LABORATORY MANNUAL

TA201- Manufacturing Processes

2016-2017Ist Semester

Instructor: Prof. Rajiv Shekhar

Department of Materials Science & Engineering
Indian Institute of Technology Kanpur
Kanpur-208016

TA201: Introduction of Manufacturing Processes

I^st^semester 2016-2017, ***Laboratory Schedule***

Day & Section ↓ / Turns→	1st Lab1 1	2nd Lab 2	3rd Lab 3	4th Lab 4	5th Lab 5	**6th Lab Exam +Drawing**	7th Pro 1	8th Pro 2	9th Pro 3	10th Pro 4	11th Pro 5	12th Pro 6	13th Project Evaluation @
Monday	1/8	8/8	**13/8***	22/8	29/8	5/9	19/9	26/9	3/10	17/10	24/10	31/10	7/11
Tuesday	2/8	9/8	16/8	23/8	30/8	6/9	20/9	27/9	4/10	18/10	25/10	1/11	8/11
Wednesday	27/7	3/8	10/8	17/8	24/8	31/8	7/9	21/9	28/9	5/10	19/10	26/10	2/11
Thursday	28/7	4/8	11/8	18/8	1/9	8/9	22/9	29/9	6/10	20/10	27/10	3/11	10/11
Friday	29/7	5/8	12/8	19/8	26/8	2/9	9/9	23/9	30/9	7/10	21/10	28/10	4/11

First Lab : July 27,2016

Independence Day : August 15, 2016 (Monday)

Mid Semester Examination : Sep.13 – Sep.18, 2016

Mid Semester Recess : Oct. 8 – Oct. 16, 2016

End Semester Examination : Nov.15 - Nov.25, 2016

***Make-up lab on Saturday from 2PM to 5 PM**

Make up Lab Date - August 13, 2016

Mr. Anil Kumar Verma
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Dr.DipakMazumdar
Lab Coordinator
7328/dipak@

Dr. Rajiv Shekhar
Course in-charge
7016/vidtan@

General Information

- Theory (Total 30%): Mid Semester Exam (2 hours) 12% & End Semester Exam (3 hours) 18%.
- Laboratory (Total 70%) : Weekly Job: 5%, Lab Exam 15% & Project 50%

Safety:

- To avoid injury, the student must take the permission of the laboratory staff before handling any machine. Careless handling of machines may result in serious injury.
- Students must ensure that their work areas are clean and dry to avoid slipping.
- A leather apron will be issued to each student during Welding Exercise. Students not wearing the apron will not be permitted to work in the laboratory. Students are required to clear off all tools and materials from machine/work place.
- At the end of each experiment, students must clear off all tools and materials from the work area.

Rules:

- Follow the lab timing with proper attire. There will be two attendances: Initial attendance (at sharp 2 PM) to be taken by TA's at the beginning of lab session and final one consists of filling the Job submission form. Do not use cell phone inside the lab during lab timing.
- ***Students must come to the laboratory wearing (i) Trousers, (ii) half-sleeve tops and (iii) Leather shoes. Half pants, loosely hanging garments and slippers are not allowed.***
- There will no Lab/Log report but you should submit the short answers of given questions in the starting of lab based on video uploaded on course website.
- Every student should obtain a copy of Manufacturing Processes Laboratory Manual. You are requested to bring your lab manual in everyday's lab. You can purchase lab manual from lab on the first turn.

Project:

- Size of the project: 1 x 1 x 1 ft^3 **(strictly to be followed)** and Total weight for casting objects
- Should not exceed 1.5 kg per project. Oversize/overweight project will affect your final evaluation.
- At least three manufacturing processes are to be incorporated in the project.
- External colour/paint can NOT be used.
- Don't polish/grind cast component used in your project.

Recommended Reading

Fundamental of Modem Manufacturing: Materials, Processes and Systems, Mikell P. Groover

Fundamental of Manufacturing, G. K. Lal&S. K. Choudhury

Materials &Processes in Manufacturing, E. P. DeGarmo, J. T. Black and Kohser

Manufacturing Engineering &Technology, S. Kalpakjian

E. P. Degarmo: Materials &Processes in Manufacturing, Macmillan

GENERAL INFORMATION FOR LABORATORY

In this laboratory you will be exposed to the common manufacturing processes such as casting, metal forming, and welding processing. Laboratory experiments will consist of hands expression and demonstration of the various manufacturing processes.

This laboratory divided into four parts:

1. Hand-on-experience and demonstration of the various manufacturing processes (5 turns)
2. Lab Examination & Drawing Submission (1 turn)
3. Project (6 turns)
4. Project Evaluation (1 turn)

Laboratory Session

Exercise	No. of Turn
Exercise ofMAG and Manual ARC Welding	1
Exercise of Brazing process	1
Exercise of Sheet Metal process	1
Demo of Closed die forging, PM, Rolling	1
Exercise of Demo ofGreen sand Moulding and Casting	1
Laboratory Examination &Project Drawing Submission	1
Project	6
Project Evaluation	1

ABOUT PROJECT

1. Plan your project carefully. Do not make it unnecessarily complicated. The project has to be entirely your work. Laboratory staff (Technical guide) will provide you only the guidelines. They will not make any part of your project.

2. Your tutor, lab in-charge and the technical staff will advise you on the design of your project.

3. There will be no extra lab turn for project.

4. The project groups will be formed by the end of the first lab turn. Maximum number of student in each group will be Six.

5. You should come with at least three ideas with the rough sketch on the third lab turnfor the discussion and to be frozen one idea.

6. On the fourth and fifth lab turns you should come with all necessary information such as drawing; manufacturing process for each part etc. The drawing should be as per the engineering norms.

7. The copy of final project drawing with material list and process plan (complete report) must be submitted on the sixth lab turn. You should select materials from the list only. (The list will be displayed on lab notice board).

8. The exact responsibilities of each group member should be specified.

9. Two best projects will be chosen from each day. There will be one overall best project award out of all the shortlisted projects. The certificates will be given to the students (winners) in a common gathering after lab viva.

10. Size of the project: 1 x 1 x 1ft^3**(strictly to be followed)** and total weight for casting objects should not exceed 1.5 kg per project. Oversized and over weighted project will be credited negative marking.

