeth.
- It is used to cut woodruff key slot in a shaft.



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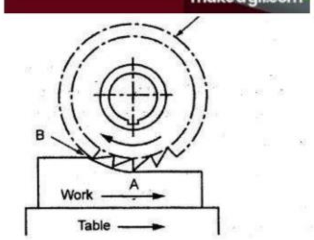
Woodruff key slot milling cutter. It is basically used to create a key slot so that you can place a key for locking. It is a small type of end milling cutter, similar to that of a plain or side milling cutter. The cutter has straight or staggered teeth. They are used for making key slots in shafts.

Milling: Method

- In peripheral milling process, the appearance of the surface and the type of chip formation are affected by the direction of cutter rotation relative to the movement of the workpiece.
- The peripheral milling process is classified into two types.
  1. Up milling or conventional milling, and
  2. Down milling or climb milling.

1. Conventional or up milling: The cutter rotates opposite to the direction of feed of the workpiece.

- In up milling, the chip thickness is minimum at the beginning of the cut.
- It reaches the maximum at the end of the cut.
- The stress on the teeth is minimum at the beginning of the cut and it increases gradually to maximum at the end of the cut.



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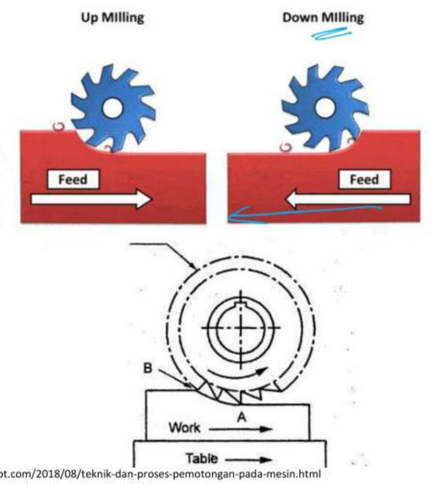
Milling: Method

2. Down milling: In this method of milling, the cutter rotates in the same direction of travel of the workpiece.

- The thickness of the chip is maximum at the beginning of the cut. The chip thickness decreases to the minimum at the end of the cut. So, the stress is maximum at the beginning of the cut.
- It gives the shock load to the teeth.



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https://mech.poriyaan.in/topic/milling-machine-31765/

So, when we look into milling methods, there are two types of milling methods. One is called up milling, and the other is called down milling. Up milling is otherwise called conventional milling. The cutter rotates opposite to the direction of the feed of the workpiece; it is called conventional milling.

You look at it: the workpiece is moving, and the cutter is going in the opposite direction. Here, what will happen is the chip will start thin and go to maximum. So, what happens?

There is a gradual entry, then a gradual exit. While exiting, it takes a larger chip. Here, the forces will start slow and then go high for each cutter. The cutter rotates opposite to the direction of the feed of the workpiece. In up milling, the chip thickness is minimum at the beginning of the cut and reaches maximum at the end.

The stress on the teeth is minimum at the beginning and maximum at the end. When we go for down milling, it is the opposite. The entry chip thickness will be very large, and the exit will be very small. So here, every time the tool undergoes an impact load and then starts cutting. In this method of milling, the cutter rotates in the same direction as the travel of the workpiece.

So, down milling. So, it travels like this and the cutter also moves like this. The thickness of the chip is maximum at the beginning and it decreases as and when it goes. There is lot of load on the cutter in down milling operation. These both holds good for horizontal milling.

Milling: Method

Up Milling	Down Milling
It is also known as conventional milling	It is also known as climb milling.
In this milling, the cutter rotates against direction of feed.	n this milling, the cutter rotates with direction of feed.
The width size of the chip is zero at initial cut and increase with feed. This will maximum at the end of feed.	The size of the chip is maximum at start of cut and decrease with the feed. This will zero at the end of feed.
The tool wear rate is more because tool runs against the feed.	The tool wear rate is less because the cutter rotates with feed.
The cutting chips fall down in front of the cutting tool.	The cutting chips fall down behind the tool
It gives less surface finish.	It gives better surface finish.

Milling: Method

Up Milling	Down Milling
Tool life is less.	Tool life is more.
This is also famous as traditional way of cutting the surface	This is non – traditional way of cutting the work piece.
The high quality cutting fluid is used.	The simple cutting fluid is used
The cutting chips are carried upward with the help of tool.	The cutting chips are carried downward with the help of the tool
The heat is diffuse to the work piece which causes the change in metal properties.	The heat is diffuse to the chip does not change the work piece properties.
Because of upward force by tool, high strength jig and fixture are used.	Because of downward force by tool, normal jig and fixture are used.
It requires high cutting force	It requires low cutting force

