KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)
(Established under Section 3 of UGC Act 1956)
Pollachi Main Road, Eachnari (Po)
COIMBATORE – 641021

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Subject Name	**: ADVANCED MANUFACTURING PROCESSES**	**L T P C**
Subject Code	**: 14BEME-E19**	**3 0 0 3**

INTENDED OUTCOMES:

- The course will enable the students to acquire a fundamental knowledge on various advanced manufacturing processes
- To introduce students to the wide range of manufacturing processes, which are currently used in manufacturing industry.

UNIT I POWDER METALLURGY PROCESS

Introduction to powder metallurgy process – preparation of powders – types and functions of binders – green compaction – sintering process and its effect on the product.

UNIT II ADVANCED WELDING PROCESSES

Percussion Welding– Electro Slag Welding, Plasma Arc Welding – Thermit Welding – Electron Beam Welding – Friction and Inertia Welding – Friction Stir Welding – Under Water Welding Process.

UNIT III SHEET METAL AND FORMING PROCESS

Working principle and application of special forming process – Hydro Forming– Rubber Pad Forming– Explosive Forming – Magnetic Pulse Forming– Peen Forming – Super Plastic Forming – Deep Drawing Process.

UNIT IV ADVANCED MACHINING PROCESS

Modern machining process: Abrasive Jet Machining, Water Jet Machining, Abrasive Water Jet Machining, Ultrasonic Machining, Electro chemical Machining, Electro chemical Grinding, Electro Discharge Machining, wire cut EDM, Electron Beam Machining, plasma arc machining, Laser Beam Machining. Ultrasonic Machining, High speed machining process – deep hole drilling process

UNIT V RAPID PROTOTYPING:

Introduction to Rapid Prototyping – Need for RPT– Stereo–lithography – Selective Laser Sintering, , Fused Deposition Modeling , Laminated Object Manufacturing, Solid Ground Curing, Ballistic Particle Manufacturing

TEXT BOOKS

S.NO	AUTHOR	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	Serope kalpakjian and Steven.R. Schmid	Manufacturing process for engineering materials	Pearson Education, Inc	2002
2	O.P.KHANNA	A Text book of Welding Technology	Dhanpat Rai Publications PvtLtd	1998

REFERENCE BOOKS

S.NO	AUTHOR	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1	P.N. Rao	Manufacturing technology Volume I	TMH Ltd	1998
2	Singh, M.K.	Unconventional Manufacturing Process	New age international	2007
3	Vijay.K. Jain	Advanced Machining Processes	Allied Publishers Pvt. Ltd	2002

WEBSITES:

1. http://web.iitd.ac.in/~pmpandey/MEL120_html/RP_document.pdf
2. http://www.me.psu.edu/lamancusa/rapidpro/rpintro2.pdf
3. http://file.guiacnc.com.br/data/PDF/PrototypeeBook2.pdf
4. http://mfg.eng.rpi.edu/gmp/WebChapters/ch39.pdf

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LESSON PLAN

Subject Name : ADVANCED MANUFACTURING PROCESSES **L T P C**

Subject Code : 14BEME-E19 **3 0 0 3**

UNIT I: POWDER METALLURGY PROCESS

S. No	Description	Hours Needed	Reference/ Supporting Materials
1	Introduction to powder metallurgy process.	1	T1 669-671 R4 1-17
2	Preparation of powders – atomization, reduction process, electrolytic deposition process.	1	T1 671-672 R4 216-233,26-30,34-35
3	Preparation of powders – carbonyl process, comminution process, mechanical alloying process and other methods.	1	R4 234-249
4	Types and functions of binders – characteristics, advantages and disadvantages.	1	R4 85-87
5	Compaction of metal powders – green compaction – isostatic pressing.	1	R4 103-109,121-124
6	Functions, applications, advantages and disadvantages of green compacting.	1	R1 452 to 456
7	Introduction to sintering process – various stages of sintering process.	1	T1 685-689
8	Types of sintering furnace, its working principle, merits and demerits	1	R4 126-174
9	Various effects of sintering process on the products.	1	W1
10	Quiz	1	GATE Questions
	Total no. of hours planned for unit – I	**10**	

UNIT II: ADVANCED WELDING PROCESSES

S. No	Description	Hours Needed	Reference/ Supporting Materials
1	Introduction to advanced welding processes, applications, advantages.	1	T1 732 R1
2	Percussion welding – introduction, application, advantages and disadvantages	1	T1 770
3	Electro slag welding - working principle, merits and demerits	1	T1 743 R1
4	Plasma arc welding - working principle, merits and demerits.	1	T1 745 R5 88-93
5	Thermit welding – working principle, application, advantages and disadvantages.	1	R1
6	Electron beam welding – working principle, applications, advantages and disadvantages.	1	T1 746-747 R1
7	Friction welding – working principle, application, merits and demerits.	1	T1 762-764 R1
8	Inertia welding – working principle, application, merits and demerits.	1	T1 763
9	Under water welding - working principle, application, advantages and disadvantages.	1	W2 & W3
10	Quiz	1	GATE Questions
	Total no. of hours planned for unit – II	**10**	

UNIT III: SHEET METAL AND FORMING PROCESS

S. No	Description	Hours Needed	Reference/ Supporting Materials
1	Introduction to special forming process.	1	T1 346-347
2	Hydro forming - working principle, applications, advantages and disadvantages.	1	T1 375-376
3	Rubber pad forming - working principle, application, advantages and disadvantages.	1	W1&W3
4	Explosive forming -working principle, application, merits and demerits.	1	T1 381-382
5	Magnetic pulse forming - working principle, application, merits and demerits of each process.	1	T1 383
6	Peen forming - working principle, application, advantages and disadvantages.	1	T1 385
7	Super plastic forming - working principle, application, merits and demerits.	1	T1 383-385&772
8	Deep drawing process - working principle, application, advantages and disadvantages.	1	T1 387-395&397

9	Other process- Creep age forming, Microforming, Straightening and Honey comb structure forming	1	T1 385-387
10	Quiz	1	GATE questions
	Total no. of hours planned for unit – III	**10**	

UNIT IV: ADVANCED MACHINING PROCESS

S. No	Description	Hours Needed	Reference/ Supporting Materials
1	Introduction to modern machining process, Abrasive Jet Machining – working principle, merits and applications.	1	R1
2	Water Jet Machining & Abrasive Water Jet Machining - Working principle, merits and demerits.	1	T1 568-569&570 R1 R2
3	Ultrasonic Machining, Electro chemical Machining - working principle, application, merits and demerits.	1	T1 552-554,558-559 R1
4	Electro chemical Grinding - working principle, application, advantages and disadvantages.	1	T1 560-561 R1
5	Electro Discharge Machining - working principle, merits, demerits and application	1	T1 561 – 563 R1
6	Wire cut EDM, Electron Beam Machining - working principle, merits and demerits.	1	T1 564-565 T1 567
7	Plasma arc machining - working principle, merits, demerits and application.	1	T1 568
8	Laser Beam Machining - working principle, merits, demerits and application.	1	T1 566-567
9	High speed machining process – deep hole drilling process.	1	T1 466-467&480
10	Quiz	1	GATE questions
	Total no. of hours planned for unit – IV	**10**	

UNIT V: RAPID PROTOTYPING

S. No	Description	Hours Needed	Reference/ Supporting Materials
1	Introduction to Rapid Prototyping	1	R5 532-535
2	Need for RPT– purpose, applications, merits and demerits	1	R5 543-545
3	Stereo–lithography – working principle, applications, advantages and disadvantages.	1	R5 537-539
4	Selective Laser Sintering - working principle, applications, advantages and disadvantages.	1	R5 539-540
5	Fused Deposition Modeling - purpose, applications, merits and demerits	1	R5 536-537
6	Laminated Object Manufacturing - purpose, applications, merits and demerits	1	R5 542-543

7	Solid Ground Curing - working principle, applications, advantages and disadvantages.	1	R5 540-541
8	Ballistic Particle Manufacturing - merits and demerits	1	R5 541-542
9	Comparison of various rapid prototyping processes.	1	W4
10	Quiz	1	MCQ of KU
	Total no. of hours planned for unit – V	**10**	

TEXT BOOKS:

Ref. No	AUTHOR	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
T1	Serope kalpakjian and Steven.R. Schmid	Manufacturing process for engineering materials	Dorling Kindersley (India) Pvt.Ltd, Noida.	2009
T2	O.P.Khanna	A Textbook of Welding Technology	Dhanpat Rai Publications Pvt Ltd, Noida	1998

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R3	Vijay. K. Jain	Advanced Machining Processes	Allied Publishers Pvt. Ltd, Mumbai	2002
R4	P.C.Angelo & R.Subramanian	Powder Metallurgy	PHI Learning Private Limited.	2015
R5	S. Kalpakjian, S. R. Schmid	Manufacturing Engineering and Technology	Dorling Kindersley (India) Pvt. Ltd, Noida.	2014

WEB REFERENCE:

W1.www.ltu.se/cms_fs/1.5838!/fafc1546.pd
W2.www.researchgate.net/publication/250166825_Underwater_Welding_-_A_Review
W3.www.metalwebnews.com/.../underwater-welding/underwater-welding.pdf
W4.http://web.iitd.ac.in/~pmpandey/MEL120_html/RP_document.pdf

TOTAL NUMBER OF COURSE HOURS : 50 Hours

UNIT I

POWDER METALLURGY PROCESS

1. Explain the various stages of powder metallurgy process in detail.

The general sequence of operations involved in the powder metallurgy process is

1. Powder production
2. Compaction
3. Sintering
4. Secondary manufacturing process

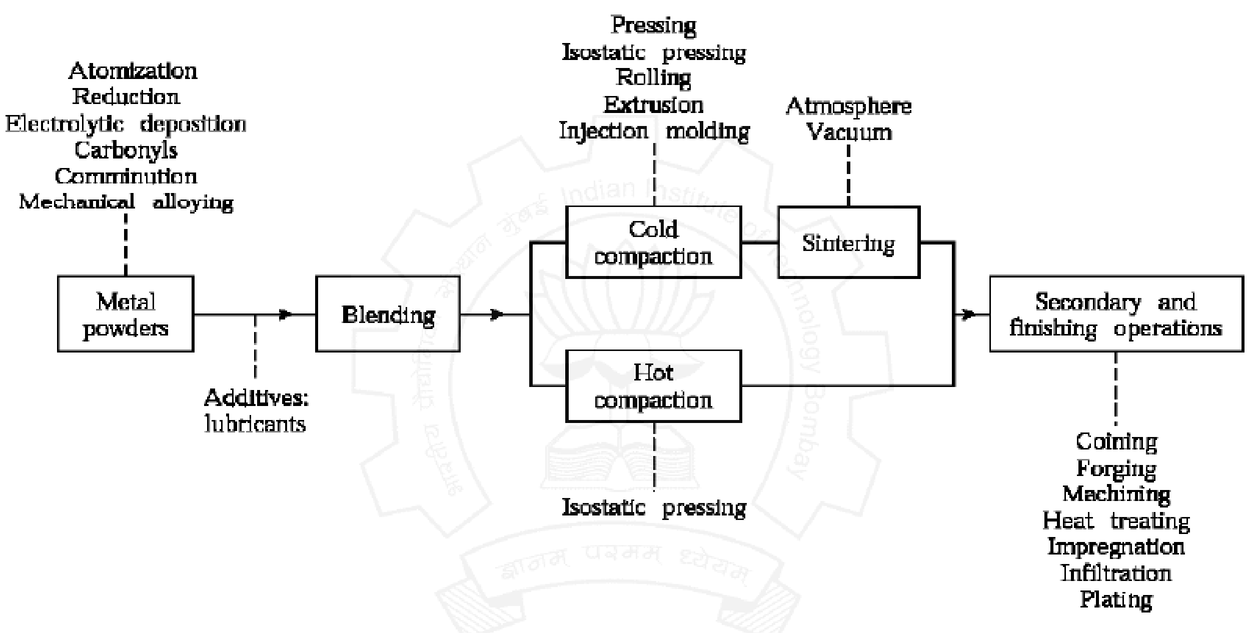


Figure 1: Stages in powder metallurgy

Powder production:

The manufacturing of the material powder is the first step in powder metallurgy processing route that it involves making, characterizing, and treating the powder which have a strong influence on the quality of the end product. Different techniques of powder making are:

a) Atomizing Process

In this process the molten metal is forced through an orifice into a stream of high velocity air, steam or inert gas. This causes rapid cooling and disintegration into very fine powder particles and the use of this process is limited to metals with relatively low melting point.

b) Gaseous Reduction

This process consists of grinding the metallic oxides to a fine state and subsequently, reducing it by hydrogen or carbon monoxide. This method is employed for metals such as iron, tungsten, copper, etc.

c) Electrolysis Process

In this process the conditions of electrode position are controlled in such a way that a soft spongy deposit is formed, which is subsequently pulverised to form the metallic powder. The particle size can be varied over a wide range by varying the electrolyte compositions and the electrical parameters.

d) Carbonyl Process

This process is based upon the fact that a number of metals can react with carbon monoxide to form carbonyls such as iron carbonyl can be made by passing carbon monoxide over heated iron at 50 – 200 bar pressure. The resulting carbonyl is then decomposed by heating it to a temperature of 200 – 3000C yielding powder of high purity, however, at higher cost.

e) Stamp and Ball mills

These are mechanical methods which produce a relatively coarse powder. Ball mill is employed for brittle materials whereas stamps are used for ductile material.

f) Granulation Process

This process consists in the formation of an oxide film in individual particles when a bath of metal is stirred in contact with air.

g) Mechanical Alloying

In this method, powders of two or more pure metals are mixed in a ball mill. Under the impact of the hard balls, the powders are repeatedly fractured and welded together by forming alloy under diffusion.

Compaction:

The principle goal of the compaction process is to apply pressurize and bond the particles to form a cohesion among the powder particles. This is usually termed as the ***green strength*****.** The *compaction* exercise imparts the following effects.

1. Reduces voids between the power particles and enhance the density of the consolidated powder,
2. Produces adhesion and bonding of the powder particles to improve green strength in the consolidated powder particles,
3. Facilitates plastic deformation of the powder particles to conform to the final desired shape of the part,
4. Enhances the contact area among the powder particles and facilitates the subsequent sintering process.

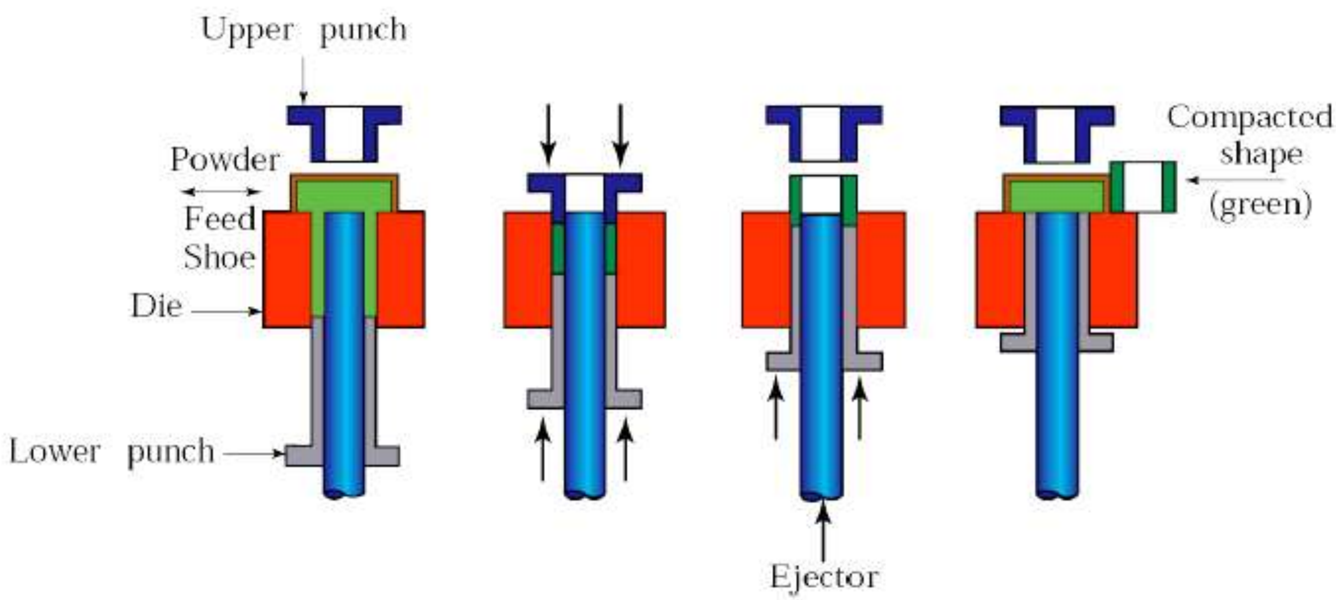


Figure 2: Compaction

Compaction is carried out by pouring a measured amount of metallic powder into the die cavity and applying pressure by means of one or more plungers. To improve uniformity of pressure and reduce porosity in the compacted part, compressive forces from both the top and the bottom sides are necessary. The requisite compacting pressure depends on the specific characteristics and initial shape of the particles, the method of blending and the application of the lubricants. Extremely hard powders are slower and more difficult to press. Some organic binder is usually required to hold the hard particles together after pressing until the sintering process is performed. Figure .2 depicts a schematic view of the powder compaction process to manufacture a typical bushing.

Sintering:

Sintering refers to the heating of the compacted powder perform to a specific temperature (below the melting temperature of the principle powder particles while well above the temperature that would allow diffusion between the neighboring particles). Sintering facilitates the bonding action between the individual powder particles and increase in the strength of the final part. The heating process must be carried out in a controlled, inert or reducing atmosphere or in vacuum for very critical parts to prevent oxidation. Prior to the sintering process, the compacted powder perform is brittle and confirm to very low green strength. The nature and strength of the bond between the particles depends on the mechanism of diffusion and plastic flow of the powder particles, and evaporation of volatile material from the in the compacted perform. Bonding among the powder particles takes places in three ways:

(1) Melting of minor constituents in the powder particles,

(2) Diffusion between the powder particles, and

(3) Mechanical bonding.

The time, temperature and the furnace atmosphere are the three critical factors that control the sintering process. Sintering process enhances the density of the final part by filling up the incipient holes and increasing the area of contact among the powder particles in the compact perform.

Finishing Operation:

After sintering, some finishing operations such as re-pressing (to impart dimensional accuracy) and machining are carried out to further improve the quality of the final part. Parts made through the powder metallurgy based processes are also subjected to other finishing operations such as heat treatment, machining and finishing depending on the requirements.

2. **Mention various methods of metal powder preparation and explain anyone in detail.**

Various methods of metal powder preparation are

1. Mechanical method
2. Physical method
3. Chemical method

Mechanical methods

Cheapest of the powder production methods; These methods involve using mechanical forces such as compressive forces, shear or impact to facilitate particle size reduction of bulk materials; Eg: Milling

Milling:

During milling, impact, attrition, shear and compression forces are acted upon particles. During impact, striking of one powder particle against another occurs. Attrition refers to the production of wear debris due to the rubbing action between two particles. Shear refers to cutting of particles resulting in fracture. The particles are broken into fine particles by squeezing action in compression force type.

Mechanism of milling: Changes in the morphology of powder particles during milling results in the following events.

1. Micro forging,
2. Fracture
3. Agglomeration
4. Deagglomeration

Micro forging => Individual particles or group of particles are impacted repeatedly so that they flatten with very less change in mass

Fracture => Individual particles deform and cracks initiate and propagate resulting in fracture

Agglomeration => Mechanical interlocking due to atomic bonding or vander Waals forces

De agglomeration => Breaking of agglomerates

Milling equipment:

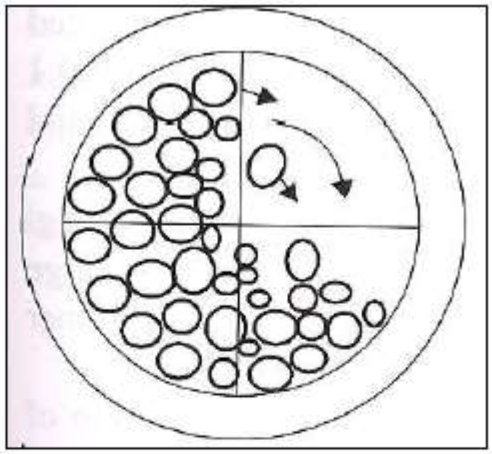
The equipments are generally classified as crushers & mills

Crushing => for making ceramic materials such as oxides of metals

Grinding => for reactive metals such as titanium, zirconium, niobium, tantalum

Ball mills:

This contains cylindrical vessel rotating horizontally along the axis. Length of the cylinder is more or less equal to diameter. The vessel is charged with the grinding media. The grinding media may be made of hardened steel, or tungsten carbide, ceramics like agate, porcelain, alumina, zirconia. During rolling of vessel, the grinding media & powder particles roll from some height. This process grinds the powder materials by impact/collision & attrition.



Ball Mill

Milling can be dry milling or wet milling. In dry milling, about 25 vol% of powder is added along with about 1 wt% of a lubricant such as stearic or oleic acid. For wet milling, 30-40 vol% of powder with 1 wt% of dispersing agent such as water, alcohol or hexane is employed. Optimum diameter of the mill for grinding powders is about 250 mm.

3. What is meant by green compaction? Explain any one compaction method in detail.

Green Compaction:

Powders are compressed into desired shape to produce green compact in powder metallurgy process and it is known as green compaction.

Compaction Method:

The following are generally used methods for compaction.

i. Die compaction
ii. Cold isostatic pressing
iii. Hot isostatic pressing

Die compaction:

The principle goal of the die compaction process is to apply pressure and bond the particles to form cohesion among the powder particles. This is usually termed as the ***green strength***. The *compaction* exercise imparts the following effects.

