बिहार सरकार

Govt. of Bihar

Department of Science & Technology

Government Polytechnic Vaishali

PRODUCTION PROCESS

Semester-IV (Mechanical Engineering)

Unit -3.1

MILLING

by

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CONTENTS

Learning Objectives

Students will be able to:

- Understand the Milling
- Types of Milling
- Terminology used for milling
- Methods of milling operations

Milling

MILLING

INTRODUCTION:

A milling machine is a machine tool that removes metal as the work is fed against a rotating multi point cutter. The cutter rotates at a high speed, and because of the multiple cutting edges it removes the metal at a very fast rate. The first milling machine came into existence in about 1770 and was of French origin.

Cutting Parameters

Spindle Speed of Revolution. Spindle speed of revolution determines the velocity of cutting edge relative to the workpiece, namely, cutting speed. Since cutting speed has the great effect on tool life, the selection of cutting speed relates to the durability of tool closely. Too low or too high cutting speed will cause the tool life to decline dramatically. Meanwhile, in the milling of thin-walled workpiece, spindle speed of revolution has a significant effect on the stability of cutting. Therefore, the spindle speed of revolution should be selected discreetly in milling process.

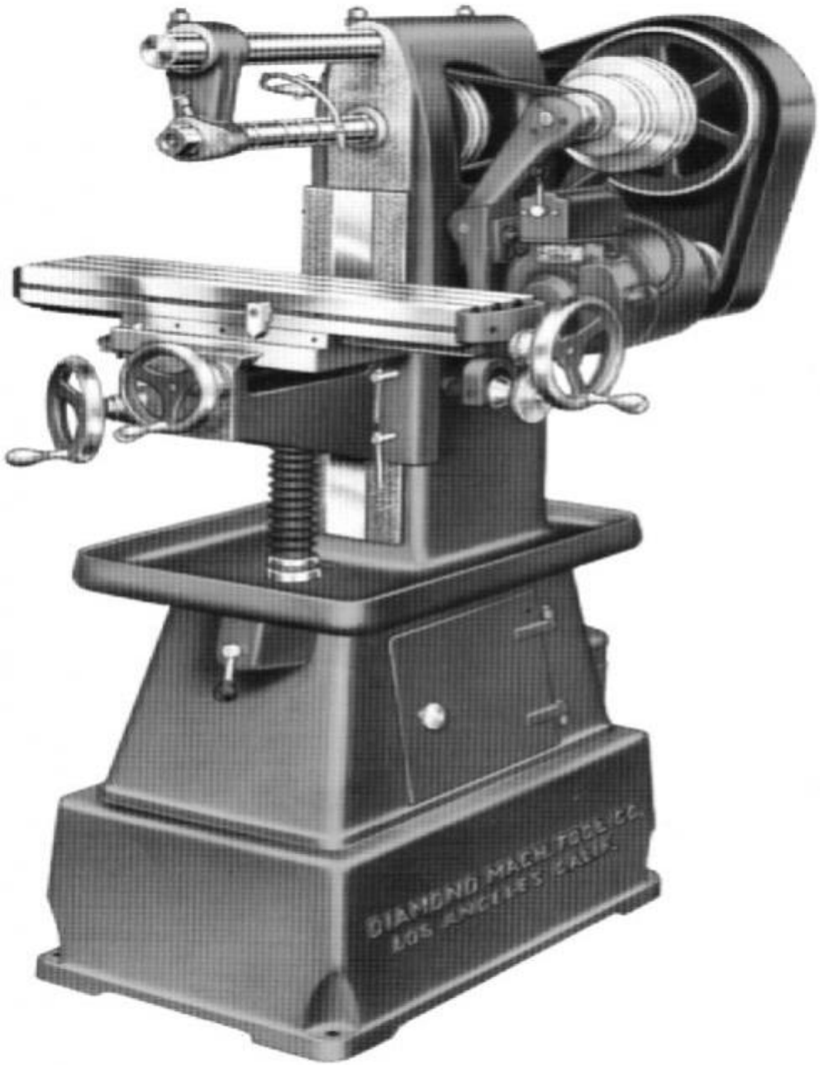
Cutting Depth and Cutting Width. Cutting depth and cutting width are restricted by spindle power, transmission power of machine tool, material type, tool parameters, coolant, machining procedure, and the stiffness of machine tool-tool-workpiece system. And, they have a great effect on tool life. Therefore, they should be selected reasonably according to machining quality, machining efficiency, and machining procedure. Generally, machining efficiency is the first goal in roughing machining, so a larger cutting depth and cutting width should be selected. Quality of workpiece surface is the main goal in finishing machining, so a less cutting depth and cutting width should be selected.

Feed Rate. Feed rate is the velocity of feed move of the cutting tool relative to workpiece in milling process. Generally, linear feed rate is adopted in practical production and it is defined as feed per minute. The feed rate of milling will affect the machining accuracy, surface quality, deformation of the workpiece, and tool life directly. And it is also restricted by tool parameters, workpiece material, tool path, stiffness of machine tool, and performance of feed system. In machining process, the feed rate of milling is selected according to part material, geometry features, quality requirements, and the capability of machine tool

TYPES

1. <u>Column & knee type:</u> Most commonly used for general shop work. The table is mounted on the knee casting, which in-turn is mounted on the vertical slides of the main column. The knee is vertically adjustable on the column, so that the table can be moved up and down to accommodate work of various heights. The table can be moved longitudinally and cross wise on the knee casting. Classification of this type is based on methods of supplying power to the table, diff. movement of the table and diff. axis of rotation of the main spindle.

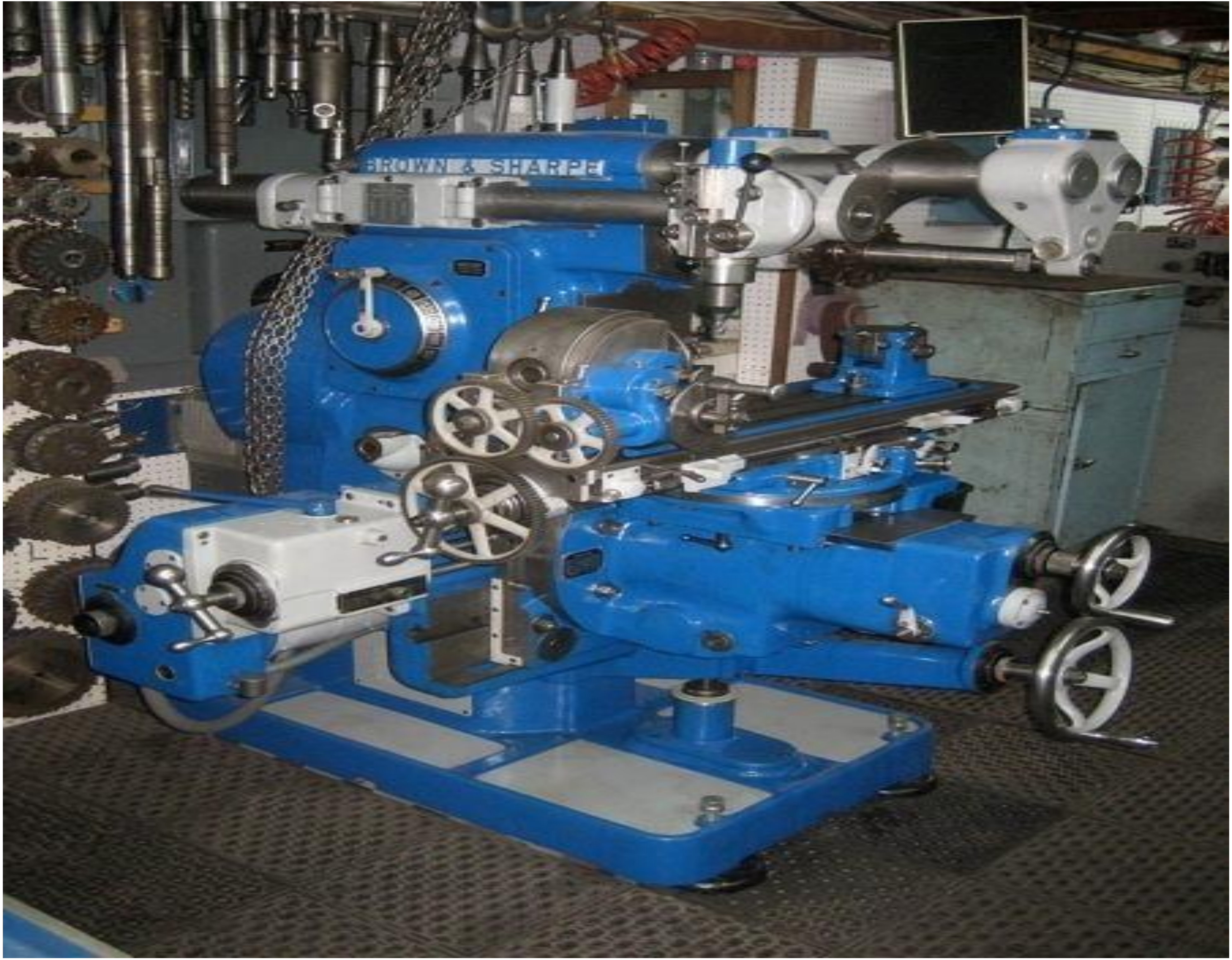
(a) Hand milling machine → Feeding is done by hand and used for light and simple operations like slots, grooves, keyways. This is available in both horizontal & vertical models Table movements are as above.



(b) <u>Plain milling machine</u> → This is a horizontal type milling m/c. This is more rigid and sturdy, for heavy work, can be fed by hand or power. Table can be fed as above.

(c) <u>Universal milling machine</u> → This is also a horizontal type milling m/c. In addition to 3 movements in plain milling machine the table has a fourth movement i.e. it is fed at an angle to milling cutter. This enable it to perform helical milling. This machine can produce spur, spiral, bevel gears, twist drills, reamers, milling cutters etc.

(d) Omniversal milling machine → This is a horizontal type milling m/c. The extra fifth movement is the table can be tilted in vertical plane by providing a swivel arrangement at the knee. This enables milling in any plane. Taper spiral groves in reamers, bevel gears etc can be done.

