GATE 2018

PRODUCTION ENGINEERING

MECHANICAL ENGINEERING

ECG Publications

ECG Publications

A Unit of **ENGINEERS CAREER GROUP**

Head O ce: S.C.O-80-81-82, 3rd oor, Sector-34/A, Chandigarh-160022

Website: www.engineerscareergroup.in **Toll Free:** 1800-270-4242

E-Mail: ecgpublica ons@gmail.com | info@engineerscareergroup.in

GATE-2018: Produc on Engineering| Detailed theory with GATE & ESE previous year papers and detailed solu ons.

First Edi on: 2016

Price of Book: *INR 725/-*

CONTENTS

CHAPTER - 1
POWDER METALLURGY

1.1 INTRODUCTION

Powder metallurgy is a manufacturing process wherein a desired shape is created from metal powder by compacting it in a die. Here, the raw material is in powdered form of metal which is compacted under high pressure in a die having the shape of object to be produced and then it is sintered, which involves the process of heating without melting.

1.2 POWDER METALLURGY MANUFACTURING PROCESS

It has five steps:

1. Formation of powder
2. Mixing of powder
3. Compaction
4. Sintering
5. Secondary Processes

1.2.1 Formation of Powder

Metal powders can be manufactured by:

1. Grindin

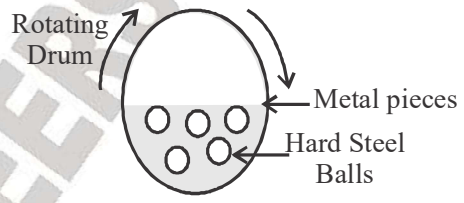
Done in vacuum to avoid reaction of metal with oxygen (i.e. no. spark takes place)

2. Electro-deposition

Metal powder can also b e obtained by carrying out this process onto an electrode dipped in an electrolyte and then scrapping the deposited metal as powder from the electrode.

3. Ball Mill

It consists of rotating drum, which is filled with hard steel balls and the material to be pulverized which gets broken into small pieces by continues impact of tumbling hard steel balls and its finally converted into a fine powder.



Ball Mill

1.2.2 Mixing of Powders

Powders of different metals and other materials are mixed in order to obtain desired characteristics for the product.

1.2.3 Compaction

Due to application of pressure the fine particles of the powder are forced together so intimately that they interlock and form mechanical bonds. The degree to which powder is compressed controls the density of part.

CHAPTER - 2
CASTING

2.1 INTRODUCTION
It is a manufacturing process in which the metal is liquefied by heating in a furnace and then the liquid metal is poured in a mould cavity where it is allowed to solidify to get the desired shape.

2.1.1 Pattern
A pattern is the replica of casting to be prepared and is used to make the mould cavity. Patterns are made up of either wood or metal.

2.2 MOULD
A mould is prepared by sand (refractory material: material which can bear high temperature). It is generally made up of two parts i.e., cope and drag.

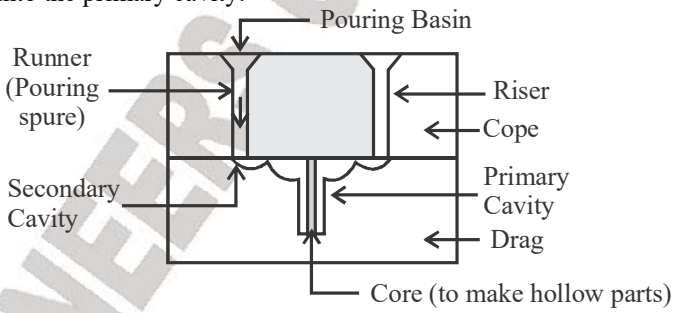
1. Cope
It is upper part of mould.

2. Drag
It is lower part of mould (major part of cavity is in drag)

2.2.1 Mould Composition
Mould consists of two cavities:

1. Primary Cavity
It is the main cavity where the casting is to be made. It replicates the shape of desired product.

2. Secondary Cavity
It is the channel through which molten material reaches the cavity i.e., for pouring and channeling the molten metal into the primary cavity.



2.2.2 Core
It is the body of sand used to form a hollow casting of desired shape. It is located in the mould with help of core prints provided on the pattern.