11. At least three operations are to be incorporated in the project.(Welding, Casting, Sheet metal)

12. Moving parts in your project will be given extra credit during evaluation.

13. External colour/paint cannot be used. Polishing/grinding of cast component used will not allow.

In case of any doubt regarding the above, please contact Mr. Anil Kumar Verma.

INTRODUCTION TO WELDING PROCESSES

Objective

To study and observe the welding and brazing techniques through demonstration and practice (ARC, MAG, Brazing)

Background

Solid materials need to be joined together in order that they may be fabricated into useful shapes for various applications such as industrial, commercial, domestic, art ware and other uses. Depending on the material and the application, different joining processes are adopted such as, mechanical (bolts, rivets etc.), chemical (adhesive) or thermal (welding, brazing or soldering). Thermal processes are extensively used for joining of most common engineering materials, namely, metals. This exercise is designed to demonstrate specifically: gas welding, arc welding, resistance welding, brazing.

WELDING PROCESSES

Welding is a process in which two materials, usually metals, and is permanently joined together by coalescence, resulting from temperature, pressure, and metallurgical conditions. The particular combination of temperature and pressure can range from high temperature with no pressure to high pressure with any increase in temperature. Thus, welding can be achieved under a wide variety of conditions and numerous welding processes have been developed and are routinely used in manufacturing.

To obtain coalescence between two metals following requirements need to be met: (1) perfectly smooth, flat or matching surfaces, (2) clean surfaces, free from oxides, absorbed gases, grease and other contaminants, (3e) metals with no internal impurities. These are difficult conditions to obtain. Surface roughness is overcome by pressure or by melting two surfaces so that fusion occurs. Contaminants are removed by mechanical or chemical cleaning prior to welding or by causing sufficient metal flow along the interface so that they are removed away from the weld zone friction welding is a solid state welding technique. In many processes the contaminants are removed by fluxing agents.

The production of quality welds requires (1) a satisfactory heat and/or pressure source, (2) a means of protecting or cleaning the metal, and (3) caution to avoid, or compensate for, harmful metallurgical effects.

ARC WELDING

In this process a joint is established by fusing the material near the region of joint by means of an electric arc struck between the material to be joined and an electrode. A high current low voltage electric power supply generates an arc of intense heat reaching a temperature of approximately 3800^{o}C. The electrode held externally may act as a filler rod or it is fed independently of the electrode. Due to higher levels of heat input, joints in thicker materials can be obtained by the arc welding process. It is extensively used in a variety of structural applications.

There are so many types of the basic arc welding process such as shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), submerged arc welding

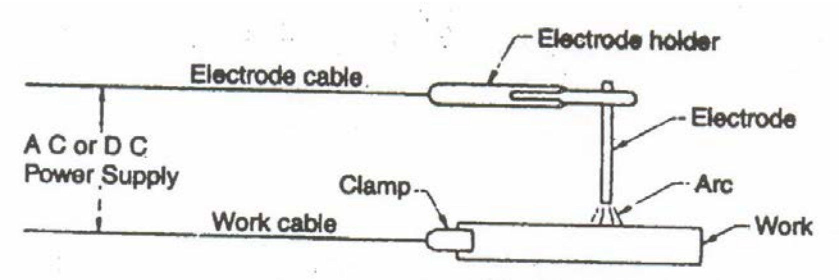


Fig 4.1: The Basic circuit for arc welding

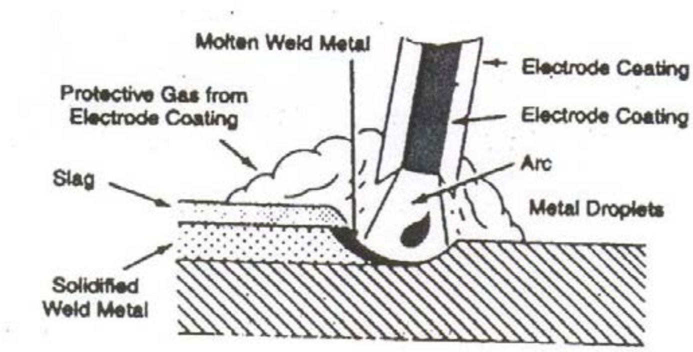
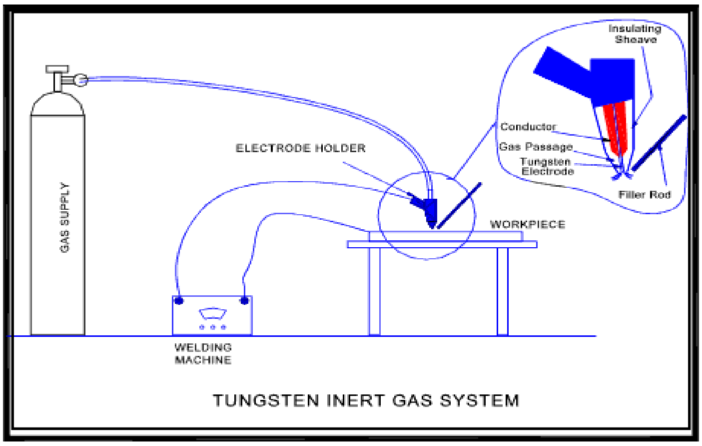


Fig 4.2: Schematic diagram of shielded metal arc welding (SMAW)



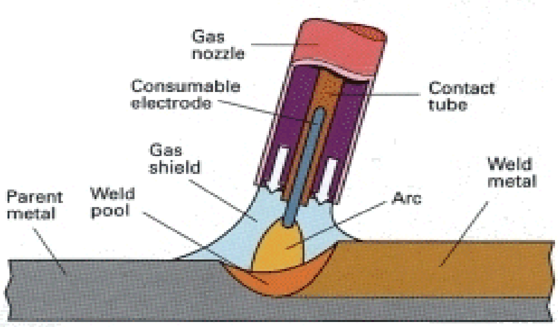


Fig 4.3: Schematic diagram of gas metal arc welding (GMAW)

LABORATORY EXERCISE-I
ARC WELDING

Objective

To prepare a butt joint with mild steel strip using MAG& MMAW technique.

