LAB MANUAL FOR THE METAL CUTTING AND TOOL DESIGN

B.Tech (Mechanical and Automation)

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METAL CUTTING AND TOOL DESIGN LAB

List of Experiments

1. To study various machine tools and machining processes.
2. To study various cutting tool materials and their applications.
3. To study and practically verify types of Chips under different cutting conditions.
4. To determine the cutting ratio and shear angle for metal cutting operation on a lathe machine.
5. To study grinding wheel and tool drill nomenclature.
6. To study single point tool nomenclature using tool maker’s microscope.
7. To measure various cutting forces using tool force dynamometer.

EXPERIMENT NO. 1

AIM To study the selected machine tools and machining processes.

THEORY:
INTRODUCTION:

Machining
Machining is a process designed to change the size,shape and surface of a material through removal of materials that could be achieved by straining the material to fracture or by thermal evaporation.

Importance of machining

- Excellent dimensional tolerances
  -Example is forged crankshaft where holes and bearing surfaces require tight tolerances.
- External and internal geometrical features
  -Sharp corners, grooves, fillets, various geometry
- Surface finish
  -Example is a copper mirror by diamond turning
- Removal of heat treat distortion
  -Parts such as crank and camshafts undergo distortion during heat treatment.
  Machining is a process for "straightening" the parts.
- Economical if small quantities.

  Constituents of machining system:
  A machining system consists of three components: machine tool, cutting tool and work piece (part to be machined)

  Fundamental machining parameters:
  Cutting speed(V): is the largest of the relative velocities of cutting tool or work piece. In turning it is the speed of the work piece while in drilling and milling it is the speed of the cutting tool. In turning it is given by the surface speed of the work piece, $V=\Pi D1N$ where D1 is the diameter of the work piece.

Conventional (Up) and climb (Down) milling

Up milling	Down milling
-Beginning chip thickness is small. Advantages 1.Oxide scale or hard surface of work does not matter. 2. Rigidity is not critical because the cutter is opposed by the feed of the work(machine is even). Drawbacks 1. Tool chatter 2. Feed marks 3. Clamp work piece(work moves up)	-Beginning chip thickness is large Advantages 1. Low temperature(long tool life) 2. Smaller feed marks 3. Downward part of cutting force holds the work piece(slender parts) Drawbacks 1. Rigid setup is needed due to the cutter pulling the workpiece along. 2. Not suitable for oxide scale surfaces.

Grinding:

It is a chip removal process that uses an individual abrasive grain as the cutting tool.

Types of grinding machines:

1. Surface
2. Cylindrical
3. Center less

EXPERIMENT NO.2

AIM To study the cutting tool materials involved in metal cutting.

THEORY A cutting tool must possess the following characteristics:-

- Hardness
- Toughness
- Wear Resistance
- Chemical Stability

Various cutting tool materials with a wide range of mechanical, physical and chemical properties are available. They are:

1. Carbon and medium alloy steel

Carbon steel are the oldest of tool materials and have been widely used for drills,taps,broaches and reamers. Low alloy and medium alloy steels were developed later for similar applications but with longer tool life. They are not fit for high speeds and the use of these steels are limited to very low cutting speed operations.

2 .High speed steels

It was developed to cut at higher speeds. They can be hardened to various depths and have good wear resistance. They are of two types:

Molybdenum(M series) : It contains 10 % molybdenum with chromium,vanadium, tungsten and cobalt as alloying elements.

Tungsten(T series) : It contains 12%-18% tungsten with chromium,vanadium and cobalt as alloying elements. Both are used in wide variety of cutting operators such as drills, reamers and gear cutters.

2. Cast-cobalt alloys

They have the following composition 38%-53% cobalt,30%-33% Chromium and 10%-20% tungsten. Because of their high hardness they have good mean resistance and can maintain hardness at elevated temperatures. They are also known as satellite tools and they are used for deep continous roughing cuts at relatively high feeds and speeds.