Some Important Points

1. As far as possible we try to have smallest portion of cavity in cope part.
2. Moulding sand has greater strength in compression as compared to tension.
3. To avoid the possible defects due to loose sand which is more frequent in cope, drag has major portion of the cavity.
4. More critical surfaces or shapes are also included in drag part for same reason.

ESE OBJ QUESTIONS

1. Consider that the following materials are usable for manufacturing dies; moulds in investment casting process for the purpose of large-scale production;
1. Aluminum alloy
2. Magnesium alloy
3. Brass
4. Low-carbon steel
Which of the above are correctly usable?

[ME ESE - 2016]

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 (d) 1, 2, 3 and 4

2. The occurrence of casting defect 'rat tail' is possible because of
1. Soft ramming of sand
2. Continuous large flat surface on the mould
3. Excessive hardness of the mould
Which of the above reasons are correct?

[ME ESE - 2016]

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

3. Components produced by die casting have finer grain, higher strength and greater hardness at the skin than at the center due to

[ME ESE - 2016]

(a) Decreased wall thickness of die cavity
(b) Rapid chilling of molten metal at the walls
(c) High temperature involved in the process
(d) High tonnage of die casting machines.

4. Statement (I):In shell moulding process, phenol formaldehyde is never used.
Statement (II):The resions used in this process are basically of the thermoplastic variety.

[ME ESE - 2016]

(a)Both Statements (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I).
(c)Statement (I) is true but Statement (II) is false.
(d)Statement (I) is false but Statement (II) is true.

5. Statement (I): Both sand and metal moulds can be used for centrifugal casting.
Statement (II): The resins used in this process are basically of the thermoplastic variety.

[ME ESE - 2016]

(a)Both Statements (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I).
(c)Statement (I) is true but Statement (II) is false.
(d)Statement (I) is false but Statement (II) is true.

6. Assertion (A): Cored induction furnace cannot be used for intermittent operation.
Reason (R): Cored induction furnace, though most efficient, requires a liquid metal charge while starting.

[ME ESE - 2015]

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R true but R is not a correct explanation of A
(c) A is true but R is false.
(d) A is false but R is true.

7. A big casting is to have a hole, to be produced by using a core of 10 cm diameter and 200 cm long. The density ρ_{metal} is 0.077 N/cm^3 and density ρ_{core} is 0.0165 N/cm^3. What is the upward force acting on the core prints?

[ME ESE - 2015]

(a) 200.5 N (b) 1100.62 N
(c) 950.32 N (d) 350.32 N

CHAPTER - 3
LIMITS , FITS AND TOLERANCES

3.1 INTRODUCTION

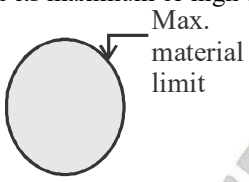
3.1.1 GENERAL TERMINOLOGY

1. Shaft

It refers to external dimension of a component. It is denoted by small letters.

(i) In case of shaft focus is on external dimension

(ii) Its maximum material limit will be its maximum or high dimension

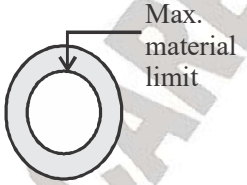


2. Hole

It refers to internal dimensions of a component. It is denoted by capital letters.

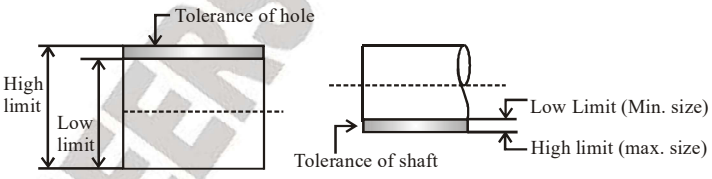
(i) The focus is on internal dimension

(ii) Maximum material limit is the minimum size



3. Tolerance

It refers to the difference between maximum size and minimum size or difference between higher limit or lower limit.



4. Limits

These are the maximum and minimum permissible sizes of the part. "Maximum Limit" is the maximum size permitted for the part. "Minimum Limit" is the minimum size permitted for the part.

5. Allowance

It is the intentional difference between maximum material limits of mating parts.

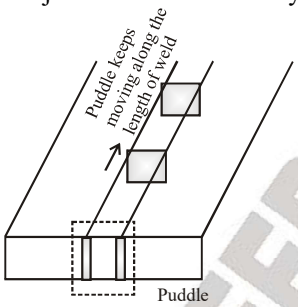
CHAPTER - 4
WELDING

4.1 INTRODUCTION

Welding is a process that joins two pieces of a metal by applying intense heat or pressure or both to melt the edges of the metal so that they fuse with each other.