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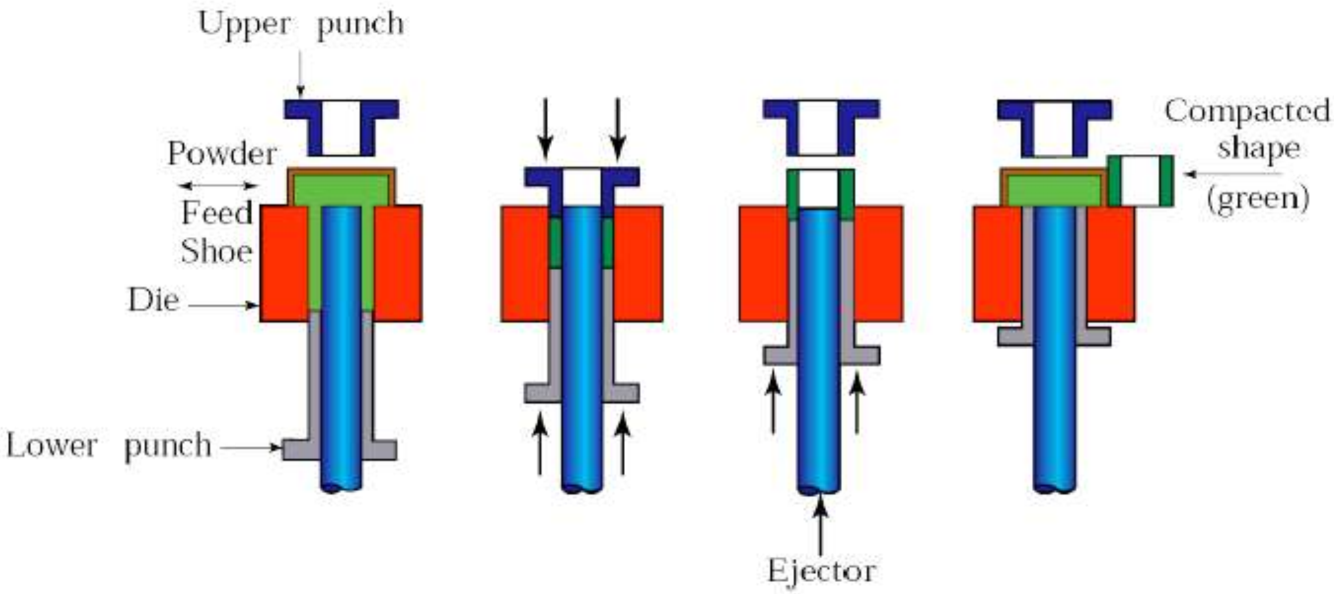

Figure 1: Die Compaction

Die compaction is carried out by pouring a measured amount of metallic powder into the die cavity and applying pressure by means of one or more plungers. The pressure can be provided by either mechanical or hydraulic power.

To improve uniformity of pressure and reduce porosity in the compacted part, compressive forces from both the top and the bottom sides are necessary. The requisite compacting pressure depends on the specific characteristics and initial shape of the particles, the method of blending and the application of the lubricants. Extremely hard powders are slower and more difficult to press. Some organic binder is usually required to hold the hard particles together after pressing until the sintering process is performed. Figure .1 depicts a schematic view of the powder compaction process to manufacture a typical bushing.

4.Explain in detail about atomization process with a neat sketch.

Atomization

This uses high pressure fluid jets to break up a molten metal stream into very fine droplets, which then solidify into fine particles.

High quality powders of Al, brass, iron, stainless steel, tool steel, super alloys are produced commercially

Types of atomization:

- Water atomization
- Gas atomization

- Soluble gas or vacuum atomization,
- Centrifugal atomization
- Rotating disk atomization
- Ultra rapid solidification process,
- Ultrasonic atomization

Water atomization: High pressure water jets are used to bring about the disintegration of molten metal stream. Water jets are used mainly because of their higher viscosity and quenching ability. This is an inexpensive process and can be used for small or large scale production. But water should not chemically react with metals or alloys used.

Gas atomization: Here instead of water, high velocity argon, nitrogen and helium gas jets are used. The molten metal is disintegrated and collected as atomized powder in a water bath. Fluidized bed cooling is used when certain powder characteristics are required.

Mechanism of atomization:

In conventional (gas or water) atomization, a liquid metal is produced by pouring molten metal through a tundish with a nozzle at its base. The stream of liquid is then broken into droplets by the impingement of high pressure gas or water. This disintegration of liquid stream is shown in figure. This has five stages

i) Formation of wavy surface of the liquid due to small disturbances
ii) Wave fragmentation and ligament formation
iii) Disintegration of ligament into fine droplets
iv) Further breakdown of fragments into fine particles
v) Collision and coalescence of particles

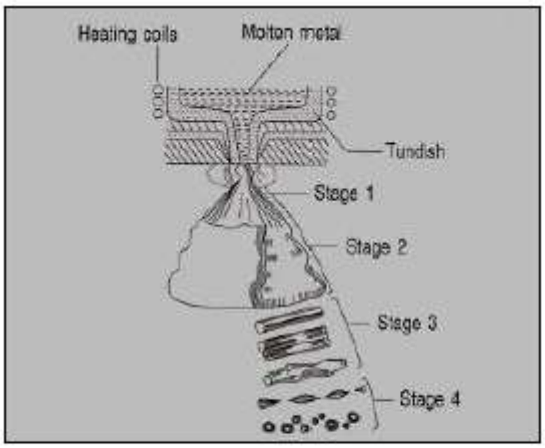

Figure: Mechanism of atomization

The interaction between jets and liquid metal stream begins with the creation of small disturbances at liquid surfaces, which grow into shearing forces that fragment the liquid into ligaments. The broken ligaments are further made to fine particles because of high energy in impacting jet.

Lower surface tension of molten metal, high cooling rate facilitates formation of irregular surface as like in water atomization

High surface tension, low cooling rates facilitates spherical shape formation as like in inert gas atomization

5. Explain in detail powder preparation process.

Powder production:

The manufacturing of the material powder is the first step in powder metallurgy processing route that it involves making, characterizing, and treating the powder which have a strong influence on the quality of the end product. Different techniques of powder making are:

Atomizing Process

In this process the molten metal is forced through an orifice into a stream of high velocity air, steam or inert gas. This causes rapid cooling and disintegration into very fine powder particles and the use of this process is limited to metals with relatively low melting point.

Types of atomization:

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- Gas atomization
- Soluble gas or vacuum atomization,
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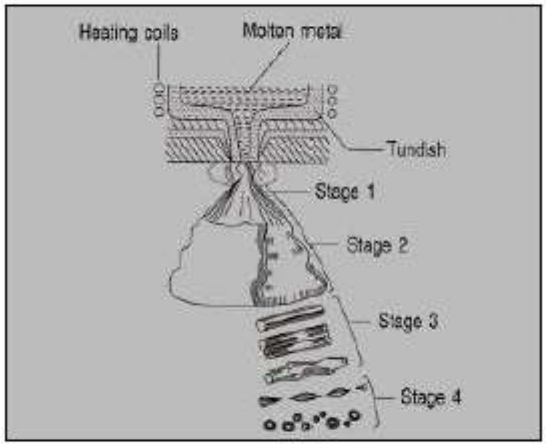

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Electrolysis Process

In this process the conditions of electrode position are controlled in such a way that a soft spongy deposit is formed, which is subsequently pulverised to form the metallic powder. The particle size can be varied over a wide range by varying the electrolyte compositions and the electrical parameters.

Carbonyl Process

This process is based upon the fact that a number of metals can react with carbon monoxide to form carbonyls such as iron carbonyl can be made by passing carbon monoxide over heated iron at 50 – 200 bar pressure. The resulting carbonyl is then decomposed by heating it to a temperature of 200 – 3000C yielding powder of high purity, however, at higher cost.

Stamp and Ball mills

These are mechanical methods which produce a relatively coarse powder. Ball mill is employed for brittle materials whereas stamps are used for ductile material.

Ball mills:

This contains cylindrical vessel rotating horizontally along the axis. Length of the cylinder is more or less equal to diameter. The vessel is charged with the grinding media. The grinding media may be made of hardened steel, or tungsten carbide, ceramics like agate, porcelain, alumina, zirconia. During rolling of vessel, the grinding media & powder particles roll from some height. This process grinds the powder materials by impact/collision & attrition.

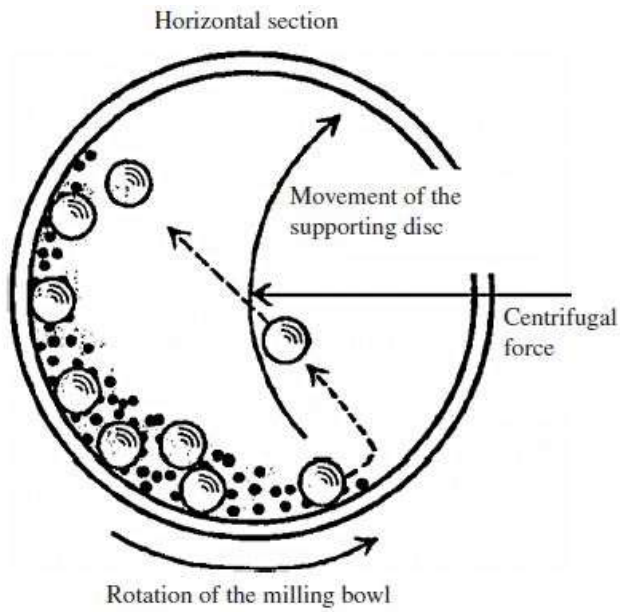

Figure: Ball Mill

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Granulation Process

This process consists in the formation of an oxide film in individual particles when a bath of metal is stirred in contact with air.

Mechanical Alloying

In this method, powders of two or more pure metals are mixed in a ball mill. Under the impact of the hard balls, the powders are repeatedly fractured and welded together by forming alloy under diffusion.

6.Explain the following processes in detail

i) Compaction

Compaction:

Powders are compressed into desired shape to produce green compact in powder metallurgy process and it is known as green compaction.

Compaction Method:

The following are generally used methods for compaction.

1. Die compaction
2. Cold isostatic pressing
3. Hot isostatic pressing

1. Die compaction:

The principle goal of the die compaction process is to apply pressure and bond the particles to form cohesion among the powder particles. This is usually termed as the ***green strength***. The *compaction* exercise imparts the following effects.

5. Reduces voids between the power particles and enhance the density of the consolidated powder,
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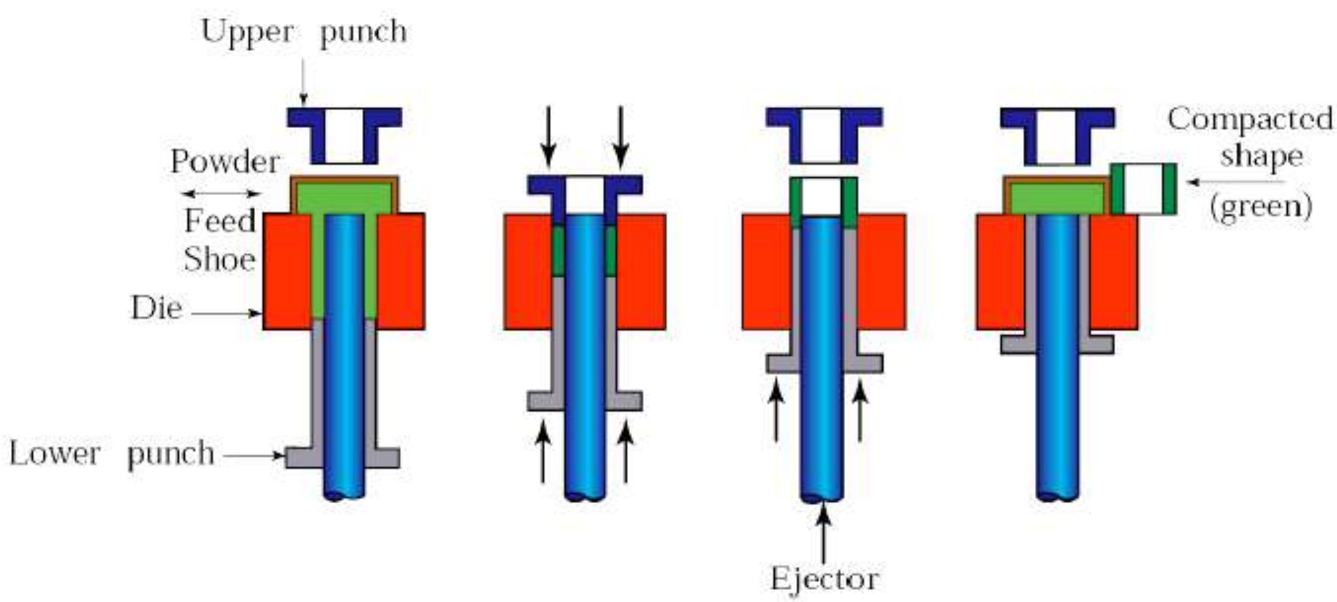

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2. Cold isostatic pressing (CIP)

Cold isostatic pressing (CIP) is a manufacturing process for the consolidation of metal and ceramic powders.

Cold isostatic pressing uses fluid as a means of applying pressure (Typical pressures range from 100-600 MPa) to the mold at room temperature. After removal the part still needs to be sintered. It is the process by which fluid medium especially liquid is preferred as a working medium. It is helpful in distributing pressure uniformly over the compaction material contained in a rubber bag.

The very high pressure enables the voids in the powder to be smaller or eliminated, through high compaction forces that will make metal powder deform due to its ductility and ceramic powders to likely crumble somewhat so that density increases and the end-product is a “green” part that can be handled, machined and sintered.

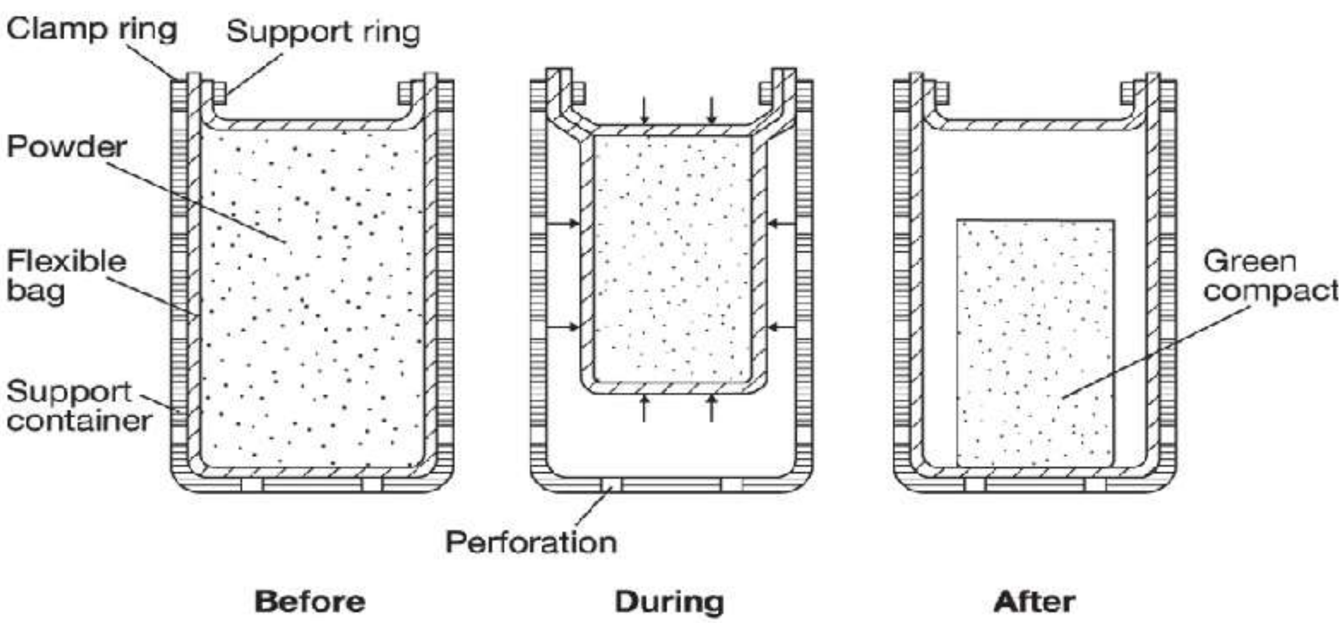


Figure: 2 Cold isostatic pressing

3. Hot isostatic pressing

HIP is a fabrication process for the densification of castings, consolidation of powder metals (as in metal injection molding or tool steels and high-speed steels), compaction of ceramics for dental and medical parts, additive manufacturing (3-D printing), and many more applications.

The pressure applied in a HIP is generally between 100 and 200 MPa using pure argon gas. However, both lower and higher pressure can be used for some special applications. Other gases like nitrogen and helium are also used, while gases like hydrogen and carbon dioxide are more seldom put into use in production units. Combinations of these gases can also be used. The application determines which gas is used for which purpose, especially since helium is quite expensive compared with argon/nitrogen and hydrogen in incorrect concentrations is very explosive.

The parts to be HIPed are initially heated either at elevated pressure or in vacuum. Introducing the gas early in the process, and while heating, causes it to expand and help to build up the pressure in the HIP furnace more effectively. The material composition and suggested HIP cycle govern the startup procedure.

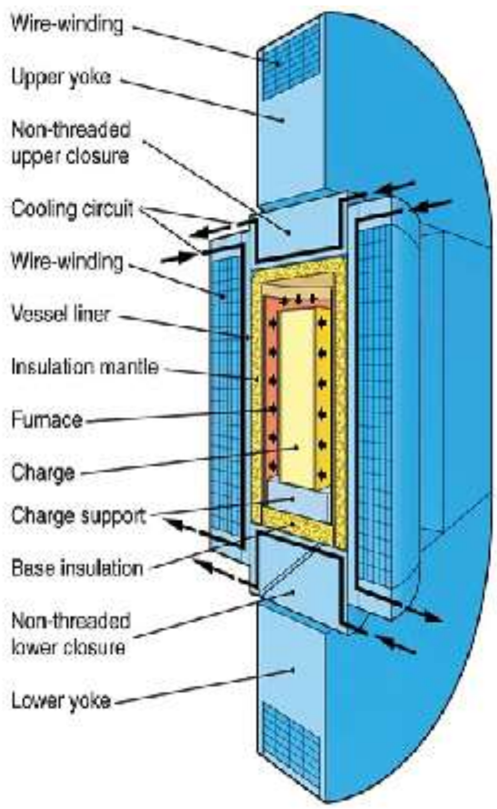


Figure: 3 Hot isostatic pressing

The three main advantages of HIP include:

Increase in Density

- Elimination of internal porosity for defect healing of castings
- Longer lifetime of HIPed parts
- Predictive lifetime
- Lighter and/or low-weight designs

Improvement of Mechanical Properties

- Fatigue life increased up to 10 times, depending on the alloy system
- Decrease in variation of properties
- Increase in ductility and toughness
- Form metallurgical bond between dissimilar materials (diffusion bonding)

More Efficient Production

- Decreased scrap/loss
- Less or no non-destructive testing (NDT)
- Freedom to choose casting methods for optimal productivity

ii) Sintering`(Refer Unit I Q.no 7)

7. Explain the mechanism of sintering in detail.

Sintering:

Sintering refers to the heating of the compacted powder perform to a specific temperature (below the melting temperature of the principle powder particles while well above the temperature that would allow diffusion between the neighboring particles).

Sintering facilitates the bonding action between the individual powder particles and increase in the strength of the final part. The heating process must be carried out in a controlled, inert or reducing atmosphere or in vacuum for very critical parts to prevent oxidation. Prior to the sintering process, the compacted powder perform is brittle and confirm to very low green strength.

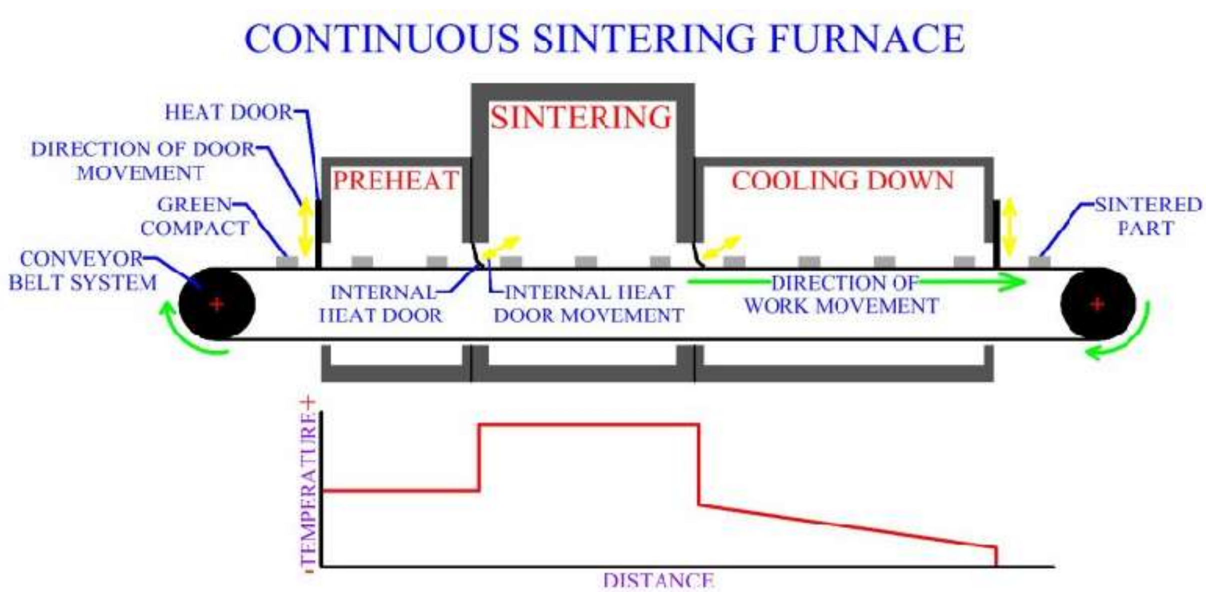


Figure: Continuous Sintering Furnace

Sintering furnace has three zones,

1**. Preheating zone**- the compact is preheated

2. **Sintering zone-**the temperature will be high in this zone and actual bonding of powder particles happens here.

3. **Cooling zone**- Here no heat energy is supplied the sintered part slowly cools here.

The time, temperature and the furnace atmosphere are the three critical factors that control the sintering process. Sintering process enhances the density of the final part by filling up the incipient holes and increasing the area of contact among the powder particles in the compact perform.

Mechanism of Sintering:

The nature and strength of the bond between the particles depends on the mechanism of diffusion and plastic flow of the powder particles, and evaporation of volatile material from the in the compacted perform.

Bonding among the powder particles takes places in three ways:

(1) Melting of minor constituents in the powder particles,

(2) Diffusion between the powder particles, and

(3) Mechanical bonding.

The main driving force that enacts this particle bonding is considered to be a reduction of energy due to a reduced surface area. Powders with a greater surface area will have a higher driving force towards bonding and a lowering of this potential energy.

Alloying of different metal powders also occurs during sintering. The sintering temperature must always be lower than the melting temperature of at least one of the powder constituents. In some cases, the sintering temperature is above the melting point of one of the materials but below the melting point of the other. This is called liquid phase sintering. Liquid phase sintering can eliminate porosity and produce parts with excellent material properties.