Equipment and materials

Welding unit, consumable mild steel wire, mild steel flats (140 x 25 x 5 mm), protecting gas, Wire Brush, Tongs etc.

Procedure

- Clean the mild steel flats to be joined by wire brush.
- Arrange the flat pieces properly providing the gap for full penetration for butt joint(gap ½ thicknesses of flats).
- Practice striking of arc, speed and arc length control
- Set the welding current, voltage according to the type of metal to be joined.
- Strike the arc and make tacks at the both ends to hold the metal pieces together duringthe welding process
- Lay beads along the joint maintaining proper speed and arc length (Speed 100-150 mm/min).
- Clean the welded zone and submit.

Report the following

1. Precautions to be taken during various arc welding processes.
2. Advantages of MAG over MMAW.
3. Difference between consumable and non-consumable arc welding.
4. Limitations of arc welding.
5. What is the difference between MMAW and ARC welding?

GAS WELDING

In this process, a joint is established by fusing the material near the region of joint by means of a gas flame. The common gas used is mixture of oxygen and acetylene which on burning gives a flame temperature of 3300^{O}C. A filler rod is used to feed molten material in the gap at the joint region and establish a firm weld. The flame temperature can be controlled by changing the gas composition i.e. ratio of oxygen to acetylene. The color of flame changes from oxidizing to neutral to reducing flame.

BRAZING

In this process metal parts to be joined are heated to a temperature below the melting point of the parts but sufficient to melt the lower fusion point filler material which is used to fill the gap at the joint and establish a bond between the edges through the filler material (Fig.3.3). This process can establish a joint between two dissimilar metals also though a proper choice of filler material. Unlike in welding the filler rod differs widely in composition from the parent material(s). Gas (oxy-acetylene mixture) is used for heating.

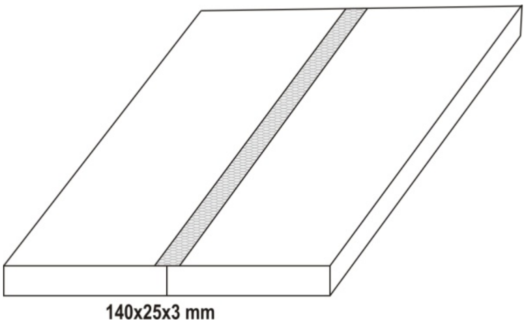
LABORATORY EXERCISE II
BRAZING

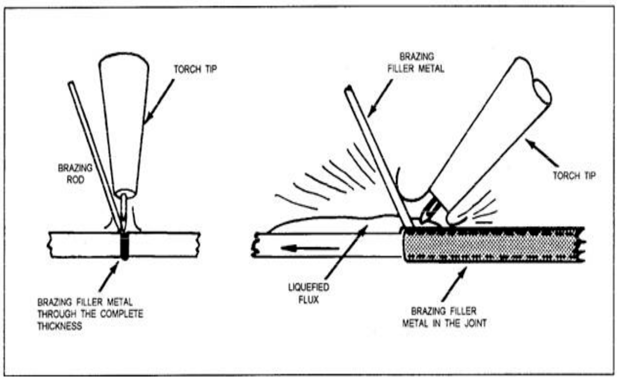
Objective

To prepare a butt joint with mild steel strips using brazing technique.

Equipment & materials

Gas welding set, brazing wire, fluxes, mild steel strips(140 x 25 x 3 mm), wirebrush, tongs etc.





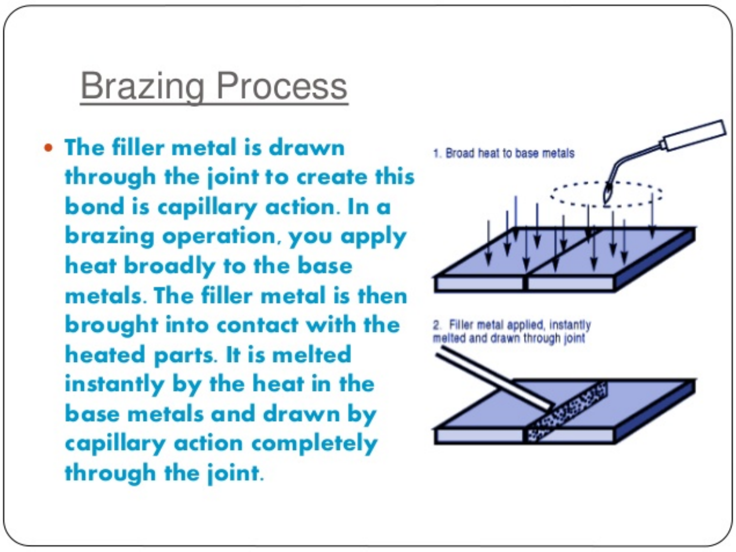


Fig: Brazing

Procedure

Brazing

- Clean the mild steel strip removing the oxide layer and flatten it.
- Keep the metal strip in butt position.
- Tack at the two ends.
- Lay brazing metal at the joint maintaining proper speed and feed.
- Clean the joint and submit

INTRODUCATION TO METAL FORMING

SHEET METAL FORMING

Many products are manufactured from sheet metal involving combination of processes such as shearing, bending, deep drawing, spinning etc. In all these operations, some plastic deformation of the metal is involved. They are essentially cold working operations.

LABORATORY EXERCISE-III
SHEET METAL FORMING

Objective

(i) To prepare a sheet metal product (Funnel).
(ii) Report the various parameters for the various passes during the rolling of the given metal piece.

Equipment & material

Mallet, hand shear, bench shear, grooving and riveting tool, metal sheet, soldering equipment.