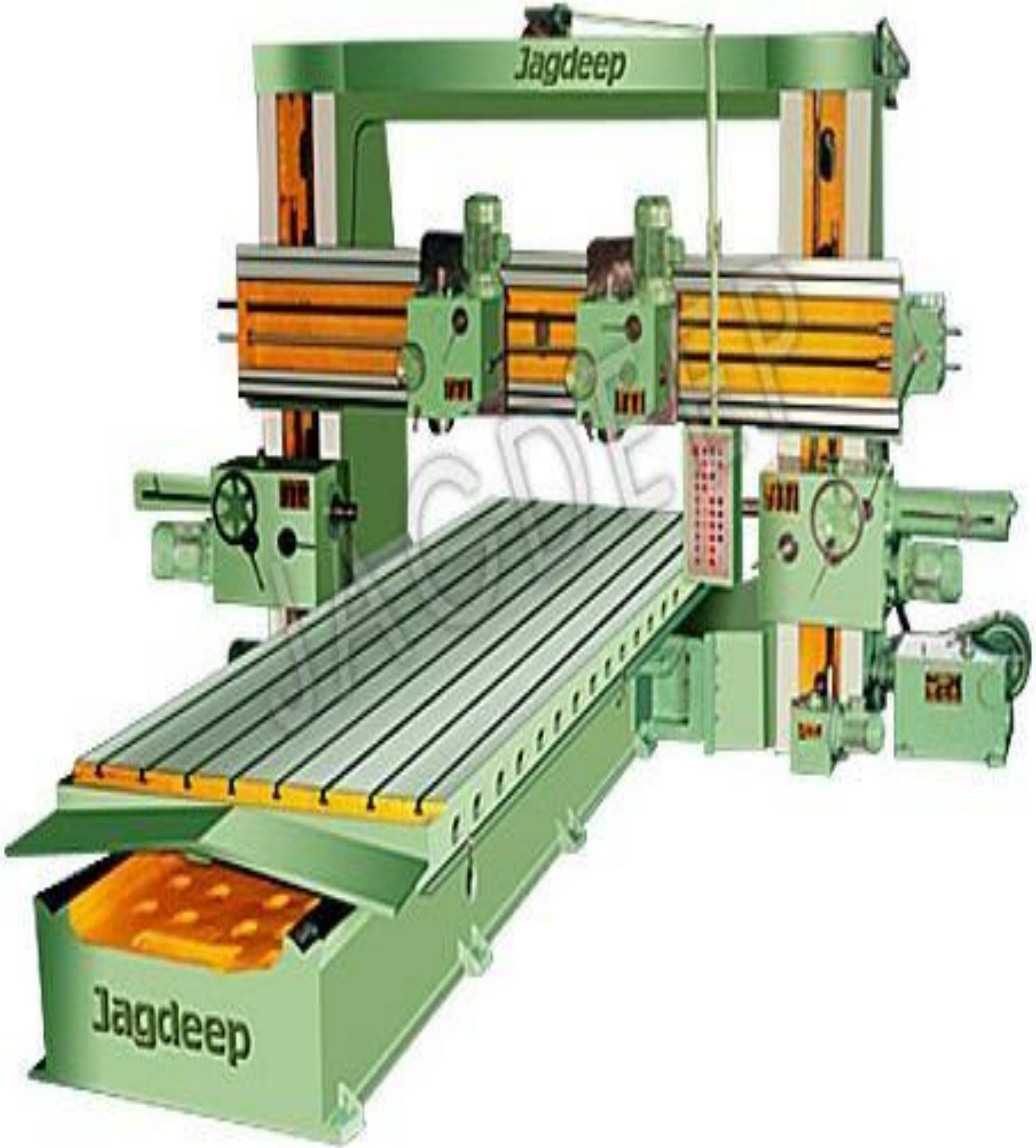

BROWN & SHARPE

(e) Vertical milling machine

Here the position of the spindle is vertical and ⊥ to the work table. The spindle head is clamped to the vertical column and can be swiveled at an angle . Also the spindle head can be adjusted up / down relative to work. The table movements are same as plain milling machine.

2. Plano Miller:

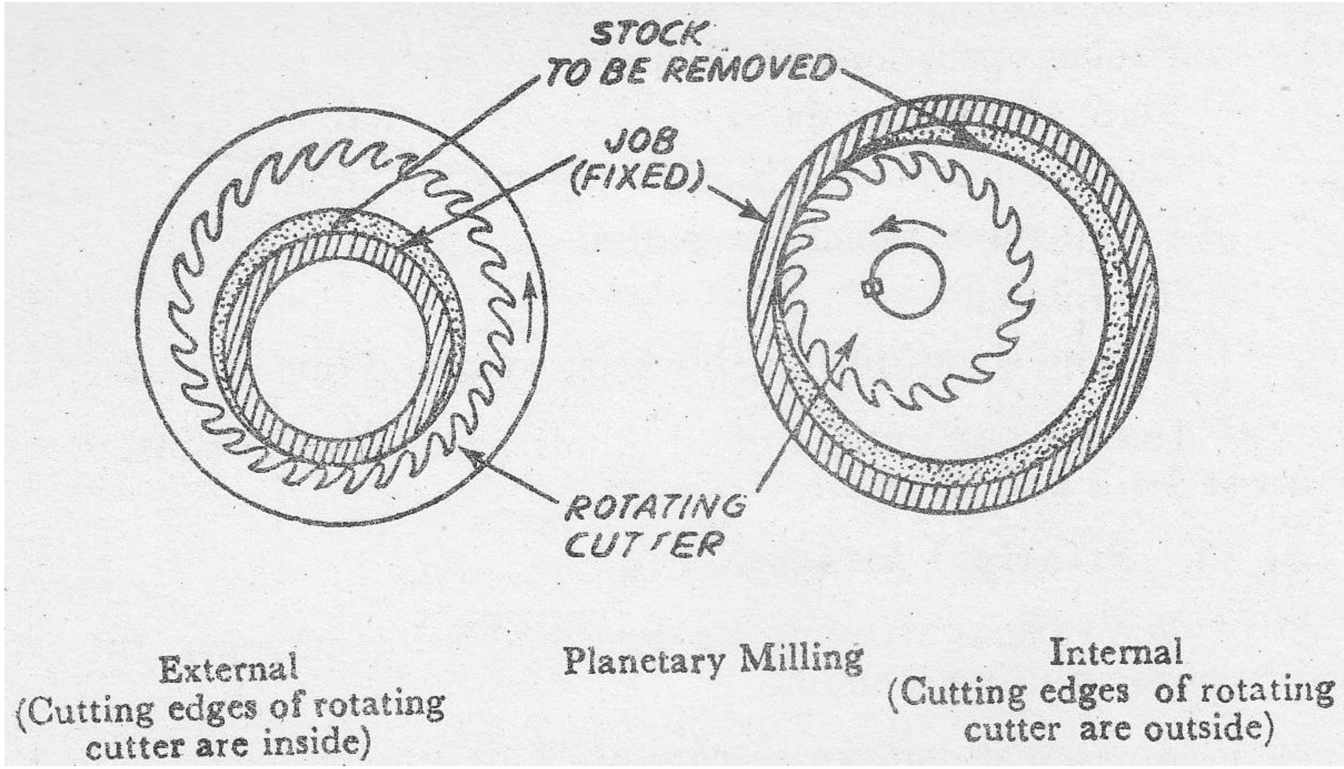
It resembles a planer. It is having two spindle heads adjustable in vertical and transverse directions. It has a cross rail which can be raised or lowered along with cutters. Hence no. of work surfaces can be machined simultaneously, thereby reducing production time. In a plano miller, the table has

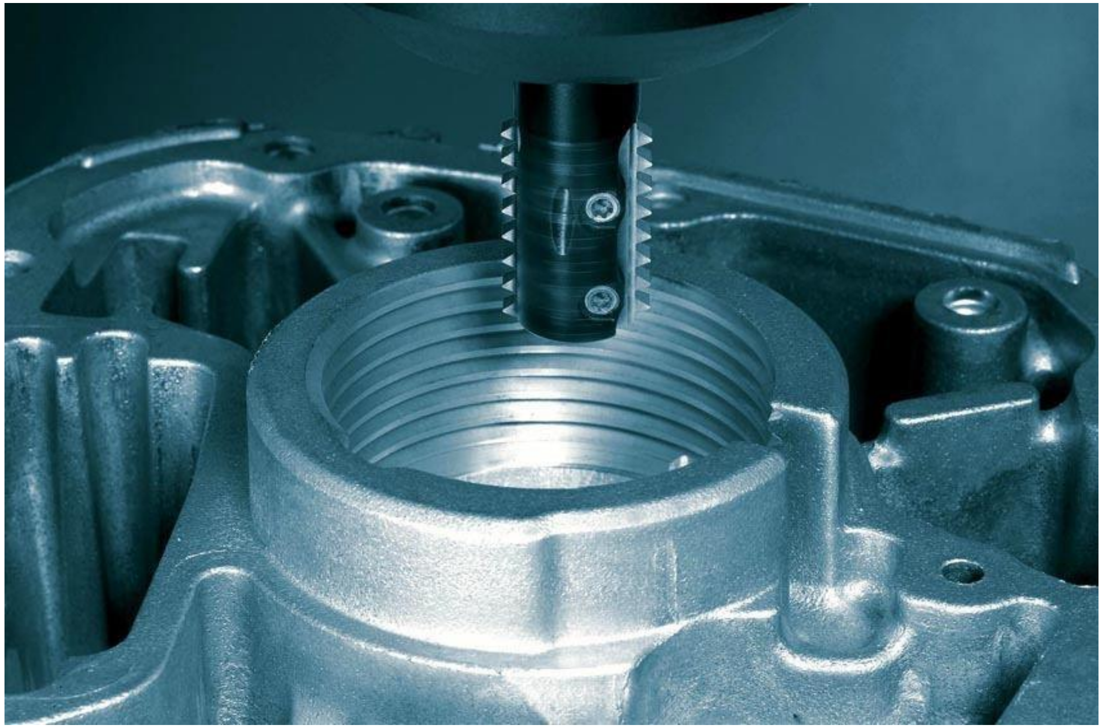


feed movement instead of reciprocation. Hence the table movement here is much slower than planning machine.

3. <u>Rotary table Machine</u> → A modification of vertical milling machine adopted for machining flat surfaces. A No. of work pieces can be mounted on a circular table which rotates about vertical axis. The face milling cutters can be mounted on tow (or) more vertical spindles and can be set at diff. heights relative to work so that when one cutter is roughing the other is finishing them. Continuous loading and unloading of work pieces can be done by the operator while milling is in progress.

4. <u>Planetary milling machine</u>: Here the work is held stationary while the revolving cutter / cutters move in a planetary path to finish a cylindrical surface on the work either internally / externally / simultaneously. This machine is particularly adopted for milling internal / external threads of different pitches.





5. Pantograph milling machine → It can duplicate a job by using a pantograph mechanism which permits the size o the work piece reproduced to be smaller than, equal to or greater than the size of a template or model used for this purpose. A pantograph is a mechanism that is generally constructed of four bars or links joined in the form of parallelogram. Pantograph machines are available in 2D or 3D models. 2-D models are used for engraving letters or other designs, 3-D models are used for copying any shape and contour of the work piece. The tracing stylus is moved manually on the contour of the model to be duplicated and the milling cutter mounted on the spindle moves in a similar path on the work piece, reproducing the shape of the model.

SPECIFICATIONS

1. The max. length of longitudinal, cross and vertical travel of the table.
2. No. of spindle speeds,
3. No. of table speeds and feeds
4. Floor space required
5. Net weight required
6. Spindle nose taper (for vertical milling machine spindle and arbors)

MILLING GEOMETRY

Peripheral cutter: As the cutting edges are arranged radially on the periphery the rake angle is called radial rake which is the cutting edges angle w.r.t to the periphery of the cutter. +ve radial rake gives better performance in peripheral milling.