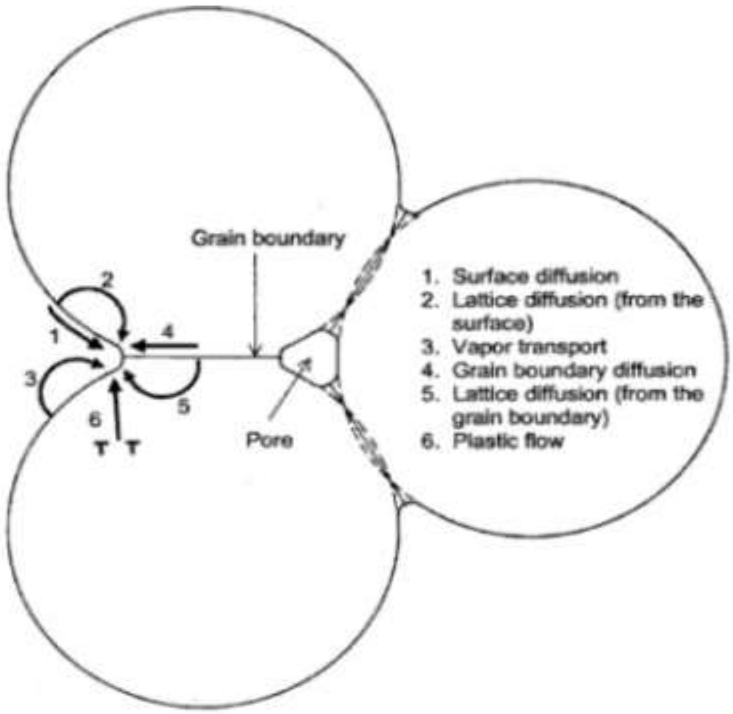


Figure: Mechanism of Sintering

8. Explain in detail about ball milling process with a neat sketch.

Ball mills:

This contains cylindrical vessel rotating horizontally along the axis. Length of the cylinder is more or less equal to diameter. The vessel is charged with the grinding media. The grinding media may be made of hardened steel, or tungsten carbide, ceramics like agate, porcelain, alumina, zirconia. During rolling of vessel, the grinding media & powder particles roll from some height. This process grinds the powder materials by impact/collision & attrition.

Milling can be dry milling or wet milling. In dry milling, about 25 vol% of powder is added along with about 1 wt% of a lubricant such as stearic or oleic acid. For wet milling, 30-40 vol% of powder with 1 wt% of dispersing agent such as water, alcohol or hexane is employed. Optimum diameter of the mill for grinding powders is about 250 mm.

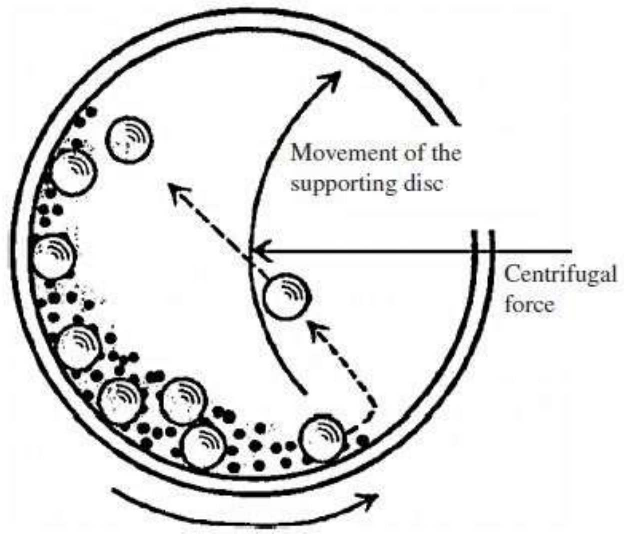


Figure: Ball Mill

Steps in ball milling method;

1. As the name suggests, the ball milling method consists of balls and a mill chamber. Therefore over all a ball mill contains a stainless steel container and many small iron, hardened steel, silicon carbide, or tungsten carbide balls are made to rotate inside a mill (drum).
2. The powder of a material is taken inside the steel container. This powder will be made into nanosize using the ball milling technique. A magnet is placed outside the container to provide the pulling force to the material and this magnetic force increases the milling energy when milling container or chamber rotates the metal balls.
3. The ball to material mass ratio is normally maintained at 2 ratio1.
4. These silicon carbide balls provide very large amount of energy to the material powder and the powder then get crushed. This process of ball milling is done approximately 100 to 150 hrs to get uniform fine powder.
5. Ball milling is a mechanical process and thus all the structural and chemical changes are produced by mechanical energy.

Merits of Ball Mill:

1. Suitable for grinding material with high hardness
2. The shape of the final products is circular
3. No pollution for the powder with ceramic ball
4. Stable performance
5. Easy installation
6. The capacity and fineness can be adjusted by adjusting the diameter of the ball

9. Explain in detail about water atomization process. (Refer Unit 1, Q.no 4)

10. Explain in detail die compaction with a neat sketch (Refer Unit 1, Q.no 3)

11. Explain in detail about hot isostatic pressing. (Refer Unit 1, Q.no 6 (i) 3)

MULTIPLE CHOICE QUESTIONS

Sl.	Question	opt 1	opt 2	opt 3	opt 4	Answer
1	A part produced by Powder metallurgy is	Welded part	Cast part	Forging part	Sintered part	Sintered part
2	Which of the following method is used to make powder from brittle metals?	Mechanical pulverisation	Electrolytic process	Chemical reduction	Atomization	Mechanical pulverisation
3	Which method is used to make powder of metals having low melting point?	Electrolytic process	Chemical reduction	Thermaldecom position	Atomization	Atomization
4	Molten metal is forced through a small orifice and broken up by a stream of compressed air in	Atomization	Electrolytic process	Ball milling	Chemical reduction	Atomization
5	The parts produced by Powder metallurgy	Always require machining	Are of higher dimensional accuracy	Cannot be heat treated	None of the above	Are of higher dimensional accuracy
6	Which of the following tool is manufactured by powder metallurgy?	High speed steel	Sintered carbides	High carbon steel	Low carbon steel	Sintered carbides
7	For powder of Aluminum and its alloys, the sintering temperature and time is	370° – 500°C, upto 24 hrs	250° – 350°C, upto	400°-600°C, upto 20 hrs	550° – 700°C, upto 22 hrs	370° – 500°C, upto 24 hrs
8	Sintering increases	Electrical conductivity, density and ductility	Electrical conductivity, density and brittleness	Porosity, electrical conductivity and brittleness	Porosity, density and ductility	Electrical conductivity, density and ductility
9	The process of infiltration in sintered products is to improve	Porosity	Dimensional accuracy	Surface finish	Coherent property	Porosity
10	Which of the following products are made by powder metallurgy?	Tungsten wire	Shafts	Clamps	Light weight structures	Tungsten wire
11	The process producing a relatively coarse powder with a high percentage of oxide is	Atomizing	Gaseous reduction	Granulation	Carbonyl	Granulation
12	The most common powders used are	Aluminum and magnesium	Copper and copper alloys	Titanium and cobalt	Iron and steel	Iron and steel
13	Water atomized particles are	Symmetrical	Irregular	Very coarse	Very fine	Irregular
14	Powders produced by mechanical method means are	Hard and brittle	Soft and malleable	Used only for work handling	Cannot be heat treated	Hard and brittle
15	Parts in a “green state” are	Anti-magnetic	At maximum strength	At minimum strength	Ready for plating or finishing	At minimum strength
16	An endothermic atmosphere includes	Oxygen	Argon	Hydrogen	Carbondioxid e	Hydrogen
17	Parts produced by injection molding have densities in the range of	50% or more	50% or less	75% or less	95% or more	95% or more
18	Total debinding and sintering time can range	5 to 10 minutes	5 to 10 hours	8 to 24 hours	15 to 30 hours	8 to 24 hours
19	After being consolidated or formed in molds or dies, the part	Green compact	Semi-finished component	Low strength component	High strength component	Green compact

	is called as					
20	“Cold isostatic pressing” takes place at	Absolute zero	Around 100°C	Around 320°C	At room temperature	At room temperature
21	A “bag” refers to a	Powder reservoir	Flexible mold	Heating enclosure	Container for excess powder	Flexible mold
22	The sintering temperatures used in powder metallurgy is	0.4 of melting temperature	0.5 of melting temperature	0.6 of melting temperature	0.7 of melting temperature	0.7 of melting temperature
23	The width of the aperture in a wire screen is	Mesh size	Mesh number	Micropore	Macro pore	Mesh size
24	The contact area between particles in a sintering is	Contact point	Neck	Net shape	Nib	Neck
25	The condition of the moulded component prior to debinding in MIM	Green compact	Green strength	Green state	Green density	Green state
26	The forming of the compact at or below room temperature	Cold pressing	HIP	Comminution	Sintering	Cold pressing
27	The development of cluster of powder particles is	Agglomeration	Deagglomera tion	Aggregate	Binder	Agglomeration
28	A material consisting ceramic particles bonded with a metal is known as	Cermet	Green compact	Ceramic cement	Core	Cermet
29	Cemented carbide tool tips are produced by	Powder metallurgy	Casting	Forging	Machining	Powder metallurgy
30	During sintering of a powder metal compact, which of the following process takes place?	All the pores reduce in size	Some of the pores grow	Bend is formed between them	None of the above	All the pores reduce in size
31	The powder metallurgy technique for the product of precision component is characterized mainly by reduction in	Material cost	Machining cost	Equipment cost	None of the above	None of the above
32	The method most widely used for production of metal powder for use in powder metallurgy is	Liquid metal spray	Crushing using impact	Electrolytic deposition	Thermal deposition	Liquid metal spray
33	_________ is a process whereby a slug of lower melting point metal is placed against sintered part	Infiltration	Impregnation	Sizing	Wetting	Infiltration
34	_________ is used to make the ceramic water suspension more uniform	Lubricant	Plasticizer	Wetting agent	Deflocculent	Deflocculent
35	The common process in which ceramic powders are used for making components is	Slip casting	Wet pressing	Injection moulding	Float method	Slip casting
36	Metal carbonyl's are formed by reaction with	CO	CO_2	He	O_2	CO
37	Accicular shape of powder is obtained by	Chemical decomposition	Atomization	Reduction of oxides	Carbonyl	Chemical decomposition
38	Flake shape of powder is obtained by	Mechanical comminution	Reduction of oxides	Carbonyl	Chemical decompositio n	Mechanical comminution
39	Porus powders are obtained by	Mechanical comminution	Reduction of oxides	Carbonyl	Chemical decompositio n	Reduction of oxides
40	Electrolytic deposition provides________________	Accicular	Flake	Spherical	Dendritic	Dendritic

	powders					
41	Which among the following uses fused salt?	Comminution	Reduction	Carbonyl	Electrolytic deposition	Electrolytic deposition
42	Which process is used to crush metal into powders?	Comminution	Carbonyl	Reduction	Atomization	Comminution

UNIT II
ADVANCED WELDING PROCESSES

12. Explain plasma arc welding process with a neat sketch.

Plasma Arc Welding Process

It is a fusion welding process wherein the coalescence is produced by heating the work with a constricted arc established between a non consumable tungsten electrode and work piece or between a non consumable electrode and constricted nozzle. The shielding of the weld pool is obtained by the hot ionized gas produced by passing inert gas through the arc and constricted nozzle. Filler material may or may not be applied.

Principle:

An arc is established between a non consumable tungsten electrode and work piece or between a non consumable electrode and constricted nozzle. An inert gas is passed through the inner orifice surrounding the tungsten electrode and subsequently the gas is ionized and conducts electricity. This state of ionized gas is known as plasma. The plasma arc is allowed to pass through the constricted nozzle causing high energy and current density. Subsequently high concentrate heat and very high temperatures are reached and weldment is created.

Operation:

There are two methods of plasma-arc welding:

In the transferred-arc method of plasma-arc welding (in pic left side), the work piece being welded is part of the electrical circuit. The arc transfers from the electrode to the work piece hence the term transferred.

In the non transferred-arc method of plasma-arc welding (in pic right side), the arc occurs between the electrode and the nozzle and the heat is carried to the work piece by the plasma gas. This thermal-transfer mechanism is similar to that for an oxy-fuel flame.

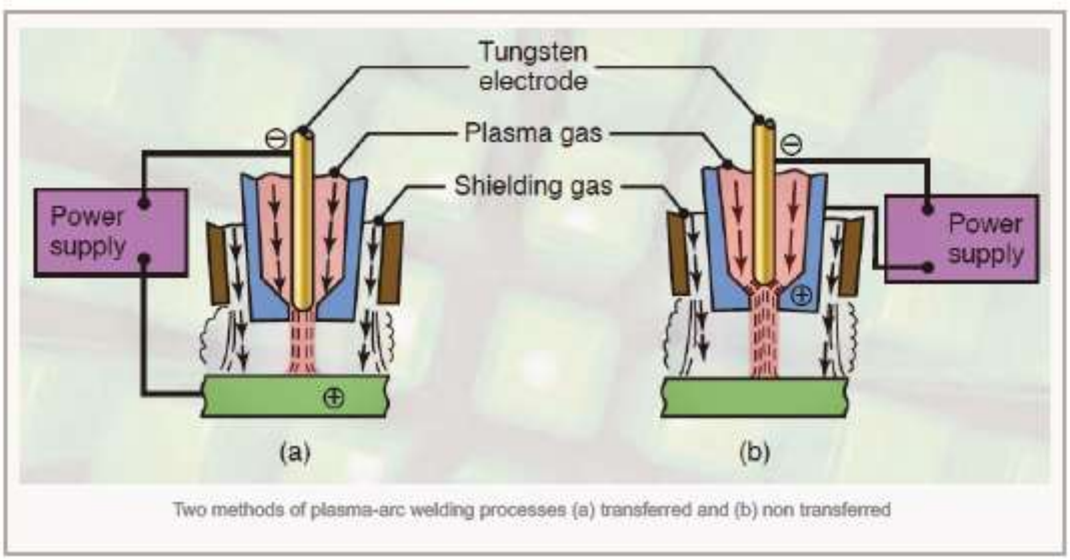


Figure: Plasma arc welding

The high heat concentration can penetrate completely through the joint with thicknesses as much as 20 mm for some titanium and aluminium alloys. In the keyhole technique, the force of the plasma arc displaces the molten metal and produces a hole at the leading edge of the weld pool. Plasma-arc welding often is used rather than Gas Tungsten-arc welding for butt and lap joints because of its higher energy concentration, better arc stability and higher speed of welding.

Applications:

This process can be used to join all the materials those can be welded by welding TIG process. Present applications of the process include:

1. Piping and tubing of stainless and titanium
2. Submarine, aeronautical industry and jet engine manufacturing
3. Electronic components.

Advantages of PAW:

1. Welding speed is higher.
2. Penetration is more.
3. Higher arc stability.
4. The distance between torch and workpiece does not affect heat concentration on the work
5. Up to some extent.
6. Addition of filler material is easier than that of TIG welding process.
7. Thicker job can be welded.
8. Higher depth to width ratio is obtained resulting in less distortion.

Disadvantages of PAW:

1. Higher radiations.
2. Noise during welding.
3. Process is complicated and requires skilled manpower.
4. Gas consumption is high.
5. Higher equipment and running cost.
6. Higher open circuit voltage requiring higher safety measures to take.

13. Explain in detail electron beam welding process with a neat sketch.

Electron Beam Welding Process:

Principle:

Electron Beam Welding (EBW) is a fusion welding in which coalescence is produced by heating the work piece due to impingement of the concentrated electron beam of high kinetic energy on the work piece.

EBW Equipment:

An EBW set up consists of the following major equipment:

a) Electron gun,
b) Power supply,
c) Vacuum Chamber, and
d) Work piece handling device

Electron-Gun: An electron gun generates, accelerates and aligns the electron beam as required onto the work piece. The gun is of two types: Self accelerated and work accelerated. In the self accelerate gun, electrons are accelerated by applying potential difference between the cathode and the anode. The work accelerated gun accelerates the electrons by providing potential difference.

Grid cup: Grid cup is a part of triode type electron gun. A negative voltage with respect to cathode is applied to the grid. The grid controls the beam.

Focusing unit: It has two parts: Electron focusing lens and deflection coil. Electron focusing lens focuses the beam into work area. The focusing of the electrons can be carried out by deflection of beams. The electromagnetic lens contains a coil encased in iron. As the electrons enter into the magnetic field, the electron beam path is rotated and refracted into a convergent beam. The extent of spread of the beam can be controlled by controlling the amount of DC voltage applied across the deflection plates.

Electron gun power supply: It consists of mainly the high voltage DC power supply source, emitter power supply source, electromagnetic lens and deflection coil source. In the high voltage DC power supply source the required load varies within 3-100 kW. It provides power supply for acceleration of the electrons. The potential difference for high voltage equipment ranges from 70-150 kV and for low voltage equipment 15-30 kV. The current level ranges from 50-1000 mA. In emitter power supply, AC or DC current is required to heat the filament for emission of electrons. However DC current is preferred as it affects the direction of the beam. The amount of current depends upon the diameter and type of the filament. The current and voltage varies from 25-70 A and 5-30 V respectively. The power to the electromagnetic lens and deflection coil is supplied through a solid state device.

Vacuum Chamber: In the vacuum chamber pressure is reduced by the vacuum pump. It consists of a roughing mechanical pump and a diffusion pump. The pressure ranges from 100 kPa for open atmosphere to 0.13-13 Pa for partial vacuum and 0.13-133 mPa for hard vacuum. As the extent of vacuum increases, the scattering of the electrons in the beam increases. It causes the increase in penetration.

Work Piece Handling Device: Quality and precision of the weld profile depends upon the accuracy of the movement of work piece. There is also provision for the movement of the work piece to control the welding speed. The movements of the work piece are easily adaptable to computer numerical control.

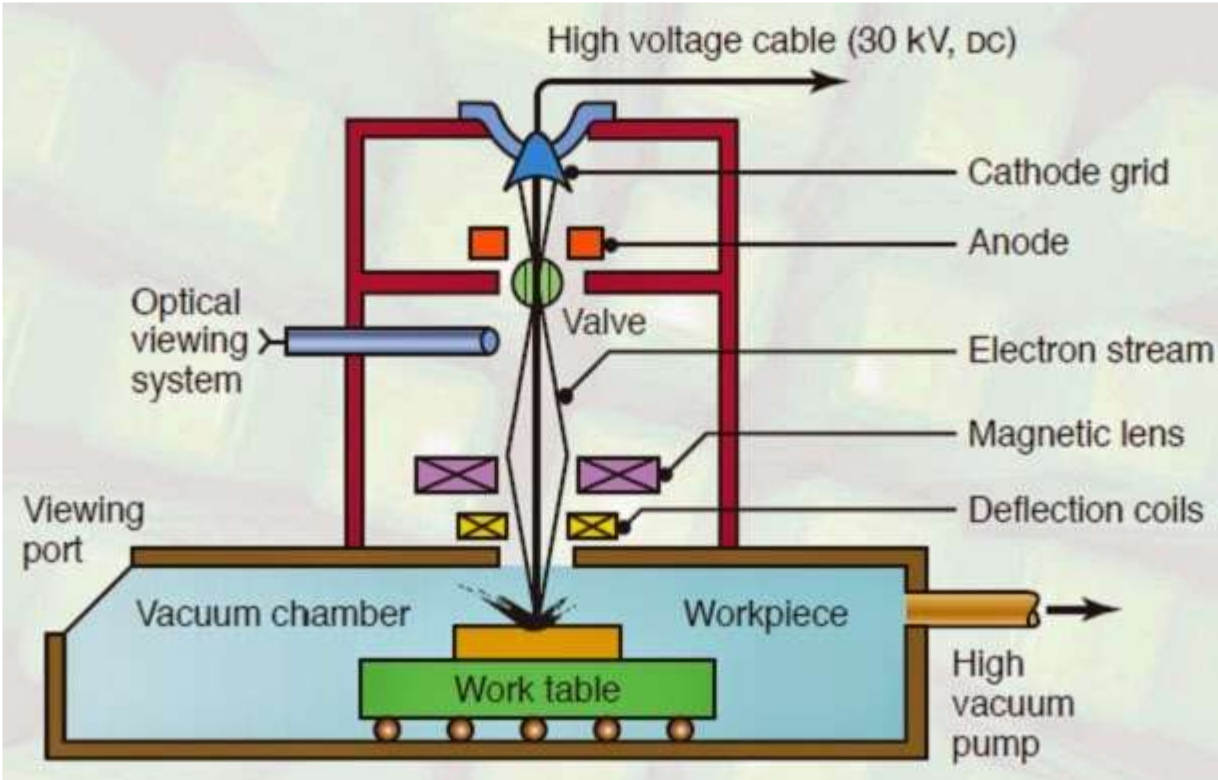


Figure: Electron Beam Welding Process

Advantages of EBW:

1) High penetration to width can be obtained, which is difficult with other welding processes.
2) High welding speed is obtained.
3) Material of high melting temperature can be welded.
4) Superior weld quality due to welding in vacuum.
5) High precision of the welding is obtained.
6) Distortion is less due to less heat affected zone.
7) Dissimilar materials can be welded.
8) Low operating cost.
9) Cleaning cost is negligible.
10) Reactive materials like beryllium, titanium etc. can be welded.
11) Materials of high melting point like columbium, tungsten etc. can be welded.
12) Inaccessible joints can be made.
13) Very wide range of sheet thickness can be joined (0.025 mm to 100 mm)

Disadvantages of EBW:

1) Very high equipment cost.
2) High vacuum is required.

Applications of EBW:

1. Electron beam welding process is mostly used in joining of refractive materials like columbium, tungsten, ceramic etc. which are used in missiles.
2. In space shuttle applications wherein reactive materials like beryllium, zirconium, titanium etc. are used.
3. In high precession welding for electronic components, nuclear fuel elements, special alloy jet engine components and pressure vessels for rocket plants.
4. Dissimilar material can be welded like invar with stainless steel.

14. Explain in detail thermit welding process with its applications.

Principle:

The thermit welding process is the result of fusion created by a chemical reaction that occurs due to the difference of free energy between aluminum and metal oxide. This difference produces enough heat to produce liquid steel or any other metal and allow without applying outside energy and causes welding.