Demonstration

Self secured sheet metal joints

(a) Internal grooved joint

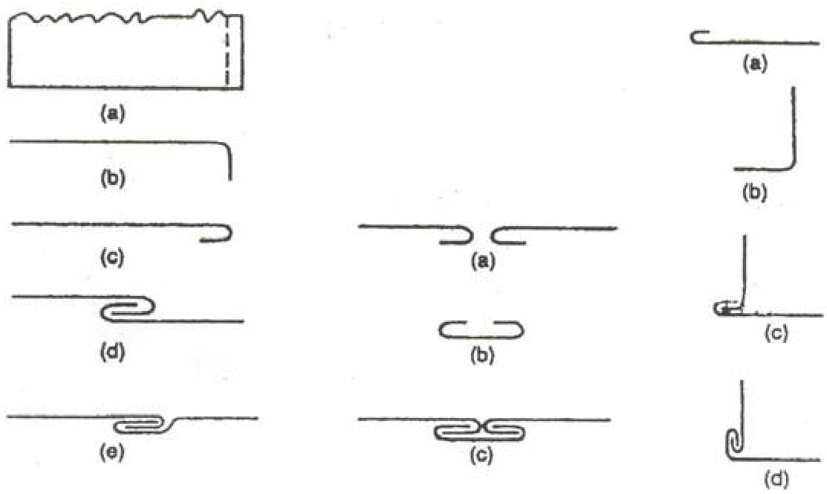
- Mark out portions of given sheets near edges to be joined with a marker (Fig. 3.1a)
- Fold the sheets at edges in the portion marked, first at right angles to the plane of thesheet (Fig. 8.1b) and then at 180^{O} to the plane (Fig.3.1c)
- Insert one folded sheet into the other (Fig. 3.1d)
- Groove the seam using grooving die (Fig. 3.1e)

(b) Double grooved joint

- Fold sheets after making them as per the instructions given (Fig. 3.2a)
- Cut a piece of sheet (called strap) of required width
- Strap width = (4x size of marked edges) + (4 x thickness of sheet)
- Close the edges of the strap slightly as shown in Fig. 3.2(b)
- Slip the strap on the bent edges of the sheets after bringing them together (Fig. 3.2c)

(c) Knocked-up joint

- Fold one sheet and close edges slightly (Fig. 3.3a)
- Bend one sheet to form a right angles band (Fig. 3.3b)
- Slip the second sheet in the folded one (Fig. 3.3c)
- Close the right angled sheet using a mallet (Fig. 3.3d)



3.1 3.2 3.3

Fig: Sheet Metal Joints

Procedure for funnel:

- Draw the elevation on full scale
- Complete the cone by extending the lines A and G
- Choose a point Z and draw curves with Z as a center, and ZA and ZX as radius
- Draw the vertical line Z3, meeting the internal curve at D, and external curve at 3
- Starting from D mark lengths DC, CB, BA, DE, EF and FG, each equal to *nd/6.*
- Again starting from 3 mark length 3-2, 2-1, 1-0, 3-4, 4-5 and 5-6, each equal to πd/6. (D and d are major and minor diameters)
- Draw another curve with Z as a center and ZX+5 mm as radius .
- Joint AO and G6 and extend it to cut the outer curve at points H and I, respectively.
- Provide a margin of 5 mm on one side, and 10 mm on another side for joint.
- Cut out the required portion and form the conical portion.
- Make the bottom half of the funnel.

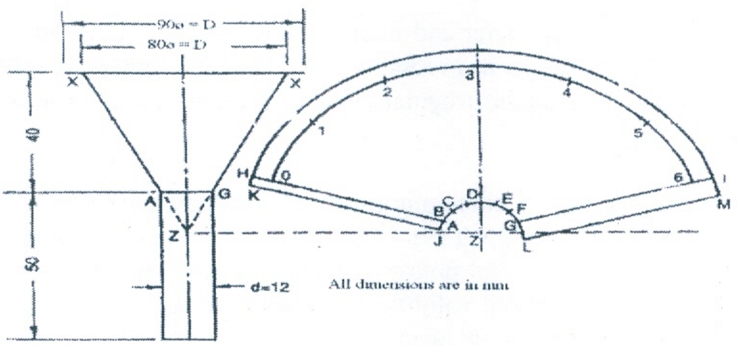


Fig: 3.4: Sheet Metal Funnel

INTRODUCTION TO CASTING PROCESSES

Objective

To study and observe various stages of casting through demonstration of Sand Casting Process.

Background

Casting is one of oldest and one of the most popular processes of converting materials into final useful shapes. Casting process is primarily used for shaping metallic materials; although it can be adopted for shaping other materials such as ceramic, polymeric and glassy materials. In casting, a solid is melted, treated to proper temperature and then poured into a cavity called mold, which contains it in proper shape during solidification. Simple or complex shapes can be made from any metal that can be melted. The resulting product can have virtually any configuration the designer desires.

Casting product range in size from a fraction of centimetre and fraction of kilogram to over 10 meters and many tons. Moreover casting has marked advantages in production of complex shapes, of parts having hollow sections or internal cavities, of parts that contain irregular curved surfaces and of parts made from metals which are difficult to machine.

Several casting processes have been developed to suit economic production of cast products with desired mechanical properties, dimensional accuracy, surface finish etc. The various processes differ primarily in mold material (whether sand, metal or other material) and pouring method (gravity, pressure or vacuum). All the processes share the requirement that the material solidify in a manner that would avoid potential defects such as shrinkage voids, gas porosity and trapped inclusions. Any casting process involves three basic steps, i.e. mold making, melting and pouring of metals into the mold cavity, and removal and finishing of casting after complete solidification.

SAND CASTING PROCESSES

Sand is one of the cheaper, fairly refractory materials and hence commonly used for making mold cavities. Sand basically, contains grains of silica (SiO_2) and some impurities. For mold making purposes sand is mixed with a binder material such as clay, molasses, oil, resin etc.

Green Sand Molding

In green sand molding process, clay (a silicate material) along with water (to activate clay) is used as binder. The mold making essentially consists of preparing a cavity having the same shape as the part to be cast. There are many ways to obtain such a cavity or mold, and in this demonstration you will learn to make it using a wooden ‘pattern’, metal ‘flasks’ and ‘green-sand’ as mold material.

A pattern is a reusable form having approximately the same shape and size as the part to be cast. A pattern can be made out of wood, metal or plastic; wood being the most common material. Green sand refers to an intimate mixture of sand (usually river sand), bentonite clay (3-7 percent by weight of sand, to provide bonding or adhesion between sand grains), and water (3-6 percent by weight of sand, necessary to activate the bonding action of the clay).

