1 UNIT

Conventional Manufacturing Process

CONTENTS

PART-1

Casting and Moulding : Metal Casting Processes and Equipment.

CONCEPT OUTLINE

Casting : It is a process of pouring molten metal into a mould cavity of desired shape and allowing it to solidify.

Continuous Casting : It consists of pouring the molten metal into the upper end of a long vertical metal mould (open at both ends) and cooling rapidly by water.

CO_2 Casting : In this process, the sand molding mixture is hardened by blowing gas over the mould. This process is favoured by hobby metal casters because a lot of cost cutting can be done.

Moulding : It is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called mould.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. What are the basic steps of the metal casting process ?

Answer

Steps involved in a casting process are as follows :

1. Making mould cavity.
2. Metal is first liquefied by proper heating in a suitable furnace.
3. Liquid metal is poured into a mould cavity where it is allowed to cool.
4. After the solidification of liquid metal, product is taken out from the mould cavity.
5. Finally, product is trimmed and cleaned.

Que 1.2. Describe the die casting and centrifugal casting.

Answer

A. Die Casting Process :

1. In die casting process, the molten metal is forced into mould cavity under high pressure.
2. The mould, called a die is made of two parts one is fixed and other movable.

3. Die materials are generally medium carbon or, low alloy steel.
4. This process generally used for low melting temperature. Die is cooled by water for efficient cooling and enhance the life of die.
5. The die casting is of two types :
   i. Hot chamber die casting, and
   ii. Cold chamber die casting.

B. Centrifugal Casting :

1. It is the process in which metal is poured into a mould which is rotated about its center rapidly.
2. Due to centrifugal force, a continuous pressure will be acting on the metal during solidification.
3. The impurities are higher than pure metal so impurities segregate towards the center.
4. This method is generally used for symmetrical cast product.
5. There are three main types of centrifugal casting :
   i. True centrifugal casting,
   ii. Semi centrifugal casting, and
   iii. Centrifuging casting.

Que 1.3. **Explain the elements of mould in brief with a neat sketch.**

Answer

Elements of a mould are as follows :

1. **Cope :** Upper portion of the moulding flask is known as cope.
2. **Drag :** Lower portion of the moulding flask is known as drag.
3. **Core :** It is used for making the hollow casting. Core is placed in the previously prepared mould cavity to produce hollow portion.
4. **Chaplet :** Chaplets are used to support the core in mould cavity.
5. **Pouring Basin :** It is made for pouring the molten metal because it is not safe to pour the metal directly into the sprue due to erosion of the mould.
6. **Sprue :** This is the passage through which the molten metal from the pouring basin reaches to the mould cavity. It also controls the flow of the molten metal.
7. **Runner :** This is the passage at parting line through which molten metal reaches to mould cavity.
8. **Riser :** It is a reservoir of molten metal made in casting. Wherever there is a reduction of molten metal due to solidification in mould cavity, metal flows back from the riser to the cavity.
9. **Gate :** This is the entry point (after the runner) to the mould cavity through which molten metal enters into the mould cavity.

10. **Chills :** Chills are metallic objects which are used to increase the cooling rate of casting in uniform manner. It is advisable to use chills in large mould cavity because they have non-uniform manner of solidification.
11. **Pattern :** It is the replica of the part to be cast with some modification. The mould cavity is made with the help of the pattern.

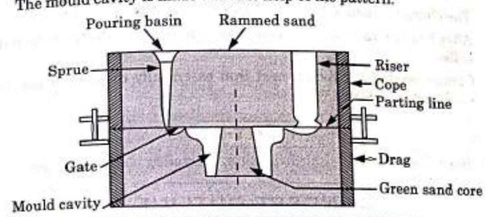

Fig. 1.3.1. Sectional view through a sand mould showing the elements of a mould.

Que 1.4. **Draw a properly labelled sketch of a cupola and write a brief account of its operation.**

Answer

1. For melting the cast iron in foundry the cupola furnace is used. A diagrammatic sketch of this furnace is given in Fig. 1.4.1.

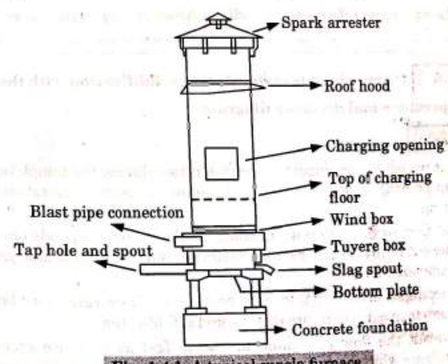

Fig. 1.4.1. A typical cupola furnace.

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2. To operate the cupola, first step is to close the drop door and coke bed of suitable height is prepared above the sand bottom and ignited through the tap hole.
3. When the coke bed is properly ignited alternate layer of charge, flux and coke are fed into cupola through the charge door.
4. The charge is then allowed to soak in the heat for some time.
5. After 5 to 10 minutes, molten metal is collected near the tap hole in the ladles.
6. Charge needed to produce cast iron essentially consists of pig iron scrap and steel scrap.

PART-2

Heat Transfer and Solidification, Shrinkage, Riser Design.

CONCEPT OUTLINE

Casting Solidification : It covers the understanding of mechanism of solidification of metals and alloys, which is essential for understanding the structure developed in casting.

Solidification Time : It is a function of volume and surface area. It is given as,

Solidification time = (Volume / Surface area)^2

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.5. **Discuss heat transfer during solidification with the help of temperature and distance diagram.**

Answer

1. Heat transfer is an important consideration during the complete cycle from pouring to solidification and cooling to room temperature, in a casting.
2. Heat flow to the different locations in the system depends on many factors relating to the casting material and the mould and process parameters.
3. For example, in casting thin sections, the metal flow rates must be high enough to avoid premature chilling and solidification.
4. However, the flow rate must not be so fast as to cause excessive turbulence which has a damaging effect on the properties of the casting.

5. Fig. 1.5.1 shows the temperature distribution in the mould-liquid-metal interface.
6. Heat from the liquid metal is given off through the mould wall and surrounding air.
7. The temperature drop at the air-mould and mould-metal interfaces is caused by the presence of boundary layers and imperfect contact at these interfaces.
8. Thermal properties of the molten metal and the mould govern the shape of the curve.

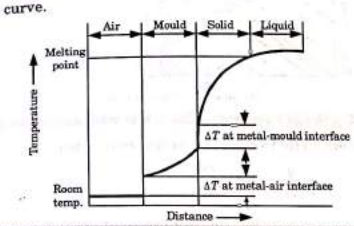


Fig. 1.5.1. Temperature distribution in different layers during solidification of metals.

Que 1.6. **Briefly describe solidification of casting.**

Answer

Solidification of casting are :

a. **Solidification of a Large Casting in an Insulating Mould :**

1. Fig. 1.6.1 shows the heat dissipation rates in different regions when mould wall is in molten metal contact.

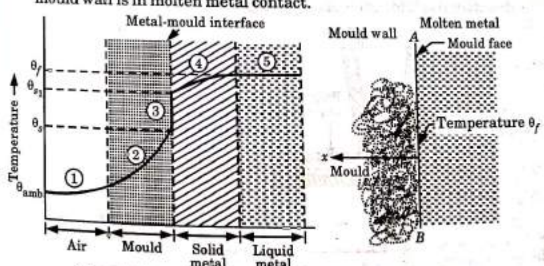


Fig. 1.6.1. Solidification of casting in insulating mould

2. This situation occurs in sand or investment castings.
3. During the solidification of a large casting in an insulating mould almost the entire thermal resistance is offered by the mould.

b. Solidification of a Simple Casting (Flat Mould Wall) :

1. Fig. 1.6.2 shows unidirectional solidification from a flat mould wall.

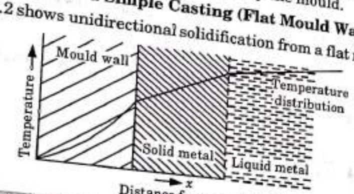


Fig. 1.6.2. Solidification from a flat mould wall (unidirectional).

2. Heat flow from metal to mould according to relation,

$$\frac{q}{A} = -K\left(\frac{\delta T}{\delta x}\right)$$

Where, $\frac{q}{A}$ = Rate of heat flow/unit area,
K = Thermal conductivity,
$\frac{\delta T}{\delta x}$ = Thermal gradient,
T = Temperature, and
x = Distance.

c. Directional Solidification :

1. When gating system controls the progressive solidification such that no portion of the casting is isolated from liquid metal feeding channels during the process of complete solidification, this is referred to as directional solidification shown in Fig. 1.6.3.

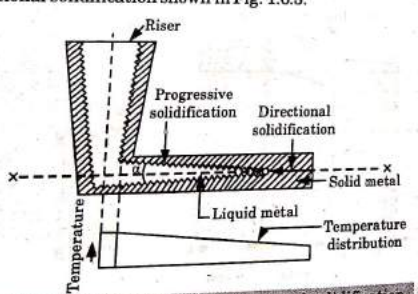


Fig. 1.6.3. Progressive and directional solidification.

2. Effective directional solidification is one which starts furthest from the feeder heads and proceeds, through the casting, towards the feeders designed to supply liquid metal throughout the freezing period.

Que 1.7. **With a solidification factor of 0.97×10^6 s/m², find the solidification time in seconds for a spherical casting of 200 mm diameter.**

Answer

Given : $K = 0.97 \times 10^6$ s/m², d = 200 mm = 0.2 m
To Find : Solidification time.

1. Solidification time,

$$t = K\left(\frac{\text{Volume}}{\text{Surface area}}\right)^2 = K\left(\frac{\frac{4}{3}\pi r^3}{4\pi r^2}\right)^2$$

$$= K\left(\frac{r}{3}\right)^2 = 0.97 \times 10^6\left(\frac{r}{3}\right)^2$$

$$= 0.97 \times 10^6\left(\frac{0.1}{3}\right)^2 \qquad \left[\because r = \frac{d}{2}\right]$$

$$= \frac{0.97 \times 10^4}{9} = 1077.78 \text{ sec}$$

Que 1.8. **What is shrinkage in casting process? Explain its types.**

Answer

A. Shrinkage :

1. Shrinkage is an internal or external change in volume that occurs during a phase change in a metal's transition from a liquid state to a solid state at the exposed surface.
2. This phenomenon occurs in processes like casting solidification. It is visible during a non-destructive test, and can be used to analyze plastic shrinkage cracks and void formation in castings.
3. Metals undergo contraction when solidified and cooled, because the specific volume is larger in the liquid state than in the solid state for standard casting metals. Therefore, it is a function of the casting material.
4. This phenomenon leads to voids and cavities when there is not enough molten metal to feed the shrinkage when casting.
5. Shrinkage results in several casting defects such as porosity and stains in the product. This can be avoided by altering the casting geometry and using risers.

B. **Types of Shrinkage :**

a. **Cavity Shrinkage :** This defect occurs when two different sources of molten material are joined to create a common front while solidification is already taking place.

b. **Sponge Shrinkage :** This usually arises in the thicker mid-section of the casting product and causes a thin lattice texture similar to filament or dendrites to develop.

c. **Filamentary Shrinkage :** This results in a network of continuous cracks of various dimensions and densities, usually under a thick section of the material.

d. **Dendritic Shrinkage :** Dendritic fractures are narrow, randomly distributed lines or cavities that are often unconnected. They are typically thinner and less dense than filamentary cracks.

Que 1.9. **Explain various methods used for designing riser.**

Answer

Methods used for designing riser are as follows :

a. **Chvorinov's Rule :**

1. Solidification time (t_s) as might be expected is directly proportional to the square of the ratio of volume v to the surface area A (through which cooling occurs).

$$t_s \propto \left(\frac{v}{A}\right)^2$$

2. Solubility of a gas S in the melt increases with the square root of the partial pressure of that gas over the melt according to Sievert's law.

$$S \propto \sqrt{p_g}$$

3. Chvorinov's equation was developed theoretically but corresponds well with the cast shapes of many varieties from plates to spheres. It is also used in the design of feeder heads (risers).

b. **Caine's Method :**

1. This method is based upon experimentally determined hyperbolic relationship between freezing times and volumes of castings and the risers.

2. According to Caine, if the casting solidifies infinitely rapidly the (feeder) riser volume should be equal to solidification shrinkage of the casting and if the feeder and casting solidify at the same rate, the feeder should be infinitely large.

3. Relative freezing time or freezing ratio R_F is defined as,

$$R_F = \frac{(A/v)_{casting}}{(A/v)_{riser}}$$

4. Volume ratios R_v is given as : $R_v = \frac{v_{riser}}{v_{casting}}$

5. Then Caine's formula is given by $R_F = \frac{a}{R_v - b} + c$

Where,
a = Freezing characteristic constant for the metal,
b = Contraction ratio from liquid to solid, and
c = Relative freezing ratio of riser and casting.

PART-3

Casting Defects, and Residual Stresses.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.10. **What are the common casting defects ? What causes them and what are the measures that can be taken to avoid them ?**

Answer

Some common casting defects and their causes are as follows :

i. **Mould Shift :** It results in a mismatching of the top and bottom parts of a casting, usually at the parting line.

a. **Causes :** It occurs due to following reasons :
1. Misalignment of pattern parts, due to worn or damaged patterns.
2. Misalignment of moulding box or flask equipment.

b. **Remedies :** This defect can be prevented by ensuring proper alignment of the pattern, moulding boxes, correct mounting of pattern on pattern plates etc.

ii. **Core Shift :** It is an abnormal variation of the dimensions which are dependent on core position.

a. **Causes :**
1. Misalignment of cores in assembling cored moulds.
2. Undersized or oversized core prints.
3. By using incorrect size of chaplet.

b. **Remedies :** This defect can be eliminated by providing the core at the proper place and must be gripped properly in the sand.

iii. **Swell :** It is an enlargement of the mould cavity by molten metal pressure resulting in localised or general enlargement of the casting.

a. **Causes :** It occurs :
   1. Due to insufficient ramming of sand.
   2. Due to insufficient weighting of the mould during casting.
   3. Due to pouring of molten metal too rapidly.

b. **Remedies :** The swells are avoided by the proper ramming of sand and uniform flow of molten metal into the mould.

iv. **Sand Wash :** It usually occurs near the in-gates as rough lumps on the surface of a casting. The sand that has been washed away appears on the upper surfaces of the castings as rough holes or depressions.

a. **Causes :** This occurs due to the following reasons :
   1. Soft ramming of sand,
   2. Weak sand,
   3. Poor pattern, and
   4. Insufficient draft.

b. **Remedies :** This defect is avoided by the proper ramming of sand.

v. **Hot Tear :** It is an internal or external ragged discontinuity in the metal casting resulting from hindered contraction occurring just after the metal has solidified.

a. **Causes :** This defect occurs due to the following reasons :
   1. Abrupt changes in section, inadequate filleting of inside corners, and improper placement of chills.
   2. Poor collapsibility of mould and core materials which will place extra stress on certain details.
   3. Improper pouring temperature.

b. **Remedies :** In order to eliminate this defect, abrupt changes in section should be avoided. The pouring temperature should be correct and there should be even rate of cooling.

vi. **Sand Blow or Blow Hole :** It is an excessively smooth depression on the outer surface of a casting. This defect is also called blow holes.

a. **Causes :** This defect occurs due to the following reasons :
   1. High moisture content in moulding sand,
   2. Low permeability of sand,
   3. Hard ramming of sand, and
   4. Defective gating system.

b. **Remedies :** This defect can be removed by proper venting, completely drying up the mould, selecting proper sand with required permeability and proper in-gate system for the flow of molten metal.

vii. **Cold Shuts and Misruns :** These occurs when the mould cavity is not completely filled and an incomplete casting results.

a. **Causes :** This defect occurs due to the following reasons :
   1. Too small gates,

   2. Too many restrictions in the gating system,
   3. Pouring head is too low, and
   4. Faulty venting of the moulds.

b. **Remedies :** In order to eliminate these defects, the casting should be designed keeping in mind the fundamental principles of gating and riser. The thin sections should be preheated and the molten metal should be poured at the correct temperature.

Que 1.11. **Explain residual stresses in casting process.**

Answer

1. Different sections of a non-uniform cross-section casting solidify at different rates depending on their cross-sectional areas.
2. This results in varying amount of contraction in different parts, producing high internal stresses, which may cause tearing or cracking of casting.
3. High residual internal stresses can be avoided by placing chills over large cross-sectional areas so that whole of casting cools at uniform rate.
4. Another method of controlling such stresses is to take out casting at an average temperature of around 750 °C and putting it in an insulated pit and allowing to cool at 5.5 °C/ hour.
5. It may be mentioned that any temperature gradient above 540 °C does not give rise to elastic strain because same is relaxed to plastic strain due to high rate of creep.
6. If high residual stresses exist in a casting, it has to be relieved by a suitable heat treatment process or by other methods of stress relieving.

PART-4

Introduction to Bulk and Sheet Metal Forming.

CONCEPT OUTLINE

Bulk Forming : It includes forging, rolling, extrusion and drawing.

Rolling : It is the process of reducing thickness or changing the cross-section of a long workpiece by compressive forces applied through a set of rolls.

Wire Drawing : It is an operation to produce wire of various sizes within certain specific techniques.

Tube Drawing : It normally makes tubes from hollow tube shells produced by extrusion. The common methods of tube drawing are tube sinking, tube drawing with a plug or stationary mandrel and tube drawing with a moving mandrel.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.12. **Define forging. Also describe the common types of forging operations.**

Answer

A. Forging :

1. Forging is the process of inducing deformation by localized compressive forces to produce the required shape.
2. Forging could be hand forging power forging, and drop forging.

B. Types of Forging Operations :

a. Upsetting :

1. It consists of increasing the cross-section of a bar at the expense of its length.
2. In this process, first of all, the work is heated to the required temperature and then the heavy blow is given by hand hammer. The swelling of work takes place at the heating portion.
3. The position and nature of upsetting depends upon the heating and upon the type of blow delivered.
4. In general, the increase in lateral swelling will be greatest at parts where the metal is hottest.
5. Fig. 1.12.1(*a*), (*b*), and (*c*) shows the effect of heavy blow when the heating is done at one end, at both ends and at the centre respectively.

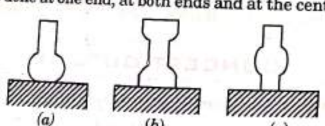


Fig. 1.12.1. Upsetting.

b. Swaging :

1. In swaging, workpiece is placed between the specially designed die which exert the repeated impact load on the workpiece by radial movement of the dies.
2. This operation is generally used for reducing the diameter and tapering of the bar.

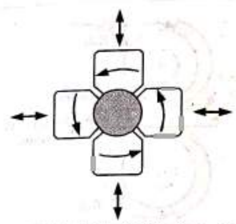


Fig. 1.12.2. Principle of rotary swaging.

c. Punching :

1. It is the process of producing holes by forcing a punch through the work.

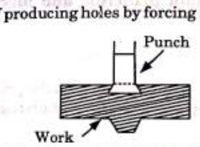


Fig. 1.12.3. Punching operation.

d. Drawing Down :

1. It is the process to increase the length of workpiece while the cross-section area is reduced.
2. For drawing down, the workpiece is heated upto plastic stage and placed on the anvil and the metal is beaten down of the edge with a hand hammer or sledge hammer.

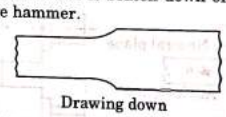


Fig. 1.12.4.

e. Roll Forging :

1. It is forging in which workpiece is placed between the semi-circular grooved roll, mounted on two parallel shafts.
2. This process is used for reducing the diameter of the rods.
3. The heated workpiece is placed between the dies in open position.
4. After a half revolution of the rolls, the workpiece is rolled out. It is then put in the smaller groove and the operation continued until the desired dimension is achieved.

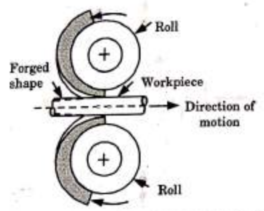


Fig. 1.12.5. Principle of roll forging.

Que 1.13. **Briefly explain principle and mechanism of rolling process.**

Answer

A. **Principle of Rolling :** Rolling is based on the principle of reducing the cross-section of a long workpiece by applying compressive forces through a set of rolls.

B. **Mechanism of Rolling :**

1. The metal is taken into the rolls by friction and subsequently compressed to obtain the final shape.
2. The reduction that could be achieved with a given set of rolls is depending upon the angle of bite.

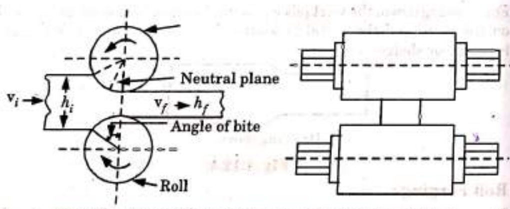


Fig. 1.13.1. Schematic diagram of the rolling process.

3. The volume of the metal that enters the rolling stand should be same as that leaving it.
4. Area of the stock gets decreased after passing through the rolling stand and metal stock leaving the rolling stand would get higher velocity than it entered.
5. When the stock entered the roll stand, its velocity is less than the peripheral velocity of roll stand but after the passes when stock leaving

the roll stand, its velocity is greater than the peripheral velocity of roll stand.

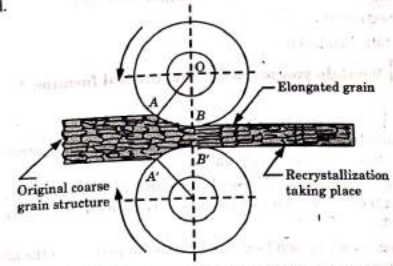


Fig. 1.13.2. Hot rolling process, showing the deformation and recrystallization of the metal being rolled.

Que 1.14. **What is extrusion ? Explain its types.**

Answer

A. **Extrusion :**

1. Extrusion is the process of confining metal in a closed cavity and then allowing it to flow from only one opening, so that the metal takes the shape of the opening.
2. The operation is identical to the squeezing of toothpaste out of a toothpaste tube.

B. **Types of Extrusion :**

a. **Hot Extrusion :**

1. It is carried out above the recrystallization temperature.
2. It consists of pressing a metal inside a chamber to force it out by high pressure through an orifice which is shaped to provide the desired form of the finished part.
3. Due to higher temperature involved, special equipment is needed and the wear rates are high.
4. The various methods of hot extrusion are as follows :
   i. Direct extrusion.
   ii. Indirect extrusion.

b. **Cold Extrusion :**

1. It is carried out below the recrystallization temperature of metal being extruded.

2. It could also be direct or reverse but extrusion ratio is lower and extrusion pressure is higher than the hot extrusion.
3. Following are the various cold extrusion processes :
   i. Impact extrusion.
   ii. Hydrostatic extrusion.

Que 1.15. **What do you mean by sheet metal forming ?**

Answer

1. Sheet metal forming consists of many complementary processes that are used to form sheet metal parts.
2. One or more of these processes is used in which a flat sheet of ductile metal is taken, and deformation forces are applied to alter the shape of the sheet.
3. Compared to casting and forging, sheet metal parts offer the advantages of light weight and versatile shape.
4. This process involves workpieces with a high ratio of surface area to thickness.
5. Sheet forming is also called press working.
6. The basic mechanisms of all sheet forming processes are stretching and bending.
7. In sheet metal forming, the metal used may be galvanized iron, aluminium, tin-brass etc.

PART-5

Plastic Deformation and Yield Criteria, Fundamental of Hot and Cold Working Process.

CONCEPT OUTLINE

Yield Criterion : It is a hypothesis concerning the limit of elasticity under any possible combination of stresses. Several yield criteria have been proposed to find out the relation between yield stresses. The most important criteria are :

i. Tresca's yield criterion, and
ii. Von Mises yield criterion.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.16. **Discuss briefly about the plastic deformation.**

Answer

1. Plastic deformation is the permanent change in the shape of a metallic body as a result of forces acting on its surface. Plastic deformation is irreversible.
2. For most metallic materials, elastic deformation persists only to strains of about 0.005. As the material is deformed beyond this point, the stress is no longer proportional to strain and plastic deformation occurs.

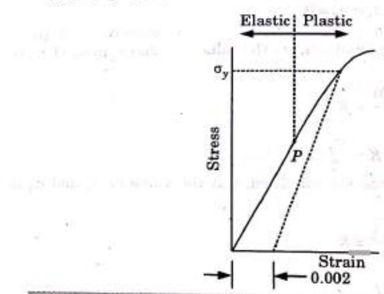


Fig. 1.16.1. Typical stress-strain behaviour for a metal showing elastic and plastic deformations.

3. From an atomic perspective, plastic deformation corresponds to the breaking of bonds with original atom neighbours and then reforming bonds with new neighbours.
4. Plastic deformation may be either desirable or undesirable, but in either case, it is important to determine the conditions where elastic behaviour transitions to plastic flow.