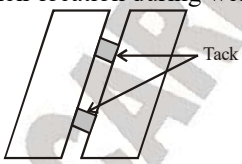
1. Puddle

It is the portion of the base metal at the joint which is melted by the heat during welding.

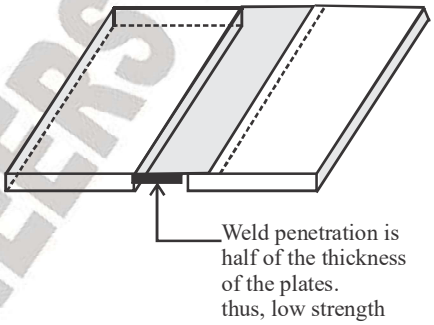


2. Tack Weld

Tacks are used to keep two plates at their location during welding.

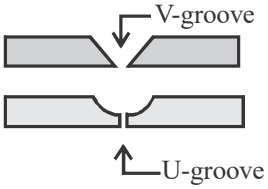


It is a temporary small weld at the end of the work pieces, to hold the work pieces together during welding.



To avoid, this low strength of the welded joint, edge preparation is carried out.

3. Edge Preparation



GATE QUESTIONS

1. In an arc welding process, welding speed is doubnled. Assuming all other process parameters to be constant, the cross sectional area of the weld bead will.

[ME GATE - 2017]

(a) Increase by 20% (b) Increase by 50 %
(c) Reduce by 25% (d) Reduce by 50%

2. Under optimal conditions of the process the temperatures experienced by a copper work piece in fusion welding, brazing and soldering are such that

[ME GATE - 2016]

(a) $T_{welding} > T_{soldering} > T_{brazing}$
(b) $T_{soldering} > T_{welding} > T_{brazing}$
(c) $T_{brazing} > T_{welding} > T_{soldering}$
(d) $T_{welding} > T_{brazing} > T_{soldering}$

3. The welding process which uses a blanket of fusible granular flux is

[ME GATE - 2016]

(a) Tungsten inert gas welding
(b) Submerged are welding
(c) Electroslag welding
(d) Thermit welding

4. Spot welding of two steel sheets each 2 mm thick carried out successfully by passing 4 kA of current for 0.2 seconds through the electrodes. The resulting weld nugget formed between the sheets is 5 mm in diameter. Assuming cylindrical shape for the nugget, the thickness of the nugget is _____ mm.

Latent hear of fusion for steel	1400 kJ/kg
Effective resistance of the weld joint	200 μΩ
Density of steel	8000 kg/m^3

[ME GATE - 2016]

5. The voltage-length characteristic of a direct current arc in a an arc welding process is V = (100 + 40ℓ), where ℓ is the length of the arc in mm and V is are arc volts. During a welding operation, the arc length varies between 1 and 2 mm and the welding current is in the range 200-250 A. Assuming linear power source, the short circuit current _____A.

[ME GATE - 2016]

6. In a linear arc welding process, the heat input per unit length is inversely proportional to

[ME GATE - 2015]

(a) Welding current
(b) Welding voltage
(c) Welding speed
(d) Duty cycle of the power source

7. A DC welding power source has a linear voltage-current (V-I) characteristics with open circuit voltage of 80 V and a short circuit current of 300 A. For maximum arc power, the current (in Amperes) should be set as _____.

[ME GATE - 2015]

8. During a TIG welding process, there are current and are voltage were 50 A and 60 V, respectively, when in the welding speed was 150 mm/mi. In another process, the TIG welding is carried out a welding speed of 120 mm/min at the same arc voltage and heat input to the material so that weld quality remains the same. The welding current (in A) for this process is

[ME GATE - 2015]

(a) 40.0 (b) 44.72
(c) 55.90 (d) 62.25

9. Which two of the following processes are autogenous?
(i)Diffusion welding
(ii)Electroslag welding
(iii)Tungsten inert gas welding
(iv)Friction welding

CHAPTER - 5
MACHINING

5.1. INTRODUCTION

5.1.1 TERMINOLOGY

1. Cutting Tool
It is a component or equipment which removes extra material through direct mechanical contact.

2. Machine Tool
The machine which provides necessary relative motion between workpiece and tool is commonly termed as machine tool eg: lathe machine, shaping and planing machine.

