Department of Mechanical Engineering

Lab Manual

Production Technology Lab

(MEC304)

Laboratory Location: Welding shop/Foundry Shop/Machine shop

Indian Institute of Technology (Indian School of Mines)
Dhanbad - 826001

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List of Experiments

Safety in the Lab

- You are only allowed in the laboratory when there is a 'responsible person' present such as a demonstrator or the laboratory staff.
- Do not touch any equipment or machines kept in the lab unless you are asked to do so.
- A tidy laboratory is generally safer than an untidy one, so make sure that you do not have a confused tangle of electrical cables. Electrical equipment is legally required to be regularly checked, which means it should be safe and reasonably reliable: do not tamper or attempt to repair any electrical equipment (in particular, do not rewire a mains plug or change a fuse - ask one of the laboratory staff to do it). Never switch off the mains using the master switches mounted on the walls. Please make yourself aware of the fire exits when you first come into the lab. When the alarm sounds please leave whatever you are doing and make your way quickly, calmly and quietly out of the lab. You must always follow instructions from your demonstrators and the laboratory staff.
- You must keep walkways clear at all times and in particular coats and bags must be stowed away safely and must not pose a trip hazard.
- It is important that you make a point of reading the "Risk Assessment" sheet included in the manuscript of each experiment before you start work on the experiment.
- Please take notice of any safety information given in your scripts. If an experiment or project requires you to wear PPE (personal protective equipment) such as gloves and safety glasses, then wear them.
- Always enter the lab wearing your shoes. It is strictly prohibited to enter the lab without shoes.
- There must be NO smoking, eating, drinking, use of mobile phones or using personal headphones in the laboratory. This last point is not because we dislike your choice of music but because you must remain aware of all activity around you and be able to hear people trying to warn you of problems.
- Keep the lab neat and clean.

Lab Report Format

Title:

- Provide a title that is a description of your lab followed by a lab number.
- The title should clearly identify the experiment's variables (independent & dependent)

Objective/Purpose/Problem:

- This is the place to explain what you are trying to find out or what you are going to do in the lab.
- Include information about the variables involved.

Hypothesis: "If………then………because………"

- This is a cause/effect statement.
- This is a prediction of what the expected outcome of the lab will be.
- Relate the hypothesis to the purpose/problem of the lab.
- Try to focus your hypothesis on the information/research you collected.

Materials:

- List all items in a column.
- Make sure to record the exact size and amount of each item required.

Procedures:

- List and number each step.
- Use complete sentences (begin with a capital letter and use end punctuation).
- Should be clear enough for someone else to use as instructions for repeating your experiment.

Observations/Data:

- Be sure to accurately record your observations/data in a chart or table.
- Create a graph to provide a visual of your data.
- Provide a verbal description of your data.
- List all quantitative (numbers) and qualitative (words) data.
- List all variables and explain what your control was.

Conclusion: "When…………….then…................"

- Match your conclusion to the purpose or the problem.
- Base your conclusion on your analysis of your observations and any data that has been collected.
- **Explain:** (The following are just suggestions and DO require elaboration.)
    - What you did in the experiment
    - What you observed (trends/patterns in your data that supported or did not support your hypothesis)
    - What you learned from the lab
    - If you think it was a fair test (i.e. – was there anything that may have impacted the accuracy of your results)
    - Questions for further research and investigation
- **Application:** Can you think of an analogous situation that applies to real life?

Experiment No: 1

Metal cutting tool grinding operation using tool cutter grinder

OBJECTIVES

- ✓ To study the construction and different configurations of the tool cutter grinder
- ✓ Study of working principle of grinding process
- ✓ Imparting the given rake angles and clearance angle to HSS square bar and verification.

OUTCOMES

- ✓ The students will learn the procedure of sharpening and re-sharpening of the single point turning tools.

Theory and Procedure:

- Re-sharpening Method is generally avoided in case of modern tools made of coated carbides, ceramics, cermets, CBN and diamond which are expensive and extremely difficult to grind. But all cutting tools made of HSS are re-sharpened by conventional grinding.
- Single-Point Tools Sharpening and re-sharpening of cutting tools refers to the restoration of sharpness and geometry of the cutting edges. Single-point tools possess two cutting edges, which are:

1. Principal cutting edge – obtained as the line of intersection of the rake surface and the principal flank surface.
2. Auxiliary cutting edge - obtained as the line of intersection of the rake surface and the auxiliary flank surface.

Therefore, it is necessary to grind three surfaces of a single-point tool to generate two sharp cutting edges. Such grinding again can be done in the different reference systems.

i) ASA system – needs extra calculation for correction of angles and use of 3-D vice.

ii) ORS - also needs correction and a 3-D vice.

iii) NRS - needs no correction but needs a 3-D vice.

iv) MRS – needs no correction and only a 2-D vice.

Therefore, single-point tools are preferably re-sharpened by grinding in maximum rake system (MRS) and minimum clearance system (MCS)

Procedure for tool making:

*Geometry of the tool to be produced

ORS – [0˚- 12˚- 9˚- 8˚- 15˚- 60˚- 0˚]

$$[\ \lambda - \gamma_0 - \alpha_0 - \alpha_0' - \phi_1 - \phi - r\ ]$$

[Inclination angle - orthogonal rake angle - orthogonal clearance of principal flank - auxiliary cutting edge angle - principal cutting edge angle - nose radius (mm)]

Grinding of rake surface: -

1. Find ϕ_r (orientation angle)

$$\phi_r = \phi - \tan^{-1}\left(\frac{\tan\lambda}{\tan\gamma_0}\right)$$

2. γ_m (setting angle)

$$\gamma_m = \tan^{-1}\left(\sqrt{\tan^2\gamma_0 + \tan^2\lambda}\right.$$

Grinding of Tool Rake Surface in MRS (operational procedure):

The sequence of procedural steps for grinding of tool-rake surface in MRS is

1. Determine the values of ϕ_r (orientation angle) and γ_m (setting angle, i.e., maximum rake angle) from the tool geometry given in ASA, ORS or NRS.

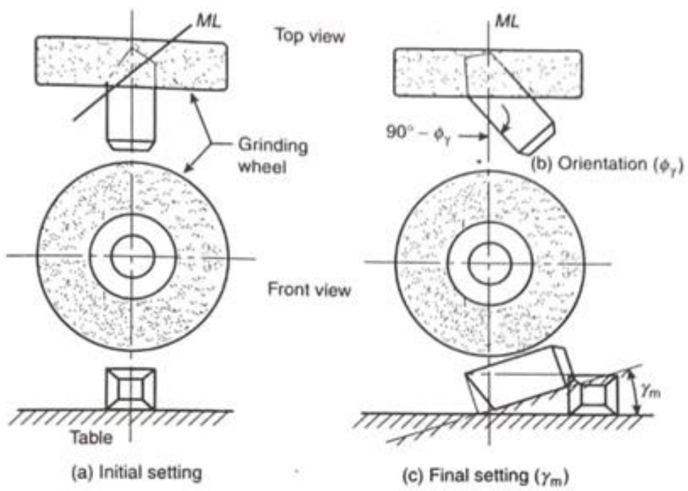


Figure 1. Setting for tool (single point) rake surface in MRS

2. Place the tool shank below the grinding wheel of the tool and the cutter grinder, keeping the shank parallel to the wheel axis as indicated in Fig.1(a).
3. Rotate (orient) the shank about the Z_m axis by on angle (90° - ϕ_r) to bring the ML parallel to the wheel axis as indicated in Fig. 1(b).
4. Rotate (tilt) the tool about the ML by maximum rake angle γ_m as shown in Fig. 1(c).
5. Reciprocate the tool-table bringing the tool (rake face) in contact with the wheel surface for grinding action
6. Repeat reciprocation with small infeed.

Grinding of Principal Flank:

1. Calculate ϕ_α (orientation angle)

$$\phi_\alpha = \phi - \tan^{-1}(\tan\alpha_0 \cdot \tan\lambda)$$

2. Calculate α_m

$$\alpha_m = cot^{-1}\left(\sqrt{cot^2\,\alpha_0 + tan^2\,\lambda}\right)$$

Grinding of Principal Flank in MRS (operational procedure)

The sequence of procedural steps for grinding of the principal Rank in MRS is

1. Determine the values of ϕ_α and α_m from the given tool geometry.
2. Place the tool shank below the grinding wheel as shown in Fig.2(a).
3. Rotate the tool about Z_m by (90° -ϕ_α) to bring the ML of the principal flank parallel to the wheel axis as indicated in Fig. 2(b).
4. Rotate the tool shank (vice) about the ML by α_m as indicated in Fig. 2(b).
5. Reciprocate the tool (flank) in contact with the wheel.
6. Repeat reciprocation with slight infeed.

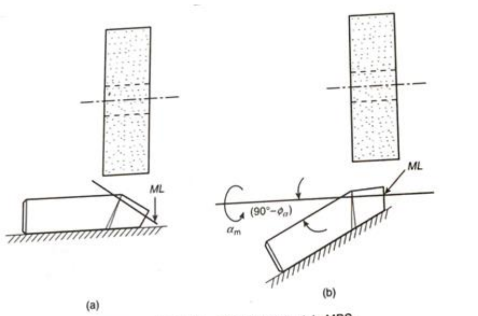


Figure 2. | Grinding of principal flank in MRS.