Que 1.17. **State Tresca's and Von Mises criteria for plastic deformation. Derive a suitable expression for both criteria.**

Answer

A. Tresca's Theory :

1. Tresca states that failure of a material (or plastic deformation) will occur when the maximum shear stress in a material reaches the value of maximum shear stress at elastic limit.
2. Let principal stresses at a point in the material are σ_1, σ_2 and σ_3 ($\sigma_1 > \sigma_2 > \sigma_3$). So maximum shear stress is given by,

$$\frac{\sigma_1 - \sigma_3}{2} = \tau_{max}$$

3. Plastic deformation occurs when τ_{max} is equal to K (K = Maximum shear stress at elastic limit or shear yield stress). So according to Tresca's theory for plastic deformation,

$$\frac{\sigma_1 - \sigma_3}{2} = K \quad ...(1.17.1)$$

4. For uniaxial tension condition,

$$\sigma_1 = \sigma_y \quad \text{(tensile yield stress)}$$
$$\sigma_2 = \sigma_3 = 0$$

5. For uniaxial compression condition,

$$\sigma_1 = \sigma_2 = 0$$
$$\sigma_3 = -\sigma_y \quad \text{(compressive yield stress)}$$

6. For uniaxial tension condition, put the value of σ_1 and σ_3 in eq. (1.17.1), we get

$$\frac{\sigma_y - (0)}{2} = K$$

$$K = \frac{\sigma_y}{2}$$

7. For uniaxial compression condition, put the value of σ_1 and σ_3 in eq. (1.17.1), we get

$$\frac{0 - (-\sigma_y)}{2} = K$$

$$K = \frac{\sigma_y}{2}$$

B. Von Mises Theory :

1. Mises states that failure (plastic deformation) of a material will occur when the total shear strain energy per unit volume in strained material reaches a value equal to the shear strain energy per unit volume at the elastic limit.
2. Energy of distortion is given as,

$$U = \frac{1}{12G}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2] \quad ...(1.17.2)$$

Here U is the shear strain energy per unit volume, σ_1, σ_2 and σ_3 are the principal stresses, G is the shear modulus.

3. So, $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 12G \times U = C$ ...(1.17.3)

Where, C = Constant.

4. For uniaxial tensile loading,

$$\sigma_1 = \sigma_y, \sigma_2 = \sigma_3 = 0$$

Putting the value in eq. (1.17.3), we get

$$(\sigma_y - 0)^2 + (0 - 0)^2 + (0 - \sigma_y)^2 = C$$
$$2\sigma_y^2 = C \quad ...(1.17.4)$$

5. Considering yielding under pure torsion,

For pure shear : $\sigma_1 = K, \sigma_2 = 0, \sigma_3 = -K$

Put these values in eq. (1.17.3), we get

$$(K - 0)^2 + (0 - (-K))^2 + (-K - K)^2 = C$$
$$6K^2 = C \quad ...(1.17.5)$$

6. Equating the eq. (1.17.4) and eq. (1.17.5), we get

$$2\sigma_y^2 = 6K^2$$

$$K = \frac{\sigma_y}{\sqrt{3}}$$

Que 1.18. **What is meant by cold working and hot working ? Give the difference between the two.**

Answer

A. Cold Working :

1. It is defined as the process which is done below recrystallization temperature.

B. Hot Working :

1. It is defined as the process which is done above recrystallization temperature but below the melting point of the metal.

C. Difference between Hot Working and Cold Working :

S. No.	Hot Working	Cold Working
1.	Working temperature is above the recrystallization temperature.	Working temperature is below the recrystallization temperature.
2.	Hardening due to plastic deformation is completely eliminated by recovery and new grain formation.	No hardening due to low temperature.
3.	Poor surface finish due to oxidation.	Better surface finish.
4.	Density of metal is increased due to new grain formation.	No such effect in the density of metal.
5.	Lighter equipment is used because less loading is required.	Heavier equipment is used due to large application.
6.	**Examples :** Hot forging, hot rolling, hot spinning, hot extrusion, hot drawing etc.	**Examples :** Cold rolling, cold extrusion, press work like bending, shearing, drawing etc.

PART-6

Load Estimation for Bulk Forming (Forging, Rolling, Extrusion, Drawing).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.19. **Derive the expression for load estimation with sliding friction and sticking friction for slab of forging process.**

Answer

1. Fig. 1.19.1 shows a typical open die plane strain forging of a flat strip. In plane strain, the specimen is not free to flow in the direction perpendicular to the plane of the page.

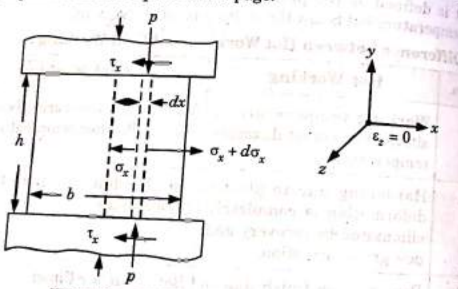


Fig. 1.19.1. Force balance in forging of a strip.

2. To simplify the analysis, following assumptions are made :
   i. The material being forged is plastically rigid.
   ii. The forging force F reaches its maximum value at the end of the process.
   iii. The coefficient of friction between the workpiece and the dies (plates) is same throughout the process.
   iv. The thickness of the workpiece is small in comparison to its other dimensions and the stress variation along y-direction is negligible.
   v. Condition of plane strain exists during forging *i.e.*, the width of the block remains constant.

3. Consider the size of strip under forging operations as $b \times h \times w$, the stresses acting on the element dx of the strip are shown in the Fig. 1.19.1.
4. Considering the equilibrium of the forces in x-direction, we get

$$(\sigma_x + d\sigma_x)hw - \sigma_x hw - 2\tau_x \, dx \, w = 0$$

$$h \, d\sigma_x - 2\tau_x \, dx = 0 \quad \text{...(1.19.1)}$$

5. Assuming σ_x and p as principal stresses *i.e.*, $\sigma_1 = \sigma_x$ and $\sigma_3 = -p$ (compressive) and using Tresca's yield theory,

$$\sigma_1 - \sigma_3 = \sigma_y = 2K$$

$$\sigma_x + p = 2K$$

$$d\sigma_x = -dp$$

Put $d\sigma_x = -dp$ in eq. (1.19.1), we get

$$dp = -2\frac{\tau_x}{h}dx \quad \text{...(1.19.2)}$$

6. For sliding friction, we know, $\tau_x = \mu p$

$$\therefore \quad dp = -2\frac{\mu p}{h}dx$$

or

$$\frac{dp}{p} = -\frac{2\mu}{h}dx$$

7. Integrating both sides,

$$\int \frac{dp}{p} = \int -\frac{2\mu}{h}dx$$

$$\ln p = -\frac{2\mu}{h}x + C \quad \text{...(1.19.3)}$$

8. At $x = \frac{b}{2}$, $\sigma_x = 0$ (stress free surface)

So, $\quad p = 2K$

then, $\quad \ln 2K = -\frac{2\mu}{h}\frac{b}{2} + C$

$$C = \ln 2K + \frac{2\mu}{h}\frac{b}{2}$$

9. On putting value of C in eq. (1.19.3), we get

$$\therefore \quad \ln p = -\frac{2\mu}{h}x + \ln 2K + \frac{2\mu}{h}\frac{b}{2}$$

or

$$\ln\left(\frac{p}{2K}\right) = \frac{-2\mu}{h}\left(x - \frac{b}{2}\right)$$

or

$$\frac{p}{2K} = e^{-\frac{2\mu}{h}\left(x - \frac{b}{2}\right)} \quad \text{...(1.19.4)}$$

a. For Mixed Friction Conditions :

1. Let x_s be the distance from the centre over which sticking takes place, then

$$\tau_x = \mu p = K \qquad \text{(Here } p = p_s \text{ (sticking))}$$

2. From eq. (1.19.4), we get

$$2Ke^{-\frac{2\mu}{h}\left(x_s - \frac{b}{2}\right)} = K/\mu$$

$$\left(x_s - \frac{b}{2}\right)\left(-\frac{2\mu}{h}\right) = \ln\frac{1}{2\mu}$$

$$x_s = \frac{b}{2} - \frac{h}{2\mu}\ln\frac{1}{2\mu}$$

Which is the distance from the centre of the strip where sticking ends.

b. Value of Forging Pressure at x_s :

1. At transition point $x = x_s$, the pressure p is given by

$$\left(\frac{p}{2K}\right)_{x=x_s} = e^{-\frac{2\mu}{h}\left(x_s - \frac{b}{2}\right)} \qquad \text{(Using eq. (1.19.4))}$$

$$\left(\frac{p}{2K}\right)_{x=x_s} = e^{-\frac{2\mu}{h}\left(\frac{b}{2} - \frac{h}{2u}\ln\left(\frac{1}{2\mu}\right) - \frac{b}{2}\right)} \qquad \left(\because x_s = \frac{b}{2} - \frac{h}{2\mu}\ln\left(\frac{1}{2\mu}\right)\right)$$

or

$$\left(\frac{p}{2K}\right)_{x=x_s} = \frac{1}{2\mu}$$

$$p_{x=x_s} = \frac{K}{\mu}$$

Que 1.20. **Derive the relation for maximum draft obtained in rolling process.**

Answer

1. From Fig. 1.20.1, draft (total reduction) is given as,

$$\Delta h = (h_i - h_f)$$
$$= 2(R - R\cos\alpha) = 2R(1 - \cos\alpha) \qquad \text{...(1.20.1)}$$

2. Horizontal component of resultant force,

$$F_x = \mu p \cos\alpha - p\sin\alpha$$

3. For rolling, $F_x \geq 0$

$$\mu p\cos\alpha - p\sin\alpha \geq 0$$
$$\mu p\cos\alpha \geq p\sin\alpha$$
$$\mu \geq \tan\alpha$$

4. For maximum value of α,

$$\tan\alpha_{max} = \mu$$

So,
$$\cos\alpha_{max} = \frac{1}{\sqrt{1+\mu^2}} \qquad \text{...(1.20.2)}$$

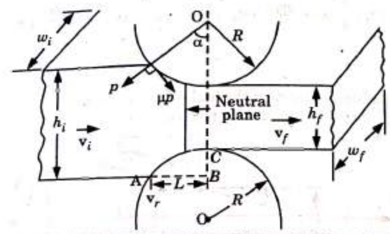


Fig. 1.20.1. Schematic representation of rolling process.

5. For maximum draft,

$$(\Delta h)_{max} = h_i - h_f$$
$$= 2R(1 - \cos\alpha_{max})$$
$$= 2R\left(1 - \frac{1}{\sqrt{1+\mu^2}}\right) \qquad \text{(using eq. (1.20.2))}$$

Que 1.21. **From first principle, derive the formula for the extrusion of wire with friction where σ refers to the stress in wire at inlet to the die, D_b and D_a are the inlet and outlet diameters of the wire, $B = \mu\cot\alpha$ (μ is coefficient of friction and α is half die angle) and K is the critical shear stress.**

Answer

1. Following assumptions are made in extrusion operation :
   i. Coefficient of friction μ and half (semi) cone angle α are small.
   ii. Yield stress σ_y is constant.
   iii. $-p$ and σ_x are principal stresses.
   iv. σ_x does not vary in radial direction.
2. In Fig. 1.21.1,

D_a = Diameter of wire at exit, and
D_b = Diameter of wire at entry.

3. Now taking an element dx at a distance x as shown in Fig. 1.21.1(a).
4. D is the diameter at one side of element and $(D + dD)$ on the other side of element.
5. Various stresses in drawing operation are shown in Fig. 1.21.1(b).

6. The equilibrium equation in x-direction is written as,

$$(\sigma_x + d\sigma_x)\frac{\pi}{4}(D+dD)^2 - \sigma_x\frac{\pi}{4}D^2 + \mu p \cos\alpha\left(\pi D\frac{dx}{\cos\alpha}\right) + p\sin\alpha\left(\pi D\frac{dx}{\cos\alpha}\right) = 0$$

7. On simplifying (Neglect the higher order terms),

$$D\,d\sigma_x + 2\sigma_x dD + 4\,\mu p\,dx + 4p\tan\alpha\,dx = 0 \quad ...(1.21.1)$$

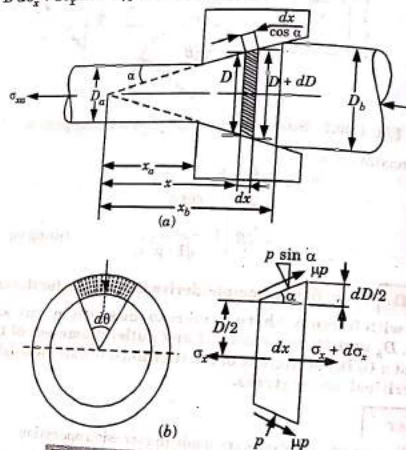


Fig. 1.21.1. Wire extrusion with friction.

8. But

$$\tan\alpha = \frac{dD/2}{dx}$$

$$dx = \frac{dD/2}{\tan\alpha}$$

9. Putting the value of dx in eq. (1.21.1), we get

$$Dd\sigma_x + 2\sigma_x dD + 2pdD\left(1+\frac{\mu}{\tan\alpha}\right) = 0 \quad ...(1.21.2)$$

10. If cylindrical state of stress is assumed, then by Tresca's criterion

$$\sigma_1 - \sigma_3 = 2K$$

Here, $\sigma_1 = \sigma_x$ and $\sigma_3 = -p$

$$\sigma_x - (-p) = 2K$$

$$\sigma_x + p = 2K$$

$$p = 2K - \sigma_x \quad ...(1.21.3)$$

Take,

$$B = \frac{\mu}{\tan\alpha} \quad ...(1.21.4)$$

11. Put the value of p and B in eq. (1.21.2), we get

$$Dd\sigma_x + 2\sigma_x dD + 2\,(2K - \sigma_x)\,dD\,(1 + B) = 0$$

$$Dd\sigma_x - 2dD\,\{B\sigma_x - 2K(1+B)\} = 0$$

$$\frac{d\sigma_x}{B\sigma_x - 2K(1+B)} = \frac{2dD}{D}$$

12. On integrating,

$$\ln\frac{1}{B}\ln[B\sigma_x - 2K(1+B)] = 2[\ln D + \ln C]$$

[ln C = Constant of integration]

$$\frac{1}{B}\ln[B\sigma_x - 2K(1+B)] = 2\ln(DC)$$

$$B\sigma_x - 2K(1+B) = (DC)^{2B}$$

$$\sigma_x = \frac{(DC)^{2B}}{B} + \frac{2K(1+B)}{B}$$

$$= \frac{C_1 D^{2B}}{B} + \frac{2K(1+B)}{B} \quad [\because C_1 = C^{2B}] \quad ...(1.21.5)$$

13. At the die exit, $\sigma_x = \sigma_{xa}$ and $D = D_a$

$$\sigma_{xa} = \frac{C_1 D_a^{2B}}{B} + 2K\left(\frac{1+B}{B}\right)$$

$$\frac{C_1 D_a^{2B}}{B} = \sigma_{xa} - 2K\left(\frac{1+B}{B}\right)$$

$$C_1 = \frac{B}{D_a^{2B}}\left[\sigma_{xa} - 2K\left(\frac{1+B}{B}\right)\right]$$

14. Substituting the value of C_1 in eq. (1.21.5), we have

$$\sigma_x = \frac{2K(1+B)}{B} + \left[\sigma_{xa} - 2K\left(\frac{1+B}{B}\right)\right]\frac{B}{D_a^{2B}} \times \frac{D^{2B}}{B}$$

$$\frac{\sigma_x}{2K} = \frac{(1+B)}{B}\left[1 - \left(\frac{D}{D_a}\right)^{2B}\right] + \frac{\sigma_{xa}}{2K}\left(\frac{D}{D_a}\right)^{2B}$$

15. At die entry, $\sigma_x = \sigma_{xb}$ (extruding pressure) and $D = D_b$

$$\frac{\sigma_{xb}}{2K} = \frac{(1+B)}{B}\left[1 - \left(\frac{D_b}{D_a}\right)^{2B}\right] + \frac{\sigma_{xa}}{2K}\left(\frac{D_b}{D_a}\right)^{2B}$$

16. If back pull is zero ($\sigma_{xa} = 0$),

$$\therefore \quad \frac{\sigma_{xb}}{2K} = \frac{(1+B)}{B}\left[1 - \left(\frac{D_b}{D_a}\right)^{2B}\right]$$

Que 1.22. **An alloy is hot extruded at 450 °C through square dies without lubrication from 150 mm dia to 50 mm dia. The extrusion speed is 50 mm/s. The flow stress of material at the above temperature is 300 MPa. The length of billet is 500 mm. Determine the extrusion load if coefficient of friction is 0.1.**

Answer

Given : D_b = 150 mm = 0.15 m, D_a = 50 mm = 0.05 m, μ = 0.1, K = 300 MPa, Extrusion speed = 50 mm/s
To Find : Extrusion load.
Data Assumed : Semi die angle, $\alpha = 10°$.

1. We know that, $B = \dfrac{\mu}{\tan\alpha} = \dfrac{0.1}{\tan 10°} = 0.5671$

2. Extrusion stress, $\sigma_x = 2K\left(\dfrac{1+B}{B}\right)\left[1-\left(\dfrac{D_a}{D_b}\right)^{2B}\right]$

$$\sigma_x = 2 \times 300\left(\frac{1+0.5671}{0.5671}\right)\left[1-\left(\frac{50}{150}\right)^{2\times 0.5671}\right]$$

$$\sigma_x = 1181.1 \text{ MPa}$$

3. Extrusion load $= \dfrac{\pi}{4} D_b^2 \sigma_x = \dfrac{\pi}{4} \times 0.15^2 \times 1181.1 = 20.9$ MN

Que 1.23. **Discuss the analysis of wire drawing. Derive an expression for maximum reduction in drawing.**

Answer

A. Analysis of Wire Drawing : Analysis of wire drawing is similar to the analysis of wire extrusion.

For Derivation : Refer Q. 1.21, Page 1–24C, Unit-1.

B. Expression for Maximum Reduction in Drawing :

1. For maximum reduction taken per pass in wire drawing, draw stress (σ_{xa}) cannot be more than the tensile yield stress (σ_y) of the work material. So

$$\frac{\sigma_{xa}}{\sigma_y} = 1 \quad ...(1.23.1)$$

2. From Tresca's criterion,

$$\sigma_y = 2K \quad \text{(maximum tensile yield stress)}$$

3. Put this value in eq. (1.23.1),

$$\frac{\sigma_{xa}}{2K} = 1$$

$$\sigma_{xa} = 2K \quad ...(1.23.2)$$

4. The formula for drawing stress (without back pull),

$$\frac{\sigma_{xa}}{2K} = \left(\frac{1+B}{B}\right)\left[1-\left(\frac{D_a}{D_b}\right)^{2B}\right] \quad ...(1.23.3)$$

5. Putting the value of σ_{xa} from eq. (1.23.2) in eq. (1.23.3), we have

$$\frac{2K}{2K} = \left(\frac{1+B}{B}\right)\left[1-\left(\frac{D_a}{D_b}\right)^{2B}\right]$$

$$1 = \left(\frac{1+B}{B}\right)\left[1-\left(\frac{D_a}{D_b}\right)^{2B}\right]$$

$$\frac{B}{1+B} = 1-\left(\frac{D_a}{D_b}\right)^{2B}$$

$$\left(\frac{D_a}{D_b}\right)^{2B} = \frac{1}{1+B}$$

$$\left(\frac{D_a}{D_b}\right)^{2} = \left(\frac{1}{1+B}\right)^{1/B} \quad ...(1.23.4)$$

6. Now, degree of drawing operation or maximum reduction is given as,

$$R = 1-\left(\frac{D_a}{D_b}\right)^2 \quad ...(1.23.5)$$

7. Putting the value of $(D_a/D_b)^2$ from eq. (1.23.4) in eq. (1.23.5), we have

$$R = 1-\left(\frac{1}{1+B}\right)^{1/B}$$

Que 1.24. **Calculate the drawing load required to obtain 30 % reduction in area on a 14 mm diameter copper wire. The following data is given $\alpha = 10°$, $\mu = 0.1$, $\sigma_0 = 260$ N/mm². Also calculate the power of the electric motor if the drawing speed is 3.0 m/s. Take motor efficiency as 97 %.**

Answer

Given : Reduction = 30 %, $\alpha = 10°$, $\mu = 0.1$, $K = 260$ N/mm², $v = 3$ m/s, $\eta_m = 0.97$, Diameter of wire, $D_b = 14$ mm
To Find : i. Drawing load.
ii. Power of motor.

1. We know that, $B = \mu \cot\dfrac{\alpha}{2} = 0.1 \cot 5° = 1.143$

2. Reduction $= 1-\left(\dfrac{D_a}{D_b}\right)^2 = 0.3$

$$\left(\frac{D_a}{D_b}\right)^2 = 0.7$$

$$D_a = 14 \times 0.7^{0.5} = 11.71 \text{ mm}$$

3. We know that, $\sigma_{xa} = 2K\left[\frac{(1+B)}{B}\left\{1-\left(\frac{D_a}{D_b}\right)^{2B}\right\}\right]$

$$\sigma_{xa} = 2 \times 260 \left[\frac{2.143}{1.143}\right][1 - 0.7^{1.143}] = 326.41 \text{ MPa}$$

4. Drawing load, $w = \frac{\pi}{4}(11.71)^2 \times 326.41 = 35153.38$ N

5. Motor power $= \frac{w \times v}{\eta_m} = 35153.38 \times \frac{1}{0.97 \times 1000} \times 3 = 115.89$ kW

PART-7

Sheet Forming (Shearing, Deep Drawing, Bending).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.25. **What is shearing? Describe the various types of shearing operations.**

Answer

A. Shearing:

1. It is a process which involves cutting sheet metal by subjecting it to shear stresses, usually between a punch and a die as shown in Fig. 1.25.1.

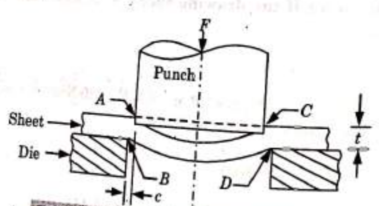


Fig. 1.25.1. Schematic illustration of the shearing process with a punch and die.

2. The major variables in the shearing process are the punch force (F), the speed of the punch, lubrication, the edge condition of the sheet, the punch and die materials, the corner radii of the punch and die and the clearance between the punch and die.

B. Types of Shearing Operations :

a. Blanking :

1. In this operation, a metal workpiece is removed from the primary metal strip or sheet when it is punched.
2. Material that is removed is the new metal workpiece or blank and the primary workpiece (sheet metal) is the scrap.

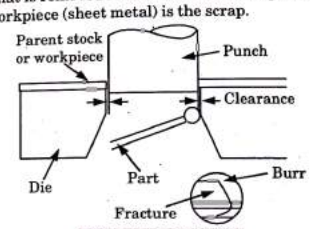


Fig. 1.25.2. Blanking.

b. Piercing :

1. The operation of cutting inside the contours, *i.e.*, holes and slots is called piercing.

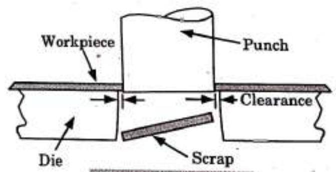


Fig. 1.25.3. Piercing.

2. This operation is similar to blanking, the difference is that metal punched out is the scrap.
3. The punch diameter determines the size of the hole created in the workpiece.

c. Notching :

1. It is a process during which metal scrap is removed from the outside edge of a metal workpiece.
2. The size of notching is much smaller than the blanking but the operation is similar to piercing.

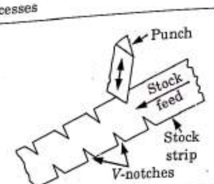


Fig. 1.25.4. Notching operation.

d. **Perforating :** It is the operation of punching many identical holes in a regular pattern in sheet. Holes are usually round but may be of any shape.

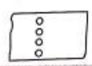


Fig. 1.25.5. Perforating.

e. **Nibbling :** It is the process of cutting out a contour or other shape by punching a series of overlapping round or square hole along the edge of the part.

Fig. 1.25.6. Nibbling.

f. **Trimming :** It is an operation used for removing excess material, irregular outline and waved edge from the walls of drawn shell.

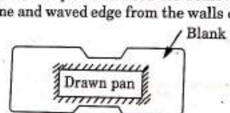


Fig. 1.25.7. Trimming.

g. **Lancing :** Lancing consists of cutting the metal through a small length and bending this small cut portion downward.

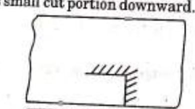


Fig. 1.25.8. Lancing.

Que 1.26. **What is deep drawing ? Discuss deep drawing operation in detail. Also list and explain different defects in deep drawing operation.**

Answer

A. **Deep Drawing :**

1. This process consists of plastic deformation of flat sheet into a recessed, three dimensional parts with a depth several times the thickness of the metal.

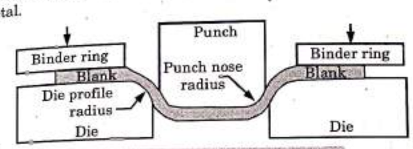


Fig. 1.26.1. Method of deep drawing.

2. Process starts with a flat sheet metal blank held on the upper surface of the die and center portion of the sheet is pressed by the stroke of the punch into the die cavity to take the desired shape and design by plastic deformation of sheet metal without collapsing the corners. This operation requires double action force.
3. One force held the blank in its position while other forces punch the sheet into shape.