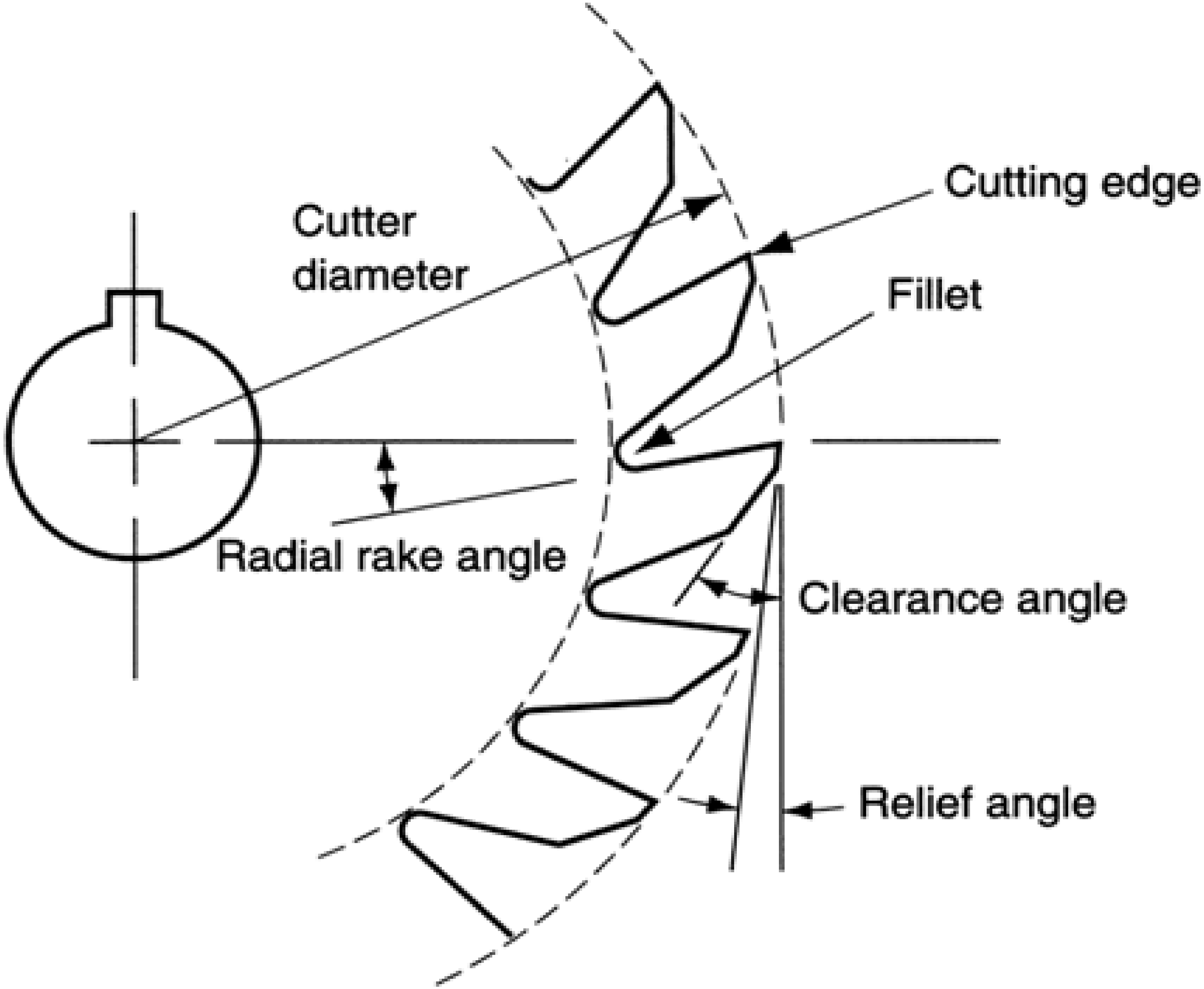
Face cutter: Two rake angles are defined here.

(a)Radial rake is the cutting insert's angle w.r.t the periphery of the cutter

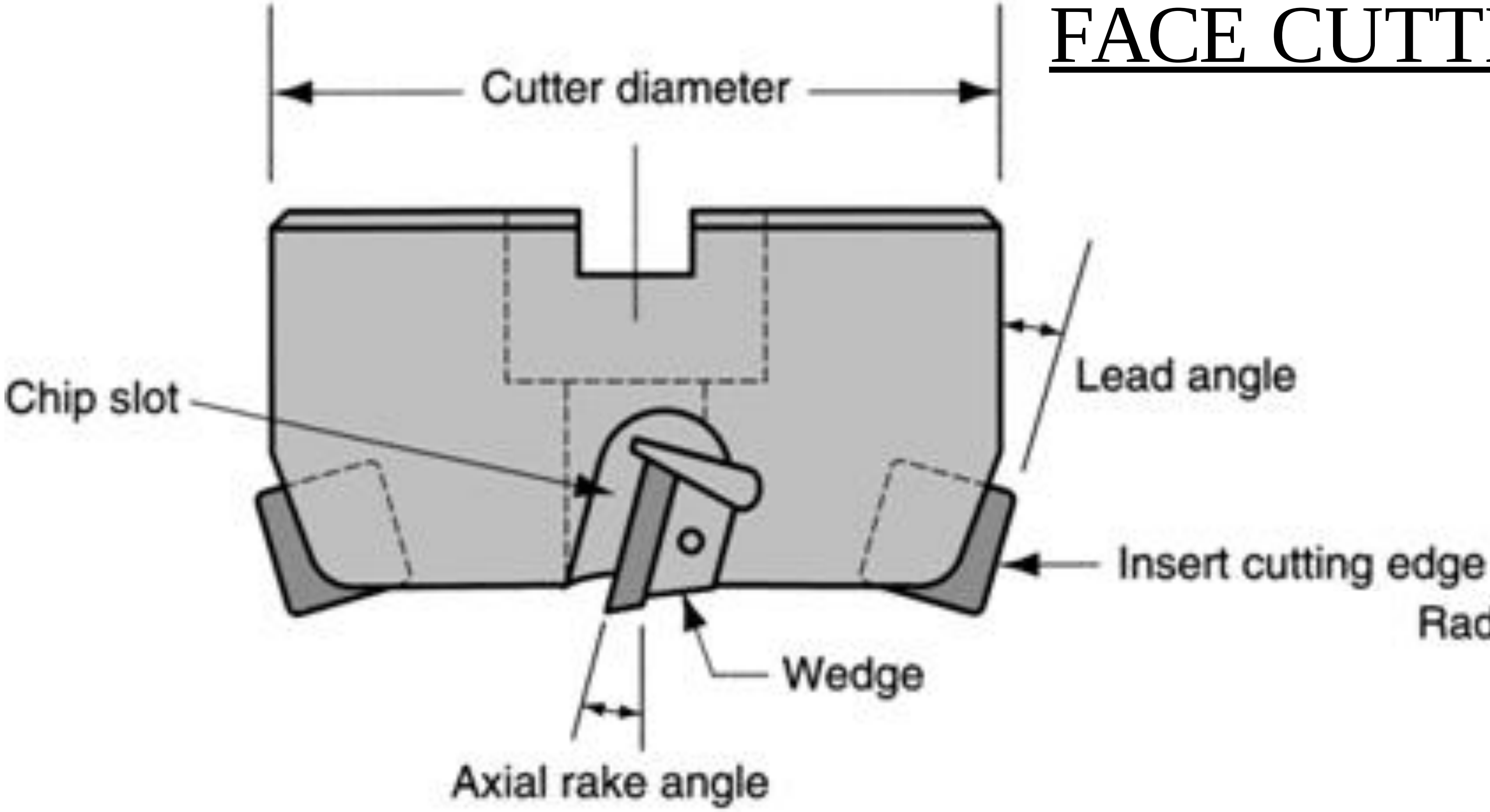
(b)Axial rake is the cutting insert's angle w.r.t the central axis of the cutter.

Axial Rake has significant effect on axial force and thrust applied to the spindle. Radial rake has major effect on tangential and radial forces. +ve axial rake, - ve radial rake gives best performance.

