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POLITEKNIK MALAYSIA
KUCHING SARAWAK

ESSENTIAL GUIDE TO MILLING MACHINE: PRINCIPLES AND PRACTICES

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MILLING MACHINE

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PREFACE

This e-book is specially written for student who are pursuing Diploma In Mechanical Engineering, Diploma in Mechanical Engineering (Manufacturing), Diploma in Mechanical Engineering (Automotive) and Diploma in Mechanical Engineering (Air-Conditioning and Refrigeration). Each chapter begin with Learning Outcome, brief explanation on related matters and quiz to improve student understanding in Milling Machine Practices.

This e-book also provides guideline illustrations, revision and exercises that are suitable for facilitate the student fulfilling the needs of Student Learning Time (SLT). This book is organized into five main chapter.

Chapter 1: Briefly explain about Introduction to Milling Machine and the Type of Milling Machine.

Chapter 2: Explain about Universal Milling Machine, characteristics, parts, Fundamental and Working Principle of Milling Machine.

Chapter 3: Explain about Basics Milling Cutter Operation.

Chapter 4: Explain about Type of Milling Cutter and Their Usage.

Chapter 5: Explain about Holding Cutting Tools and Workpiece.

ABSTRACT

"Essential Guide to Milling Machine: Principles and Practices" offers an in-depth exploration of milling machine technology, tailored for both beginners and seasoned professionals in the machining industry. The book systematically covers the core concepts of milling, including the various types of milling machines, their structural components, and the wide range of materials they can handle. Readers will find step-by-step instructions on machine setup, operation, and maintenance, along with strategies for achieving precise and efficient milling results. Advanced sections discuss CNC milling, troubleshooting, and the latest industry standards and practices. Richly illustrated with diagrams and practical examples, this guide provides invaluable insights into maximizing machine performance, ensuring safety, and mastering the intricacies of milling. Whether for educational purposes or as a practical reference, this book is an essential resource for mastering the art and science of milling.

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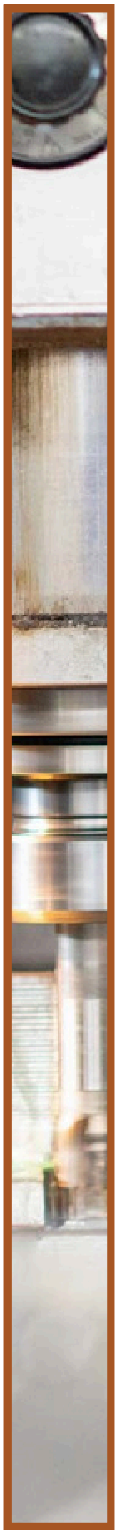
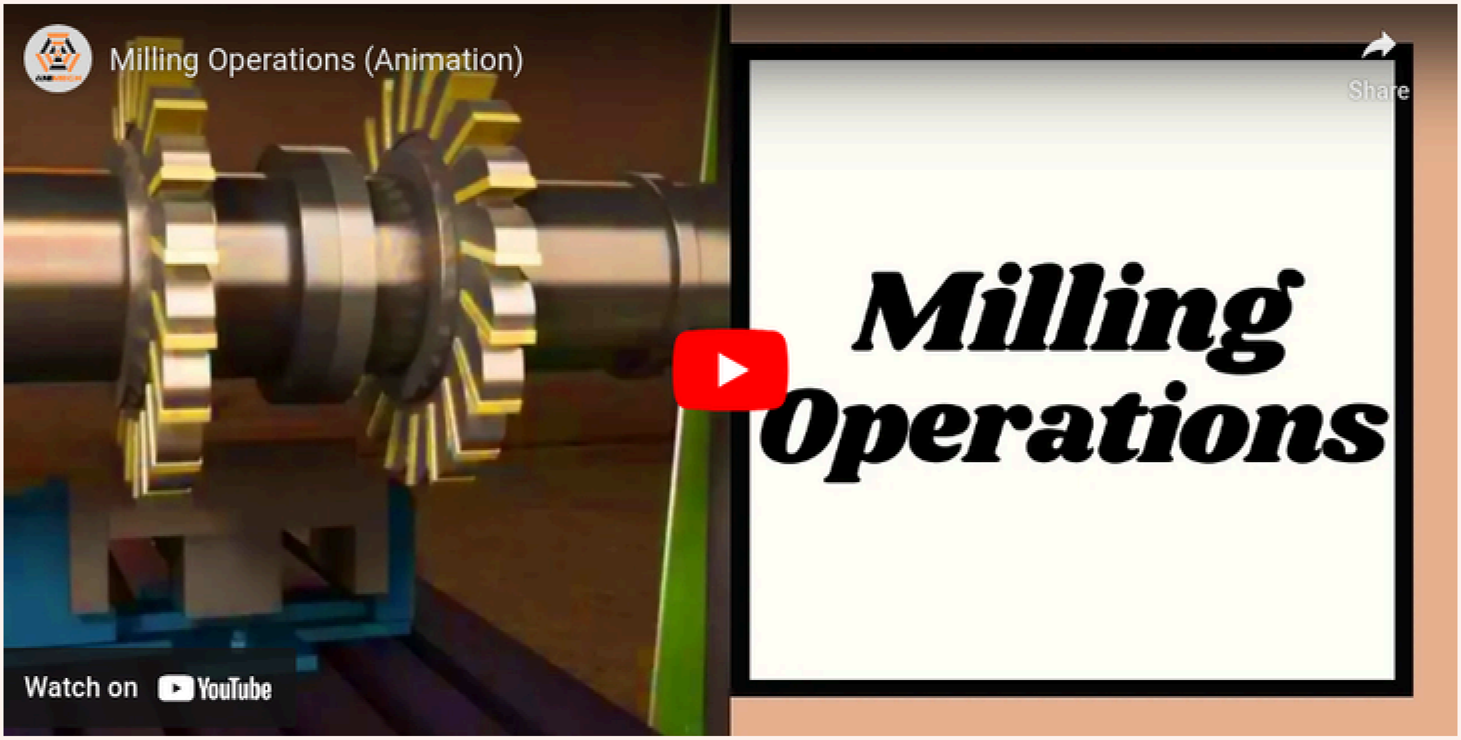


DEFINITION

1. Milling is the machining process in which the removal of metal takes place due to the cutting action of a rotating milling cutter.

2. In a milling machine, the cutter is rotating due to this workpiece is fed againstit. This can hold more than one tool at a time. The cutter rotates at a high speed and because of the many cutting edges, it removes metal at a very fast rate.

3. The machine can also hold one or several cutters at a time. Thus, the milling machine is one of the most important machines in the workshop. In this machine, all the operations can be performed with high accuracy.



TYPE OF MILLING MACHINE

COLUMN AND KNEE TYPE

- Hand milling machine
- Plain or horizontal milling machine
- Vertical milling machine
- Universal milling machine

MANUFACTURING TYPE OR FIXED BED TYPE

- Simplex Milling Machine
- Duplex Milling Machine
- Triplex Milling Machine

ROTARY TABLE MILLING MACHINE

- Rotary Table Milling Machine
- Drum Milling Machine
- Profile Milling Machine
- Planetary Milling Machine
- Tracer Controlled Milling Machine
- Pantograph Milling Machine
- NC/CNC Milling Machine

TYPE OF MILLING MACHINE

COLUMN AND KNEE TYPE

For general shop work, the most used type of milling machine is the column and knee type machine. where the table is mounted on the knee-casting which in turn is mounted on the vertical slides of the main column. The knee vertical adjustable on the column so that the table can be moved up and down to accommodate work of various heights. The column and knee type milling machines are classified.

·According to the various methods of supplying power to the table.

·Different movements of the table.

·The different axis of rotation of the main spindle.

HAND MILLING MACHINE

It simplest of all types of milling machine in which table feeding is controlled by hand. The cutter is mounted on a horizontal arbor and is rotated by power.

This type of milling machine is of small in size and suitable for light and simple milling operations. For Example, machining slots, grooves, and keyway.

TYPE OF MILLING MACHINE

PLAIN MILLING MACHINE

These are much stronger than hand millers. The table feeding is done either by hand or power. the plain milling machine having a horizontal spindle is also called as a horizontal spindle milling machine. The table may be fed in a longitudinal, cross, or vertical directions.

The feed is:

·Longitudinal - when the table is moved at right angles to the spindle.

·Cross - when the table is moved parallel to the spindle.

·Vertical - when the table is adjusted in the vertical plane.

UNIVERSAL MILLING MACHINE

It can be adaptedto a wide range of milling operations. Here the table can be swiveled to any angle up to 45-degrees on either side of the normal position.

In addition to 3 movements as mentioned earlier in a plain milling machine, the table may have the fourth movement when it is fed at an angle to the millingcutter. Helical millingoperation can also be performed. The capacity of this type of machineis increased by using specialattachments such as

·Dividing head or index head.

·Vertical milling attachment.

·Rotary attachment.

·Slotting attachment.

TYPE OF MILLING MACHINE

VERTICAL MILLING MACHINE

Here the position of the spindle is vertical or perpendicular to the table. This type of machine is adapted for machining grooves, slots, and flat surfaces.

The machine may be of the plain or universal type and has all the movements of the table for a proper setting and feeding the work.

The spindle head is clamped to the vertical column which is swiveled at an angle. It allowing the milling cutter fixed on the spindle to work on angular surfaces. In some machines, the spindle can also be adjusted up or down relative to the work.

MANUFACTURING MILLING MACHINE

These machines are large, heavy and rigid in construction.These machines differfrom column and knee type milling machines by the construction of its table mounting.

The table is mounted directly on the ways of a fixed bed.The table movementis restricted to reciprocating at a right angle to the spindle axis with no provisions for cross or vertical adjustment.

It is classified as simplex, duplex,triplex based on a machine provided with the single, double and triple spindle heads respectively.

·Simplex - single spindlehead.
·Duplex - two-spindle head.
·Triplex - three spindle head.

TYPE OF MILLING MACHINE

PLANER TYPE MILLING MACHINE

These types of milling machine are also called "Plano-Miller". It is a massive machine used for heavy-duty work having spindle heads adjustable in the vertical and transverse direction.

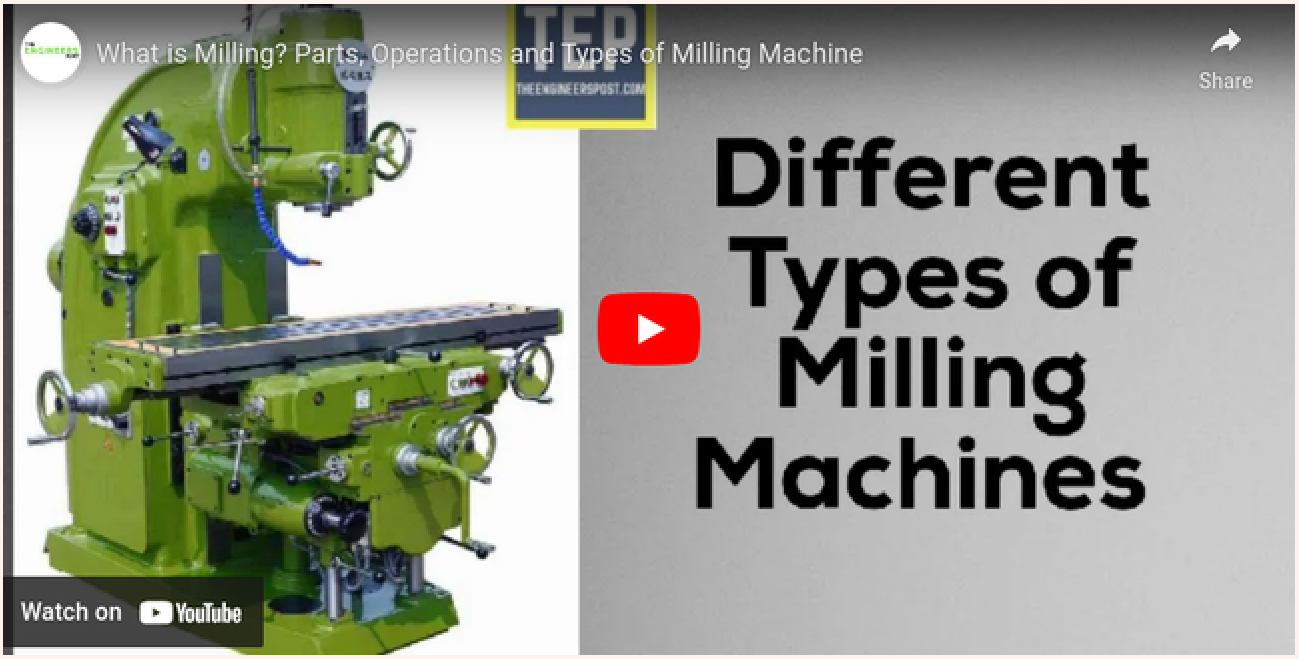
It relates to a planer and is like a planning machine. This machine has a cross rail capable of being raised or lowered carrying the cutters. It has their heads, and the saddles all supported by rigid uprights.

This arrangement of driving multiple cutter spindles enables several work surfaces to be machined. Thereby it obtains a great reduction in production time.

It relates to a planer and like a planning machine. This machine has a cross rail capable of being raised or lowered carrying the cutters. It has their heads, and the saddles, all supported by rigid uprights.

This arrangement of driving multiple cutter spindles enables a number of work surfaces to be machined. Thereby it obtains a great reduction in production time.

The essential difference between a planer and a Plano-miller lies in the table movement. In a planer, the table moves to give the cutting speed. But in a Plano-milling machine, the table movement gives the feed.



TYPE OF MILLING MACHINE

SPECIAL TYPE OF MILLING MACHINE

Milling machines of non-conventional design have been developed to suit special purposes. This machine has a spindle for rotating the cutter and provision for moving the tool or the work in different directions. The following special types of machines of interest are described below:

ROTARY TABLE MILLING MACHINE

Here the table is circular in nature and rotates about a vertical axis. Here cutters are set at different heights. Which results in one cutterroughing the workpieceand other one cutter finishing them.

The advantage of this machineis that continuous loading and unloading of workpieces can be done by the operator, while is in progress.

DRUM MILLING MACHINE

It is like a rotary table milling machine.But its workpiece supporting table is called as "DRUM" and it rotates in the horizontal axis.

The face milling cuttersmounted on three or four-spindle heads rotate in a horizontal axis and remove metal from workpieces supported on both the faces of the drum. The finished machined parts are removed after one complete turn of the drum, and then the new ones are clamped to it.

TYPE OF MILLING MACHINE

PLANETARY TYPE MILLING MACHINE

Here workpiece is held stationary while the revolving cutter. The cutter moves in a travelling path to finish acylindrical surface on the workpiece either internally or externally. This machine is also adapted for milling internal and external threads.

PANTOGRAPH MILLING MACHINE

A pantograph machinecan duplicate a job by using a pantograph mechanism. It allows the size of the workpiece reproduced to be smaller than, equal to or greater than the size of a template. Also used for the different model for special purposes.

A pantograph is a mechanism that is generallyconstructed of four bars or links which are connected in the form of a parallelogram.

Pantograph machines are available in two dimensional and three- dimensional models.The two-dimensional pantograph is used for engraving letters or other designs. Whereas three-dimensional models are employedfor copying any shape and contour of the workpiece.

TYPE OF MILLING MACHINE

PROFILING MILLING MACHINE

A profiling machine duplicated the full size of the template attached to the machine. Here the spindle can be adjusted vertically and the cutter horizontally across the table.
A hardenedguide pin regulates the movement of the cutter. The longitudinal movement of the table and the crosswise movement of the cutter head follows the movement of the guide pin on the template.

TRACER CONTROL MILLING MACHINE

The tracer controlled milling machine reproduces irregular or complex shapes of dies, molds by synchronized (matched) movements of the cutter and tracing elements.
The movement of the stylus energized an oil relay system which in turn operates the main hydraulic system for the table. This arrangement is termed as a servomechanism.

Hand milling machine

Plain or horizontal milling machine

COLUMN AND KNEE TYPE

Universal milling machine

Vertical milling machine

Simplex Milling Machine

MANUFACTURING TYPE OR FIXED BED TYPE

Duplex Milling Machine

Triplex Milling Machine

Rotary Table Milling Machine

Drum Milling Machine

ROTARY TABLE MILLING MACHINE

Tracer Controlled Milling Machine

Profile Milling Machine

Planetary Milling Machine

NC/CNC Milling Machine

Pantograph Milling Machine

MULTIPLE CHOICE

QUESTION 1

Which type of milling machine is best for heavy-duty milling?

- A. Knee Type
- B. Ram Type
- C. Universal Type
- D. Column and Knee Type

Answer

B. Ram Type

MULTIPLE CHOICE

QUESTION 2

Which milling machine allows for both vertical and horizontal milling?

- **A** Bed Type
- **B** Planer Type
- **C** Universal Type
- **D** Tracer Controlled

Answer

C. Universal Type

MULTIPLE CHOICE

QUESTION 3

Which milling machine is considered as the most versatile type?

- **A** Column and Knee Type
- **B** Universal Type
- **C** Tracer Controlled
- **D** Planer Type

Answer

B. Universal Type

MULTIPLE CHOICE

QUESTION 4

Which type of milling machine is used for producing duplicate parts?

- A Tracer Controlled
- B Planer Type
- C Column and Knee Type
- D Universal Type

Answer

A. Tracer Controlled

MULTIPLE CHOICE

QUESTION 5

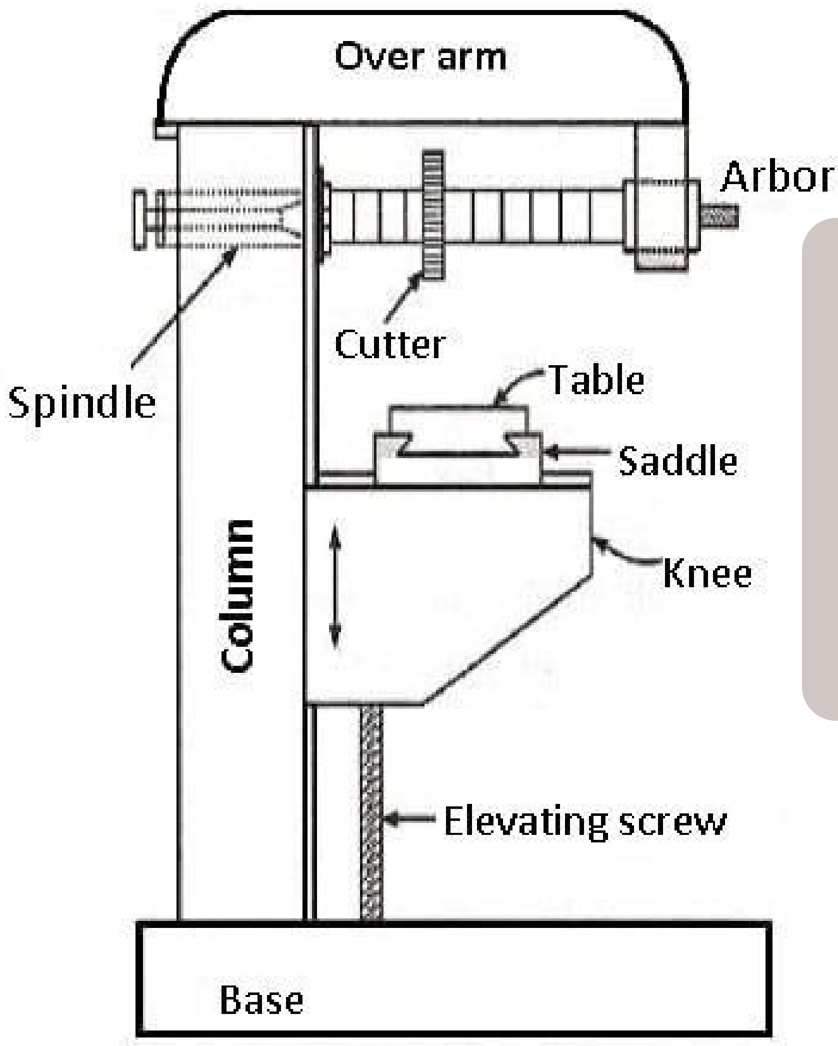
Which milling machine is used for machining large and heavy workpieces?