3. Reconditioning of Tool
When the tools particularly HSS gets worn out, they are reconditioned or re-sharpened for further use. These are usually grounded on tool and cutter grinders.

Reconditioning may also involve recoating the used tool with titanium nitride.

5.2 BRIEF DESCRIPTION OF COMMON MACHINING PROCESSES

5.2.1 Shaping
In shaping the surface obtained is plane, the cutting tool is given reciprocating motion and after every cutting stroke, the work is fed perpendicularly (during the return stoke the work is advanced by a small distance) in order to provide a layer of uncut material to the tool.
Since, the cutting is not continuous hence this type of machining is known as Intermittent.

5.2.2 Cutting
Shaping uses quick return mechanism.

The average cutting speed in shaping is given as, $V = \frac{NS(1+R)}{2}$

Where V is cutting speed in (m/min)
N is RPM
S is Stroke length
R is Quick Return Ratio

5.2.3 Planing
In case of a long workpiece, it becomes inconvenient and difficult to provide long cutting strokes to cutting tools. In such cases, the workpiece is provided with cutting motion and feed motion is given to the cutting tool.

5.2.4 Turning
This is a very basic operation carried out on lathe machine. It produces a cylindrical surface. In a typical turning operation, a workpiece in form of cylindrical bar is rotated about its axis of symmetry. Tool moves along the work axis and is provided with feed motion. It is significant to mention. With respect to workpiece, the tool has helical motion.

ESE OBJ QUESTIONS

1. In developing abrasive ceramics which are used to wear, grind or cut away other materials which are (necessarily) softer, they should have, besides wear resistance,
1. A high degree of toughness
2. A low degree of toughness
3. Refractoriness
Which of the above is/are correct?
[ME ESE - 2016]
(a) 1 only (b) 2 only
(c) 1 and 3 (d) 2 and 3

2. A 125 mm long, 10 mm diameter stainless steel rod is being turned to 9 mm diameter, 0.5 mm depth of cut. The spindle rotates at 360 rpm with the tool traversing at an axial speed of 175 mm/min, the metal removal rate is nearly.
[ME ESE - 2016]
(a) 2200 mm^3min (b) 2400 mm^3/min
(c) 2600 mm^3/min (d) 2800 mm^3/min

3. The feed in face milling for a width of 70 mm with a cutter of 160 mm, diameter, having 10 inserts and rotating at 360 rpm, with a feed rate of 0.5 m/min, is nearly.
[ME ESE - 2016]
(a) 0.21 mm/tooth (b) 0.18 mm/tooth
(c) 0.14 mm/tooth (d) 0.11 mm/tooth

4. A lathe consumes 500 W when running idle and 2500 W when cutting a steel specimen at 30 m/min. If depth of cut is 4 mm and feed rate is 0.25 mm/rev, the cutting force and the approximate value of torque at a spindle run of 120 rpm will respectively be
[ME ESE - 2016]
(a) 4000 N and 160 N-m
(b) 3000 N and 160 N-m
(c) 4000 N and 100 N-m
(d) 3000 N and 100 N-m

5. For a shaper, the length of stroke is 210 mm, the number of double strokes per minute is 32 and the ratio of return time to cutting time is 2 : 3. The cutting speed will be
[ME ESE - 2016]
(a) 8.1 m/min (b) 11.2 m/min
(c) 14.3 m/min (d) 17.4 m/min

6. The headstock of a lathe 9 speeds with minimum speed of 100 r.p.m. and maximum speed of 1600 r.p.m. If the speeds are in geometric progression, then the ratio is
[ME ESE - 2016]
(a) 1.06 (b) 1.22
(c) 1.41 (d) 1.64

7. Flank wear occurs mainly on the
1.Nose part of the cutting tool
2.Front relief face and side relief face of the cutting tool
3.Face of the cutting tool at the shortest distance from the cutting edge.
Which of the above is/are correct?
[ME ESE - 2016]
(a) 1 and 2 (b) 1 and 3
(c) 2 only (d) 1 only