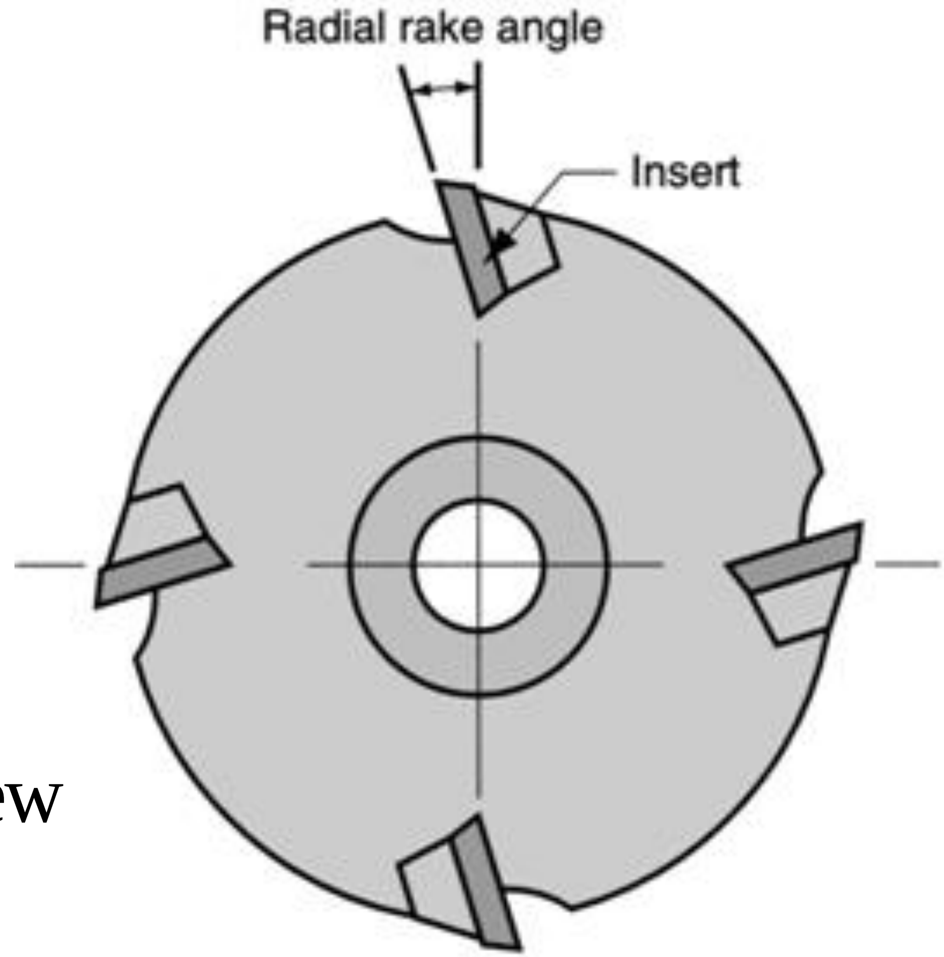
PERIPHERAL CUTTER



FACE CUTTER



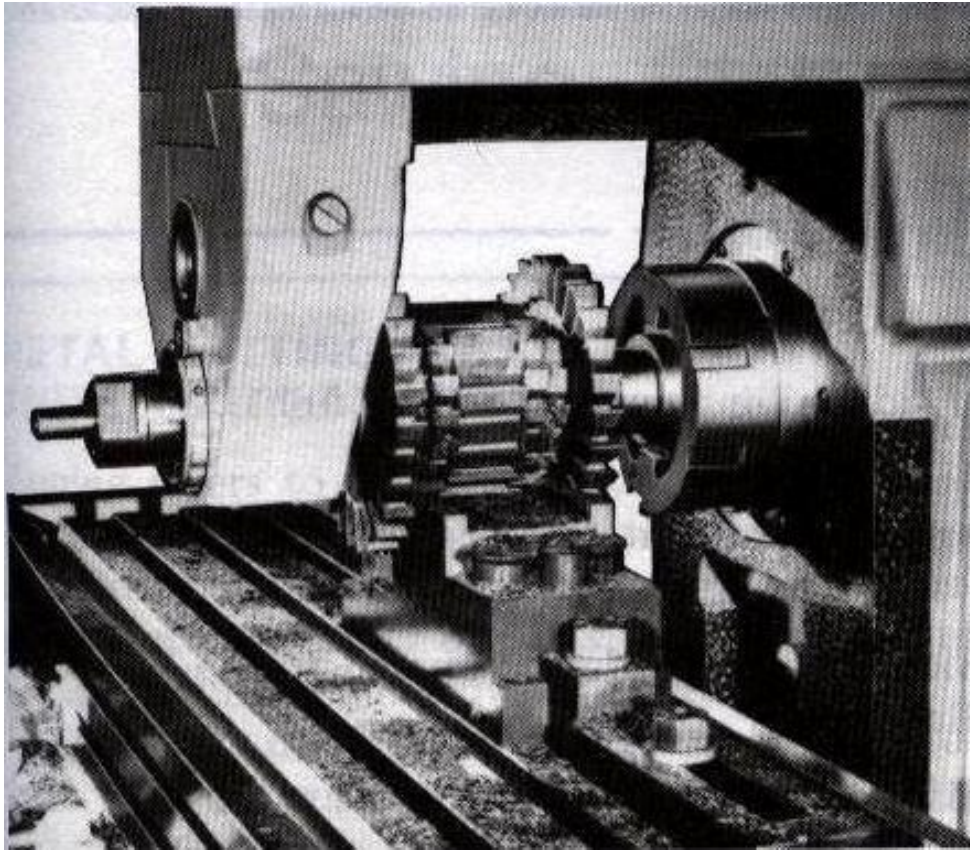
Side View



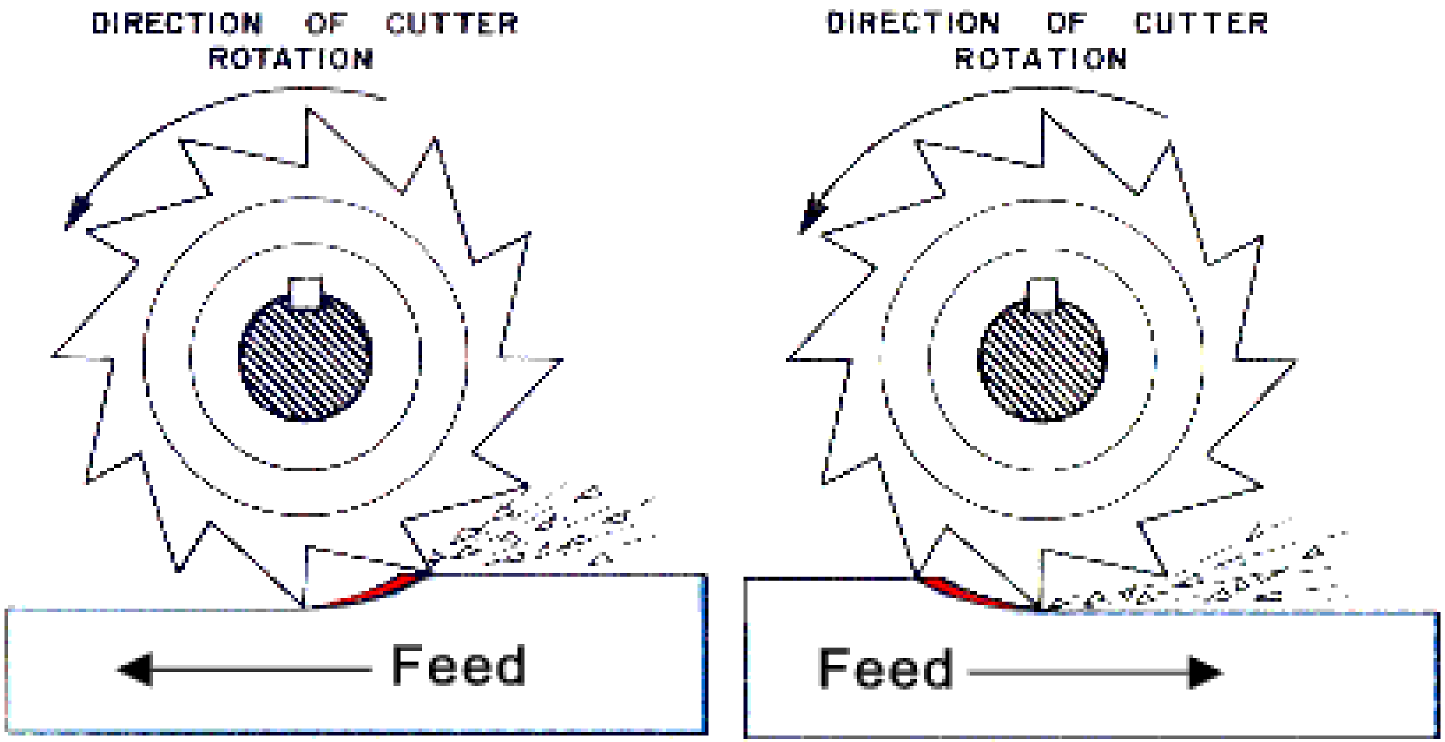
Bottom View

METHODS OF MILLING

1. Peripheral Milling: It is the operation performed by a milling cutter to produce a machined surface parallel to the axis of rotation of the cutter. Here the cutting force is not uniform throughout the length of cut by each tooth. Due to this reason, a shock is developed in the mechanism of the machine that leads to a vibration. The quality of surface generated and the shape of the chip formed is dependent upon the rotation of the cutter relative to the direction of feed movement of the work. According to the relative movement between the tool and work, the peripheral milling is classified into two types:



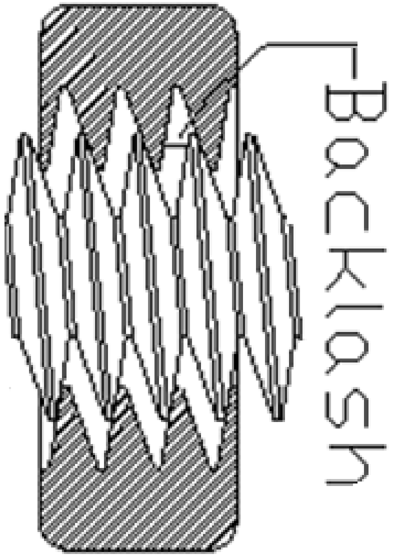
(a) <u>Up milling/ Conventional milling:</u> The metal is removed by the cutter which is rotated against the travel of the W.P. The thickness of the chip is min. at the beginning of cut max. when the cut terminates. The cutting force is directed up wards and this tends to lift the work from the fixtures. This is used for roughing operations. The chips accumulate at the cutting zone, and may be carried over with the cutter, spoiling the work surface. It generates a poor finish. Cutting force and power are more.

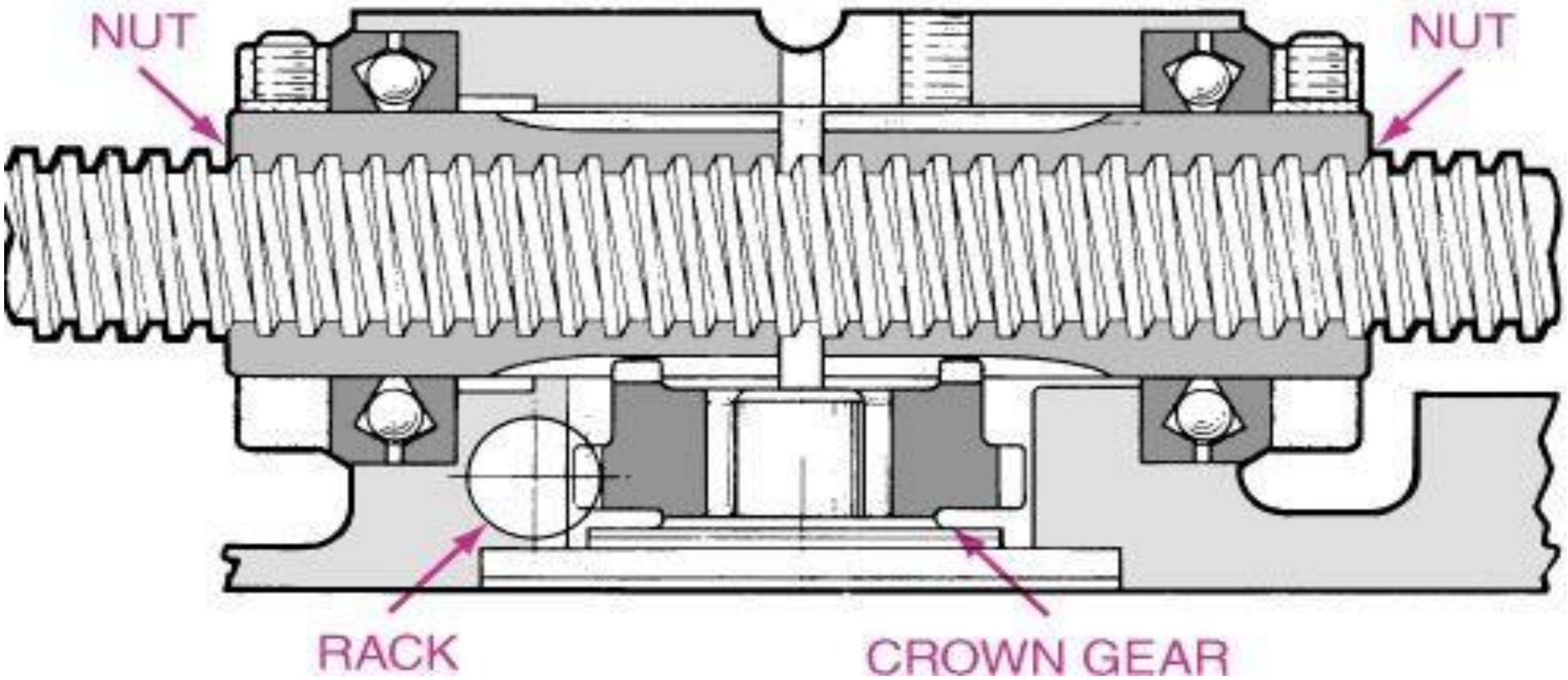


Conventional Up Milling

Down Milling

(b) Down milling/ Climb milling: The metal is removed by the cutter which is rotated in the same direction of travel of the W.P. The thickness of the chip is max. when the tooth begins its cut and it reduces to the min. when the tooth leave the work. The cutting force is directed down wards and this tends seat the work firmly in the work holding devices. Hence fixture design is easier. This operation cannot be used on old machine as the back lash error present in the screw elements that may cause vibration and damages the work surface considerably. Hence this operation should be performed on rigid machines provided with back last eliminator. This is used for finishing operations. The chips are also disposed off easily and do not interfere with the cutting. This results in improved surface finish. Cutting force and power are less.





<u>BACKLASH ELIMINATOR</u>: This eliminates the backlash (play) between nut and table lead screw. Two independent nuts are mounted on lead screw. The nuts engage common crown gear which meshes with rack. The axial movement of rack is controlled by the backlash eliminator, engaging a knob on front of saddle. Turning the knob forces the nuts to move along lead screw in opposite directions.

