MADE EASY

RPSC AEn-2024 Main Test Series

MECHANICAL ENGINEERING | **Test 7**

Test Mode : • Offline • Online

Subjects : Materials Science and Manufacturing Processes

DETAILED EXPLANATIONS

1. Solution:
Solid solutions are of two types: substitutional solid solution, where solute atoms replace solvent atoms, and interstitial solid solution, where small atoms occupy interstitial spaces.

2. Solution:
Hardenability is the ability of steel to harden in depth when quenched, indicating the extent to which martensite can form throughout the section.

3. Solution:
The four surface hardening processes are carburizing, nitriding, cyaniding, and flame hardening, which increase surface hardness while maintaining a tough core.

4. Solution:
Resistance welding is a welding process in which heat is generated by electrical resistance at the joint, and pressure is applied to produce coalescence of metals.

5. Solution:
SMART materials are materials that can change their properties in response to external stimuli such as temperature, pressure, electric or magnetic fields, light, or chemical environment, and return to their original state.

6. Solution:
In punching, the removed portion is scrap and the remaining sheet is the product, while in blanking, the removed portion is the product and the remaining sheet becomes scrap.

7. **Solution:**

Degree of polymerization is the average number of repeating monomer units present in a polymer chain, indicating the molecular size and influencing mechanical properties.

$$\text{Degree of polymerisation} = \frac{\text{Molecular weight of a polymer}}{\text{Molecular weight of a single monomer}}$$

8. **Solution:**

NC part programming is the process of writing a sequence of instructions for a Numerical Control (NC) machine to perform desired machining operations on a workpiece accurately.

9. **Solution:**

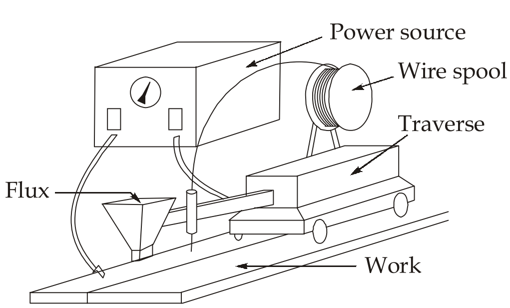
Honing is a finishing process to improve surface finish and accuracy by removing small amounts of material, while grinding is a material removal process for shaping or sizing workpieces.

10. **Solution:**

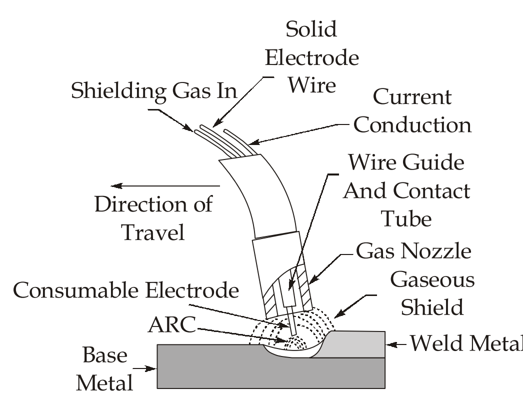
In abrasive jet machining, a high-velocity jet of compressed gas carrying abrasive particles strikes the workpiece surface, eroding material through repeated micro-cutting and impact action.

11. **Solution:**

Submerged arc welding (SAW) is a welding process in which an arc is struck between a continuously fed electrode and the workpiece beneath a layer of granular flux. The flux shields the molten weld pool from atmospheric contamination, stabilizes the arc, and can add alloying elements to the weld. The process is primarily used for thick steel plates and long welds.



(a)



(b)

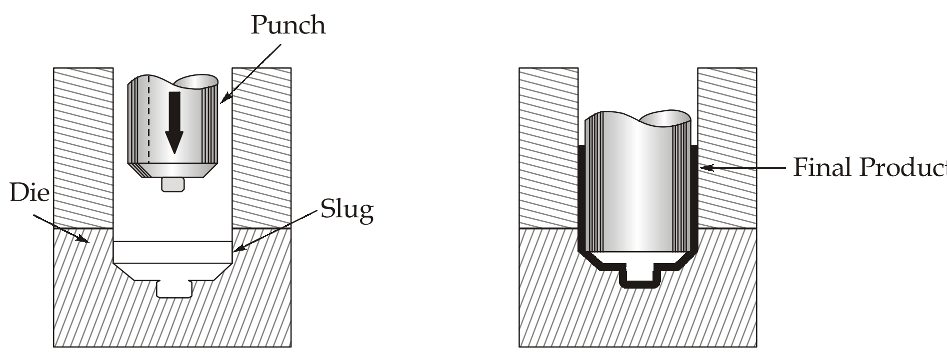
SAW process

Advantages: High deposition rate, Deep weld penetration, Minimal spatter and smoke, Good weld quality and repeatability.