3. Carbides (Inserts)

They are also known as Cemented or sintered carbides. Because of their high hardness over a wide range of temperatures, high elastic modules and thermal conductivity with low thermal

expansion, carbides are among the most important, versatile and cost effective tool.
The two basic groups of carbides are Tungsten Carbide and Titanium Carbide.

a)Tungsten Carbide(Wc)

It is composite material consisting of Tungsten Carbide particles bonded together with cobalt also known as cemented carbides. The tools are manufactured with power metallurgy techniques.

b)Titanium Carbide (TiC)

It has higher wear resistance than WC. TiC is suitable for machining hard materials mainly steels and cast iron for cutting at higher speeds.

INSERTS: They are individuals cutting tools with several cutting tools with several cutting points for example a square insert has eight cutting points and a triangular insert for six. Inserts are clamped on the tool shank with various locking mechanism. Inserts are used at high feeds and high speeds but at light feed, low speed and chatter are detrimental because they tend to damage the tools cutting edge.

4. Coated Tools

They have high strength and toughness but are generally abrasive and chemically reactive with tool materials. Commonly used coating materials are titanium nitride (TiN) ,Titanium Carbide (TiC), Titanium carbo nitride (TiCN) and Aluminium Oxide (Al_2O_3). These coatings are in thickness range of 2-15 μm are applied on cutting tools and inserts by the following techniques
i)Chemical vapour preposition (CVD)
ii)Physical vapour deposition (PVD)

Coatings for cutting tool should have the following properties:

- High hardness
- Chemical Stability
- Low thermal conductivity
- Good bonding
- Little or no porosity

5. Aluminium Based Cemamics

They consist of high purity Al_2O_3. They are cold pressed into insert shaped under high pressure and sintered at high temperature. Addition of TiC and Zirconium Oxide helps to improve properties such as toughness and thermal shock. These tools have high abrasive resistance and hot hardness. Mostly used in cutting, cast irons and steels.

6. Cubic Boron Nitride (CBN)

After diamond CBN is the hardest material presently available which is also an abrasive. At elevated temperature CBN is chemically inert to iron and nickel and its resistance to oxidation is higher. Thus its most suitable for cutting hardened ferrous and high temperature alloys.

7. Silicon Nitride Based Ceramic

They consists of silicon nitride with various additions of Al2O3, yitrium oxide. The tools have toughness, hot hardness and good thermal shock resistance. An example is silicon which is recommended for machining cast irons and nickel based super alloys at intermediate cutting speeds.

8. Diamond

The hardest known substance to mankind is diamond. It has low friction, high wear resistance and ability to maintain sharp cutting edge. It is used when good surface finish, dimensional accuracy and required particularly with soft non-ferrous alloys and abrasive non-metallic materials.

9. Whisker Reinforced Tool Material

Amongst the most recent developments, whiskers are used as reinforcing fibersion composition cutting tool materials. Example are silicon nitride based tools reinforced with silicon carbide (SiC) whiskers and Al2O3 based tools reinforced with SiC whiskers. Sometimes with the addition of zirconium oxide.

EXPERIMENT NO. 3

AIM: To study and practically verify effect of workpiece material on chip formation process.

MATERIALS USED:

Cutting tool material: H.S.S.

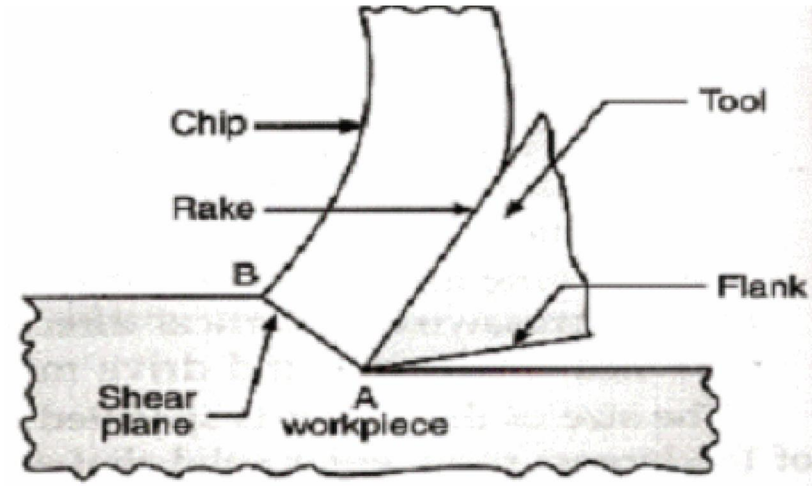
Workpiece material: Aluminium,Brass

THEORY:

Though chips are only by-products of machining operations, they are very important in the study of machinability of metals as well as the study of cutting tool wear. The classification of chips is generally into three groups:

Discontinuous chips; Continuous chips and Chips with built-up-edges (not continuous chip with built up edges). This is based on the chip formation theory of a single shear plane. The material immediately in front of the tool is bent upward and is compressed in a narrow zone of shear which is shaded on the drawing above. For most analyses, this shear area can be simplified to a plane.

As the tool moves forward, the material ahead of the tool passes through this shear plane. If the material is ductile, fracture will not occur and the chip will be in the form of a continuous ribbon. If the material is brittle, the chip will periodically fracture and separate chips will be formed. It is within the shear zone that gross deformation of the material takes place which allows the chips to be removed. As on the stress-strain diagram of a metal, the elastic deformation is followed by plastic deformation. The material ultimately must yield in shear.



Three main categories of chips are:

Discontinuous chips

Continuous chips

Continuous chips with built-up-edge(BUE)

Discontinuous Chips: These chips are small segments, which adhere loosely to each other. They are formed when the amount of deformation to which chips undergo is limited by repeated fracturing. Hard and brittle materials like bronze, brass and cast iron will produce such chips.

Continuous chips :In continuous chip formation, the pressure of the work piece builds until the material fails by slip along the plane. The inside on the chip displays steps produced by the intermittent slip, but the outside is very smooth. It has its elements bonded together in the form of long coils and is formed by the continuous plastic deformation of material without fracture ahead of the cutting edge of the tool and is followed by the smooth flow of chip up the tool face.

Continuous chips with built-up-edge(BUE) :

This type of chip is very similar to that of continuous type, with the difference that it is not as smooth as the previous one. This type of chip is associated with poor surface finish, but protects the cutting edge from wear due to movement of chips and the action of heat causing the increase in tool life.

Cutting conditions are the main causes for discontinuous chips

- Very low or very high cutting speed
- Large depth of cut
- Low rake angle
- Lack of cutting fluid
- Vibration on the machine tool

METHODOLOGY:

The experiment was carried out on a lathe machine. Two types of work piece materials were used: Aluminium,Brass.

Cutting operations are carried out dry, that is, without the use of coolants for all the three work-piece materials used for this experimental works. Cutting conditions were chosen are: cutting speed, V(45m/min recommended); cutting feed, s, and depth of cut, t.

RESULTS:

The types of chips which normally comes with the type of workpiece chosen were studied and verified successfully under the performed cutting operation on lathe machine.

EXPERIMENT NO. 4

AIM : To determine the cutting ratio and shear angle for metal cutting operation on lathe machine.

EXPERIMENTAL CONDITIONS:

Workpiece material:Aluminium,initial diameter:25 mm approx.

Tool Material: High Speed Steel

Tool Geometry: rake angle:8°,nose radius : 2 mm

THEORY:

The orthogonal Cutting Model

The machining process is a complex 3D operation. A simplified 2D model of machining is available that neglects many of geometric complexities, yet describes the process quite well.Orthogonal cutting uses a wedge-shaped tool in which the cutting edge is perpendicular to the cutting direction. As the tool is forced into the material, the chip is formed by shear deformation along shear plane oriented at an angle φ (shear angle) with the surface of the workpiece. Along the shear plane,plastic deformation of work material occurs.

The tool in orthogonal cutting has two main elements of geometry: (1) rake angle and (2) clearance angle. The rake angle α determines the direction of chip flow as it is formed; and the clearance angle provides a small clearance between tool flank and newly generated work surface.

Chip Thickness Ratio:

r = t1/t2

t1 = chip thickness prior to deformation.(uncut chip thickness)

t2 = chip thickness after deformation(cut chip thickness)

As the chip is formed along the shear plane, its thickness increases to t2.

The ratio of t1 to t2 is called chip thickness ratio and is always less than 1.