Mixing the above ingredients in a sand4 muller best provides the intimate mixing action. In practice, a major part of this sand mixture consists of ‘return sand’, i.e. the reusable portion of the sand left after the solidified metal casting has been removed from the mold. Molding flasks are rectangular frames with open ends, which serve as containers in which the mold is prepared. Normally a pair of flasks is used; the upper flask is referred to as ‘Cope’ and the lower one as ‘drag’. A riddle is a relatively coarse sieve. Riddling the green sand helps in breaking the lump and aerates the sand.

Sometimes the casting itself must have a hole or cavity in or on it. In that case the liquid metal must be prevented from filling certain portions of the mold. A ‘core’ is used to block-off portions of the mold from being filled by the liquid metal. A core is normally made using sand with a suitable binder like molasses. Core is prepared by filling the core-box with core sand to get the desired shape and the baking this sand core in an oven at suitable temperature.

During mold making a suitable ‘gating system’ and a riser’ is also provided. The gating system is the network of channels used to deliver the molten metal from outside the mold into the mold cavity. The various components of the gating system are pouring cup, sprue, runners and gates. Riser or feeder head is a small cavity attached to the casting cavity and the liquid metal of the riser serves to compensate the shrinkage in the casting during solidification.

Fig. 1.1 shows the various parts of a typical sand mold. Several hand tools, such as rammer, trowel, sprue pin, draw spike, slick, vent wire, gate cutter, strike off bar etc. are used as aids in making a mold.

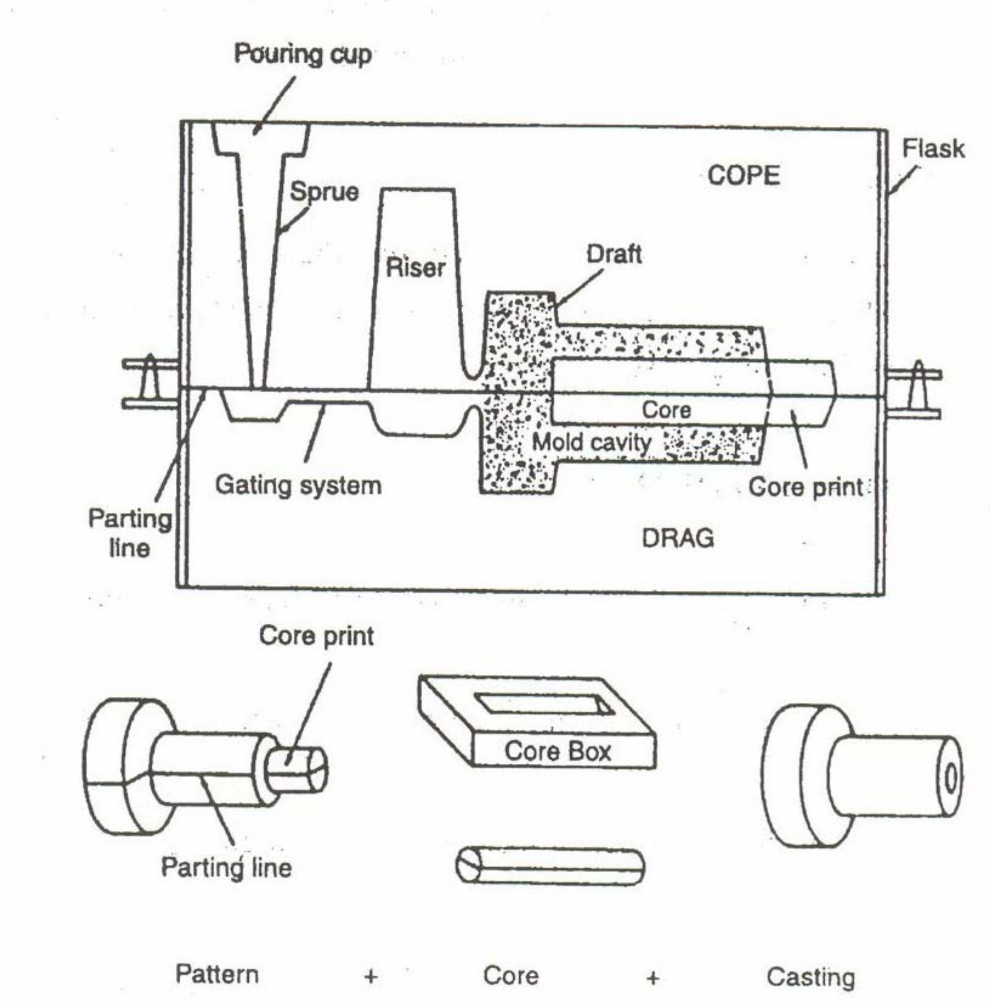


Fig: 1.1: Cross Section of a typical two-part sand mold, indicating various mold components and terminology.