- A Column and Knee Type
- B Universal Type
- C Planer Type
- D Tracer Controlled

Answer

B. Planer Type

CHARACTERISTICS



Following are the parts ofmilling machine:

1.Base
2.Column
3.Saddle
4.Table
5.Overhanging arm
6.Front brace
7.Spindle
8.Arbor

PARTS AND COMPONENT BREAKDOWN

BASE

·The base of the machine is grey iron casting and serves as a foundation member for all other parts which rests on it.
·The base carries the column at its one end. In some other machines, the base is hollow and works as a reservoir for cutting fluid.

COLUMN

·The column is the main supporting frame mounted on the base.
·It is box-shaped and houses all the driving mechanism for the spindle and feed table. The front vertical face of the column is precisely machined and is equipped with dovetail guideways for supporting the knee.
·The top of the column is finished to hold an overarm that extends beyond the front of the machine.

KNEE

·The knee is a fixed grey iron casting that slides up and down on the vertical ways of the column face.
·The adjustment of height is affected by an elevating screw mounted on the base that also supports the knee.
·The knee houses the feed mechanism of the table and controls to operate it.
·The top face of the knee forms a slideway for the saddle that gives cross travel to the table.

PARTS AND COMPONENT BREAKDOWN

SADDLE

·On the top of the knee is placed the saddle, which slides on guideways set exactly at 90 degrees to the column face.
·A cross feed screw near the top of the knee engages a nut on the bottom of the saddle to move it horizontally, by hand or power, to apply cross-feed.
·The top of the saddle is precisely machined to provide guideways for the table.

TABLE

·It rests on guideways on the saddle and travels longitudinally.
·The top of the table is finished accurately, and T-slots are provided for clamping the work and other fixtures.
·A leadscrew is provided under the table that engages with a nut on the saddle, it helps to move the table horizontally by hand or power.
·The longitudinal travel of the table is possibly limited by fixing trip dogs on the side of the table.
·In universal machines, the table may also be swiveled horizontally. For this purpose, the table is mounted on a circular base, which in its turn is mounted on the saddle.
·The circular base is graduated in degrees.

OVERHANGING ARM

·Overhanging arm act as a support for the arbor.
·It is mounted on the top of the column extends outwards the column face and works as bearing support for the other end of the arbor.
·The Overhanging arm is adjustable so that the bearing support may be provided nearest to the cutter.
·More than one bearing support can be provided for the arbor.

PARTS AND COMPONENT BREAKDOWN

FRONT BRACE

·It is extra support, which provides rigidly to the arbor and the knee. The front base is fitted between the knee and overarm.

·The front brace is slotted to allow for the adjustment of the height of the knee relative to the overarm.

SPINDLE

·The spindle of the machine is located in the upper part of the column and receives power from the motor through belts, gears, and clutches and transmit it to the arbor.

·The front end of the spindle just projects from the column face and is provided with a tapered hole into which various cutting tools and arbor may be inserted.

·The accuracy in metal machining by the cutter depends on the strength, accuracy and rigidity of the spindle.

ARBOR

·Arbor is an extension of the machine spindle on which milling cutters are securely mounted and rotated.

·These are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose.

·The taper shank of the arbor match to the Morse taper or self-release taper whose value is 7:24.

·The arbor may be supported at the farthest end from the overhanging arm or maybe of cantilever type which is called stub arbor.

FUNDAMENTAL OF MILLING MACHINE

The milling process performed may be grouped under three separate headings.

1.Peripheral milling

2.Face milling

3.End milling.

Peripheral Milling

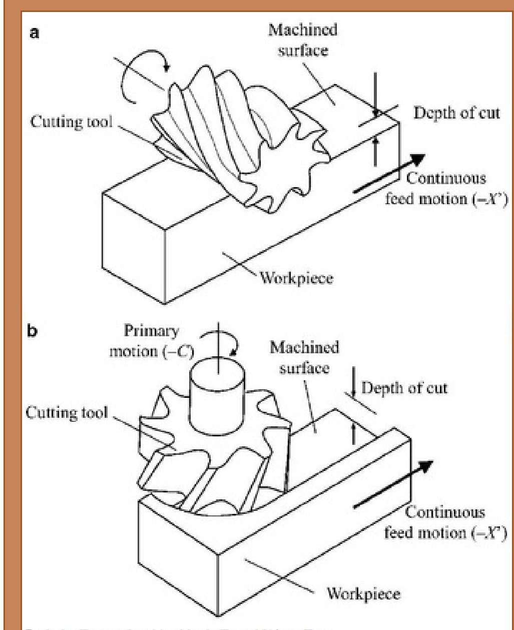
It is the operation performed by milling cutter to produce a machined surface parallel to the axis of rotation of the cutter.

Peripheral milling's goal is the effective removal of large amounts of material from workpieces. This effectiveness comes from using the cutter's sides rather than its tip, which enables faster material removal rates. Peripheral milling maximizes the use of the cutter's whole periphery, unlike face milling, which just exposes the cutter's tip to the workpiece. It is the best option for applications requiring quick material removal and productivity benefits.

Peripheral milling is classified under 2 types.

1.Up milling

2.Down milling



Two basic milling operations: (a) peripheral milling and (b) face milling

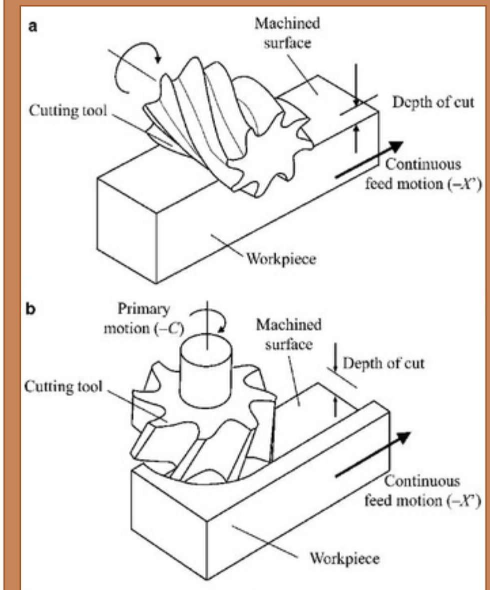
FUNDAMENTAL OF MILLING MACHINE

Face Milling

It is the operation performed by a milling cutter to produce a flat-machined surface perpendicular to the axis of rotation of the cutter.

The purpose of face milling is to create a flat surface on the workpiece, achieved by cutting with the ends of the cutter rather than the sides. This process is essential for achieving precise, flat, and smooth surfaces on materials, such as plates or bars. Face mills, with their larger diameter compared to the workpiece width, commonly allow for efficient material removal in a single pass, making them ideal for tasks in which a flat, even face is required.

The peripheral cutting edges of the cutter do the actual cutting, whereas the face cutting edges finish up the work surface by removing a very small amount of the metal.



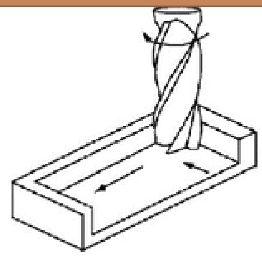
Two basic milling operations: (a) peripheral milling and (b) face milling

FUNDAMENTAL OF MILLING MACHINE

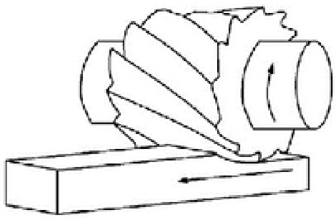
End Milling

End milling is a machining process used to cut or shape materials using a rotating cutting tool with multiple cutting edges. End milling is the combination of peripheral and face milling. The tool, called an end mill, has cutting edges on the bottom and sides. It rotates against the workpiece to remove material, creating features such as slots, pockets, and contours.

During end milling, the end mill rotates while being fed into the workpiece along one or more axes. This motion removes material from the workpiece to create the desired shape or feature. End milling is commonly used in machining operations across various industries, including manufacturing, aerospace, automotive, and more.



(a) End milling



(b) Peripheral milling

FUNDAMENTAL OF MILLING MACHINE

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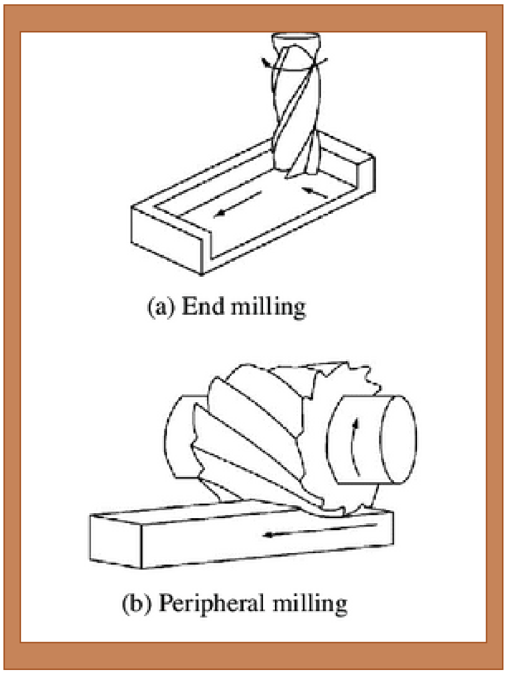
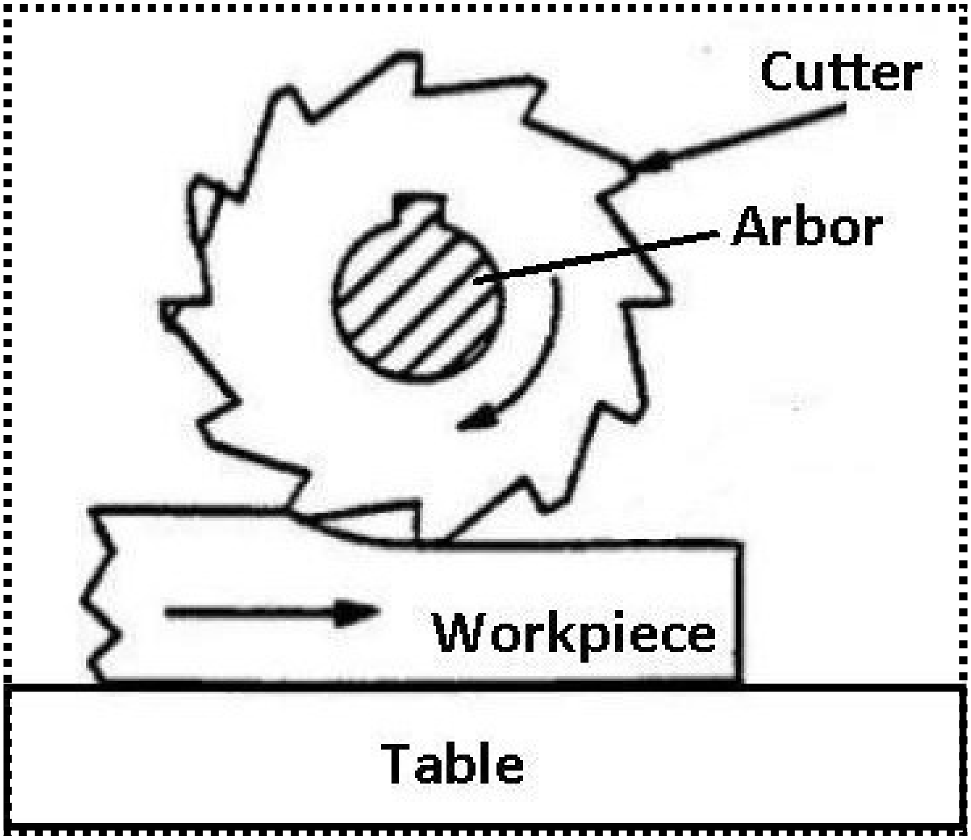


WORKING PRINCIPLE OF MILLING MACHINE

- The working principle of the milling machine, applied in the metal removing operation on a milling machine.
- The work is rigidly clampedon the table of the machine and revolving multi teeth cutter mounted either on a spindle.

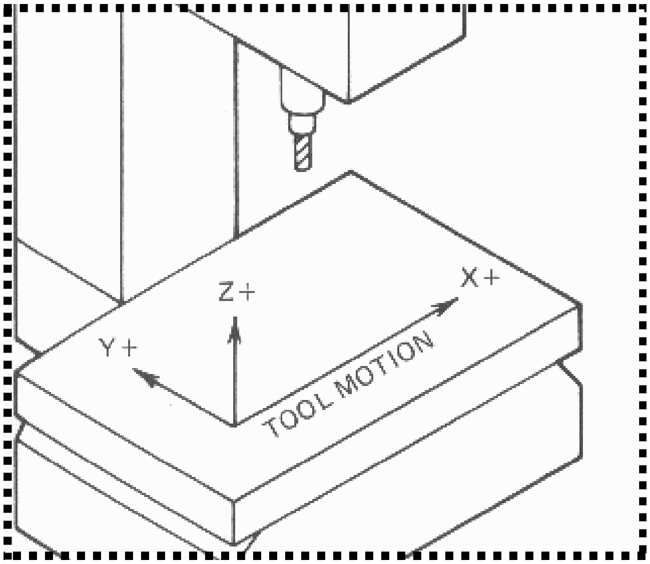


- The cutter revolves at a normal speed and the work fed slowly past the cutter. The work can be fed in a longitudinal, vertical, or cross direction. As the work progress further, the cutter teeth remove the metal from the work surface to produce the desired shape.

WORKING PRINCIPLE OF MILLING MACHINE

Principle of X,Y and Z

- **In milling, the X, Y, and Z axes define a three-dimensional coordinate system that controls the movement of the cutting tool and the workpiece. Understanding these axes is essential for creating precise and intricate designs.**



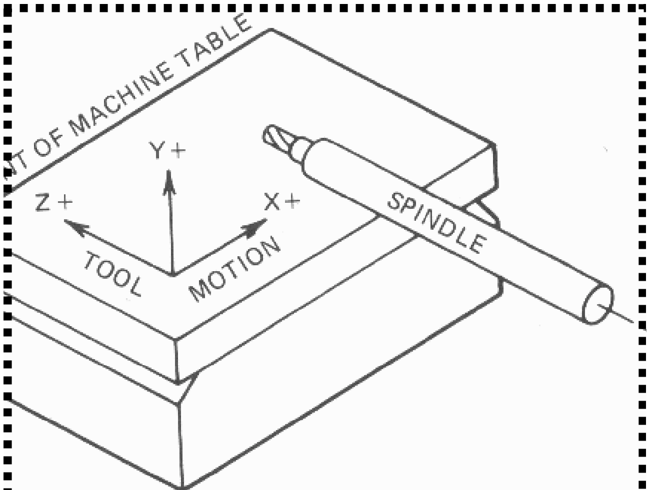


FIGURE 2.2 Axis nomenclature for a horizontal spindle N/C mill.

Here's a breakdown of each axis and its principle:

- **X-axis: This represents the leftward and rightward movement of the table (or sometimes the spindle depending on the machine). A positive X movement shifts the table to the left relative to the tool, effectively moving the tool to the right.**
- **Y-axis: This represents the forward and backward movement of the table. A positive Y movement moves the table away from the operator, again causing the tool to move forward relative to the workpiece.**
- **Z-axis: This represents the upward and downward movement of the cutting tool itself. A positive Z movement raises the tool away from the workpiece, while a negative Z movement feeds the tool deeper into the material.**

WORKING PRINCIPLE OF MILLING MACHINE

Principle of X,Y and Z

- **It's important to note that these are the most common conventions, and some machines might have variations. Always refer to the specific machine's documentation for exact axis definitions.**
- **Here are some additional points to consider:**
- **A common reference point (often the bottom left corner of the workpiece) is used as the origin (0, 0, 0) for the coordinate system.**
- **Milling programs use G-code instructions that specify movements along these axes to create the desired toolpath.**
- **More advanced CNC milling machines may have additional rotary axes (often designated A, B, C) that allow for more complex machining operations on multiple sides of a workpiece.**

REVISION

Parts of milling machine:
1.Base
2.Column
3.Saddle
4.Table
5.Overhanging arm
6.Front brace
7.Spindle
8.Arbor

The milling process performed may be grouped under three separate headings.
1.Peripheral milling
2.Face milling
3.End milling.

In milling, the X, Y, and Z axes define a three-dimensional coordinate system that controls the movement of the cutting tool and the workpiece.

FILL IN THE BLANKS

QUESTION 1

In a milling machine, material is _______ by the rotating cutter.

removed

FILL IN THE BLANKS

QUESTION 2

The main motion in a milling operation is when the _______ moves against the workpiece.

cutter

FILL IN THE BLANKS

QUESTION 3

The role of the feed motion in a milling operation is to _______ the workpiece under the cutter.

move

FILL IN THE BLANKS

QUESTION 4

During climb milling, the cutter rotates in the _______ direction as the feed.

same

FILL IN THE BLANKS

QUESTION 5

Using a large depth of cut in a milling operation results in _______ tool life.

decreased

Different types of operations performed on milling machine

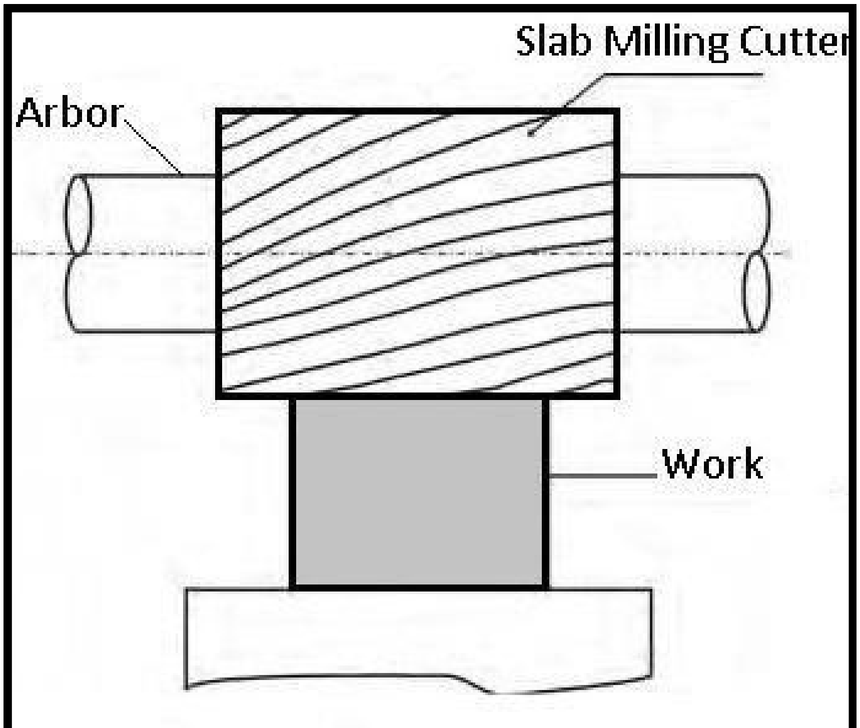
Following are the different types of operations performed on milling machine:

- ·Plain Milling Operation
- ·Face Milling Operation
- ·Side Milling Operation
- ·Straddle Milling Operation
- ·Angular Milling Operation
- ·Gang Milling Operation
- ·Form Milling Operation
- ·Profile Milling Operation

- ·End Milling Operation
- ·Saw Milling Operation
- ·Milling Keyways, Grooves, and Slot
- ·Gear Milling
- ·Helical Milling
- ·Cam Milling
- ·Thread Milling

Different types of operations performed on milling machine

PLAIN MILLING

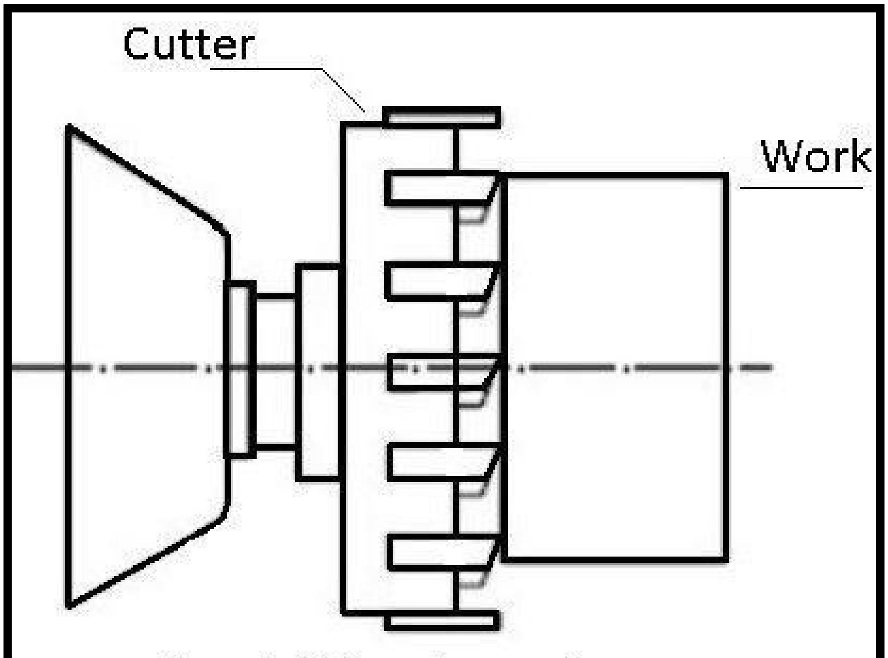


Plain Milling Operation

- The plain milling is the most common types of milling machine operations.
- Plain milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.
- To perform the operation, the work and the cutter are secured properly on the machine.
- The depth of cut is set by rotating the vertical feed screw of the table. And the machine is started after selecting the right speed and feed.