Also, t1 . L1 = t2 . L2

Where L1 = length of metal before cut

L2 = length of chip

i.e r = t1/t2 = L2/L1

An important relationship exist between chip thickness ratio,rake angle and shear plane angle.

$$\tan \Phi = \frac{r \cos ά}{1- r \sin ά}$$

where Φ = shear plane angle

r = chip thickness ratio

ά = rake angle

METHODOLOGY:

Workpiece mounted on the lathe machine is provided with a groove of approx. 2mm. Workpiece is made to revolve at a slow speed and tool is fed against the work so that chip material is removed.Collect the chips as soon as chips are generated.

DETAILS ON DETERMINING CHIP THICKNESS RATIO AND SHEAR ANGLE:

Length of metal before cut,L1(for one revolution) = Π D – 2mm

Where D = Initial diameter of workpiece in mm

Length of chip (L2) is measured using a thread and a scale.

Ratio of L2 and L1 is calculated.

After determining r,shear plane angle Φ can be determined using r and ά .

RESULTS: The calculated values for r and Φ are:

r = ____________________

Φ = ____________________

EXPERIMENT NO. 5

AIM To study grinding wheel and tool drill nomenclature

Grinding wheels are a multipoint cutting tool composed of selectively sized abrasive grains held together by a bonding material. Abrasive materials are Aluminium oxide or Silicon Carbide in conventional range.

Grinding is a process of material removal, which happens in the form of chips by the mechanical action of regularly shaped abrasive particles bonded together in a grinding wheel. Grinding is done to get required Size, Form, and Finish. Grinding wheel is a multilayer consisting of minimum of 54% abrasive grain and 26% bond maximum with 15- 20% porosity .Nomenclature of a grinding wheel is as below is shown in Table 1.

Table 1: Grinding wheel nomenclature (1)

Type of abrasive	Grain size	Grade/ Hardness	Structure	Type of bond	Manufacturer's reference
A	**36**	**L**	**5**	**V**	**23** **23/80**

Abrasive Types

Aluminum Oxide

Silicon Carbide

Cubic Boron Nitride (CBN)

Synthetic Diamond

A – is the Aluminium oxide material.

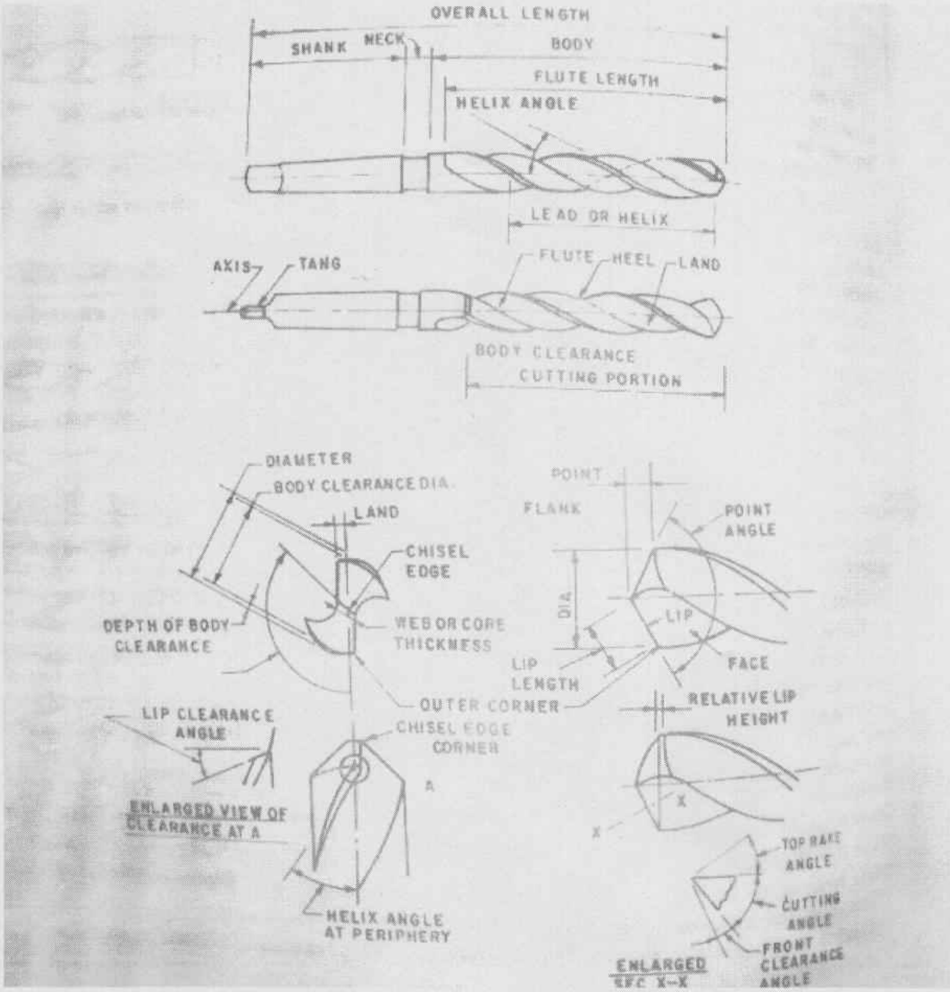
Grain size plays a part in Metal removal rate and also in the finish of the job for grinding. Grit size typically runs from coarse (16 -24 grit), medium (36 - 60 grit) and fine (80-120 grit). Superfine grits run from 150 and higher. Grinding wheels usually will be between 24 and 100 grit. Honing stones and jointing stones and other polishing abrasives will be 150 grit and higher. Use a coarse grit for fast, aggressive stock removal and finer grits for less stock removal but better surface finish.