Angle conversion ORS to ASA

$$tan\,\gamma_x = tan\,\gamma_0\,sin\,\phi - tan\,\lambda\,cos\,\phi$$

$$\tan\gamma_y = \tan\gamma_0 \cos\phi + \tan\lambda \sin\phi$$
$$\cot\alpha_x = \cot\alpha_0 \sin\phi - \tan\lambda \cos\phi$$
$$\cot\alpha_y = \cot\alpha_0 \cos\phi + \tan\lambda \sin\phi$$
$$\phi_5 = 90^0 - \phi$$
$$\phi_1 = \phi_e$$

Observation table:

Parameters	Desired value	Experimental value	Error %
Rake angle			
Principal clearance angle			

Questions:

1. Write the significance of the Maximum rake system.
2. What is master line? And discuss different configuration of master line.
3. Why tool angle conversion to different system of reference is important.

Experiment No. - 2

Measurement and analysis of cutting forces in turning operation

OBJECTIVES

- ✓ To study the different operations performed on lathe machine, including working principle of cutting force measurement with the help of the dynamometer.
- ✓ Measurement and analysis of cutting forces in turning operation.

OUTCOMES

- ✓ Comparative analysis of input variable (Depth of cut, feed rate & cutting speed) on cutting force, thrust force & feed force.

Brief Theory:

In orthogonal cutting, the cutting edge of the tool is perpendicular to the cutting velocity vector, whereas in oblique cutting it is set at some angle other than 90° to the cutting velocity vector (Figure 1.1). Using the following assumptions the free body diagram (fig. 1.2) and Merchant circle diagram (fig. 1.3) can be drawn:

- ✓ The tool is sharp and chip flows only along the rake face.
- ✓ Cutting edge is perpendicular to V (i.e, Orthogonal cutting).
- ✓ Shear occurs on a thin plane called the shear plane.
- ✓ Continuous chip without built up edge (BUE) is formed.
- ✓ The material is rigid and perfectly plastic.
- ✓ Coefficient of friction μ remains constant.
- ✓ R and R’ are equal, opposite and collinear.

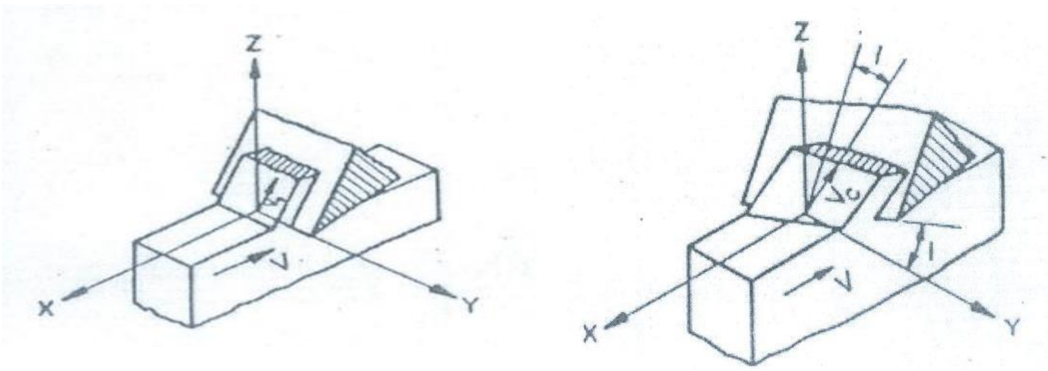
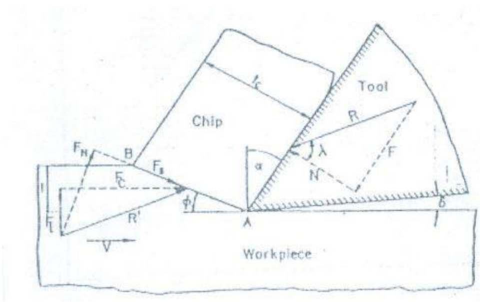


Figure 1.1 (a) Orthogonal cutting (b) Oblique cutting



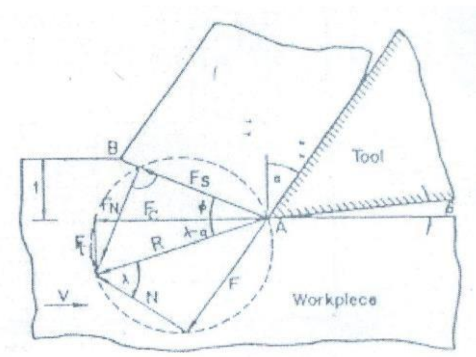


Figure 1.2

Figure 1.3

In Figure 1.2 and 1.3, F is the friction force, N is the normal force, is shear force, is force normal to the shear plane, is the cutting force, is thrust force, R and R' are the Resultant forces, α is the rake angle, ƛ is the friction angle and ∅ is the shear angle.

Using Fig. 1.4, the theoretical value of forces can be estimated as

- $\boldsymbol{F_c = F_s \frac{\cos(\lambda-\alpha)}{\cos(\phi+\lambda-\alpha)}}$

- $\boldsymbol{F_t = F_c \tan(\lambda-\alpha)}$

- $\boldsymbol{F_s = \frac{tw\tau}{\sin\phi}}$
- $\boldsymbol{F_c = 2\tau wt\cot\phi}$

- $\boldsymbol{F_c = \tau wt(\cot^2\phi - 1)}$

Where τ is the yield shear stress of workpiece material.

Shear angle ϕ can be estimated from the merchant's shear angle relationship

$$\boldsymbol{\varphi = \frac{\pi}{4} - 0.5(\lambda - \alpha)}$$

Where λ is the friction angle. (Take μ=0.5 for Mild steel–HSS combination)
Substituting for ϕ in the above equations gives

Shear angle is evaluated using the chip length ratio method.

- ✓ Shear angle ϕ is defined as the angle made by the shear plane with the cutting velocity vector V and can be evaluated using the relationship.

$$\tan\varphi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

- ✓ Where the chip thickness ratio is = $\frac{t}{t_c}$ = r

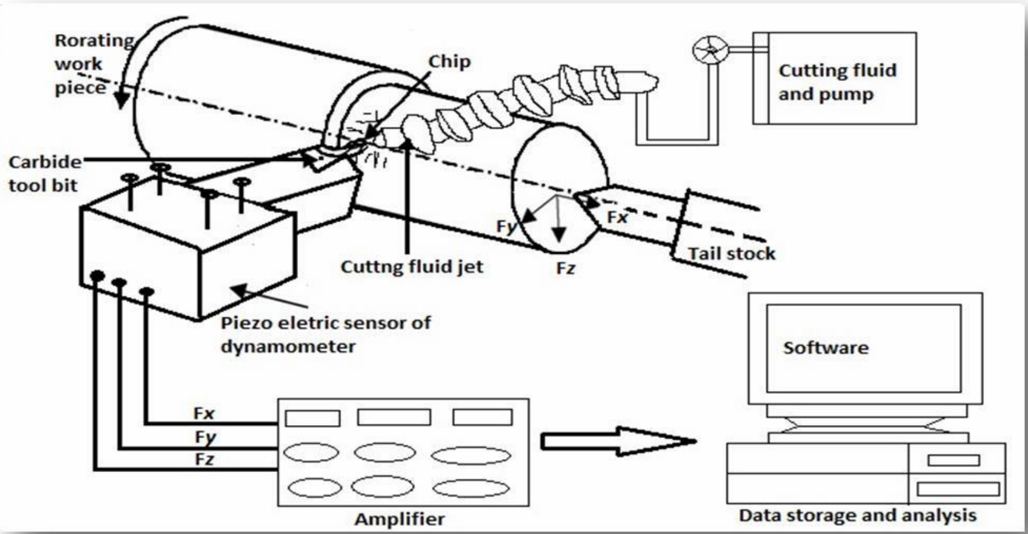
- ✓ It is the uncut chip thickness, t is the uncut chip length, t_c is the chip thickness, l_c is the chip length and α is the rake angle.

Take a chip and accurately measure its length and weight. Using volume constancy, the weight of chip.

$$W = \rho l_c t_c w_c$$

$$l = \frac{W}{\rho t w}$$

The orthogonal cutting test is carried out using a solid cylindrical rod on a lathe to study the effect of cutting speed, feed rate, depth of cut and rake angle of cutting forces. Cutting forces are measured using a piezo crystal type dynamometer 9047C, NI DAQ card through Cutting force measurement (CFM) software figure 1.1 shows a schematic diagram for the measurement of cutting force. HSS/Carbide tool and mild steel/stainless steel work piece are used for the experiments.



1.4 Schematic diagram of Experimental Setup

PROCEDURE

- ✓ Calibrate the dynamometer for measuring forces in two directions. Plot the calibration curve. (Calibration values are provided).
- ✓ Measure tool angles (**α_b, α_s and γ_s**) using the tool microscope.
- ✓ Set-up the experiment and let the instruments warm up for 15 minutes.
- ✓ Measure cutting forces and temperature by varying (i) cutting speed (ii) feed rate and (iii) Depth of cut.
- ✓ Collect chips during experiments and measure their lengths and obtain their weights on a semi-micro balance.