B. **Various Deep Drawing Operations :**

a. **Ironing :**

1. This operation is used to reduce the thickness of the shell wall and smoothened the surface.
2. This operation is similar to the drawing except that clearance between the die and punch is smaller than that is used in drawing operation.

b. **Redrawing :**

1. If ratio of blank diameter and final cup diameter is too large, operation is performed in more than one stroke of the ram. These successive operations are known as redrawing.
2. The amount of reduction that may be effected at each operation depends upon various factors like quality of material, die edge radius, bottom radius, material, thickness, thickening allowed etc.

c. **Reverse Drawing :**

1. In this operation, a drawn cup is subjected to bending in the opposite direction to its originally drawn direction.

C. **Defects in Deep Drawing Operation :**

a. **Earing :**

1. It is the formation of ears or edges around the top of a drawn shell.

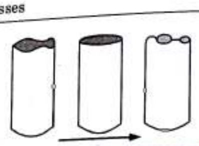


Fig. 1.26.2. Earing in cup drawing (the arrow indicates rolling direction).

b. Buckling :

1. It is uncontrolled deformation in perpendicular direction of the surface of a sheet due to compressive stress.
2. Due to buckling, a bend, kink or other wavy condition may appear.

c. Bulging :

1. This defect may appear due to increase in the diameter of cylindrical shell at some place of drawn shell.

d. Surface Scratch :

1. This occurs on the surface of a drawn cup.

Que 1.27. **What is bending in sheet metal working ? Also describe the various types of bending operation.**

Answer

A. Bending :

1. Bending refers to the operation of deforming a flat sheet around a straight axis where the neutral plane lies.
2. Due to application of force, the top layer is in tension and bottom layer is in compression.
3. The plane with no stress is called neutral axis. The neutral axis should be at the center when the material is elastically deformed, but when the material reaches plastic range, the neutral axis moves downward, since the material opposes compression much better than tension.

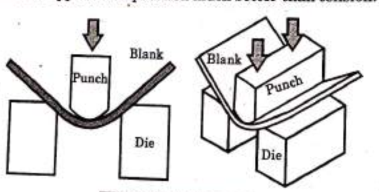


Fig. 1.27.1. Bending.

B. Types of Bending Operations :

a. **Air Bending :** It is a bending process in which punch touches the workpiece and the workpiece does not bottom in the lower cavity.

b. **Bottoming :** It is bending process where the punch and workpiece bottom on the die. This makes for a controlled angle with very little springback.

c. **Coining :** It is a bending process in which the punch and workpiece bottom on the die and compressive stress is applied to the bending region to increase the amount of plastic deformation. The amount of springback is very low in this bending.

d. ***V*-bending :** In *V*-bending the clearance between punch and die is constant.

e. ***U*-die Bending :** It is performed when two parallel bending axis are produced in the same operation. A backing pad is used to force the sheet contacting with the punch bottom.

f. **Double-die Bending :** It can be described as two wiping operations acting on the workpiece one after another. Double bending can enhance strain hardening to reduce springback.

g. **Rotary Bending :** It is performed by using the rocker instead of punch. It is used for bending the sheet metal more than 90°.

PART-8

Principles of Powder Metallurgy.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.28. **What is powder metallurgy ? Also write advantages and limitations of powder metallurgy.**

Answer

A. Powder Metallurgy :

1. Powder metallurgy is a process in which metallic powders are heated below their melting point temperatures to achieve bonding.
2. In reality, this process involves metal and alloy powders to be compacted into the desired shape after blending, and then to be heated in a controlled atmosphere at a temperature below their melting points in order to achieve bonding of the particles to get the desired properties.

B. Advantages :

1. There is no wastage of material throughout the entire manufacturing process, thus material is saved.
2. The parts produced have accurate dimension and surface finish, thus the need for machining operations is eliminated.
3. The large quantity production is relatively economical to machine parts.

4. The skilled workers are not required to operate presses or other equipment, thus the labour cost is low.

C. **Limitations :**
1. The production of high purity powders is highly expensive.
2. It is used only for large scale production due to expensive tools and equipments such as dies, punches, presses and sintering equipment.
3. It is not possible to completely eliminate the porosity in the parts.
4. The size of the part is limited as it depends upon the compression ratio of the powders and the capacity of press used.

Que 1.29. **Explain the basic steps of powder metallurgy process.**

Answer

Basic steps of powder metallurgy are listed below :

a. **Powder Production :**
1. The fine and high purity metal powders are produced by processes such as atomization, chemical reduction, electrolytic techniques etc.
2. Particle sizes generally range from 0.1 μm to 1000 μm.
3. The following processes are commonly used for producing metal powder:
i. Atomization.
ii. Electrolysis.
iii. Crushing.
iv. Reduction Process.

b. **Blending :**
1. Blending or mixing is essential when powders of the different metals with the same particle size or when powders of the same metal with different particle size are used.
2. It helps to produce uniformity of particle size and shape throughout the large amount of powder.

c. **Compaction :**
1. After the blending operation, compacting or briquetting is done.
2. It is a process of converting loose powder particles into a green compact of the desired shape and size.

d. **Sintering :**
1. Sintering is the means by which powder particles are welded together and a strong metal part is produced.
2. The sintering temperatures are between 60 % and 90 % of the melting point of the particular metal or alloys.
3. During sintering, recrystallization occurs and the interparticle boundaries become grain boundaries.

e. **Secondary Processes :**
1. Many of the products can be used as they come out from sintering, but where close tolerance and better surface finish are required, further processing is necessary. These processes are referred as secondary processes.
2. Secondary processes are performed to increase density, improve surface finish and accuracy etc.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Draw a properly labelled sketch of a cupola and write a brief account of its operation.

Ans. Refer Q. 1.4, Unit-1.

Q. 2. What is shrinkage in casting process? Explain its types.

Ans. Refer Q. 1.8, Unit-1.

Q. 3. What are the common casting defects ? What causes them and what are the measures that can be taken to avoid them ?

Ans. Refer Q. 1.10, Unit-1.

Q. 4. Define forging. Also describe the common types of forging operations.

Ans. Refer Q. 1.12, Unit-1.

Q. 5. What is extrusion ? Explain its types.

Ans. Refer Q. 1.14, Unit-1.

Q. 6. What is meant by cold working and hot working ? Give the difference between the two.

Ans. Refer Q. 1.18, Unit-1.

Q. 7. From first principle, derive the formula for the extrusion of wire with friction where σ refers to the stress in wire at inlet to the die, D_b and D_a are the inlet and outlet diameters of the wire, $B = \mu \cot \alpha$ (μ is coefficient of friction and α is half die angle) and K is the critical shear stress.

Ans. Refer Q. 1.21, Unit-1.

Q. 8. What is shearing ? Describe the various types of shearing operations.

Ans. Refer Q. 1.25, Unit-1.

Q. 9. Explain the basic steps of powder metallurgy process.

Ans. Refer Q. 1.29, Unit-1.

☺☺☺

2

UNIT

Metal Cutting

CONTENTS

PART-1

Single and Multi Point Cutting, Orthogonal Cutting.

CONCEPT OUTLINE

Machining (Metal cutting) : Metal cutting or machining is the process of producing a workpiece by removing unwanted material from a block of metal in the form of chips.

Orthogonal Cutting : In this, the cutting edge of the tool is arranged perpendicular to the direction of the motion of tool.

Oblique Cutting : In this, cutting edge of the tool is set at some angle other than to the direction of motion of tool with an inclined angle.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. **What do you understand by single point cutting tool ? Briefly explain its various angles.**

Answer

A. Single Point Cutting Tool :

1. It has only one cutting edge.
2. It is designed with the sharp edge to minimize rubbing contact between tool and workpiece.

B. Various Tool Angles of Single Point Cutting Tool :

a. Rake Angle :

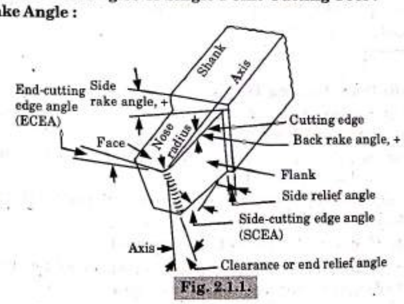


Fig. 2.1.1.

1. The nominal rake angle is the angle made by the face of tool and the plane parallel to the base of cutting tool.
2. If the rake angle is measured in the direction of tool shank, it is called back rake angle and if measured in a direction at right angles to it, then it is called side rake angle.

b. End Cutting Edge Angle :

1. It is the angle between the end or auxiliary cutting edge and the work axis, and it varies between 0 to 30°.
2. It provides the required clearance to the trailing edge and reduces the drag that tends to cause chatter.

c. Clearance Angle :

1. It is the angle of the end or side surfaces which are below the cutting edge when the tool is in a horizontal position as for turning.
2. The purpose of this angle is to avoid any frictional drag of the tool on the job and prevent the tool from rubbing on the surface already cut.

d. Side Clearance Angle :

1. It is the angle between the portion of the side flank immediately below the cutting edge and a plane drawn from the cutting edge perpendicular to the base.

e. Cutting Angle :

1. The true cutting angle is the angle between the face of tool and the line tangent to the machined surface at the cutting point.

f. Lip Angle :

1. It is the angle between the tool face and the ground end surface of flank.
2. It is usually between 60° to 80°.

Que 2.2. **What is multi point cutting tool ? Also give advantages and disadvantages of it.**

Answer

A. Multi Point Cutting Tool :

1. A multi point cutting tool contains more than two main cutting edges that simultaneously engage in cutting action in a pass.
2. Sometime, cutters with two cutting edges (more than one) are also considered multi point cutting tools.
3. The number of cutting edges present in a multi point cutter may vary from three to few hundreds.

B. Advantages of Multi Point Cutting Tool :

1. Since total feed rate or depth of cut is equally distributed among all cutting edges, so chip load on each cutting edge reduces greatly. Thus

higher feed rate or depth of cut can be utilized to improve material removal rate for enhancing productivity.

2. Due to lesser period of engagement and lesser heat accumulation within the tool body, tool wear rate also reduces. Consequently, life of the cutter increases.

C. Disadvantages of Multi Point Cutting Tool :

1. Due to intermittent cutting, cutting edges or teeth are subjected to fluctuating load. This creates noise, vibration and endurance failure of the cutter.
2. Design and fabrication of the cutter is comparatively difficult. This makes such cutter costlier.

Que 2.3. **Differentiate between orthogonal and oblique cutting.**

AKTU 2014-15, Marks 05

Answer

S. No.	Orthogonal Cutting	Oblique Cutting
1.	The cutting edge of the tool is perpendicular to the direction of tool travel.	The cutting edge is inclined at an angle with the normal to the direction of tool travel.
2.	The cutting edge clears the width of the workpiece on either ends.	The cutting edge may or may not clear the width of the workpiece.
3.	Chip flows normal to the cutting edge in a flat spiral.	Chip flows sideways in a long curl.
4.	Only two components of cutting force are acting on the tool.	Three components of force are acting on the tool.
5.	Maximum chip thickness occurs at its middle.	Maximum chip thickness may not occur at middle.
6.	Tool life is less.	Tool life is more.
7.	Less heat generation.	More heat generation.

PART-2

Various Force Components, Chip Formation.

CONCEPT OUTLINE

Normal Component : $F_t = \dfrac{\tau w t \cos(\beta - \alpha)}{\sin\phi \cos(\phi + \beta - \alpha)}$

Normal Force : $F_N = F_c \cos\alpha - F_t \sin\alpha$

Merchant's Shear Angle Relationship :

$$2\phi + \beta - \alpha = \frac{\pi}{2}$$

Chip Thickness Ratio : $r = \dfrac{t}{t_c}$

Chip Formation : It is a part of the process of cutting materials by mechanical means, using tools such as saws, lathes and milling cutters.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.4. **Discuss the various types of chips produced during metal machining with neat sketch.** **AKTU 2016-17, Marks 10**

Answer

Following are the various types of chips produced during metal machining :

a. **Continuous Chips :**

1. In continuous chip formation, the pressure of the workpiece builds until the material fails by slip along the slip plane.
2. The inside of the chip displays steps produced by the intermittent slip but outside of the chip is burnished smooth by chip rubbing on tool surface.

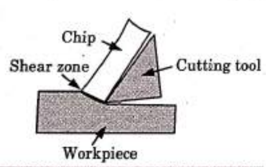


Fig. 2.4.1. Continuous chip formation.

3. It has its elements bonded together in the form of long coils and is formed by the continuous plastic deformation of metal without fracture ahead of the cutting edge of tool and is followed by the smooth flow of chip up the tool face.

4. The chips so obtained have same thickness throughout.

b. **Built-up Edge Chips :**

1. A Built-up edge (BUE), consisting of layers of material from the workpiece that are gradually deposited on the tool, may form at the tip of the tool during cutting.
2. As it becomes larger, the BUE becomes unstable and eventually breaks up.
3. Part of the BUE material is carried away by the tool side of the chip, the rest is deposited randomly on the workpiece surface.
4. The process of BUE formation and destruction is repeated continuously during the cutting operation, unless measures are taken to eliminate it.

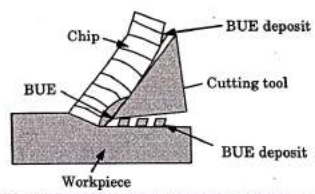


Fig. 2.4.2. Formation of built-up edge (BUE).

c. **Discontinuous Chips :**

1. These consist of segments that may be firmly or loosely attached to each other.
2. These are formed when the amount of deformation which the chips undergo is limited by repeated fracturing.

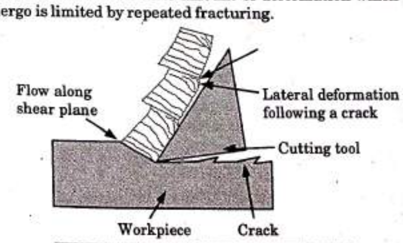


Fig. 2.4.3. Discontinuous chip formation.

Que 2.5. **Consider the various forces acting on the chip, draw Merchant force diagram. State the assumptions.**

AKTU 2014-15, Marks 10

OR

Explain "Merchant force circle" along with assumptions.

AKTU 2016-17, Marks 10

Answer

A. Merchant's Force Circle Diagram :

1. In orthogonal cutting, the tool approaches the workpiece with its cutting edge parallel to the uncut surface and at right angles to the direction of cutting. Thus tool approach angle and cutting edge inclination are zero.
2. The study of forces acting on a tool during the process of metal cutting is necessary, though the relationship among the all forces had been found by the Merchant force circle diagram.
3. Merchant's force circle diagram is shown in Fig. 2.5.1.

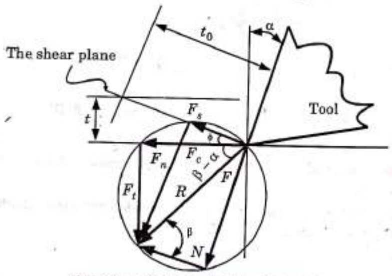


Fig. 2.5.1. Merchant's force circle.

Where,
ϕ = Shear angle,
α = Helix angle,
F_n = Normal shear force,
F_s = Shear force,
F = Friction force,
β = Friction angle,
F_t = Thrust force, and
N = Normal force.

B. Assumptions :

1. The tool is perfectly sharp and there is no contact along the clearance face.
2. The primary deformation takes place in a very thin zone adjacent to the shear plane.
3. The cutting edge is a straight line, extending perpendicular to the direction of motion and generates a plane surface as the work moves past it.
4. There is no side flow of the chip.
5. The depth of cut is constant.
6. Width of the tool is greater than that of workpiece.
7. Work moves with a uniform velocity.
8. A continuous chip is produced with no built-up edge.
9. Uncut chip thickness is constant.
10. Stresses on the shear plane are uniformly distributed.

Que 2.6. **Draw Merchant's force circle diagram and develop expression for power required in metal cutting and derive Merchant's shear angle relationship.**

AKTU 2015-16, Marks 10

OR

Explain Merchant's force circle diagram and derive the merchant's shear angle relationship.

AKTU 2017-18, Marks 10

Answer

A. Merchant's Force Circle Diagram : Refer Q. 2.5, Page 2–7C, Unit-2.

B. Cutting Power :

1. Cutting power (P_c) is the product of cutting speed (v) and cutting force (F_c).

   So, $P_c = F_c \times v$
2. If we take F_c in Newton's and v in m/s

   Then, $P_c = \dfrac{F_c \times v}{1000}$ kW

C. Shear Angle Relationship :

1. According to Merchant's hypothesis to determine ϕ, we assumed that the minimum energy principle applied in metal cutting is so that the deformation process adjusted itself to a minimum energy condition.
2. We know that, cutting force

$$F_c = \frac{\tau w t \cos(\beta - \alpha)}{\sin\phi \cos(\phi + \beta - \alpha)} \quad ...(2.6.1)$$

3. Hence, on differentiating eq. (2.6.1) wrt ϕ, we get

$$\frac{dF_c}{d\phi} = \frac{\tau wt \cos(\beta-\alpha)\cos(2\phi+\beta-\alpha)}{\sin^2\phi\cos^2(\phi+\beta-\alpha)} = 0$$

or $\cos(2\phi+\beta-\alpha) = 0$

or $2\phi+\beta-\alpha = \pi/2$

So, $\phi = 45° + \alpha/2 - \beta/2$

4. A plot of ϕ against $(\beta-\alpha)$ is shown in Fig. 2.6.1, having intercept of $\pi/4$ and a slope of $-1/2$.

$$\phi = 45° + \frac{\alpha}{2} - \frac{\beta}{2}$$

5. Lee and Shaffer's shear angle relationship is,

$$\phi = 45° + \alpha - \beta \quad ...(2.6.2)$$

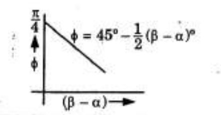


Fig. 2.6.1. Merchant's relationship.

Que 2.7. **During an orthogonal cutting the following data is obtained : Rake angle = 15°, chip thickness ratio = 0.39, uncut chip thickness, t = 0.6 mm, width of cut, b = 3.3 mm, yield shear stress of material in shear = 280 N/mm², average coefficient of friction on the tool face = 0.7, calculate normal and tangential forces on the tool face.**

AKTU 2017-18, Marks 10

Answer

Given : $\alpha = 15°$, $r = 0.39$, $t = 0.6$ mm, $W = 3.3$ mm, $\mu = 0.7$, $\tau = 280$ N/mm²

To Find : i. Normal force. ii. Tangential force.

1. Shear angle, $\tan\phi = \dfrac{r\cos\alpha}{1-r\sin\alpha} = \dfrac{0.39\cos 15°}{1-0.39\sin 15°}$

$\phi = 22.73°$

2. We know that, $\mu = \tan\beta$

$\beta = \tan^{-1}(0.7)$

$= 34.99 \approx 35°$

3. Cutting force, $F_c = \dfrac{\tau wt\cos(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$

$$F_c = \frac{280\times3.3\times0.6\cos(35°-15°)}{\sin 22.73°\times\cos(22.73°+35°-15°)} = 1835.5 \text{ N}$$

4. Thrust component, $F_t = \dfrac{\tau wt\sin(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$

$$F_t = \frac{280\times3.3\times0.6\sin(35°-15°)}{\sin 22.73°\times\cos(22.73°+35°-15°)}$$

$= 668.1$ N

5. Normal force, $F_N = F_c\cos\alpha - F_t\sin\alpha$

$= 1835.5\cos 15° - 668.1\sin 15°$

$= 1600$ N

Que 2.8. **The following data relate to orthogonal cutting of mild steel part : Cutting speed = 195 m/min, tool rake angle = 12°, width of cut = 1.75 mm, uncut thickness = 0.25 mm, coefficient of friction between chip and tool = 0.52, shear stress of the work material = 385 N/mm², calculate :**

i. Shear angle, and

ii. Cutting and thrust component of machining force.

AKTU 2018-19, Marks 07

Answer

Given : v = 195 m/min, $\alpha = 12°$, $w = 1.75$ mm, $t = 0.25$ mm, $\mu = 0.52$, $\tau = 385$ N/mm²

1. We know that,

$2\phi + \beta - \alpha = 90°$

$2\phi + 27.47° - 12° = 90°$

$\phi = 37.265°$ [$\because \beta = \tan^{-1}\mu = \tan^{-1}0.52 = 27.47°$]

2. Cutting force, $F_c = \dfrac{\tau wt\cos(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$

$$= \frac{385\times1.75\times0.25\cos(27.47°-12°)}{\sin 37.265°\cos(37.265°+27.47°-12°)}$$

$= 278.178$ N

3. Also thrust component,

$F_t = \dfrac{\tau wt\sin(\beta-\alpha)}{\sin\phi\cos(\phi+\beta-\alpha)}$

$$= \frac{385\times1.75\times0.25\sin(27.47°-12°)}{\sin 37.265°\cos(37.265°+27.47°-12°)}$$

$= 76.988$ N

PART-3

Tool Wear and Tool Life, Surface Finish and Integrity.

CONCEPT OUTLINE

Tool Life : The total cutting time accumulated before tool failure occurs is termed as tool life.

Taylor's Relationship between Cutting Speed and Tool Life :

$vT^n = C$

Where,
v = Cutting speed,
T = Tool life,
C = Constant, and
n = Exponent which depends on cutting condition

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.9. What do you understand by tool wear ? Explain its basic types.

Answer

A. Tool Wear :

1. Tool wear is generally a gradual process, much like the wear of the tip of an ordinary pencil.
2. It adversely affects tool life, the quality of the machined surface, and its dimensional accuracy, and consequently, the economics of cutting operations.
3. The rate of tool wear depends on following factors :
   i. Tool and workpiece material,
   ii. Tool shape,
   iii. Cutting fluid,
   iv. Process parameters such as cutting speed, feed and depth of cut, and
   v. Machine tool characteristics.

B. Types of Wear :

a. Crater Wear :

1. Crater wear occurs on the rake face of the tools and by changing the chip-tool interface geometry, it affects the cutting process.
2. The most significant factors influencing crater wear are temperature at the tool-chip interface and the chemical affinity between the tool and workpiece materials.

3. Additionally, the factors influencing flank wear also influence crater wear.
4. Crater wear described in terms of a diffusion mechanism is the movement of atoms across the tool-chip interface. Since diffusion rate increases with increasing temperature, crater wear increases as temperature increases.

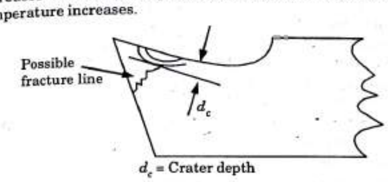


Fig. 2.9.1.

b. Flank Wear :

1. It takes place on the flanks of the cutting edge. Abrasion and adhesion are primarily responsible for the flank wear.
2. The worn area called wear land is usually taken as a measure of the amount of wear and can be readily determined by means of a tool maker's microscope.
3. It extends from the top to a distance on the flank surface which is abraded away as cutting continues.
4. Flank wear is caused by friction between the newly machined surface of the workpiece and the contact area on the tool flank. This is usually the most common type of wear.

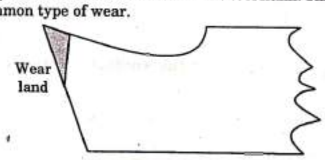


Fig. 2.9.2.

Que 2.10. How do you define tool life ? What are the factors upon tool life depends ?

Answer

A. Tool Life :

1. The length of the period for which a tool can be used is defined as the tool life.
2. It is also defined as the actual cutting time between two successive grinds.

B. Factors Affecting Tool Life :

a. Cutting Conditions :

1. The effect of various cutting conditions *i.e.*, cutting speed, feed and depth of cut is given by tool life equation. When any of these conditions increases, the tool life decreases.

b. Tool Geometry :

1. Increasing the rake angle decreases the cutting forces and heat produced at the tool tip, thereby increasing tool life.
2. However, increasing the rake angle to a large value reduces the tool material available at the tool tip for conducting heat generated, thus increasing the tool tip temperature. This decreases the tool life.

c. Work Material :

1. It also greatly affects tool life.
2. The physical microstructure, constituent phases and the hardness of the material makes a large difference in the actual tool life values.

d. Rigidity of Workpiece :

1. Lower the rigidity of the system, higher is the chance of tool failure, because it means that the job will have some vibration, even the tool might vibrate which induces chipping of the tool.
2. This is due to impact loading on the tool because of intermittent cutting.

e. Effect of Lubricant :

1. Lubricant decreases the cutting forces. The effect of cutting fluid is more predominant over the lower range of cutting speed rather than at higher cutting speeds.
2. At lower speeds, the cutting fluid reduces the friction at tool-chip interface.

Que 2.11. **Discuss about the surface finish process in metal cutting.**

Answer

1. Machinability is often assessed by surface finish after the machining operation. A good surface finish is affected by many variables in single or multiple point machining.
2. The factors improving surface finish are light cuts, small feeds, high cutting speeds, cutting fluids, round nose tools and increased rake angles on well ground tools.
3. Many of these features, while highly desirable, may shorten tool life, increase forces and may not be economical overall.
4. The outermost boundary of a body adjacent to the air is called a surface. When this surface is deformed by a sharp cutting edge, the term surface finish describes the boundary.

5. When a rotating cylindrical body in contact with a tool has an existing surface removed, the substrate surface provides the new boundary.
6. If the surface was magnified many times, it would have the appearance of successive jagged mountain ranges.
7. Despite the seemingly random natural appearance of a mountainous profile, there is mathematical form and geometry to the topography. This analogy extends to the microscopic texture of grooves turned by a tool on a lathe.

Que 2.12. **Write short note on surface integrity.**

Answer

1. Surface integrity is the surface condition of a workpiece after being modified by a manufacturing process. The surface integrity of a workpiece or item changes the material's properties.
2. It consists of a wider spectrum of surface characteristics that also includes surface roughness.
3. Apart from basic topographic information about the surface, several metallurgical, mechanical and physical properties, which may be altered during manufacturing processes, also come under the preview of surface integrity.
4. Thus it can be concluded that surface integrity encompasses wider characteristics of a solid surface that are required to clearly display overall surface quality, while the surface roughness is one such parameter that come under integrity.
5. In fact, surface finish is the most common and widely used parameter to characterize the solid surface.