Advantages of Down Milling

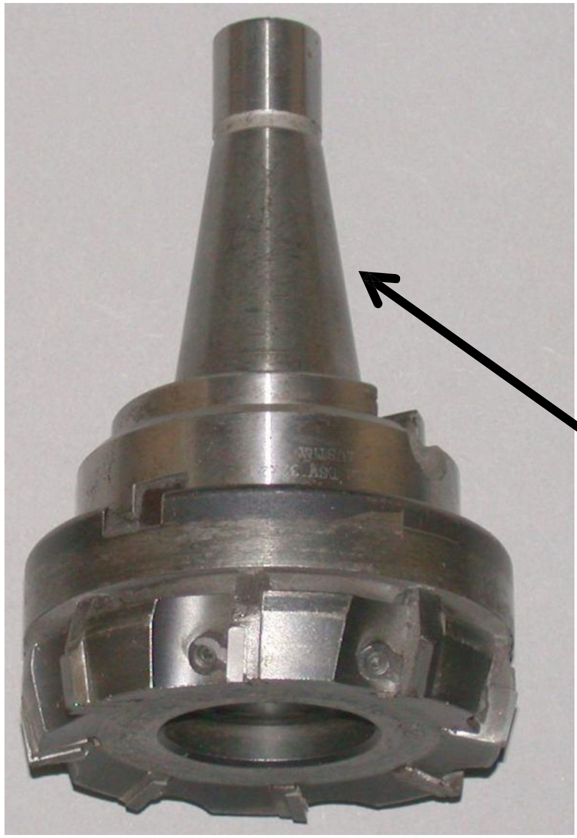
1. Suited to machine thin and hard-to-hold parts since the workpiece is forced against the table or holding device by the cutter.
2. Work need not be clamped as tightly.
3. Consistent parallelism and size may be maintained, particularly on thin parts.
4. It may be used where breakout at the edge of the workpiece could not be tolerated.
5. It requires upto 20% less power to cut by this method.
6. It may be used when cutting off stock or when milling deep, thin slots.

Disadvantages of Down Milling

1.It cannot be used unless the machine has a backlash eliminator and the table jibs have been tightened.

2.It cannot be used for machining castings or hot rolled steel, since the hard outer scale will damage the cutter.

2. <u>Face Milling</u>: This is performed to produce a flat machined surface to the axis of rotation of the cutter. In this operation both up milling and down milling may be considered to be performed simultaneously on the work surface. When the cutter rotates through half of the revolution the direction of movement of the cutter tooth is opposite to the direction of feed and the condition reverse when the cutter rotates through other half of revolution. The chip thickness is min. at the beginning and at the end o the cut, and it is max. when the work passes through the centre line of cutter. The surface generated in face milling is characterized by the tooth circular marks of the cutter. Face milling gives superior finish than peripheral milling.

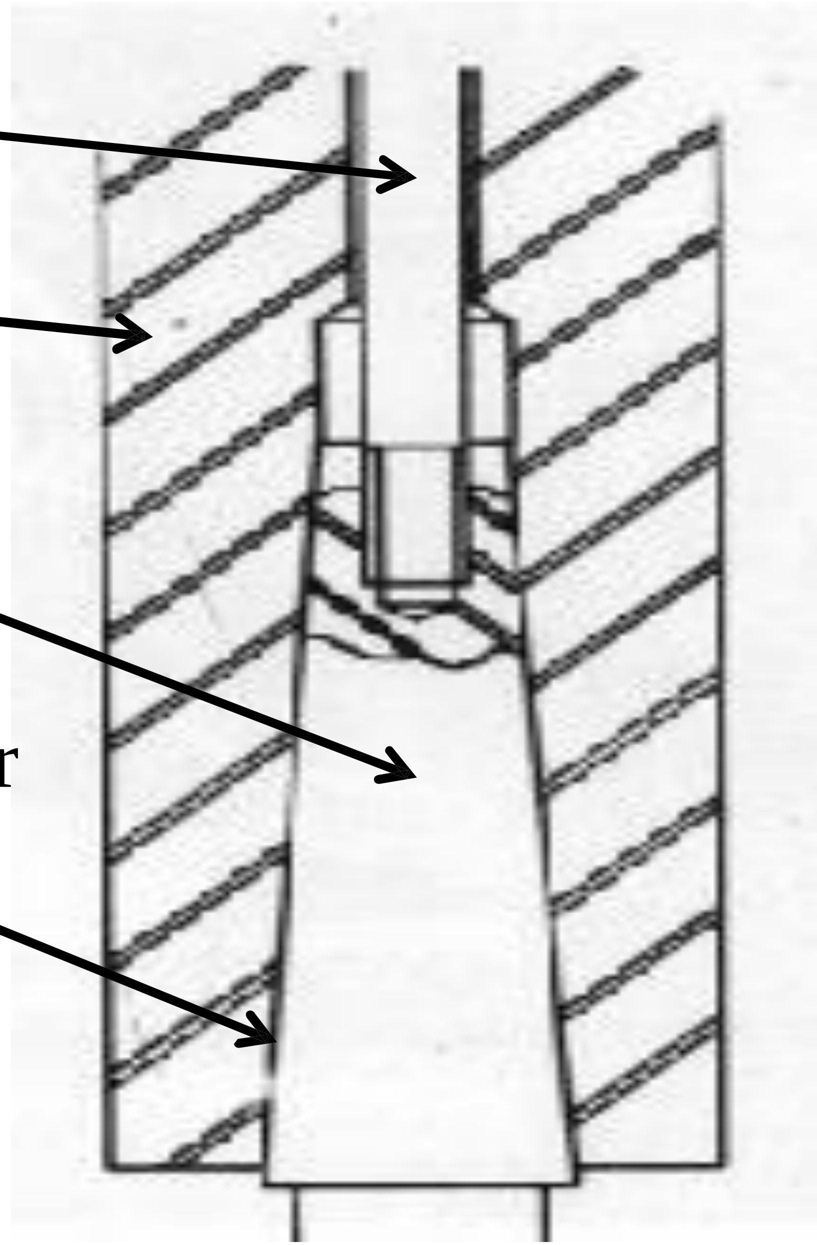


Draw Bolt

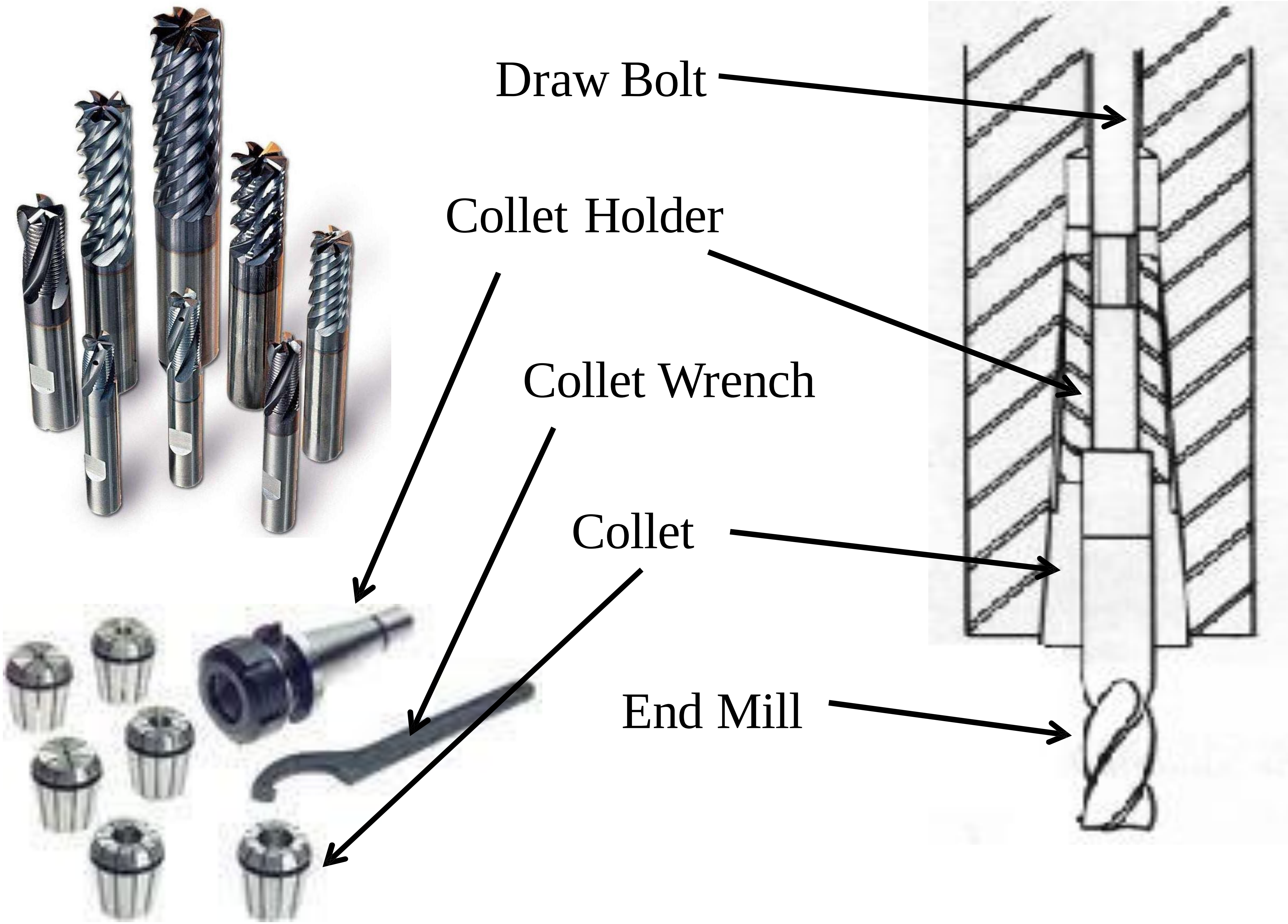
Spindle

Cutter Holder

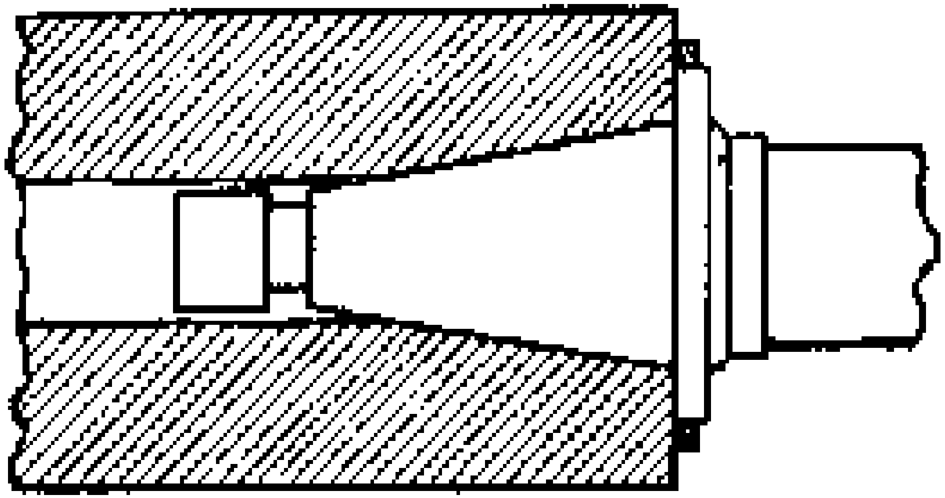
Spindle Nose Taper



3. End Milling: It is a combination of peripheral and face milling operations. The cutter has cutting edges both on the end face and on the periphery. The cutting characteristics may be of peripheral or face milling type according to the particular cutter surface used. When end cutting edges are only used to remove metal, the direction of rotation and direction of cutters should be same. When peripheral cutting edges are used, they must be opposite to each other.