Disadvantages: Limited to flat or horizontal welding positions, High initial setup cost, Not suitable for thin sections or non-ferrous metals.

12. Solution:

Impact extrusion: This comes under the cold extrusion process. In impact extrusion a heavy punch is allowed to fall over the material and material takes the shape of the die by flowing in the clearance between punch and die. Collapsible tubes is made by this. This is used to make collapsible tubes of soft alloys such as tooth paste containers. This process is limited to soft and ductile materials.



Impact extrusion

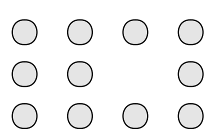
13. Solution:

Compacting (or briquetting) in powder metallurgy is done to compress the metal powder mixture into the desired shape or size. The component after this stage is called a green compact component. The purpose of compacting is to provide higher density and uniformity in the properties to the components. The compacting process is carried out using steel dies and punches. For thin components, a single punch is sufficient for compacting, but a double punch is required for thick parts to ensure uniformity of compactness or density.

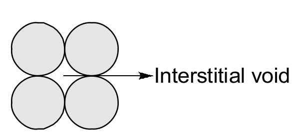
14. Solution:

Defects in metallic materials:

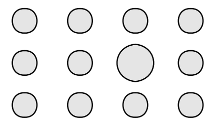
1. **Vacancy Defect :** It appears due to the missing of atom from the lattice.



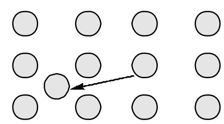
2. **Interstitial defect:** When the foreign atom occupies the interstitial site then the defect is called interstitial defect.



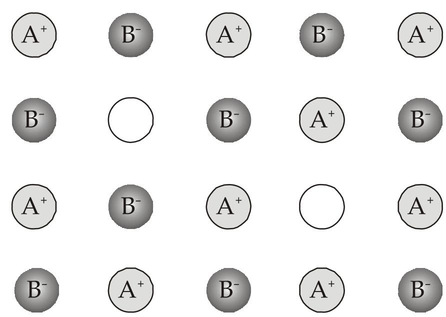
3. **Substitutional defect :** If the regular atom is replaced by another foreign atom this defect is called substitutional defect.



4. **Frenkel defect :** When the atom in the lattice point goes and occupies the interstitial void of other atom then it is called Frenkel defect.



5. **Schottky defect :** If the combination of cation and anion from different places in lattice disappear and there is a vacancy defect then it is called Schottky defect.



15. Solution:

3-2-1 principle or six point location principle: The locating of work piece on six pins in order to restrict extra movement of jig or fixture is called 3-2-1 or six point location principle.

Jigs: A device which holds and positions a work, locates or guides the cutting tool relative to work is called jig. It is usually not fixed with machine table and is lighter in construction. Generally jigs are used on drilling, reaming, tapping and counter-boring.

Fixture: A fixture is a work holding device, which holds and positions the work but does not itself guide the cutting tool. The setting of tool is done separately. It is usually bolted or clamped with table and is heavier in construction. Generally fixtures are used in turning, milling, grinding, shaping, planning, etc.

16. Solution:

$\because$ Given: T_1 = 20 min at N_1 = 200 rpm, T_2 = 5 min at N_2 = 400 rpm

Taylor's tool life equation for drilling

$$N_1 T_1^n = N_2 T_2^n = \text{constant} \quad \text{...(i)}$$

$$\therefore \quad 200(20)^n = 400(5)^n$$
$$4^n = 2$$
$$\therefore \quad n = 0.5$$
$$\therefore \quad \text{Tool life at } N_3 = 300 \text{ rpm}$$
$$\therefore \quad N_1 T_1^{\,n} = N_3 T_3^{\,n}$$
$$200(20)^{0.5} = 300.T_3^{\,0.5}$$
$$T_3 = 20\left(\frac{200}{300}\right)^2 = 8.89 \text{ min.}$$

17. Solution:

Additive manufacturing (AM), also known as 3D printing, is a manufacturing process in which components are produced by adding material layer by layer directly from a digital 3D model. Unlike subtractive manufacturing, material is deposited only where required, resulting in minimal waste.

Principle: A CAD model is converted into an STL file and sliced into thin layers. The machine builds the component by successively depositing or solidifying material according to these layers.

Major processes: Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), and Electron Beam Melting (EBM).

Applications: Rapid prototyping, aerospace and automotive parts, medical implants, tooling, and customized components.