Hardness represents the amount of grain to bond ratio in a grinding wheel,which is tuned, based on application requirement. Hardness is ated from A-Z with 'A' being the weakest bond and 'Z' being the strongest. A weak bond is preferred for grinding harder materials while a stronger bond is desired for softer materials. Hardness is dependant on the grit type, the material being ground, the amount of stock removed, and a number of other factors.

Structure is basically the spacing between abrasive grains. An open structure would be 12 or higher while a closer structure would be 6 or so. Here again, the structure depends on a variety of factors not the least of which is how difficult the material is to grind. One would think that a closer spacing would make a for tougher wheel but this is only true to a point: With less bond holding the true for individual abrasive grains, the softer the wheel would be. Also, the same holds a very open structure: If the grains are wide spaced you have fewer grains to grind with but a greater amount of bond holding each grain -- This could make the wheel tougher. Grinding wheel engineers will typically adjust the Bond Strength depending on the application.

Bond typeV- represents Vitrified bond, B for resin bond grinding wheel. There are various bond types but the most common are vitrified and resin.Vitrified wheels are commonly used for bench, surfaceand tool room applications such as surface grinding while resin wheels are commonly seen in cutoff wheels, centerless wheels and superabrasive wheels (diamond & CBN).

Nomenclature of Twist Drills



Axis: The imaginary straight line which forms the longitudinal center line of the Drill

Body: The portion of the drill extending from the shank or neck to the outer corners of the cutting lips

Body Diameter Clearance: That portion of the land that has been cut away so it will not rub against the walls of the hole

Chisel Edge: The edge at the end of the web that connects the cutting lips

Flutes: Helical or straight grooves cut or formed in the body of the drill to provide cutting lips, to permit removal of chips, and to allow cutting fluid to reach the cutting lips

Face: That portion of the flute surface adjacent to the lip on which chip impinges as it is cut from the work.

Flank: The surface on a drill point which extends behind the lip to the following flute.

Heel: The trainling edge of the land

Land: The peripheral portion of the body between adjacent flutes

Lips: The cutting edges of a two flute drill extending from the chisel edge to the Periphery

Neck: The section of reduced diameter between the body and the shank of a drill

Point: The cutting end of a drill, made up of the ends of the lands and the web; in

Web Thickness: The thickness of the web at the point, unless another specific location is indicated

Chisel Edge Angle: The angle included between the chisel edge and the cutting lip, as viewed from the end of the drill

Helix Angle: The angle made by the leading edge of the land with a plane containing the axis of the drill

Point Angle: The angle included between the cutting lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips

Rake angle: The angle between the frame and a line parallel to the drill axis. At the periphery of the drill it is equal to the helix angle.