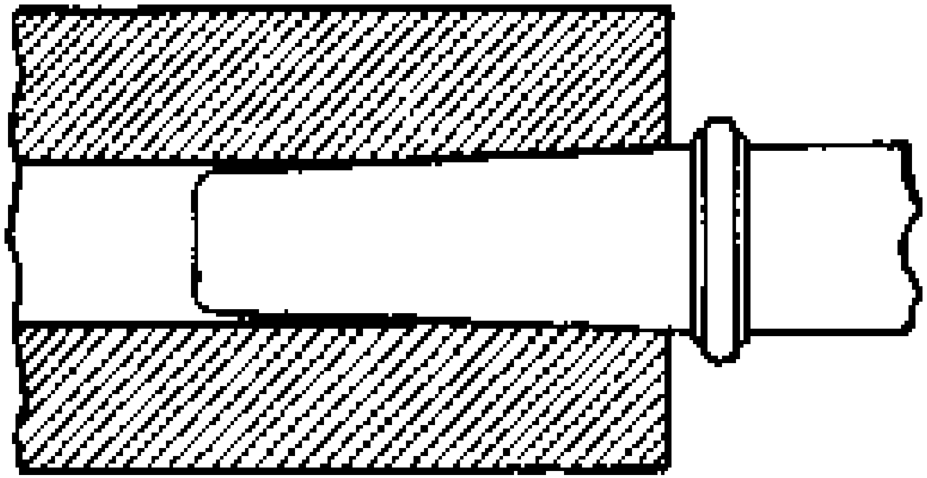

Draw Bolt
Collet Holder
Collet Wrench
Collet
End Mill

TAPER USED IN MILLING MACHINES



STANDARD TAPER

American Standard Taper of 3.5” per foot is made standard taper in all milling machines built in U.S.

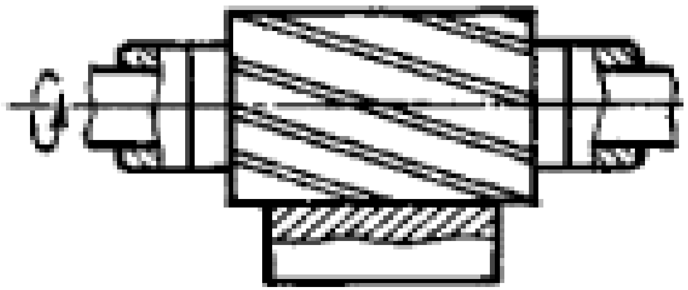
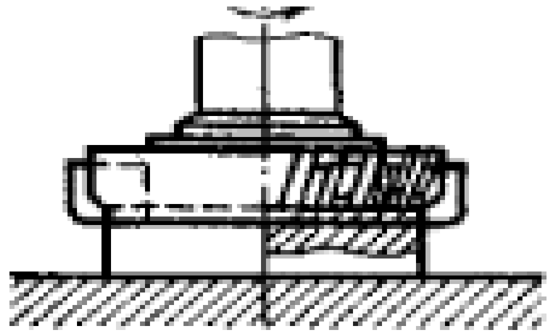


BROWN AND SHARPE TAPER

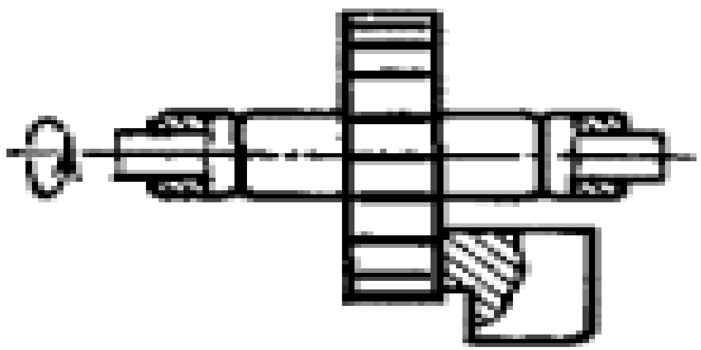
Brown and Sharpe Taper of 0.5” per foot is also widely used on collets, end mills, arbors, milling machine spindles and grinding machine spindles.

OPERATIONS

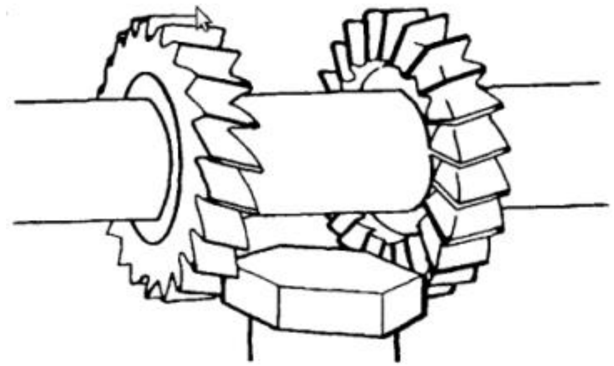
1. Plain Milling : Producing plain, flat horizontal surface. This is called slab milling if performed with a peripheral cutter and called face Milling if a face milling cutter is used.

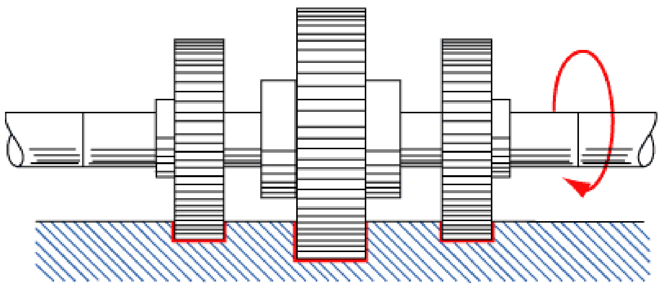
2. Side Milling: Producing flat vertical surface on the side of a work piece by using side milling cutter.

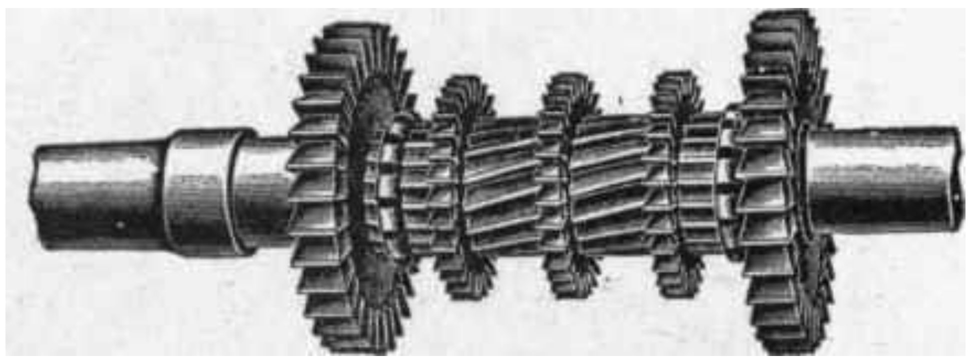



3. Straddle Milling: Producing flat vertical surfaces on both sides of the work piece by using two side milling cutter mounted on the same arbor. The distance between the two cutter can be adjusted by using spacing colors.

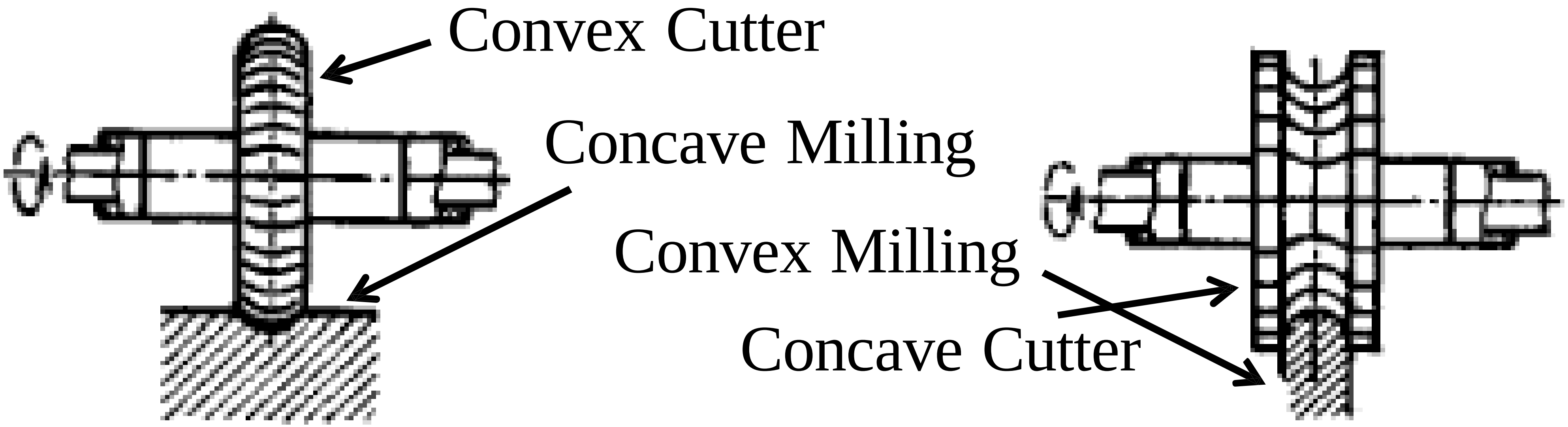


4. Gang Milling:Machining several surfaces simultaneously using a No. of cutters of same or diff. diameters mounted on the arbor of the machine, used widely for repetitive work

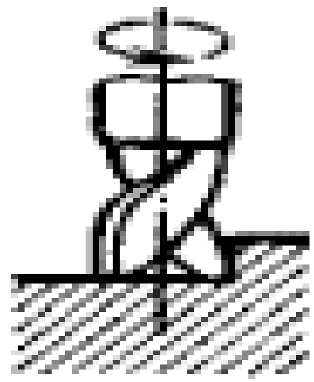




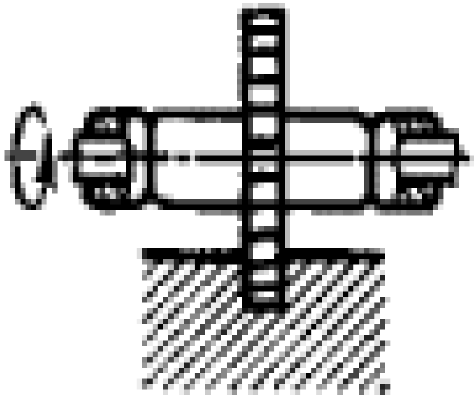
5. Form Milling: Producing irregular contours using form cutters like concave, convex or any other shape.



6. End milling: Producing flat surfaces which may be vertical, horizontal or at an angle in reference to the table surface like slots, grooves, key ways, steps etc. A vertical milling machine is most suitable for end milling.



7. Saw milling: Producing narrow slots or grooves using saw milling cutter. It can also be performed for complete parting off operation.