RESULTS

1. Evaluate the theoretical and experimental values of component of cutting forces for turning operation.
2. Tabulate the results as shown below.

Tool material: HSS, Tungsten carbide

Work material: Mild Steel, Stainless steel

Carbide Inserts Tips

Tooltip – Carbide insert (CCMT 09T304 – TN 2000)

Company – Widia

Tool holder – SCL CR1212F09 D 3J

Shear Strength: 400 N/mm^2

Observation Table:

Expt No.	Depth Of Cut (Mm)	Cutting Velocity (Mm/Min)	Feed Rate (Mm/Rev)	Cutting Force (F_c) N		Thrust Force (F_t) N		Shear Angle Φ (Deg)		Tool Temperature (Θ_b)		Friction Angle λ (Deg)
				Theo.	Expt.	Theo.	Expt.	Φ_1	Φ_2	Theo.	Expt.	
1												
2												
3												

Questions:

4. Identify some of the reasons why machining is commercially and technologically important?
5. What are the parameters of machining operations that are included within the scope of cutting conditions?
6. Why is the orthogonal cutting model model useful in the analysis of metal machining?

Experiment No. - 3

Demonstration of Gear Manufacturing on hobbling/ Shaping machine tool and Gear Manufacturing on Milling machine

Objective

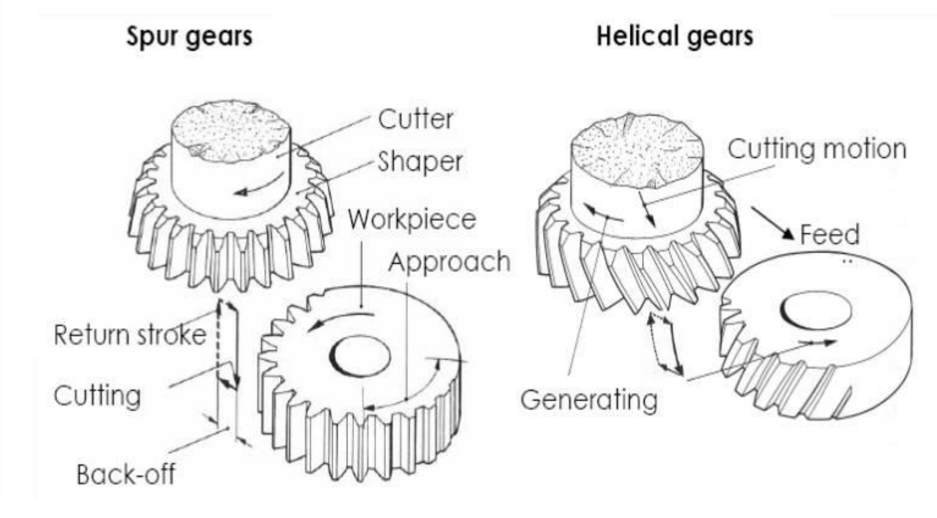
Demonstration of Gear Hobbing/Shaping machine tool and Gear Manufacturing on the Milling machine using Indexing method

Equipments

Gear Hobbing machine, Gear shaping machine, Milling machine, milling cutter, Gear blank, Universal indexing head

Principle:

Gear Shaping: This process uses a pinion shaped cutter carrying clearance on the tooth face and sides and a hole at its centre for mounting it on a stub arbour or spindle of the machine. The cutter is mounted by keeping its axis in vertical position. It is also made reciprocating along the vertical axis up and down with adjustable and pre-decided amplitude. The cutter and the gear blank both are set to rotate at very low rpm about their respective axis. The relative rpm of both (cutter and blank) can be fixed to any of the available value with the help of a gear train. This way all the cutting teeth of cutter come is action one-by-one giving sufficient time for their cooling and incorporating a longer tool life. The specific advantages of the process over other processes, its product cycle time is very low and negligible dimensional variability from one unit to other in case of mass production. This process produces external as well as internal gears.

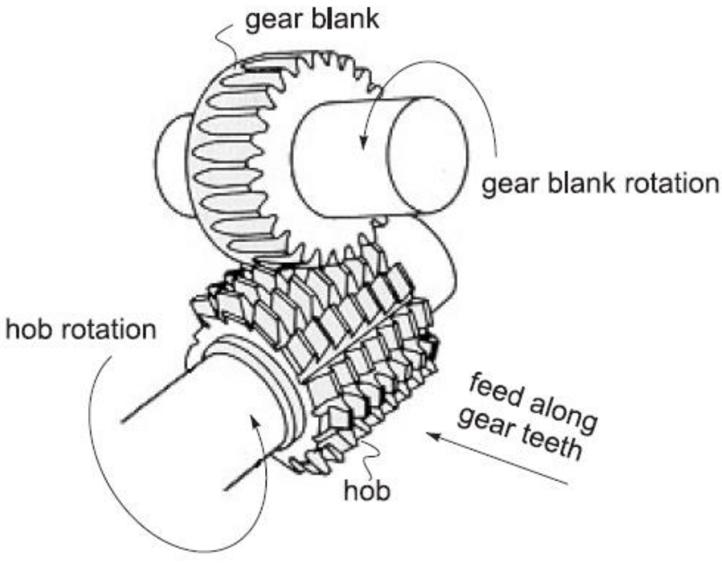


Indexing Motion

Indexing motion is equivalent to feed motion in the gear shaping operation. Slow rotations of the gear cutter and workpiece provide the circular feed to the operation. These two rpms are adjusted with the help of a change gear mechanism. The rpm are relatively adjusted such that each rotation of the cutter the gear blank revolves through n/N revolution.
Where,
n = Number of teeth of cutter, and
N = Number of teeth to be cut on the blank.

Gear Hobbing: Hobbing is a machining process for gear cutting, cutting splines and cutting sprockets on a hobbing machine. The teeth or splines are progressively cut into the workpiece by a series of cuts made by a cutting tool called a **hob.** All motions in hobbing are rotary, and the hob and gear blank rotate continuously as in two gears meshing until all teeth are cut.

Hobbing uses a hobbing machine with two skew spindles, one mounted with a blank workpiece and the other with the hob. The angle between the hob's spindle and the workpiece's spindle varies, depending on the type of product being produced. For example, if a spur gear is being produced, then the hob is angled equal to the helix angle of the hob; if a helical gear is being produced then the angle must be increased by the same amount as the helix angle of the helical gear. The two shafts are rotated at a proportional ratio, which determines the number of teeth on the blank; for example, if the gear ratio is 40:1 the hob rotates 40 times to each turn of the blank, which produces 40 teeth in the blank. if the hob has multiple threads then the speed ratio must be multiplied by the number of threads on the hob. The hob is then fed up into workpiece until the correct tooth depth is obtained. Finally the hob is fed through the workpiece parallel to the blank's axis of rotation.



Setup of gear hobbing opeartion.

Gear Milling: To cut blank gear using the given gear blank diameter and number of teeth and calculate the indexing, module, tooth depth, and tooth width.

Given Data and Formulae:

Blank Dia. = 46.9mm

Number of teeth (T) = 41

Indexing calculation = 40/T

Blank Dia. = (T+2) x m

Tooth depth = 2.25 x m

Tooth width = 1.57 x m

Procedure:

1. The dividing head and the tail stock are bolted on the machine table. Their axis must be set parallel to the machine table.
2. The gear blank is held between the dividing head and tail stock using a mandrel. The mandrel is connected with the spindle of the dividing head by a carrier and catch plate.
3. The cutter is mounted on the arbor. The cutter is centered accurately with the gear blank.
4. Set the speed and feed for machining.
5. For giving depth of cut, the table is raised till the periphery of the gear blank just touches the cutter.
6. Then the table is raised further to give the required depth of cut.
7. The machine is started and feed is given to the table to cut the first groove of the blank.
8. After the cut, the table is brought back to the starting position.
9. Then the gear blank is indexed to the next tooth space.
10. This continues till all the gear teeth are cut.

Calculations and Results:

Experiment No. - 4

Manufacturing of bolt and nut with hexagonal head

OBJECTIVE

Machining of bolt and nut with hexagonal head.

OUTCOME

Understanding of Lathe operations, milling operations, indexing

Theoretical background:

Lathe is one of the most versatile and widely used machine tools. It is commonly known as the mother of all other machine tool. The main function of a lathe is to remove metal from a job to give it the required shape and size. The job is secure1y and rigid1y held in the chuck or in between centers on the lathe machine. Lathe removes undesired material from a rotating work piece in the form of chips with the help of a tool which is traversed across the work and can be fed deep in work. The tool material should be harder than the work piece. The tool may be given linear motion in any direction. A lathe is used principally to produce cylindrical surfaces and plane surfaces, at right angles to the axis of rotation. It can also produce tapers and bellows etc.