18. Solution:

Length of uncut chip, $l = \dfrac{\pi(70+68)}{2} = 216.769$ mm

$$\text{Cutting ratio} = \frac{t}{t_c} = \frac{L_c \text{ (Length of chip)}}{L \text{(Uncut length)}} = \frac{68.9}{216.769} = 0.318$$

$$\tan\phi = \frac{r\cos(\alpha)}{1 - r\sin\alpha} = \frac{0.318 \times \cos 10°}{1 - 0.318 \times \sin 10°} = 0.33147$$

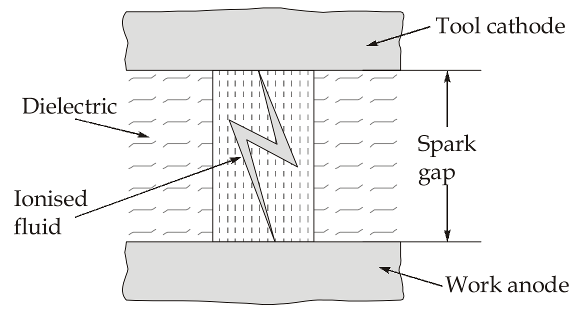
$$\phi = 18.34°$$

19. Solution:

Principle: It has been recognised for many years that a powerful spark will cause pitting or erosion of the metal at both the anode (+) and cathode (–) e.g., automobile battery terminals, loose plug points, etc. This process is utilized in electric discharge machining. This process is also called as spark machining or spark erosion machining. The *EDM* process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the tool and workpiece separated by a small gap of about 0.01 to 0.50 mm.

This spark gap is either flooded or immersed in a dielectric fluid. The controlled pulsing of the direct current between the tool and the work produces the spark discharge.

- Initially, the gap between the tool and the workpiece, which consists of the dielectric fluid, is not conductive.

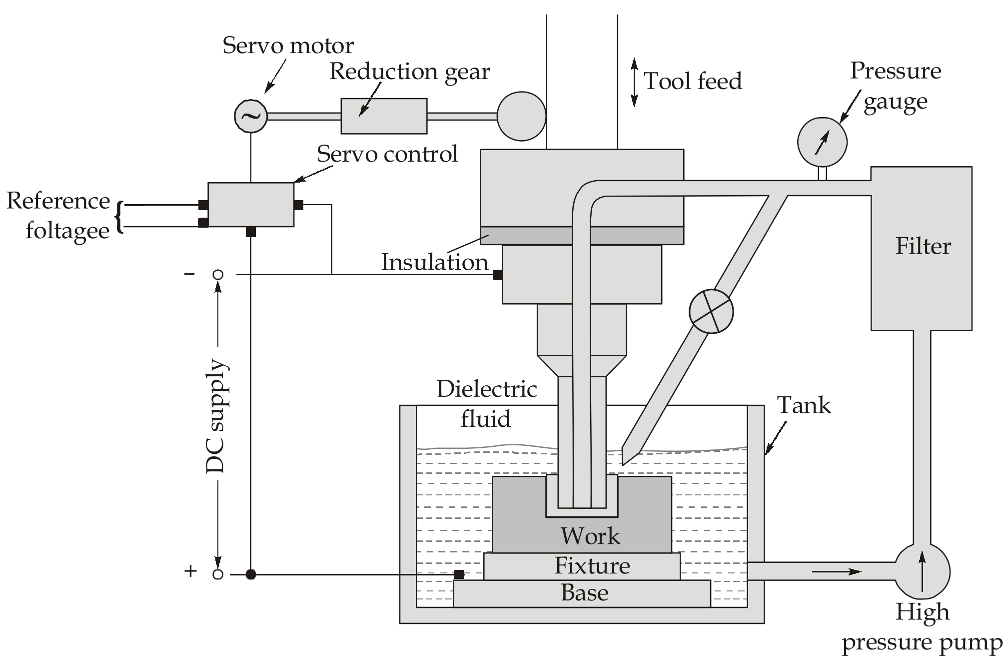


Schematic of the arc formation in EDM process

However, the dielectric fluid in the gap is ionised under pulsed application of *DC* as shown in the above figure, thus enabling the spark discharge to pass between the tool and the work.

Heat transfer from the spark to both tool and the workpiece melts, partially vaporises and partially ionises the metal in a thin surface layer.

- Due to the inertia of the surrounding fluid, the pressure within the spark becomes quite large and may possibly assist in 'blasting' the molten material from the surface leaving a fairly flat and shallow crater. The amount of metal removed per spark depends upon the electrical energy expended per spark and the period over which it is expended.



- In electro-discharge machining (*EDM*) process, the control of erosion of the metal is achieved by the rapidly recurring spark discharges produced between two electrodes, one tool and the other work, and spark impinging against the surface to the workpiece which must be an electrically conducting body. A suitable gap (0.01 to 0.5 mm) known as spark gap, is maintained between the tool and the work by a servomotor.