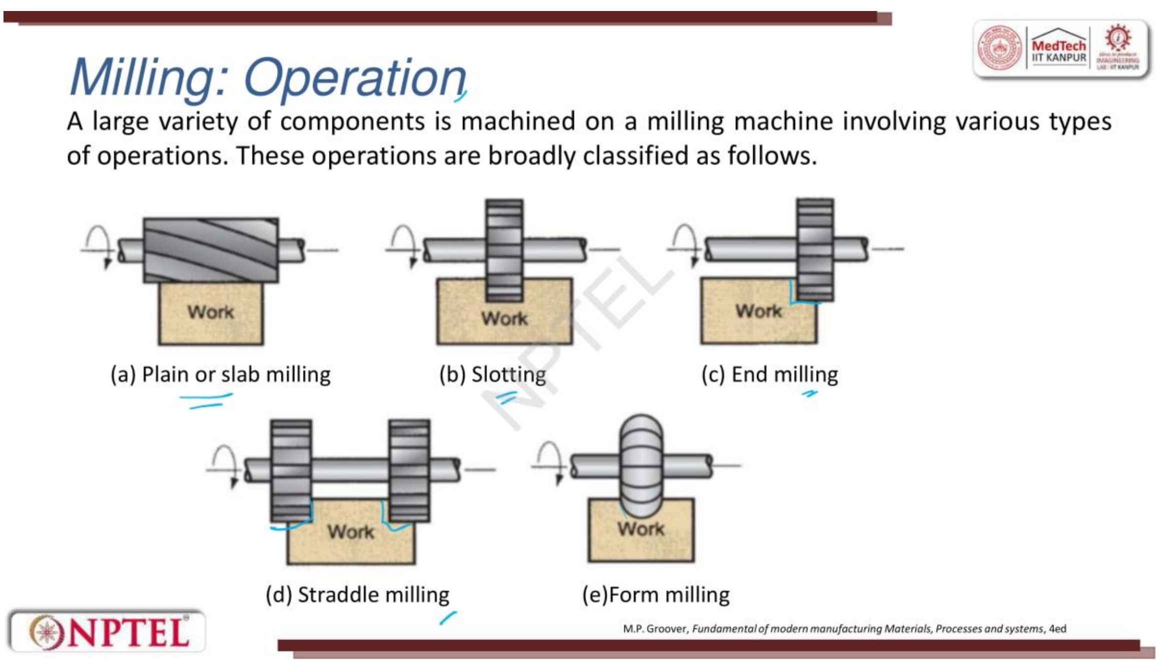
So, what are the difference between up milling and down milling? The up milling is otherwise called as conventional milling. It is called as climb milling. So, the cutter rotates against the feed direction here along the feed direction. The width of the chip is 0 to max, max to 0.

The tool wear is more because the tool run against the feed. The tool wear is less because it runs along the feed. The tool chip falls down in front of the cutter. The tool chip falls behind the cutter. The surface finish is poor.

The surface finish is good. So, this is a comparison between up milling and down milling. In up milling, the tool life is less, the tool life is more. So, this is also famous as a traditional way of cutting a surface. This is a non-traditional way of cutting the surface.

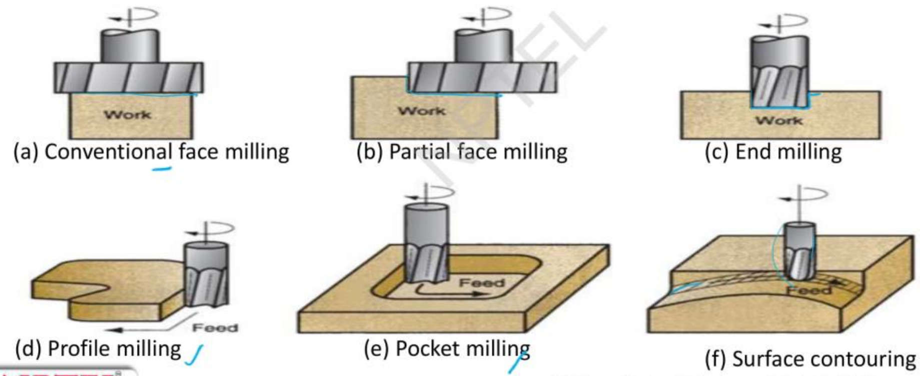
The high quality cutting fluid is used, a simple cutting fluid is used here. The tool chip are carried away with the help of the tool. The tool chip are carried downward with the help of the tool. The heat is diffused to the workpiece which causes damage to the metal property. The heat is diffused to the chip and does not change the workpiece quality.

Because of the upward force, the strength of the jig and fixture should be very strong. Here it pushes it down so the fixture can be slightly diffused. Little lesser strength or lesser rigidity can be there. It requires higher cutting force, it requires lower cutting force.



Milling: Operation

Face milling involves machining with a cutter whose axis is perpendicular to the surface, utilizing cutting edges on both the end and periphery. It includes following milling operations,



M.P. Groover, *Fundamental of modern manufacturing Materials, Processes and systems*, 4ed

So, generally the milling operations are this is plain or slab milling which I told you with respect to slab milling cutters, then you can do slotting operation, you can do end milling operation, you can have straddle milling, straddle milling on the both sides you can do simultaneously straddle mill, you can also do form milling.

So, these are all done with respect to the horizontal axis; you can also do it with respect to the vertical axis. So, in the vertical axis, we have conventional face milling. So, the top face is milled. Then, we can have partial face milling. We can have end milling for making slots.

Slotting here can also be done horizontally. Here, it is done vertically. Then, you can do form milling. You can also do pocket milling. So, the video we first showed was pocket milling.

Form milling is to generate a form outside; pocket milling is to generate within the workpiece. Then, you can also do surface contouring. Surface contouring is possible. So, that also tries to give a preform. Suppose you want to make a turbine blade; surface forming can be done.

To recapitulate

- Introduction to milling
- Types of Milling Machine
- Parts of Milling Machine
- Holding devices in milling
- Milling cutters and types
- Milling methods
- Milling operations

Friends, to recap what we went through in this lecture, we saw the introduction to milling, then the types of milling machines, the parts involved in a milling machine, holding devices, different types of cutters in horizontal and vertical orientations, and finally, we saw different types of milling methods and various milling operations.

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These were the reference materials we used for making this lecture.

Thank you very much.