Feed Mechanism in Lathe

Feed mechanism is the combination of different units through which motion of headstock spindle is transmitted to the carriage of lathe machine. Following units play role in feed mechanism of a lathe machine-

1. End of bed gearing
2. Feed gear box
3. Lead screw and feed rod
4. Apron mechanism

The gearing at the end of bed transmits the rotary motion of headstock spindle to the feed gear box. Through the feed gear box the motion is further transmitted either to the feed shaft or lead screw, depending on whether the lathe machine is being used for plain turning or screw cutting. The feed gear box contains a number of different sizes of gears. The feed gear box provides a means to alter the rate of feed, and the ration between revolutions of the headstock spindle and the movement of carriage for thread cutting by changing the speed of rotation of the feed rod or lead screw. The apron is fitted to the saddle. It contains gears and clutches to transmit motion from the feed rod to the carriage, and the half nut which engages with the lead screw during cutting threads.

$$Gear\ Ratio = \frac{RPM\ of\ the\ driving\ gear}{RPMof\ the\ driven\ gear} = \frac{No.\ of\ teeth\ on\ the\ driven\ gear}{No. of\ teeth\ on\ the\ driving\ gear}$$

Thread Cutting Mechanism:

A thread is a uniform helical groove cut on or in a cylinder or cone. Thread cutting on a lathe requires a thorough knowledge of the principles and procedures of thread cutting. The half nut or split nut is used for thread cutting in a lathe. It engages or disengages the carriage with the lead screw so that the rotation of the lead screw is used to traverse the tool along the workpiece to cut screw threads. The direction in which the carriage moves depends upon the position of the feed reverse lever on the headstock.

Milling:

Milling is the operation of removing a layer of material from the surface of work piece or producing a slot in the component using a rotating multipoint cutting tool called as milling cutter.

Indexing:

The operation of rotating the job through the required angle between two successive cuts is called as indexing.

Simple indexing:

In simple indexing if N no. of divisions are to be made on the circumference of the job then required crank rotations = $\frac{40}{N}$.

Example: If 6 divisions are to be made on the job then find the crank rotation required.

Given: N=6

Therefore crank rotation (CR) = $\frac{40}{6} = 6\,\frac{4}{6} = 6\,\frac{2}{3} = 6\,\frac{2\times5}{3\times5} = 6\,\frac{10}{15}$.

Hence the crank rotation required after every cut is 6 complete rolution and 10 holes in a 15 holes circle.

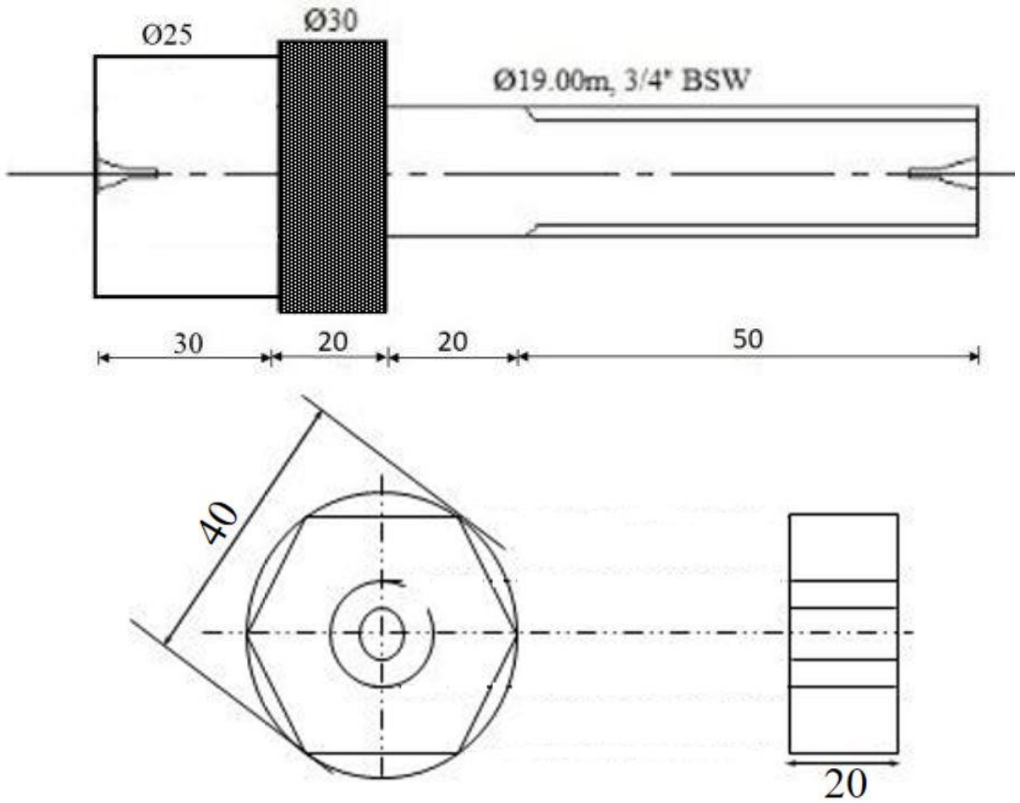


Figure 1: Engineering drawing of the Bolt and Nut

Raw material: Ø35× 120 mm, MS round bar, Ø 40 × 20 mm, MS round bar.

Machine tool required: Lathe, Milling machine

Specification of Lathe:

Specification of Milling machine:

Tools required:

i. Steel rule

ii. Outside calliper

iii. Vernier calliper

iv. Surface gauge
v. Pitch gauge
vi. HSS single point cutting tool
vii. Centre drill
viii. Adjustable wrench
ix. Milling cutter
x. Threading tap

Operations to be performed:

On Lathe:

i. Centering
ii. Facing
iii. Centre drilling
iv. Marking
v. Plain turning
vi. Step turning
vii. Thread cutting
viii. Chamfering
ix. Knurling

On Milling machine:

i. Facing
ii. Marking
iii. Job setting
iv. Drilling
v. Indexing
vi. Surface milling

By Threading tap:

i. Internal threading

Questions:

1. What is indexing and what are the different indexing methods?
2. What are the different types of milling cutters?
3. What are the steps followed in making the threaded hexagonal nut?
4. What are the units of cutting speed and feed on machine tools?
5. What is the use of back gear arrangement in a lathe headstock?
6. List the type of surfaces produced by turning
7. What is the relation between spindle speed and cutting speed?
8. How is the size of lathe specified?

Annexure I

Major components of Lathe Machine:

A simple lathe comprises of a bed made of grey cast iron on which headstock, tailstock, carriage and other components of lathe are mounted. The major parts of lathe machine are given as under:

Bed

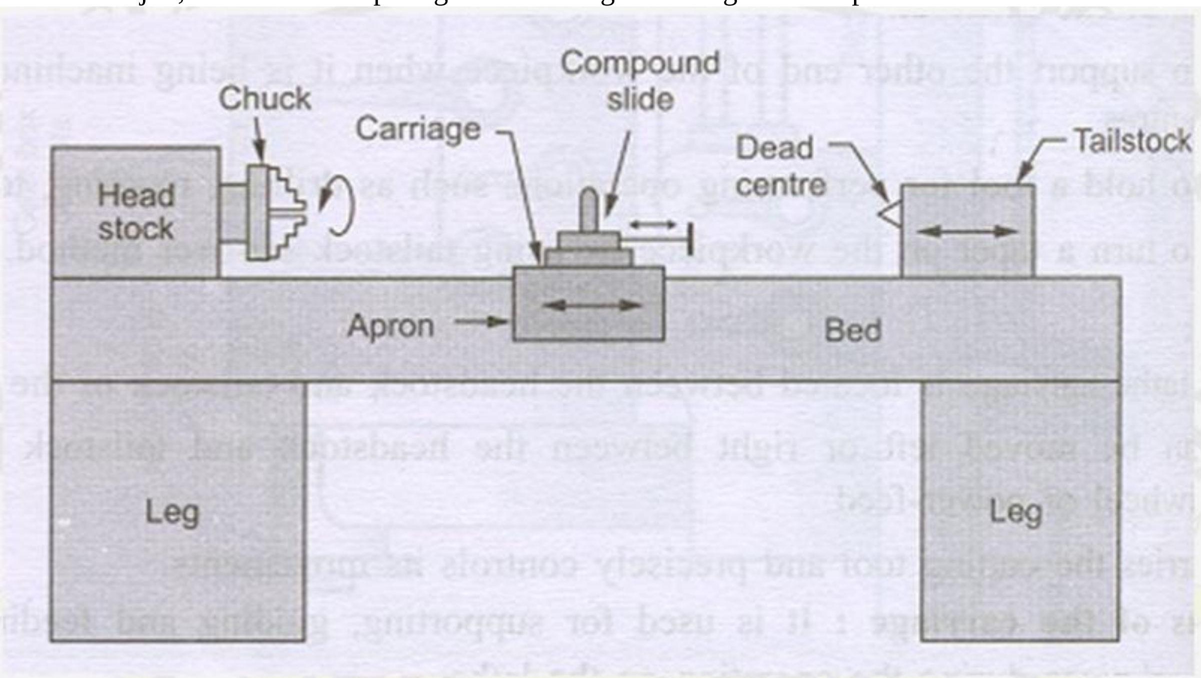
The bed of a lathe machine is the base on which all other parts of lathe are mounted. It is massive and rigid single piece casting made to support other active parts of lathe. On left end of the bed, headstock of lathe machine is located while on right side tailstock is located. The carriage of the machine rests over the bed and slides on it. On the top of the bed there are two sets of guideways-innerways and outer ways.