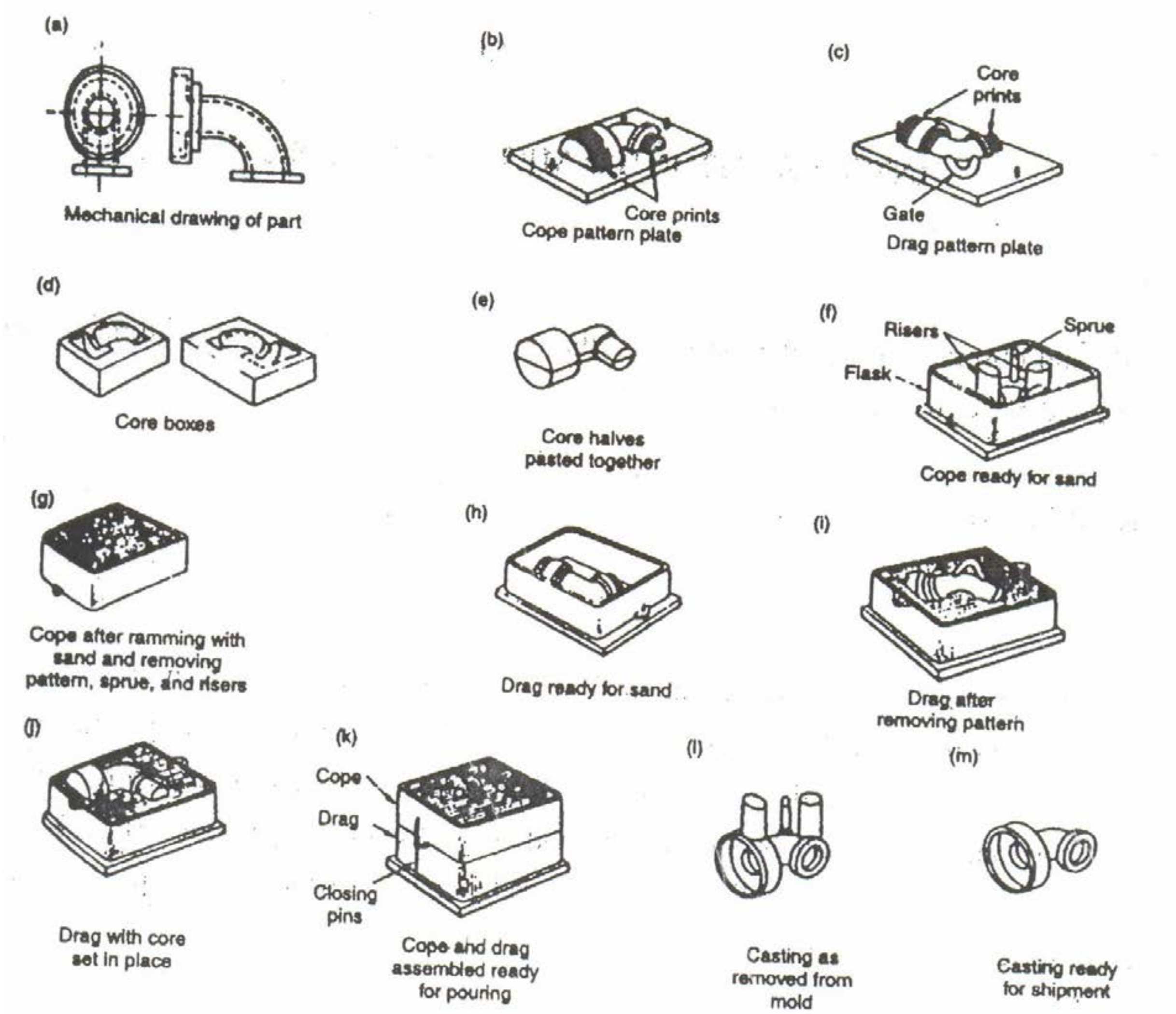


Fig 1.2: Schematic illustration of the sequence of operations for sand casting.

Melting and Pouring of Metals

The next important step in the making of casting is the melting of metal. A melting process must be capable of providing molten metal not only at the proper temperature but also in the desired quantity, with an acceptable quality, and within a reasonable cost. In order to transfer the metal from the furnace into the molds, some type of pouring device, or ladle, must be used. The primary considerations are to maintain the metal at the proper temperature for pouring and to ensure that only quality metal will get into the molds. The operations involved in melting of metal in oil fired furnace/induction furnace and pouring of liquid metal into the mold cavity will be shown during the demonstration.

Removal and Finishing of Castings

After complete solidification, the castings are removed from the mold. Most castings require some cleaning and finishing operations, such as removal of cores, removal of gates and risers, removal of fins and flash, cleaning of surfaces, etc.

LABORATORY EXERCISE-IV
MOLD MAKING & CASTING

Objective

1. To prepare a pattern for given object for lost form casting.
2. To prepare a Green sand mold from the prepared pattern.
3. To melt and pour Aluminium metal into the mold.

Equipment and Materials

Pattern, core box, molding flasks, molding tools, sand muller, riddle, sand,bentonite, core baking oven, thermocole, melting furnace, fluxes, pouring ladle, pyrometer, hacksaw, file.

Procedure

Mold Making

(i) Place the drag part of the molding flask and riddle moldinggreen sand to a depth of 2 cm in the drag.

(ii) Place the pattern at the centre of the drag (flask)

(iii) Pack the sand carefully around the pattern with figures. Heap more molding sand in the drag and ram with rammer carefully

(iv) Place the core half of the pattern over the drag pattern matching the guide pins and also place the gating system with sprue and riser in proper positions.

(v) Complete the cope half by repeating steps 3. Remove the extra sprue and riser pins and make a pouring basin.

Melting and Pouring

(i) Melt the metal in the furnace. Use appropriate fluxes at proper stages and measure metal temperature from time to time.

(ii) Pour the molten metal into the pouring ladle at a higher temperature (say 100oC higher) than the pouring temperature. As soon as the desired pouring temperature is reached, pour the liquid metal into the mold in a steady stream with ladle close to the pouring basin of the mold. Do not allow any dross or slag to go in.

(iii) Allow sufficient time for the metal to solidify in the mold. Break the mold carefully and remove the casting.

(iv) Cut-off the riser and gating system from the casting and clean it for any sand etc.

(v) Inspect the casting visually and record any surface and dimensional defects observe.

LABORATORYDEMONSTRATIONS - V

Part -1, ROLLING

Objective

To study and observe the plain and grooved Rolling techniques through demonstration.

Rolling is the process of plastic deformation of metals by squeezing action as it passes between a pair of rotating rolls, either plane or grooved. The process may be carried out hot or cold. The most common rolling mill is the 2-high rolling mill, which consists of two rolls usually mounted horizontally in bearings at their ends and vertically above each other (Fig. 2.1). The rolls may be driven through couplings at their ends by spindles, which are coupled, to pinions (or gears), which transmit the power from the electric motor.

To control the relative positioning of rolls, a roll positioning system is employed on the mill stand. In small mills, such as the one in the laboratory, the roll positioning system called the 'mill screw' is hand driven, while in commercial mills they are motor driven.

The 2-high mills could be either reversing or non-reversing type. In the reversing type, which is the most common one, the direction of motion of the rolls can be reversed, and therefore the work can be fed into the mill from both sides by reversing the direction of rotation of rolls.