Lip clearance angle: The angle made by the flank and a plane at right angles to the drill axis. The angle is normally measured at the periphery of the drill.

EXPERIMENT NO. 6

AIM To study angle measurement of single point cutting tool using Tool Makers Microscope.

TOOL MAKERS MICROSCOPE

The large Tool Maker's Microscope (TMM) essentially consists of the cast base, the main lighting unit, the upright with carrying arm and the sighting microscope. The rigid cast base is resting on three foots screws by means of which the equipment can be leveled with reference to the build-in box level. The base carries the co-ordinate measuring table, consists of two measuring slides; one each for directions X and Y and a rotary circular table provided with the glass plate (Fig.1). The slides are running on precision balls in hardened guide ways warranting reliable travel. Two micrometer screws each of them measuring range of 0 to 25 mm permit the measuring table to be displaced in the directions X and Y. The range of movements of the carriage can be widened up to 150 mm in the X direction and up to 50mm in the Y direction with the use of gage blocks.

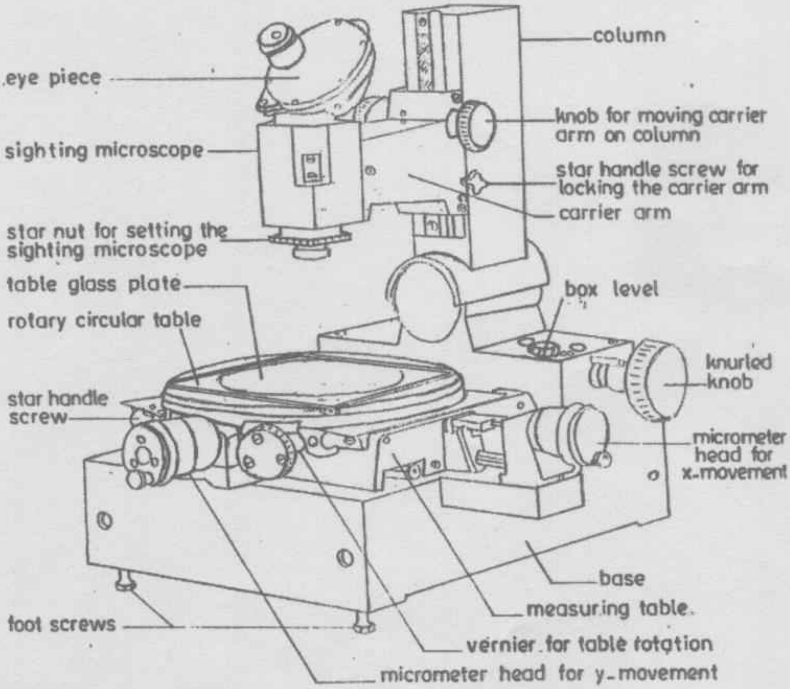


Fig. 1 Tool Makers Microscope

The rotary table has been provided with 360 degrees graduation and with a three minute vernier. The rotary motion is initiated by activation of knurled knob and locked with star handle screw. Slots in the rotary table serve for fastening different accessories and completing elements.
The sighting microscope has been fastened with a carrier arm to column. The carrier arm can be adjusted in height by means of a rack and locked with star handle screw. Thread measuring according to the shadow image permits the column to be tilted in X direction to either side about an axis on centre plane level. The corresponding swivel can be adjusted with a knurled knob with a graduation cellar. The main lighting unit has been arranged in the rear of the cast base and equipped with projection lamp where rays are directed via stationary mounted mirror through table glass plate into the sighting microscope.

Measuring principle

The work piece to be checked is arranged in the path of the rays of the lighting equipment. It produces a shadow image, which is viewed with the microscope eyepiece having either a suitable mark for aiming at the next points of the objects or in case of often occurring profiles. e.g. Threads or rounding – standard line pattern for comparison with the shadow image of the text object is projected to a ground glass screen. The text object is shifted or turned on the measuring in addition to the comparison of shapes. The addition to this method (shadow image method), measuring operations are also possible by use of the axial reaction method, which can be recommended especially for thread measuring. This involves approached measuring knife edges and measurement in
axial section of thread according to definition. This method permits higher precision than shadow image method for special measuring operations.