Different types of operations performed on milling machine

FACE MILLING

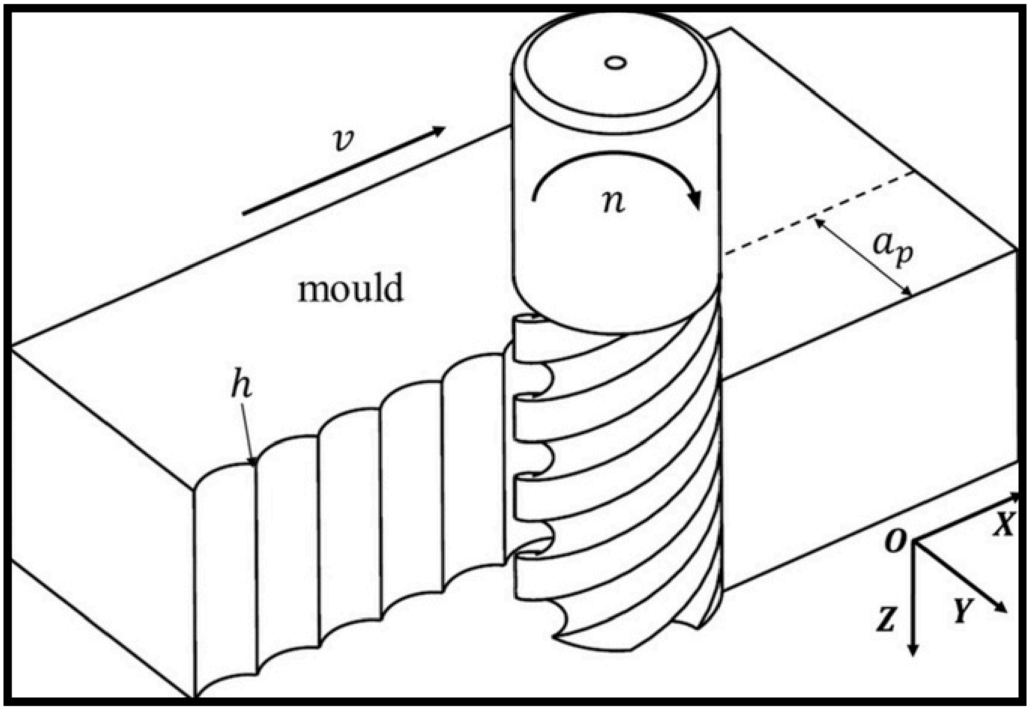


Face Milling Operation

- **The face milling is the simplest milling machine operations.**
- **This operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface.**
- **The operation is carried in plain milling, and the cutter is mounted on a stub arbor to design a flat surface.**
- **The depth of cut is adjusted by rotating the cross feed screw of the table.**

Different types of operations performed on milling machine

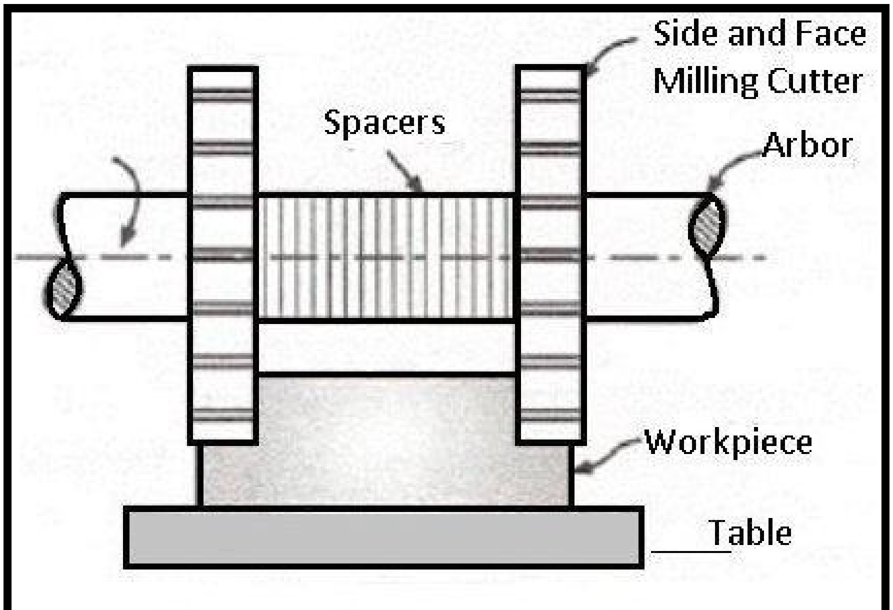
SIDE MILLING



- Side milling is the operation of producing a flat vertical surface on the side of a workpiece by using a side milling cutter.
- The depth of cut is set by rotating the vertical feed screw of the table.

Different types of operations performed on milling machine

STRADDLE MILLING

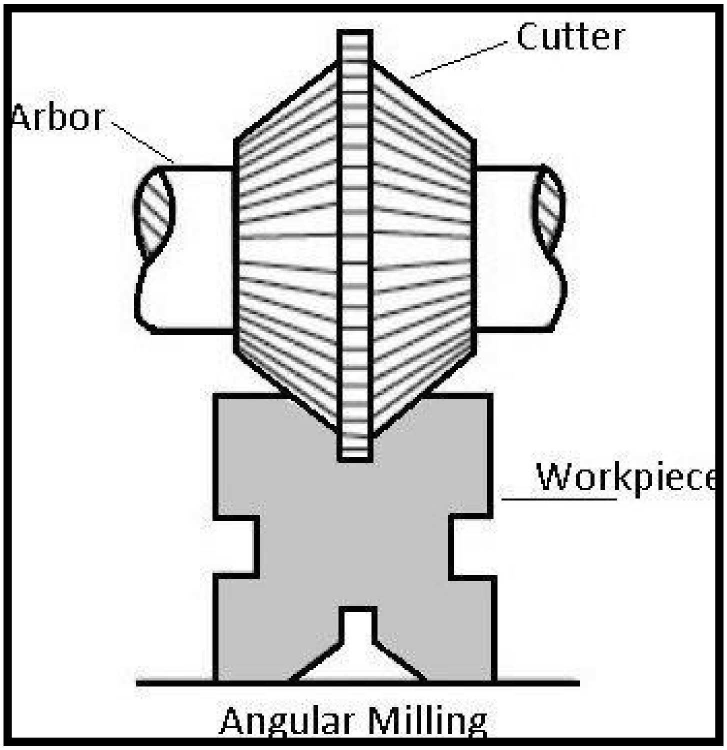


Straddle Milling Operation

- **Straddle milling is the operation of producing a flat vertical surface on both sides of a workpiece by using two side milling cutters mounted on the same arbor.**
- **Distance between the two cutters is adjusted by using suitable spacing collars.**
- **The straddle milling is commonly used to design a square or hexagonal surfaces.**

Different types of operations performed on milling machine

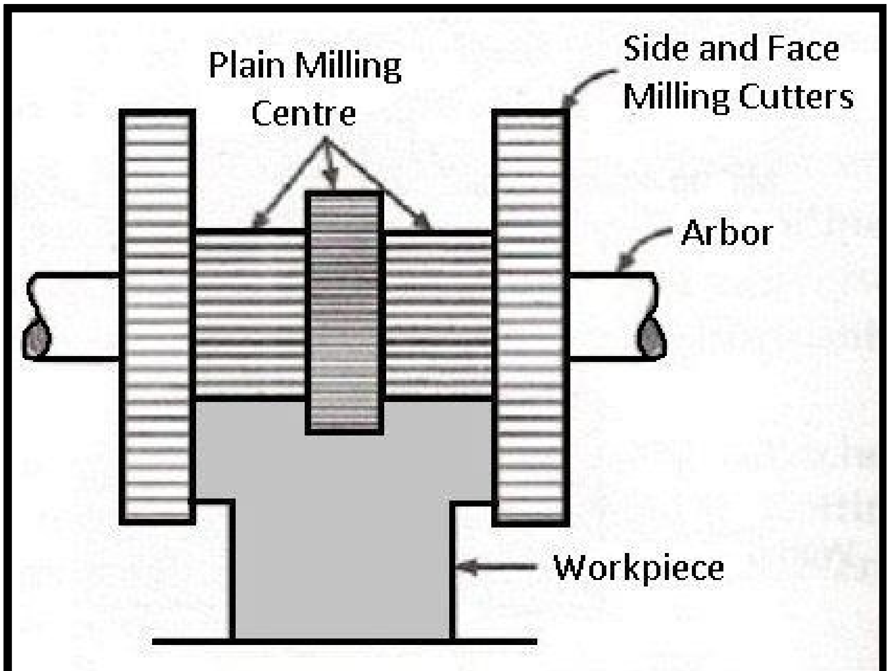
ANGULAR MILLING



- The angular milling is the operation of producing an angular surface on a workpiece other than at right angles of the axis of the milling machine spindle.
- The angular groove may be single or double angle and may be of varying included angle according to the type and contour of the angular cutter used.
- One simple example of angular milling is the production of V-blocks.

Different types of operations performed on milling machine

GANG MILLING

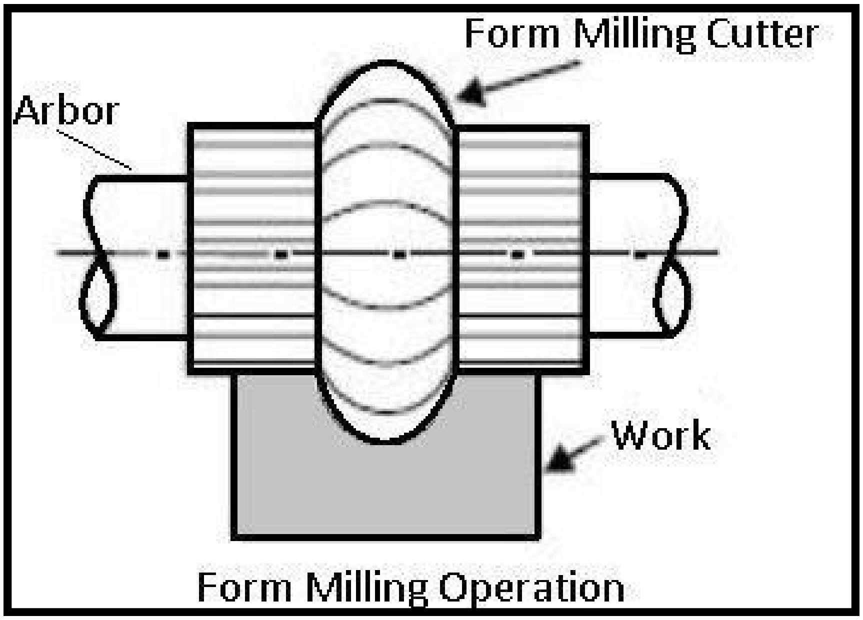


Gang Milling Operation

- **The gang milling is the operation of machining several surfaces of a workpiece simultaneously by feeding the table against a number of cutters having the same or different diameters mounted on the arbor of the machine.**
- **The method saves much of machining time and is widely used in repetitive work.**
- **Cutting speed of a gang of cutters is calculated from the cutter of the largest diameter.**

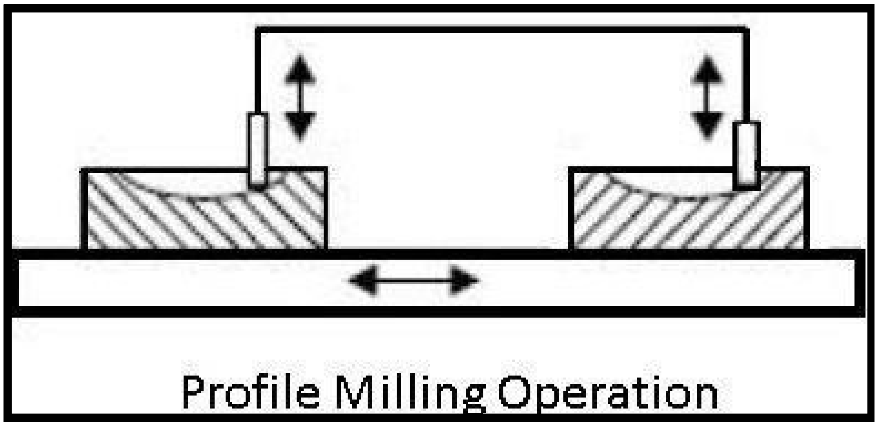
Different types of operations performed on milling machine

FORM MILLING



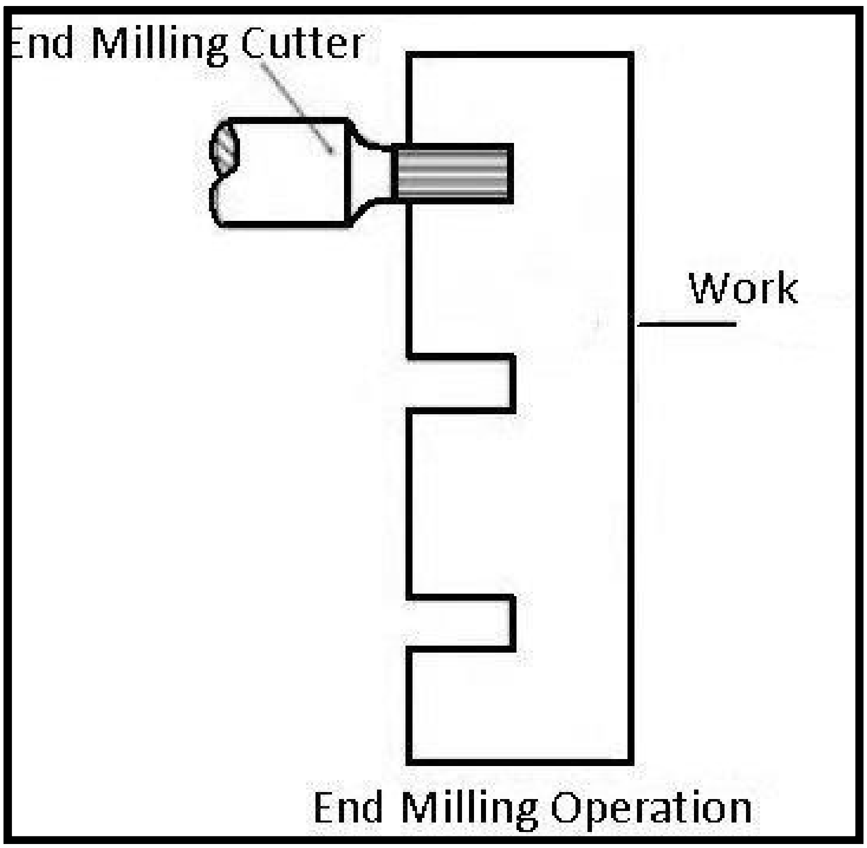
- The form milling is the operation of producing irregular contours by using form cutters.
- The irregular shape may be convex, concave, or of any other shape. After machining, the formed surface is inspected by a template gauge.
- The cutting rate for form milling is 20% to 30%less than that of the plain milling.

PROFILE MILLING



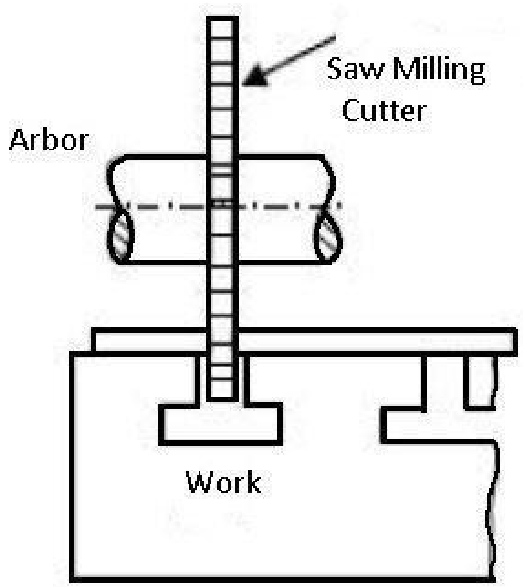
- Profile milling is the operation of reproduction an outline of a template or complex shape of a master dies on a workpiece.
- Different cutters are used for profile milling. An end mill is one of the widely used milling cutters in profile milling work.

END MILLING



- The end milling is the operation of producing a flat surface which may be vertical, horizontal or at an angle in reference to the table surface.
- The cutter used is an end mill. The end milling cutters are also used for the production of slots, grooves or keyways.
- A vertical milling machine is more suitable for end milling operation.

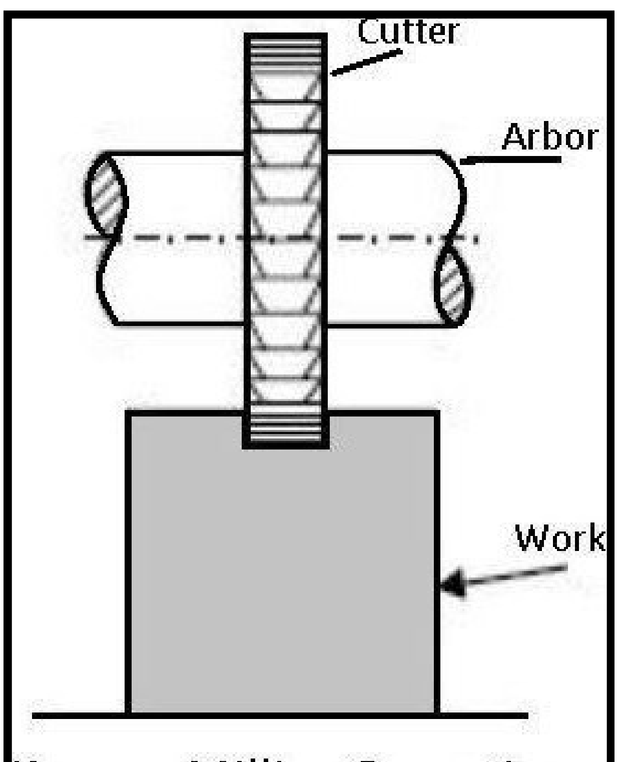
SAW MILLING



Saw Milling Opeartion

- **Saw-milling is the operationof producing narrow slots or grooves on a workpiece by using a saw-milling cutter.**
- **The saw-milling also performed for complete parting-off operation.**
- **The cutter and the workpiece are set in a mannerso that the cutter is directly placedover one of the T-slots of the table.**

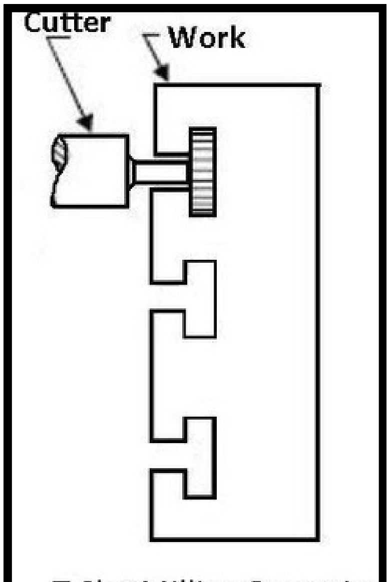
END MILLING



Keyway Milling Operation

- **The operation of producing keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.**
- **It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.**
- **The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using endmills.**

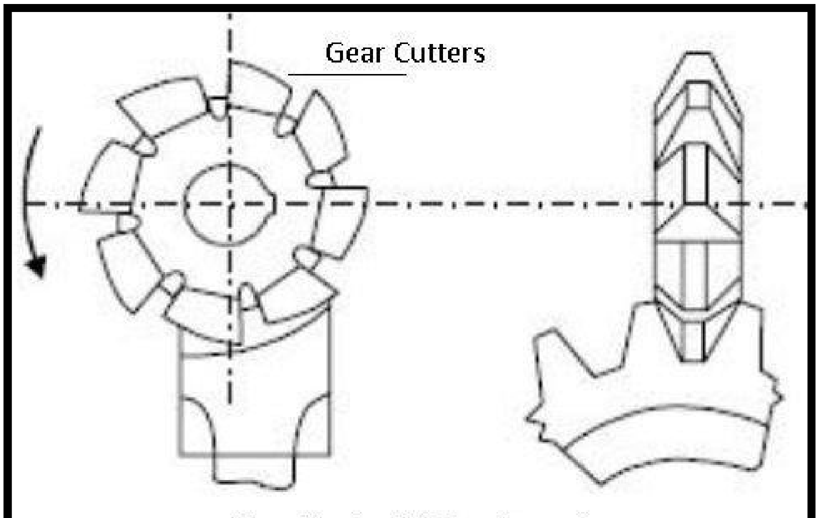
T SLOT MILLING



T-Slot Milling Operation

- A dovetail slot or T-slot is manufactured by using special types of cutters designed to give the required shape on the workpiece.
- The second slot is cut at right angles to the first slot by feeding the work past the cutter.
- A woodruff key is designed by using a woodruff key slot cutter.
- Standard keyways are cut on the shaft by using side milling cutters or end mills.
- ·The cutter is set exactly at the center line of the workpiece and then the cut is taken.