Head Stock

The main function of headstock is to transmit power to the different parts of a lathe. It comprises of the headstock casting to accommodate all the parts within it including gear train arrangement. The main spindle is adjusted in it, which possesses live centre to which the work can be attached. It supports the work and revolves with the work, fitted into the main spindle of the headstock.

Tail Stock

The tail stock of central lathe, which is commonly used for the objective of primarily giving an outer bearing and support the circular job being turned on centers. Tail stock can be easily set or adjusted for alignment or non-alignment with respect to the spindle centre and carries a centre called dead centre for supporting one end of the work. Both live and dead centers have 60° conical points to fit centre holes in the circular job, the other end tapering to allow for good fitting into the spindles.



Different parts of central lathe.

Carriage

Carriage is mounted on the outer guide ways of lathe bed and it can move in a direction parallel to the spindle axis. It comprises of important parts such as apron, cross-slide, saddle, compound rest, and tool post. The lower part of the carriage is termed the apron in which there are gears to constitute apron mechanism for adjusting the direction of the feed using clutch mechanism and the split half nut for automatic feed. The cross-slide is basically mounted on the carriage, which generally travels at right angles to the spindle axis. On the cross-slide, a saddle is mounted in which the compound rest is adjusted which can rotate and fix to any desired angle. The compound rest slide is actuated by a screw, which rotates in a nut fixed to the saddle.

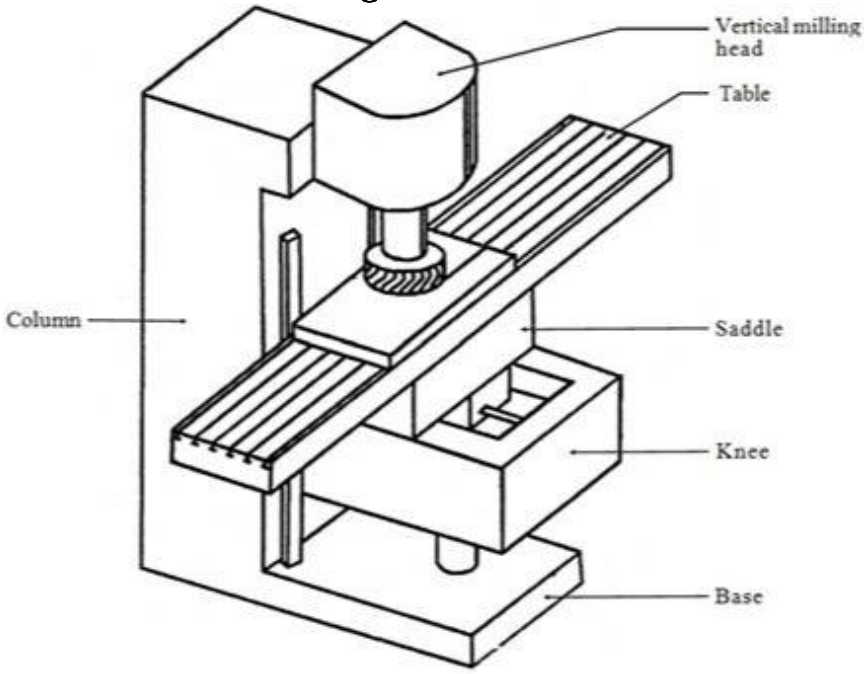
Basic functions and purposes of using milling machines:

The basic function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution, helical surfaces and contoured surfaces of various configurations. Such functions are accomplished by slowly feeding the work piece into the equispaced multiedge circular cutting tool rotating at moderately high speed.

Working Principle:

The workpiece is holding on the worktable of the machine. The table movement controls the feed of workpiece against the rotating cutter. The cutter is mounted on a spindle or arbor and revolves at high speed. Except for rotation the cutter has no other motion. As the workpiece advances, the cutter teeth remove the metal from the surface of workpiece and the desired shape is produced.

Different parts of a vertical milling machine:



Different parts of a vertical milling machine

Base: It gives support and rigidity to the machine and also acts as a reservoir for the cutting fluids.

Column: The column is the main supporting frame mounted vertically on the base. The column is box shaped, heavily ribbed inside and houses all the driving mechanisms for the spindle and table feed.

Knee: The knee is a rigid casting mounted on the front face of the column. The knee moves vertically along the guide ways and this movement enables to adjust the distance between the cutter and the job mounted on the table. The adjustment is obtained manually or automatically by operating the elevating screw provided below the knee.

Saddle: The saddle rests on the knee and constitutes the intermediate part between the knee and the table. The saddle moves transversely, i.e., crosswise (in or out) on guide ways provided on the knee.

Table: The table rests on guide ways in the saddle and provides support to the work. The table is made of cast iron, its top surface is accurately machined and carries T-slots which accommodate the clamping bolt for fixing the work. The worktable and hence the job fitted on it is given motions in three directions:

a). Vertical (up and down) movement provided by raising or lowering the knee.

b). Cross (in or out) or transverse motion provided by moving the saddle relative to knee.

c). Longitudinal (back and forth) motion provided by hand wheel fitted on the side of feed screw.

In addition to the above motions, the table of a universal milling machine can be swiveled 45° to either side of the centre line and thus fed at an angle to the spindle.

Purpose of using milling machine:

- Flat surface in vertical, horizontal and inclined planes

- Making slots of various sections
- Cutting teeth in piece or batch production of spur gears, straight toothed bevel gears, worm wheels, sprockets, clutches etc.
- Producing some features like grooves, flutes, gushing and profiles in various cutting tools, e.g., drills, taps, reamers, hobs, gear shaping cutters etc.

Classification of milling machines:

According to the orientation of the spindle(s)

Plain horizontal knee type
Vertical spindle type
Universal head milling machine

Broad classifications of milling cutters

Milling cutters are mainly classified as,

- End milling cutter
- Peripheral milling cutter

Experiment No. - 5

Demonstration on gravity Die Casting process

OBJECTIVES

The objectives of Gravity die casting process is

- ✓ To study the components of furnace.
- ✓ To understand the procedure of fabrication of MMC

OUTCOMES

The expected outcome of Gravity die casting process lab is that the students will be able

- ✓ To operate the gravity die casting furnace.
- ✓ To fabricate the composite material by casting process.
- ✓ To understand the difficulties that can be faced during composite fabrication.

Theory:

Composite: A composite is defined as a material that consists of at least two constituents (distinct phase or combination of phases) which preexists the composite. The composite is produced via physical combination of at least two pre-existing ingredient materials; this distinguishes a composite from other multiphase materials which are produced by bulk processes where one or more phases result from phase transformation. Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites.

Metal Matrix Composites (MMC) is a composite material in which one constituent is a metal or alloy, forming at least one percolating network. The other constituent is embedded in this metal matrix and usually serves as reinforcement.

Reinforcement is a constituent phase or combination of phases of the metal matrix composite originating from the ingredient material, which is combined with a metal or an alloy to produce a metal matrix composite. The reinforcements are characterized by their composition, shape, dimensions, property of ingredient materials, volume fraction and there spatial distribution in the matrix.

Based on the method of preparation metal matrix composites are classified into two types:

i). Ex-situ metal matrix composite: Here, the reinforcement materials are prepared separately prior to composite fabrication and there after incorporated into the host metal matrix.

ii). In-situ metal matrix composite: In-situ metal matrix composites are defined as a multiphase material whose reinforcing phases are formed in situ during the fabrication of the metal by the reaction between the precursors materials used.

Die casting process: Die casting is a metal casting process that is characterized by forcing molten metal under high pressure and under gravity into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process. The split mould used under this type of casting is reusable. Die casting is categorized two types namely- hot chamber and cold chamber. Metals like Zinc, tin and lead alloys are casted in hot chamber die casting having melting point below 3900C whereas aluminum alloys are casted in cold chamber die casting machine. Aluminum dissolves ferrous parts in the die chamber and hence preferred to be used in cold chamber die casting.

Advantages:

- High production rate.
- High accuracy in part dimensions.
- Smooth surface finish for minimum mechanical finishing.
- Ability to make many intricate parts such as hole opening slot trademark number etc.
- Much thinner wall sections can be produced which can't be produced by other casting methods.
- Varieties of alloys can be used as per design requirements. For example zinc can be used
- For intricate forms and plasticity, aluminum for higher structural strength, rigidity and lightweight.
- Ability to cast inserts such as pins studs shafts, fasteners etc.

Disadvantages:

- Micro porosity in the die casting products is a common problem because of faster Solidification trapped air and vaporized die lubricants.
- Undercuts cannot be found in simple two piece dies.
- Hollow shapes are not readily casted because of the high metal pressure.
- Limited sizes of the products can be produced based on the availability of the equipment
- High melting temperature alloys are practically not die casted

- Flash is present except for very small zinc die casting.