PART-4

Machinability, Cutting Tool Materials, Cutting Fluids, Coating.

CONCEPT OUTLINE

Cutting Fluids : Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and quality of work.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.13. **Write a short note on machinability.**

Answer

1. Machinability is the property of a metal that how easily a metal is machined and give a satisfactory finish.
2. The machinability of a material is usually defined in terms of four factors :
   i. Surface finish and integrity of the machined part,
   ii. Tool life obtained,
   iii. Force and power requirements, and
   iv. Chip control.
3. Good machinability indicates good surface finish and integrity, long tool life, and low force and power requirements.
4. Because of the complex nature of cutting operations, it is difficult to establish relationships that quantitatively define the machinability of a material.
5. In manufacturing plants, tool life and surface roughness are generally considered to be the most important factors in machinability.

Que 2.14. **What are the desirable characteristics of cutting tool materials ? Describe them briefly.**

AKTU 2014-15, Marks 10

Answer

Desirable characteristics of cutting tool material are as follows :

1. **Hot Hardness :** It is the ability of the cutting tool to withstand high temperature without losing its cutting edge.
2. **Bending Strength :** It is defined as the stress in a material just before it yields in a flexure test. High bending strength is the desirable quality of a cutting tool.
3. **Toughness :** It is the ability of a material to absorb energy and deform plastically without fracturing. High toughness is also the desirable quality of a cutting tool.
4. **Wear Resistance :** Wear is the removal and deformation of material from a surface as a result of mechanical action on the surface. Wear is an undesirable effect. The cutting tool should have a high wear resistance.
5. **High Thermal Shock Resistant and Fatigue Resistant :** They must withstand rapidly alternating temperature cycle during the cutting process.
6. **High Impact Strength :** They must resist the impact force due to vibrations or any other interrupted cutting.

7. **Chemical Stability :** Chemical stability or inertness with respect to the workpiece material, so that any adverse reactions contributing to tool wear were avoided.

Que 2.15. **What are the cutting fluids ? Discuss various properties of cutting fluids used during machining.**

AKTU 2015-16, Marks 10

Answer

A. **Cutting Fluids :**

1. Cutting fluids are also called as lubricant in the form of solid, liquid or gas, which is applied to a tool during a cutting operation for removal of chips and to reduce the heat generation.
2. It is very effective for improving the overall machinability.
3. It also prevents the formation of built-up edge (BUE).
4. It permits the use of higher cutting speeds and larger metal removal rates.

B. **Properties of Cutting Fluids :**

1. They have a large specific heat and thermal conductivity.
2. They have a low viscosity and small molecular size (to help rapid penetration to the chip-tool interface).
3. These contain suitable reactive constituent (for forming a low strength compound after reacting with the work material).
4. These non-poisonous and non-corrosive.
5. These inexpensive and easily available.

Que 2.16. **What are the purpose of cutting fluids ? What are their types ?**

AKTU 2014-15, Marks 10

Answer

A. **Purpose of Cutting Fluids :**

1. Cooling down of the chip-tool-work zone by carrying away some of the generated heat.
2. Reduce the coefficient of friction at the chip-tool interface due to the formation of a weaker compound at the interface.
3. Reduce the thermal distortion caused by temperature gradients generated during machining.
4. Wash away the chips and clearing the machining zone.
5. Protecting the finished surface from corrosion.

B. Types of Cutting Fluids :

a. **Aqueous Fluids :** These are mainly emulsion or soluble oils. These are generally cheapest and have maximum use where coolant properties are important factor *i.e.*, conventional cutting of metals.

b. **Oil-type Fluids :** These fluids are referred to petroleum products which are usually known as sharp cutting oils or mineral oils.

c. **Synthetic Fluids :** These fluids are transparent in nature which allows operator to observe the cutting clearly and mainly used on grinding machines. These are mainly used in diluted form.

d. **Gaseous Fluids :** These fluids are mainly carbon dioxide, compressed air, argon, helium, nitrogen etc and have limited application due to high cost, but these are used where liquids are avoided *i.e.*, cutting an absorbent material.

Que 2.17. **What are the various methods of coating ? Explain any two of them.**

Answer

A. **Various Methods of Coating :** Various methods of coating are as follows :

1. Hot dipping.
2. Galvanising.
3. Tin plating.
4. Lead coating.
5. Metal cladding.
6. Anodising.
7. Parkerising.
8. Diffusion.

B. Galvanising :

1. It is the name given to the coating of zinc by hot dipping.
2. The quality of the coating is directly related to its thickness which is measured in gms/m^2 of surface for all products except sheet where it is measured in gms/m^2 of sheet (2 sides).
3. Heavy coatings of zinc are more easily applied by hot dipping than electrolytically.
4. The purity of zinc affects its bonding property and the appearance of the coating, and besides that it has no effect. So where bonding does not matter, low grades of zinc can be used.
5. It is mainly used in roofing, wire fencing for gardens, etc., buckets and water cans, steel pipes and for structure purposes exposed to atmosphere.

C. Tin Plating :

1. Tin plating has a pleasing appearance, good corrosion resistance and it solders well. Copper wire is very often tin plated to increase its suitability for soldering.
2. This coating is usually applied by hot dipping before the wire has been drawn down to final diameter and the subsequent operations draw down the copper and tin coating together.

3. The various applications of tin plating include tin cans for food, biscuit tins, kitchen utensils, copper wire, copper tube used in refrigeration etc.

PART-5

Turning, Drilling, Milling and Finishing Processes.

CONCEPT OUTLINE

Milling : The process of removing metal from a workpiece to obtain the required shape, dimensions and surface, by a rotating multiple tooth cutters (called milling cutter) is known as milling.

Finishing Processes : These processes are used to ensure a smooth surface, to improve appearance or to provide a protective coating.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.18. **What do you understand by plain turning, step turning and taper turning ?**

Answer

A. **Plain Turning :**

1. It is an operation of removing excess amount of material from the surface of the cylindrical workpiece.
2. In this operation, the work is held either in the chuck or between centres and the longitudinal feed is given to the tool either by hand or power.

B. **Step Turning :**

1. It is an operation of producing various steps of different diameters in the workpiece.
2. This operation is carried out in the similar way as plain turning.

C. **Taper Turning :**

1. It is an operation of producing an external conical surface on a workpiece.
2. A small taper may be produced with the help of a forming tool or chamfering tool, but the larger tapers are produced by swivelling the compound rest at the required angle or by offsetting the tailstock or by taper turning attachment.

$$\text{Taper} = \frac{D-d}{L}$$

Que 2.19. **Describe twist drill nomenclature using sketches.**

AKTU 2014-15, Marks 10

Answer

a. **Body :** It is that part which carries flutes and extends from the dead centre.

b. **Shank :** It is that part which fits into the holding device.

c. **Point :** It is the entire cone-shaped surface at the cutting end of the drill.

d. **Cutting Edge :** It is that part of the point which is sharp like a knife and cuts the metal during drilling.

e. **Margin :** The cylindrical portion of the land which is not cut away to provide clearance.

f. **Web :** It is the central portion of the body that joins the lands. The extreme end of the web forms the chisel edge on a two flute drill.

g. **Lip Relief Angle :** It is the axial relief angle at the outer corner of the lip. It is measured by projection into a plane tangent to the periphery, at the outer corner of the lip.

h. **Helix Angle :** It determines the rake angle of the cutting edge of the drill. Smaller helix angles 10 to 13° are used for drilling harder and 35 to 45° for softer materials.

i. **Chisel Edge Angle :** It is the angle between the chisel edge and the cutting lip. It varies from 130 to 145°, larger values for smaller drills.

j. **Neck :** It is the smaller diameter cylindrical portion which separates the body and the drill shank.

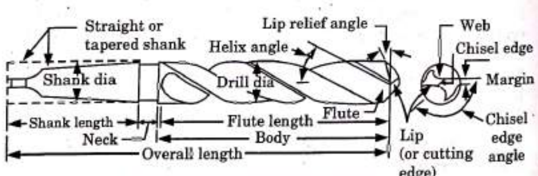


Fig. 2.19.1. Parts of a twist drill.

Que 2.20. **Explain various drilling operation with neat sketch.**

Answer

Various drilling operation are as follows :

a. **Drilling :** The operation of making round holes in workpieces is known as drilling. It is done with the help of a drilling machine.

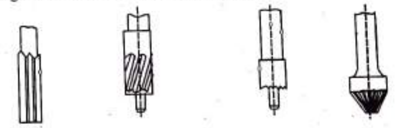
b. **Boring :** It is an operation of enlarging the diameter or bore of a pre-drilled hole using a larger size drill. It produces circular internal profiles in hollow workpieces.

c. **Reaming :** It is the operation of sizing, enlarging, and finishing the drilled holes to accurate dimension with the help of a reamer which is a rotary cutting tool of cylindrical shape.

d. **Counter Boring :** It is an operation of enlarging the mouth of a drilled hole to set bolt heads and nuts below the surface so that they may not project out from the surface level.

e. **Spot Facing :** It is an operation to finish off a small portion of rough surface around a drilled hole to provide smooth seat for bolt head.

f. **Counter Sinking :** It is an operation to bevel the top of a drilled hole for making a conical seat for a flat head screw.



(a) Reamer (b) Counter boring drill (c) Spot facing drill (d) Counter sunk drill

Fig. 2.20.1. Drilling operations.

Que 2.21. **Explain up milling and down milling with a neat sketch.**

AKTU 2016-17, Marks 10

Answer

A. **Up Milling :**

1. In an up milling process, the direction of cutter rotation is opposite to that of feed motion.
2. Chip thickness is zero in the beginning of operation and increases to maximum at the end of cut.
3. The cutting forces vary from zero to maximum.
4. In up milling, the cutter force is higher at the end of the cut and the direction is such as to tend to lift the work from the fixture, thus proper fixing arrangement is desired.

5. Advantage of up milling is that the cutter is not subjected to heavy forces and vibrations.

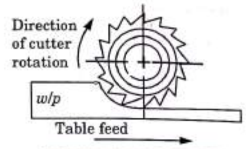


Fig. 2.21.1. Up milling.

B. Down Milling :

1. In this method, the direction of cutter rotation is same as that of feed motion.

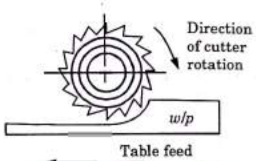


Fig. 2.21.2. Down milling.

2. In down milling, chip thickness is maximum at the start of cut and decreases to zero at the end of cut.
3. The resulting cutting forces in down milling act in downward direction and try to drag the workpiece into the cutter. This is the reason why workpiece is securely held in the table.
4. Advantage of down milling lies in the fact that cutting forces tends to held workpiece against the work table and therefore lower clamping forces are required.
5. Down milling produces better surface finish and improved dimensional accuracy.

PART-6

Introduction to CNC Machining, Additive Manufacturing.

CONCEPT OUTLINE

CNC : Computer numerical control (CNC) is a NC system that utilizes a dedicated, stored program computer to perform some or all of the basic numerical control functions.

Features of CNC System : CNC system has :
1. Control system features,
2. Memory features,
3. Programming features,
4. Programmable logic control features, and
5. Diagnostic features.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.22. **What is computer numerical control (CNC) system ? Explain.**

Answer

1. A CNC machine is essentially a NC machine with a dedicated computer as its integral part working as MCU.
2. It has more flexibility compared to an NC machine.
3. A bare minimum of electronic hardware is used for control.
4. Software is used for obtaining the basic functions.
5. The change in trend from hardware to software has increased productivity and flexibility in manufacturing.
6. When compared to NC machines, CNC machines have the added advantage of reading, storing and editing the part programs.
7. RAM contains the part programs and ROM contains control programs for slide movement, interpolation etc.
8. CNC machines also provide graphical capabilities, diagnostic procedures and system trouble shooting.
9. The schematic diagram of CNC system is shown in Fig. 2.22.1.

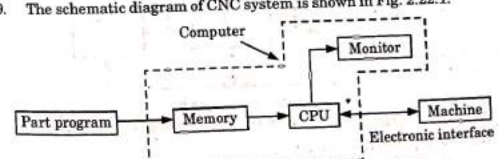


Fig. 2.22.1. General configuration of CNC system.

10. The monitor continuously displays the machine status to enable the machine operator to communicate with the machine.
11. CNC lathe (turning centre) and CNC milling (horizontal and vertical machining centres) are very commonly used CNC machines.

Que 2.23. **Explain various elements of a CNC system.**

Answer

Various elements of a CNC system are as follows :

a Part Program :

1. The part program is a program of instructions that defines cutting tool path, spindle speed, feed rate, tool changes, coolant on/off and several other functions of machine tool that can be automatically controlled.
2. The commands also define the position of machine tool spindle or the cutting tool with respect to the work table on which the workpiece is fixtured.

b. Computer :

1. The computers used with NC are either mini or micro computers, both are classified as digital type computers.
2. Their operations are to move information from one unit of the computer to another, e.g., to and from the memory and the central processing unit (CPU).
3. Other operations involve arithmetical and logical functions, such as adding two numbers together.
4. The computer is ordered to execute a particular operation by giving it an instruction.

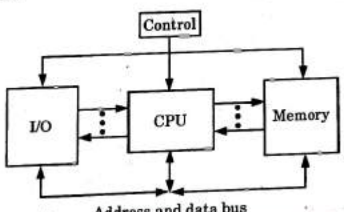


Fig. 3.23.1. Principal structure of a digital computer.

c. Equipment / Machine :

1. This is another important component of CNC equipment, because this is the component that performs useful work.

2. For example, in a CNC lathe, the processing equipment is the usual lathe machine (excluding MCU) which performs the actual machining operation.

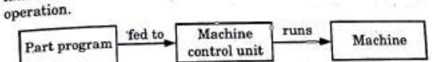


Fig. 2.23.2. A typical NC system.

Que 2.24. **What is additive manufacturing ? Write its advantages and disadvantages.**

Answer

A. Additive Manufacturing :

1. It is the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.
2. Additive manufacturing uses computer, 3D modeling software (Computer Aided Design or CAD), machine equipment and layering material.
3. Once a CAD sketch is produced, the additive manufacturing equipment reads in data from the CAD file and lays down or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object.
4. The term additive manufacturing encompasses many technologies including subsets like 3D printing, rapid prototyping (RP), direct digital manufacturing (DDM), layered manufacturing and additive fabrication.

B. Advantages of Additive Manufacturing :

1. Reduced lead times.
2. Elimination of design constraints.
3. Dimensional accuracy.

C. Disadvantages of Additive Manufacturing :

1. High initial investment.
2. It is not suitable for mass production.
3. Non weldable cannot be processed by additive manufacturing.

PART-7

Rapid Prototyping and Rapid Tooling

CONCEPT OUTLINE

Rapid Prototyping : It is a group of techniques used to quickly fabricate a side model of a physical part or assembly using 3D CAD data.

Need of Rapid Prototyping : It is needed for :

1. Product customizations.
2. Higher accuracy level in designing.
3. Quick changes or modification.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.25. **Write down the advantages, limitations and applications of rapid prototyping.**

Answer

A. Advantages of Rapid Prototyping :

1. Product development time and cost will be greatly reduced compared to the conventional prototyping techniques used.
2. Communications between marketing, engineering, manufacturing, and purchasing are enhanced due to the availability of physical prototypes.
3. It is possible to have the physical model at critical design reviews, thereby the decision making process becomes more accurate.
4. In some cases, it is possible to perform functional prototype testing before committing to the actual tooling.

B. Limitations of Rapid Prototyping :

1. The initial cost of the equipment is relatively high.
2. The material choices for different processes are limited in terms of their properties. In some cases, only plastic materials could be used.

C. Applications of Rapid Prototyping :

1. Checking the feasibility of new design concepts.
2. Making functional models with the limitation of the material to do any testing.
3. Conducting market tests/evaluation.
4. Fabricating a master pattern for silicon and epoxy moulds.
5. Manufacture many exact copies of models simultaneously.

Que 2.26. **Write down the uses of rapid tooling and also discuss its types in short.**

Answer

A. Uses of Rapid Tooling : It is used for :

1. Minimize the cost.
2. Increase the productivity.
3. Increase dimensional accuracy.
4. Decrease total time.

B. Types of Rapid Tooling :

a. **Direct Rapid Tooling :** It allow injection moulding and die casting inserts to build directly from 3D CAD models.

b. **Indirect Rapid Tooling :** Indirect tooling methods are intended as prototyping or pre-production tooling processes and not production methods. Most any rapid prototyping process can yield patterns for indirect tooling.

PART-8

Joining and Fastening Process, Physics of Welding, Brazing and Soldering.

CONCEPT OUTLINE

Joining : When two or more components are joined together to produce the required product by any suitable process, the process is known as joining. It includes welding processes, brazing, soldering, diffusion bonding, adhesive bonding etc.

Fastening : The act of joining the components with the help of fasteners is called fastening. Fastening may be permanent or temporary.

Soldering : In this process, the melting point temperature of filler material is less than 430 °C and it is also less than melting point temperature of base material.

Brazing : In this process, the melting point temperature of filler material is more than 430 °C but less than the melting point temperature of base material.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.27. **Describe physics of welding in detail.**

Answer

1. The physics of welding deals with complex physical phenomena associated with welding including heat, electricity, magnetism, light etc.
2. Majority of welding processes require the application of heat which is obtained through :
   i. Flame,
   ii. Arc,
   iii. Contact resistance,
   iv. Electron beam,
   v. Laser, and
   vi. Exothermic reactions, etc.
3. AC/DC electric power supply is used to generate heat for many welding processes.
4. Magnetic fields set up due to the flow of current through the electrode and the arc generate pinch effect and influence the welding arcs. Arc blow, plasma streaming and metal transfer are some of the welding arc features strongly influenced by the presence of magnetic fields.

PART-9

Design Consideration in Welding.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.28. **Write down the main design consideration in welding.**

Answer

Following are the main design considerations in welding :

1. Use the minimum possible number of welds.
2. Select the same thickness for the parts to be welded together.
3. Locate the welds at the areas in the design where stresses and deflections are not critical.
4. Effect of shrinkage and distortion should be minimized by post welding annealing and stress relief operations.

5. Decide proper welding sequence.
6. Design welding in the flat or horizontal position and not in the overhead position.
7. Use only the amount of weld metal that is absolutely required.

PART-10

Solid and Liquid State Joining Processes, Adhesive Bonding.

CONCEPT OUTLINE

Adhesive Bonding : It is the process of joining two surfaces together, usually with the creation of a smooth bond. It is most commonly used in the aircraft and automobile industries.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.29. **Write short note solid and liquid state joining processes.**

Answer

1. In solid and liquid joining process, the bulk material is not welded. A molten filler material is used for joint making.
2. It includes various processes which are discussed below :
   i. **Soldering :** Refer Concept Outline, Part 8, Page 2–26C, Unit-2.
   ii. **Brazing :** Refer Concept Outline, Part 8, Page 2–26C, Unit-2.
   iii. **Adhesive Bonding :** Refer Concept Outline, Part 10, Page 2–28C, Unit-2.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. What do you understand by single point cutting tool ? Briefly explain its various angles.

Ans. Refer Q. 2.1, Unit-2.

Q. 2. Discuss the various types of chips produced during metal machining with neat sketch.

Ans. Refer Q. 2.4, Unit-2.

Q. 3. Draw Merchant's force circle diagram and develop expression for power required in metal cutting and derive Merchant's shear angle relationship.

Ans. Refer Q. 2.6, Unit-2.

Q. 4. What do you understand by tool wear ? Explain its basic types ?

Ans. Refer Q. 2.9, Unit-2.

Q. 5. What are the purpose of cutting fluids ? What are their types ?

Ans. Refer Q. 2.16, Unit-2.

Q. 6. Describe twist drill nomenclature using sketches.

Ans. Refer Q. 2.19, Unit-2.

Q. 7. Explain up milling and down milling with a neat sketch.

Ans. Refer Q. 2.21, Unit-2.

☺☺☺

3

UNIT

Grinding and Super Finishing

CONTENTS

PART-1

Grinding Wheels, Abrasive and Bonds, Cutting Action.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. **Define grinding and grinding wheel.**

Answer

A. **Grinding :**

1. It is a material removal process by the abrasive action of a revolving wheel on the workpiece surface.
2. During the process, the material is removed in the form of fine or small chips.
3. Generally, it is considered as finishing operation because a very small amount of material is removed from the surface during this operation.

B. **Grinding Wheel :**

1. The wheel used for performing the grinding operation is known as grinding wheel.
2. Grinding wheel consists of sharp crystals which are called as abrasives, held together with bonding material or bond.

Que 3.2. **Write down the factors to be considered in selection of grinding wheel.**

Answer

The factors to be considered in selection of a grinding wheel are as follows :

1. Type of the bond present.
2. Grade of the grinding wheel.
3. Structure of the grinding wheel.
4. Area of contact between the wheel and work.
5. Wheel speed.

Que 3.3. **Define abrasive. What are its different types ?**

Answer

A. **Abrasive :**

1. An abrasive is a very hard material with adequate toughness, which when fractured, has the formation of many sharp cutting edges and corners.
2. It consists of small particles known as abrasive grains.

B. **Types of Abrasives :**

a. **Natural Abrasives :**

1. The abrasives found in the earth's surface are known as natural abrasive.
2. These abrasives are sand stone, corundum and quartz.
3. Due to the presence of impurities in the natural abrasives which hinder the cutting action and create non-uniformity in the abrasive wheels, use of natural abrasives is largely discontinued.

b. **Artificial Abrasives :**

1. The quality and composition of these particles can be easily controlled and their efficiency is far better than natural abrasives.
2. The artificial abrasives break with sharp clear fracture and thereby present new cutting edge to the work.
3. Now-a-days, the commonly used artificial abrasives are :

i. **Silicon Carbide :**

1. The various ingredients of silicon carbide are silicon sand (52 %), petroleum coke (34 %), common salt (2 %) and sand dust (12 %).
2. The silicon carbide is the hardest manufactured abrasive but at the same time, it is very brittle. This property makes it more efficient for grinding materials of low tensile strength, such as cemented carbides, cast iron, brass, bronze, copper, aluminium, glass, marble, granite, ceramic materials etc.
3. It is an efficient abrasive for grinding tungsten carbide tipped tools.

ii. **Aluminium Oxide :**

1. It is produced by heating the mixture of mineral bauxite, hydrated aluminium oxide, clay containing silica, iron oxide, titanium oxide etc., in an arc type electric furnace. After cooling, the mass is crushed and graded by passing through screens.
2. It is slightly softer than silicon carbide but it is much tougher.
3. Due to its exceptionally fast and cool cutting properties, it is especially suitable for grinding materials of high tensile strength, such as most steels, carbon steel, high speed steel, annealed malleable iron, wrought iron etc.

Que 3.4. **Define bond. What are its different types ?**

Answer

A. Bond :

1. The material which holds together the abrasive grains in the form of a wheel is known as bond.
2. The degree of hardness possessed by the bond is called the grade of the wheel.

B. Types of Bonds :

a. Vitrified Bond :

1. Vitrified is basically a vitreous glass much like pottery fired in a kiln.
2. Vitrified tools are very rigid and used for surface grinding of bench surface and tool room application.

b. Silicate Bond :

1. These are the bond system which use silicate and magnesium oxychloride.
2. They have low strength of bond which keeps heat generation minimum but it may lack the life and durability of resin bonded wheels.

c. Rubber Bond :

1. These are the bonded abrasive product with a rubber or elastomer bond system between the abrasive grains.

d. Shellac Bond :

1. These are the bonded abrasive product with a shellac bond system between the abrasive grains.

e. Resinoid Bond :

1. It is made from synthetic organic materials and is strong and fairly flexible.
2. It is used for making very strong wheels and for surface speeds upto 3000 m/min.

Que 3.5. **What is the function of bonds in grinding wheel ? Indicate bonding materials and name their corresponding grinding wheel.**

AKTU 2014-15, Marks 05

Answer

A. Function of Bonds :

1. It acts as a binder to hold the abrasive grains together.
2. Bonds increase the strength of the wheel, increasing the life of grinding wheel.

B. Bonding Material with Corresponding Grinding Wheels :

a. Vitrified :

1. In this, bonding clay and abrasive grains are mixed together with water and the uniform mixture, thus produced, is poured into moulds for drying.

2. Corresponding grinding wheel : Vitrified wheels.

b. Silicate :

1. In this, wheels are made by mixing abrasive grains with silicate or soda or water glass.
2. Corresponding grinding wheel : Silicate bonded wheels.

c. Resinoid :

1. In this, abrasive grains are mixed with synthetic resins and other compounds by moulding and heating at 200 °C.
2. Corresponding grinding wheel : Resinoid wheels.

d. Shellac :

1. In this, abrasives and shellac are mixed in heated containers and later pressed and baked in heated molds at 150 °C.
2. Corresponding grinding wheel : Elastic bonded wheels.

e. Rubber :

1. In this, abrasive grains are mixed with pure rubber and sulphur and the mixture is rolled into sheets from which wheels are punched out and later vulcanized.
2. Corresponding grinding wheel : Rubber bonded wheels.