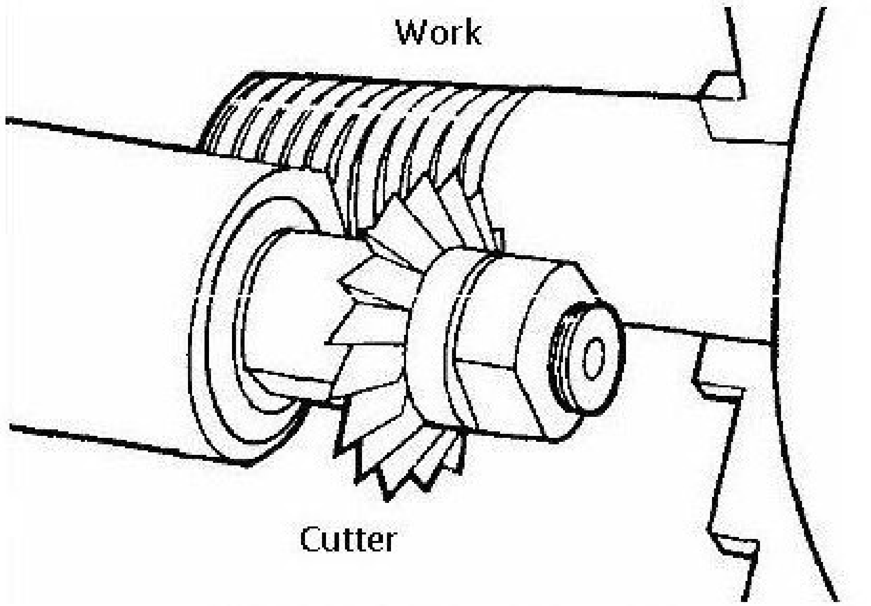
GEAR CUTTING MILLING



Gear Cutting Milling Operation

- The gear cutting operation is performed in a milling machine by using a form-relieved cutter. The cutter may be a cylindrical type or end mill type.
- ·The cutter profile fits exactly with the tooth space of the gear.
- ·Equally spaced gear teeth are cut on a gear blank by holding the work on a universal diving head and then indexing it.

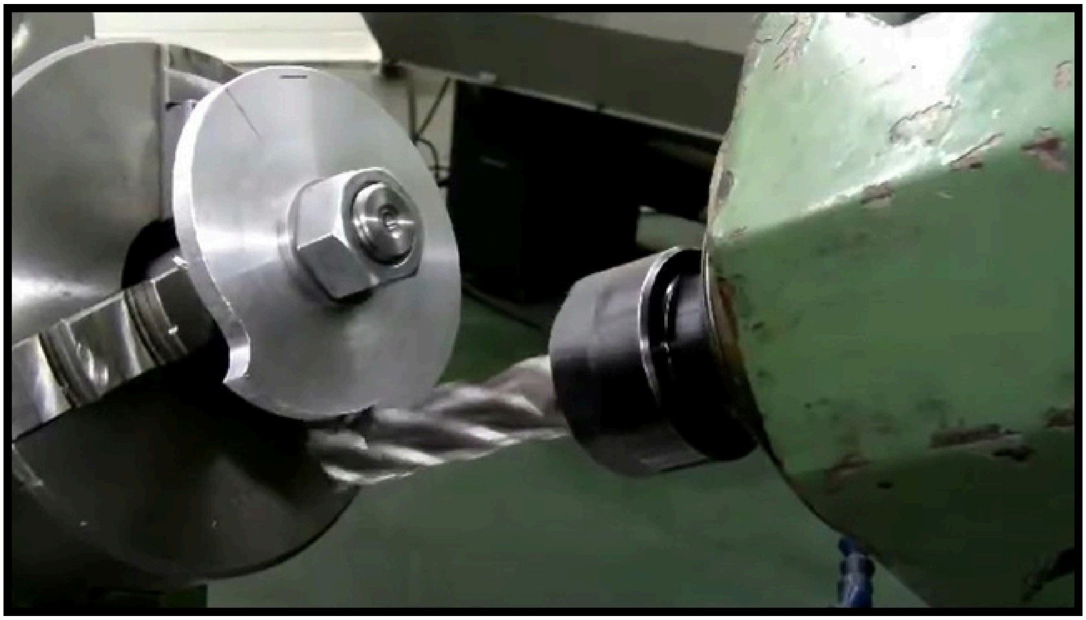
HELICAL MILLING



Helical Milling Operation

- **The helical milling is the operation of producing helical flutes or grooves around the periphery of a cylindrical or conical workpiece.**
- **The operation is performed by rotating the table to the required helix angle. And then by rotating and feeding the workpiece against rotary cutting edges of a milling cutter.**
- **Production of the helical milling cutter, helical gears, cutting helical grooves or flutes on a drill blank or a reamer.**

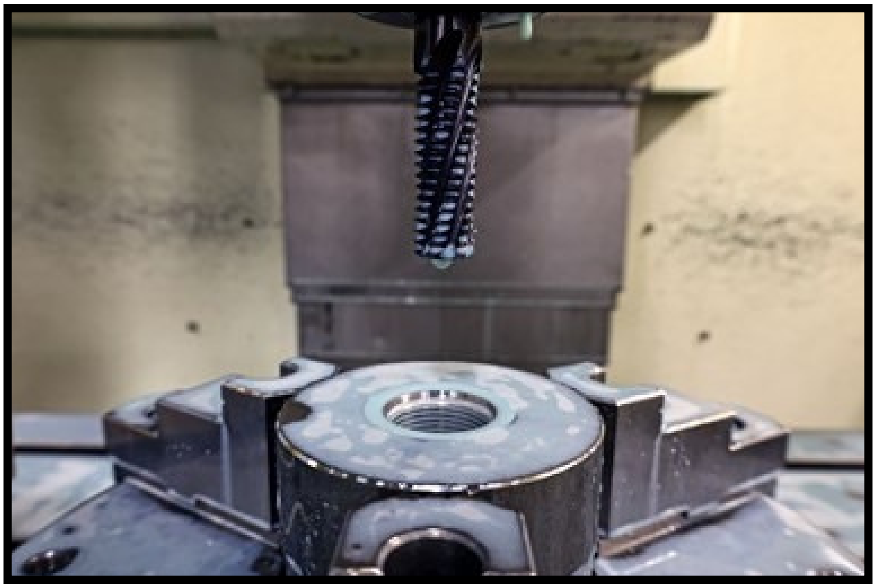
CAM MILLING



- The cam milling is the operation of producing cams in a milling machine by the use of universal dividing head and a vertical milling attachment. The cam blank is mounted at the end of the dividing head spindle and an end mill is held in the vertical milling attachment.

- The axis of the cam blank and the end mill spindle should always remain parallel to each other when setting for cam milling. The dividing head is geared to the table feed screw so that the cam is rotated about its axis while it is fed against the end mill. The axis of the cam can be set from 0 to 90° in reference to the surface of the table for obtaining a different rise of the cam.

THREAD MILLING



- The thread milling machine operations are used to produce threads by using a single or multiple thread milling cutter. Thread milling operation is performed in special thread milling machines to produce accurate threads in small or large quantities.

- The operation requires three driving motions in the machine. One for the cutter, one for the work and the third for the longitudinal movement of the cutter.

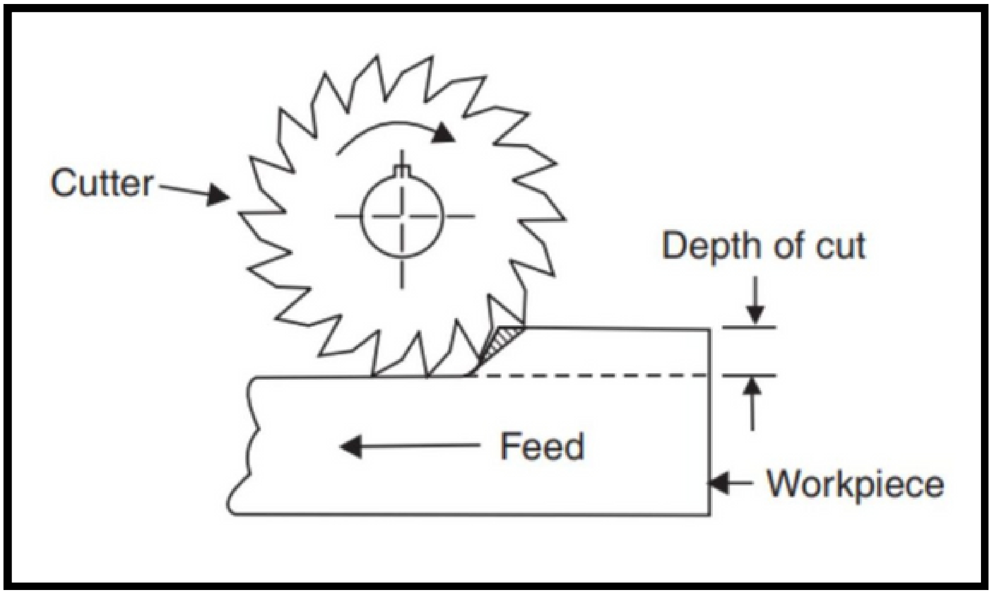
- When the operation is performed by a single thread milling cutter, the cutter head is swiveled to the exact helix angle of the thread. The cutter is rotated on the spindle and the workpiece revolves slowly about its axis. The thread is completed in one cut by setting the cutter to the full depth of the thread and then feeding it along the entire length of the workpiece.

- When the thread is cut by multiple thread milling cutter, the cutter axis and the work spindle are set parallel to each other after adjusting the depth of cut equal to the full depth of the thread. The thread is completed by simply feeding the revolving cutter longitudinal through a distance equal to the pitch length of the thread while the work is rotated through one complete revolution.

Up cut and down cut milling methods

- Each time a milling edge enters a cut, it is subjected to a shock load.
- The right type of contact between the edge and material at the entry and the exit of a cut must be considered for successful milling.
- In a milling operation, the workpiece is fed either with or against the direction of the cutter rotation which affects the start and finish of the cut and if down milling or up milling method is used.

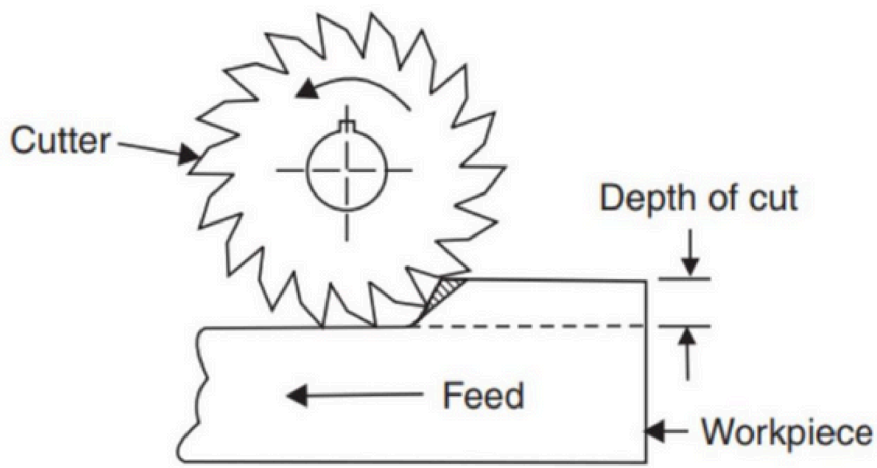
DOWN MILLING



- In down milling (climb milling), the cutting tool is fed with the direction of rotation. Down milling is always the preferred method wherever the machine tool, fixture and workpiece will allow.
- In peripheral down milling, the chip thickness will decrease from the start of cut, gradually reaching zero at the end of cut. This prevents the edge from rubbing and burnishing against the surface before engaging in the cut.
- The large chip thickness is advantageous, and the cutting forces tend to pull the workpiece into the cutter, holding the cutting edge in the cut.
- However, as the cutter tends to be pulled into the workpiece, the machine needs to handle the table-feed play using back-lash elimination. If the tool pulls into the workpiece, feed is unintentionally increased which can lead to excessive chip thickness and edge breaking. Consider using up milling in such cases.

DOWN MILLING

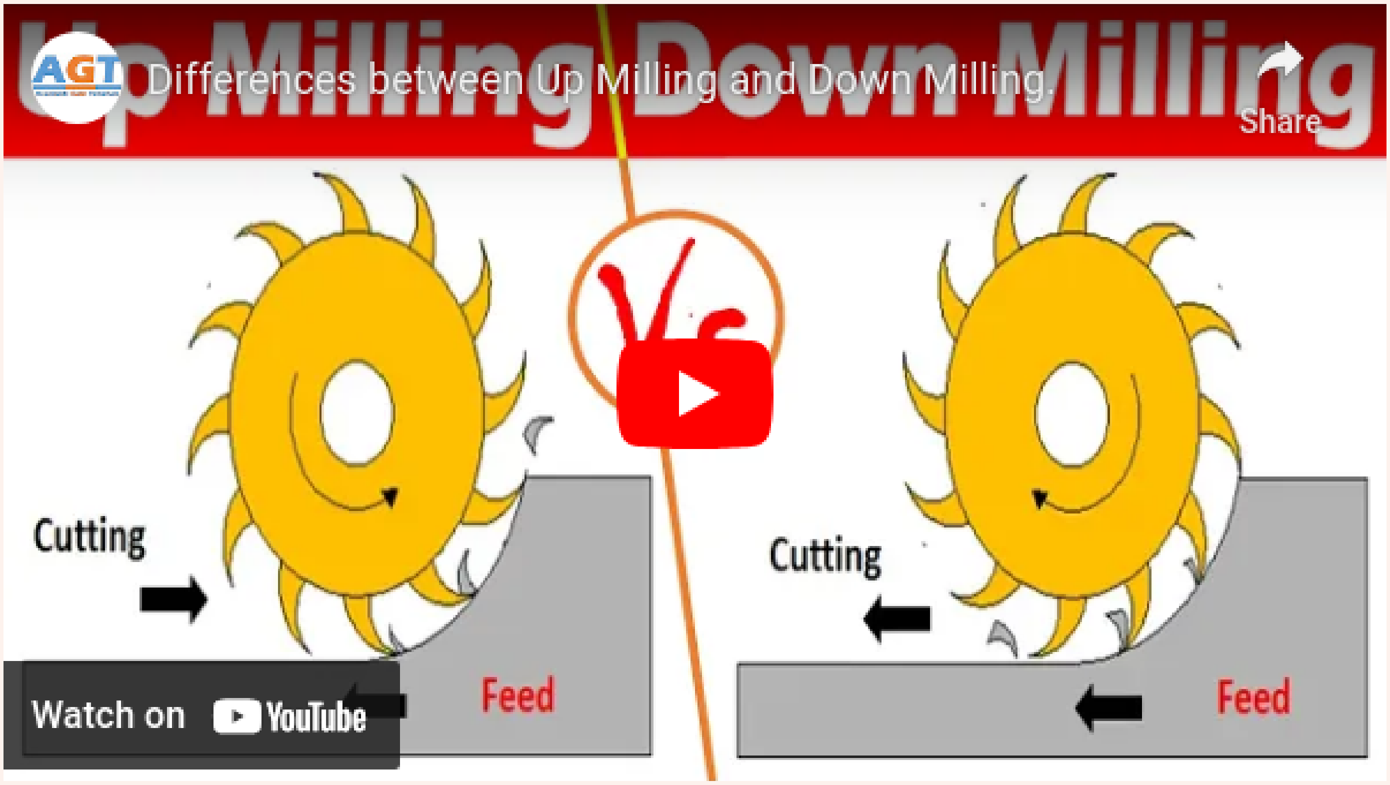
- In up milling (conventional milling), the feed direction of the cutting tool is opposite to its rotation.
- The chip thickness starts at zero and increases toward the end of the cut. The cutting edge must be forced into the cut, creating a rubbing or burnishing effect due to friction, high temperatures and, often times, contact with a work-hardened surface caused by the preceding edge. All this reduces the tool life.



- The thick chips and higher temperature at the exit from cut will cause high tensile stresses that will reduce tool life and often result in rapid edge failure. It can also cause chips to stick or weld to the cutting edge, which will then carry them around to the start of the next cut or cause momentary edge frittering.
- Cutting forces tend to push the cutter and workpiece away from each other and radial forces will tend to lift the workpiece from the table.
- Up milling may be advantageous when large variations in working allowance occur. It is also recommended to use up milling when using ceramic inserts in heat resistant alloys, because ceramics are sensitive to impact at workpiece entry.

Difference Between Up Milling and Down Milling

	Up Milling	Down Milling
Tool rotation direction	Up	Downward
Tool Engagement	Gradual	Rapid
Cutting Forces	Low	High
Tool Life	Increased	Decreased
Surface Finish	Better, Smoother	Challenging
Chip Thickness	Thin	Thick
Vibration and Instability	Less Likely	More Likely
Setup and Control	Cautious approach	Requires careful handling



Different types of operations performed on milling machine:

- ·Plain Milling Operation
- ·Face Milling Operation
- ·Side Milling Operation
- ·Straddle Milling Operation
- ·Angular Milling Operation
- ·Gang Milling Operation
- ·Form Milling Operation
- ·Profile Milling Operation

- ·End Milling Operation
- ·Saw Milling Operation
- ·Milling Keyways, Grooves, and Slot
- ·Gear Milling
- ·Helical Milling
- ·Cam Milling
- ·Thread Milling

Difference Between Up Milling and Down Milling

	Up Milling	Down Milling
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QUESTION 1

In a milling machine, the cutter rotates while the workpiece remains stationary.

TRUE

QUESTION 2

The feed motion in a milling operation is used to control the speed of the cutter.

FALSE

QUESTION 3

During climb milling, the cutter rotates in the opposite direction to the feed.

FALSE

QUESTION 4

Using a large depth of cut in a milling operation results in increased tool life.

FALSE

QUESTION 5

The arbor in a milling machine is used to hold the workpiece.

FALSE

Understanding Milling Cutters

- A milling machine is a machine tool that cuts metal as the workpiece is fed against a rotating multipoint cutter.
- The milling cutter rotates at a very high speed because of the multiple cutting edges, it cuts the metal at a very fast rate. This machine can also hold single or multiple cutters at the same time.