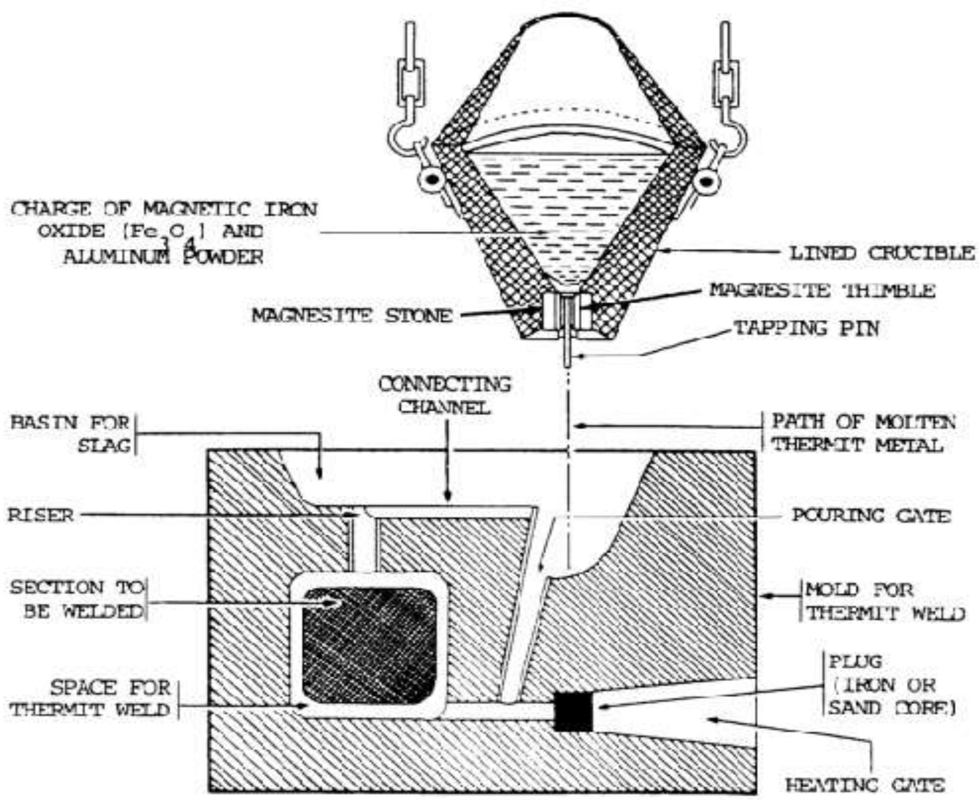


Figure: Thermit Welding Process

Key Units:

Crucible: The thermit chemical reaction takes place in a vessel called a crucible
Mixture: A mixture of finely divided aluminum, metal oxide with the addition of any required alloying metals
Mold: This is a mold that is formed around parts that need to be welded. The mode receives the molten metal.
Reaction: The chemical reaction between aluminum and metal oxide. The reaction produces an aluminum oxide slag and superheated molten metal.
Process:

In preparing the joint for thermit welding, the parts to be welded must be cleaned, alined, and held firmly in place. If necessary, metal is removed from the joint to permit a free flow of the thermit metal into the joint. A wax pattern is then made around the joint in the size and shape of the intended weld. A mold made of refractory sand is built around the wax pattern and joint to hold the molten metal after it is poured. The sand mold is then heated to melt out the wax and dry the mold. The mold should be properly vented to permit the escape of gases and to allow the proper distribution of the thermit metal at the joint. A thermit welding crucible and mold is shown in figure below.

Advantages:

- This process is used for welding of damaged wobblers and large broken crankshafts
- To restore the broken teeth on gears

Disadvantages:

- Not feasible for low melting points
- High skill operators are required
- Reduces the risks to operate
- Low deposition rate
- High level of fume

Application:

- Mainly this technique is used in the repair works of rails in railways.
- For welding large gear teeth.

15. Explain in detail about friction welding process with a neat sketch.

Friction Welding Process:

Principle: Friction welding (FRW) is a solid-state welding process that generates heat through mechanical friction between work pieces in relative motion to one another, with the addition of a lateral force called "upset" to plastically displace and fuse the materials.

Because no melting occurs, friction welding is not a fusion welding process in the traditional sense, but more of a forge welding technique. Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.

Friction welding (FRW) is classified into two types

1. Direct friction welding process (without fly wheel)

2. Inertia welding process (with fly wheel)

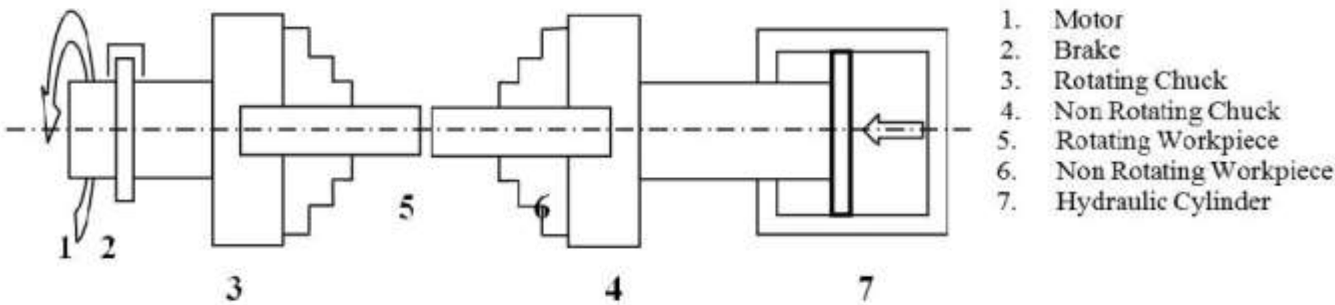


Figure 1: Direct friction welding process

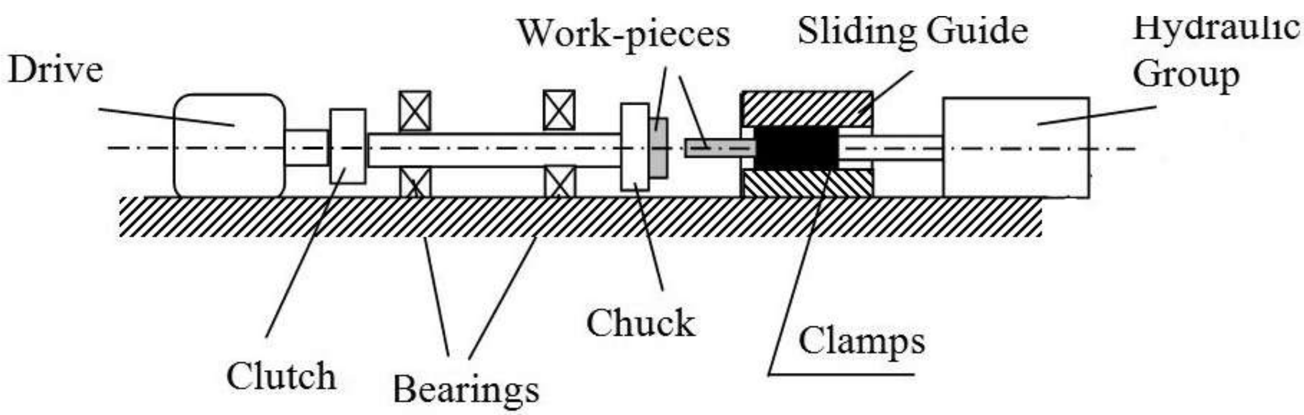


Figure 2: Inertia welding process

In friction welding the heat required to produce the joint is generated by friction heating at the interface. The components to be joined are first prepared to have smooth, square cut surfaces. One piece is held stationary while the other is mounted in a motor driven chuck or collet and rotated against it at high speed.

A low contact pressure may be applied initially to permit cleaning of the surfaces by a burnishing action. This pressure is then increased and contacting friction quickly generates enough heat to raise the abutting surfaces to the welding temperature.

As soon as this temperature is reached, rotation is stopped and the pressure is maintained or increased to complete the weld. The softened material is squeezed out to form a flash. A forged structure is formed in the joint. If desired, the flash can be removed by subsequent machining action. Friction welding has been used to join steel bars upto 100 mms in diameter and tubes with outer diameter upto 100 mm

Inertia welding is a modified form of friction welding, where the moving piece is attached to a rotating flywheel. The flywheel is brought to a specified rotational speed and is then separated.

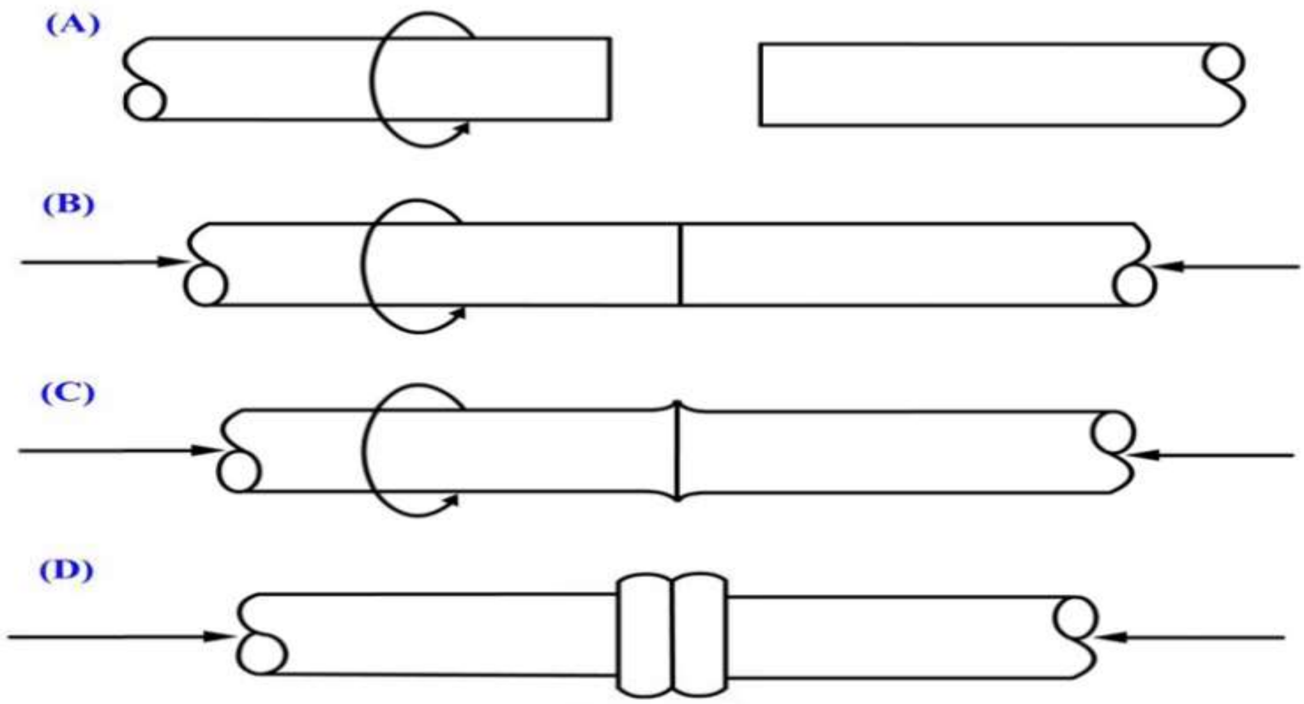


Figure: Basic steps in Friction welding (FRW)

Advantages of friction welding process:

1. Minimal joint preparation
2. Faster Weld Cycles
3. Join Dissimilar Materials

16. Explain in detail about friction stir welding process with a neat sketch.

Frictions stir welding process:

Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing work pieces without melting the work piece material.

Heat is generated by friction between the rotating tool and the work piece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure.

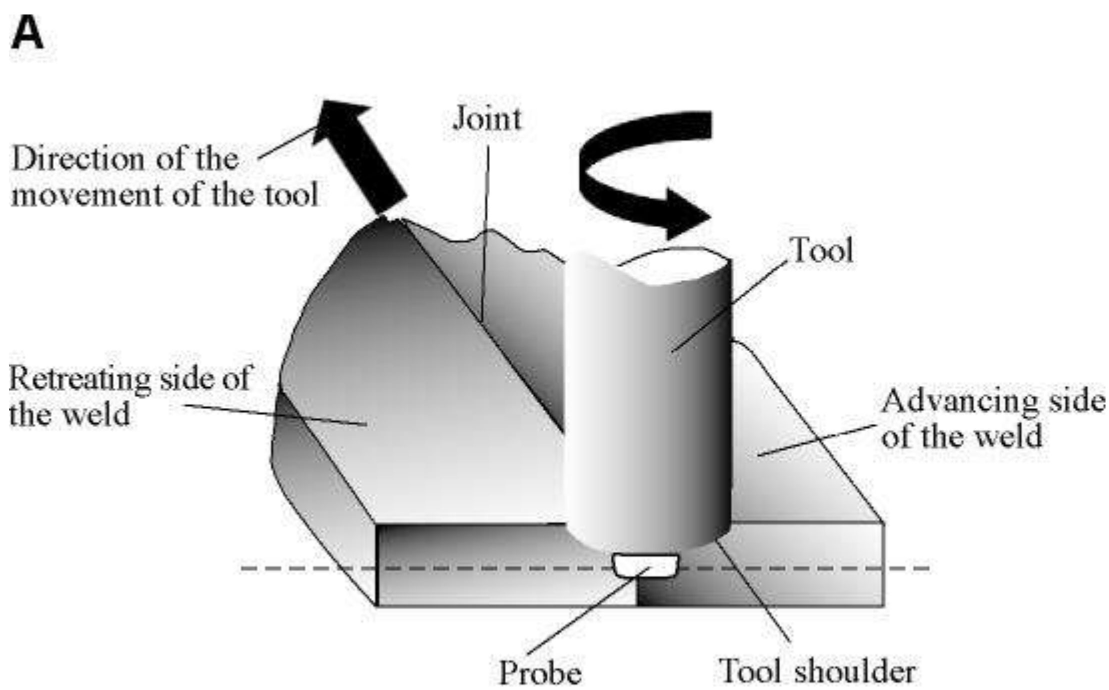


Figure: Friction Stir Welding

Working:

A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped work pieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the work pieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed.

Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the tool is moved forward, a special profile on the probe forces plasticised material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

The necessity of Friction Stir Welding:

The basic problems with fusion welding of aluminum and its alloys are that they possess:

- Cast brittle dendritic structure,
- Micro porosity,
- Inferior mechanical and fatigue properties,
- Loss of strength in heat affected zone,
- Solidification and liquation cracking,
- Loss of alloying elements from the weld pool.

Disadvantages of the process

- Exit hole left when tool is withdrawn.
- Large down forces required with heavy-duty clamping necessary to hold the plates together.
- Less flexible than manual and arc processes (difficulties with thickness variations and non-linear welds).
- Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

17. Explain in detail Electro slag welding process and list its applications.

Electro slag welding (ESW):

Working:

Electro slag welding (ESW) is a highly productive, single pass welding process for thick (greater than 25 mm up to about 300 mm) materials in a vertical or close to vertical position.

(ESW) is similar to electro gas welding, but the main difference is the arc starts in a different location. An electric arc is initially struck by wire that is fed into the desired weld location and then flux is added.

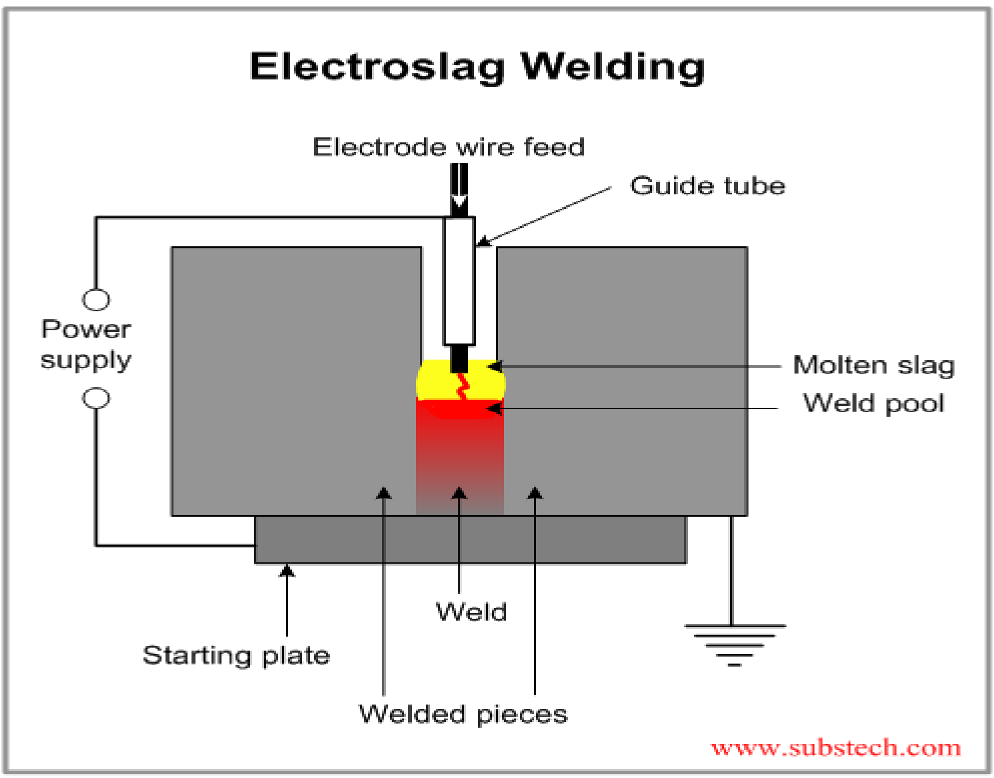


Figure: Electro-slag welding

Additional flux is added until the molten slag, reaching the tip of the electrode, extinguishes the arc. The wire is then continually fed through a consumable guide tube (can oscillate if desired) into the surfaces of the metal work pieces and the filler metal are then melted using the electrical resistance of the molten slag to cause coalescence.

The wire and tube then move up along the work piece while a copper retaining shoe that was put into place before starting (can be water-cooled if desired) is used to keep the weld between the plates that are being welded.

This process uses a direct current (DC) voltage usually ranging from about 600A and 40-50V, higher currents are needed for thicker materials.

Advantages:

- High metal deposition rate
- Ability to weld thick materials
- Very efficient a single pass is sufficient for welding

Disadvantages:

- Coarse grain structure of the weld;
- Low toughness of the weld;
- Only vertical position is possible

Applications:

- Electro slag welding is used mainly to join low carbon steel plates and/or sections that are very thick.
- It can also be used on structural steel if certain precautions are observed.

18. Explain the working principle of percussion welding.

Percussion welding (PEW)

Percussion welding is a type of resistance welding that blends dissimilar metals together. Percussion welding creates a high temperature arc that is formed from a short quick electrical discharge. Immediately following the electrical discharge, pressure is applied which forges the materials together. This type of joining brings the materials together in a percussive manner.

Percussion welding is similar to flash welding and upset welding but is generally considered to be more complex. It is considered to be more complex because it uses an electric discharge at the joint, followed by pressure being applied to join the materials together. Percussion welding is used to join dissimilar metals together, or used when flash is not required at the joint. Percussion welding is used on materials that have small cross sectional areas.

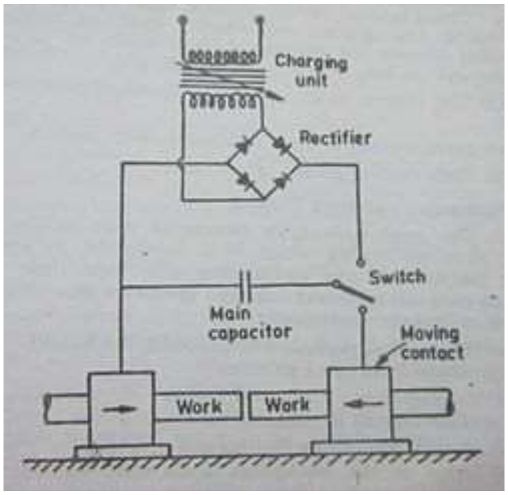


Figure: Percussion Welding

Advantages of using percussion welding types includes

- A shallow heat affected zone
- The time cycle involved is very short. Typical times can be found to be less than 16 milliseconds.

MULTIPLE CHOICE QUESTIONS

SL	QUESTIONS	opt 1	opt 2	opt 3	opt 4	Answer
1	Which of the following joint have high corrosion resistance?	Welding joint	Riveted joint	Bolted joint	None of the above	Welding joint
2	Which of the following ray is not produced during welding?	Gamma rays	Visible light rays	Infrared ray	Ultra violet rays	Gamma rays
3	Single-V and single-U butt welds are used for sheets of thickness	Upto 10 mm	5-15 mm	10-20 mm	15-25 mm	5-15 mm
4	Double-V and double-U butt welds are used for plates of thickness	1-5 mm	5-10 mm	10-15 mm	Over 15 mm	Over 15 mm
5	Which of the following types is not fillet weld?	Butt joint	Lap joint	T-joint	Corner joint	Butt joint
6	The metals having good weldability, in descending order are	Cast steel, iron, carbon steel, cast iron	Carbon steel, iron, cast steel, cast iron	Iron, carbon steel, cast steel, cast iron	Cast iron, iron, carbon steel, cast steel	Cast steel, iron, carbon steel, cast iron
7	In fusion welding, penetration is the ratio of	Width of the weld to its depth	Length of the weld to its depth	Depth of the weld to its width	Depth of the weld to its length	Width of the weld to its depth
8	Which of the following is an example of plastic welding?	Gas welding	Arc welding	Forge welding	Thermit welding	Forge welding
9	Which of the following is an example of fusion welding?	Arc welding	Forge welding	Resistance welding	Thermit welding with pressure	Arc welding
10	Which of the following process is used for welding of sheet metals?	Shield metal arc welding	Gas tungsten arc welding	Thermit welding	Resistance welding	Resistance welding
11	Heat is created by chemical reaction in	Shield metal arc welding	Plasma arc welding welding	Tungsten arc welding	Thermit welding	Thermit welding
12	The voltage used in resistance welding is generally kept between	4-12 volts	12-20 volts	20-28 volts	28-36 volts	4-12 volts
13	The heat generated (H) in resistance welding is expressed by	I^2Rt	IR^2t	Irt^2	2IRT	I^2Rt
14	The voltage needed in resistance welding does not depend upon	Composition	Area	Thickness of weld	Length of weld	Length of weld
15	In resistance welding, two electrodes are made of	Aluminium	Copper	Ferrous	Bronze	Copper
16	Which of the following is not a resistance welding?	Spot welding	Butt welding	Pressure welding	Percussion welding	Pressure welding