Que 3.6. **What is meant by grit, grade and structure of grinding wheel ?**

AKTU 2014-15, Marks 10

OR

What is meant by grit, grade and structure of grinding wheel ? Explain.

AKTU 2016-17, Marks 09

Answer

A. Grit :

1. In grinding, the cutting elements are grains of abrasive material known as grit.
2. This applies to products using abrasive grains held in a matrix or bonded to a surface such as coated abrasives.
3. Grit size typically runs from coarse (12-30 grit), medium (36-70 grit) and fine (80-150 grit).
4. Superfine grits run from 160 and from higher. Grinding wheels are usually between 24 and 100 grit.
5. A coarse grit is used for fast, aggressive stock removal and finer grits for less stock removal but better surface finish.

B. Grade :

1. The grade of the wheel is a measure of the ability to retain grit.

2. The hardness of the material to be ground also affects the choice of the wheel grade or hardness.
3. A harder grade can be used on soft, easily penetrated materials than on hard materials which naturally tend to dull the wheel faster.
4. However, the softer grade wheel releases the dulled grains more readily, enabling the new, sharp grains lying under it to do the work.
5. Hardness is rated from A-Z with 'A' being the weakest bond and 'Z' being the strongest.
6. A weak bond is preferred for grinding harder materials while a stronger bond is desired for softer materials.

C. Structure :

1. It represents density of grains and voids for collection of chips.
2. With too small voids (8 – 0), chips stay in wheel, blocking the voids which causes inefficient cutting.
3. Too large voids (9 – 16) offer less cutting edges and inefficient cutting action.
4. For grinding ductile materials, larger chips are produced and thus open structure is preferred to avoid loading of wheel.
5. For hard and brittle materials, closed structure is preferred.
6. For rough cut, open structure is more suitable.
7. Surface grinding needs more open structure than cylindrical or tool and cutter grinding.

Que 3.7. **What do you understand by cutting action of grinding wheel ?**

Answer

1. A grinding wheel consists of abrasive particles which are bonded by bond materials and these abrasive material act as cutting tool tip.
2. In cutting process, the abrasive particles at cutting edge become dulled, and these become cracked along the cleavage planes due to resistance offered by workpiece material which resist the cutting action.
3. Thus new cutting points are produced which carry out further cutting action. This process continues till the abrasive grains get come down the level of bond.
4. Fig. 3.7.1 showing edge of abrasive grains projecting from the face of the grinding wheel. Each abrasive particle projecting acts as separate cutting tool.

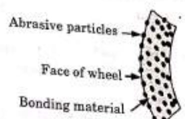


Fig. 3.7.1.

PART-2

Grinding Wheel Specification, Grinding Wheel Wear, Attritious Wear, Fracture Wear.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.8. **Explain grinding wheel specification.**

AKTU 2017-18, Marks 10

Answer

A grinding wheel is specified by the following parameters :

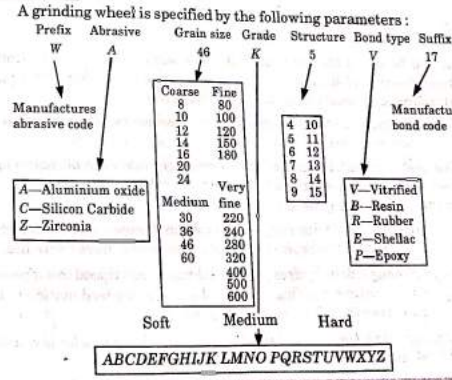


Fig. 3.8.1. Standard marking system for grinding wheels.

1. The type of grit material.
2. The grit size.
3. The bond strength of the wheel, commonly known as wheel hardness.
4. The structure of wheel denoting the porosity.
5. The type of bond material.
6. Other than these parameters the wheel manufacture may add their own identification code prefixing or suffixing the standard code.

Que 3.9. **Describe any four types of bonds for bonded abrasive on a grinding wheel. Explain grinding wheel wear in detail.**

AKTU 2017-18, Marks 10

Answer

A. **Types of Bonds :** Refer Q. 3.4, Page 3–3C, Unit-3.

B. **Grinding Wheel Wear :**

1. Fig. 3.9.1 shows how a grinding wheel wears with more and more grinding (removal of work material).

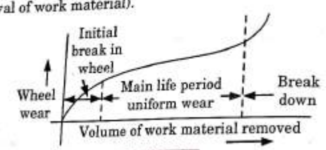


Fig. 3.9.1.

2. It will be noted that initially with new wheel, wear is more (initial breakdown period), but once the loose particles are out, wheel gets stabilised and wear takes place at uniform rate.
3. After the uniform wear period ends, the wheel needs to be reconditioned otherwise wear will be heavy.
4. The usable period depends on wheel wear (gradual wear of sharp edges known as attrition wear and by fracture of portion of abrasive) and also on the loading and glazing of the wheel.
5. While loading and glazing may not be problem if proper wheel is selected, but wear is natural phenomenon as abrasive grains have finite life.
6. Reconditioning is done by dressing *i.e.*, holding a hard tipped tool (dresser) against the rotating grinding wheel and giving some feed motion to the dresser to cover the whole width of the wheel.
7. During dressing, the dull and used layer of abrasive particles is crushed and fresh surface of abrasive particles is exposed.

8. The performance of a grinding wheel is characterised by the parameter grinding ratio which is the ratio of volume of work material removed and the volume of wheel worn away.

Que 3.10. **Explain three different ways in which the wear of grinding wheel takes place. What can be done to prevent them ?**

Answer

Different ways of wear of grinding wheel and their prevention is explained below :

a. **Attritious Wear :**

1. In attritious wear, the cutting edges of a sharp grain will become dull by attrition which is similar to flank wear in cutting tools.
2. In this, the wear is caused by interaction of the grain with the workpiece material, involving both physical and chemical reactions.

i. **Prevention :** Attritious wear is low when two materials are chemically inert with respect to each other.

b. **Grain Fracture or Wear :**

1. If the flat wear caused by attritious wear is excessive, the grain becomes dull and grinding becomes inefficient and produces undesirably high temperatures which directly causes to grain fracture.
2. The grain should fracture or fragment at a moderate rate, so that new short cutting edges are produced continuously during grinding.

i. **Prevention :** This can be prevent by using different combinations of the materials such as aluminium oxide, silicon carbide, diamond, cubic boron nitride, etc.

c. **Bond Fracture :**

1. The strength of the bond (grade) is a significant parameter in grinding.
2. If the bond is too strong, dull grains cannot be dislodged. This prevents other sharp grains along the circumference of the grinding wheel from contacting the workpiece to remove chips, and the grinding process becomes inefficient.
3. On the other hand, if the bond is too weak, the grains are easily dislodged and the wear rate of the wheel increases. In this case, maintaining dimensional accuracy becomes difficult.

i. **Prevention :** Softer bonds are recommended for harder materials and for reducing residual stresses and thermal damage to the workpiece while hard grade wheels are used for softer material and for removing large amounts of materials at high rates.

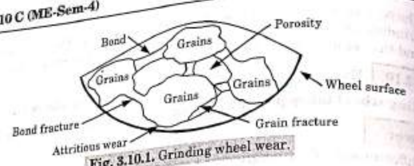


Fig. 3.10.1. Grinding wheel wear.

Que 3.11. **How are grinding wheels specified ? Clearly differentiate between grade and structure of a grinding wheel ?**

AKTU 2015-16, Marks 10

Answer

A. Grinding Wheels Specification : Refer Q. 3.8, Page 3–7C, Unit-3.

B. Difference between Grade and Structure :

S. No.	Grade	Structure
1.	It is the representation of the strength of the bonding material.	It represents density of grains and voids for collection of chips.
2.	It is denoted by English alphabet : *i.e.*, *A* for softest *Z* for hardest	It is denoted by numbers : *i.e.*, 1 to 8 for dense 8 to 15 or higher for open
3.	The selection of particular grade of wheel depends on following factors : a. Nature of workpiece. b. Composition of workpiece. c. Size and hardness of workpiece.	The selection of particular structure depends on following factors : a. Hardness of workpiece. b. Type of grinding operation. c. Quality of surface finish required on the workpiece.

PART-3

Dressing and Truing.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.12. **What do you understand by dressing and truing ?**

Answer

A. Dressing :

1. Wheel dressing is defined as the act of improving the cutting action. It can also be described as sharpening operation.
2. It becomes necessary from time to time during the course of working to correct uneven wear and to open up the face of the wheel so as to obtain efficient cutting conditions.
3. It may be accomplished by using metal crushers, abrasive sticks, abrasive wheels, single point diamonds etc.

B. Truing :

1. Wheel truing is defined as act of restoring the cutting face of a grinding wheel by removing the abrasive material from the cutting face and sides of the wheel, so that it will run true with respect to the axis of rotation and produce perfect round or flat work.
2. It also includes the altering of the cutting face shape to produce special contours.
3. It also produces concentricity or parallelism of faces.

Que 3.13. **Explain three different ways in which the wear of grinding wheel takes place. What can be done to prevent them ? Differentiate dressing and truing.**

AKTU 2015-16, Marks 10

Answer

A. Types of Grinding Wheel Wear and their Prevention : Refer Q. 3.10, Page 3–9C, Unit-3.

B. Difference between Dressing and Truing :

S. No.	Dressing	Truing
1.	Dressing of wheel is done to recover proper cutting action of wheel face.	Truing is the act of regenerating the required geometry on the grinding wheel.
2.	Dressing removes the loading of wheel.	Truing is done to make the periphery of the wheel concentric with its axis.

PART-4

Maximum Chip Thickness and Guest Criteria, Surface and Cylindrical Grinding, Centreless Grinding.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.14. **Explain the working mechanism of cylindrical and surface grinding.**

AKTU 2016-17, Marks 10

OR

Show that the maximum chip thickness t_m in surface grinding, using grinding wheel diameter D is given by

$$t_m = \frac{2\,v_t}{b\,C\,V_w}\sqrt{\frac{d}{D}}$$

Where v_t is the table feed, C is the number of abrasive grains per unit area of the grinding wheel surface, V_w is the grinding wheel surface speed, b is the width and d is the depth of cut.

AKTU 2018-19, Marks 07

Answer

A. Cylindrical Grinding :

1. An external cylindrical grinding operation is shown in Fig. 3.14.1.
2. It is assumed that the cutting grains of the grinding wheel are arranged on its periphery with equal spacing of grains per linear distance.
3. During grinding, an abrasive grain engages with the workpiece at the point C. This grain cuts into the workpiece, till the point A shifts to point B. This result in the formation of chip '$CEAB$' shown in Fig. 3.14.1 by the shaded portion.
4. It can be seen from the Fig. 3.14.1, that the maximum chip thickness is 'EB'.
5. The time of engagement of an abrasive grain is given as

$$T = \frac{1}{V}$$

Where, T = Time of engagement of an abrasive, and
V = Grinding wheel speed,

6. Now, $$AB = vT = \frac{v}{V} \qquad ...(3.14.1)$$

Where, v = Peripheral speed of workpiece.

7. Since the chip produced in grinding is very small, hence the shape EAB can be approximated as a triangle with the angle EAB equal to $(\alpha + \beta)$.

$\therefore$ Maximum chip thickness : $EB = t_m = AB \sin(\alpha + \beta)$

or $$t_m = \frac{v}{V}\sin(\alpha + \beta) \qquad ...(3.14.2)$$

8. To find the value of $(\alpha + \beta)$, we refer to triangle O_1O_2A.

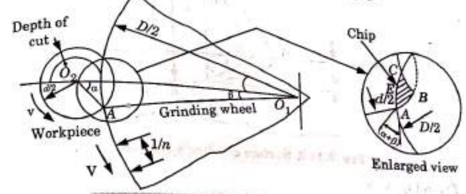


Fig. 3.14.1. External cylindrical grinding operation.

$$O_1O_2 = O_1A + O_2A - C$$

$$O_1O_2 = \frac{D}{2} + \frac{d}{2} - C$$

Where, C = Grains per unit square of the surface of the wheel.

9. We know that

$$(O_1O_2)^2 = (O_1A)^2 + (O_2A)^2 - 2(O_1A)(O_2A)\cos[(180° - (\alpha + \beta)]$$

$$\left(\frac{D}{2} + \frac{d}{2} - C\right)^2 = \left(\frac{D}{2}\right)^2 + \left(\frac{d}{2}\right)^2 + 2\left(\frac{D}{2}\right)\left(\frac{d}{2}\right)\cos(\alpha + \beta)$$

Simplifying, we get

$$\cos(\alpha + \beta) = 1 - 2C\left[\frac{1}{d} + \frac{1}{D}\right] \text{ (Neglecting } C^2 \text{ term which is very small)}$$

10. Also, $$\sin(\alpha + \beta) = \sqrt{1 - \cos^2(\alpha + \beta)} \qquad ...(3.14.3)$$

Substituting value of $\cos(\alpha + \beta)$ in eq. (3.14.3), we get

$$\sin(\alpha + \beta) = 2\sqrt{C\left(\frac{1}{d} + \frac{1}{D}\right)} \qquad ...(3.14.4)$$

11. Substituting eq. (3.14.4) in eq. (3.14.2), we get maximum chip thickness as

$$t_m = \frac{2v}{V}\sqrt{C\left(\frac{1}{d} + \frac{1}{D}\right)} \qquad ...(3.14.5)$$

B. Surface Grinding :

1. Fig. 3.14.2 shows the metal removal by a single abrasive grit in a surface grinding operation.
2. This metal removal process is similar to a milling machine.

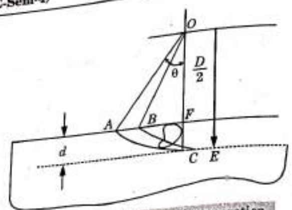


Fig. 3.14.2. Surface grinding operation.

3. From Fig. 3.14.2,

$$\cos\theta = \frac{OF}{OA} = \frac{OC - FC}{OA}$$

$$= \frac{D/2 - d}{D/2} \quad ...(3.14.6)$$

or

$$d = \frac{D}{2}(1 - \cos\theta)$$

4. Also,

$$AF = \frac{D}{2}\sin\theta$$

$$= \frac{D}{2}\sqrt{1 - \cos^2\theta} \quad ...(3.14.7)$$

Substituting the value of cos θ from eq. (3.14.6) in eq. (3.14.7), we get,

$$AF = \frac{D}{2}\sqrt{1 - \left(1 - \frac{d}{D/2}\right)^2}$$

or

$$AF = \frac{D}{2}\sqrt{Dd - d^2}$$

5. Let l_s = Arc length of AC ≈ Chord length AC

$$l_s = AS = \sqrt{AF^2 + d^2} = \sqrt{Dd} \quad ...(3.14.8)$$

Eq. (3.14.8) is valid when $v << V_W$, where v is the workpiece velocity and V_W is the velocity of grinding wheel.

6. When both workpiece and grinding wheel speeds are taken into consideration, then the chip length (l_s) is given as,

$$l_s = \left(1 + \frac{v}{V_W}\right)\sqrt{Dd} \quad ...(3.14.9)$$

7. The shape of the chip can be approximated as a triangle as shown in Fig. 3.14.3.

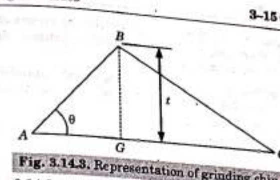


Fig. 3.14.3. Representation of grinding chip.

8. From Fig. 3.14.3, $t_m = AB\sin\theta$

$$= 2AB\sqrt{\frac{d}{D} - \left(\frac{d}{D}\right)^2} = 2AB\sqrt{\frac{d}{D}}$$

Since d/D is very small, hence $(d/D)^2$ is neglected.

Where, t_m = Maximum chip thickness.

9. AB is the distance moved by the table during the time when the grinding wheel makes $1/K$ revolutions.

So,
$$AB = \frac{v_t}{KN}$$

Where, v_t = Table speed,
N = Grinding wheel rpm, and
K = Number of abrasive grains on the surface.

10. Hence,
$$t_m = \frac{2v_t}{KN}\sqrt{\frac{d}{D}}$$

11. If there are C grain per cutting unit square of the surface of the wheel and if the average width of each cut is b, then

$$K = \pi DbC$$

$$t_m = \frac{2v_t}{bCV_W}\sqrt{\frac{d}{D}}$$

Where, V_W = Grinding wheel surface speed.

Que 3.15. **Briefly describe the main features of surface grinding.**

AKTU 2014-15, Marks 10

Answer

Various features of surface grinding are as follows :

1. Flat surfaces are ground on surface grinding machines.
2. The precision achieved by surface grinding is upto ± 0.002 mm.
3. Angular or formed surfaces can also be ground by using special fixtures and from dressing devices.

4. Heavy workpieces are clamped on the table by means of pads, strap clamps and other devices or they are held in fixtures. Small work is usually held by a magnetic chuck.
5. The surface grinders are available with horizontal spindle and vertical spindle and with either reciprocating table or rotary table.
6. In horizontal spindle reciprocating table grinder, grinding is done with the periphery of a straight wheel, besides its rotary motion, the grinding wheel also has a crossfeed motion at each full stroke of the table (back and forth).
7. The other motion is the infeed of the wheel in which it is fed to the depth of cut.
8. In horizontal-spindle rotary-table grinders also use the periphery of the grinding wheel, but the workpieces are held, usually by a magnetic chuck, on a revolving table.

Que 3.16. **Enlist the typical categories of grinding machines and briefly explain them. What are the cylindrical grinding and centerless grinding ?**

AKTU 2017-18, Marks 10

Answer

Typical categories of grinding machine are as follows :

a. **Surface Grinding :**
1. Surface grinding is used for flat or plain surfaces and done with the help of surface grinders
2. We can also give finishing to angular or formed surfaces by using special fixtures and form dressing devices.
3. Types of surface grinding are as follows :
i. Horizontal spindle with reciprocating table,
ii. Horizontal spindle with rotary table,
iii. Vertical spindle with rotary table, and
iv. Vertical spindle with reciprocating table.

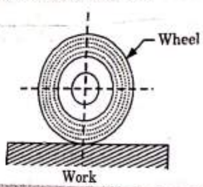


Fig. 3.16.1. Surface grinding (horizontal spindle).

b. **Cylindrical Grinding :**
1. The principle of cylindrical grinding is that the workpiece is held between the centers, it is rotated by a dag and a face plate and rotating wheel is seed against it.
2. Cylindrical grinding is used for grinding cylindrical surfaces which may be parallel, tapered, fillets grooves, shoulders and other formed surfaces of revolution.
3. In the cylindrical grinding, rotating grinding wheel is used, sometimes cylindrical grinder may have multiple grinding wheels.

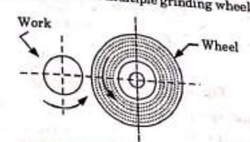


Fig. 3.16.2. Cylindrical grinding.

c. **Internal Grinding :** Internal grinding is similar to other forms of rotational grinding except that as the part rotates the internal features are around by a smaller wheel.

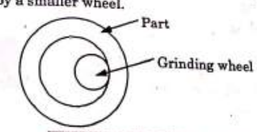


Fig. 3.16.3. Internal grinding.

d. **Centre Grinding :**
1. In centre grinding, the part is secured between two pointed cone shaped centre.
2. It is used to grind multi-diameter shafts and control their concentricity. Centre grinding involves the fixturing part on a spindle axis as it is ground.

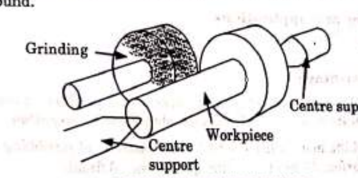


Fig. 3.16.4. Centre grinding.

e. Centreless Grinding :

1. It is the combination of grinding wheel and regulating wheel. Thus centreless grinding does not require centre holes and fixtures for holding the workpiece.

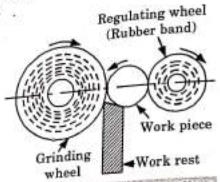


Fig. 3.16.5. Centreless grinding.

2. Centreless grinding is popular as a high speed, low cost operation.
3. Centreless grinding is similar to centred grinding except that there is no spindle.
4. Centreless grinding is of following three types :
   - i. Through feed grinding.
   - ii. In-feed grinding.
   - iii. End-feed grinding.

PART-5

Super Finishing : Honing, Lapping, Polishing.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.17. **What is super finishing ? Mention its advantages, disadvantages and applications.**

Answer

A. Super Finishing :

1. Super finishing is a micro finishing process that produces a controlled surface condition on parts which is not obtainable by any other method.
2. Super finishing also called 'microstoning' consists of scrubbing a stone against a surface to produce a fine quality metal finish.

3. The process includes removing chatter marks and fragmented or smear metal from the surface of a dimensionally finished parts. The method is performed by rapidly reciprocating a fine grit stone with a soft bond and pressing it against a revolving round workpiece.
4. The stone quickly wears to conform to the contour of the workpiece. The workpiece and tool are flooded with a cutting fluid to carry away heat and particles of metal and abrasive.

B. Advantages of Super Finishing :

1. Produces excellent surface finish in a minimum time.
2. Type of surface finish may be pre-selected.
3. Process is easily adapted to high volume production.

C. Disadvantages of Super Finishing :

1. Superfinishing cannot be used to correct feature location, such as concentricity or out of squareness.

D. Application of Super Finishing :

1. Automobile components such as gudgeon pins.
2. Textile and paper mill calendars.
3. Aircraft components.

Que 3.18. **Discuss the honing process in detail with neat sketch.**

AKTU 2014-15, Marks 05

Answer

1. Honing is an operation used primarily to give holes a fine surface finish.
2. The honing tool consists of a set of aluminum-oxide or silicon-carbide bonded abrasives, called stones (Fig. 3.18.1).

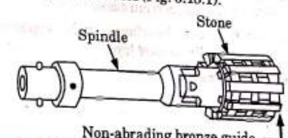


Fig. 3.18.1. Schematic illustration of a honing tool.

3. They are mounted on a mandrel that rotates in the hole, applying a radial force with a reciprocating axial motion, this action produces a cross-hatched pattern.
4. The stones can be adjusted radially for different hole sizes. Honing is also done on external cylindrical or flat surfaces and to remove sharp edges on cutting tools and inserts.

5. The fineness of surface finish can be controlled by the type and size of abrasive used, the pressure applied, and speed. Surface speeds range from about 45 m/min to 90 m/min.
6. A fluid is used to remove chips and to keep temperatures low.
7. If not done properly, honing can produce holes that are neither straight nor cylindrical, but with shapes that are wavy, barrel shaped, or tapered.

Que 3.19. **Explain the lapping process. State its advantages, limitation and uses.**

Answer

A. Lapping :

1. Lapping is a finishing operation used on flat or cylindrical surfaces.
2. The lap is usually made of cast iron, copper, leather, or cloth. The abrasive particles are embedded in the lap, or they may be carried through slurry.

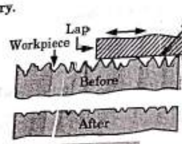


Fig. 3.19.1.

3. Depending on the hardness of the workpiece, lapping pressures range from 7 kPa to 140 kPa.
4. Material removal in lapping usually ranges from 0.003 to 0.3 mm but may reach 0.08 to 0.1 mm in certain cases.
5. Lapping is also done on curved surfaces, such as spherical objects and glass lenses, using specially shaped laps.

B. Advantages of Lapping :

1. Extreme accuracy in both tolerance and geometry.
2. Fast stock removal.
3. No clamping or heat distortion.
4. No expensive tooling required.
5. Irregular shaped parts can be easily processed.

C. Limitations of Lapping :

1. Since lapping is a finishing operation, parts should not be far from the expected size and geometry before lapping.
2. Residue of compound left on the surface of the part after lapping must be removed.

D. Uses of Lapping :

1. Aircraft piston pins.
2. Automotive wrist pins.
3. Diesel engine injector pumps parts.

Que 3.20. **Write short note on following :**
a. **Polishing,**
b. **Chemical mechanical polishing, and**
c. **Electropolishing.**

Answer

a. Polishing :

1. Polishing is a process that produces a smooth, lustrous surface finish.
2. Two basic mechanisms are involved in the polishing process :
   i. Fine scale abrasive removal, and
   ii. Softening and smearing of surface layers by frictional heating during polishing.
3. The shiny appearance of polished surfaces results from the smearing action.
4. Parts with irregular shapes, sharp corners, deep recesses, and sharp projections are difficult to polish.

b. Chemical Mechanical Polishing :

1. Chemical mechanical polishing is a process in which a chemically reactive surface is polished with ceramic slurry in a sodium hydroxide solution.
2. A major application of this process is the polishing of silicon wafers.

c. Electropolishing :

1. It is an electrochemical process that removes material from a metallic workpiece.
2. Mirror like finishes can be obtained on metal surfaces by electropolishing.
3. Because there is no mechanical contact with the workpiece, this process is particularly suitable for polishing irregular shapes.
4. The electrolyte attacks projections and peaks on the workpiece surface at a higher rate than the rest of the surface, producing a smooth surface.
5. Electropolishing is also used for deburring operations.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. What is meant by grit, grade and structure of grinding wheel ?

Ans. Refer Q. 3.6, Unit-3.

Q. 2. Explain grinding wheel specification.

Ans. Refer Q. 3.8, Unit-3.

Q. 3. Explain three different ways in which the wear of grinding wheel takes place. What can be done to prevent them ?

Ans. Refer Q. 3.10, Unit-3.