Following are the different types of milling cutters:

1.Solid Cutter

A solid cutter has teeth with the cutter body. The cutters are of smaller diameter and made of one piece material usually of (HSS) high-speed steel.

2.Inserted Teeth Cutter

In large milling cutters, the teeth or blades are inserted or secured in a body of less expensive materials. The blades are held in the cutter body by mechanical means. This arrangement reduces the cost of the cutter and enables economy in maintenance, as a single tooth if broken can be readily replaced.

3.Profile Relieved Cutter

In this category of milling cutters, a relief to the cutting edges is provided by grinding a narrow land at the back of the cutting edges. The profile relieved cutters generate flat, curved or irregular surfaces.

4.Form Relieved Cutter

Form relived cutter also known as surface milling. These cutters have curved relief provided at the backside of the cuttingedges. These cuttersare sharpened by grinding the faces of the teeth. The form relieved cutters are used for generating formed or contoured surfaces.

Understanding Milling Cutters

5.Tipped Solid Cutter

A tipped solid cutter is similar to a solid cutter, except that the cutter teeth are made of cemented carbide or stellite tips which are brazed on the tool shanks of an ordinary tool steel cutter body to lower the cost of the cutter.

6. Arbor Type Cutter

The arbor type cutters are provided with a central hole having a keyway for mounting them directly on the milling machine arbor. Milling cutter shaving tapered or threaded holes are also available. They are mounted on arbors of different designs.

7.Shank Type Cutter

The shank type cutters are provided with straight or tapered shank integral with cutter body. The straight or tapered shanks are inserted into the spindle nose and are fixed to it by a draw bolt.

8.Facing Type Cutter

The facing type cutters are either bolted or attached directly to the spindle nose, or secured on the face of a short arbor called stub arbor. The facing type cutters are mainly used to produce flat surfaces.

9.Right Hand Cutter

A milling cutter is designated as a right-hand cutter which rotates in an anticlockwise direction when viewed from the end of the spindle.

10.Left Hand Cutter

A milling cutter is designated as a left-hand cutter which rotates in a clockwise direction when viewed from the end of the spindle.

Understanding Milling Cutters

11.Parallel or Straight Teeth Cutter

The parallel or straight teeth cutters have their straight or parallel to the axis of rotation of the cutter. The helix angle of parallel teeth cutters is equal to zero.

12.Right Hand Helical Teeth Cutter

These cutters have their teeth cut at an angle to the axis of rotation of the cutter. The cutters may be distinguished by viewing it from one of its end faces when the helical groove or flute will be found to lead from left to right-hand direction of the cutter body.

13.Left Hand Helical Teeth Cutter

These cutters have their teeth cut at an angle to the axis of rotation of the cutter. The cutter may be distinguished by viewing it from one of its end faces when the helical groove or flute will be found to lead from right to left-hand direction of the cutter body.

14.Alternate Helical Teeth Cutter

In some cutters, the alternate teeth are provided with right and left and helical angles.

15.Standard Helical Teeth Cutter

These cutters are a conventional type of milling cutters whose dimensions such as cutter diameter and width, the diameter of the center hole, width and depth of keyways, etc. are standardized.

16.Special Milling Cutter

Special milling cutters are designed to perform special operations which may be the combination of several standard operations. The cutters may have standard or non-standard dimensions.

Types of Milling Cutters

Following are the different types of standard milling cutters:

1.Plain milling cutter.

- Light duty plain milling cutter.
- Heavy-duty plain milling cutter.
- Helical plain milling cutter.

2.Side milling cutter

- Plain side milling cutter.
- Staggered teeth side milling cutter.
- Half side milling cutter.
- Interlocking side milling cutter.

3.Metal slitting saw

- Plain metal slitting saw
- Staggered teeth metal slitting saw

4.Anglemilling cutter

- Single angle milling cutter
- Double angle milling cutter

5.Endmill

- Taper shank end mill
- A straight shank end mill
- Shell end mill

6.Formed cutter

- Convex cutter
- Concave milling cutter
- Corner rounding milling cutter
- Gear cutter
- Thread milling cutter

7.T-slot milling cutter

8.Woodruff key slot milling cutter

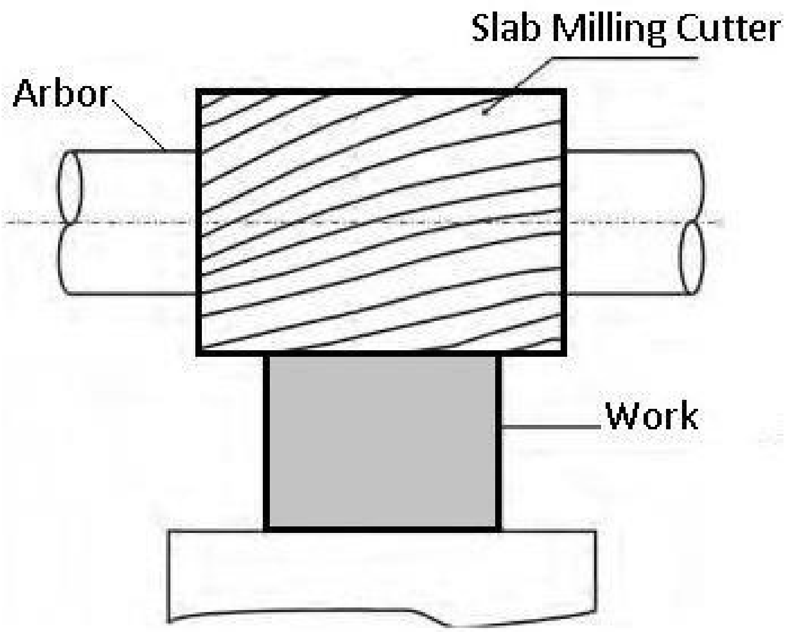
9.Fly cutter

10.Tap and reamer cutter

Types of Milling Cutters

Plain MillingCutter

- This types of milling cutters are circular in shape and have teeth on the circumferential surface only.
- The cutters are intended for the production of the flat surface parallel to the axis of rotation of the spindle.
- The plain milling cutter teeth may be helical or straight according to the size of the cutter.



Plain Milling Operation

- The figure shows a straight teeth plain milling cutter.
- Very wide plain milling cutters are termed as the slabbing cutter.
- These cutters have nicked teeth.
- The nicks are uniformly distributed on the entire periphery of the cutter.
- The object of the nicks is to break up the chips and enable the cutter to take coarse feed. The plain milling cutters are available in diameters from 16 to 160 mm and the width of the cutters range from 20 to 160mmFig.
- A helical plain milling cutter. The different varieties of plain milling cutters are described below.

Types of Milling Cutters

Light Duty Plain Milling Cutter

- **The light-duty plain milling cutters have a face width less than 20 mm and are made with straight teeth parallel to the axis.**
- **The wider cutters are made with helical teeth, with a helix angle of fewer than 25 degrees. These are relatively fine-tooth cutters.**

Heavy Duty Milling Cutter

- **The helical duty plain milling cutters are wider cutters and are used for heavy-duty work.**
- **The helical angle of the teeth ranges from 25 to 45 degree.**
- **The cutters have fewer teeth on the periphery that increases chip space allowing them to take deeper cuts.**
- **They are also known as coarse tooth milling cutters.**

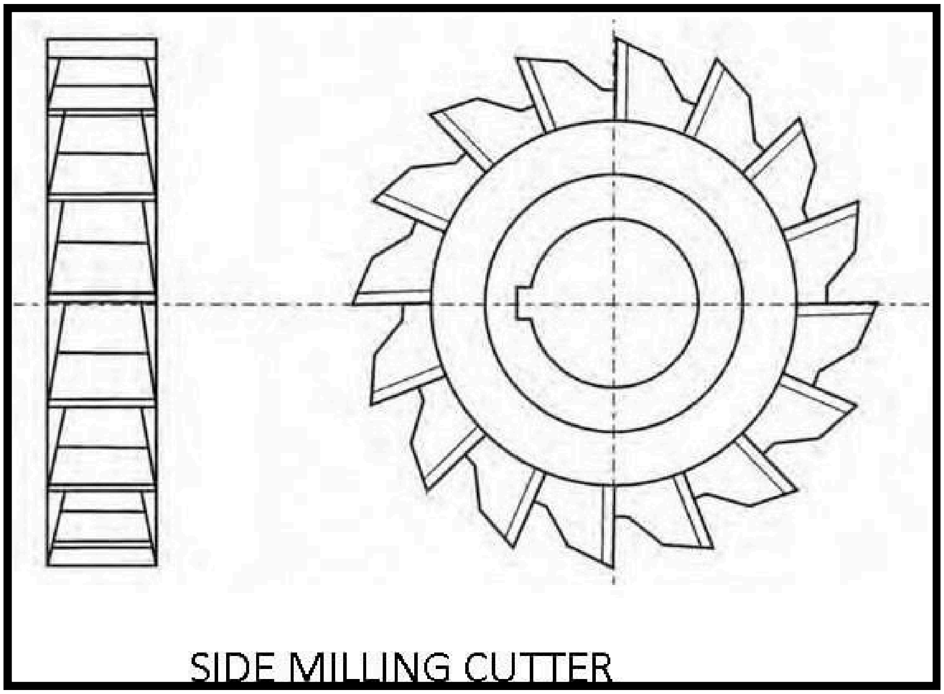
Helical Plain Milling Cutter

- **The helical plain milling cutters have further coarse pitch and the helix angle of the teeth ranges from 45 to 60 degree.**
- **The cutter is useful in profile milling work due to its smooth cutting action and is adapted for taking light cuts on soft steel or brass and where wide surfaces are to be machined.**

Types of Milling Cutters

Side Milling Cutter

- The side milling cutter has teeth on its periphery and on one or both of its sides.
- These types of milling cutters are intended for removing metals from the side of a work a side milling cutter



- The side milling cutter. The side milling cutters are available from 50 to 200 mm in diameter and the width of the cutter ranges from 5 to 32 mm. The diverse types of side milling cutters are described below.

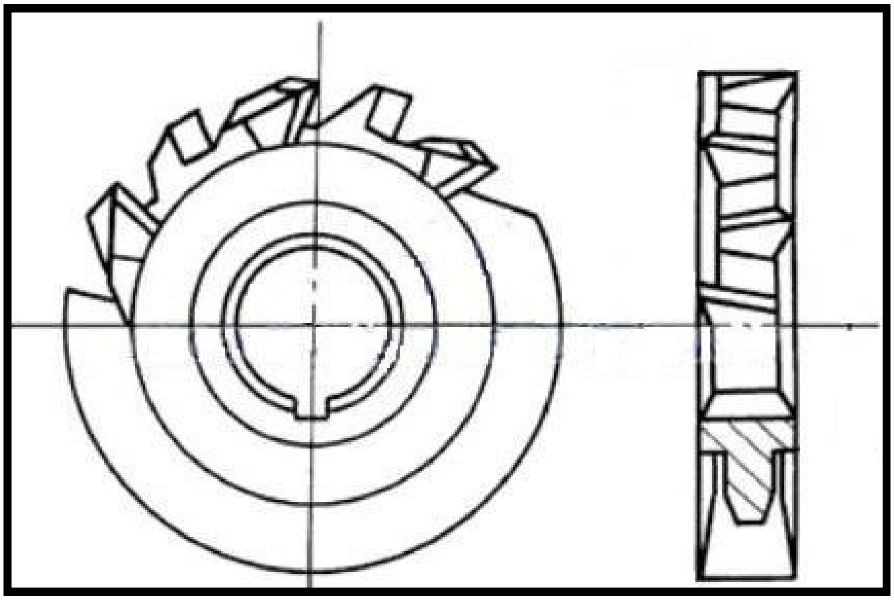
Types of Milling Cutters

Plain Side Milling Cutter

- **The plain side milling cutter has straight circumferential teeth and has side teeth on both of its sides. Two or more such cutters may be mounted on the arbor and different faces of the workpiece may be machined simultaneously.**

Staggered TeethSide Milling Cutter

- **These cutters have an alternate tooth with opposite helix angle and are made of high-speed steel for long lasting durability.**
- **This design of the cutter teeth mostly maximizes the chip space. The cutter is suitable for milling deep, narrow slots or keyways on workpieces. staggered teeth side milling cutter.**



Types of Milling Cutters

Half Side Milling Cutter

- **The half side milling cutter has straight or helical teeth on its circumferential surface and on one of its sides only.**
- **The periphery teeth do the actual cutting, whereas the side teeth size and finish the work.**
- **While straddle milling, when two half side milling cutters are mounted on the arbor at a fixed distance apart to mill the two end faces of the work simultaneously, the cutters are chosen with one having right-hand helical teeth and the other having left-hand helix to counter-balance the end thrust on the arbor.**

Metal SlittingSaw

- **The metal slitting saws resemble a plain milling cutter or a side milling cutter in appearance, but they are of exceedingly small width.**
- **These cutters are used for slotting or for parting-off operation.**
- **A metal slitting saw. The distinct types of metal slitting saws are described below.**

Plain Metal Slitting Saw

- **The plain metal slitting saws are thinner in construction and the width of the cutters is limited to 5mm.**
- **The sides of the cutter are relieved in order that the side faces may not rub against the work.**

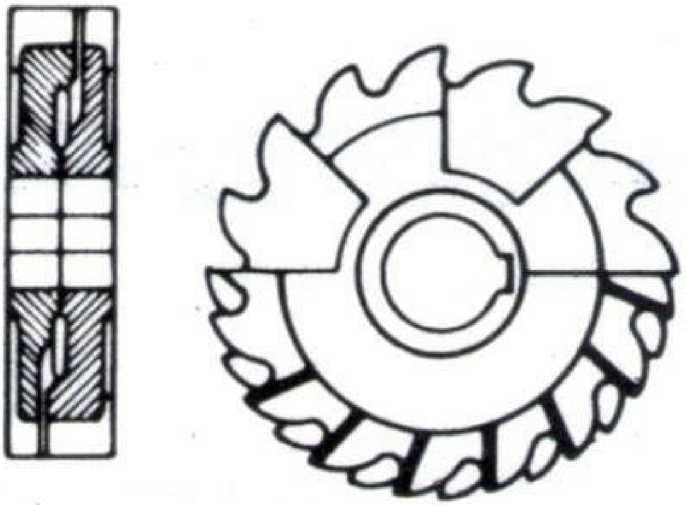
Staggered Teeth Metal Slitting Saws

- **The staggered teeth metal slitting saws resemble a staggered teeth side milling cutter, but the width of the cutter is limited to 6.5 to 7 mm.**
- **The cutter is employed for heavy sawing in steel.**

Types of Milling Cutters

Interlocking Side Milling Cutter

- **The interlocking side milling cutters are formed out of two half side milling cutters or two staggered which are made to interlock to form one unit.**
- **The teeth of the two cutters may be plain or of paths of the teeth overlap when the cutters are assembled.**



INTERLOCKING SIDE MILLING CUTTER

- **The cutters are used for milling cutters in wider slots of accurate width.**
- **The width of the cutter may be varied by inserting spacers of suitable thickness between the two halves of the cutters.**
- **This features the cutter to maintain an accurate width even after repeated sharpening.**
- **The width of the cutter ranges from 10 mm to 32 mm with an adjustment to the maximum of 4 mm.**
- **The cutters are available in diameters ranging from 50 to 200mm. an interlocking side milling cutter.**

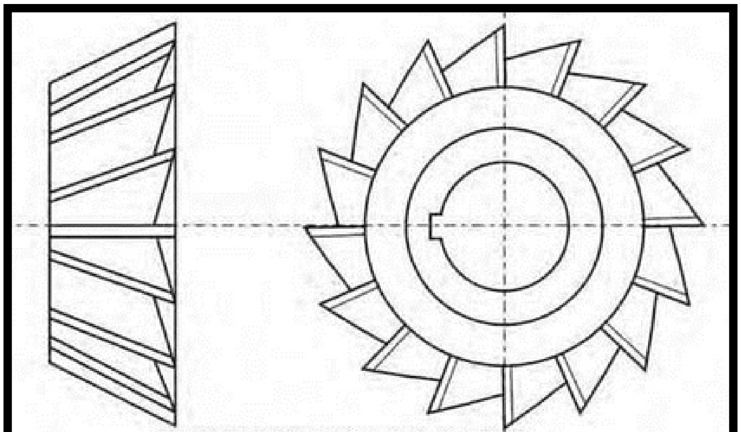
Types of Milling Cutters

Angle MillingCutter

- **These types of milling cutters are made as single or double angle cutters and are used to machine angles other than 90 degrees.**
- **The cutting edges are formed at the conical surface around the circumferential surface of the cutter.**
- **The distinct types of angles milling cutters are described below.**

Single Angle Milling Cutter

- **The single angle milling cutters illustrated in fig, have teeth on the conical or angular face of the cutter and on the large flat side.**
- **The angle of the cutter is identified by the combined angle between the conical face and the large flat face of the cutter.**

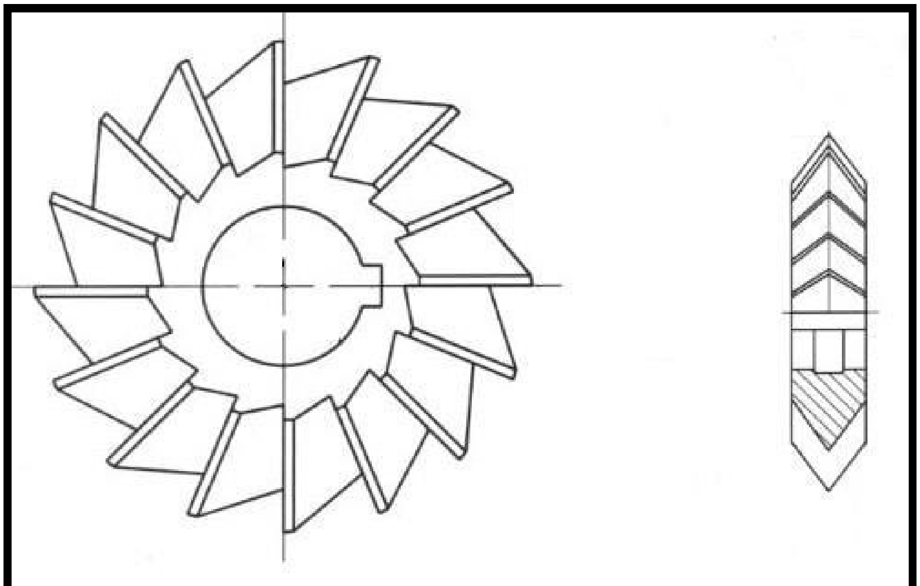

SINGLE ANGLE MILLING CUTTER

- **The cutters having different included angles of 30°, 45°, 60°, 65°, 70°, 75°, 80°, and 85° are available with a diameter of 50mm and width of 12mm. There is another set of cutters having the same range of included angle, but the diameter of the cutters is 63mm and width 28mm.**
- **There is a third set of cutters having included angle of 78°, 75° and 80° degrees, all having 63mm in diameter and 28mm in width.**

Types of Milling Cutters

Double Angle Milling Cutter

- **The double angle milling cutters illustrated in fig. have V-shaped teeth with both conical surfaces at an angle to their end faces.**
- **The angles of teeth may not be symmetrical with respect to a plane at right angles to the cutter axis.**



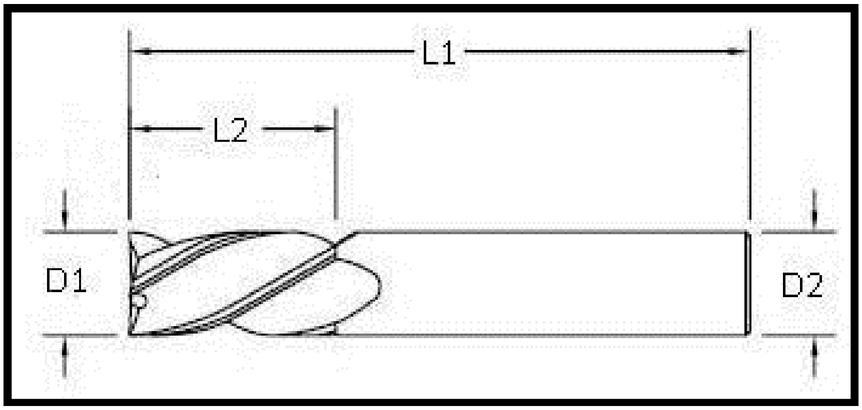
DOUBLE ANGLE MILLING CUTTER

- **The unsymmetrical double angle cutters are available in diameters of 50, 63, 80 and 100 mm and their width vary from 12 to 36 mm.**
- **The cutters are available in different included angles of 55°, 60°, 65°, 70°, 75°, 80°, 90° and 100° degrees.**
- **The equal angles cutters are available in diameters from 56 to 100 mm and having a width ranging from 10 to 18 mm. The included angle of the cutter may be 45°, 60° or 90°.**
- **The double angle milling cutters are used for cutting spiral grooves on a piece of the blank.**

Types of Milling Cutters

End Mill

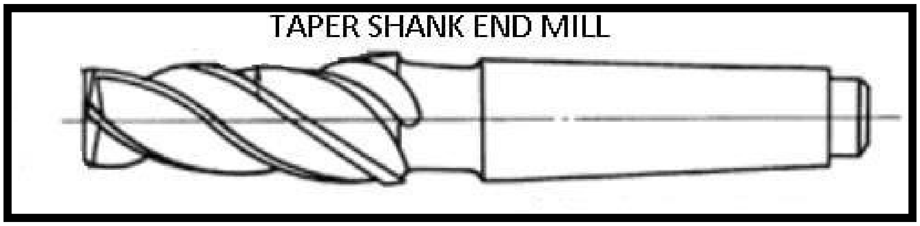
- The end mills have cutting teeth on the end as well as on the periphery of the cutter.
- The peripheral teeth may be straight or helical and helix may be right hand or left hand.