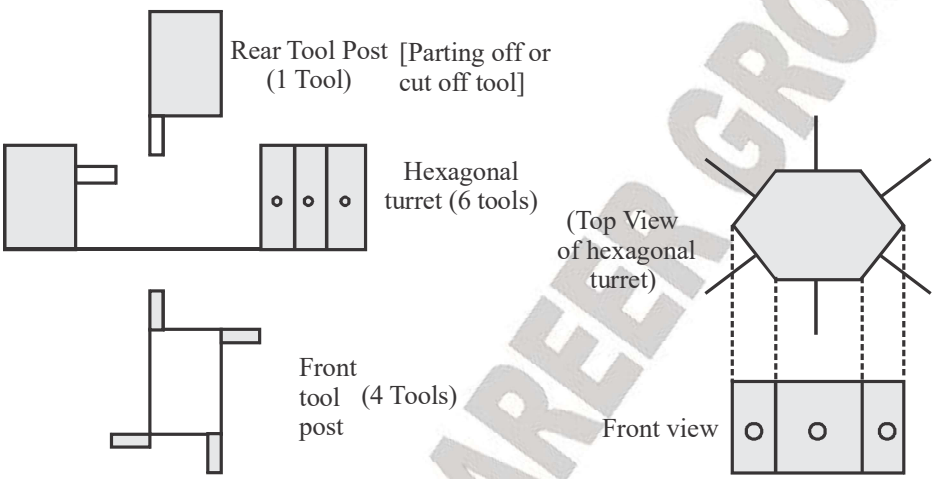
8. In a machining test, a cutting speed of 100 m/min indicated the tool life as 16 min and a cutting speed of 200 m/min indicated the tool life as 4 min. The values of n and c are
[ME ESE - 2016]
(a) 0.5 and 200 (b) 0.25 and 200
(c) 0.5 and 400 (d) 0.25 and 400

9. During the formation of chips in machining with a cutting tool, which one of the following relations holds good
[ME ESE - 2016]
(a) $\frac{V}{\cos(\phi-\alpha)} = \frac{V_S}{\cos\alpha} = \frac{V_C}{\sin\alpha}$
(b) $\frac{V}{\cos(\phi-\alpha)} = \frac{V_S}{\cos\alpha} = \frac{V_C}{\cos\alpha}$

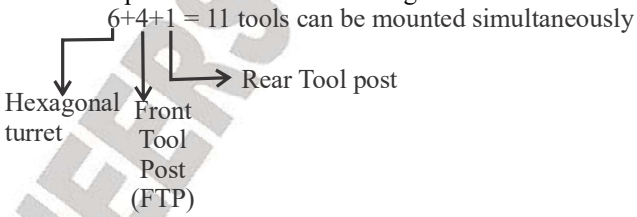
CHAPTER - 6
TURRET AND CAPSTAN LATHE

6.1 TURRET AND CAPSTAN LATHE

Turret and capstan lathes are also called as production lathe. These are special purpose lathe by which increased rate of production can be obtained by saving the time lost in changing and setting of tools. In these lathe, the complete job can be finished in a single setting of tools and more then one tool can be employed simultaneously i.e. through these lathes we are able to delete non productive time.



Unlike simple lathe, the tailstock has been replaced by hexagonal turret which carries 6 tools. In turret and capstan lathes there is no lead screw. Lead screw in central lathes is used for cutting threads. Unlike central lathes, turret and capstan lathes are more rigid and robust and can withstand larger force. Due to high rigidity, higher feed can be given. Usually parting off or cut off tool is mounted at the rear tool post. As seen from the diagram.



Hence, the biggest advantage is reduction in total changing time and thereby tool changing cost. The turret can be rotated either in clockwise or anticlockwise direction. The major difference between turret lathe and capstan lathe are:

Turret are larger machines used for machining of large sized jobs whereas capstan are smaller machines used for machining of smaller sized jobs.

CHAPTER - 7
SHEET METAL OPERATIONS

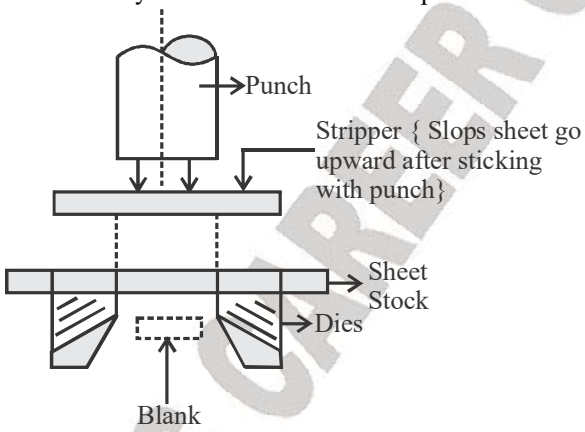
7.1 INTRODUCTION

Any specimen whose thickness is lesser than length and breadth, will be called as sheet. If its thickness is less than 5 mm, it is called as sheet. If thickness is more than 8 mm, we can call it as plate. Machine tool by which different sheet metal operations are performed is called as press. A press is specified by its tonnage capacity. Different sheet metal operations are: Punching , Blanking, Coining and Embossing.