Applications:

Die casting process is preferred for nonferrous metal parts of intricate shapes. Examples of products are automobiles appliances, hand tools, computer peripherals, toys, optical and photographic equipment etc.

Experimental procedure:

Switch on the Vacuum Switch, Please wait for some times for vacuum generation in the Crucible Die set up. When, vacuum gauge increase from 0 to -760 mmHg then switch off thevacuum. Now open the Gas (Ar) control valve, decrease the vacuum gauge from-760 to 0mmHg.

<u>Programmer setting:</u>

Home display

Pv		30	
Sv		0	
set	shift	down	up

- Press Seven times the set key the controller will display

Seg.n-1
0000

[Set here the required temperature]

- Press set key the controller will display

Time-1
00.0 first two digits-hours
Second two digits-minute

[Set here the time for reaching the temperature] normal heating rate 5^0C per minute

- Press set key the controller will display

Out-1
0000-This is power required for the controller to reach the temperature

- Every segment set the this formula only (soaking and cooling also)

Other segment values set to zero.

<u>Programmer Start:</u>

- When programmer setting over after to start the programmer -press the up key continues few seconds now in the programmer – the pro & out.1led will start to blink.
- Switch on the furnace switch.

<u>Meld setup:</u>

When reach the temperature, wait for 60 minutes. Now connect the motor to stirrer, set the rpm 200 to 250, running the motor for required time. Now open the pneumatic set up.

Wait for 10 to 15 minutes, and then get the mold.

Stop Mode:

- In case you want change the programmer first programmer reset. To stop the programmer press & hold the down key and set key, simultaneously. Now the pro &out1 led will goes to off.

Furnace off:

- Now switch off the furnace switch.

Parameters setting and Experimental setup:

Parameters	Values
Operating temperature	850ºC
Time to reach the setting temp.	1 hour 30 min.
Soaking time	60 min.
Stirring speed	200-300 rpm
Stirring time	~ 5 min.

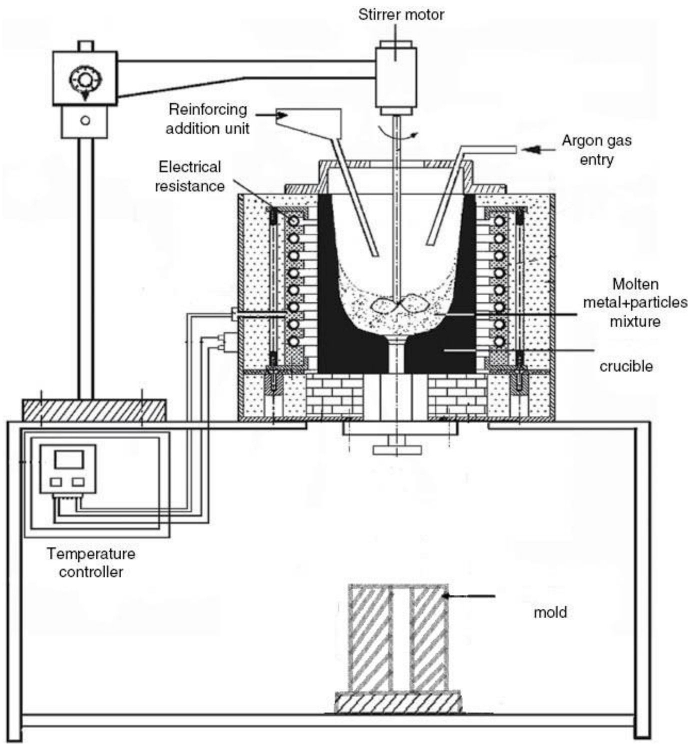


Fig. 1. Schematic diagram of Die casting furnace.

Operating Procedure:

- *Clean the melting crucible, stirrer and apply non-stick paste*
- *Fix the crucible, stirrer motor in their places*

- *Switch on the chiller and set for 24 Deg C*
- *Switch on the compressor and maintain air pressure 6kg/cm^2*
- *Load the material (Al or Mg) in the crucible to the required quantity*
- *Close the lid and valves*
- *Switch on the vacuum pump and wait till getting full vacuum*
- *Close the vacuum pump valve and purge the neutral gases*
- *Switch on the water circulation*
- *Start the furnace operation*
- *Wait for till getting 850 Deg C/60 minutes for soaking*
- *Add preheated (300^{o}C) reinforcement particle through the channel*
- *Now connect the stirrer motor and run to required rpm.*
- *Pull the pneumatic cylinder to open the melt path*
- *Then melt will flow to die*
- *Slowly shut off all the operation*
- *Open the die box and take out the mold.*

Safety & Precautions:-

1. The pouring gate should be close before furnace switch ON.
2. Do not disturb the program setting, once the operation is started.
3. Must wear leather shoes or boots.
4. Never touch the die just after the pouring. It is very hot as the temperature of melt metal is very high.

Experiment No. - 6

Demonstration of different welding process and investigation of input process parameters in the MIG welding

OBJECTIVES

The objectives of Welding Process laboratory are:

- To demonstrate the different welding processes.
- Edge preparation for Butt welding joint
- To investigate the influence of input process parameters in the MIG welding process.
- To study the thermal cycle and peak temperature at various welding parameter.

OUTCOMES

The expected outcome of Welding Process lab is that the students will be able:

- ✓ A practical hand on experience of Welding Process to the students
- ✓ Design and edge preparation for Butt welding joint
- ✓ Effect of input process parameters in the MIG Welding process and Metal Deposition rate
- ✓ Effect of input process parameters on the cooling curve of the deposited bead.
- ✓ A practical hand on experience of the Dye penetrate test

Theory:

Welding is a fabrication process which is defined as a localized coalescence of metals or non-metals produced either by heating the materials to the welding temperature, with or without the application of pressure, or by the application of pressure alone, with or without the use of filler metal. During welding, the pieces to be joined (the work pieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint.

Types of Arc Welding Process:

- Gas metal arc welding (MIG)
- Plasma arc welding
- Submerged arc welding
- Gas tungsten arc welding (TIG)

[1]. MIG WELDING

MIG (Metal Inert Gas) welding, also known as MAG (Metal Active Gas) and in the USA as GMAW (Gas Metal Arc Welding), is a welding process that is now widely used for welding a variety of materials, ferrous and nonferrous. The essential feature of the process is the small diameter electrode wire, which is fed continuously into the arc from a coil. As a result this process can produce quick and neat welds over a wide range of joints. MIG welding is carried out on DC electrode (welding wire) positive polarity (DCEP). However DCEN is used (for higher burn off rate) with certain self-shielding and gas shield cored wires.

MIG Torch

This provides the method of delivery from the wire feed unit to the point at which welding is required. The MIG torch can be air cooled or water cooled and most modern air cooled torches have a single cable in which the welding wire slides through a Liner.

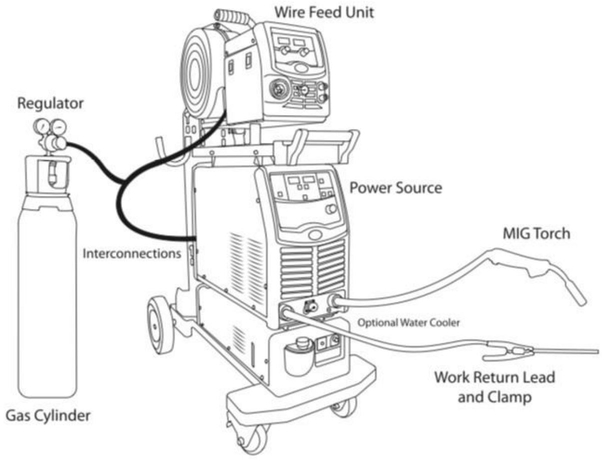


Fig: A Typical MIG welding setup

Power Source

MIG welding is carried out on DC electrode (welding wire) positive polarity (DCEP). However DCEN is used (for higher burn off rate) with certain selfshielding and gas shield cored wires. DC output power sources are of a transformer-rectifier design, with a flat characteristic (constant voltage power source). The most common type of power source used for this process is the switched primary transformer rectifier with constant voltage characteristics from both 3-phase 415V and 1- phase 240V input supplies.

Shielding Gas

This is a complicated area with many various mixtures available, but the primary purpose of the shielding gas in the MIG process is to protect the molten weld metal and heat affected zone from oxidation and other contamination by the atmosphere. Different gases used for shielding are Argon, Helium, CO_2, Ar-CO_2 Mixture etc.

[2]. TIG Welding Process

TIG (Tungsten Inert Gas) welding also known as GTA (Gas Tungsten Arc) in the USA and WIG (Wolfram Inert Gas) in Germany, is a welding process used for high quality welding of a variety of materials, especially, Stainless Steel, Titanium and Aluminium.

Power Source

TIG welding can be carried out using DC for Stainless Steel, Mild Steel, Copper, Titanium, Nickel Alloys etc and AC for Aluminium and its Alloys and Magnesium. Further information on the TIG Welding Process follows information on equipment used in this document. The Power Source is of a transformer design with or without a rectifier, with a drooping characteristic (constant current power source).