- The end mills are used for small milling operations like cutting slots, producing narrow flat surfaces, machining accurate holes and for profile milling operations.
- The distinct types of end mills are described below.

Taper Shank End Mill

- This cutter has a taperedshank or extensionon one end for mountingand driving the cutters. The cutters may be double fluted or multiple flutes.

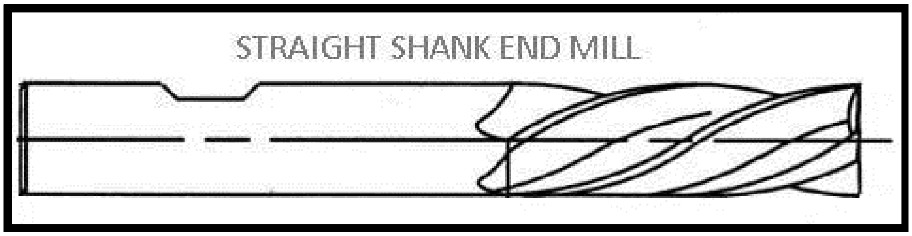


- The teeth are provided on the periphery as well as on both sides of the cutter.
- The taper shank end mills are available from 10 to 63 mm in diameter and may have a tanged end or tapped end for mounting on the arbor. The taper shanks conform to Morse taper No. 1 to No. 5.

Types of Milling Cutters

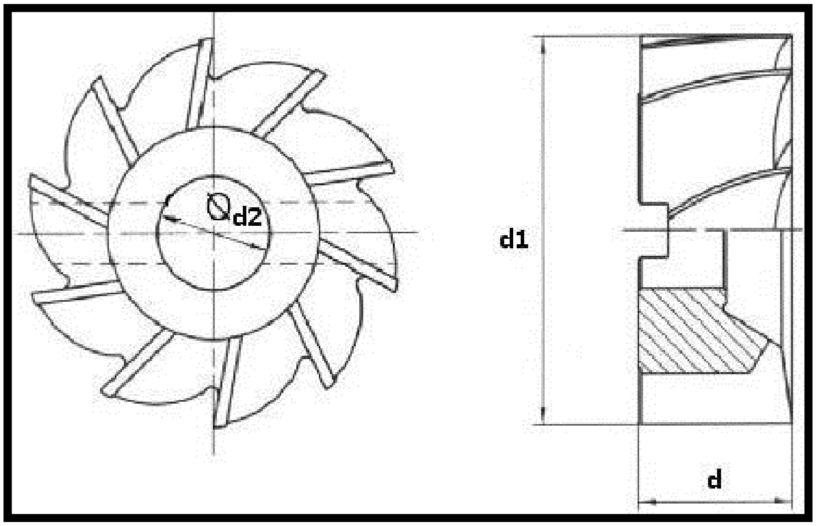
Straight Shank End Mill

- This cutterhas a round shank for mounting and driving the cutters. The cutters teethmay be straight or helical. The diameter of the cutter ranges from 2 mm to 63 mm.



Shell End Mill

- The shellend mills are larger and heavier, and mills providedwith a central hole for mountingthe cutter on a short arbor. This design of the cutter gives economy in tool material as the cutters having different diameter may be interchanged on a single shank.

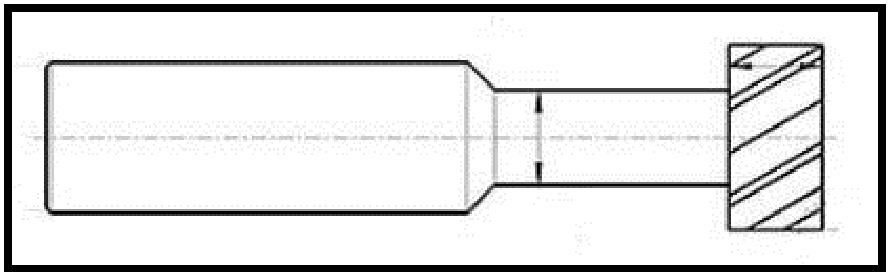


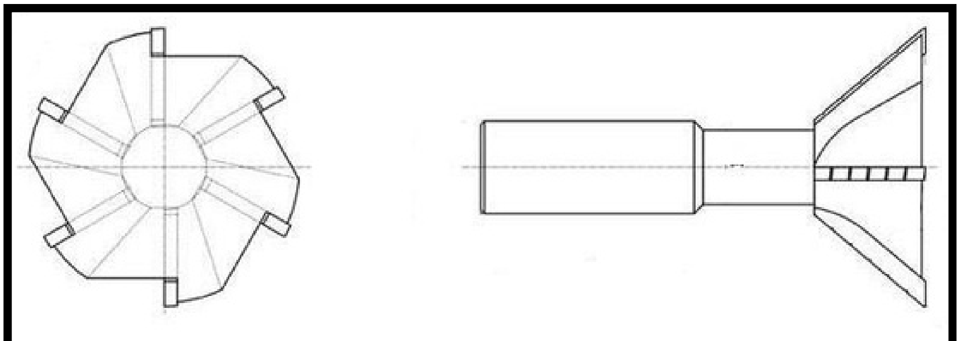
- The cutting edges are provided at the end and round the periphery of the cutter.
- The teeth may be straight or helical and may be left or right-handed.
- The diameter of cutters ranges from 40 to 160 mm and width from 32 to 63 mm.
- The bore diameter of cutters ranges from 16 to 50 mm.

Types of Milling Cutters

T-Slot MillingCutter

- The T-slot milling cutters are a special form of end mills for producing T-slots. Fig illustrated a T-slot and dovetail slot milling cutter.





DOVETAIL SLOT MILLING CUTTER

- The teeth are provided on the periphery as well as on both sides of the cutter.

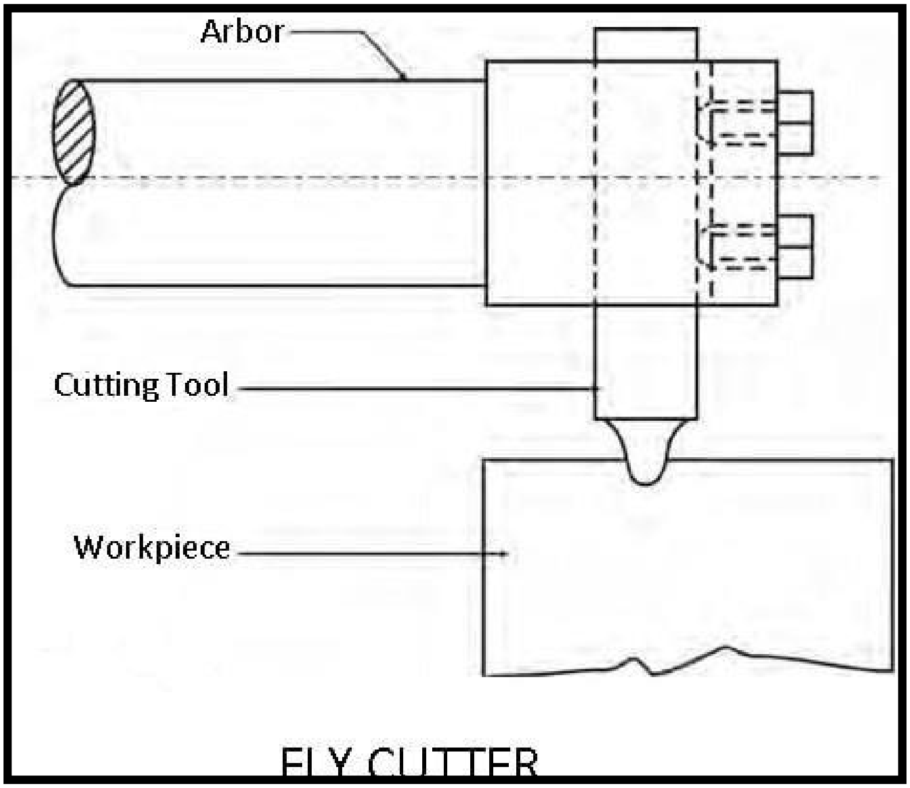
Woodruff Key Slot Milling Cutter

- These cutters are small and similar in construction to a thin, small diameter plain milling cutter, employed to produce Woodruff key slots.
- The cutter is provided with a shank and has staggered or straight teeth.

Types of Milling Cutters

Fly Cutter

- **The fly cutters are simple in form and are used in tool room works.**
- **The fly cutter consists of a single point cutting tool mounted to the end of an arbor.**
- **The forefront formed to reproduce the contoured surface.**
- **This cutter is considered as an emergency tool when the standard cutters are not available.**



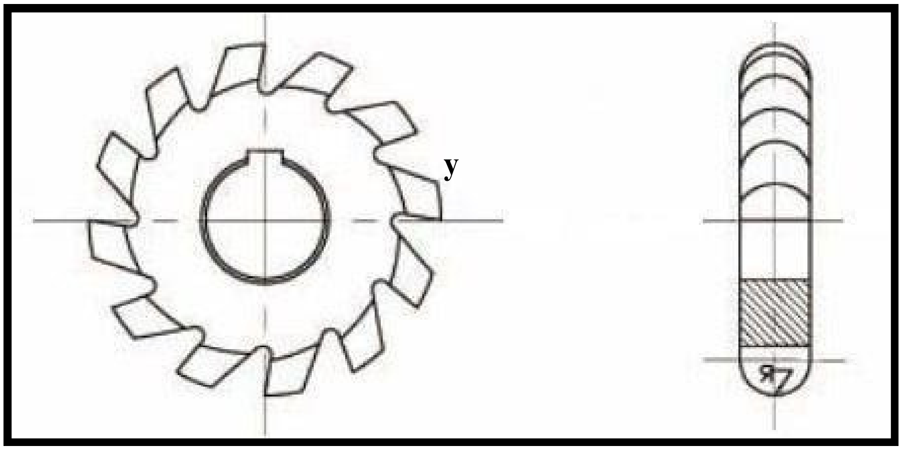
Formed Cutter

- **The formed cutter shave irregular profiles on the cutting edges to generate an irregular outline of the work. The distinct types of standard formed cutters are described below.**

Types of Milling Cutters

Convex Milling Cutter

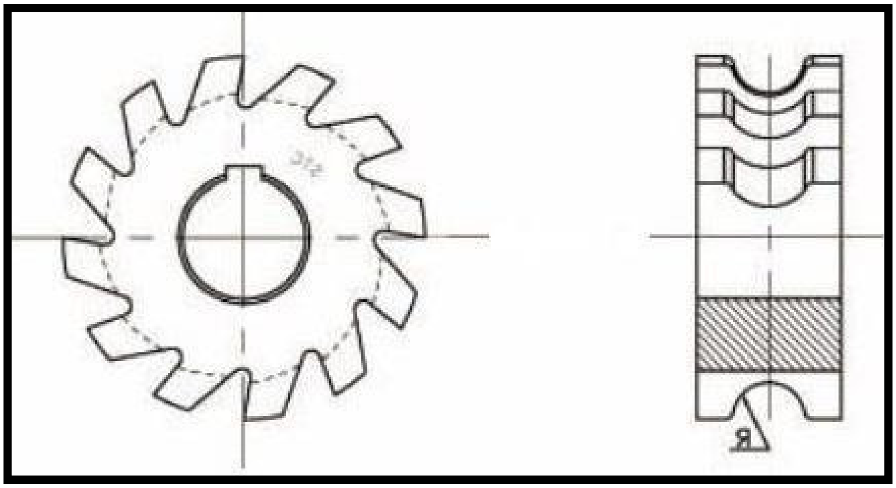
- **The convex milling cutters have teeth curved outwards on the circumferential surface to form the contour of a semicircle.**



- **The cutter produces a concave semicircle surface on a workpiece.**
- **The diameter of the cutter ranges from 50 mm to 125mm. And the radius of the semicircle varies from 1.6 to 20mm.**

Concave Milling Cutter

- **The concave milling cutters have teeth curved inwards on the circumferential surface to form the contour of a semicircle.**

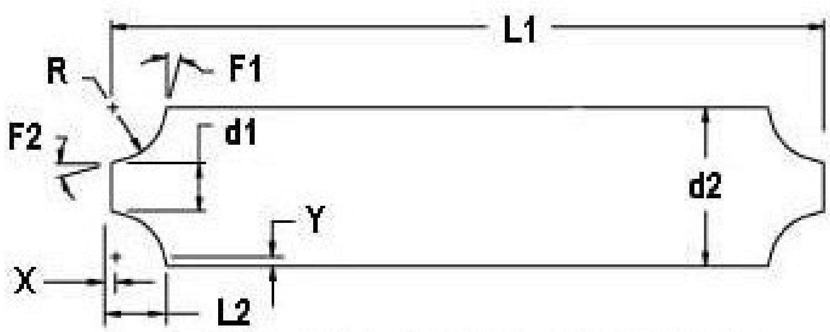


- **The concave milling cutters produce a convex semicircle surface on a work piece.**
- **The diameter of the cutter ranges from 56 to 110 mm and the radius of the semicircle varies from 1.5 to 20 mm.**

Types of Milling Cutters

Corner Rounding Milling Cutter

- The corner rounding milling cutters have teeth curved inward on the circumferential surface to form the contour of a quarter circle.



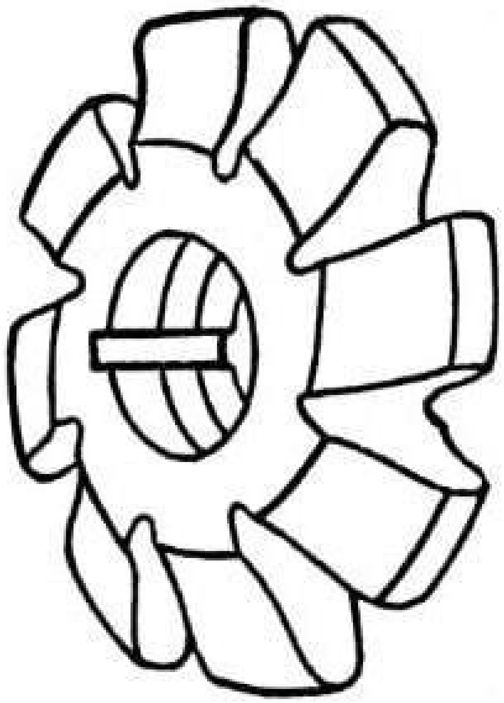
CORNER ROUNDING MILLING CUTTER

- The cutter produces a convex surface having a contour of a quarter circle. The cutter is used for cutting a radius on the corners or edges of the work. The diameterof the cutter ranges from 56 to 110mm and the radius of the quarter circle varies from 1-5 to 20 mm.

Types of Milling Cutters

Gear Cutter

- The gear cutter has formed cutting edges which reproduce the shape of the cutter teeth on the gear blank.
- The shape of the cutter teeth may be involute or cycloidal according to the gear tooth profile.



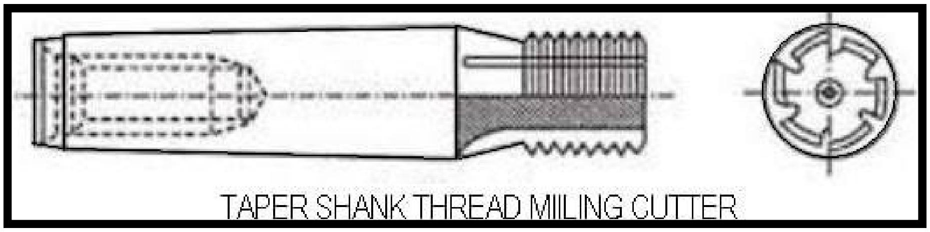
GEAR CUTTER

- The cutter tooth profile should be differently shaped for each pitch of the gear and for each change in a number of teeth on the gear which it is going to cut.
- But in practice, a compromise is affected by using one cutter to cover a range of gear sizes.
- Thus, for cutting gear teeth of the involute profile, eight numbers of cutters are required to cut from a pinion of twelve teeth to a rack and for cutting different numbers of gear teeth.
- A list of cutters with the number of teeth they are intended to cut is given in the table.

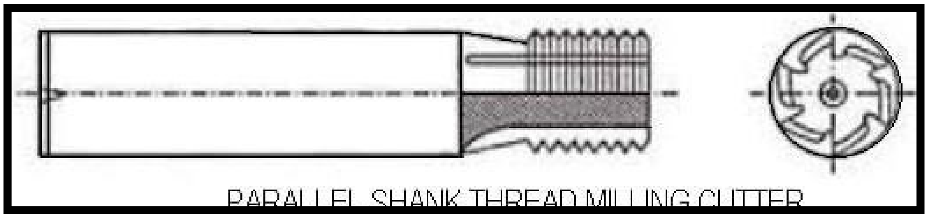
Types of Milling Cutters

Thread Milling Cutter

- The threadmilling cutters are designed to mill threadof specific form and size on a workpiece.
- Usually, worms and acme threads are produced by thread milling cutters.



- The cutters may have parallel or taper shanks.
- The parallel shank thread milling cutters are available in diameters ranging from 8 to 20 mm and the length of the threaded portion varies from 8 to 33 mm.



- The pitch of the thread corresponds to the diameter of the cutter.
- The taper shank thread milling cutters are available in diameters ranging from 16 to 25 mm and the length of threaded portion varies from 16 to 40 mm.

Tap and Reamer Cutter

- The tap and reamer cutters are special type double angle cutters intended for producing grooves of flutes in tap or reamers.
- The pointed end of the tooth is rounded, and the tooth profile corresponds to the type of groove that it is going to make.

The purpose of a milling cutter is to remove material from a workpiece. With that said, milling cutters don't consist of a single blade. While turning operations performed using a lathe generally feature a single-bladed cutting tool, milling cutters consist of multiple blades

Following are the different types of standard milling cutters:

1.Plain milling cutter.

- Light duty plain milling cutter.
- Heavy-duty plain milling cutter.
- Helical plain milling cutter.

2.Side milling cutter

- Plain side milling cutter.
- Staggered teeth side milling cutter.
- Half side milling cutter.
- Interlocking side milling cutter.

3.Metal slitting saw

- Plain metal slitting saw
- Staggered teeth metal slitting saw

4.Anglemilling cutter

- Single angle milling cutter
- Double angle milling cutter

5.Endmill

- Taper shank end mill
- A straight shank end mill
- Shell end mill

6.Formed cutter

- Convex cutter
- Concave milling cutter
- Corner rounding milling cutter
- Gear cutter
- Thread milling cutter

7.T-slot milling cutter

8.Woodruff key slot milling cutter

9.Fly cutter

10.Tap and reamer cutter

MULTIPLE CHOICE QUESTIONS

QUESTION 1

Which type of milling cutter is used for slotting and slitting operations?