7.1.1 Applications of Sheet Metal Operations

1. Automobile bodies
2. Making of coins

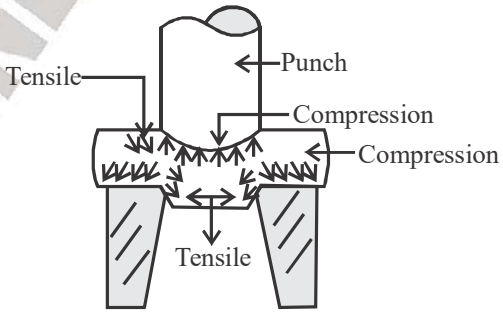
Cutting tool used in presses to carry out various sheet metal operations is called as punch.



Shape of cross-section of punch is as required on the workpiece. The punch hits the sheet stock while passing through the stripper and stripper prevents upward movement of sheet & hence punch gets free from sheet stock.

7.2 PUNCHING AND BLANKING

When blank is useful product, process is called blanking. When hole is required product, process is called punching. Both punching and blanking takes place due to shearing acting at the sheet between punch and die.



GATE QUESTIONS

1. In a sheet metal of 2 mm thickness a hole of 10 mm diameter needs to be punched. The yield strength in tension of the sheet material is 100 MPa and its ultimate shear strength is MPa. The force required to punch the hole (in kN) is _____.

[ME GATE - 2016]

2. A rectangular hold of size 100m × 50 mm is to be made on a 5 mm thick sheet of steel having ultimate tensile strength and shear strength of 500 MPa and 300 MPa, respectively. The hole is made by punching process. Neglecting the effect of clearance, the punching force (in kN) is

[ME GATE - 2014]

(a) 300 (b) 450
(c) 600 (d) 750

3. A mild steel plate has to be rolled in one pass such that the final plate thickness is $2/3^{rd}$ of the initial thickness, with the entrance speed of 10 m/min and roll diameter of 500 mm. If the plate widens by 2% during rolling, the exit velocity (in m/min) is ____.

[ME GATE - 2014]

4. In a rolling process, the maximum possible draft, defined as the difference between the initial and the final thickness of the metal sheet, mainly depends on which pair of the following parameters ?
P : Strain
Q : Strength of the work material
R: Roll diameter
S : Roll Velocity
T : Coefficient of friction between roll and work

[ME GATE - 2014]

(a) Q, S (b) R, T
(c) S, T (d) P, R

5. A single riveted lap joint of two similar plates as shown in the figure below has the following geometrical and material details

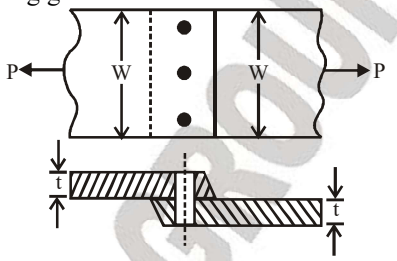


Plate width W = 200 mm
Plate thickness t = 5 mm
Number of rivets n = 3
Rivet diameter d_r = 10 mm
Rivet hole diameter d_h = 11 mm
Allowable tensile stress of plate σ_p = 200 MPa
Allowable bearing stress of rivet σ_c = 150 MPa
If the plates are to be designed to avoid tearing failure, the maximum permissible load P in kN is

[PI GATE - 2013]

(a) 83 (b) 125
(c) 167 (d) 501

6. Match the correct pairs
Processes
A. Friction Welding
B. Gas Metal Arc Welding
C. Tungsten Inert Gas Welding
D. Electroslag Welding
Characteristics/Application
(i) Jon-consumable Electrode
(ii) Joining of Thick Plates
(iii) Consumable Electrode Wire
(iv) Joining of Cylindrical Dissimilar Materials

[PI GATE - 2013]