17	The resistance welding process suitable for welding upto 8mm thickness is	Spot welding	Projection welding	Butt welding	Pressure welding	Spot welding
18	In spot welding, for lap joint, the diameter of welded zone should be	4t+2.5mm	8t+2.5mm	12t+2.5mm	2t+2.5mm	2t+2.5mm
19	In spot welding, the spacing between two spot welds is	4t	8t	12t	16t	12t
20	In spot welding, the tip diameter of electrode is about	$\sqrt{t}$	$\sqrt{2t}$	$2\sqrt{t}$	$\sqrt{3t}$	$\sqrt{t}$
21	In projection welding, the depth of projection is about	20% of sheet thickness	40% of sheet thickness	60% of sheet thickness	80% of sheet	60% of sheet thickness
22	In which of the following a large number of welds can be carried out simultaneously	Spot welding	Projection welding	Seam welding	Percussion welding	Projection welding
23	Which process is used for making two overlapping pieces of sheet metals?	Spot welding	Projection welding	Percussion welding	Seam welding	Projection welding
24	The current is not passed continuously in	Projection welding	Seam welding	Spot welding	Percussion welding	Seam welding
25	In which of the following welding process, electrodes of two copper wheels are used	Projection welding	Flash welding	Seam welding	Percussion welding	Seam welding
26	Electric resistance welded (ERP) pipes are manufactures by	Projection welding	Flash welding	Percussion welding	Seam welding	Seam welding
27	For underwater welding which of the following process is not used?	Electroslag welding	Shielded metal arc welding (SMAW)	Gas tungsten arc welding (GTAW)	Gas metal arc welding (MIG)	Electroslag welding
28	The greater directional stability due to passage of arc through copper orifice is in	Plasma arc welding	Percussion welding	Electron beam welding	Electroslag welding	Plasma arc welding
29	The process which employ an exothermal chemical reaction is	Electroslag welding	Plasma arc welding	Thermit welding	Percussion welding	Thermit welding
30	During exothermal chemical reaction , the temperature is of the order of	2100°C	2700°C	3100°C	3500°C	2700°C
31	Which process is used for repairing of tracks and spokes of driving wheels?	Electroslag welding	Plasma arc welding	Thermit welding	Electron beam welding	Thermit welding
32	Which process allows	Electron beam	Friction	Plasma arc	Electroslag	Electron

	fusion welds of great depth with minimum width	welding	welding	welding	welding	beam welding
33	A projection weld is a type of	Resistance weld	Electron beam welding	Plasma arc welding	Thermit welding	Resistance weld
34	The advantage of Thermit welding is that	All parts of the weld section are molten	Weld cools almost uniformly	Results in a minimum problem with internal residual stresses	All of the above	All of the above
35	The welding process used in joining mild steel shanks to high speed drills, is	Spot welding	Seam welding	Flash butt welding	Upset butt welding	Flash butt welding
36	Seam welding is best adopted for metal thickness ranging from	0.025 to 3 mm	3 to 5 mm	5 to 8 mm	8 to 10 mm	0.025 to 3 mm
37	The electron beam welding can be carried out in	Open air	A shielded gas environment	Vacuum	A pressurized inert gas chamber	Vacuum
38	________ is continuously interrupted as the molten electrode metal bridges the arc gap	ARC	Short ARC	ARC length	ARC blow	Short ARC
39	Which one among the following welding processes uses non-consumable electrode	Gas metal arc welding	Submerged arc welding	Flux coated arc welding	Gas tungsten arc welding	Gas tungsten arc welding
40	What type of fusion welding process is used for welding sheet metals	Thermit welding	Electroslag welding	Resistance welding	Submerged arc Welding	Resistance welding
41	When two main plates are kept in alignment for butting each other and riveted,then it is a	Single riveted joint	Double riveted joint	Rivetless joint	Multi riveted joint	Double riveted joint
42	In a ___metal arc welding process, a gas metal arc welding with magnetized flux is used	Globular transfer	Spray transfer	GMAW practice	Dip transfer	GMAW practice
43	Flux is prepared in the form of a coarse powder and granulated flux is spread over the joint in	Electric arc welding	Submerged arc welding	Plasma arc welding	Thermit welding	Submerged arc welding
44	The common welding error that occurs due to shrinkage of weld metal is	Distortion	Warping	Porous weld	Poor fusion	Warping
45	If leads are arranged in work as Negative pole and electrode as Positive pole then it is	Fusion	Reverse polarity	Forward welding	Direct polarity	Reverse polarity

46	In arc welding, the electric arc is produced between the work and the electrode by	Voltage	Flow of current	Contact resistance	Air gap	Contact resistance
47	In welding copper alloys with TIG arc welding	Direct current with straight polarity is used	Direct current with reversed polarity is used	Alternating current is used	Any one of these	Direct current with straight polarity is used
48	In submerged arc welding, an arc is produced between a	Carbon electrode and the work	Metal electrode and the work	Bare metal electrode and the work	Two tungsten electrodes and the work	Bare metal electrode and the work
49	In shielded arc welding	Large electrode is used	Welding rod coated with slag is used	Welding rod coated with fluxing material is used	None of the above	Welding rod coated with fluxing material is used
50	The electrodes used in spot welding have a tip of	Stainless steel	Aluminium	Copper	Brass	Copper
51	In _______welding, the weld may be made either from left to right or from right to left.	Fore-hand	Back-hand	Vertical	Horizontal	Vertical
52	In spot welding, the spacing between two spot weld should not be less than	D	1.5d	3d	6d	3d
53	For welding plates of thickness less than 5 mm, its edges	Do not require bevelling	Should be bevelled to a single-V or U-groove	Should have a double-V or U-groove on one side	Should have a double-V on both sides	Do not require bevelling
54	In electric resistance welding, voltage required for heating is	1 to 5 volts	6 to 10 volts	11 to 20 volts	50 to 100 volts	6 to 10 volts
55	The current in electric resistance welding can be regulated by	Varying the input supply	Changing the primary turns of the transformer	Changing the secondary turns of the transformer	Any one of the above	Changing the primary turns of the transformer
56	The electron beam welding can be carried out in	Open air	Shielded gas environment	Vacuum	Pressurised inert gas chamber	Vacuum
57	Joining the two surfaces of metal under pressure and frictional heat is done in	Electron beam welding	Thermit welding	Plasma arc welding	Inertia welding	Inertia welding
58	Thermit welding is often used in	Joining thick sections	Joining thin strips	Joining rails and replacing broken gear teeth	Joining electronic components	Joining rails and replacing broken gear teeth
59	Thermit, used in thermit welding, is a mixture of	Charcoal and iron oxide	Charcoal and aluminium	Iron oxide and aluminium	Charcoal, iron oxide and aluminium	Iron oxide and aluminium
60	The advantage of	Weld cools	All parts of the	Minimum	All of the	All of the

	thermit welding is that	almost uniformly	weld section are molten at the same time	problem with internal residual stresses	above	above

UNIT III

SHEET METAL AND FORMING PROCESS

19. Explain in detail with a neat sketch hydro forming process and list its applications.

Hydro forming process:

Hydro forming is a cost-effective way of shaping ductile metals such as aluminum, brass, low alloy steel, and stainless steel into lightweight, structurally stiff and strong pieces.

Principle:

Hydro forming, as shown schematically in figure 1 is a specialized type of die forming that uses pressurized hydraulic fluid to form typical metallic sheets in to a desired shape with a die cavity.

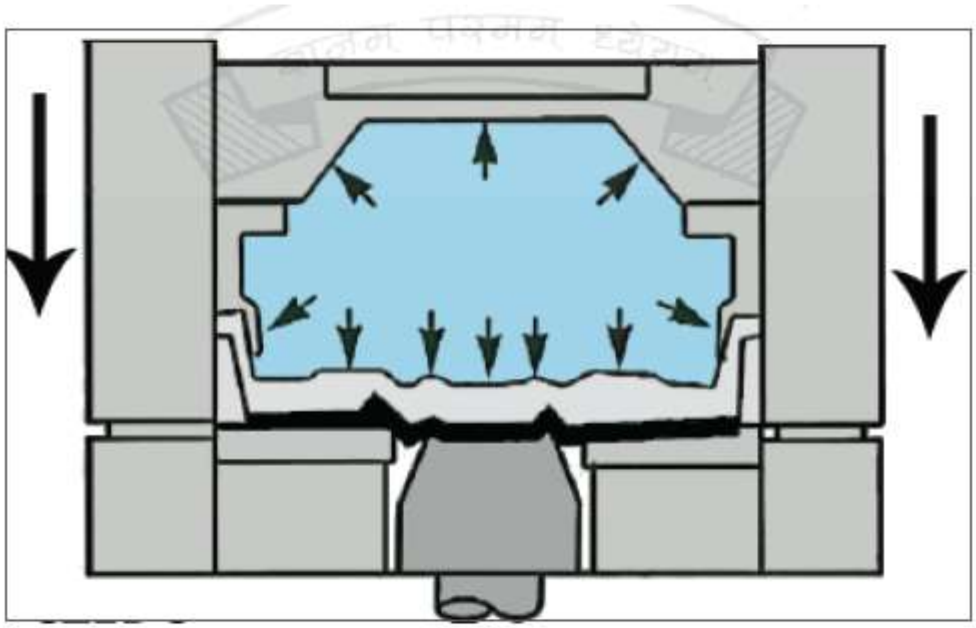


Figure 1. Hydro forming

Construction:

Hydro forming consist a high pressure chamber where liquid fluid is filled and pressure built up in the chamber for deforming the metal blank..

Working:

The liquid is pressurized by an external source, the pressurized fluid since incompressible distributes pressure equally and compress the sheet metal blank to obtain the aspired shape and size.

Advantages:

1. Hydro forming allows complex shapes with concavities to be formed, which would be difficult or impossible with standard solid die stamping.

2. Hydro formed parts can often be made with a higher stiffness-to-weight ratio and at a lower per unit cost than traditional stamped or stamped and welded parts.

Applications:

Virtually all metals capable of cold forming can be hydro formed, including aluminum, brass, carbon and stainless steel, copper and high strength alloys.

20. Explain in detail with a neat sketch rubber pad forming process with its merits and demerits.

Rubber pad forming process:

Rubber pad forming is a metal working process where sheet metal is pressed between a die and a rubber block to obtain required shape and size.

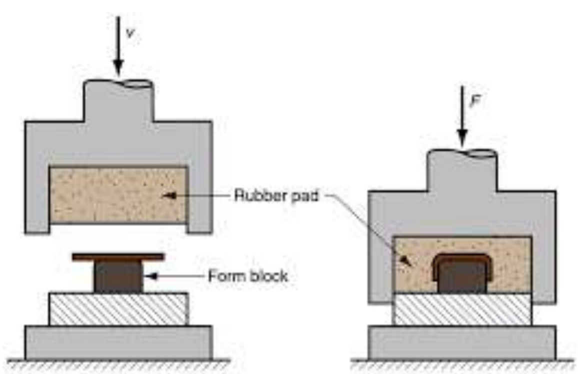


Figure 2 Rubber pad forming process

Construction:

An elastic upper die, usually made of polyurethane is connected to a hydraulic press. A rigid lower die, often called a form block, provides the mold for the sheet metal.

Working:

A sheet metal blank is placed over the top of form block. Under pressure, the rubber and sheet metal are driven into the die and conform to its shape, forming the part. The rubber pad can be driven by hydraulic ram.

Merits:

1. Since the upper (male) die can be used with separate lower (female) dies, the process is relatively cheap and flexible.
2. The worked metal is not worn as quickly as in more conventional processes such as deep drawing.

Demerits:

1. Rubber pads wear more quickly than steel parts.
2. Rubber pads exert less pressure which may lead to less definition in forming.

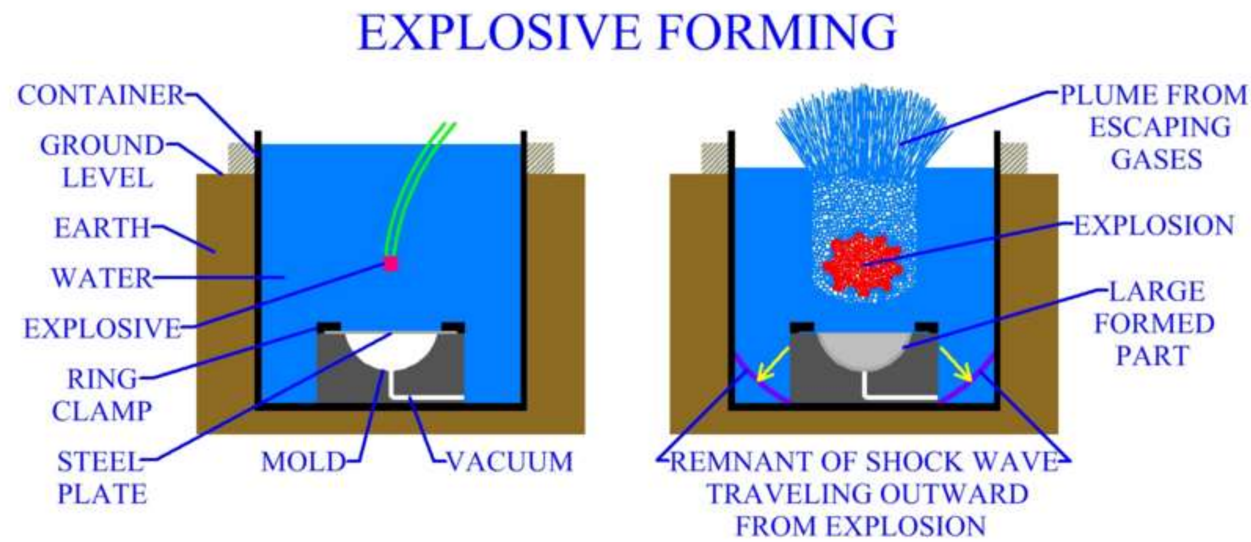
Applications:

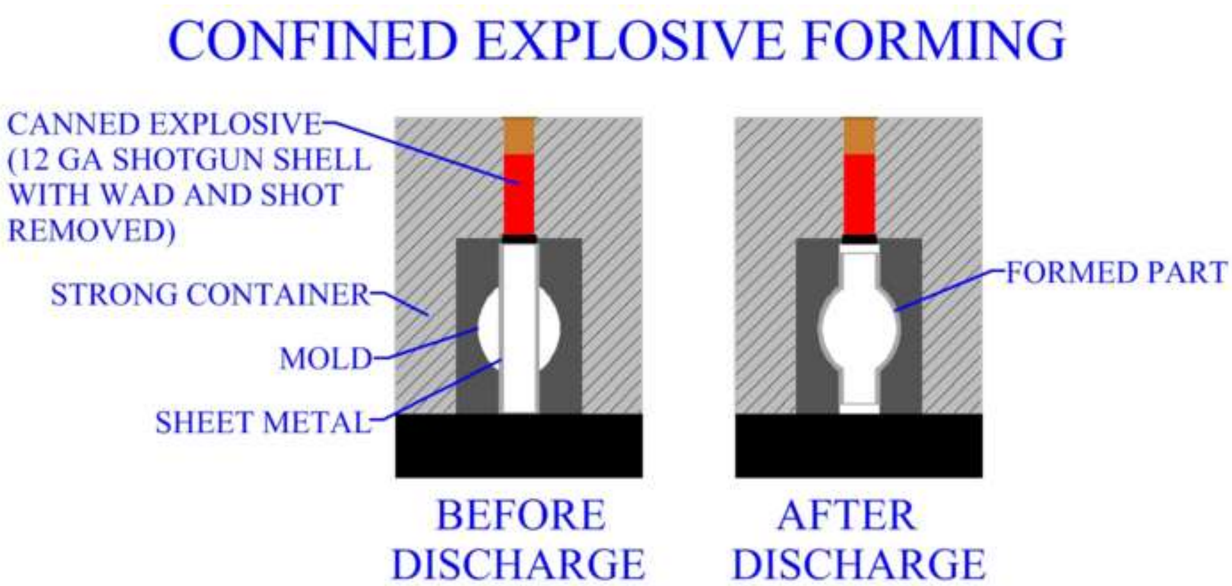
1. Using the rubber pad forming process, the frames are formed according to the specific dimensions for aircraft applications.

21. Explain in detail with a neat sketch explosive forming process with its merits and demerits.

Explosive Forming Process:

Explosives can deliver a huge amount of power. Although most explosive detonations are destructive, the power from an explosive charge can be used to manufacture parts. An explosive forming process commonly used for the production of large parts is called a standoff system. Typically the mold and work piece are submerged in water. The sheet metal is secured over the mold by a ring clamp. Air is drawn out, creating a vacuum in the die cavity. An explosive is placed between the die cavity and the work, a certain distance from the work. This distance is called the standoff distance. Standoff distance depends on the size of the work, for larger parts it is usually about half the diameter of the blank. The explosive itself is also deeply submersed in water. Upon detonation, the shock wave travels through the water and delivers great energy to the work, forming it to the die cavity near instantaneously. This high energy rate forming process can be used to form big thick plates.





Explosive forming has a long cycle time and is suitable for low quantity production of large, unique parts.

Mechanical properties imparted to the material as a result of the explosive forming process are similar to mechanical properties imparted to work manufactured by other forming processes. Molds can be made out of inexpensive or easy to shape materials, or molds can be made more permanent. Materials for molds include aluminum, wood, concrete, plastic, iron and steel. If a mold is manufactured from a material such as plastic, the low modulus of elasticity will greatly reduce spring back in the sheet metal, resulting in higher accuracy.

The amount of explosive depends upon the type of system used and the amount of pressure needed to form the part. The shock wave generated by the explosive travels along an expanding spherical front. Much of the energy from the shock wave is not absorbed by the work piece. A modified setup of the standoff system uses reflectors to focus the energy surge. This provides a more effective use of power and a smaller explosive can be used to form the same part. Another system called a confined system uses a canned explosive or cartridge. This is usually used for relatively smaller parts than the standoff system. All of the energy is directed into a closed container, the walls of which contain the die cavity. The energy from the canned explosive forces the sheet metal into the walls of the mold, forming the part. Safety is always a consideration when manufacturing by explosive forming, particularly with the confined system, where die failure is a significant concern.

22. Explain in detail with a neat sketch Peen forming process with its merits and demerits.

Peen forming process:

Peening is the process of working a metal's surface to improve its material properties, usually by mechanical means, such as hammer blows, by blasting with shot (shot peening), or blasts of light beams with laser peening. Peening is normally a cold work process. It tends to expand the surface of the cold metal, thereby inducing compressive stresses or relieving tensile stresses already present. Peening can also encourage strain hardening of the surface metal.

Working principle:

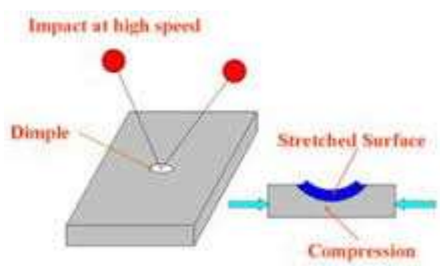


Figure: Peen forming process (Impact of metal ball on sheet metal surface)

The Metal Improvement Company's shot peen forming service is a die less process performed at room temperature, whereby small round steel shot impact the surface of the work piece. Every piece of shot acts as a tiny peening hammer, producing elastic stretching of the upper surface and local plastic deformation that manifests itself as a residual compressive stress. The combination of elastic stretching and compressive stress generation causes the material to develop a compound, convex curvature on the peened side.

The shot peen forming process is ideal for forming large panel shapes where the bend radii are reasonably large and without abrupt changes in contour. Shot peen forming is best suited for forming curvatures where radii are within the metal's elastic range. Although no dies are required for shot peen forming, for severe forming applications, stress peen fixtures are sometimes used. Shot peen forming is effective on all metals, even honeycomb skins and ISO grid panels.

Shot peen forming is often more effective in developing curvatures than rolling, stretching or twisting of metal. Saddle-back shapes also are achievable. Because it is a dieless process, shot peen forming reduces material allowance from trimming and eliminates costly development and manufacturing time to fabricate hard dies. The shot peen forming process also is flexible to design changes, which may occur after initial design. Metal Improvement Company can make curvature changes by adjusting the shot peen forming process.

Parts formed by shot peen forming exhibit increased resistance to flexural bending fatigue. Unlike most other forming methods, all surface stresses generated by shot peen forming are of a compressive nature. Although shot peen formed pieces usually require shot peening on one side only, the result causes both sides to have compressive stress. These compressive stresses serve to inhibit stress corrosion cracking and to improve fatigue resistance. Some work pieces should be shot peened all over prior to or after shot peen forming to further improve fatigue and stress corrosion cracking resistance.

Shot peening of parts that have been cold formed by other processes overcomes the harmful surface tensile stresses set up by these other forming processes.

Merits:

- Prevents cracking due to wear
- Prevents hydrogen embrittlement
- Prevents corrosion
- Prevents galling
- Prevents fretting

Demerits:

- The shot peening method is only operated on materials which can be cold hardened.

23. Explain in detail with a neat sketch Magnetic pulse forming process with its merits and demerits.

Magnetic pulse forming process:

Magnetic pulse forming process is a type of high velocity, cold forming process for electrically conductive metals, most commonly copper and aluminium.

Working

The work piece is placed in or near a coil, figure. A high charging voltage is supplied for a short time to a bank of capacitors connected in parallel. (The amount of electrical energy stored in the bank can be increased either by adding capacitors to the bank or by increasing the voltage). When the charging is complete, which takes very little time, a high voltage switch triggers the stored electrical energy through the coil. A high – intensity magnetic field is established which induces eddy currents into the conductive work piece, resulting in the establishment of another magnetic field. The forces produced by the two magnetic fields oppose each other with the consequence that there is a repelling force between the coil and the tubular work piece that causes permanent deformation of the work piece.

Magnetic forming can be accomplished in any of the following three ways, depending upon the requirements.

- Coil surrounding work piece. When a tube – like part x is to fit over another part y (shown as insert in Fig 9.3(i)), coil is designed to surround x so that when energized, would force the material of x tightly around y to obtain necessary fit.
- Coil inside work piece. Consider fixing of a collar on a tube – like part, as shown in Fig 9.3(ii). The magnetic coil is placed inside the tube – like part, so that when energized would expand the material of the part into the collar.
- Coil on flat surface. Flat coil having spiral shaped winding can also be designed to be placed either above or below a flat work piece, see Fig 9.3(iii).These coils are used in conjunction with a die to form, emboss, blank, or dimple the work piece.