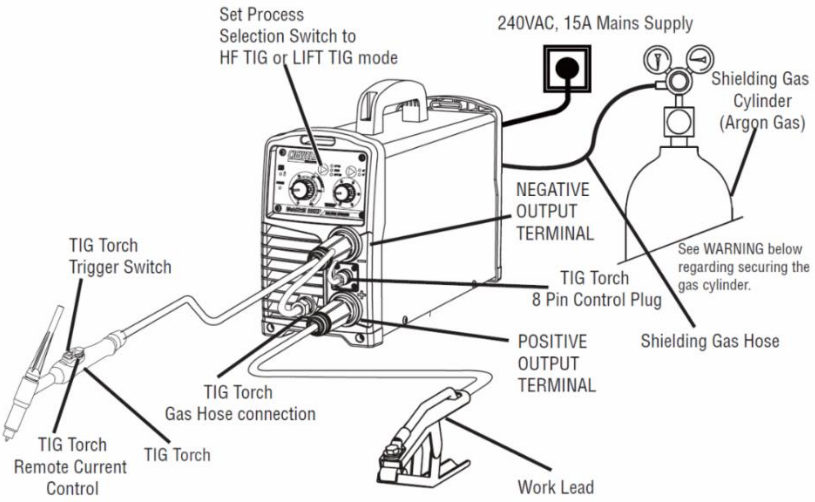


Fig. B TIG Welding Setup

[3]. Submerged Arc Welding (SAW) Process

Submerged arc welding (SAW) is a welding process where the tubular electrode is fed continuously to join two metals by generating heat between electrode and metal. The area of the arc and molten zone gets its protection from the atmospheric contamination by submerging under a blanket of granular flux. The flux layer covers the area completely preventing spatter, sparks, fumes, and UV radiation.
The process provides higher deposition rates than other Welding processes. Arc formation between the wire electrode and work piece happens as in the MIG welding process. But this process has an additional advantage of shielding by the granular flux making the SAW welding as spatter, fumes, and UV light free. Submerged arc welding can be used with DC or AC.

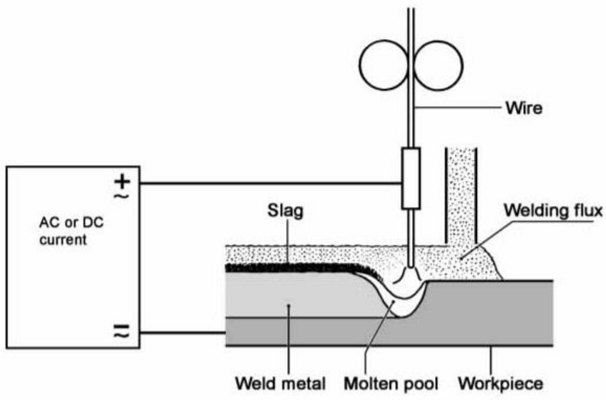


Fig. C Schematic diagram for SAW

Power Source

Equipment consists of a welding machine or power source, the wire feeder and control system, the welding torch for automatic welding or the welding gun and cable assembly for semiautomatic welding, the flux hopper and feeding mechanism, usually a flux recovery system, and a travel mechanism for automatic welding. Submerged arc welding is used to weld low- and medium-carbon steels, low-alloy high-strength steels, quenched and tempered steels, and many stainless steels. Experimentally, it has been used to weld certain copper alloys, nickel alloys, and even uranium. Metal thicknesses from 1/16 to 1/2 in. (1.6 to 12.7 mm) can be welded with no edge preparation. With edge preparation, welds can be made with a single pass on material from 1/4 to 1 in. (6.4 to 25.4 mm).

[4] Edge preparation

Edge Preparation: Proper edge preparation and fit-up are essential to achieve a good quality welds. There are two main steps of edge preparation,
a) Cleanliness of faying surface and b) Cutting of faying surface of base metal to be welded by fusion arc welding process.

Necessity of Edge Preparation:
The edge preparation influences the performance of a weld joint. The edge preparation is necessary to
1. Achieve the good quality welds. 2. Get fault less joint 3. Reduce welding time 4. Get the joint as strong as base metal 5. Reduce the cost of the welded joint

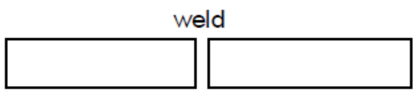
The following steps are performed in edge preparation

I. Cleaning of the faying surfaces:
The faying surfaces having scale, rust, dirt, soot, heavy oxide coatings, paint coating, organic materials and other forms of corrosion can make the task of welding more difficult as well as produce weaker welds. Impurities on the surface of a base metal or filler material can increase porosity and even cracking. These impurities include dirt, grease, rust, paint, plastic, oil and other contaminants. The Sand blasting process for cleaning, solvent cleaning and wire brush are common alternatives. Power tools like brushes, grinding wheels, and disc grinding can also be used for certain applications. The acidic solution, alkaline solution and flame are used to clean the oily surfaces as well as surfaces of fragile jobs.

II. Preparation of desired shape/geometry of faying surfaces (surfaces to be welded) by beveling or grooving
To get sound / strong and attractive welded joints at low cost, the beveling or grooving is done by different methods such as plasma cutting / gas cutting, machining and grinding. Factors which influence choice of edge preparation: 1) Thickness 2) Material 3) Welding process 4) Extent of penetration required 5) Welding distortion 6) Cost

Experiment :

Job: To make a Butt- Joint



Observation Table :

Table 1: MIG Welding

Sl No.	Current (A)	Voltage (V)	Intial weight (gm)	Final weight (gm)	Time (second)	Metal Deposition Rate (gm/sec)
1.						
2.						
3.						

[5]. Dye penetrantion Test:

Liquid penetrant examination is one of the most popular Nondestructive Examination (NDE) methods in the industry. It is economical, versatile, and requires minimal training when compared to other NDE methods. Liquid penetrant exams check for material flaws open to the surface by flowing very thin liquid into the flaw and then drawing the liquid out with a chalk-like developer.

The test is widely used to detect surface discontinuities like cracks, fractures, porosity, grinding defects, incomplete fusion, and flaws in joints. It is suitable for both ferrous and non-ferrous materials and is highly economical as compared to the other non-destructive inspection methods. The Dye Penetration test works on the philosophy of capillary action. A liquid with low surface tension can penetrate into a clean and dry surface if the liquid is kept for a certain time called "Dwell Time".

Six Basic steps are as follow:

(1) Pre-clean part (2) Apply penetrant (3) Remove penetrant (4) Apply developer (5) Evaluate indications (6) Post-clean part

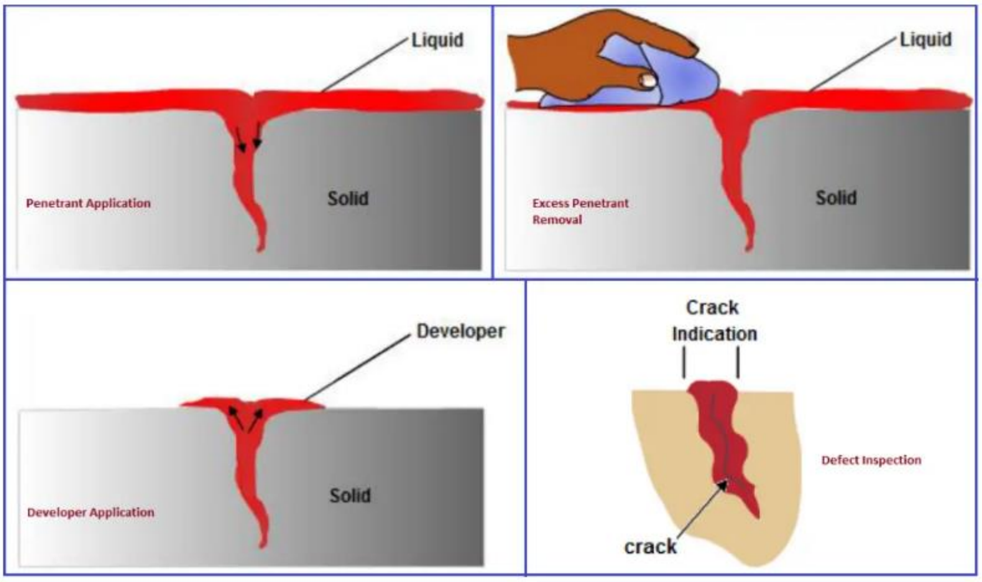
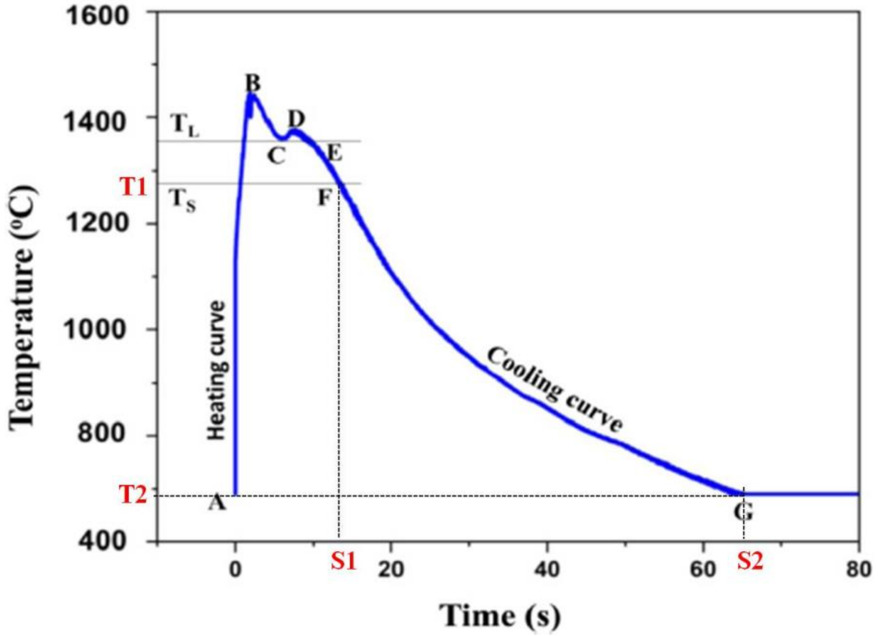