Codes:
(a) A-iv, B-iii, C-i, D-ii
(b) A-iv, B-ii, C-iii, D-i
(c) A-ii, B-iii, C-iv, D-i
(d) A-ii, **B**-iv, C-i, D-iii

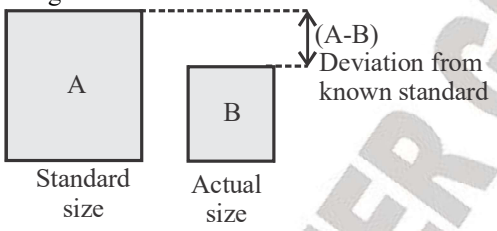
7. Match the correct pairs

CHAPTER - 9
METROLOGY

9.1 INTRODUCTION

It is science of measurement. Measurement can be defined as determination of a dimension .On contrary gauging is defined as acceptability of a given dimension whether or not it lies within its specified or allowable limits.

Direct reading instruments gives absolute dimension of component eg. a measuring tape or scale, whereas, comparator is an indirect measuring instrument which compares the given dimension against a known standard and gives information about deviation from the known standard.



9.2 LINEAR MEASUREMENT

Instruments available for linear measurement are

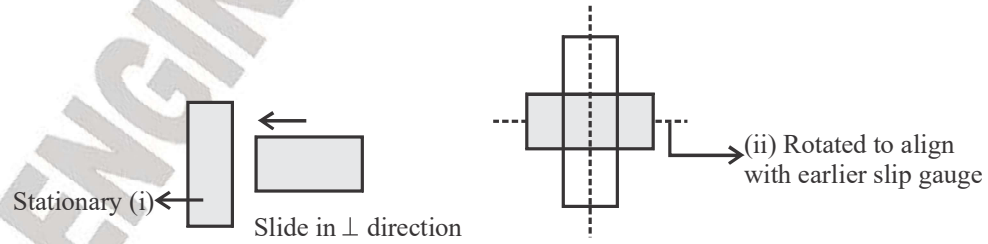
1. Vernier caliper
2. Micrometer
3. Slip gauges

Slip gauges are rectangular blocks with thickness representing dimensions of block. Cross-section of blocks is 32mm by 9mm .Slip gauges are hardened and finished to size .Measuring surfaces of gauge blocks have very high degree of surface finish , flatness and accuracy.

All these pieces are properly polished and lapped. Slip gauges comes in sets with different number of pieces in a given set to suit requirements of measurements

9.2.1 Wringing of Slip Gauges

The slip gauges are wrung together to avoid any error in measurement due to airgap in between them



Slip gauges are made of surface hardened steel to minimize wear and tear to maximum extent.

CHAPTER - 10
FORMING

10.1 INTRODUCTION

Forming can be defined as a process in which desired size & shape are obtained through plastic deformation of material. Stresses induced are greater than yield strength but less than fracture strength. It is one of the most economical process as the desired size, shape & finish can be obtained without any significant loss of material.Forming process can be classified into cold forming and hot forming . If working temperature is higher than recrystallisation temperature, process is called hot forming otherwise it is called cold forming.

Recrystalization temperature is the temperature at which recrystallization takes place i.e. distorted grain structure is replaced by strain free structure. The deformed grains are replaced by new set of undeformed grains that nucleate and grow until original deformed grains have been entirely consumed. Recrystallization is companied by.

1. Reduction in strength.
2. Reduction in hardness
3. Increase in ductility

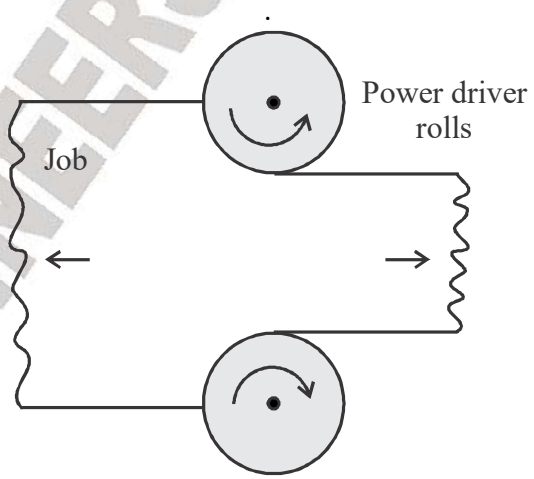
Most important industrial application of recrystallization is softening of metals which have been hardned by cold working and rendered brittle. It also helps in controlling grain structure in final product.