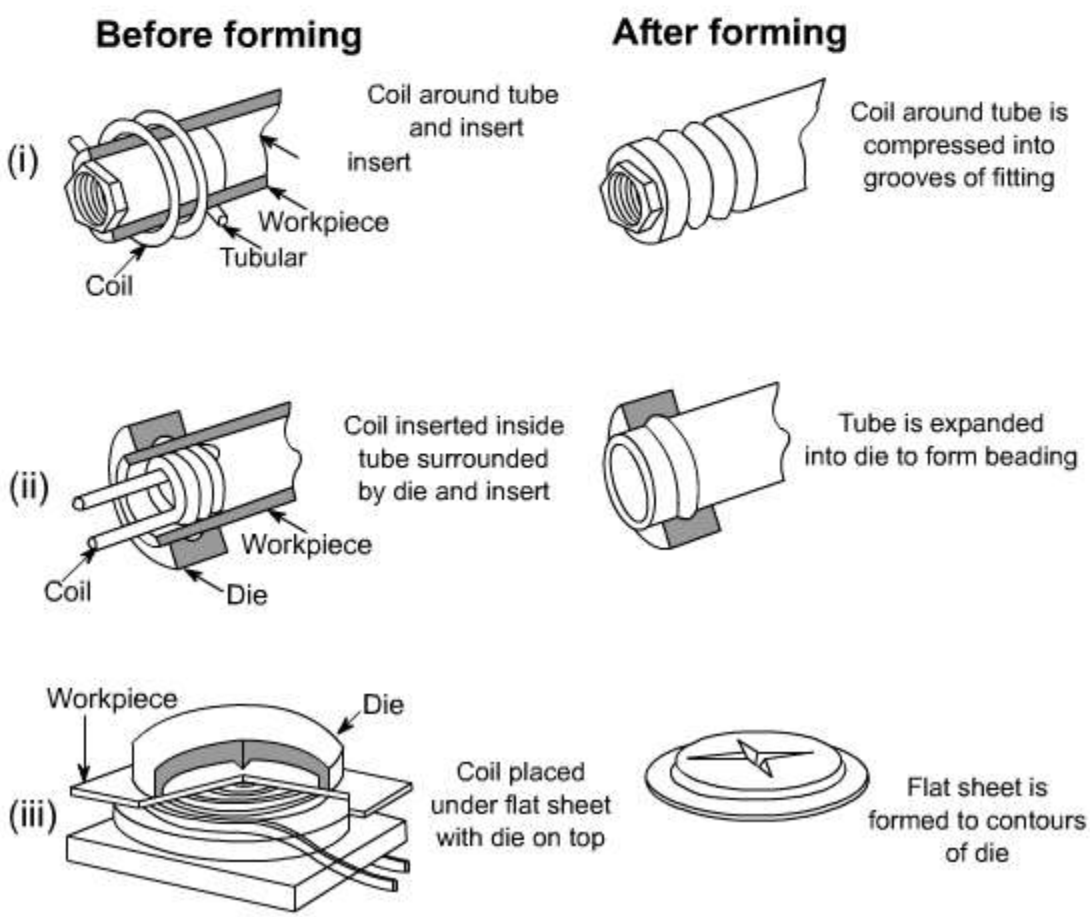


Figure 9.3 Magnetic pulse forming process

Merits:

a. Easy to control
b. Allows forming of metals to any material
c. No contact eliminates many requirements such as lubricants, heat dissipation, surface repair, etc.
d. Parts are uniform
e. No tool wear
f. Minimal operator skill
g. Very strong joints
h. Energy efficient
i. Easy installation
j. High production rates (typically a few seconds)

Demerits:

a. Complex shapes not possible
b. No pressure variations over work
c. Limits forming pressures

Applications:

1. Electromagnetic forming process is capable of a wide variety of forming and assembly operations. It has found extensive applications in the fabrication of hollow, non – circular, or asymmetrical shapes from tubular stock. The compression applications involve swaging to produce compression, tensile, and torque joints or sealed pressure joints, and swaging to apply compression bands or shrink rings for fastening components together. Flat coils have been used on flat sheets to produce stretch (internal) and shrink (external) flanges on ring and disc – shaped work pieces.
2. Electromagnetic forming has also been used to perform shearing, piercing, and rivettting.

24. Explain in detail with a neat sketch deep drawing process with its merits and demerits

Deep Drawing Process:

Deep drawing is a manufacturing process that is used extensively in the forming of sheet metal into cup or box like structures.

Working:

A basic deep drawing operation could be the forming of a flat sheet into a three dimensional shape.

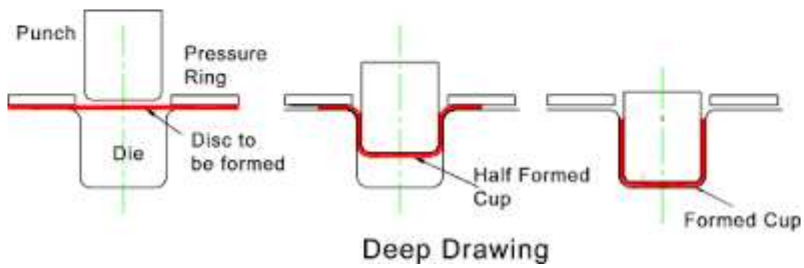
Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance.

This setup is similar to sheet metal cutting operations. As in cutting, clearance is the lateral distance between the die edge and the punch edge.

The sheet metal work piece, called a blank, is placed over the die opening. A blank holder, that surrounds the punch, applies pressure to the entire surface of the blank, (except the area under the punch), holding the sheet metal work flat against the die.

The punch travels towards the blank. After contacting the work, the punch forces the sheet metal into the die cavity, forming its shape.

Equipment for sheet metal deep drawing processes would involve a double action, one for the blank holder and one for the punch. Both mechanical and hydraulic presses are used in manufacturing industry. Typically the hydraulic press can control the blank holder and punch actions separately, but the mechanical press is faster. Punch and die materials, for the deep drawing of sheet metal, are usually tool steels and iron. However, the range of materials for punch and die can span from plastics to carbides. Parts are usually drawn at speeds of 4 to 12 inches per second.



Advantages:

- Deep drawn parts are created from a single sheet of metal
- Large quantities of products are easily manufactured through deep drawing
- Deep drawing delivers exceptional detailing and accuracy
- Deep drawing is especially beneficial when producing high volumes
- Once the tooling and dies have been created, the process can continue with very little downtime
- Tool construction costs are lower in comparison to similar manufacturing processes
- Reduced technical labor

Demerits:

a. Radial drawing stress and tangential compressive stress are common concerns, as these stresses may result in wrinkling, fracturing, and/or cracking in some processes
b. The cost of press setup is remarkably high and requires significant experience and expertise, rendering deep drawing more expensive for short run

Applications:

a. Deep Draw closed-end containers, sleeves and housings in aluminum, stainless and copper
b. High carbon steels and pre-coated steels are the primary materials used in deep draw stamping for cups and housings for needle and ball bearing applications
c. From industrial valves to appliance controls, deep draw stamping components serve as hose fittings, sensor housings, and thermostatic applications.

MULTIPLE CHOICE QUESTIONS

SL	QUESTION	Opt 1	Opt 2	Opt 3	Opt 4	Answer
1	In sheet metal blanking, shear is provided on punches and dies so that	Press load is reduced	Good cut edge is obtained	Warping of sheet is minimized	Cut blanks are straight	Press load is reduced
2	Blanking and piercing operations can be performed simultaneously in a	Simple die	Progressive die	Compound die	Combination die	Compound die
3	In sheet metal work, the cutting force on the tool can be reduced by	Grinding the cutting edges sharp	Increasing the hardness of tool	Providing shear on tool	Increasing the hardness of die	Grinding the cutting edges sharp
4	Notching is the operation of	Cutting a straight line	Removal of metal from the edge	Cutting a sheet of metal through part of its length	Bending a sheet of metal along a curved axis	Removal of metal from the edge
5	The operation of straightening a curved sheet metal, is known as	Drawing	Squeezing	Coining	Planishing	Planishing
6	The operation of cutting a cylindrical hole in a sheet of metal by the punch and die is called	Shearing	Piercing	Punching	Blanking	Piercing
7	Sheet metal return back after the load is removed and it is known as	Spring back	Elasticity	Plasticity	Roll back	Spring back
8	The blank sheet is driven into the die by high pressure water on one side of the sheet to form the desired shape it is known as	Rubber pad forming	Explosive forming	Hydro forming	Peen forming	Hydro forming
9	A hollow part is formed from a tube, any profile or two blanks, by applying internal pressure in __________ process	Hydro forming	Rubber pad forming	Explosive forming	Magnetic pulse forming	Hydro forming
10	A sheet metal forming process in which a rubber pad is used to form sheet metal	Hydro forming	Rubber pad forming	Explosive forming	Magnetic pulse forming	Rubber pad forming
11	__________________ is used to produce male die in rubber pad forming	Aluminum	Copper	Polyurethane	Epoxy	Polyurethane
12	Explosive forming is a metalworking technique in which an explosive charge is used instead of a	Male die	Power source	Female die	None of the above	Male die
13	The 'spring back' effect in metal working is	Elastic recovery of the sheet metal	Regaining the original shape of the sheet metal	Release of stored energy	Partial recovery of the sheet metal	Elastic recovery of the sheet metal
14	The partial rebounding of formed material caused by its elasticity is	Spring back	Rebound	Elastic rebound	Roll back	Spring back
15	The straight line on the surface of the sheet, on either side of the bend,	Bend line	Neutral line	Flange length	Bend length	Bend line

	that defines the end of the level flange and the start of the bend is.					
16	____________________ is equal to the difference between the mold line distance and the flange length.	Bend line	Bend axis	Set back	Bend length	Set back
17	The act of bending results ______________ in the sheet metal	Tension	Compression	Both tension and compression	Either tension or compression	Both tension and compression
18	The________________ is the boundary line inside the sheet metal, along which no tension or compression forces are present.	Neutral axis	Bend axis	Bend angle	Bend radius	Neutral axis
19	The_____________ location in the sheet that is neither stretched nor compressed, and therefore remains at a constant length	Neutral axis	Bend axis	Bend angle	Bend radius	Neutral axis
20	A punch forces the part into a different die, stretching the part to a greater depth each time in _____________________	Deep drawing	Hydroforming	Rubberpad forming	Explosive forming	Deep drawing
21	Removing material to use for parts is ________________	Shearing	Blanking	Piercing	Punching	Blanking
22	Drinking cans are manufactured by ______________ process	Rubber pad forming	explosive forming	Hydro forming	Deep drawing	Deep drawing

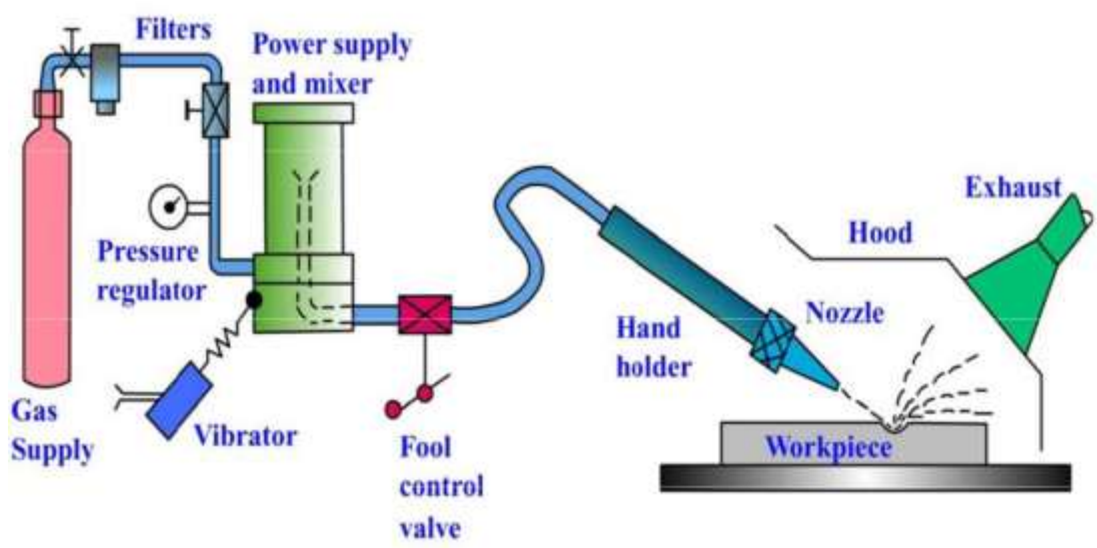
UNIT-IV

ADVANCED MACHINING PROCESS

25. Explain in detail abrasive jet machining process with its applications

Abrasive jet machining process:

In abrasive jet machining g (AJM) material removal occurs on account of impact of high velocity air / gas stream m of abrasive particles on the work piece. The abrasives are propelled by a high velocity gas to erode material from the work piece. As an outcome me of impact of the abrasive particles on the work piece, tiny brittle fractures occur at the surface of the work piece and the carrier gas carries away the fractured fragments. AJM is also called as abrasive blasting process. It is also known by several other names such as abrasive micro-blasting, pencil blasting and micro-abrasive blasting. AJM is an effective machining method for hard and brittle materials such as glass, silicon, tungsten and ceramics. Typically the process is used for cutting intricate shapes or forms of specific edges. The process is inherently free from chatter, vibration and heat problems because t e tool never touches the substrate. The schematic of AJM process se t up is shown in Figure 3.3.1



Schematic of the AJM set-up

Merits:

a. AJM process is a highly flexible process wherein the abrasive media is carried by a flexible hose, which can reach out to some difficult areas and internal regions.
b. AJM process creates localized forces and generates lesser heat than the conventional machining processes.
c. There is no damage to the work piece surface and also the process does not have tool-work piece contact, hence lesser amount of heat is generated.
d. The power consumption in AJM process is low.

Demerits:

a. The material removal rate is low
b. The process is limited to brittle and hard materials.
c. The wear rate of nozzle is very high
d. The process results in poor machining accuracy
e. The process can cause environmental pollution

Applications:

In Metal working:

1. De-burring of some critical zones in the machined parts.
2. Drilling and cutting of the thin and hardened metal sections.
3. Removing the machining marks, flaws, chrome and anodizing marks.

In Glass manufacturing industries:

1. Cutting of the optical fibers without altering its wavelength. Cutting, drilling and frosting precision optical lenses.
2. Cutting extremely thin sections of glass and intricate curved patterns. Cutting and etching normally inaccessible areas and internal surfaces. Cleaning and dressing the grinding wheels used for glass.

As Grinding:

1. Cleaning the residues from diamond wheels, dressing wheels of any shape and size.

26. Explain in detail about ultrasonic machining process and list its merits

Ultrasonic machining is a non-traditional machining process. USM is grouped under the mechanical group NTM processes. Fig. 9.2.1 briefly depicts the USM process.

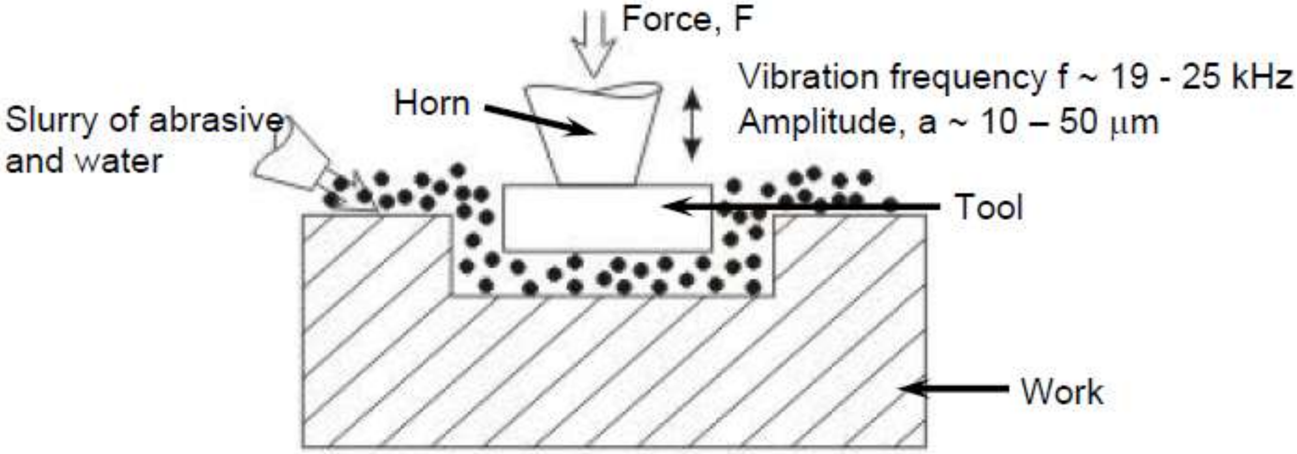


Figure: Ultrasonic Machining Process

In ultrasonic machining, a tool of desired shape vibrates at an ultrasonic frequency (19 ~ 25 kHz) with an amplitude of around 15 – 50 µm over the work piece. Generally the tool is pressed downward with a feed force, F. Between the tool and work piece, the machining zone is flooded with hard abrasive particles generally in the form of water based slurry. As the tool vibrates over the work piece, the abrasive particles act as the indenters and indent both the work material and the tool. The abrasive particles, as they indent, the work material, would remove the same, particularly if the work material is brittle, due to crack initiation, propagation and brittle fracture of the material. Hence, USM is mainly used for machining brittle materials {which are poor conductors of electricity and thus cannot be processed by Electrochemical and Electro-discharge machining (ECM and ED)}.

The process parameters which govern the ultrasonic machining process have been identified and the same are listed below along with material parameters

- Amplitude of vibration (a_o) – 15 – 50 µm
- Frequency of vibration (f) – 19 – 25 kHz
- Feed force (F) – related to tool dimensions
- Feed pressure (p)
- Abrasive size – 15 µm – 150 µm
- Abrasive material - Al_2O_3

- SiC
- B_4C
- Boronsilicarbide
- Diamond

Machine:

The basic mechanical structure of an USM is very similar to a drill press. However, it has additional features to carry out USM of brittle work material. The work piece is mounted on a vice, which can be located at the desired position under the tool using a 2 axis table. The table can further be lowered or raised to accommodate work of different thickness. The typical elements of an USM are shown in above figure.

• Slurry delivery and return system

• Feed mechanism to provide a downward feed force on the tool during machining

• The transducer, which generates the ultrasonic vibration

The horn or concentrator, which mechanically amplifies the vibration to the required amplitude of 15 – 50 μm and accommodates the tool at its tip.

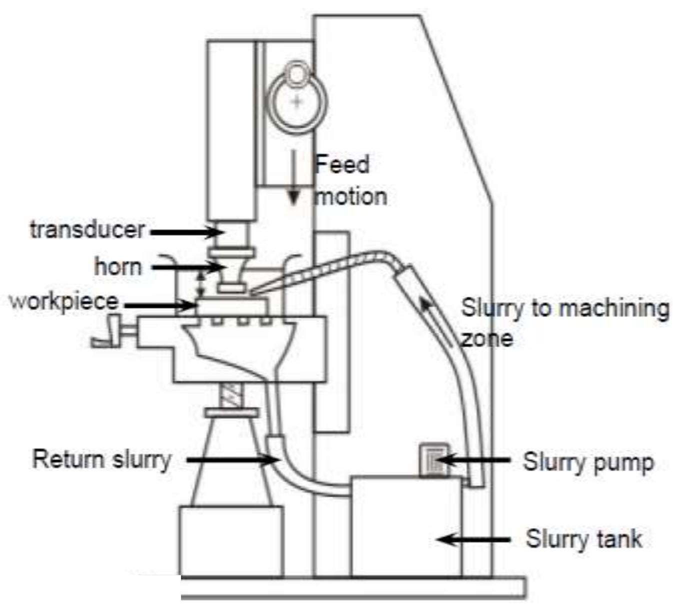


Fig. 9.2.7 Schematic view of an Ultrasonic Machine

The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator followed by power amplifier. The transducer for USM works on the following principle

- Piezoelectric effect
- Magnetostrictive effect
- Electrostrictive effect

Magnetostrictive transducers are most popular and robust amongst all. Above Figure shows a typical magnetostrictive transducer along with horn. The horn or concentrator is a wave-guide, which amplifies and concentrates the vibration to the tool from the transducer.

Applications

- Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.
- Used for machining round, square, irregular shaped holes and surface impressions.
- Machining, wire drawing, punching or small blanking dies.

Limitations

- Low MRR
- Rather high tool wear
- Low depth of hole

27. Explain in detail electro chemical machining process with its applications

Electrochemical machining:

Electrochemical machining is a method of removing metal by an electrochemical process. It is used for machining extremely hard materials or materials that are difficult to machine using conventional methods. Its use is limited to electrically conductive materials.

The schematic of “electrochemical machine” is shown in below figure.

Working:

1. At the anode, the metal dissolves electrochemically and its rate of dissolution depends upon number of factors such as the ionic charge, atomic weight, the current and the time of current passage.

2. The rate of dissolution is not influenced by the hardness of the work piece material or any other metal characteristics.

3. At the cathode, only the hydrogen gas is evolved. The electrode shape remains unaltered during the electrolysis process. This is the most relevant feature of ECM being used as a metal shaping process

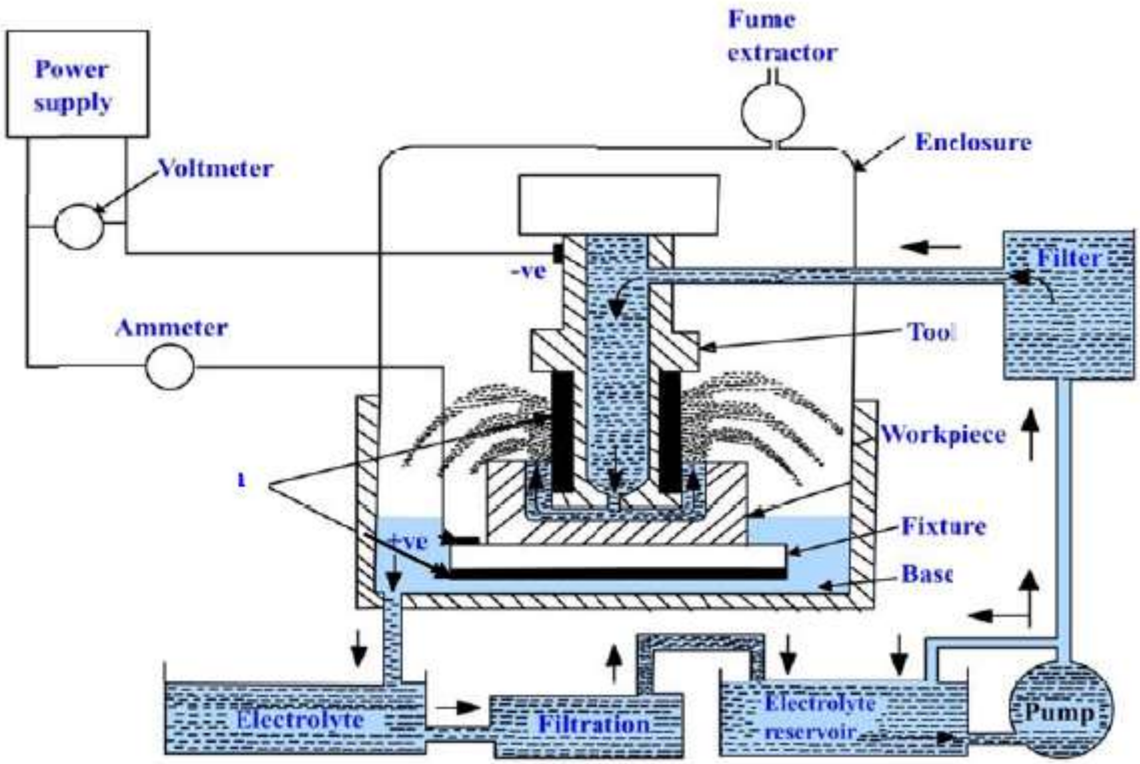


Figure: Schematic of Electrochemical machine

Mechanism of Material Removal in ECM

The working principle of ECM is schematically shown in Fig. (a and b), the work piece and tool are the anode and cathode respectively. In the electrolytic cell a constant potential difference, usually of about 10 V is applied across them. A suitable electrolyte, for example an aqueous sodium chloride (table salt) solution is commonly chosen. In-order to remove the products of machining, the electrolyte is pumped through the gap between the two electrodes. The rate at which metal is then removed from the anode is approximately in inverse proportion to the distance between the electrodes. As the machining proceeds there is a simultaneous movement of the cathode towards the anode. The width of the gap along the electrode length will gradually tend towards a steady-state value. Under such conditions, a shape which is roughly complementary to that of the cathode will be reproduced on the anode.