- The moment spark occurs, sufficient pressure is developed between work and tool. The repetitive sparks release their energy in the form of local heat, as a result of which, local temperature of the order of 10000°C is reached at the spot hit by electrons and at such a high pressure and temperature some metal is melted and eroded. Some of it is vaporised and under it fine material particles are carried away by dielectric medium (liquid) circulated around it, forming a crater on the workpiece. In this way a true replica of the tool surface is produced on the workpiece. Figure shows the schematic representation of the process illustrating the various components involved in the process.

Advantages:

- Any complex shape required in dies and mould can be easily produced to the required degree of accuracy and finish.
- The process is not affected by the hardness of the work material. Hence, even the hardened material can be machined thus avoiding the possible distortions due to heat treatment process on the final geometry.
- The material removal rates are almost comparable with that of the conventional machining processes.
- Since there are no cutting forces acting on the tool, high aspect ratio surfaces can be machined using *EDM* process.
- The process is generally highly automated with very little operator skill required.
- The actual surface produced by *EDM* consists of small craters, which may help in the retention of the lubricants.

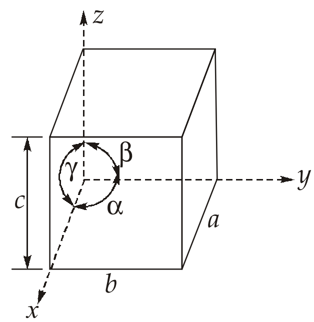
Disadvantages:

- The wear rate on the electrode is considerably higher. Sometimes it may be necessary to use more than one electrode to finish the job.
- The workpiece should be electrically conductive to be machined using the *EDM* process.
- The energy, required for the operation is more than that of the conventional process and hence will be more expensive.

20. Solution:

Unit cell: The atomic order in crystalline solids, indicates that small group of atoms that form a repetitive pattern.

$$a, b, c = \text{Lattice parameters}$$
$$\alpha, \beta, \gamma = \text{Interfacial angles}$$



Effective number of lattice points/ atoms in the unit cell of cubic lattices.

1. **Simple cubic structure:** In simple cubic structure, with atoms located at each of the corners of a unit cell.

$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8}$$

$$= 8 \times \frac{1}{8} = 1 \text{ atoms}$$

2. **Body centered cubic structure (BCC):** In this crystal structure a cubic unit cell with atoms located at all eight corner and a single atom at the cube center.

$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8} + \text{Body centered atom } (N_B)$$

$$= 8 \times \frac{1}{8} + 1 = 2 \text{ atoms}$$

3. **Face centered cubic structures (FCC):** In face centered cubic structure a unit cell with atoms located at each of the corners and the centers of all the cube faces.

$$\text{Number of atoms} = \text{Number of corner atoms } (N_C) \times \frac{1}{8} + \text{Number of face centered atom} \times \frac{1}{2}$$

$$= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4 \text{ atoms}$$

Diamond cubic structure (Si): Si has a diamond cubic structure. In this structure 8 atoms are arranged at corners and 6 atoms are arranged at face centers and 4 atoms are arranged inside cell on 4 body diagonal.

Average number of atoms in the diamond cubic unit cell = $\frac{1}{8} \times 8$ (Corner atoms) + $\frac{1}{2} \times 6$ (Face centered atoms) + 1×4 (Atoms inside the cell)

$$= 1 + 3 + 4 = 8$$

Relations between atomic radius (R) and lattice parameter (a)

$$R = \frac{a\sqrt{3}}{8}$$

Lattice parameter (a) = 5.431×10^{-10} m

$$\text{Atomic radius (R)} = \frac{5.431\times10^{-10}\sqrt{3}}{8} = 1.1758 \times 10^{-10}\text{ m}$$

Volume unit cell = $a^3 = (5.431 \times 10^{-10})^3$

$$\text{Atomic packing factor} = \frac{N_{av}\times\frac{4}{3}\pi R^3}{a^3} = \frac{8\times\frac{4}{3}\times\pi(1.1758\times10^{-10})^3}{(5.431\times10^{-10})^3} = 0.3400$$

% APF = 34.00%

$$\text{Density} = \frac{N_{av}\times\text{Atomic weight}}{\text{Avagadro number}\times\text{Volume of unit}}$$

$$= \frac{8\times(2\times\text{atomic number})}{6.023\times10^{23}\times(5.431\times10^{-10})^3}$$

$$= \frac{8\times2\times14\times10^{-3}}{9.64833\times10^{-5}} = 2321.645\,\text{kg/m}^3$$

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