10.2 TYPES OF FORMING PROCESSES AND THEIR BRIEF INTRODUCTION

1.Rolling	2.Forging	3.Drawing
4.Deep drawing	5.Extrusion	6.Bending

10.2.1 Rolling

In this process job is drawn by means of friction through a regulated opening between two power driven rolls. It is very useful for production of sheet metals and various common sections e.g. rail, channel, angle etc.

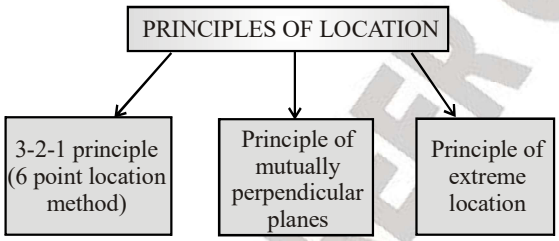


CHAPTER - 11
JIGS AND FIXTURE

11.1 INTRODUCTION

1. Jigs
It is a device which locates the workpiece and also guides the tool. Jigs are used for drilling reaming, tapping and boring.

2. Fixture
It is device which locates component wrt. Tool but doesn't guide a tool. eg. chuck of a lathe, bench vice.
Fixture holds the component but a jig may or may not hold the component.



For any component in free space, there are 12 degrees of freedom. For carrying out any machining operation all the 12 degrees of freedom are to be restricted. By using 3-2-1principle, we are able to restrict 9 D.O.F. and rest 3 D.O.F. are restricted by using clamping devices.

GATE QUESTIONS

1. Match the following:

Device

A. Jig
B. Fixture
C. Clamp
D. Locator

Function

(i)Helps to place workpiece in the same position cycle after cycle
(ii)Holds the workpiece only
(iii)Holds and position the workpiece
(iv)Holds and position the workpiece and guides the cutting tool during a machining operation.

[PI GATE - 2009]

Codes:

(a) A-iv, B-iii, C-i, D-ii
(b) A-i, B-ii, C-iii, D-iv
(c) A-i, B-iv, C-iii, D-ii
(d) A-iv, B-iii, C-ii, D-i

2. When 3-2-1 principle is used to support and locate a three dimensional work-piece during machining, the number of degrees of freedom that are restricted is

[ME GATE - 2005]

(a) 7 (b) 8
(c) 9 (d) 10

SOLUTIONS

Sol. 1. (d)

Sol. 2. (c)

CHAPTER - 12
MATERIAL SCIENCE

12.1 INTRODUCTION

12.1.1 Classification of Materials

Solid material can be grouped into three basic classifications i.e. metals, ceramics and polymers. The scheme is primarily based on chemical composition and atomic structure and most of the materials fall into one of these groups. In addition there are 3 other groups of important engineering materials i.e. composites, semiconductors and biomaterials.

1. Metals

(i) They are very good conductors of heat and electricity and are not transparent to visible light.
(ii) Most metals have lustrous appearance.

2. Ceramics

(i) As regards mechanical behavior ceramics are extremely hard and brittle.
(ii) Most common example of ceramics are glass, cement etc.
(iii) They can bear high temperatures.
(iv) They are mostly oxides, Nitrides & carbides,
(v) They can resist very harsh environment (acids, chemicals or water do not have any adverse effect)

3. Polymers

(i) These include plastic and rubber materials.
(ii) They have very large molecular structures.
(iii) Polymers are extremely flexible.

12.1.2 Composites, Semiconductors, Bio-Materials

1. Composites

It consist of more than one material type. Most common example is fibre glass in which glass fibres are embedded in a polymeric material. A composite is designed to display combination of best characteristics of each of the component. For example in fibre glass, glass gives strength and polymer gives flexibility.

2. Semiconductors

They have electrical properties. They are intermediate between conductors and insulator. The electrical characteristics of semiconductor are extremely sensitive to the presence of minute concentration of impurity atoms. Semiconductors are frequently used in electronic circuits and computer industries.

3. Biomaterials

They are implanted into the human body for replacement of damaged body parts. These materials must be compatible with body tissues and must not produce toxic substance.

12.1.3 Some Basic Definitions

1. Strain

It is the measure of the deformation produced on the member due to application of load. For example, Let L is the length of the specimen having cross sectional area A. If a tensile load P is applied, let it extends by small quantity Δ, then