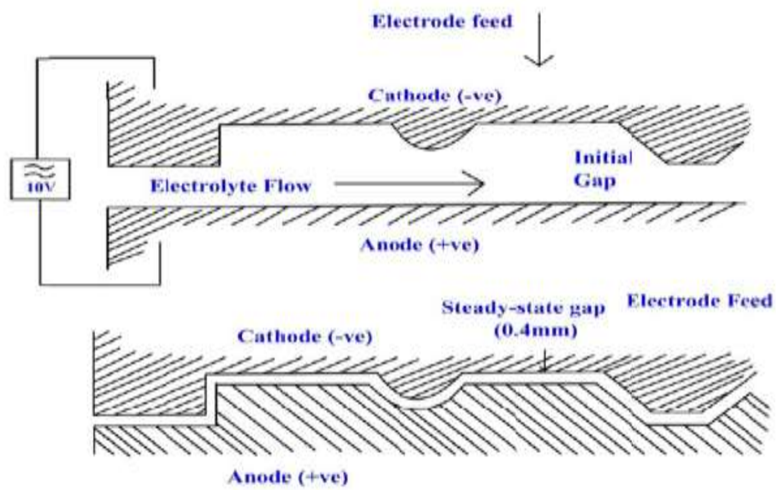


Figure a&b : Working principle of ECM

Merits of ECM:

- No heat affected zone is formed
- Harder metals than the tool can be machined
- No tool wear occurs
- Burr free products can be made
- No tool to work piece contact
-

Demerits of ECM:

- High tooling cost
- Saline electrolyte causes corrosion
- High initial cost on electrode design
- Sharp corners and flat surfaces are difficult to make since corrosive electrolyte will corrode.

28. Explain in detail about wire cut EDM process and list its applications.

This non-traditional machining process is widely used to pattern tool steel for die manufacturing, to cut intricate components for the electric and aerospace industries

Construction:

This process is usually used in conjunction with CNC and will only work when a part is to be cut completely through.

The wires for wire EDM is made of brass, copper, tungsten, molybdenum, zinc or brass coated wires are also used extensively in this process. The wire used in this process should posses' high tensile strength and good electrical conductivity.

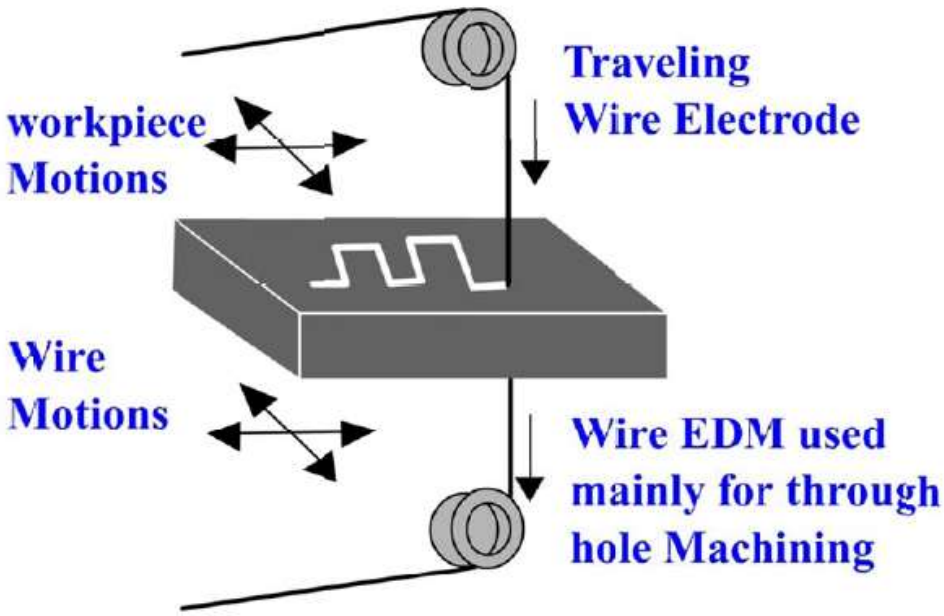


Figure 1: Schematic of Wire cut EDM

Working:

In this process, a slowly moving wire travels along a prescribed path and removes material from the work piece. Wire EDM uses electro-thermal mechanisms to cut electrically conductive materials. The material is removed by a series of discrete discharges between the wire electrode and the work piece in the presence of di electirc fluid, which creates a path for each discharge as the fluid becomes ionized in the gap. The area where discharge takes place is heated to extremely high temperature, so that the surface is melted and removed. The removed particles are flushed away by the flowing dielectric fluids.

The melting temperature of the parts to be machined is an important parameter for this process rather than strength or hardness. The surface quality and Material Removal Rate (MRR) of the machined surface by wire EDM will depend on different machining parameters such as applied peak current, and wire materials. Wire EDM can also employ to cut cylindrical objects with high precision. The sparked eroded extrusion dies are presented in below Figure 2.

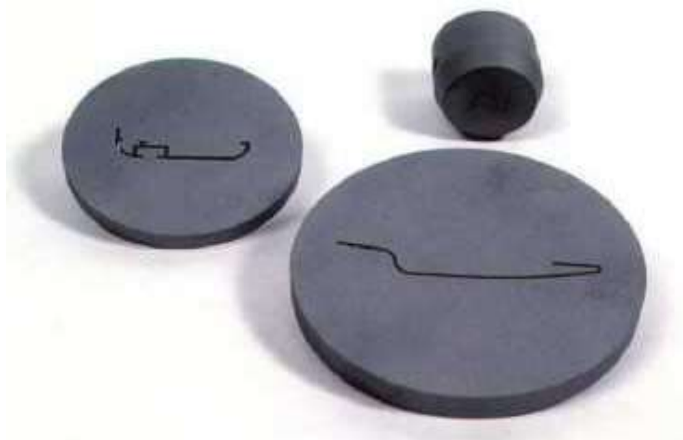


Figure 2: The sparked eroded extrusion dies

Applications of Wire-Cut EDM

- Wire EDM is used for cutting aluminium, brass, copper, carbides, graphite, steels and titanium.
- Aerospace, Medical, Electronics and Semiconductor applications
- Tool & Die making industries.
- For cutting the hard Extrusion Dies
- In making Fixtures, Gauges & Cams
- Cutting of Gears, Strippers, Punches and Dies
- Manufacturing hard Electrodes.
- Manufacturing micro-tooling for Micro-EDM, Micro-USM and such other micromachining

29. Explain in detail electro discharge machining process with its applications

Electro Discharge Machining Process:

It is an advanced machining process primarily used for hard and difficult metals which are difficult to machine with the traditional techniques. Only electrically conducting materials are machined by this process.

Working:

EDM is a thermal process which makes use of spark discharges to erode the material from work piece surface. The cavity formed in EDM is a replica of the tool shape used as the erosions occur in the confined area. Since spark discharges occur in EDM, it is also called as "spark machining". The material removal takes place in EDM through a rapid series of electrical discharges. These discharges pass between the electrode and the work piece being machined. The fine chips of material removed from the work piece gets flushed away by the continuous flowing di-electric fluid. The repetitive discharge creates a set of successively deeper craters in the work piece until the final shape is produced.

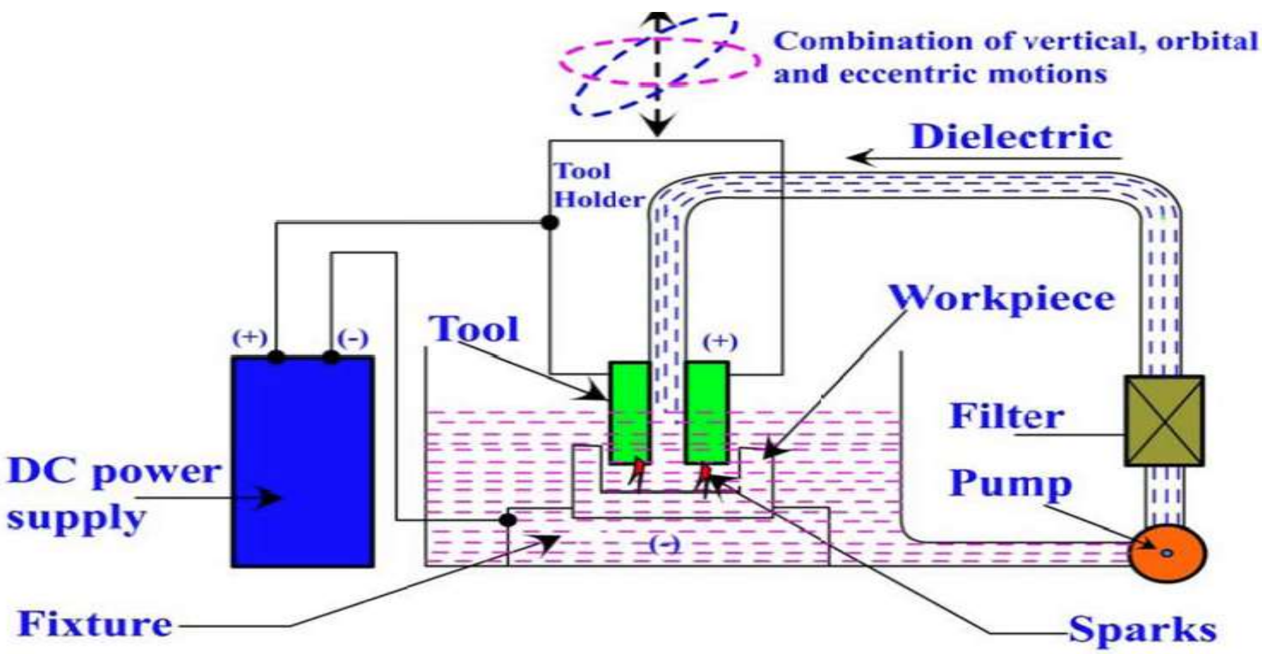


Figure: Electron Beam Machining Process

Applications:

The EDM process is best suited for making intricate cavities and contours which would be difficult to produce with normal machines like grinders, end-mills or other cutting tools.

Metals such as hardened tool-steels, carbides, titanium, Inconel are easily machined through EDM.

30. Explain in detail about plasma arc machining process and list its applications.

Plasma arc machining (PAM):

Plasma arc machining is a nontraditional thermal process. Plasma is defined as a gas that has been heated to a sufficiently high temperature to become partially ionized and therefore electrically conductive.

Principles of operation

In PAM, constricting an electric arc through a nozzle, as shown in Fig. 1 generates the basic plasma jet. Instead of diverging into an open arc, the nozzle constricts the arc into a small cross section. This action greatly increases the power of the arc so that both temperature and voltage are raised. After passing through the nozzle, the arc exists in the form of a high-velocity, well-columnated and intensely hot plasma jet.

The basic heating phenomenon that takes place at the workpiece is a combination of heating due to energy transfer of electrons, recombination of dissociated molecules on the workpieces, and connective heating from the high-temperature plasma that accompanies the arc. In some cases, it is desirable to achieve a third source of heating by injecting oxygen into the work area and taking advantage of the exothermic oxidation reaction. Once the material has been raised to the molten point, the high-velocity gas stream effectively blows the material away.

For an optimized PAM cutting or machining operation, up to 45% of the electrical power delivered to the torch is used to remove metal from the workpiece. Of the remaining power, approximately 10% go into the cooling water in the plasma generator and the rest is wasted in the hot gas and in heating the workpiece.

The jet stream of ionized gases exits at sonic speed and tends to maintain a slightly diverging columnar shape until deflected by solid material. This ionized jet serves as a conductor for the arc; it provides directional stability. The ionized gas may be further shielded from dispersion and heat loss, which result from impacting air molecules, as it exits from the nozzle by means of another annular stream of gas that surrounds the plasma as it leaves the orifice nozzle.

The ionized plasma gas is usually inactive to protect the electrode from combustion and ensure long life. When oxygen is added as either the plasma ionized gas or the secondary enveloping gas, the speed of cutting steel is increased. Use of a secondary envelope of gas improves the kerf wall appearance on certain metals. This envelope also acts as a protective shield for the nozzle during extensive piercing operations.

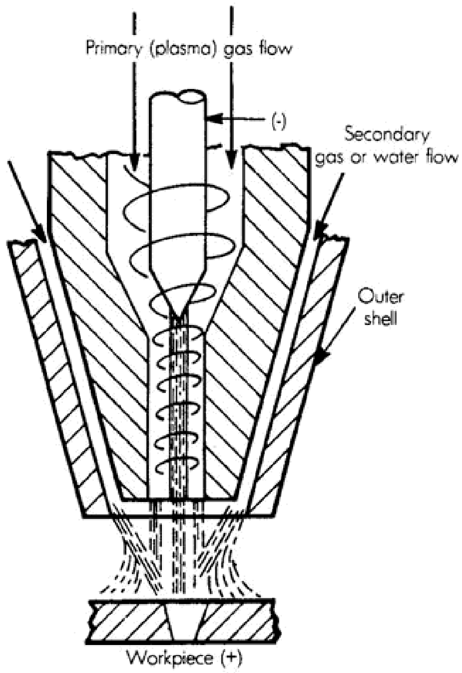


Figure: Plasma arc machining

Applications:

1. Cutting
2. Hole piercing
3. Material removal by machining

31. Explain in detail about abrasive water jet machining process and list its applications.

Abrasive Water Jet Machining Process:

In abrasive water jet machining g (AWJM) material removal occurs on account of impact of high velocity air / water stream of abrasive particles with water on the work piece. The abrasives are propelled by a high velocity water to erode material from the work piece. As an outcome me of impact of the abrasive particles on the work piece, tiny brittle fractures occur at the surface of the work piece and the water carries away the fractured fragments. AWJM is an effective machining method for hard and brittle materials such as glass, silicon, tungsten and ceramics. Typically the process is used for cutting intricate shapes or forms of specific edges. The process is inherently free from chatter, vibration and heat problems because t e tool never touches the substrate. The schematic of AWJM process se t up is shown in Figure.

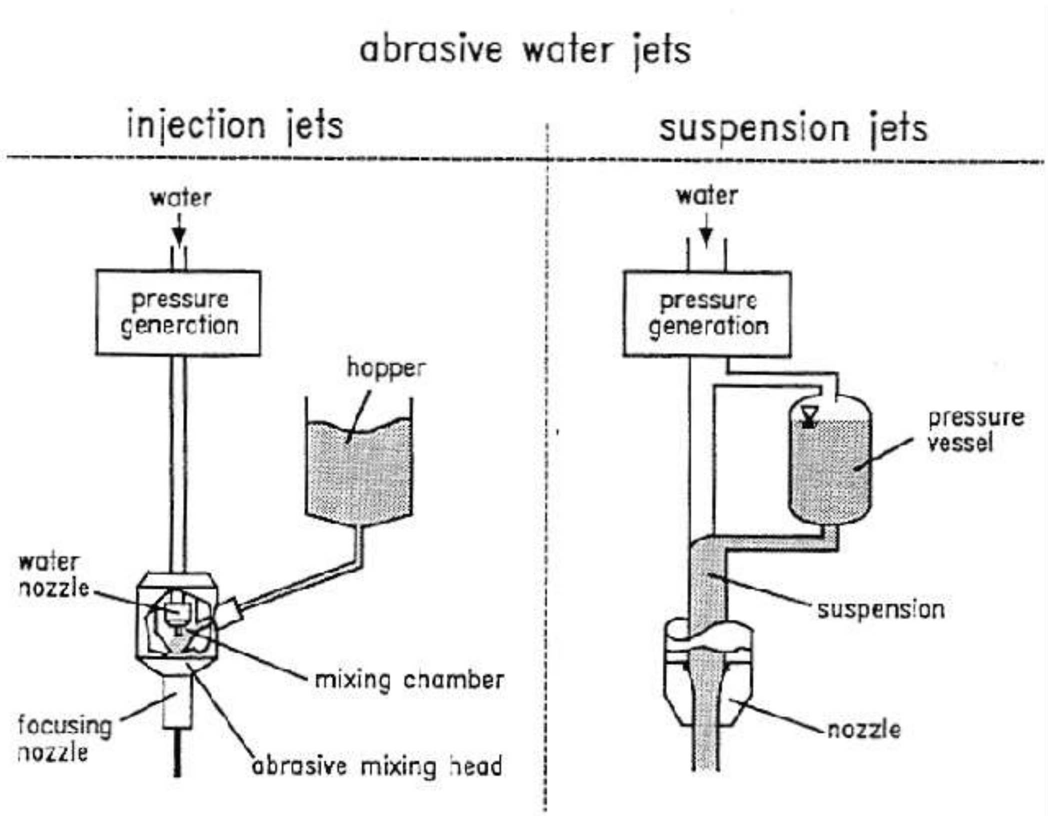


Figure : Abrasive Water Jet Machining Process

Merits:

- AWJM process is a highly flexible process wherein the abrasive media is carried by a flexible hose, which can reach out to some difficult areas and internal regions.
- AWJM process creates localized forces and generates lesser heat than the conventional machining processes.
- There is no damage to the work piece surface and also the process does not have tool-work piece contact, hence lesser amount of heat is generated.
- The power consumption in AWJM process is low.

Demerits:

- The process is limited to brittle and hard materials.
- The wear rate of nozzle is very high.

Applications:

In Metal working:

- De-burring of some critical zones in the machined parts.
- Drilling and cutting of the thin and hardened metal sections.

- Removing the machining marks, flaws, chrome and anodizing marks.

In Glass manufacturing industries:

- Cutting of the optical fibers without altering its wavelength.
  Cutting, drilling and frosting precision optical lenses.
- Cutting extremely thin sections of glass and intricate curved patterns.
  Cutting and etching normally inaccessible areas and internal surfaces.
  Cleaning and dressing the grinding wheels used for glass.

As Grinding:

- Cleaning the residues from diamond wheels, dressing wheels of any shape and size.

MULTIPLE CHOICEQUESTIONS

SL	QUESTIONS	Opt 1	Opt 2	Opt 3	Opt 4	ANSWER
1	Which of the following statement is wrong about ultra-sonic machining?	It is best suited for machining hard and brittle materials.	It cuts materials at very slow speeds.	It removes large amount of material.	It produces good surface finish.	It removes large amount of material.
2	The machining of titanium is difficult due to	High thermal conductivity of titanium	Chemical reaction between tool and work	Low tool-chip contact area	High tool-chip contact area	Chemical reaction between tool and work
3	In ultra-sonic machining, the metal is removed by	Using abrasive slurry between the tool and work	Direct contact of tool with the work	Maintaining an electrolyte	Spark discharges	Using abrasive slurry between the tool and work
4	In hot machining, tool is made of	Tungsten carbide	Brass or copper	Diamond	Stainless steel	Tungsten carbide
5	Which of the following statement is correct about EDM machining?	It can machine hardest materials	It produces high degree of surface finish	The tool and work are never in contact with each other	All of these	All of these
6	Which of the following statements are true for Electro-Chemical Machining (ECM)?	Capable of machining metals irrespective of its strength and hardness	No cutting forces are involved	Consumes very high power	All of these	All of these
7	In which process the material is removed due to the action of abrasive grains?	Electro-Chemical Grinding (ECG)	Ultrasonic Machining (USM)	Laser Beam Machining (LBM)	Electrical Discharge Machining (EDM)	Ultrasonic Machining (USM)
8	Which of the following is generally applied for dentistry work , to drill fine holes	Electrical Discharge Machining (EDM)	Electron Beam Machining (EBM)	Laser Beam Machining (LBM)	Ultrasonic Machining (USM)	Ultrasonic Machining (USM)
9	Which of the following process has highest rate of metal removal?	Electron Beam Machining (EBM)	Electric Discharge Machining (EDM)	Electro-Chemical Machining (ECM)	Ultrasonic Machining (USM)	Electro-Chemical Machining (ECM)
10	Which of the following is not a media of energy transfer on which the advanced machining processes are classified?	Reactive atmosphere	Electrons	Electrolyte	Chemical ablation	Chemical ablation
11	The spark gap in Electrical Discharge Machining (EDM) process is maintained such that	The gap voltage is around 99% of supply voltage	The gap voltage is around 70% of supply voltage	The gap voltage is around 50% of supply voltage	The gap voltage is around 10% of supply voltage	The gap voltage is around 70% of supply voltage
12	Which of the following	Brass	Copper	Graphite	All of the	All of the

	materials is/are used for Electrical Discharge Machining (EDM) process?				above	above
13	In Electrical Discharge Machining (EDM) process the metal removal is carried out by	Electrolysis	Melting and vaporization	Fracture of work material due to impact of grains	All of the above	Melting and vaporization
14	In an ultrasonic machining (USM) process, the material removal rate (MRR) is plotted as a function of the feed force of the USM tool. With increasing feed force, the MRR exhibits the following behavior	Increases linearly	Decreases linearly	Does not change	First increases and then decreases	First increases and then decreases
15	The non-traditional machining process that essentially requires vacuum is	Electron beam machining	Electro chemical machining	Electro chemical discharge machining	Electro discharge machining	Electron beam machining
16	Electrolyte is used in	Electro-chemical machining	Electron beam machining	Abrasive jet machining	Laser Beam Machining	Electro-chemical machining
17	The silicon carbide abrasive is chiefly used for grinding	Cemented carbide	Ceramic	Cast iron	All of the above	All of the above
18	The tool made of cemented carbide wear out faster at	Slow speeds	Medium speeds	Fast speeds	Very fast speeds	Slow speeds
19	The method of grinding used to produce a straight or tapered surface on a work piece, is	Internal cylindrical grinding	Form grinding	External cylindrical grinding	Surface grinding	External cylindrical grinding
20	Which of the following is an advantage of Laser beam machining?	Laser can be sent to longer distance	No contact between tool and work piece	Material property on machining will not change	None of the above	None of the above
21	In EDM the selected tool for machining hard materials must be	Hard	Soft	With good electrical conductivity	None of the above	With good electrical conductivity
22	Surface finish on WC produced by electrochemical grinding can be in the range of __________ micron	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8	0.8 to 0.9	0.2 to 0.4
23	_______________governs metal removal rate in electrochemical machining	Flemings rule	Newton’s law	Faraday's law	Lentz law	Faraday's law
24	Ultrasonic machining is based on	Uniform heating	Uniform grinding	Vibratory waves of high frequency	Uniform machining	Vibratory waves of high frequency
25	In Ultrasonic machining the rate of penetration is	Action of slurry	Action of abrasive	Reduction of a chemical	All of these	Action of abrasive

	dependent on		grains			grains
26	In Ultrasonic machining the rate of penetration is also dependent on	Flow path	Slurry	Area of tool tip	All of these	All of these
27	In Ultrasonic machining longitudinal waves are preferred because they can	Travel at high velocity	Easily generated	Can be propagated in solid, liquid and gas	All of these	All of these
28	Tool tip is attached to the tool cone by	Welding	Press fitting	Silver soldering	Nut and bolt	Silver soldering
29	_________ process is used for making a complicated contour in a carbide piece	Laser machining	Electro chemical machining	Plasma arc machining	Electro discharge machining	Electro discharge machining
30	Slurry used in USM is	Only alkaline	Alcohol based	Mercury based	Water based	Water based
31	Erosion of metal in EDM is	Proportionate to spark	Continuous	Discontinuous	Proportionate to spark and continuous	Proportionate to spark
32	Ajmis used for	Only plastic	Only ductile metals	Only brittle metals	Only rubber	Only brittle metals
33	In USM slurry is fed by	Pump	Manual system	Drilled shaft	Either by pump or manual system	Either by pump or manual system
34	Selection of tool material in EDM is influenced by which of the following?	Required tolerance	Volume of metal to be removed	Size of electrode	None of the above	None of the above
35	Time required for machining by EDM in comparison to conventional machining is	Less	Equal	More	Unpredictable	Less
36	In EDM metal removal rate is proportional to	Frequency of charging	Energy delivered in each spark	Frequency of charging and energy delivery	Wave generation	Frequency of charging and energy delivery
37	Abrasive jet machining uses a jet of	Abrasive particles suspended in oil	Abrasive particles suspended in air	Abrasive particles suspended in water	Abrasive particles suspended in inert gas	Abrasive particles suspended in air
38	In ultrasonic machining tool used is	Oscillates at a frequency of 20 to 30 kHz	Exactly to that of a hole	Made of soft material	All of these	All of these
39	Abrasive jet machining is used for	Cutting thin section	Removing flash and parting lines	Demurring and polishing	All of these	All of these
40	____________ process needs high velocity of electrons for machining	Abrasive jet	Ultrasonic	Electro discharge	Electron beam	Electron beam
41	In Abrasive jet machining material removal happens because of	Machining	Corrosion	Erosion	Melting	Erosion
42	What is the principle of water jet machining	Air and water mix jet is used	Surface is dipped in water	Water is impinged at high velocity	Water is sprayed at different pressures	Water is impinged at high velocity