Applications

The large tool maker's microscope is suitable for the following fields of applications;Length measurement in cartesian and polar co-ordinates.
Angle measurements of tools; threading tools punches and gauges, templates etc.Thread measurements i.e., profile major and minor diameters, height of lead, thread angle, profile position with respect to the thread axis and the shape of thread. (rounding, flattering, straightness of flanks)
Comparison between centres and drawn patterns and drawing of projected profiles.

Single point lathe tool angle measurements

The various tool angles as per machine reference system (American System of Tool Nomenclature-ASA) are as follows; Back rake angle (γy) is the angle between the tool face and the ym axis and is measured in ym - zm Plane (Fig.2). Side rake angle (γx) is the angle between the tool face and the xm axis measured in xm - zm plane. End relief angle (αy) is the angle between the end flank and the zm axis measured in ym - zm plane. Side relief angle (αx) is the angle between the side flank of the tool and the zm axis and is measured in xm - zm plane. End cutting edge angle (□e) is the angle between the trailing edge of the tool and the xm axis and is measured in xm - ym plane. Side cutting edge angle (□s) is the angle between the side cutting edge of the tool and the ym axis and is measured in the xm - ym plane.

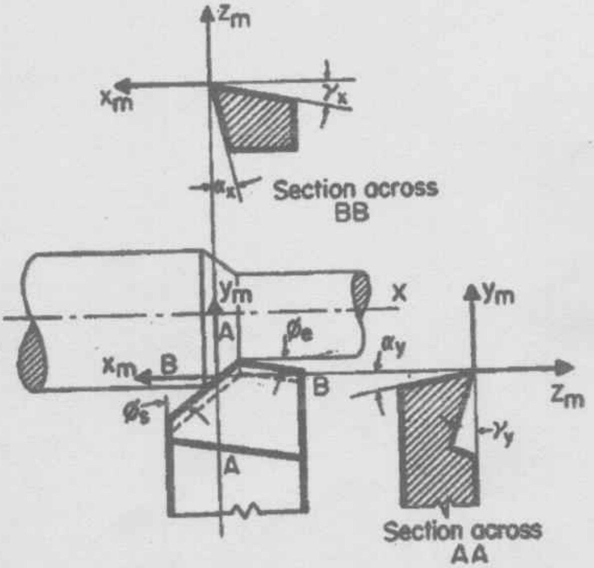
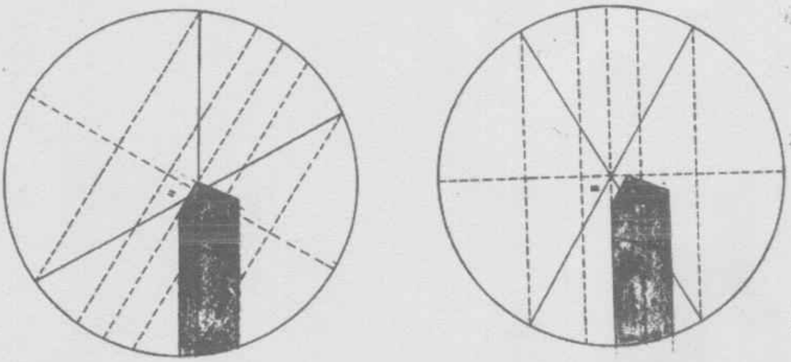


Fig.2 Orientation of face and flank surfaces with respect to machine reference system (American System of Tool Nomenclature)

Procedure of measurement with TMM

Place the tool bit on the glass stage so as to obtain a clear image on which angular measurements are done. Focus the microscope to get a real image super imposed on the graticule pattern of the eyepiece. Tilt the graticule pattern so as to align the shank edge with the reference hair line. Read microscope angle scale. Tilt the angle so as to bring the cutting edge of the tool to align with the reference hairline. If necessary X, Y movements may be made to retain the edge in the field of view. A typical field of vision before and after adjustment is shown in Fig 3.