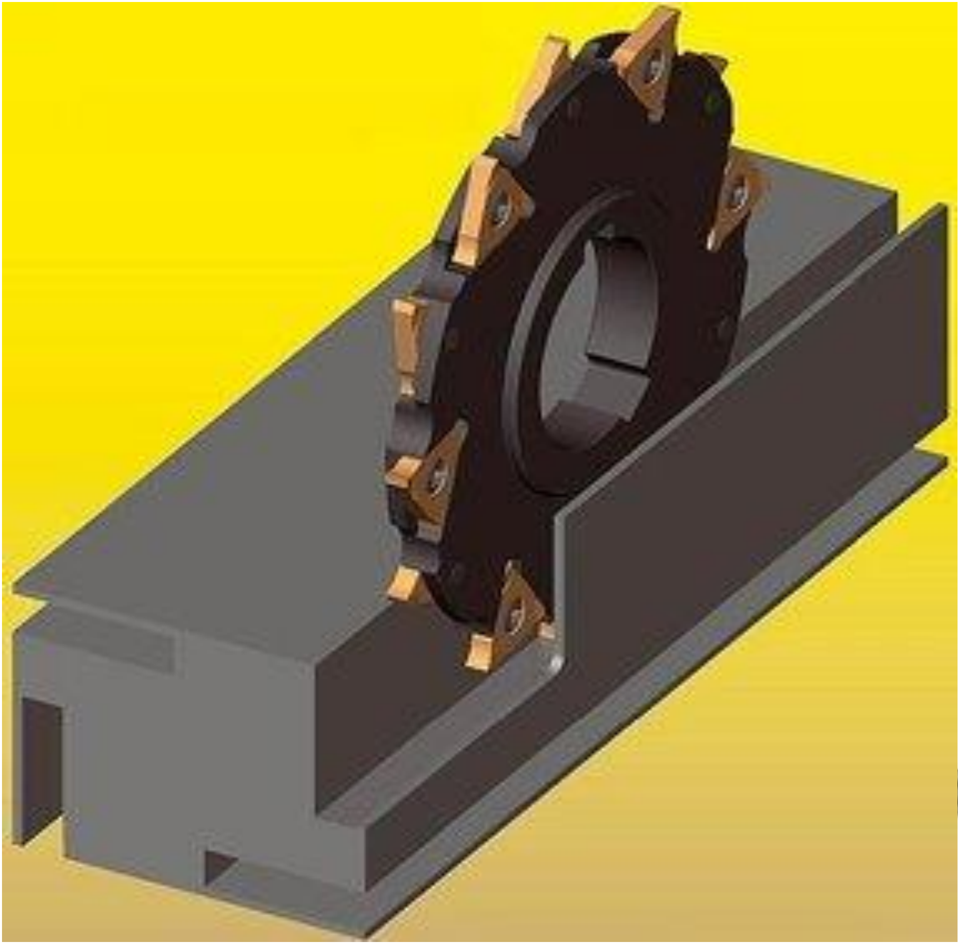
8. Gear cutting: By using form relieved cutter having the same profile of the tooth space of the gear.

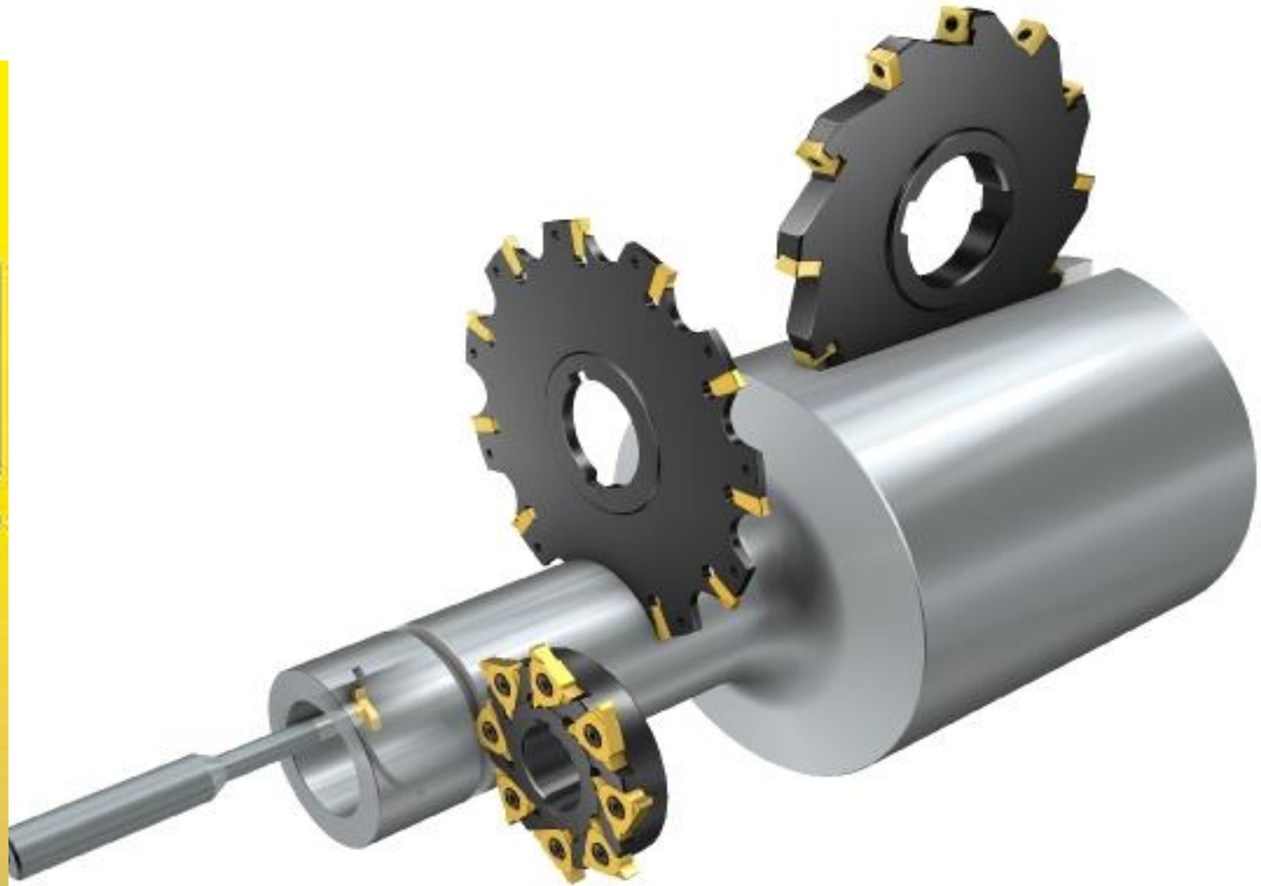
9. Helical Milling: Producing helical flutes or grooves around the periphery of a cylindrical or conical work piece.

10. Cam Milling: Producing cams by using universal dividing head and a vertical milling attachment.

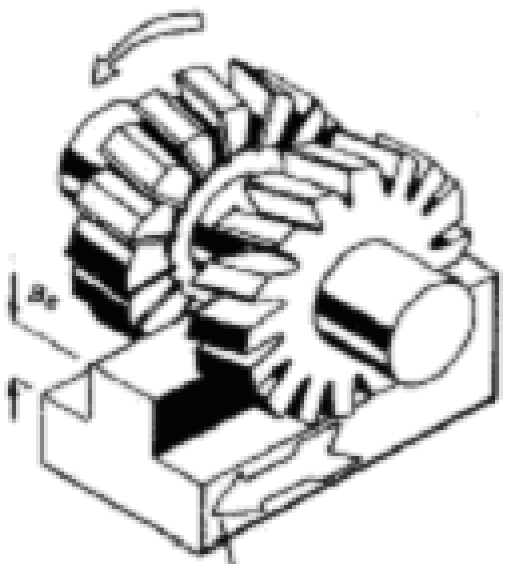
Note: 8, 9, 10, above can be done in indexing.

Side and slot milling cutters

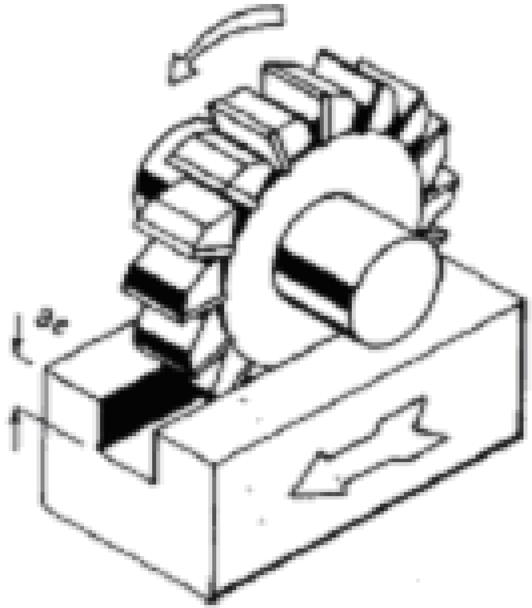




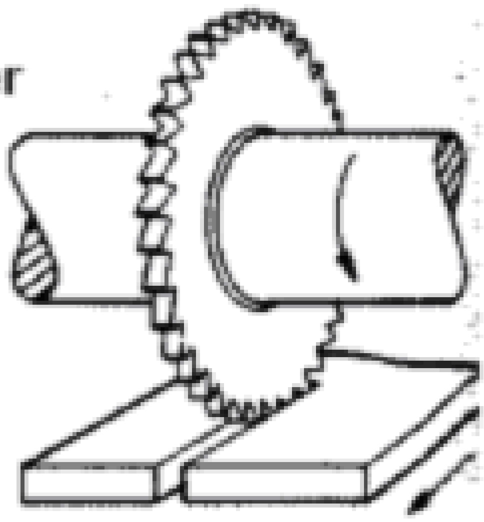
Slitting saw or parting tool



(a) parallel facing by
two side (single) cutter

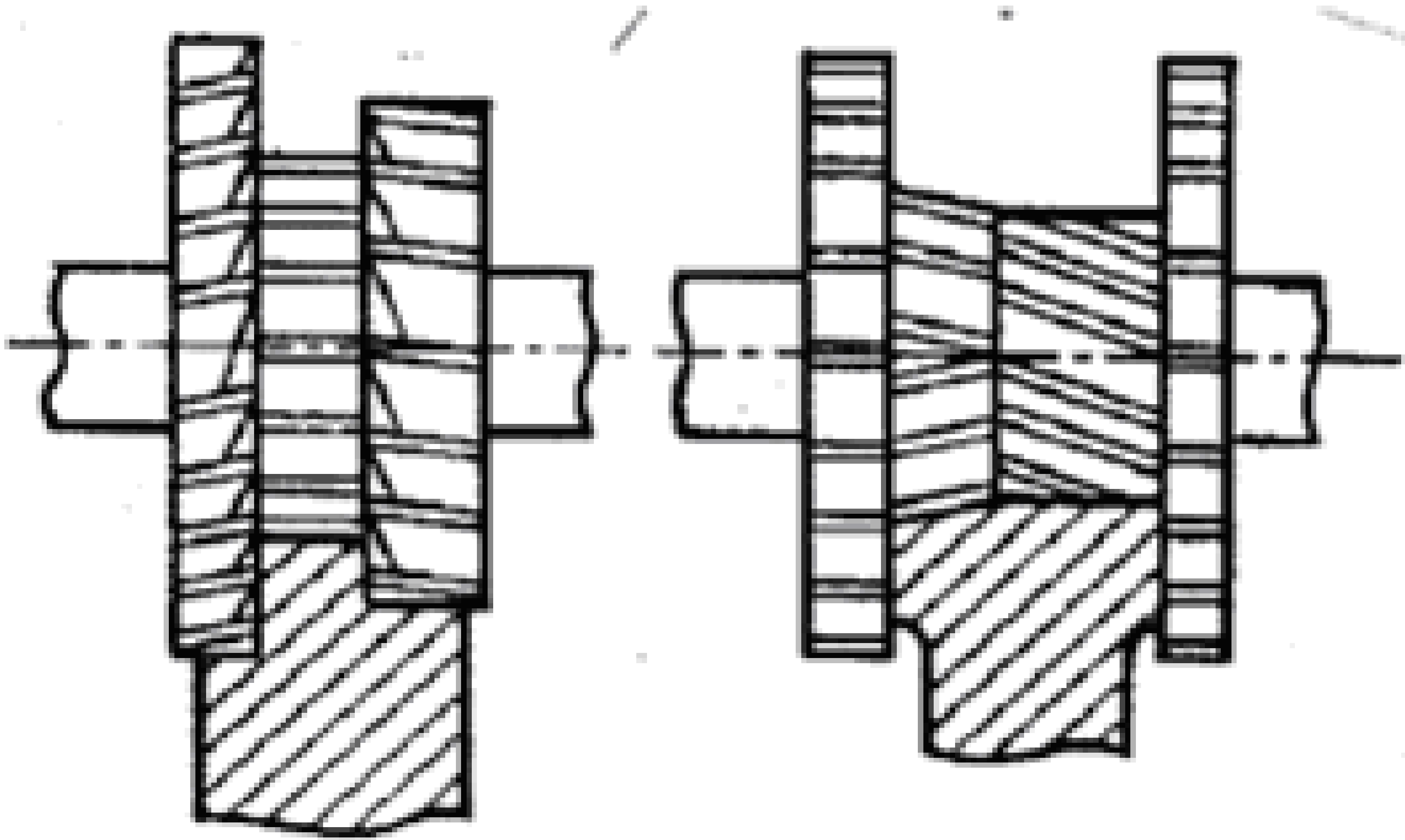


(b) slotting by side (double sided)
milling cutter



(c) Parting by slitting saw

Gang milling



Milling Velocity

The cutting speed in milling is the surface speed of the milling cutter.