Fig. D. The Dye Penetration Test Procedure

[6]. IR Pyrometer:

An infrared thermometer, sometimes called an infrared pyrometer or radiation thermometer, is a device used for non-contact temperature measurement. Infrared pyrometers collect radiated energy from a target area and focus it onto a detector inside the instrument. The thermo-cycle of the weld molten pool was monitored using an IR pyrometer (Make: Micro-Epsilon, Model: 2MH1-SF-CB3). The acquisition time, working temperature range, and accuracy of the pyrometer are 1 ms, 490–2000 °C, and ± (0.3 % of reading + 2 °C).



AB: Heating curve; BG: Cooling curve; **B: Peak Temperature**

$T_{L:}$ Liquidus Temperature; $T_{s:}$ Solidus Temperature

C: Solidification Starts

F: Solidification Ends

Cooling rate (°C/s) = $\frac{T1 - T2}{S2 - S1}$

Safety & Precautions:-

1. Must wear auto-darkening welding mask or Manual masks whichever is available.
2. Wear gloves and protective clothing to protect you from molten metal splattering off of your work piece.
3. Must wear leather shoes or boots.
4. Weld in a well ventilated area.
5. Never touch the work piece just after the welding. It is very hot as the temperature during welding is very high.

Experiment No. 7: Microstructure Inspection and analysis of welding joints

OBJECTIVES

Analysis of Weld Joint

- To Prepare the standard metallographic sample
- To study the microstructure of the welded joint.

OUTCOMES

The expected outcome of the analysis of welding joint lab that the students should have

- ✓ Learn standard metallographic sample preparation procedure such as sectioning, mounting, grinding, polishing, and acid etching.
- ✓ An understanding of the microstructure of the welded joint
- ✓ Use of image analysis software.

Theoretical Background:

The microstructure of a material can only be viewed in the metallurgical microscope after a specimen has been adequately prepared. Metallurgists have developed extensive techniques and accumulated knowledge of metal specimen preparations for over a century. In principle, we can use these techniques to examine not only metallic materials but also ceramics and polymers; The main steps of specimen preparation for light microscopy include the following. 1. Sectioning 2. Mounting 3. Grinding 4. Polishing and 5) Etching

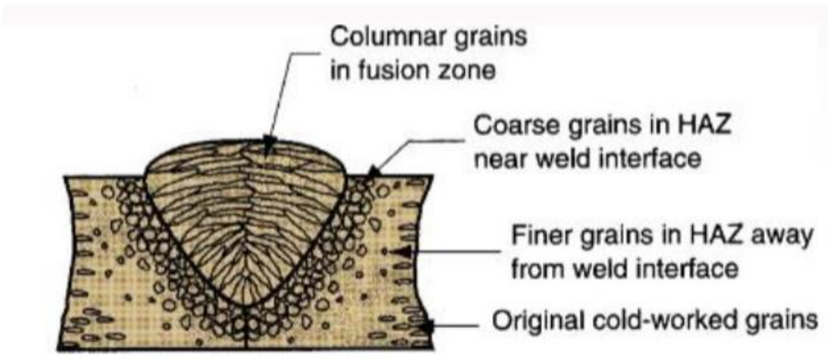


Fig. Cross-sectional representation of the welding joint

After welding, abrasive cutting is the most commonly used method for sectioning materials. Specimens are sectioned by a thin rotating disc in which abrasive particles are supported by suitable media. Abrasive cutting requires cooling media to reduce friction heat. To reduce the frictional damage of the sample, commonly used cooling media consist of water-soluble oil and rust-inhibiting chemicals. Sectioning serves two purposes: generating a cross-section of the specimen to be examined, and reducing the size of a specimen to be placed on a stage of a light microscope, or reducing the size of the specimen to be embedded in mounting media for further preparation processes.

Mounting refers to embedding specimens in mounting materials (commonly thermosetting polymers) to give them a regular shape for further processing. Mounting is not necessary for large specimens, but it is required for specimens that are too small or oddly shaped to be handled or when the edge of a specimen needs to be examined in the transverse section. There are two main types of mounting techniques: hot mounting and cold mounting. Hot mounting uses hot-press equipment. A specimen is placed in the cylinder of a press and embedded in polymeric powder. The surface to be examined faces the bottom of the cylinder. Then, the specimen and powder are heated at about 150°C under constant pressure for a specified time. Heat and pressure enable the powder to bond with the specimen to form a cylinder. Phenolic (Bakelite) is the most widely used polymeric powder for hot mounting.

Polishing is the last step in producing a flat, scratch-free surface. Polishing generates a mirror-like finish on the specimen surface to be examined. Polishing is commonly conducted by placing the specimen surface against a rotating wheel either by hand or by a motor-driven specimen holder. Abrasives for polishing are usually diamond paste, alumina or other metal oxide slurries. Polishing includes coarse and fine polishing. Coarse polishing uses abrasives with a grit size in the range from 3 to 30µm; the 6-µm diamond paste is the most popular. The abrasive size for fine polishing is usually less than 1µm. Alumina slurries provide a wide range of abrasive size, ranging down to 0.05µm. A polishing cloth covers a polishing wheel to hold the abrasives against the specimen during polishing. After each polishing step, the surface should be cleaned in running water with cotton or tissue, followed by alcohol or hot air drying. Alcohol provides fast drying of surfaces without staining.

Chemical etching is a method to generate contrast between microstructural features in specimen surfaces. The etching is a controlled corrosion process by electrolytic action between surface areas with differences in electrochemical potential. Electrolytic activity results from local physical or chemical heterogeneities, which render some microstructural features anodic and others cathodic under specific etching conditions. During etching, chemicals (etchants) selectively dissolve areas of the specimen surface because of the differences in the electrochemical potential by electrolytic action between surface areas that exhibit differences. For example, grain boundaries in polycrystalline materials are more severely attacked by the etchant and thus are Light Microscopy.

The samples are then studied under an optical microscope for their microstructural study. Optical microscopy is the primary means for scientists and engineers to examine the microstructure of materials.

Procedure:

1. Sectioning-. The first step is to cut a representative sample from the parent material. This is typically done using a saw, but other methods such as wire EDM or laser cutting can also be used. The goal is to create a flat, smooth surface that is perpendicular to the desired plane of observation.
2. Mounting-. The sectioned sample is then mounted in a resin or epoxy to provide support and prevent it from warping or deforming during the subsequent grinding and polishing steps.
3. Coarse grinding- The mounted sample is then ground on a series of progressively finer abrasive papers to remove the saw marks and create a smooth, flat surface. The coarse grinding step is typically done using 80- to 220-grit papers.
4. Fine grinding.-The coarse-ground surface is then further refined using a series of progressively finer abrasive papers, typically up to 1,200 grit. The goal of the fine grinding step is to produce a scratch-free surface that is free of visible defects.
5. Polishing.-The fine-ground surface is then polished using a polishing compound and a cloth-covered wheel. The polishing compound removes the remaining scratches and defects, leaving a mirror-like finish.
6. Etching.-The polished sample is then etched with a chemical solution to reveal the microstructure of the material. The etchant selectively attacks different phases of the material, causing them to appear different under the microscope.
7. Microscopic examination.-The etched sample is then examined under a microscope to observe the microstructure. The microstructure can be used to determine the composition, heat treatment, and mechanical properties of the material.

Observation and Results:

Welding Method:

Electrode/Filler material:

Material:

Etchant:

Etching Time:

Microscopic Analysis (Include the image):

Welding Defects:

Microscopic Analysis

1. The size and shape of the grains in the microstructure.
2. The presence of any defects, such as voids, cracks, or inclusions.

Report and questions:

a) Write down the detailed procedure of welding joint analysis?

b) Write down about the different grit sizes of polishing papers and polishing mechanisms?

c) Describe the standard metallographic sample preparation procedure.

d) Write down the list of welding defects?

e) A short note on welded joint microstructure with variation in different zone morphology?

f) Difference between TIG and MIG welded joint microstructure?