Q. 4. Show that the maximum chip thickness t_m in surface grinding, using grinding wheel diameter D is given by

$$t_m = \frac{2\,v_t}{b\,C\,V_w}\sqrt{\frac{d}{D}}$$

Where v_t is the table feed, C is the number of abrasive grains per unit area of the grinding wheel surface, V_w is the grinding wheel surface speed, b is the width and d is the depth of cut.

Ans. Refer Q. 3.14, Unit-3.

Q. 5. Enlist the typical categories of grinding machines and briefly explain them. What are the cylindrical grinding and centerless grinding ?

Ans. Refer Q. 3.16, Unit-3.

Q. 6. Discuss the honing process in detail with neat sketch.

Ans. Refer Q. 3.18, Unit-3.

☺☺☺

4 UNIT

Metal Joining (Welding)

CONTENTS

PART-1

Survey of Welding and Allied Processes, Gas Welding and Cutting, Process and Equipment.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. **What is welding ? Explain the importance of welding.**

Answer

A. Welding :

1. The term welding is used to cover a wide range of bonding techniques.
2. It is defined as 'a localized coalescence of metals, wherein coalescence is obtained by heating to suitable temperature with or without the application of pressure and with or without use of filler metal. The filler metal has a melting point approximately the same as that of base metal.
3. A good welded joint is as strong as the parent metal. The product is known as weldment.

B. Importance of Welding :

1. The welding process is readily adaptable to stream line structure and the welded joints are very tight.
2. Welding provides adequate strength to the parts as per the requirements.
3. Welding done in an organised way will provide leak-proof joints.
4. Welding is most rapid and easiest way of fabrication and assembly of metal parts.
5. Welding is extensively used in the following fields : automobiles industry, aircraft machine frames, structural work, tanks, machine repair work, ship building, refineries, and fabrication of metal structures.

Que 4.2. **Classify welding processes.**

Answer

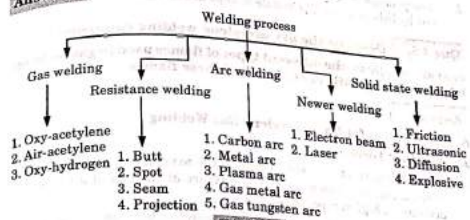


Fig. 4.2.1.

Que 4.3. **Briefly describe the gas welding process.**

Answer

1. Gas welding is a process that uses fuel gas and oxygen to weld.
2. In gas welding, a welding torch is used to weld metals.
3. Welding metal results when two pieces are heated to a temperature that produces a sharp pool of molten metal.
4. The molten pool is generally supplied with additional metal called filler metal.
5. Filler material depends upon the metals to be welded.

Que 4.4. **Describe gas cutting process.**

Answer

1. Gas cutting is the most commonly and convenient method in use now-a-days for cutting of metals.
2. The principle on which it is based is that oxygen has a strong affinity for iron and steel at elevated temperatures (760–870 °C), the action being less at low temperatures.
3. At high temperature oxygen forms iron oxide (rust) with iron which has low melting temperature and at high temperatures it melts out and the metal is cut.
4. Thus if steel is first heated to a red colour and then a jet of pure oxygen is blown on the surface, instantaneously the steel is burned in an iron oxide slag-like appearance which under pressure falls down and steel is cut.

5. The process is very rapid and metals upto thickness of 7.5 cm can be cut by this process. The nozzle is kept about 4 mm above the work.

Que 4.5. **Describe the oxy-acetylene welding equipments with neat sketch. Draw the different types of flames used in gas welding. What are the specific uses of each of these flames ?**

Answer

A. Equipment for Oxy-Acetylene Gas Welding :

a. Welding Torch :

1. The welding torch is a tool for mixing the oxygen and acetylene in the desired volumes and burning the mixture at the end of a tip, which produces a high temperature flame.
2. The welding torches have a handle at one end with two inlet connections for gases.

b. Welding Torch Tip :

1. The welding torch tip (also called nozzle) is that portion of torch through which the gases pass just prior to their ignition and burning.
2. The tips are made of high thermal conductivity material, such as copper or copper alloy.

c. Pressure Regulators : The pressure regulators perform the following functions :

1. It reduces the source pressure (from generator, cylinder manifold or pipe line) to a workable pressure.
2. It maintains the constant delivery pressure and gas volumetric rate regardless of pressure variations at the source.
3. It permits adjustment to deliver gas at a certain desired pressure within its rated pressure range.

d. Hose and Hose Fittings :

1. The hose for welding torches should be strong, durable, non-porous, light and flexible.
2. Two lengths of hose (one for oxygen and one for acetylene) are required to connect the regulator and the torch.
3. The standard colour for oxygen hose is black and for acetylene hose is red.
4. The special hose fittings or connections are provided for attachments to the torch and pressure regulators.

e. Gas Cylinders :

1. The oxygen and acetylene are usually obtained from strong steel cylinders, which are filled by commercial suppliers of these gases.

2. The oxygen cylinders are usually filled at a pressure of 12.5 to 14 MN/m^2 and have capacity of 6.23 cubic meter.
3. The acetylene is stored in cylinders under an initial pressure of 1.545 kN/m^2 and has the capacity of 7.6 cubic meter.

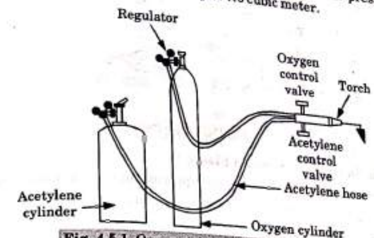


Fig. 4.5.1. Oxy-acetylene welding equipment.

f. Spark Lighter :

1. It provides a convenient and instant means for lighting the welding torch.

B. Types of Flame :

a. Neutral Flame :

1. This type of flame is obtained by supplying equal volumes of oxygen and acetylene.
2. The neutral flame, as shown in Fig. 4.5.2 has the following two sharply defined zones :
   i. An inner luminous cone, and
   ii. An outer cone or envelope of bluish colour.

Uses : The most of the oxy-acetylene welding (e.g., welding of steel, cast iron, copper, aluminium etc.) is done with the neutral flame.

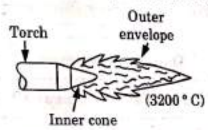


Fig. 4.5.2. Neutral flame.

b. Oxidizing Flame :

1. This type of flame is obtained where, there is an excess of oxygen.

2. It is similar to neutral flame but the inner cone is less luminous and shorter as shown in Fig. 4.5.3.

Uses : It is used for welding brass and bronze.

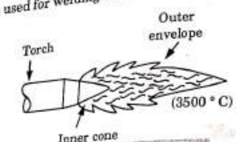


Fig. 4.5.3. Oxidizing flame.

c. **Reducing or Carburizing Flame :**

1. This type of flame is obtained by supplying an excess of acetylene.
2. This flame, as shown in Fig. 4.5.4 has the following three zones :
   i. An inner cone,
   ii. An intermediate cone of whitish colour, and
   iii. An outer cone of bluish colour.

Uses : This flame is used where it is required to keep oxidation to a minimum. It is used for welding of molten metal, certain alloy steels, many of the non- ferrous, hard surfacing materials.

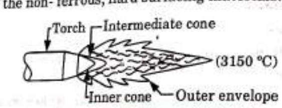


Fig. 4.5.4. Carburizing flame.

PART-2

Arc Welding, Power Sources and Consumables, TIG and MIG Processes and their Parameters.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.6. **What is arc welding ? Discuss different types of arc in arc welding.**

AKTU 2017-18, Marks 10

Answer

A. **Arc Welding :**

1. Arc welding is a welding process wherein coalescence is produced by heating with an electric arc.
2. Most of the electric arc welding is done by without pressure and with or without use of filler metal depending upon the parent plate thickness.
3. Electric arc is formed when an electric current passes between two electrodes separated by a short distance from each other.
4. In arc welding, one electrode is the welding rod or wire while other is the metal to be welded (workpiece).
5. Arc connected to the supply, one to the positive terminal and other to the negative terminal.
6. Arc is started by momentarily touching the electrode on the plate and then withdrawing it to about 3 to 4 mm from the plate.
7. When the electrode touches the plates, a current flows and as it is withdrawn from the plate the current continues to flow in the form of a spark across the very small gap first formed, this cause the air gap to become ionised or made conducting and as a result the current is able to flow across the gap.

B. **Different types of Arc in Arc Welding :**

a. **Short Arc :**

1. With small current, the droplet does not form until it touches the weld pool, this mode of arc is so called short arc.

b. **Globular Arc :**

1. The arc mode changes to a globular arc when the current is increased so that a small electromagnetic force is generated.
2. In globular arc, the diameter of the droplet is bigger than the electrode and the droplet is formed by the gravitational force.

c. **Spray Arc :**

1. By further increasing the current, the type of arc changes to a projected spray arc, then a streaming arc and finally a rotating arc.
2. A spray arc is categorized in following three types :

i. Projected spray,
ii. Rotating spray, and
iii. Streaming spray.

Que 4.7. **What are various types of arc welding power sources ? Give the advantages and limitations of each.**

AKTU 2015-16, Marks 10

Answer

A. Various Types of Arc Welding Power Sources :

a. DC Power Sources : These are :

1. DC generator set,
2. AC-DC rectifiers, and
3. Thyristor controlled rectifiers.

b. AC Power Sources : These are :

1. AC generators.
2. AC transformers.

B. Advantages and Disadvantages of DC Power Sources :

a. Advantages of DC :

1. Straight and reverse polarity can be employed.
2. Welding at all positions.
3. Nearly all ferrous and non-ferrous alloys can weld.
4. Generator output is not affected by power line.

b. Limitations of DC :

1. High initial cost.
2. Higher maintenance cost.
3. Noisy machine operation.

C. Advantages and Disadvantage of AC Power Source :

a. Advantages of AC :

1. Least expensive and small welding machine.
2. Freedom of magnet arc blow.
3. Workpiece does not get magnetized.
4. Operation is noiseless and wearless.

b. Limitations of AC :

1. Polarity cannot be changed.
2. Starting the arc is difficult.
3. Poor power factor.

Que 4.8. **Explain TIG and MIG welding process and enumerate its advantages.**

AKTU 2016-17, Marks 10

Answer

A. TIG Welding :

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job.
2. A shielding gas (argon, helium, nitrogen etc.) is used to avoid atmospheric contamination of the molten weld pool.

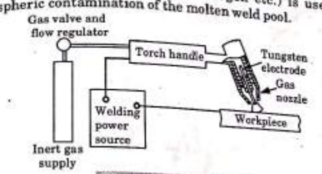


Fig. 4.8.1. TIG welding.

3. This method avoids breaking of electrode tip, job contamination and tungsten loss.
4. TIG welding is also known as gas tungsten arc welding (GTAW).
5. Both the AC and DC power source can be used for GTAW.
6. Electrodes employed varies in diameter from 0.5 to 6.5 mm carrying current from 5 A to 6.5 A.
7. GTAW is an all position welding and gives the highest quality weld amongst commonly used arc welding processes.

i. Advantages of TIG Welding :

1. No flux is required because inert gas shields molten metal. So no slag and slag inclusion problems.
2. High quality and strong welding achieved by TIG.
3. It can produce joint with deep penetration.
4. TIG are suitable for welding of very thin sections.
5. TIG can work with and without filler metal.
6. Non-corrosive and ductile joints.
7. The minimum amount of flames and spark. Less distortion due to small heat zone.

B. MIG Welding :

1. It is an arc welding process wherein coalescence is produced by heating the job with an electric arc established between a continuously fed metal electrode and the job.
2. No flux is used but the arc and molten metal are shielded by an inert gas, which may be argon, helium, carbon dioxide or a gas mixture.
3. MIG welding is also known as gas metal arc welding (GMAW).
4. In general, metal transfer takes place from electrode to workpiece in the form of spray at high rate of current.

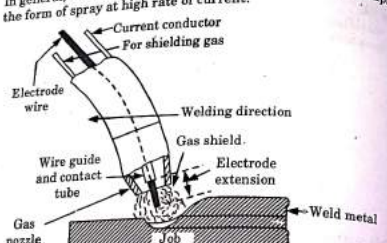


Fig. 4.8.2. MIG welding operation.

i. Advantages of MIG Welding :

1. High quality welds can be produced much faster.
2. There is no chance for the entrapment of slag in the weld metal resulting in high quality welds.
3. The gas shield protects the arc so that there is very little loss of alloying elements.
4. MIG welding is versatile and can be used with a wide variety of metals and alloys.
5. The MIG process can be operated in several ways, including semi and fully automatic.

Que 4.9. Differentiate TIG welding and MIG welding.

AKTU 2014-15, Marks 05

Answer

S. No.	Tungsten Inert Gas Welding (TIG)	Metal Inert Gas Welding (MIG)
1.	In TIG welding, a non-consumable electrode is used.	In MIG welding, a consumable electrode is used.
2.	TIG welding electrode serves the purpose of producing the arc only, filler rod needed if any.	MIG welding wire serves both the purpose of producing the arc as well as of filler metal.
3.	TIG welding process is not as faster as MIG welding process as separate filler rod is added.	MIG is faster process as compared to TIG because no filler rod is added separately.
4.	TIG welding requires a skill operator.	Not so much skill operator is needed.
5.	TIG welding torch may be water cooled.	MIG welding torch is not water cooled.
6.	Penetration is not so much deeper as compared to MIG.	Deeper penetration can be achieved very easily.
7.	TIG welding is not recommended for greater than 6 mm thickness of sheet.	No such condition applicable in MIG welding.

Que 4.10. It is required to weld a low carbon steel plate by manual metal arc welding process using a linear VI characteristics DC power source. The following data are available :
Open circuit voltage = 62 V, short circuit current = 130 A, arc length = 4 mm, transverse speed of welding = 15 cm/min. Voltage = 20 + 1.5 L (L is arc length), efficiency of heat input = 0.84, calculate the heat input to the workpiece.

AKTU 2018-19, Marks 07

Answer

Given : V_{oc} = 62 V, I_{sc} = 130 A, L = 4 mm, v = 15 cm/min, $V = 20 + 1.5\,L$, $\eta_{input} = 0.84$

To Find : Heat input to the workpiece.

1. We know that,

$$\frac{I}{I_{sc}} + \frac{V}{V_{oc}} = 1$$

$$\frac{I}{130} + \frac{V}{62} = 1$$

$$V = 62\left(1 - \frac{I}{130}\right)$$

2. At stable operation, arc characteristics equal to supply characteristics,

$$62 - \frac{62\,I}{130} = 20 + 1.5\,L$$

$$\therefore \quad 130\,(42 - 1.5\,L) = 62\,I$$

$$I = \frac{130}{62}(42 - 1.5\,L) \qquad [\because L = 4]$$

$$I = \frac{130}{62}(42 - 1.5 \times 4) = 75.48 \text{ A}$$

3. Voltage at $L = 4$ mm, $V = 20 + 1.5 \times 4 = 26$ V

4. $$\text{Heat input} = \left(\frac{\text{Voltage} \times \text{Current}}{\text{Welding speed}}\right) \times \eta_{input}$$

$$= \left(\frac{26 \times 75.48}{150}\right) \times 0.84 = 10.98 \text{ J/mm}$$

PART-3

Resistance Welding, Spot, Seam, Projection Welding.

CONCEPT OUTLINE

Resistance Welding : Resistance welding is a group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part and by the applications of pressure. No filler metal is needed.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.11. **Briefly describe the main features of resistance welding process with a neat sketch.** **AKTU 2014-15, Marks 10**

Answer

1. In resistance welding, a heavy electric current is passed through the metals to be joined over a limited area causing them to be locally heated to plastic state and the weld is completed by the application of pressure for a prescribed period of time. No additional filter metal is required.

2. Resistance welding is employed mainly for mass production.
3. It is easily adapted to those components which can be moved to the machine and are light.
4. The operation is extremely rapid and simple.
5. This is the only process where heat can be controlled and which permits a pressure action at the weld.
6. This process is suited to nearly all metals except tin, lead, zinc etc. which exhibit many problems.
7. Resistance welding is also one of the types of pressure welding process during which the pressure is applied.
8. Basic working principle of resistance welding depends upon,

$$H = I^2RT$$

Where, H = Heat generated,
I = Current required during welding,
R = Resistance, and
T = Time in second during which current flow.

9. The voltage can be low, typically 0.5 to 10 V, but current is very high.
10. However, heavy current can be easier and more efficiently applied through transformers, and therefore, in practice only alternating current is used in resistance welding.

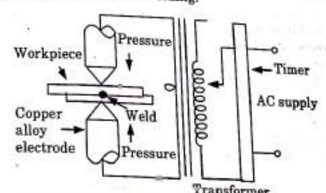


Fig. 4.11.1. Resistance welding block diagram.

Que 4.12. **Classify resistance welding. Also write down the advantages, disadvantages and applications of resistance welding.**

Answer

A. **Types of Resistance Welding :**
1. Spot welding,
2. Seam welding,
3. Projection welding,

4. Percussion welding,
5. Flash butt welding, and
6. Resistance (upset) butt welding.

B. Advantages of Resistance Welding :

1. No filler rod or electrode is required.
2. High rate of production.
3. Semi-skilled operator can perform welding very easily.
4. No part warping or distortion.
5. No need of edge preparation.

C. Disadvantages of Resistance Welding :

1. All types of metal cannot be welded.
2. Complex shapes and bigger jobs cannot be joined.
3. Welding joint is not so strong.
4. Initial cost of equipment is high.

D. Applications of Resistance Welding :

1. This is used for joining sheets, tubes, aircraft and automobile parts, fuel tank, wire fabrics, grills and containers.

Que 4.13. **Write a short note on the following types of resistance welding :**
a. Spot welding,
b. Seam welding, and
c. Projection welding.

Answer

A. Spot Welding :

1. In resistance spot welding, the overlapping metal parts are held between two bar type metal electrodes which apply pressure, while an electric current is passed through them.

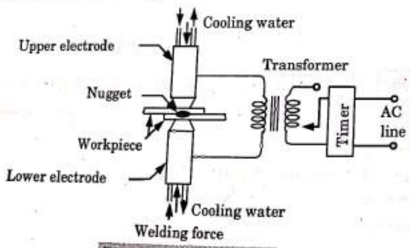


Fig. 4.13.1. Spot welding.

2. When the current is switched on and applied for as predetermined number of cycles, the lapped pieces of metal are heated in a restricted area.
3. The generated heat melts the surface layer of metal in the central, more highly heated, area of contact with the electrodes, and the adjacent layers of metal are softened to a plastic state.
4. Then the current is switched off and the electrodes are pressed and the pressure is released only after weld nugget has solidified.
5. It is fast and efficient process.

B. Seam Welding :

1. Seam welding is the process of joining two similar or dissimilar materials at the seam by the use of electric current and pressure.
2. A series of spot welds along a line can be obtained more conveniently and rapidly in seam welding where the electrodes are in the form of rotating disc electrodes, with the work being welded moving continuously by the electrodes.
3. Rollers may vary in diameter from 40 to 350 mm.
4. Welding currents range from 2000 to 5000 A while the force applied to the rollers may be as high as 5 to 6 kN and welding speed is from 0.5 to 3.5 m/min.
5. In most cases of seam welding, a stream of water is directed over the disc electrodes except the joint interface.

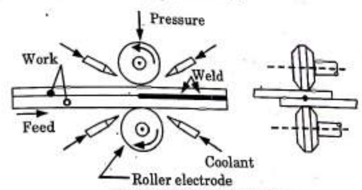


Fig. 4.13.2. Seam welding.

C. Projection Welding :

1. In this welding, the current is concentrated at the spots to be welded when small projections are embossed on one of the sheets.
2. When the current is applied, the projections soften and are pushed back in place by the electrode pressure as the weld nuggets form.
3. Also, because larger diameter electrodes can be used with a greater heat capacity, the need for water cooling is often eliminated.
4. The projections tend to localize the heat, permitting thicker materials to be welded resulting in a stronger weld structure.

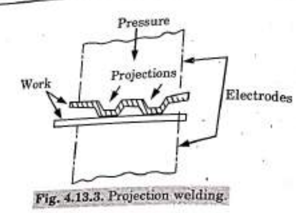


Fig. 4.13.3. Projection welding.

5. This is used in automobile industry for joining nuts, bolts and studs to steel plates in car bodies.

PART-4

Other Welding Processes Such as Atomic Hydrogen, Submerged Arc Welding.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.14. Explain the principle and working of atomic hydrogen welding process. What is resistance welding ? Write its advantages, limitations and applications. **AKTU 2017-18, Marks 10**

Answer

A. Atomic Hydrogen Welding :

a. Principle : In atomic hydrogen welding, heat is obtained from an electric arc maintained between two electrodes of tungsten in an atmosphere of shielding gas (hydrogen).

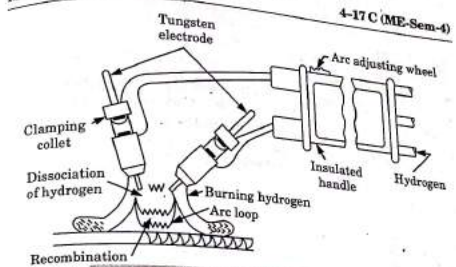


Fig. 4.14.1. Principle of atomic hydrogen welding.

b. Working :

1. Atomic hydrogen welding process is a combination of electric arc welding process and gas welding process.
2. In this process electrode holder consists of two tungsten electrode which are arranged in an inclined position and hydrogen nozzle is placed in between the tips of these electrodes to eject the hydrogen.
3. Thus hydrogen molecules break into atomic hydrogen as electric arc strikes and when this atomic hydrogen touches the cold metal, it recombines into molecular hydrogen due to which heat generates and this heat melts the metal.
4. This molten metal is further used for welding and the atomic hydrogen proceeds with the absorption of heat involving reaction as,

$$H_2 \rightleftharpoons 2H - 421.2 \text{ kJ/mol}$$

5. This atomic hydrogen recombines to form molecular hydrogen outside the arc involving reaction as,

$$2H \rightleftharpoons H_2 + 421.2 \text{ kJ/mol}$$

B. Resistance Welding : Refer Q. 4.11, Page 4-12C, Unit-4.

C. Advantages, Limitation and Application : Refer Q. 4.12, Page 4-13C, Unit-4.

Que 4.15. Explain the working of submerged arc welding with the help of suitable diagram, also write down their specific application and advantages and limitations. **AKTU 2018-19, Marks 07**

Answer

A. Working of SAW :

1. In this kind of welding, the flux begins for depositing on the joint to be welded. Whenever the flux is cold, then it acts as an insulator.
2. The arc can be started by moving the tool by the work portion. The arc struck will constantly remain below a wide coating of flux, and the generated heat by the arc softens the granular flux.

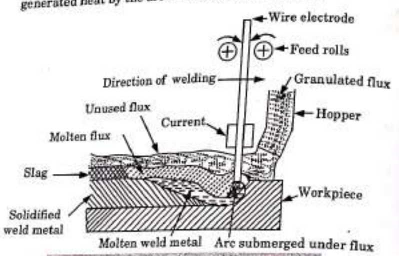


Fig. 4.15.1. Submerged arc welding operation.

3. Once the flux is melted by the heat of the arc, then it will become highly conductive.
4. The flow of current begins to flow the electrode through the melted flux that can be in contact by the atmosphere.
5. At a fixed speed, the electrode from the roll is constantly fed toward the joint to be linked.
6. With the help of the self-adjusting arc principle, the length of the arc is kept stable. When the arc length reduces, the arc voltages will increase and this will increase the arc.
7. This result in the welding of the workpiece.

B. Advantages of SAW :

1. Deep weld penetration.
2. Sound welds are readily made with good process design and control.
3. High speed welding of thin sheet steels at over 2.5 m/min is possible.
4. Minimal welding fume or arc light is emitted.

C. Limitations of SAW :

1. Limited to ferrous (steel or stainless steels) and some nickel based alloys.

2. Normally limited to long straight seams or rotated pipes or vessels.
3. Requires relatively troublesome flux handling systems.
4. Flux and slag residue can present a health and safety issue.
5. Requires inter-pass and post weld slag removal.

D. Applications of SAW :

1. Fabrication of pipes, penstocks, pressure vessels, boilers, structural shapes, rail road, and earth moving equipment, cranes, bridge girders and under structure of railway coaches and locomotives.
2. Automotive, Aviation, ship-building and nuclear power industry.
3. For welding metals like mild steel, medium and high tensile low alloy steels.

PART-5

Electroslag, Friction Welding.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.16. **What is electroslag welding ? Also write down the advantages and disadvantages of electroslag welding.**

Answer

A. Electroslag Welding :

1. Electroslag welding is a type of arc welding wherein the coalescence is produced by molten slag which melts the filler metal and the surface of the work to be welded, electroslag welding is quite similar to vertical submerged arc welding.
2. In electroslag welding process, a granular flux is placed in the gap between the plate being welded and as the current is turned on, welding takes place in a water cooled copper shoes that bridge the gap of the joint as the flux melts, a slag blanket from 25.4 to 38.1 mm thickness is formed, high resistance of the slag causes most of the heating for the remainder of the weld thus electroslag welding is a progressive process of melting and solidification from the bottom to upward.
3. The maximum thickness that can be weld by this process is upto 100 mm.

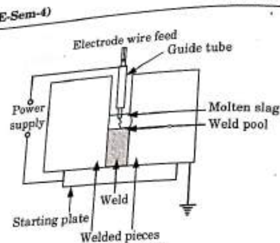


Fig. 4.16.1.

4. Molten metal and slag are retained in the joint by means of copper shoes that automatically move upward as the weld progresses by means of a temperature sensitive mechanism.