(a) before adjustment (b) after adjustment

Fig. 3 Field of vision of sighting microscope of TMM

EXPERIMENT NO. 7

AIM : 1. To measure various cutting forces using tool force dynamometer.
2. To investigate the relationship between the cutting variables: speed and the cutting forces produced.
3. To calculate frictional force between the tool and the chip,the normal force between the tool and the chip,the shear force and the force normal to the shear plane.

APPARATUS: Lathe machine,Tool force dynamometer,tool,workpiece.

THEORY:

Design requirements for Tool – force Dynamometers

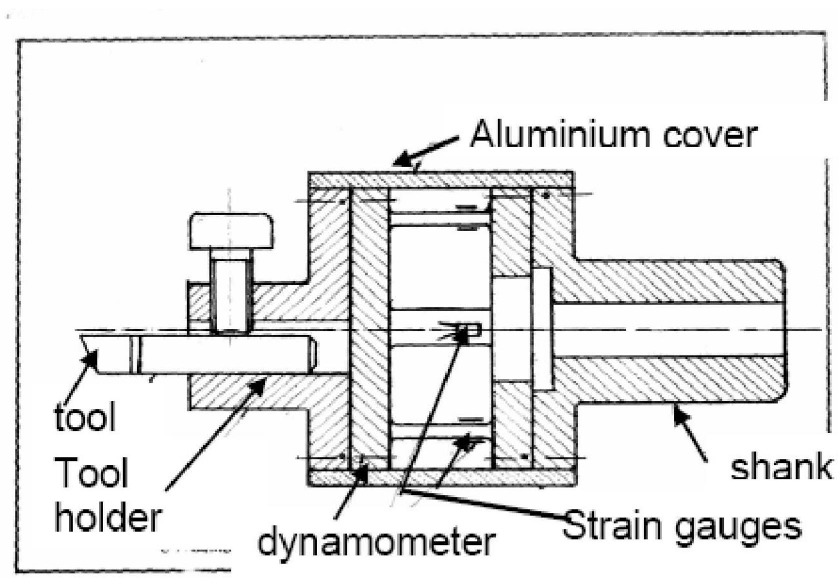
For consistently accurate and reliable measurement, the following requirements are considered during design and construction of any tool force dynamometers :

- Sensitivity : the dynamometer should be reasonably sensitive for precision measurement
- Rigidity : the dynamometer need to be quite rigid to withstand the forces without causing much deflection which may affect the machining condition
- Cross sensitivity : the dynamometer should be free from cross sensitivity such that one force (say PZ) does not affect measurement of the other forces (say PX and PY)
- Stability against humidity and temperature
- Quick time response
- High frequency response such that the readings are not affected by vibration within a reasonably high range of frequency
- Consistency, i.e. the dynamometer should work desirably over a long period.

Turning dynamometers may be strain gauge or piezoelectric type and may be of one, two or three dimensions capable to monitor all of PX, PY and PZ.

For ease of manufacture and low cost, strain gauge type turning dynamometers are widely used and preferably of 2 – D (dimension) for simpler construction, lower cost and ability to provide almost all the desired force values.

Design and construction of a strain – gauge type 2 – D turning dynamometer are shown schematically in Fig. 10.8 and photographically in Fig. 10.9 Two full bridges comprising four live strain gauges are provided for PZ and PX channels which are connected with the strain measuring bridge for detection and measurement of strain in terms of voltage which provides the magnitude of the cutting forces through calibration.



Schematic view of a strain gauge type 2 – D turning dynamometer.

CALCULATIONS :

From forces that were measured directly the cutting force, F_c , and the tangential force, F_t and the other variables such as rake angle,, and cutting velocity, V_c, the other forces such as the frictional force between the tool and the chip, F, the normal force between the tool and the chip, N, the shear force, F_s , and the force normal to the shear plane, F_n , will be calculated.

OBSERVATION TABLE:

S.NO	RPM(N)	Cutting Speed(ΠDN/1OOO) (m/min)	Feed (mm/rev)	Fc (N)	Ft (N)

Plot graph between Fc,Ft and cutting speed.

RESULTS :