A. End Mill

B. Slab Mill

C. Ball Nose Cutter

D. Hollow Mill

B. Slab Mill

MULTIPLE CHOICE QUESTIONS

QUESTION 2

Which milling cutter is used for machining surfaces perpendicular to the cutter axis?

A. Face Mill

B. Woodruff Cutter

C. Hollow Mill

D. T-Slot Cutter

A. Face Mill

MULTIPLE CHOICE QUESTIONS

QUESTION 3

Which type of milling cutter is used for milling T-slots in machine tool tables?

A. Woodruff Cutter

B. T-Slot Cutter

C. Hollow Mill

D. Ball Nose Cutter

B. T-Slot Cutter

MULTIPLE CHOICE QUESTIONS

QUESTION 4

Which milling cutter is used for milling spherical surfaces and contours?

A. Ball Nose Cutter

B. Hollow Mill

C. T-Slot Cutter

D. Woodruff Cutter

A. Ball Nose Cutter

MULTIPLE CHOICE QUESTIONS

QUESTION 5

Which type of milling cutter is used for milling deep slots and cut-off operations?

A. Slab Mill

B. Woodruff Cutter

C. Hollow Mill

D. T-Slot Cutter

C. Hollow Mill

Cutter Holding Devices for Milling Machines

There are several types of holding devices used in a milling machine to hold the cutting tools. Here are some of them:

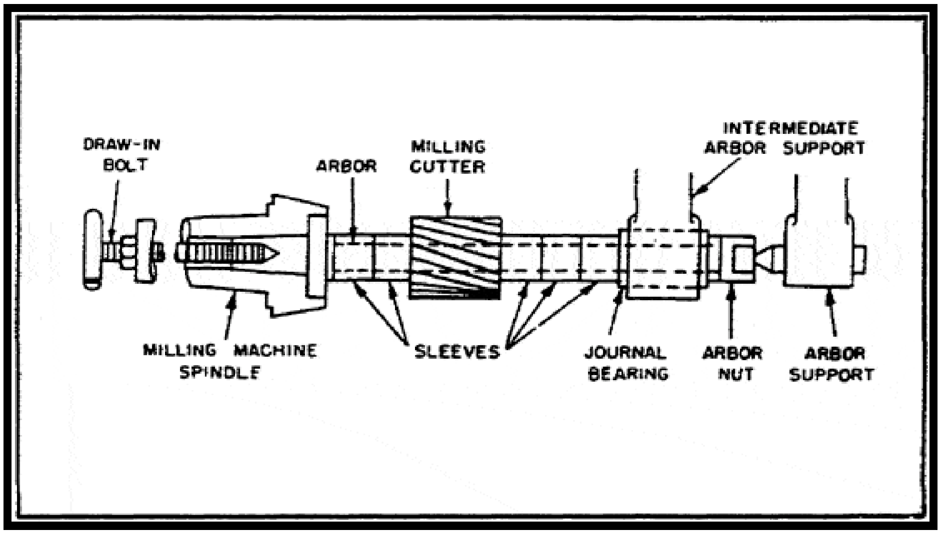
ARBOR

An Arbor is a cutter holding device with a taper shank to fit the spindle taper hole of the machine. The short or long shaft end is used to mount and drive one or more cutters.

Cutter Holding Devices for Milling Machines

DRAW IN BAR

It is fitted through the spindle, screws into the Arbor, and holds it too firmly in the spindle. Drive keys on the spindle nose fit into the slots on the Arbor flange provide positive (no slip) drive



ADAPTER

An adapter also has a taper shank to fit the spindle hole, but the opposite end has either a straight or taper hole for holding end mills, taper collets, spring collects, and small arbores.

Cutter Holding Devices for Milling Machines

SPRING CHUCK

A spring chuck is an adapter that can be mounted in the spindle for holding and driving spring collets.

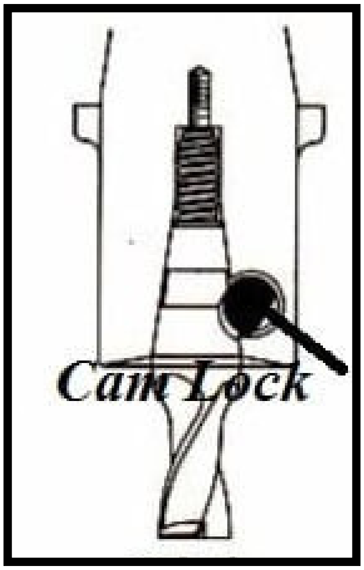
SLEEVES

These are used to reduce the spindle or adapter internal taper to receive a smaller tapered shank tool

Cutter Holding Devices for Milling Machines

CAM LOCK

A cam lock is a device in cutter adapters; it is designed to give positive locking, drive, and quick release to end mills and to other adapters held in them.



QUICK CHANGE SPINDLE NOSE

- **It is a specially designed attachment that can be clamped to the spindle nose for holding arbores and adapters.**
- **Various cutting tools needed to machine a job can be mounted in adapters or on an Arbor and each used in sequence without changing the set-up of the job.**
- **A special clamping ring, threaded on the outside, is bolted to the spindle nose.**
- **The adapters and arbores are placed in this clamping ring and held in a place by a ring nut.**
- **Because a draw-in bolt is not necessary much time can be saved when changing cutters.**

Work Holding Devices

Holding a workpiece securely during its machining on a milling machine is crucial for effective operations. The cutting pressure exhorted by milling cutter is quite high comparing the single point tool of a lathe machine. Therefore, the workpiece must be secured rigidly to avoid any vibration. The following are the usual methods of holding work on the milling machine.

Features of Work Holding Devices:

The work holding devices should have the following uniqueness:

- **Work holding devices must have required accuracy and must have matching reference surfaces with the reference system.**
- **Work holding devices are allowed to perform several operations on different faces in a single setting.**
- **Work holding devices must enable quick loading and unloading.**
- **Work holding devices must be fool proofing to avoid incorrect loading of the job.**
- **Work holding devices must be sufficient rigidity to fully withstand the cutting forces.**
- **Work holding devices must be safe in use and loading and unloading.**
- **Work holding devices must have a sufficient clamping force for the use of full roughing cuts.**
- **Work holding devices must be simple in construction maximum as possible.**

Work Holding devices used For Milling Machines:

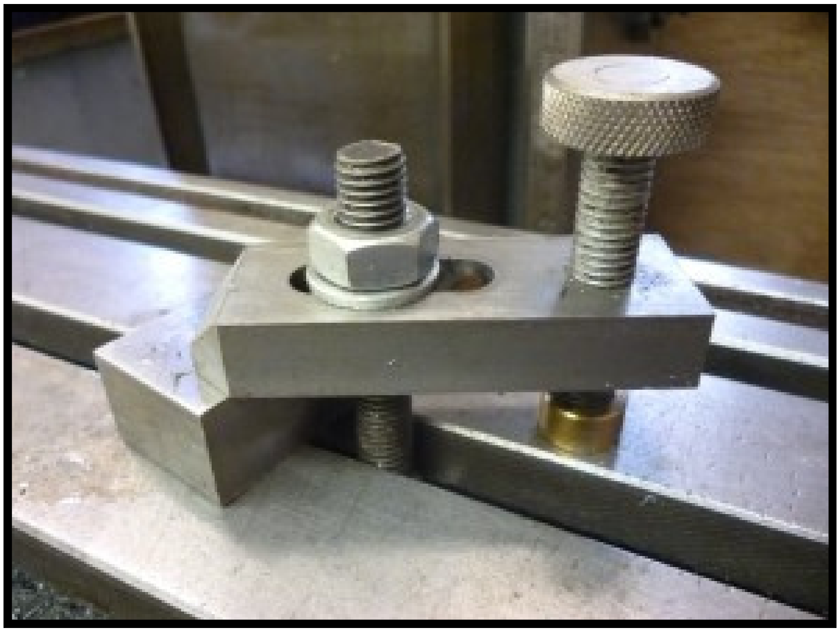
Various types of work holding devices are used for milling machine operations they are explained as follows:

- **T-bolts and clamps**
- **Angle Plates**
- **V – Block**
- **Machine Vices**
- **Dividing Head**
- **Special Fixture**
- **Circular Table or Indexing Table**
- **Parallels**
- **Magnetic chuck / Vacuum chuck / Collet chuck**

Work Holding Devices

T-BOLT & CLAMPS

Bulky workpieces of irregular shapes are clamped directly on the milling machine table using T-bolts and clamps. Different types of clamps are used for different patterns of work.



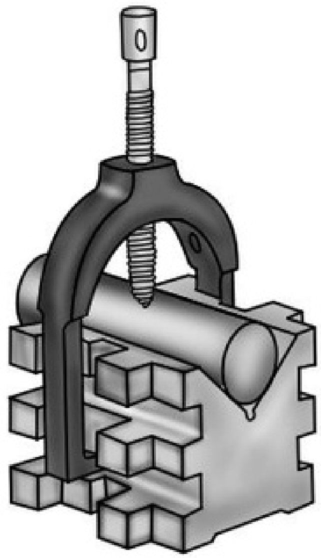
ANGLE PLATES

When work surfaces are to be milled at right angles to another face, angle plates are used for supporting the work1. The angle plate is made from high-quality material that has been stabilized to prevent further movement or distortion.

Work Holding Devices

V BLOCK

V-Blocks are used to hold cylindrical workpieces for milling and drilling.



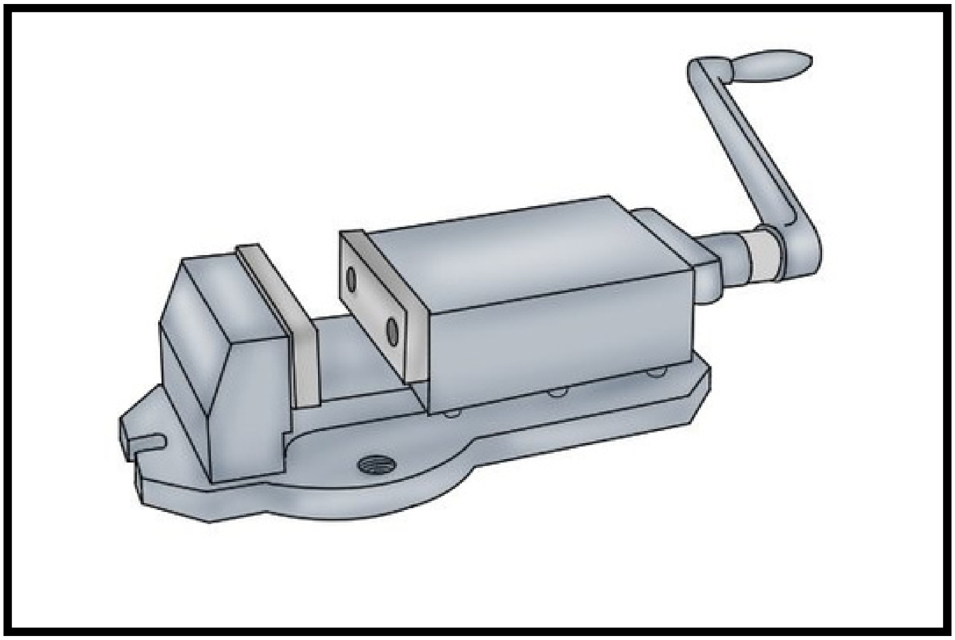
Work Holding Devices

MACHINE VICES

A machine vice is a device used to hold a workpiece while operating a drill or milling machine. According to its quick loading and unloading arrangement. Vices are of three types,

a. Plain Vice

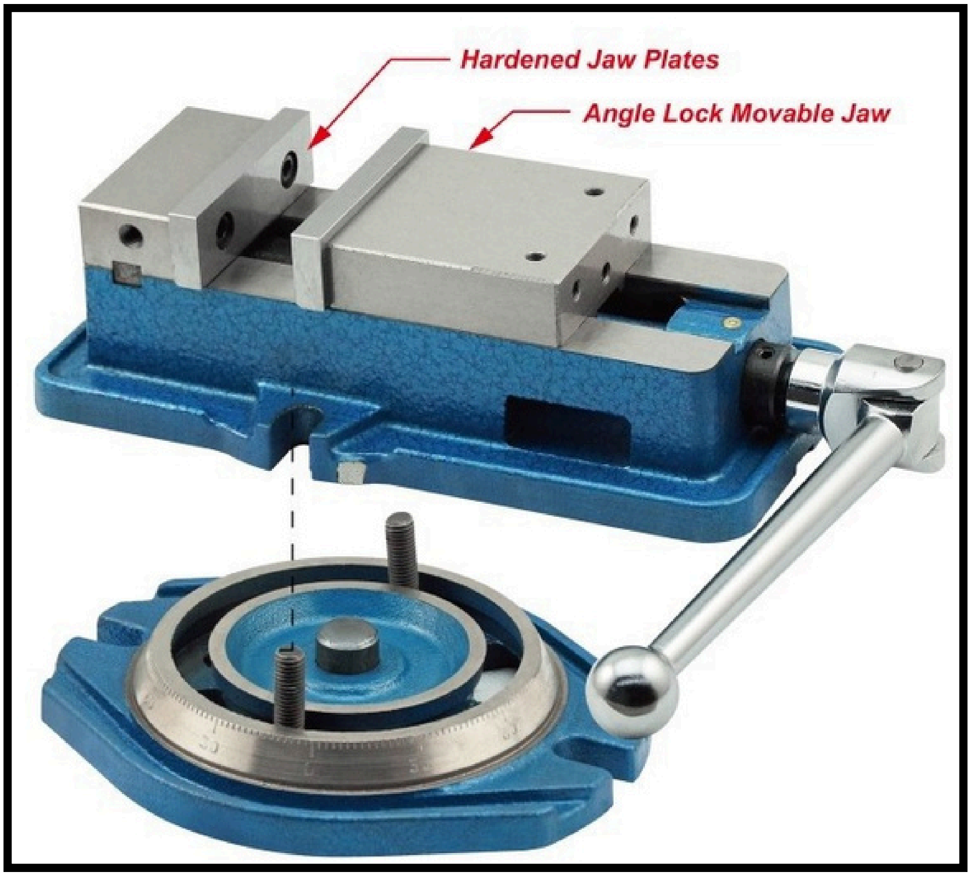
- **The plain vice is directly bolted on the milling machine table is the most common type of vice used on plain milling operations, which involves heavy cuts, such as in slab milling.**
- **Its especially low construction enables the work to remain quite close to the table.**
- **This reduces the chance of vibration to a minimum.**
- **The base carries slots to accommodate 'T' bolts to fix the vice on the table.**
- **Work is clamped between the fixed and movable jaw and for holding workpieces of irregular shape special jaws are sometimes used.**



Work Holding Devices

b. Swivel Vice

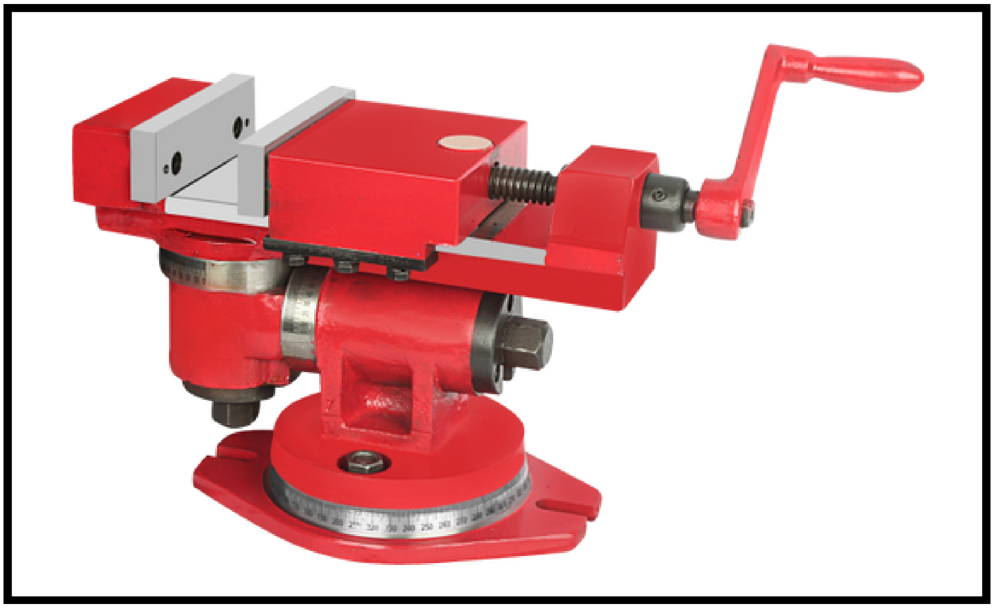
- The swivel vice is used to mill an angular surface in relation to a straight surface without removing the work from the vice.
- It has got a circular base graduated in degrees.
- The base is clamped on the table by means of T- bolts.



Work Holding Devices

c. Universal Vices

- It can be swiveled in a horizontal plane like a swivel vice and can also be tilted in any vertical position for an angular cut.
- The vice is not rigid in construction and is used mainly in tool room work. It enables the milling of various surfaces, at an inclination to one another, without removing the workpiece

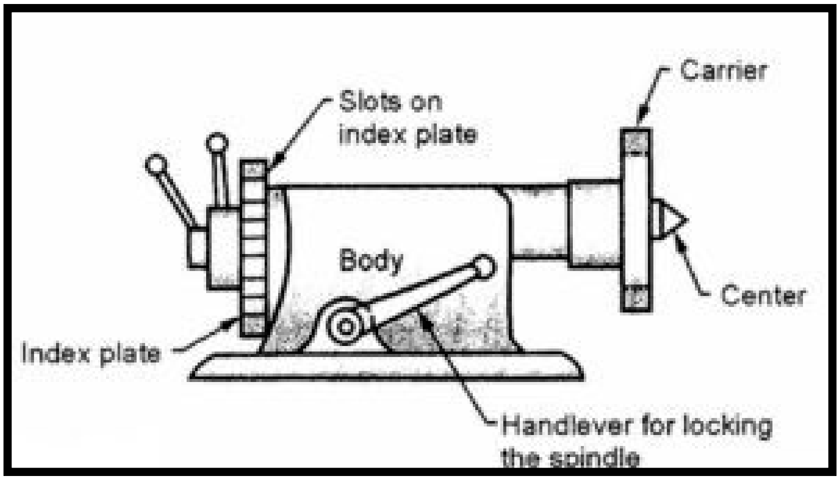


Plain Dividing Head

Plain dividing head is the simplest of all types of dividing heads. Plain dividing head is classified into two types.