B. Advantages of Electroslag Welding :

1. Joint preparation is quite simple as compared to other welding processes.
2. Very high thickness plate can be very easily welded in a single pass more economically.
3. It gives extremely high deposition rate.
4. Distortion and thermal stresses are in very low percentage.
5. Flux consumption is very low.

C. Disadvantages of Electroslag Welding :

1. Process is only limited to vertical position.
2. Electroslag welding tends to produce rather large grain size.
3. Complex shape joint cannot be welded by this process.
4. More chances of hot cracking and notch sensitivity in the heat affected zone.

Que 4.17. **What do you understand by friction welding process ? Also give its advantages and disadvantages.**

Answer

A. Friction Welding :

1. Friction welding is defined as a solid state welding process wherein coalescence is produced by heat obtained from mechanically induced sliding motion between the rubbing surfaces. The parts are held together under pressure.

2. In this welding process, one part is rotated at relatively high speed and under pressure against the second part which is held stationary.
3. The frictional work at the contacting surfaces is transformed into heat.
4. The contacting surfaces are thus heated to a high temperature below the melting temperature.
5. At this point, the relative motion between the two is stopped.
6. The weld is then completed due to the pressure which still continues or additional pressure may be necessary to produce a solid state weld.

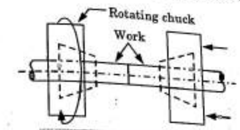


Fig. 4.17.1. Friction welding.

7. This method is most suitable for circular parts, that is, butt welding of round bars or tubes.

B. Advantages of Friction Welding :

1. Low initial capital cost and power requirement.
2. Annealing of weld zone is not necessary.
3. Very little loss of material through exclusions.
4. The process welds the whole surface of contact.
5. No flux, gas filler metal or slag present to cause imperfection in weld, no smoke too.
6. Heat affected zone is very narrow.

C. Disadvantages of Friction Welding :

1. Process is limited to only butt welding, complicated or complex shape cannot be welded.
2. Process is limited only for joining of small pieces in the form of bar stock.
3. Occasionally heavy flash is formed.
4. Process is not suitable for short run production.

PART-6

Soldering and Brazing, Adhesive Bonding.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.18. Discuss soldering and brazing process.

AKTU 2017-18, Marks 10

Answer

A. **Soldering :**

1. It is a method of joining two or more pieces of metal sheets by means of a fusible alloy or metal, called solder, applied in the molten state.
2. The melting point of the filler metal is above 427 °C.
3. Soldering operation is performed by bringing molten solder in contact with the preheated surfaces and heating the joint area to a good wetting temperature about 55 to 80 °C above the melting point of soldering alloy.
4. Solder is then left to cool and freeze as quickly as possible to avoid development of internal cracks in the joint.
5. Due to molecular attraction surface molecules of solder enter within the parent metal molecules and form a strong bond.

B. **Brazing :**

1. Brazing is used for joining the two similar or dissimilar metal pieces together by heating the surface and by using a non-ferrous filler metal having its melting point above 427 °C but below the melting point of metal to be brazed.
2. The molten filler metal is distributed between the joint surfaces by the capillary action which on cooling results in a sound joint.
3. The main advantage of brazing process is joining of dissimilar metals and thin sections.
4. In addition to it, it is a quick process and the joint requires minimum of finishing operations.

Que 4.19. Write a note on various brazing methods.

AKTU 2016-17, Marks 06

Answer

Various methods of brazing are as follows :

a. **Torch Brazing :**

1. It is used to join relatively small assemblies made from materials that either do not oxidise at the brazing temperature or can be protected from oxidation with a flux.
2. Aluminium-silicon alloys, silver base alloys and copper-zinc alloys are used as the filler metals with proper flux. The self fluxing copper-phosphorus alloys are also used.

b. **Furnace Brazing :**

1. It can be used if the parts to be joined can be pre-assembled and placed in a jig and the filler metal can be placed in contact with the joint, or the part can survive uniform heating.
2. Although brazing can be done in an air furnace with a flux, a protective atmosphere depending upon the materials being brazed and the filler metals used is usually necessary.

c. **Dip Brazing :**

1. It is frequently used to braze aluminium assemblies because the temperature of the molten flux bath can be closely controlled. The molten bath serves as the heating medium as well as the fluxing agent.
2. Parts are cleaned and assembled together in fixtures during brazing.
3. Parts are normally preheated before immersion.

d. **Resistance Brazing :**

1. It is used when small areas are to be brazed and the electrical conductivity of the joint members is high.
2. Brazing is done by the conventional resistance welding machines.

e. **Infrared Brazing :**

1. The heat source in infrared brazing is a high intensity quartz lamp.
2. This process is particularly suitable for brazing very thin components, usually less than 1 mm thick.

Que 4.20. Write down the advantages, disadvantages and applications of brazing.

Answer

A. **Advantages of Brazing :**

1. Cast and wrought material can be joined easily.
2. Metallurgical properties of the base material are not seriously distributed.
3. Assemblies can be brazed in a stress free condition.
4. Material of different thickness can be joined easily.

5. Little or no finishing is required by the brazed joints.

B. Disadvantages of Brazing :

1. It requires tightly mating parts and proper cleaning.
2. Joints are not successful at elevated temperature.
3. Colour of the filler metal may not match that of the base metal.
4. High degree of skill is required.

C. Applications of Brazing :

1. Parts of bicycle such as frames and rims.
2. Pipe joints subjected to vibrations.
3. Exhaust pipe in motor engine.
4. Band saws and tipped tool.

Que 4.21. Explain various methods of soldering. Also write advantages, disadvantages and applications of soldering.

Answer

A. Methods of Soldering :

a. Torch Soldering Method :

1. A torch soldering is used to provide heat and is the fast and versatile process of heating.
2. Soldering torches are available in different design for example gasoline blow torch, oxy-acetylene soldering torch etc.
3. These types of torches ensure a clean flame to heat the surfaces to be soldered, heat of flame is easily adjustable.
4. This process of soldering finds extensive use in refrigeration and air conditioning plants, building up of irregular surfaces to get a finished surface threaded connections in plumbing are being replaced by soldering.

b. Dip Bath Method :

1. In this type of soldering method, solder is melted in a pot and protected against atmospheric contamination by using a hood or cover on the pot or by providing a chemical coverage by powdered charcoal.
2. The workpiece is first dipped in the flux bath and later in the solder bath.
3. The object soldered with this method are required to be cleaned before they are coated with flux and soldered as the moisture present on the workpiece may produce instant high temperature steam leading to the explosion of bath.

c. Wave Soldering Method :

1. This is an automatic process of soldering used for the manufacturing of printed circuit boards wherein the components are pass over a wave of molten solder.
2. All components of the circuit are bonded in one quick operation as the molten solder is pumped vertically upward through a narrow slot forming a steady wave.
3. This way, the dynamic movement of the solder across the work surface improves melting, minimize heat distortion resulting in an oxide free bright surface of solder.

B. Advantages of Soldering :

1. Low investment cost.
2. Simplicity and cheapness of the equipment.
3. Properties of parent metal are not affected due to low operating temperature.
4. Good and effective sealing in fabrication as compared to other process like riveting, spot welding and bolts.

C. Disadvantages of Soldering :

1. Large sections cannot be joined.
2. Fluxes may contain toxic components.
3. Low strength of joints.

D. Applications of Soldering :

1. Connections in wireless set, TV sets, and wiring joints in electrical connections, battery etc.
2. Drain water gutters and pipes.
3. Radiator brass tube for motor car.
4. When halved bearings are to be line with Babbitt metal.
5. Copper tubing carrying liquid fuel, gas or air used on engine.

Que 4.22. Write short note on adhesive bonding.

Answer

1. The adhesive bonding process is most commonly used in the aircraft and automobile industries where sheet metals are joined in various configurations.
2. In adhesive bonding, unlike in brazing and soldering, there is no uncertainty about the flow of the adhesive in the joint. This is so because the adhesive is first applied on the surfaces and the joint is made with subsequent application of heat and pressure.
3. Two types of bonding forces take part in an adhesive joint. Of these, one is the Van der Waals force due to the constant movement of the positive and the negative charges of molecules. The other is the polar force between the adhesive and the relatively brittle oxide film due to the dipole adhesive molecules.

4. The coefficient of thermal expansion and the elastic properties of the adhesive normally differ widely from those of the metals to be joined. Therefore, the mechanical properties of an adhesive joint need a careful examination.
5. The factors that affect the strength and the other mechanical properties of such a joint are :
   i. The nature and dimension of the joint,
   ii. The contact angle at the solid-liquid interface, and
   iii. The residual stress and the stress concentration.

PART-7

Weld Decay in HAZ

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.23. **What is HAZ in welding ? Why weld usually fails in HAZ ?**

Answer

A. Heat Affected Zone (HAZ) :

1. HAZ is the portion near the weld metal zone which is composed of parent metal and did not melt but heat to a enough high temperature for a sufficient period. Due to this heating, mechanical properties and microstructure of this zone have been changed.
2. The HAZ in low carbon steel of normal structure welded in one run with coated electrodes or by submerged arc welding process comprises of following three metallurgical different regions :

a. Grain Growth Region :

i. This region is immediately adjacent to the weld metal zone.

ii. In this zone, base metal is heated to a temperature well above the upper critical temperature. This results in grain growth and coarsening of the structure.

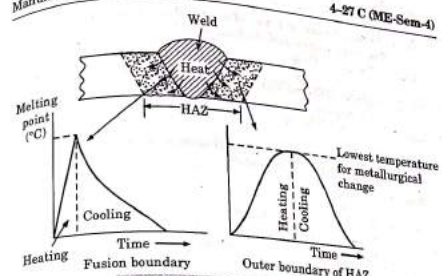


Fig. 4.23.1. HAZ boundary.

b. Grain Refined Region :

i. This region is adjacent to the grain growth region. In this region, base metal is heated just above the upper critical temperature where grain refined is completed and finest grain structure exists.

c. Transition Zone :

i. This region exists in a temperature range between the upper and lower critical transformation temperatures where partial allotropic recrystallization takes place.

B. Reasons for the Failure of Weld in HAZ : The failure of weld is due to weld decay. The weld decay caused by following reasons :

1. The time and the temperature of exposure.
2. The composition and prior treatment of the weld.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Describe the oxy-acetylene welding equipments with neat sketch. Draw the different types of flames used in gas welding. What are the specific uses of each of these flames ?

Ans. Refer Q. 4.5, Unit-4.

Q. 2. What are various types of arc welding power sources ? Give the advantages and limitations of each.

Ans. Refer Q. 4.7, Unit-4.

Q. 3. Explain TIG and MIG welding process and enumerate its advantages.

Ans. Refer Q. 4.8, Unit-4.

Q. 4. Briefly describe the main features of resistance welding process with a neat sketch.

Ans. Refer Q. 4.11, Unit-4.

Q. 5. Explain the principle and working of atomic hydrogen welding process. What is resistance welding ? Write its advantages, limitations and applications.

Ans. Refer Q. 4.14, Unit-4.

Q. 6. Explain the working of submerged arc welding with the help of suitable diagram, also write down their specific application and advantages and limitations.

Ans. Refer Q. 4.15, Unit-4.

Q. 7. Discuss soldering and brazing process.

Ans. Refer Q. 4.18, Unit-4.

Q. 8. What is HAZ in welding ? Why weld usually fails in HAZ ?

Ans. Refer Q. 4.23, Unit-4.

☺☺☺

5 UNIT

Unconventional Machining Processes

CONTENTS

PART-1

Abrasive Jet Machining, Water Jet Machining, Abrasive Water Jet Machining.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. **Explain abrasive machining process. Also classify abrasive machining process. Explain centerless grinding with the help of neat sketch.**

AKTU 2018-19, Marks 07

Answer

A. Abrasive Machining Process :

1. Abrasive machining is a machining process where material is removed from a workpiece using a multitude of small abrasive particles.
2. Common examples include grinding, honing, and polishing. Abrasive processes are usually expensive, but capable of tighter tolerances and better surface finish than other machining processes.
3. Abrasive machining works by forcing the abrasive particles or grains into the surface of the workpiece so that each particle cuts away a small bit of material.
4. Abrasive machining is similar to conventional machining, such as milling or turning, because each of the abrasive particles acts like a miniature cutting tool.
5. Abrasive machining is less power efficient and generates more heat.
6. The grain size may be different based on the machining. For rough grinding, coarse abrasives are used and for fine grinding, fine abrasives are used.

B. Classification of Abrasive Machining Process :

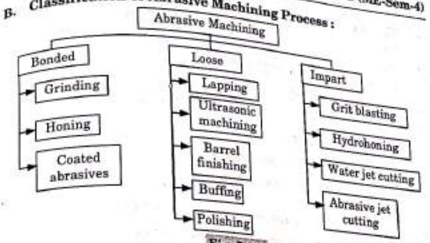


Fig. 5.1.1.

C. Centerless Grinding : Refer Q. 3.16, Page 3-16C, Unit-3.

Que 5.2. **Explain how the operation of AJM is carried out. What are the limitations of AJM ?**

AKTU 2014-15, Marks 10

Answer

A. Operation of Abrasive Jet Machining (AJM) :

1. The principle of abrasive jet machining is the use of a high speed stream of abrasive particles carried by a high pressure gas on the workpiece through a nozzle.
2. The material removal will take place due to erosion caused by the abrasive particles imparting the workpiece surface at high speed.
3. When abrasive particles are propelled by inert gas at very high velocity on the workpiece, the erosion will occur on the surface of the workpiece.

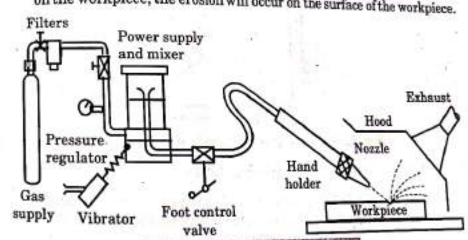


Fig. 5.2.1. Abrasive jet machining.

4. The material removal occurs through a chipping action which is especially effective on hard and brittle materials.
5. In this process, there is no thermal damage because the abrasive propellant gas carries heat away.

B. Limitation of AJM :

1. There is a possibility, that particles can be embedded into workpiece.
2. It have low metal removal rate.
3. Requirement of dust removal system.
4. Possibility of stray abrasive action.

Que 5.3. **What is abrasive jet machining (AJM) ? Describe its working with suitable diagram. Also explain the effect of stand-off distance and abrasive grit size on material removal rate in the AJM.**

AKTU 2018-19, Marks 07

Answer

A. Abrasive Jet Machining and Working of AJM : Refer Q. 5.2, Page 5–3C, Unit-5.

B. Effect of Stand-off Distance On MRR :

1. The MRR increases as the stand-off distance increases but when it reaches to maximum value, it decreases.
2. As the stand-off distance increases, all the particles are effectively utilised thus increasing the MRR, so the kinetic energy of the particles touching the surface decreases.

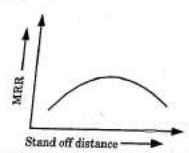


Fig. 5.3.1. Variation of MRR with stand off distance.

C. Effect of Abrasive Grain Size on MRR :

1. Bigger size of abrasive grain gives higher material removal rate for any flow rate of the abrasive, but the bigger size particles are limited because of internal diameter of the nozzle.

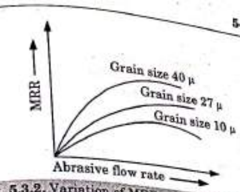


Fig. 5.3.2. Variation of MRR with abrasive flow rate.

Que 5.4. **With neat sketch briefly explain the principle and working of water jet machining (WJM). Also write down its advantages, disadvantages and applications.**

Answer

A. Principle :

1. In the water jet machining process, water is forced through tiny nozzles under very high pressure to machine the materials like, polymer, brick and paper.

B. Working :

1. Water is pumped at a high pressure (200 – 400 MPa) using intensifier technology.
2. An intensifier works on the simple principle of pressure amplification using hydraulic cylinders of different cross-sections.
3. When water at such pressure is issued through a suitable orifice (generally of 0.2 – 0.4 mm diameter), the potential energy of water is converted into kinetic energy.
4. This high velocity water jet can machine thin sheets of aluminium, leather, textile etc.

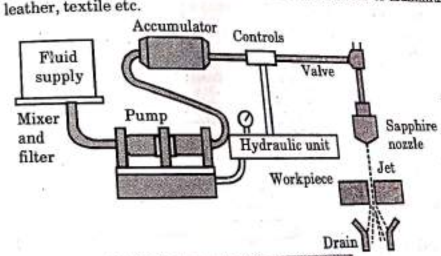


Fig. 5.4.1. Water jet machining.

C. **Advantages :**

1. There is no heat generation.
2. There is no distortion during machining.
3. There is no need of pre-machining.
iv. It does not leave any rough edge.

D. **Disadvantages :**

1. Limited number of material can cut economically.
2. This process is costly.
3. It cannot machine thick sheets.

E. **Applications :**

1. Used in paint removal.
2. Used in cutting soft materials.
3. Used in drilling and turning.
4. Used in textile and leather industry.

Que 5.5. Explain the working principle of abrasive water jet machining.

Answer

1. Abrasive water jet machining (AWJM) is a non-conventional machining process.
2. In this process, the mechanical energy of water and abrasive phases is used to achieve material removal or machining.
3. The cutter is commonly connected to a high pressure water pump where the water is then ejected from the nozzle, cutting through the material by spraying it with the jet of high speed water.
4. Additives in the form of suspended grit or other abrasives, such as garnet and aluminum oxide can assist in this process.
5. An abrasive jet starts out the same as a pure water jet.
6. As the thin stream of water leaves the nozzle, abrasive is added to the stream and mixed.

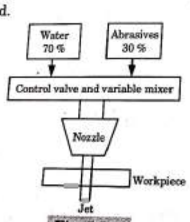


Fig. 5.5.1.

7. The beam of water accelerates abrasive particles to speed fast enough to cut through much harder materials.
8. The mixing of abrasive particles in water jet is in such a manner that water jet's momentum is transferred to the abrasives.
9. The coherent abrasive water jet that exits the nozzle has the ability to cut various materials such as metals, glass ceramics and composites.

PART-2

Ultrasonic Machining, Principle and Process Parameters.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.6. What is ultrasonic machining process (USM) ? Giving suitable sketch, describe its working and also give its advantages, disadvantages and applications.

Answer

A. **Ultrasonic Machining :**

1. It is a mechanical type non-traditional machining process.
2. It is employed to machine hard and / or brittle materials (both electrically conductive and non-conductive) having hardness usually greater than 40 RC.

B. **Principle :** In ultrasonic machining process, the high frequency electrical signal is converted into the high frequency mechanical motion.

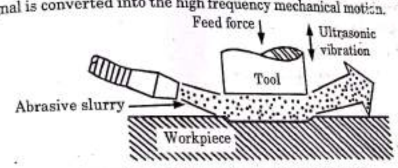


Fig. 5.6.1. Ultrasonic machining.

C. **Working :**

1. In ultrasonic machine, the abrasive slurry (contain water and abrasive particles) is filled between the vibrating tool and workpiece.
2. Material removal take place when the abrasive particle suspended in the slurry is struck by the vibrating tool.
3. This struck cause the cutting action in the workpiece, hence the workpiece is machined.

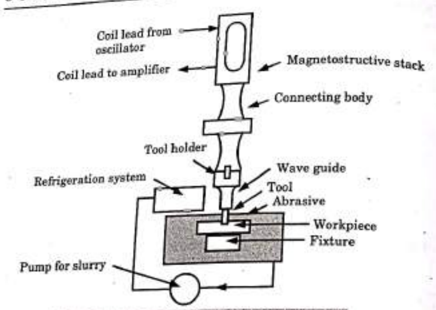


Fig. 5.6.2. Components of USM machine.

D. Advantages :

1. There are no thermal effects on machining.
2. It gives good surface finish.
3. There is less distortion.
4. There is no change in physical properties of workpiece.
5. This process is free of unpleasant sound.
6. It can machine non-conductive material.

E. Disadvantages :

1. High tool wear.
2. It has low material removal rate.
3. It has high power consumption.
4. It is not economical for soft materials.
5. Difficulty in tool designing.

F. Applications :

1. It can be used for coining, lapping, deburring and broaching.
2. Drilling and finishing of wire drawing dies made of tungsten carbide and diamond.
3. Machining of circular and non-circular holes with straight or curved axes.
4. Threads can be cut in a drilled hole.
5. Dentistry work to drill fine holes of desired shape in teeth.

Que 5.7. **Write down the process parameters of USM and their effects on MRR.**

Answer

Various process parameters of USM are as follows :

a. **Frequency :** The MRR increases linearly with the frequency.
b. **Amplitude :** When the amplitude of vibration is increased, the MRR is also increased.
c. **Static Loading (Feed Force) :** With an increase in static loading (i.e., the feed force), the MRR tends to increase.
d. **Grain Size :** MRR increases with the increase in the grain size.
e. **Concentration of Abrasive in the Slurry :** It does not have much effect on MRR, concentration of abrasive in the slurry slightly increase the MRR.

PART-3

Electrical Discharge Machining, Principle and Process Parameters, MRR, and Surface Finish.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.8. **Explain the principle and working of electro discharge machining (EDM) process with suitable sketch. What are the parameters that control the material removal rate in EDM ?**

Answer

A. Principle of EDM :

1. This process involves a thermal process that uses spark discharges to erode electrically conductive material.

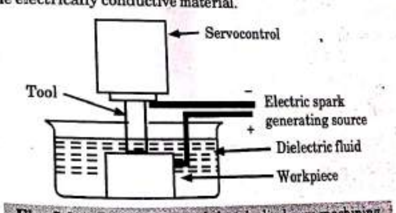


Fig. 5.8.1. Basic scheme of electric discharge machining.

2. When a discharge takes place between anode and cathode, the heat is generated near the zone which melts and evaporates the material in the sparking zone.

B. Working of EDM :

1. In electrical discharge machining (EDM) process, machining is done by melting a large number of very small particles of metal by bombarding of sparks from electrode to the metal workpiece.
2. The electrode and workpiece are connected in an electric circuit utilizing DC voltage up to 45 V and current varying from 5 A to 60 A or more depending upon area of electrode.
3. When electrode and workpiece come close to each other, the sparks generate which have temperature up to 5500 °C. This spark melts and vaporizes a spot in the metal and the same process will give a finish to workpiece metal.

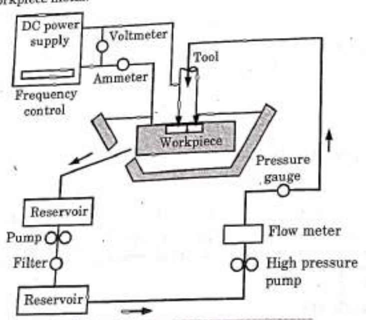


Fig. 5.8.2. Components of an EDM system.

C. Parameters Controlling the Material Removal Rate :

1. Tool material,
2. Properties of electrode,
3. Dielectric fluid used, and
4. Effect of resistance and capacitance.

Que 5.9. **Derive the expression for the material removal rate of electro discharge machining.**

Answer

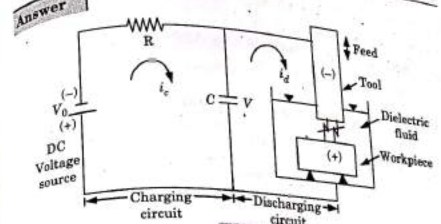


Fig. 5.9.1.

1. At time t, the current flowing in charging circuit,

$$i_c = \frac{V_0 - V}{R} \quad \text{...(5.9.1)}$$

2. Also,

$$i_c = C\frac{dV}{dt} \quad \text{...(5.9.2)}$$

Where, V_0 = Applied voltage for charging the circuit the condenser,
V = Charged voltage of condenser,
R = Charging resistance, and
C = Capacitance of the condenser.

3. On equating eq. (5.9.1) and eq. (5.9.2), we have

$$\frac{V_0 - V}{R} = C\frac{dV}{dt}$$

or

$$\frac{dV}{V - V_0} = \frac{-1}{RC}dt$$

On integrating both sides, we have

$$\int_0^V \frac{dV}{V - V_0} = -\int_0^t \frac{1}{RC}dt$$

$$\log_e (V - V_0) = \frac{-t}{RC} + K$$

Where, K = Constant.

4. Taking antilog on both side,

$$V - V_0 = e^{\left(\frac{-t}{RC} + K\right)}$$

$$V - V_0 = e^{\frac{-t}{RC}} e^K$$

$$V - V_0 = e^{\frac{-t}{RC}} K_1 \quad (\because K_1 = e^K) \qquad \text{...(5.9.3)}$$

Where, K_1 = Constant.

5. On applying boundary conditions in eq. (5.9.3), we get

$$t = 0,\ V = 0$$

$$\therefore \quad K_1 = -V_0$$

6. On substituting the value of K_1 in eq. (5.9.3), we get

$$V - V_0 = e^{\frac{-t}{RC}} (-V_0)$$

$$V = V_0\left[1 - e^{\frac{-t}{RC}}\right] \qquad \text{...(5.9.4)}$$

$$\frac{V}{V_0} = 1 - e^{\frac{-t}{RC}}$$

$$e^{\frac{-t}{RC}} = 1 - \frac{V}{V_0}$$

7. Taking log on both side, we get

$$\frac{t}{RC} = -\log_e\left[1 - \frac{V}{V_0}\right]$$

$$t = RC \log_e\left[\frac{1}{1 - \frac{V}{V_0}}\right]$$

$$t = RC \log_e\left[\frac{V_0}{V_0 - V}\right]$$

8. Now, the frequency is given as,

$$f_c = \frac{1}{t} = \frac{1}{RC \log_e\left(\frac{V_0}{V_0 - V}\right)} \qquad \text{...(5.9.5)}$$

Where, t = Charging time, and

f_c = Sparking frequency.