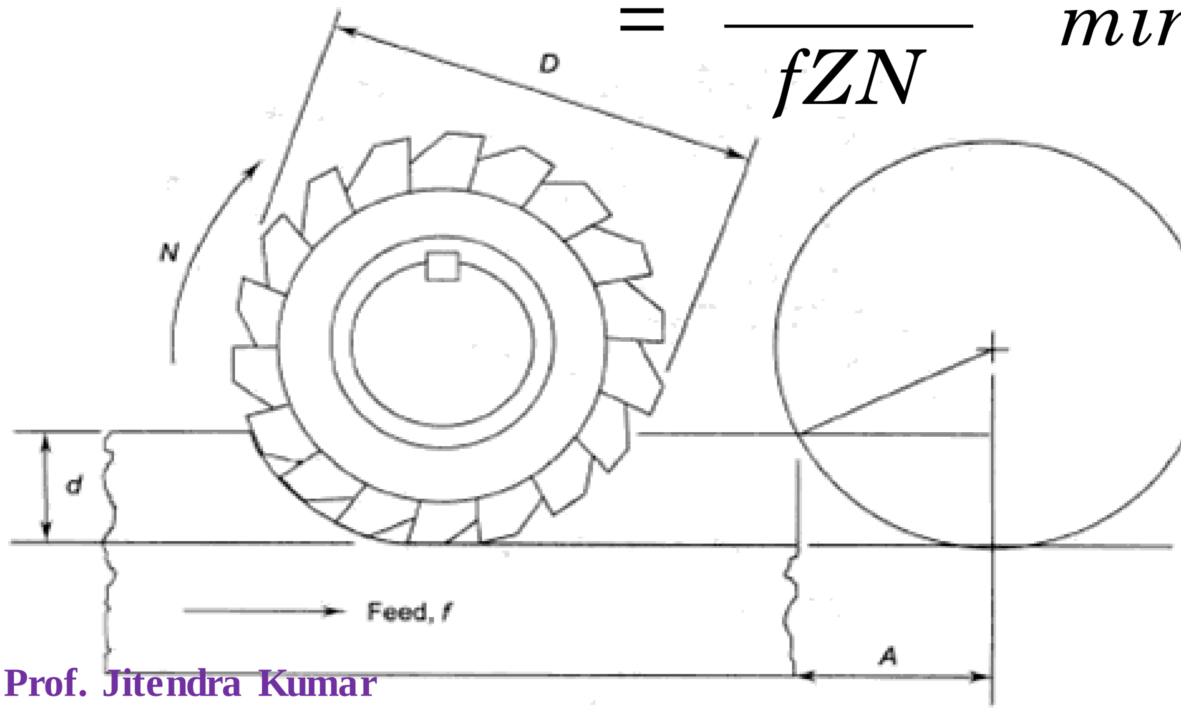
$$V = \frac{\pi DN}{1000}$$

Milling Time: Slab or Slot Milling

$$Approach\ distance,\ A=\sqrt{\left(\frac{D}{2}\right)^2-\left(\frac{D}{2}-d\right)^2}=\sqrt{d\left(D-d\right)}$$

$$Time\ for\ one\ pass = \frac{L+A}{fZN}\quad minutes\ (For Rough\ Milling)$$

$$= \frac{L+2A}{fZN}\quad minutes\ (For\ Finish\ Milling)$$



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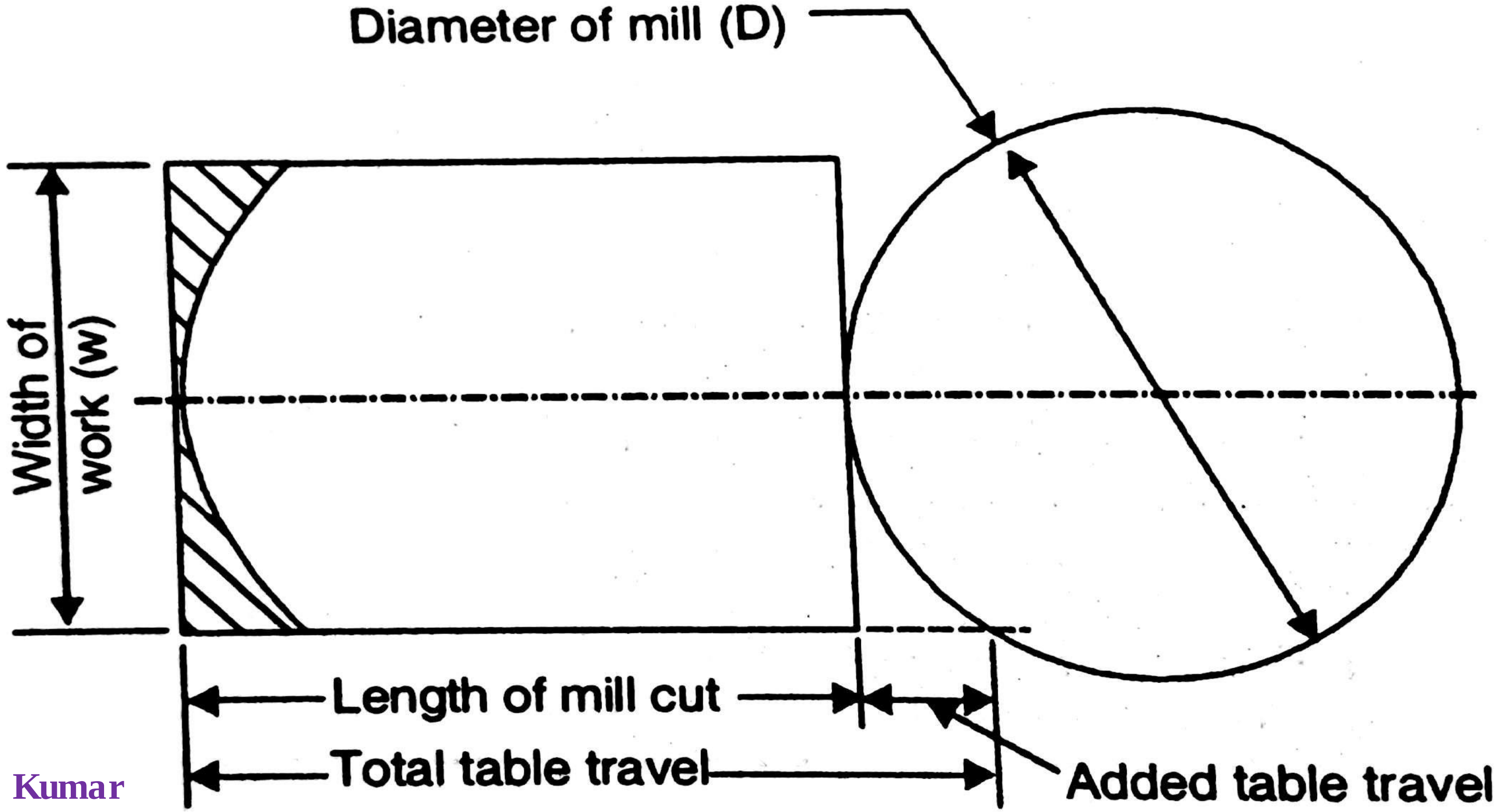
Milling Time: Face Milling

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

$$Time\ for\ one\ pass = \frac{L + A}{fZN}\ \ minutes$$



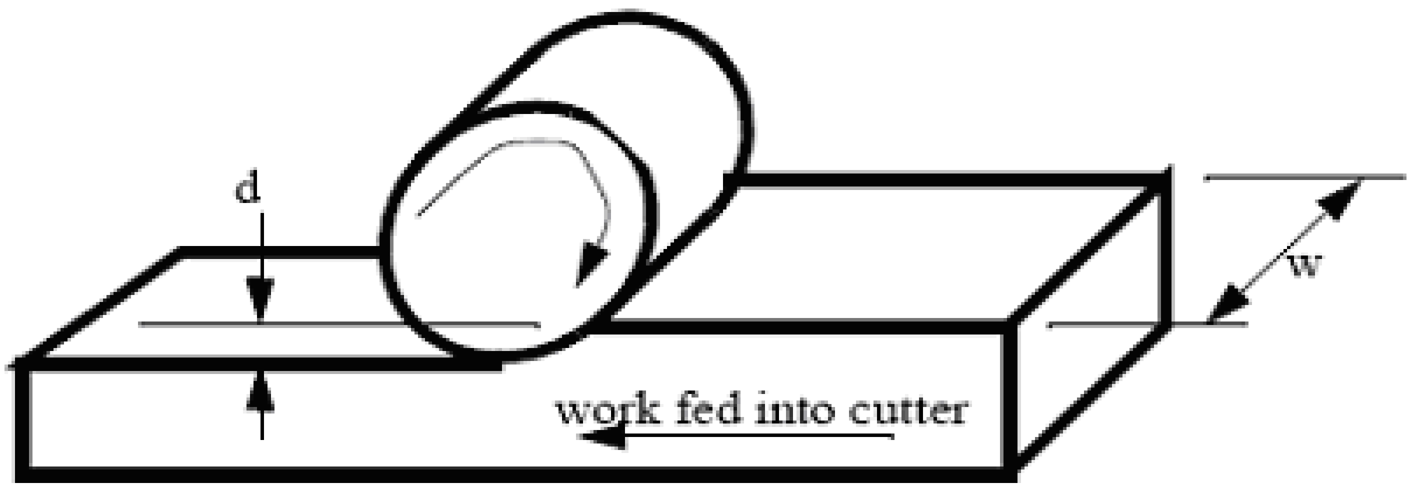
MRR in Milling

Considering the parameters defined in the discussion of speeds and feeds, etc, the MRR is given below,

Where,

$$MRR = w \times d \times F$$

where, w = width of cut, d = depth of cut



Some Formulae for Milling

Maximum uncut chip thickness $(t_{max}) = \frac{2f}{NZ}\sqrt{\frac{d}{D}}$

Average uncut chip thickness $(t_{avg}) = \frac{f}{NZ}\sqrt{\frac{d}{D}}$

Peak to valley surface roughness $(h_{max}) = \frac{f^2}{4DN^2Z^2}$

IES - 2007

What is the process of removing metal by a milling cutter which is rotated against the direction of travel of the work piece, called?

(a) Down milling (b) Up milling

(c) End milling (d) Face milling