43	In EDM metal removal takes place as	Chemical reaction	Erosion of metal	Dissolution of metal	Melting	Erosion of metal
44	In EDM the required property of tool is	Resistivity	Dielectric strength	Conductivity	Corrosion resistance	Conductivity
45	For converting electrical energy into mechanical energy, which of the effect form the basis of USM?	Chemical reaction	Piezoelectric effect	Hall effect	Any of these	Piezoelectric effect
46	In EDM ____________ unit is provided to maintain the predetermined gap	Servo control	Manual system	Open loop system	Hydraulic actuator	Servo control
47	Chemical __________ is employed for selective or overall metal removal of thicker work pieces	Grinding	Milling	Leaching	Any of these	Milling
48	The action of abrasive grains is involved in	Abrasive jet	Ultrasonic	Electro discharge	Electron beam	Ultrasonic

UNIT-V

RAPID PROTOTYPING

32. Explain in detail about Selective Laser sintering process.

Selective Laser Sintering process:

In Selective Laser Sintering (SLS) process, fine polymeric powder like polystyrene, polycarbonate or polyamide etc. (20 to 100 micrometer diameter) is spread on the substrate using a roller. Before starting CO_2 laser scanning for sintering of a slice the temperature of the entire bed is raised just below its melting point by infrared heating in order to minimize thermal distortion (curling) and facilitate fusion to the previous layer. The laser is modulated in such away that only those grains, which are in direct contact with the beam, are affected. Once laser scanning cures a slice, bed is lowered and powder feed chamber is raised so that a covering of powder can be spread evenly over the build area by counter rotating roller. In this process support structures are not required as the un sintered powder remains at the places of support structure. It is cleaned away and can be recycled once the model is complete. The schematic diagram of a typical SLS apparatus is given in figure 7.

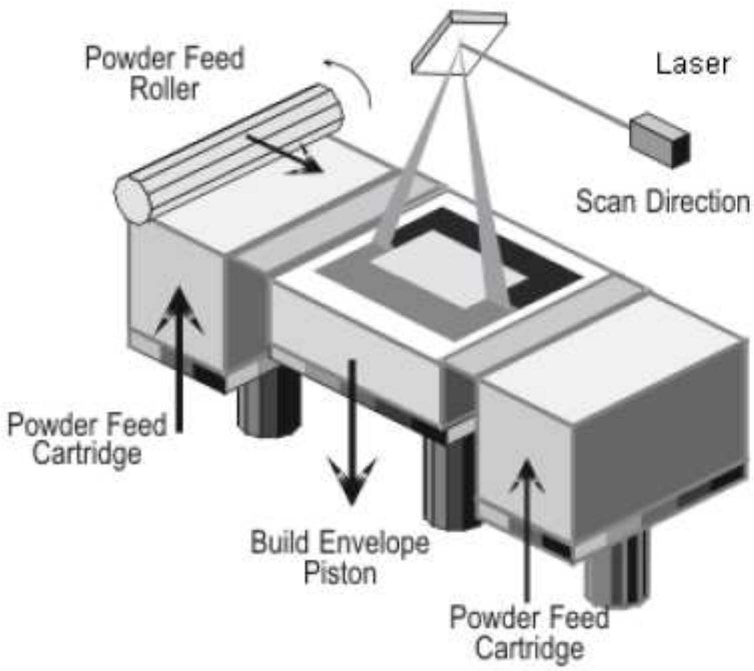


Figure 7: Selective Laser Sintering System

33. Explain in detail about Laminated Object manufacturing with its merits and demerits.

Laminated Object Manufacturing

Typical system of Laminated Object Manufacturing (LOM) has been shown in figure 9. It can be seen form the figure that the slices are cut in required contour from roll of material by using a 25-50 watt CO_2 laser beam. A new slice is bonded to previously deposited slice by using a hot roller, which activates a heat sensitive adhesive. Apart from the slice unwanted material is also hatched in rectangles to facilitate its later removal but remains in place during the build to act as supports.

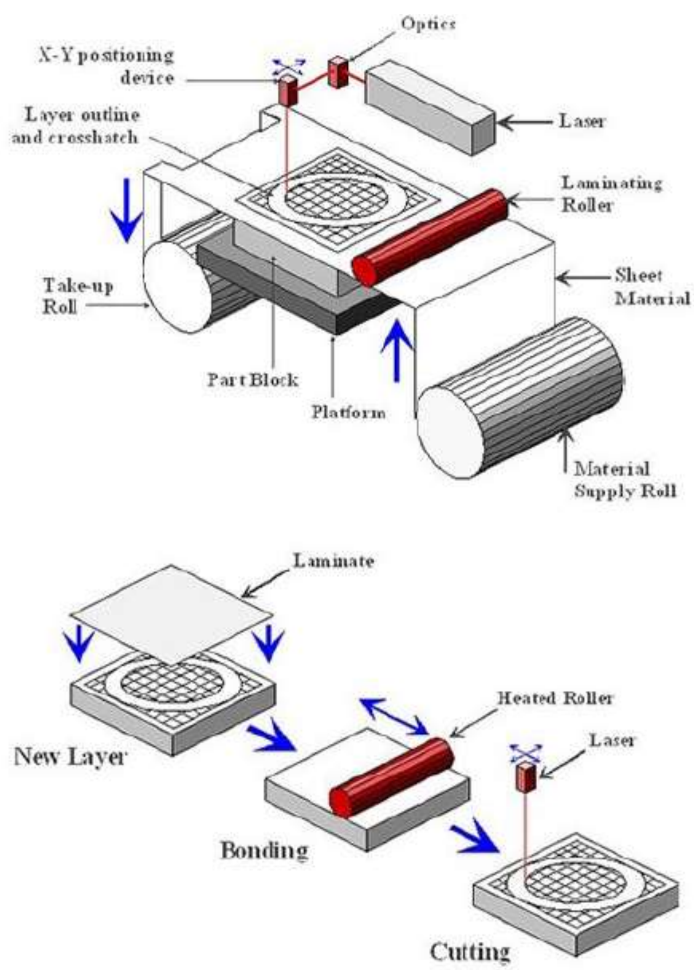


Figure: Laminated Object Manufacturing

Once one slice is completed platform can be lowered and roll of material can be advanced by winding this excess onto a second roller until a fresh area of the sheet lies over the part. After completion of the part they are sealed with a urethane lacquer, silicone fluid or epoxy resin to prevent later distortion of the paper prototype through water absorption.

In this process, materials that are relatively cheaper like paper, plastic roll etc. can be used. Parts of fiber-reinforced glass ceramics can be produced. Large models can be produced and the building speed is 5-10 times as compared to other RP processes. The limitation of the process included fabrication of hollow models with undercuts and reentrant features. Large amount of scrap is formed. There remains danger of fire hazards and drops of the molten materials formed during the cutting also need to be removed.

34. Explain in detail about Solid ground curing process and list its merits.

Solid ground curing process:

Solid ground curing utilizes the general process of hardening of photopolymers by a complete lighting and hardening of the entire surface, using specially prepared masks. In SGC process, each layer of the prototype is cured by exposing to an ultra violet (UV) lamp instead of by laser scanning. So that, every portion in a layer are simultaneously cured and do not require any post-curing processes. The process contains the following steps.

1. The cross section of each slice layer is calculated based on the geometric model of the part and the desired layer thickness.
2. The optical mask is generated conforming to each cross section.
3. After leveling, the platform is covered with a thin layer of liquid photopolymer.
4. The mask corresponding to the current layer is positioned over the surface of the liquid resin, and the resin is exposed to a high-power UV lamp.
5. The residual liquid is removed from the work piece by an aerodynamic wiper.
6. A layer of melted wax is spread over the work piece to fill voids. The wax is then solidified by applying a cold plate to it.
7. The layer surface is trimmed to the desired thickness by a milling disk.
8. The current work piece is covered with a thin layer of liquid polymer and step 4 to 7 is repeated for each succeeding upper layer until the topmost layer has been processed.
9. The wax is melted away upon completion of the part.

The primary advantage of the solid ground curing system is that it does not require a support structure since wax is used to fill the voids. The model produced by SGC process is comparatively accurate in the Z-direction because the layer is milled after each light-exposure process. Although it offers good accuracy coupled with high throughput, it produces too much waste and its operating costs are comparatively high due to system complexity.

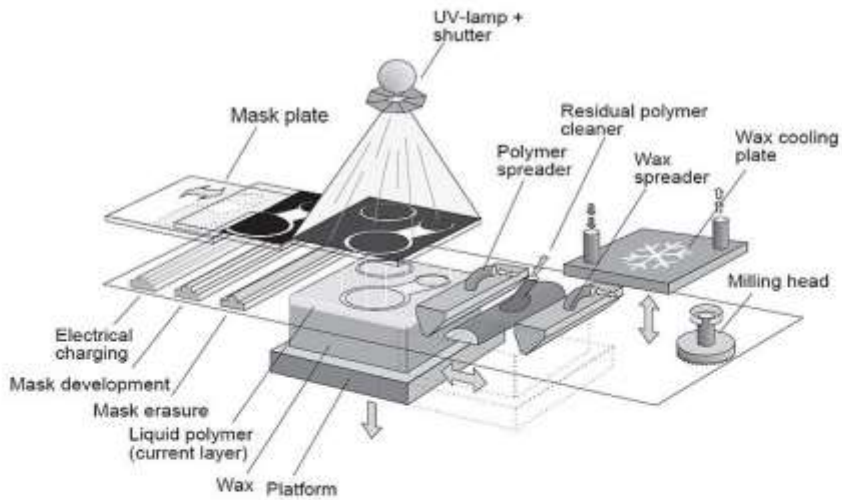


Figure: Solid ground curing process

35. Explain in detail about fused deposition modeling process and list its merits.

Fused Deposition Modeling (FDM):

In Fused Deposition Modeling (FDM) process a movable (x-y movement) nozzle on to a substrate deposits thread of molten polymeric material. The build material is heated slightly above (approximately 0.5 C) its melting temperature so that it solidifies within a very short time (approximately 0.1 s) after extrusion and cold-welds to the previous layer as shown in figure. Various important factors need to be considered and are steady nozzle and material extrusion rates, addition of support structures for overhanging features and speed of the nozzle head, which affects the slice thickness. More recent FDM systems include two nozzles, one for part material and other for support material. The support material is relatively of poor quality and can be broken easily once the complete part is deposited and is removed from substrate. In more recent FDM technology, water-soluble support structure material is used. Support structure can be deposited with lesser density as compared to part density by providing air gaps between two consecutive roads.

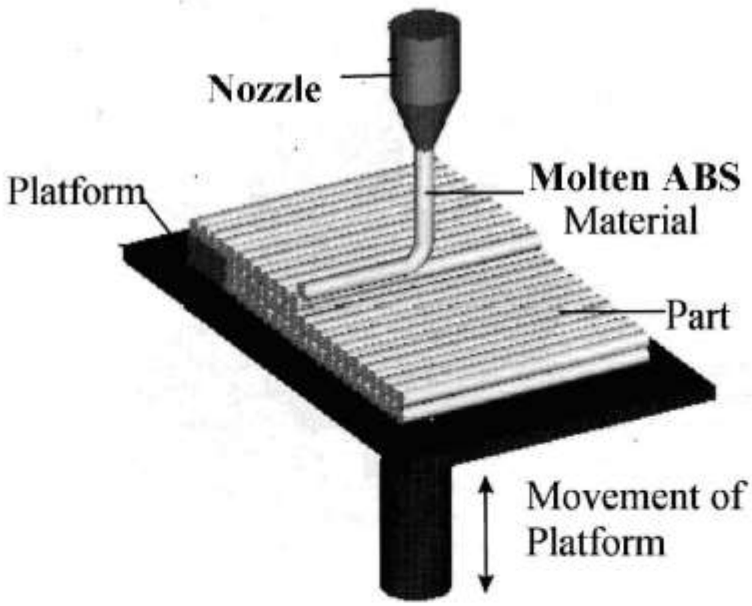


Figure:- Fused Deposition Modeling

Merits:

- Fused deposition modeling works with standard materials, for instance ABS or PC.
- Parts can be post-processed as any plastic part produced with conventional manufacturing.

Demerits:

- Through the deposition of extruded material layer-by-layer, parts have anisotropy in the z-direction (vertical direction), the surface has a step-structure and fine details cannot be realized.

Application areas:

- Prototypes are produced for form / fit and functional testing in standard materials by FDM
- Support parts (jigs, fixtures, helps) can be produced directly
- Small series parts down to one of a kind are built in standard materials by fused deposition modeling.

36. Explain in detail about stereo lithography process and list its merits.

In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. Due to the absorption and scattering of beam, the reaction only takes place near the surface and voxels of solid polymeric resin are formed. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a Ultra Violet Helium-Cadmium or Argon ion laser. The laser scans the first layer and platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation. The new slice is then scanned. Schematic diagram of a typical Stereo lithography apparatus is shown in figure. In new SL systems, a blade spreads resin on the part as the blade traverses the vat. This ensures smoother surface and reduced recoating time. It also reduces trapped volumes which are sometimes formed due to excessive polymerization at the ends of the slices and an island of liquid resin having thickness more than slice thickness is formed. Once the complete part is deposited, it is removed from the vat and then excess resin is drained. It may take long time due to high viscosity of liquid resin. The green part is then post-cured in an UV oven after removing support structures.

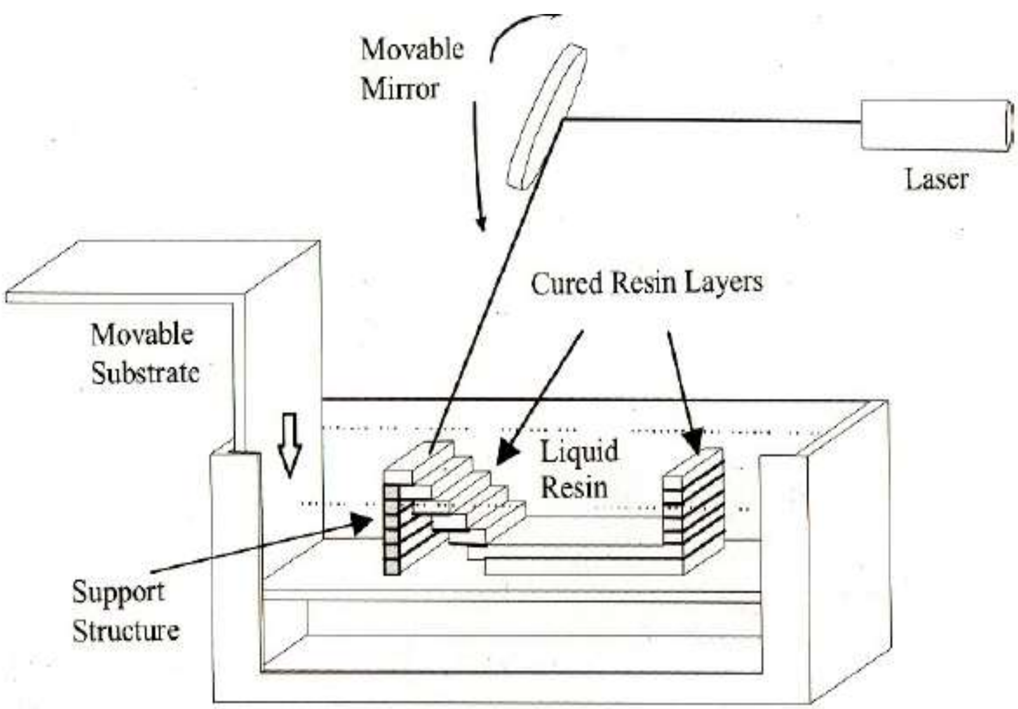


Figure: Stereo Lithography Process

Overhangs or cantilever walls need support structures as a green layer has relatively low stability and strength. These overhangs etc. are supported if they exceed a certain size or angle, i.e., build orientation. The main functions of these structures are to support projecting parts and also to pull other parts down which due to shrinkage tends to curl up. These support structures are generated during data processing and due to these data grows heavily specially with STL files, as cuboid shaped support element need information about at least twelve triangles. A solid support is very difficult to remove later and may damage the model. Build strategies have been developed to increase build speed and to decrease amount of resin by depositing the parts with a higher proportion of hollow volume. These strategies are devised as these models are used for making cavities for precision castings. Here walls are designed hollow connected by rod-type bridging elements and skin is introduced that close the model at the top and the bottom. These models require openings to drain out uncured resin.

MULTIPLE CHOICE QUESTIONS

SL	QUESTIONS	Opt 1	Opt 2	Opt 3	Opt 4	Answer
1	The major advantage of rapid prototyping is?	Cut cost and time	More practical and efficient model	Computer based model	Quick process	Cut cost and time
2	Which of the following rapid prototyping process uses powder as a starting material?	Selective laser sintering	Stereo lithography	Ballistic-particle manufacturing	Fused deposition modeling	Selective laser sintering
3	__________ type of rapid prototyping system uses a laser to fuse powdered metals, plastics, or ceramics:	Selective laser sintering	Solid ground curing	Stereo lithography	Fused deposition modeling	Selective laser sintering
4	__________allows the designer to conceptualize objects more easily without having to make costly illustrations, models, or prototypes	CAM	CAD	CAE	CAP	CAD
5	Which one of the following RP technologies uses solid sheet stock as the starting material	Droplet deposition manufacturing	Fused-deposition modeling	Laminated-object manufacturing	Selective laser sintering	Laminated-object manufacturing
6	Which of the following are problems with the current rapid prototyping	Limited material variety	Part accuracy	Poor mach inability	Part shrinkage	Limited material variety
7	Photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept in	Stereo lithography	Solid ground curing	Selective laser sintering	Fused deposition modeling	Stereo lithography
8	Fine polymeric powder like polystyrene is spread on the substrate in	Selective laser sintering	Solid ground curing	Stereo lithography	Fused deposition modeling	Selective laser sintering
9	In _______________ process a movable (x-y movement) nozzle on to a substrate deposits thread of molten polymeric material.	Solid ground curing	Stereo lithography	Selective laser sintering	Fused deposition modeling	Fused deposition modeling
10	In _______________ process the slices are cut in required contour from roll of material by using a 25-50 watt CO2 laser beam	Fused-deposition modeling	Laminated Object Manufacturing	Stereo lithography	Selective laser sintering	Laminated Object Manufacturing
11	After completion of the part ,sealing of the part is done by _________________ in Laminated Object Manufacturing to prevent water absorption	Epoxy	Rubber	Aluminum	Polyvinyl chloride	Epoxy
12	Poor surface quality of RP parts is a major limitation and is primarily due to _______________	No slicing	Stair case effect	Thick slicing	Thin slicing	Stair case effect
13	In SLS process problem arises with downward facing layers as these layers do not have a layer underneath and are slightly thicker and generates	Slicing error	Poor surface finish	Dimensional error	Poor surface finish	Dimensional error
14	During part deposition generally two types of errors are observed and are namely	Curing errors and control errors	Tessellation and slicing errors	Tessellation and Curing errors	Control and slicing errors	Curing errors and control errors
15	The maximum error (cusp height) results along _____________ direction and is equal to slice thickness	X	Y	Z	X and y	Z
16	Which of the following rapid	Ballistic-	Stereo	Fused	Selective	Stereo

	prototyping process starts with a photosensitive liquid polymer to fabricate a component?	particle manufacturing	lithography	deposition modeling	laser sintering	lithography
17	_________________ process uses liquid as a starting material	Ballistic-particle manufacturing	Selective laser sintering	Stereo lithography	Laminated-object manufacturing	Stereo lithography
18	_________________ are cured layer by layer into solid polymers	Liquid monomers	Powders	Solid sheets	Semi solids	Liquid monomers
19	_________________are laminated to create the solid part in RP	Solid sheets	Liquid monomers	Powders	Semi solids	Solid sheets
20	Prototyping or model making is one of the important steps to finalize	Product design	Product aesthetics	Product production feasibility	None of the above	Product design
21	In rapid prototyping the component is produced by?	Layer by layer deposition	Pressurized die casting	High pressure forming	Machining	Layer by layer deposition
22	RP process belong to________________ production processes	Generative	Forming	Generative and subtractive	None of the above	Generative
23	A Stereo lithography machine consists of a build platform know as ___________	Substrate	Depositer	Bed	Preform	Substrate
24	In Stereo lithography laser scans the first layer and platform is lowered equal to one slice thickness and left for short time it is known as	Dip delay	Delay period	Incubation period	Settling time	Dip delay
25	In Selective Laser Sintering (SLS) process, fine polymeric powder is spread on the substrate using a	Blade	Spray gun	Roller	Series of shafts	Roller