9. The energy released per spark is given as,

$$E = \frac{1}{2} CV^2$$

10. Total energy / second = $Ef_c = \frac{1}{2} f_c CV^2$

11. Now metal removal rate is directly proportional to the energy,

$$\therefore \quad \text{MRR} \propto \frac{1}{2} f_c CV^2$$

$$\text{MRR} = K \frac{1}{2} f_c CV^2 \qquad \text{...(5.9.6)}$$

Where, K = Constant of proportionality.

12. On putting the value of f_c from eq. (5.9.5) in eq. (5.9.6), we get

$$\text{MRR} = \frac{1}{2} K\, CV^2 \times \frac{1}{RC \log_e\left(\frac{V_0}{V_0 - V}\right)}$$

$$\text{MRR} = \frac{KV^2}{2R \log_e\left(\frac{V_0}{V_0 - V}\right)}$$

Que 5.10. **Discuss about the metal removal rate and surface finish obtained in EDM.**

Answer

1. Metal removal rate (volume of metal removed from the work per unit time) depends upon current density and it increases with current. But high removal rates produce poor finish.
2. Therefore, the usual practice in EDM is a roughing cut with a heavy current followed by a finishing cut with less current.
3. Metal removal rates are usually low, approximately 80 mm^3/s, but this can be increased on machines having more efficient pulse generators.
4. Tolerances of the order of ± 0.05 to 0.13 mm are commonly obtainable and with extra care, tolerances of the order of ± 0.003 to 0.013 mm are possible. Surface finish of the order of 0.2 μm Ra is possible.
5. In addition to current density or the electric energy expended per spark, the MRR per spark also depends upon the period over which it is expended.

PART-4

Tool Wear, Dielectric, Power and Control Circuits, Wire EDM.

CONCEPT OUTLINE

Tool Wear : Tool wear is given in terms of wear ratio which is defined as,

$$\text{Wear ratio} = \frac{\text{Volume of metal removed (work)}}{\text{Volume of metal removed (tool)}}$$

Dielectric : A dielectric is an electrical insulator that can be polarised by an applied electric field. Ceramics, mica, glass, plastics, etc are the some examples of dielectric.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.11. **Discuss the different types of spark generator used in EDM.**

Answer

Following are the different types of spark generator used in EDM :

a. **Relaxation Generators :**

1. The relaxation or the *R-C* circuit was the first to be used in EDM. The circuit (Fig. 5.11.1) comprises a DC power source that charges a capacitor '*C*' across a resistance '*R*'.
2. If the condenser is initially uncharged and the DC supply is switched on, a heavy current will flow into the circuit with the condenser voltage rising continuously.
3. The condenser voltage at the instant *t* can be described by the relationship,

$$U_{i(t)} = U_s[1 - e^{-t/RC}] \quad ...(5.11.1)$$

4. Eq. (5.11.1) predicts that the condenser voltage will approach the supply voltage (U_s) with a time constant equal to *RC* and after $t = RC$, the condenser voltage will be 63 per cent of the supply voltage (U_s).
5. A discharge, across the working gap will occur if $U_{i(t)}$ equals the breakdown voltage (U_b) of the dielectric within the gap.

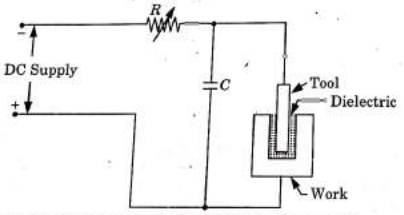


Fig. 5.11.1. Elementary relaxation circuit for EDM.

6. After the discharge, the dielectric deionizes, the capacitor is recharged and the cycle repeats itself.
7. In a relaxation generator, the spark repetition rate, for a given supply voltage and capacitance, cannot be increased beyond a critical value and is determined by the speed at which the spark gap is deionized.

8. The fundamental advantages of relaxation circuits are their comparative cheapness, simplicity of design, robustness and relatively extensive range of discharge.

b. **Rotary Pulse Generators :**

1. In order to increase the metal removal rates, motor generator sets have been developed to supply the required machining power in EDM.
2. These generators are commonly referred as the rotary pulse generators and produce asymmetric output waves so that the advantage of the equivalent of a DC power supply can be maintained.
3. The basic circuit of a rotary pulse generator is given in Fig. 5.11.2.

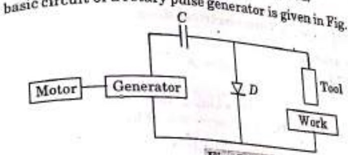


Fig. 5.11.2.

4. During operation, the capacitor '*C*' is charged through the diode '*D*' on half cycle. On the following half cycle, the sum of the voltage from the generator and charged capacitor is applied to the gap.
5. This circuit allows a standard high frequency AC generator to be used to produce unidirectional pulses.
6. This circuit permits high metal removal rates but produces exceedingly rough surfaces.

c. **Controlled Pulse Circuit :**

1. The need for a faster method of stopping the current in the event of short circuits resulted in the development of circuits with electronic tubes and transistors.
2. These circuits are known as controlled pulse circuits (static pulse generator) and offer the advantage of faster rate of metal removal and low tool electrode wear.
3. The use of controlled pulse generators enables wide variations in pulse duration frequency and in the intensity of spark discharges, and employs power transistor triodes as switching devices.
4. These are switched by low power square wave generators and allow independent 'on' and 'off' controls, and the whole system provides unidirectional square-wave pulses to the electrodes.
5. Fig. 5.11.3 illustrates a transistor circuit.
6. In this circuit, switching is done by the oscillator at a selected imposed frequency and does not require the use of capacitors.
7. The oscillator is also controlled by the gap conditions so that the transistors can be turned off in case of a short circuit.

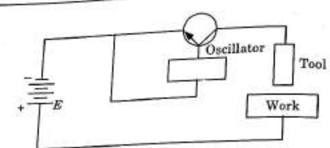


Fig. 5.11.3.

Que 5.12. Explain wire electrical discharge machining (WEDM) with neat sketch.

Answer

1. Wire electrical discharge machining (WEDM) is characterized by a path programmed cut of the workpiece contour by a traveling wire electrode.
2. The kinematics of WEDM is comparable to that of a band saw.
3. The wire electrode is fed from a spool and cuts the workpiece along the programmed contour.
4. Either the workpiece or the wire is moved relatively to each other in the x and y directions. For this reason, only two-dimensional shapes can be machined. Conical shapes can be manufactured by a sloping position of the wire.
5. Here, the upper guide of the unwinding wire tool electrode is relatively adjustable in the u and v directions (Fig. 5.12.1) to the lower guide.
6. Due to wear and an associated decrease of the wire diameter, the wire electrode can only be used once. A reuse causes an increasing risk of tearing the wire electrode and of deviations in contour.

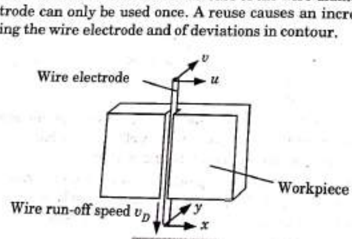


Fig. 5.12.1.

Que 5.13. Define dielectric fluid. Write function of dielectric fluid used in EDM.

Answer

A. Dielectric Fluid :

1. A dielectric fluid is a medium that does not conduct electricity.
2. The commonly used dielectric fluids are kerosene oil, petroleum, transformer oil and silicon oil.

B. Functions of Dielectric Fluid Used in EDM :

1. It acts as an insulating medium.
2. It cools the spark region and helps in keeping the tool and workpiece cool.
3. It maintains a constant resistance across the gap.
4. It carries away the eroded metal particles.

PART-5

Electrochemical Machining, Etchant and Maskant, Process Parameters, MRR and Surface Finish.

CONCEPT OUTLINE

Etchants : These are the chemical substances generally used for bathing the cutting areas. These react with the material in the area to be cut and cause the solid material to be dissolved.

Maskant : Masking material which is called maskant is used to protect workpiece surface from chemical etchant.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.14. Explain the principle and working of electrochemical machining (ECM). Also give its advantages, disadvantages and applications.

Answer

A. Principle : The principle of ECM is based on the Faraday's law of electrolysis. These are :

i. **Faraday's First Law :** It states that the mass of a substance liberated at an electrode is directly proportional to the charge passing through the electrolyte.

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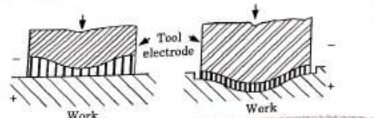

Fig. 5.14.1. Schematic arrangement of electrochemical machining.

ii. **Faraday's Second Law :** It states that the mass of a substance liberated at an electrode by a given amount of charge is directly proportional to their chemical equivalent weights of the substance.

B. Working :

1. In this process, a high current and low voltage DC power supply is connected between an electrically conductive tool and workpiece.

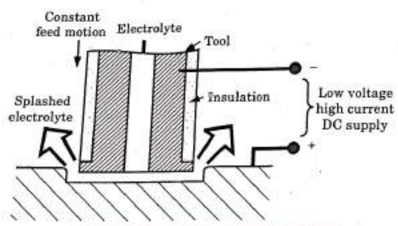

Fig. 5.14.2. Electrochemical machining.

2. The tool is connected to the negative polarity and workpiece is connected to the positive and a conductive electrolyte flows through a small gap that is maintained between the tool and workpiece.
3. The direction of current that flow from workpiece to the tool and material is removed from the workpiece. At the same time the electrolyte flows through the gap at a high velocity and remove the workpiece material before it has a chance to collect on the tool surface.

C. Advantages :

1. It has long tool life.
2. It can do machining of complicated shapes.
3. It can also do machining of hard materials.
4. It has low tool wear.

5. It has good surface finish and faster removal stock ability.

D. Disadvantages :

1. Workpiece should be electrically conductive.
2. The energy consumption is high.
3. It has high set up cost.

E. Applications : ECM is used for machining the part of jet engines, turbine wheels, alloys, small holes and hard materials etc.

Que 5.15. **Explain the mechanics of metal removal process in ECM. Also discuss the electrochemistry behind ECM process and find the relation for volumetric removal rate.** **AKTU 2017-18, Marks 10**

Answer

A. Mechanics of Metal Removal Process in ECM :

1. ECM is a machining process that relies on the removal of atoms from the surface of the workpiece.
2. It is an electrolytic process in which the metal removal is performed by the electrochemical dissolution of the workpiece.
3. In ECM process, a higher MRR is needed to perform machining at a higher electrolyte flow rate.
4. When a potential difference is applied across the electrolytic solution, several possible reactions may occur at the anode and cathode.
5. Anode reaction : $Fe \rightarrow Fe^{2+} + 2e^-$

   Cathode reaction : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$
6. The result of the electrochemical reactions is the production of iron hydroxide *i.e.*,

$$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$$

B. Relation for Volumetric Removal Rate :

1. According to the laws of Faraday,

$$m \propto It\epsilon$$

Where, m = Weight of metal dissolved or deposited,

I = Current,

t = Time, and

ϵ = Gram equivalent weight of the metal.

2. On removing the proportionality sign, we get

$$m = \frac{It\epsilon}{F} \quad ...(5.15.1)$$

Where, F = Faraday's constant (= 96,500 Coulombs).

3. The gram equivalent weight of the metal is,

$$\epsilon = \frac{A}{Z} \quad ...(5.15.2)$$

Where, A = Atomic weight of the metal (in grams), and

Z = Valency of the cation.

4. On putting the value of ϵ from eq. (5.15.2) to eq. (5.15.1), we get

$$m = \frac{AIt}{ZF} \quad ...(5.15.3)$$

5. Now, the total weight of metal removal is,

$$m = ah\rho$$

Where, a = Machined area,

h = Depth of metal removed, and

ρ = Density of metal.

6. Metal removal rate in terms of depth of metal removed per unit time is given as,

$$\text{MRR} = \frac{m}{a\rho t} \quad ...(5.15.4)$$

7. Substituting the value of m from eq. (5.15.3) to eq. (5.15.4), we get

$$\text{MRR} = \frac{AIt}{ZFa\rho t} = \frac{AI}{ZFa\rho} \text{ cm/sec}$$

8. Now, volumetric removal rate is,

$$Q_{\text{MRR}} = \frac{AI}{ZF\rho} \text{ cm}^3\text{/sec}$$

Que 5.16. **Derive the expression for the material removal rate of electro discharge machining. Also differentiate between EDM and ECM process.** **AKTU 2018-19, Marks 07**

Answer

A. **Expression for Material Removal Rate of EDM :** Refer Q. 5.9, Page 5–10C, Unit-5.

B. **Difference between EDM and ECM Process :**

S. No.	EDM	ECM
1.	Economical for tools of smaller cross-section.	Economical for tools of large cross-section.
2.	Tool design is easier.	Tool design is complicated.
3.	Heat affected zone exist.	No heat affected surface is produced.
4.	Surface finish is affected by rate of removal and is best with low current density.	Surface finish is best when current density is maximum possible. Also surface finish improves with high feed rate.
5.	Structural changes occur in work material. The process leaves residual compressive stresses.	No mechanical damage to the machined surface (*i.e.*, stress free surface)
6.	Tool wear will be more than material removal, if proper machining conditions are not applied.	No tool wear occurs.

Que 5.17. **Discuss about the surface finish obtained in ECM process.**

Answer

1. ECM can produce surface finish of the order of 0.4 μm by rotation of tool/work. Any defect on the tool face produces replica on workpiece. Tool surface should therefore be polished.
2. The finish is better on harder materials. Cobalt alloys give mirror like finish and copper and aluminium give a matt finish.
3. For optimum surface finish, careful electrode design, maximum feed rate and surface improving additives in electrolyte are selected.
4. Low voltage decreases the equilibrium machining gap and results in better surface finish and tolerance control.
5. Low electrolytic concentration decreases the equilibrium machining gap and thus better surface finish and tolerance. Low electrolyte temperature also promotes better surface finish.

Que 5.18. **ECM is performed to remove material from an iron surface of 20 mm × 20 mm under the following condition.**

Interelectrode gap = 0.2 mm, supply voltage = 12 V, specific resistance of electrolyte = 2 ohm-cm, atomic weight of iron = 55.85, valency of iron = 2, Faraday's constant = 96540 coulomb, find the material removal rate in g/sec.

AKTU 2018-19, Marks 07

Answer

Given : Area, $a = 20 \times 20$ mm², $l = 0.2$ mm, $V = 12$ V, $\rho = 2$ ohm-cm
$A = 55.85$, $F = 96540$ Coulomb, $Z = 2$
To Find : Material removal rate in g/sec.

1. We know that, $R = \dfrac{\rho l}{A} = \dfrac{20 \times 0.2}{20 \times 20} = 0.01\ \Omega$
2. Also, from Ohm's law

$$V = IR$$
$$12 = I \times 0.01$$
$$I = \frac{12}{0.01} = 1200 \text{ A}$$

3. $$\text{MRR} = \frac{AI}{ZF} = \frac{55.85 \times 1200}{2 \times 96540} = 0.347 \text{ g/sec}$$

PART-6

Laser Beam Machining (LBM).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.19. **What does LASER stands for ? Explain its working with neat sketch. How metal removal takes place by LBM ?**

AKTU 2017-18, Marks 10

Answer

A. **LASER :** Laser stands for "Light Amplification by Stimulated Emission of Radiation".

B. **Working of Laser :**

1. The basic requirement to the Laser action is that there must be more atoms in metastable state than the ground state, *i.e.*, population inversion of metastable state should be greater than population of ground state.

2. The following steps take place in Laser action :

Step 1 : Pumping : Fig. 5.19.1, shows the energy levels E_0, E_1 and E_2 of an atom of Laser medium. Here, E_0 is the ground level and $E_2 > E_1$, where E_1 is the metastable energy level.

By supplying energy from the external source, the atoms in the ground state (E_0) are pumped to excited state E_2. In the optical pumping, the Laser medium is irradiated by radiation of frequency υ_0 such that $h\upsilon_0 = (E_2 - E_0)$. The atoms are excited by stimulated absorption.

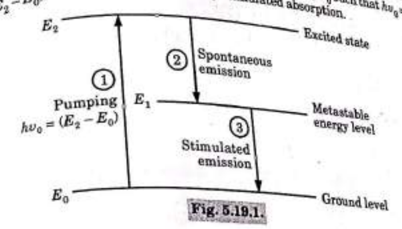

Fig. 5.19.1.

Step 2 : Population Inversion : The atoms from energy level E_2 may drop to the metastable level E_1 by spontaneous emission. As E_1 is a metastable state, the excited atoms stay comparatively for a longer time. As a result, soon the number of atoms in energy level E_1 becomes much larger than in energy level E_0. In this way population inversion occurs between energy levels E_1 and E_0.

Step 3 : Stimulated Emission : A photon of energy $h\upsilon = (E_1 - E_0)$ may be emitted due to spontaneous emission. This photon will pass through laser medium. Now this photon produces stimulated emission from energy level E_1 to E_0. The resulting beam is highly monochromatic and coherent.

C. **Metal Removal by LBM :** In LBM, a narrow beam of coherent light (monochromatic light) is focused on the workpiece by lens to give extremely high energy density to melt and vaporise any material.

Que 5.20. **Explain laser beam machining process (LBM), giving suitable sketch. Give advantages, disadvantages and its applications.**

Answer

A. **Working of LBM :**

1. In the laser beam machining ruby laser is usually used.

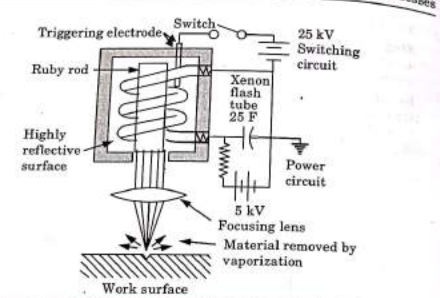

Fig. 5.20.1. Schematic diagram of laser beam machining.

2. A Xenon flash tube is placed around the ruby rod and the internal surface of the body is highly reflective through which maximum light falls on the ruby rod for the pumping operation.
3. First of all, the capacitor is charged, by which voltage is passed to the electrode for the flash.
4. Due to the flash pumping operation, laser beam is emitted by the ruby rod which is focused by the lens system *i.e.*, focusing lens on the workpiece for the machining.

B. Advantages of LBM :

1. There is no direct contact between tool and workpiece. So there is no problem of tool wear.
2. It is useful for both metals and non-metals.
3. It is useful for machining extremely small holes.
4. It is a smooth process and gives good surface finish.
5. It is a fastest process for machining.
6. Laser machining can be done in any environment.

C. Disadvantages of LBM :

1. Overall efficiency of laser is extremely low.
2. Laser beam machining requires safety procedures.
3. Cost is high.
4. Life of flash lamp is too short.

D. Applications of LBM :

1. Automobile industry.

2. Aircraft industry.
3. Use for machining steel and its alloy, titanium, niobium, nickel and its alloy, PVC, polyethylene, glass, ceramics, mica etc.

PART-7

Plasma Arc Machining (PAM).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.21. **Explain in detail about plasma arc machining (PAM) with suitable sketch.**

Answer

1. Basically, plasma arc machining (PAM) is a metal cutting process where metals are cut with plasma arc, tungsten-inert gas arc or a torch. It is mostly used for the metals that cannot be cut by an oxy-acetylene torch.
2. Plasma arc machining consists of a plasma gun. Plasma gun has an electrode made up of tungsten situated in the chamber.
3. Here, this tungsten electrode is connected to the negative terminal of DC power supply. Thus, the tungsten acts as a cathode.
4. While the positive terminal of DC power supply is connected to the nozzle. Thus, the nozzle of the plasma gun acts as an anode.
5. As we give the power supply to the system, an electric arc develops between the cathodic tungsten electrode and an anodic nozzle.
6. As the gas comes in contact with the plasma, there is a collision between the atoms of gas and electrons of an electric arc and as a result, we get an ionised gas which is known as plasma.

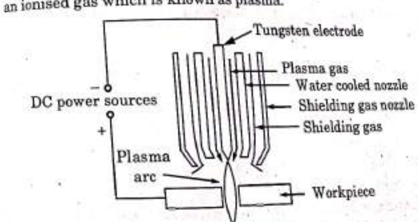

Fig. 5.21.1.

7. Now, this plasma is targeted towards the workpiece with a high velocity and the machining process starts.
8. In the whole process, high temperature conditions are required. As hot gases come out of nozzle there are chances of overheating. In order to prevent this overheating, a water jacket is used.

Que 5.22. **Write advantages, disadvantages and applications of PAM.**

Answer

A. Advantages of PAM :

1. In plasma arc machining, hard as well as brittle metals can be easily machined.
2. It can be applied to almost all types of metals.
3. It has high cutting rate.
4. It has better dimensional accuracy in case of machining small cavities.

B. Disadvantages of PAM :

1. Cost of equipment is very high.
2. Process consumes a high amount of inert gases.
3. Production of narrower surfaces takes place which is unnecessary.
4. The most harmful part of PAM is that metallurgical changes takes place on the surface.

C. Applications of PAM :

1. It is mostly used for cryogenic, high temperature corrosion resistant alloys.
2. It is also used in case of titanium plate upto 8 mm thickness.
3. PAM is used in nuclear submarine pipe system.
4. PAM is prominent for the applications related to stainless tube and tube mills.

PART-B

Electron Beam Machining.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.23. **Explain the principle and working of electron beam machining (EBM). Also give its advantages, disadvantages and applications.**

Answer

A. Principle : Electron beam machining based on the principle that the kinetic energy of the electrons is converted into the heat necessary for the rapid melting and vaporization of any material.

So, $E = \frac{1}{2}mv^2$

Where, E = Kinetic energy,

m = Mass of electrons, and

v = Velocity of electrons from the electron gun.

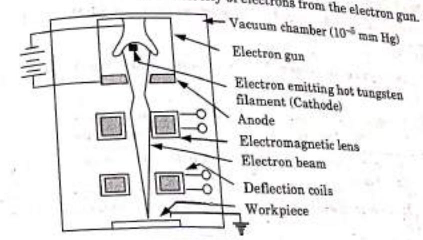

Fig. 5.23.1. Schematic view of electron beam machine.

B. Working :

1. In electron beam machining, when tungsten filament is heated up, it emits electrons.
2. The emitted electron from the heated filament carries negative charge, which repelled by the cathode electrode and these electrons are pass through the central hole of the anode.
3. Both the electrodes concentrate and propel the electrons and this electron beam is then focused by a lens to the workpiece. Hence machining is done in EBM.

C. Advantages :

1. This machining process is very accurate and fast.
2. It has high drilling rates.
3. It can machine many materials.

4. There is no distortion.

D. Disadvantages :

1. It has high energy consumption.
2. It needs skilled labour.
3. It is an expensive process.

E. Applications :

1. It is used in drilling small hole with accuracy.
2. It is used to produce wire drawing dies.
3. It is used in nuclear reactors, rotors and aircraft engines to drill gas orifices.

Que 5.24. **Differentiate between non-conventional and conventional machining. Also give advantages of EBM over USM.**

Answer

A. Difference between Non-conventional Machining and Conventional Machining :

S. No.	Non-conventional Machining	Conventional Machining
1.	It can machine hard materials.	It cannot machine hard materials.
2.	It has high material removal rate.	It has low material removal rate.
3.	It gives good surface finish.	It doesn't give good surface finish.
4.	In this process, there is less distortion.	In this process, there is high distortion.
5.	Tool wear is less.	Tool wear is large.
6.	High power consumption.	Low power consumption.

B. Advantages of EBM over USM :

1. EBM is a faster than USM.
2. It has more accuracy than USM.
3. There is no distortion.
4. It has high drilling rate.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Explain abrasive machining process. Also classify abrasive machining process. Explain centerless grinding with the help of neat sketch.

Ans. Refer Q. 5.1, Unit-5.

Q. 2. What is abrasive jet machining (AJM) ? Describe its working with suitable diagram. Also explain the effect of stand-off distance and abrasive grit size on material removal rate in the AJM.

Ans. Refer Q. 5.3, Unit-5.

Q. 3. What is ultrasonic machining process (USM) ? Giving suitable sketch, describe its working and also give its advantages, disadvantages and applications.

Ans. Refer Q. 5.6, Unit-5.

Q. 4. Explain the principle and working of electro discharge machining (EDM) process with suitable sketch. What are the parameters that control the material removal rate in EDM ?

Ans. Refer Q. 5.8, Unit-5.

Q. 5. Explain the mechanics of metal removal process in ECM. Also discuss the electrochemistry behind ECM process and find the relation for volumetric removal rate.

Ans. Refer Q. 5.15, Unit-5.

Q. 6. Derive the expression for the material removal rate of electro discharge machining. Also differentiate between EDM and ECM process.

Ans. Refer Q. 5.16, Unit-5.

Q. 7. Explain in detail about plasma arc machining (PAM) with suitable sketch.

Ans. Refer Q. 5.21, Unit-5.

Q. 8. Explain the principle and working of electron beam machining (EBM). Also give its advantages, disadvantages and applications.

Ans. Refer Q. 5.23, Unit-5.

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