First type Plain Dividing Head

- **The first type carries an indexing plate directly mounted on its spindle and there is no use of worm and worm wheel.**

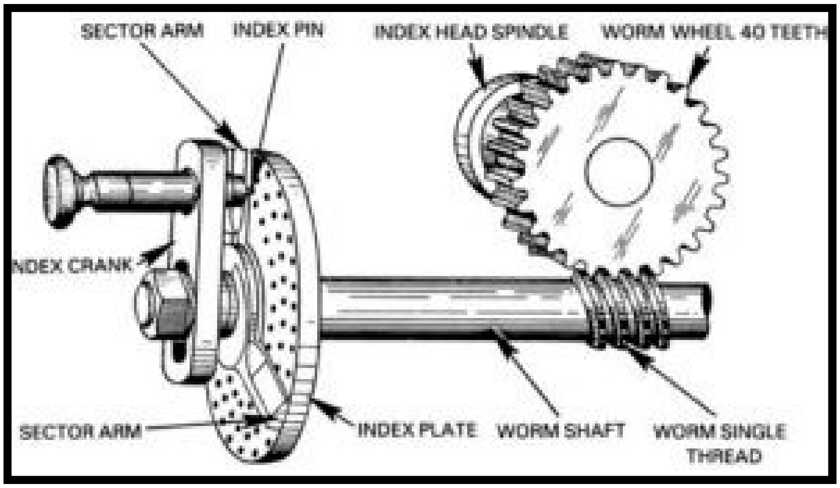


- **The index plate carries 12-24 equipage slots on its periphery.**
- **The workpiece is held between two centers i.e. one on the dividing head spindle and the other on the tailstock.**
- **For locking the spindle in its position hand lever is used.**
- **The plate, together with the spindle can be rotated by means of hand i.e. provided on the left-hand side of the dividing head.**

Plain Dividing Head

Second Type Plain Dividing Head

- **The second type of plain dividing head uses a worm and worm wheel mechanism.**
- **In this indexing, the plate movement is obtained by the worm which is rotated by hand.**

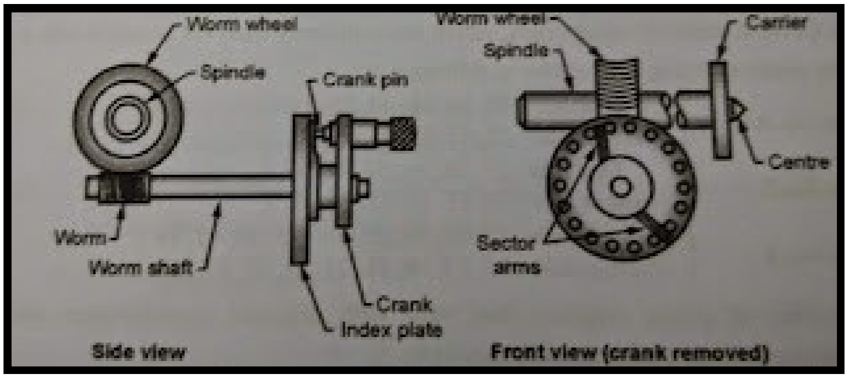


- **Plain dividing head is commonly used in operations where average accuracy is required such as fluting taps, reamers, milling rectangles, squares, hexagons, etc.**

Plain Dividing Head

Universal Dividing Head

- Universal Dividing Head/Indexing Head consists of a robust body and a worm drive is enclosed in it. It is having a worm and worm wheel as shown in fig 2.
- Picture below shows details of the internal mechanism of the Universal Dividing Head. In this, the dividing head spindle carries a worm wheel that meshes with the worm.



- This worm carries a crank at its outer end. The index pin works inside the spring-loaded plunger, which can slide radially along a slot provided in the crank.
- This plunger can slide, adjust the pin position along a desired hole circle on the index plate.
- The index plate is mounted on the same spindle as the crank, but on a sleeve, hence the crank and worm spindle can move independently on the index plate.
- To set a definite distance along the desired hole circle, sector arms are used. Sector arms are of a detachable type and can be set at the desired angles with one another. The index plates are available in a set of two or three, with several hole circles generally on both sides.

Spindle Speed, Feed Rate, and Cutting Time Calculation

Understanding Spindle Speed, Feed Rate, and Cutting Time

- **In the intricate world of milling operations, precision, efficiency, and optimal results are the ultimate goals.**
- **Achieving these milestones requires a deep understanding of the fundamental parameters that govern the machining process.**
- **At the heart of this mastery lie three critical elements: spindle speed, feed rate, and cutting time.**
- **Spindle speed, feed rate, and cutting time serve as the backbone of milling operations, intricately woven into every aspect of the machining process.**
- **They dictate material removal rates, surface finish quality, tool longevity, and production efficiency. Their influence is undeniable, shaping the very essence of milling operations.**
- **From the moment the cutting tool engages with the workpiece to the final disengagement, spindle speed, feed rate, and cutting time play a pivotal role in determining the outcome.**
- **They are the guiding principles that machinists rely on to navigate the complexities of milling operations, ensuring precision and performance at every turn.**

Spindle Speed (Revolutions Per Minute)

- **Spindle, or Revolutions Per Minute, is the heartbeat of milling operations.**
- **It dictates the speed at which the cutting tool rotates, directly impacting material removal rate, surface finish, and tool longevity.**
- **Spindle speed serves as the cornerstone for achieving the delicate balance between cutting forces and machining efficiency.**
- **By understanding and controlling spindle speed, machinists can fine-tune the cutting process to match the specific requirements of the material being machined.**
- **Whether it's achieving high-speed precision or maximizing tool life, spindle speed plays a pivotal role in determining the success of milling operations.**

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- **The spindle speed formula is a fundamental equation used to calculate the spindle speed required for a milling operation. It is expressed as:**

- **For metric units:**
- **Where:**
- **N is the spindle speed in revolutions per minute (rev/min).**
- **Vcis the surface speed of the cutter in meters per minute (m/min)**
- **D is the diameter of the milling cutter in millimetres (mm)**
- **π (pi) is a constant approximately equal to 3.14159.**

Spindle Speed, Feed Rate, and Cutting Time Calculation

Factors Influencing Spindle Speed Calculation:

Several factors influence spindle calculation, including:

- **Cutter Diameter: Larger diameter cutters require lower spindle to maintain the same cutting speed.**
- **Material Type: Different materials have varying optimal cutting speeds, affecting the required spindle speed.**
- **Cutting Speed: The desired cutting speed dictates the spindle speed needed for efficient machining.**

Feed (Table feed)

- **Feed is the rate at which the cutting tool advances along the workpiece's surface during machining and represented by the following formula:**

$$V_f = f_z \times N \times Z$$

Where:

- V_f is the feed in mm/min.
- N is the spindle speed in rev/min.
- Z is the number of teeth on the cutter; and
- f_z is the feed per tooth (chip load) in mm.

- **The feed directly impacts material removal rate and chip formation, making it a key determinant of machining efficiency.**
- **Striking the right balance between feed rate and cutting forces is crucial for achieving smooth, chatter-free cuts and extending tool life.**

Factors Affecting Feed Calculation:

- **Several factors influence feed rate calculation, including:**
- **Cutter Geometry: Different cutter geometries require varying feed rates for optimal performance.**
- **Material Hardness: Harder materials typically require lower feed rates to prevent excessive tool wear.**
- **Desired Chip Load: The desired thickness of the chip being removed affects the feed rate selection.**

Spindle Speed, Feed Rate, and Cutting Time Calculation

Machining Time

- Machining or cutting time is the duration required to complete a machining operation, encompassing all stages from tool engagement to disengagement.
- It encompasses the combined effects of spindle speed and feed, offering insights into machining cycle times and production scheduling.
- Understanding cutting time allows machinists to optimize machining processes for maximum productivity and resource utilization.
- By minimizing cutting time through strategic parameter adjustments, manufacturers can enhance throughput, reduce lead times, and meet stringent production deadlines.

Estimating Cutting Time

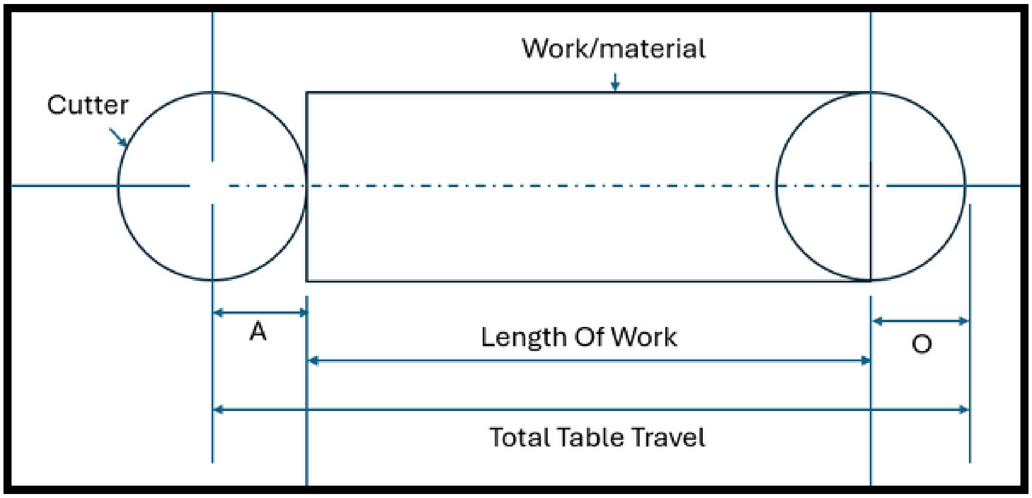
- Milling machine is a very versatile machine.
- The milling machine employs a multipoint tool, called milling cutter, for machining.
- The various operations done on a milling machine are facing, forming or profile machining, slotting, keyway cutting, etc.
- Factor to be considered in estimating the machining time:
  a. Total length of cut
  b. Approach – the distance through which the cutter must move before the full depth of cut is acquired.
  c. Over run – the distance through which the cutter must move further after the job length is over, to be clear of the job.
  d. Number of cuts (pass).
  e. Cutting speed and feed rate

- Cutting time estimation is essential for assessing machining efficiency and production scheduling in milling operations.

Spindle Speed, Feed Rate, and Cutting Time Calculation

Estimating Cutting Time

- **In milling machine. The formula for machining time is given by.**



$$Machining\ Time, T_m = \frac{Length\ of\ cut\ (Total\ Table\ Travel)}{Feed\ rate}$$

$$Total\ table\ travel = length\ of\ job + added\ table\ travel\ (approach\ allowance)$$

$$Approach\ allowance, A = cutter\ approach\ (A_c) + over\ travel(O)$$

$$T_m = \frac{L + A}{V_r}$$

Where:

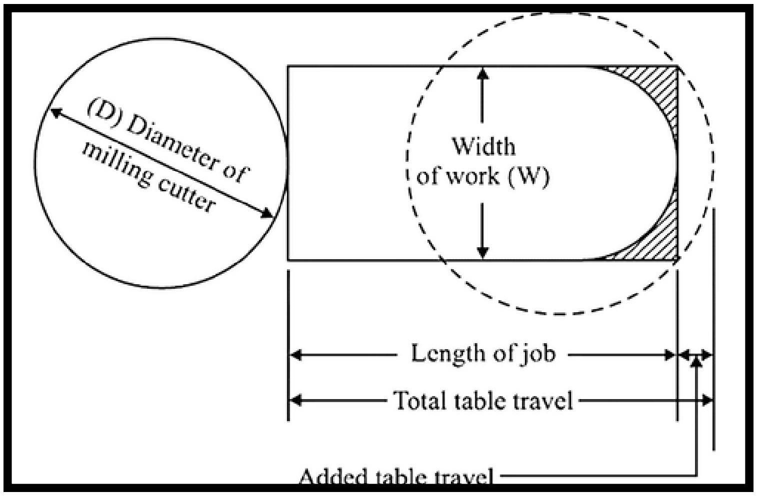
- T_m is the machining (milling) time in minute (min).
- L is the length of material in meter (m) for metric units and inch (in) for U.S units.
- V_r is the feed rate in mm/min (metric) and in/min (U.S); and
- A is the approach allowance (distance required to fully engage the cutter with work)

- **The approach allowance will be dependent upon the type of milling operation.**

Spindle Speed, Feed Rate, and Cutting Time Calculation

For face milling:

- **In a face milling operation, the milling cutter traverse to the length of face.**
- **Even after the milling cutter traverse to workpiece length, some portion will be left un-machined as shown in the shaded part of the figure given below.**
- **To complete milling the cutter must travel an additional distance (added table travel, A)**

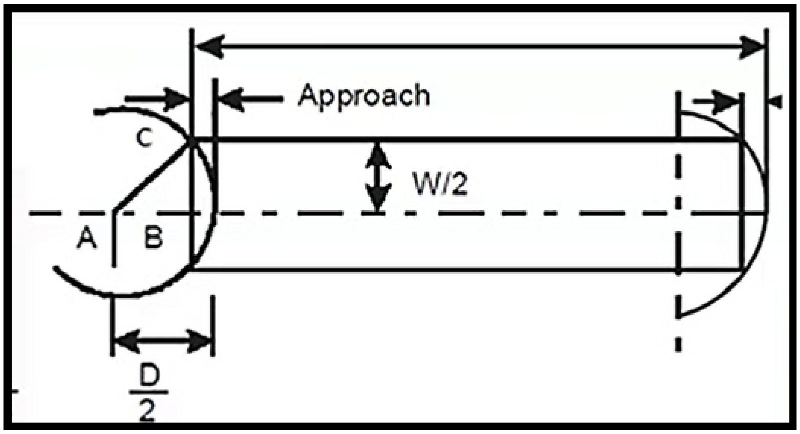


- **For face milling there three different cases to considered for calculate cutting time:**

Spindle Speed, Feed Rate, and Cutting Time Calculation

- **For face milling there three different cases to considered for calculate cutting time:**

If a face milling diameter has a greater than workpiece width,



$$A = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

- If a face milling cutter diameter is the exact as the width of work, $D = W$

$$A = \frac{D}{2}$$

- If a face milling cutter diameter smaller than the width of work, $D < W$

$$A = \frac{D}{2}$$

But it will take more than one transverse to complete one cut on the face width.

Where:

- D is the diameter of cutter, mm (in)
- W is the width of work piece, mm (in)
- A is the approach, mm (in)

Impact of RPM, Feed Rate, and Cutting Time on Material Removal Rate, Tool Wear, and Productivity

- In the dynamic realm of milling operations, spindle speed, feed, and cutting time are not just abstract numbers but potent forces that directly influence critical aspects of the machining process.
- Understanding how these parameters impact material removal rate, tool wear, and productivity is essential for achieving optimal results and maximizing efficiency. Let's explore their effects in detail:

Material Removal Rate (MRR):

- ***Spindle Speed:*** Higher RPM typically leads to increased material removal rates by facilitating faster cutting speeds. However, excessive RPM may result in excessive heat generation and tool wear if not properly controlled.
- ***Feed:*** A higher feed rate can enhance material removal rates by increasing the volume of chips removed per unit time. However, excessive feed rates may cause tool deflection, poor surface finish, or even tool breakage.
- ***Cutting Time:*** Cutting time directly influences material removal rates by determining the duration of machining operations. Shorter cutting times generally result in higher productivity and material removal rates.

Tool Wear:

- **Spindle Speed:** Improper RPM selection can accelerate tool wear due to excessive heat generation or inadequate chip evacuation. Optimal RPM selection ensures proper chip formation and reduces tool wear.
- ***Feed:*** Inadequate feed rates can lead to excessive tool rubbing and accelerated wear, while excessively high feed rates may cause tool chipping or breakage. Finding the right balance is crucial for minimizing tool wear.
- ***Cutting Time:*** Prolonged cutting times can lead to increased tool wear due to prolonged exposure to cutting forces and heat. Minimizing cutting times through efficient parameter optimization helps reduce tool wear.

Impact of RPM, Feed Rate, and Cutting Time on Material Removal Rate, Tool Wear, and Productivity

Productivity:

- ***Spindle Speed:*** **Proper RPM selection can enhance productivity by balancing cutting speed with tool life, allowing for efficient material removal without compromising tool longevity.**
- ***Feed Rate:*** **Optimizing feed rates ensures efficient chip evacuation, minimal tool deflection, and consistent machining quality, leading to improved productivity.**
- ***Cutting Time:*** **Minimizing cutting times through effective parameter optimization and toolpath strategies boosts overall productivity by reducing idle time and increasing throughput.**

Safety Procedures

Here are some key safety procedures for operating a milling machine, presented in point form:

1.Training and Familiarization:

Ensure operators are adequately trained in the operation of milling machines before allowing them to work independently.

2.Wear Personal Protective Equipment (PPE):

Safety glasses or goggles to protect eyes from flying debris.
Ear protection to guard against the loud noise generated by the machine.
Proper attire, including gloves and long sleeves, to protect against cuts and burns.

3.Machine Inspection:

Before use, inspect the machine for any signs of damage or wear.
Check for loose or damaged parts, such as belts, gears, and cutting tools.
Ensure all safety guards and shields are in place and functioning correctly.

4.Secure Workpiece and Work Area:

Use clamps or fixtures to secure the workpiece firmly to the milling table.
Clear the work area of any debris, tools, or obstructions that could interfere with the operation of the machine.

5.Set Speeds and Feeds Appropriately:

Refer to the machine's manual or manufacturer guidelines to determine the correct speed and feed rates for the material being milled.
Avoid exceeding the recommended limits to prevent overheating or tool breakage.

6.Use Proper Cutting Tools:

Select cutting tools appropriate for the material being milled.
Ensure cutting tools are sharp and in good condition to prevent binding or kickback.

7.Start-Up Procedure:

Before starting the machine, ensure all adjustments and controls are set correctly.
Start the machine at a low speed to prevent sudden movements or vibrations.

Safety Procedures

8.Stay Alert and Focused:
Always maintain full attention on the milling operation.
Avoid distractions and refrain from engaging in other tasks while the machine is running.

9.Feed Direction:
Feed the workpiece against the rotation of the milling cutter to minimize the risk of kickback.

10.Emergency Stop:
Familiarize yourself with the location and operation of the emergency stop button.
In case of any unexpected situation, immediately stop the machine by pressing the emergency stop button.

11.Shutdown Procedure:
After completing the milling operation, turn off the machine and wait for all moving parts to come to a complete stop before attempting any maintenance or adjustments.

12.Maintenance and Servicing:
Regularly inspect and maintain the milling machine according to the manufacturer's recommendations.
Lubricate moving parts as required and replace worn or damaged components promptly.

Importance of safety in milling machine operations

Safety in milling machine operations is paramount for several reasons:

1.Personal Safety: Milling machines operate at high speeds and can exert significant force. Ensuring safety measures are followed prevents accidents that could cause severe injuries to operators, such as cuts, crush injuries, or even loss of limbs.

2.Machine Integrity: Mishandling or improper operation of milling machines can lead to damage or wear and tear on the equipment. Adhering to safety protocols ensures the longevity and effectiveness of the machines, reducing the need for repairs and replacements.

3.Workplace Safety Culture: Emphasizing safety in milling machine operations fosters a culture of safety in the workplace. When employees see that safety is a priority, they are more likely to follow protocols and be vigilant in other aspects of their work, contributing to overall workplace safety.

4.Product Quality: Proper operation of milling machines ensures precision and accuracy in the products being manufactured. Safety measures help prevent errors or mistakes that could compromise the quality of the finished products, reducing waste and rework.

5.Legal Compliance: Many jurisdictions have regulations and standards in place regarding workplace safety. Adhering to these regulations not only ensures the safety of workers but also helps companies avoid legal issues and potential fines for non-compliance.

6.Risk Mitigation: Operating milling machines without proper safety precautions poses various risks, including fire hazards, electrocution, and exposure to hazardous materials. Implementing safety measures mitigates these risks, creating a safer working environment for everyone involved.

7.Employee Morale and Productivity: Workers who feel safe and secure in their workplace are more likely to be productive and engaged. By prioritizing safety in milling machine operations, employers demonstrate their commitment to the well-being of their employees, which can boost morale and ultimately lead to higher productivity levels.

CONCLUSION

The "Essential Guide to Milling Machine: Principles and Practices" offers an in-depth and detailed exploration of milling machines, making it an indispensable resource for machinists at all levels of expertise. The guide meticulously covers the fundamental principles of milling, providing a thorough understanding of the various types of milling machines, their components, and their specific functions. It delves into the historical development of milling machines, highlighting key advancements that have shaped modern milling practices.

One of the standout features of this guide is its focus on practical applications. It not only explains the theoretical aspects but also provides detailed instructions and illustrations for setting up, operating, and maintaining milling machines. The step-by-step procedures ensure that even beginners can follow along and gain hands-on experience with confidence. Advanced users will find the sections on precision techniques, complex operations, and troubleshooting particularly valuable, as they offer insights into optimizing machine performance and addressing common issues effectively.

Safety is another critical aspect covered comprehensively in the guide. It emphasizes the importance of adhering to safety protocols to prevent accidents and injuries, providing a list of best practices and safety measures to follow. This focus on safety underscores the guide's practical orientation and its commitment to promoting a safe working environment.
Moreover, the guide addresses the maintenance of milling machines, outlining routine checks and preventive measures to ensure the longevity and reliability of the equipment. This section is crucial for both individual machinists and workshop managers, as regular maintenance can significantly reduce downtime and repair costs.

In conclusion, the "Essential Guide to Milling Machine: Principles and Practices" is a well-rounded and thorough manual that equips users with the knowledge and skills necessary to excel in milling operations. Its blend of theoretical insights, practical guidance, and safety protocols makes it a valuable addition to any machinist’s library. Whether you are a beginner seeking to learn the basics or an experienced professional looking to refine your skills, this guide offers essential information that enhances proficiency and ensures successful milling outcomes.

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THANK YOU

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