For rolling to take place the roll separation or roll gap must be less than the in going size of the stock. After rolling, the height of the stock is reduced and length is increased. The difference in height of ingoing and outgoing is called 'draught'. Fig. 2.1 shows a flat piece of metal of thickness h1, through a pair of rolls of radius R. The AC is called the 'arc of contact'. The angle θ subtended at the roll center by the arc of contact is called the 'angle of contact' and can be evaluated from

$$\text{Cos } \theta = [1 - (ho - h1) /2R]$$

If there is no elastic deflection of rolls during rolling, the final thickness of metal h1 is same as the roll gap. If elastic deflection of rolls occur, the final thickness of metal after rolling h1, is greater than the roll gap fixed before rolling.

Depending upon the condition under which the metal is introduced into the roll gap, two situations can occur:

- The metal is gripped by the rolls and pulled along into the roll gap.

- The metal slips over the roll surface.

The process of rolling depends upon the frictional forces acting between the surfaces of the roll and the metal. The condition of biting or gripping of metals into rolls is $\mu \geq \tan \theta$, where μ is the coefficient of friction between the roll and metal surfaces. The maximum value of θ ($\theta max = \tan\text{-}1\lambda$) is often called the angle of bite. The average coefficient of friction can now be estimated as $\mu = \tan \theta max$.

Rolling of a metal plate on a two high rolling mill will be demonstrated. The demonstration of the situations when (a) metal slips on the roll surface, and (b) metal is gripped by the rolls, would also be shown to you.

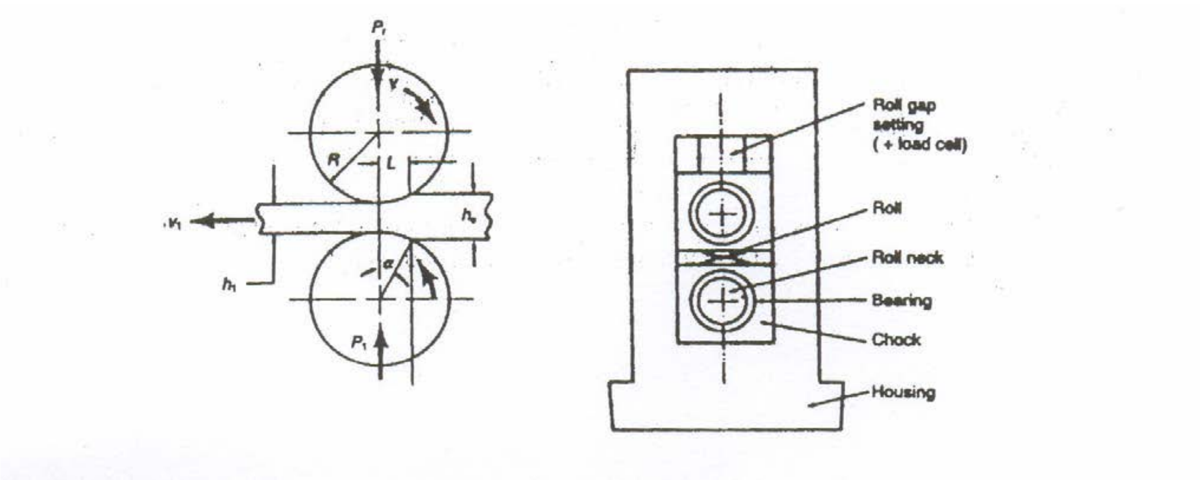


Fig.2.1: Rolling is steady state process that (a) reduces the thickness of the work piece (b) in rolling mills of considerable stiffness

Observations

1. Report the various parameters in a tabular form for the various passes during the rolling of the given metal piece as shown in rolling demonstration.

   Metal used:
   Roll diameter:
   Roll speed:

Pass No.	Initial Dim. L W T	Passive Roll Gap	Final Dim. L W T	Draught	% Inc. L W T	Spring back	Bite Angle	Coefficient of Friction
1.								

(L: Length, W: Width, T: Thickness, Inc: Increase, Red: Reduction, Dim: Dimension)

Part-2, POWDER METALLURGY

Objective

To study and observe the Powder Metallurgy techniques through demonstration.

Powder metallurgy (PM) is a term covering a wide range of ways in which materials or components are made from metal powders. PM processes can avoid, or greatly reduce, the need to use metal removal processes, thereby drastically reducing yield losses in manufacture and often resulting in lower costs.

Powder metallurgy is also used to make unique materials impossible to melt or form in other ways. A very important product of this type is tungsten carbide (WC). WC is used to cut and form other metals and is made from WC particles bonded with cobalt. It is very widely used in industry for tools of many types and globally ~50,000t/yr is made by PM. Other products include sintered filters, porous oil-impregnated bearings, electrical contacts and diamond tools.

The PM press and sinter process generally consists of three basic steps: powder blending(pulverisation), die compaction, and sintering. Compaction is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure and under carefully controlled atmosphere composition. Optional secondary processing such as coining or heat treatment often follows to obtain special properties or enhanced precision.[1]

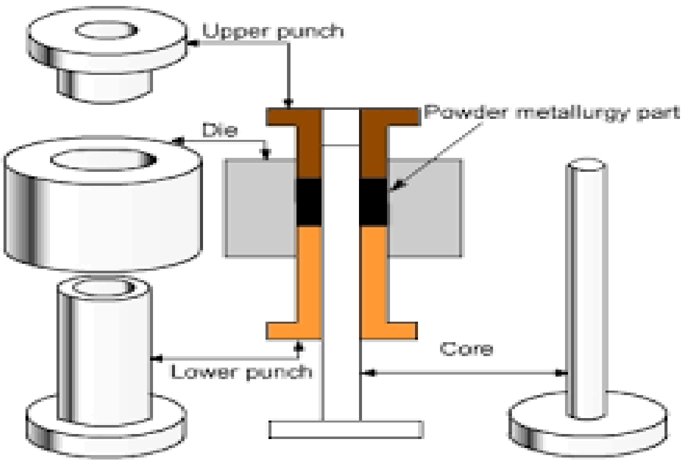
One of the older such methods, and still one used to make around 1Mt/yr of structural components of iron-based alloys, is the process of blending fine (<180 microns) metal (normally iron) powders with additives such as a lubricant wax, carbon, copper, and/or nickel, pressing them into a die of the desired shape, and then heating the compressed material ("green part") in a controlled atmosphere to bond the material by sintering. This produces precise parts, normally very close to the die dimensions, but with 5-15% porosity, and thus sub-wrought steel properties. There are several other PM processes which have been developed over the last fifty years. These include:

- Powder forging. A "preform" made by the conventional "press and sinter" method is heated and then hot forged to full density, resulting in practically as-wrought properties.
- Metal injection moulding (MIM). Here the powder, normally very fine (<25microns) and spherical, is mixed with plastic or wax binder to near the maximum solid loading, typically around 65vol%, and injection moulded to form a "green" part of complex geometry. This part is then heated or otherwise treated to remove the binder (debinding) to give a "brown" part. This part is then sintered, and shrinks by ~18% to give a complex and 97-99% dense finished part. Invented in the 1970s, production has increased since 2000 with an estimated global volume in 2014 of 12,000t worth €1265millions.[2]
- Electric current assisted sintering (ECAS) technologies rely on electric currents to densify powders, with the advantage of reducing production time dramatically (from 15 minutes of the slowest ECAS to a few microseconds of the fastest), not requiring a long heat furnace and allowing to obtain near to theoretical densities but with the drawback of simple shapes. Powders employed in ECAS can avoid binders thanks to the possibility of direct sintering, without the need of pre-pressing and a green

compact. Molds are designed for the final part shape since the powders densify while filling the cavity under an applied pressure thus avoiding the problem of shape variations caused by non isotropic sintering and distortions caused by gravity at high temperatures. The most common of these technologies is hot pressing, which has been under use for the production of the diamond tools employed in the construction industry. Spark plasma sintering and electro sinter forging are two modern, industrial commercial ECAS technologies.

- Additive manufacturing (AM) is a relatively novel family of techniques which use metal powders (among other materials, such as plastics) to make parts by laser sintering or melting. This is a process under rapid development as of 2015, and whether to classify it as a PM process is perhaps uncertain at this stage. Processes include 3D printing, selective laser sintering (SLS), selective laser melting (SLM), and electron beam melting (EBM).

Simple Die and Punch



Products by Powder Metallurgy Process

Part-3, CLOSED DIE FORGING

Objective

To study and observe the Closed Die Forging techniques through demonstration.

Description

Closed Die Forging is a forging process in which dies (called tooling) that contain a precut profile of the desired part move towards each other and covers the workpiece in whole or in part. The heated raw material, which is approximately the shape or size of the final forged part, is placed in the bottom die. The shape of the forging is incorporated in the top or bottom die as a negative image. Coming from above, the impact of the top die on the raw material forms it into the required forged form. Parts from a few ounces to 60,000 lbs. can be made using this process. Some of the smaller parts are actually forged cold.

Process Capabilities

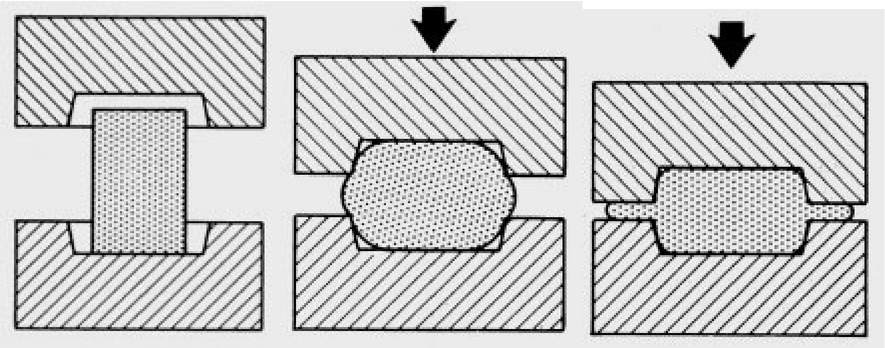
As the name implies, two or more dies containing impressions of the part shape are brought together as forging stock undergoes plastic deformation. Because metal flow is restricted by the die contours, this process can yield more complex shapes and closer tolerances than open-die forging processes. Additional flexibility in forming both symmetrical and non-symmetrical shapes comes from various pre-forming operations (sometimes bending) prior to forging in finisher dies.

Part geometry's range from some of the easiest to forge simple spherical shapes, block-like rectangular solids, and disc-like configurations to the most intricate components with thin and long sections that incorporate thin webs and relatively high vertical projections like ribs and bosses. Although many parts are generally symmetrical, others incorporate all sorts of design elements (flanges, protrusions, holes, cavities, pockets, etc.) that combine to make the forging very non-symmetrical. In addition, parts can be bent or curved in one or several planes, whether they are basically longitudinal, equi-dimensional or flat.

Most engineering metals and alloys can be forged via conventional impression-die processes, among them: carbon and alloy steels, tool steels, and stainless, aluminum and copper alloys, and certain titanium alloys. Strain-rate and temperature-sensitive materials (magnesium, highly alloyed nickel-based super-alloys, refractory alloys and some titanium alloys) may require more sophisticated forging processes and/or special equipment for forging in impression dies.

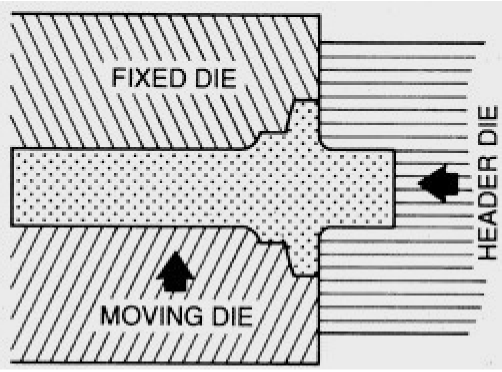
Closed Die Forging Process Operations

In the simplest example of impression die forging, two dies are brought together and the workpiece undergoes plastic deformation until its enlarged sides touch the side walls of the die. Then, a small amount of material begins to flow outside the die impression forming flash that is gradually thinned. The flash cools rapidly and presents increased resistance to deformation and helps build up pressure inside the bulk of the workpiece that aids material flow into unfilled impressions.



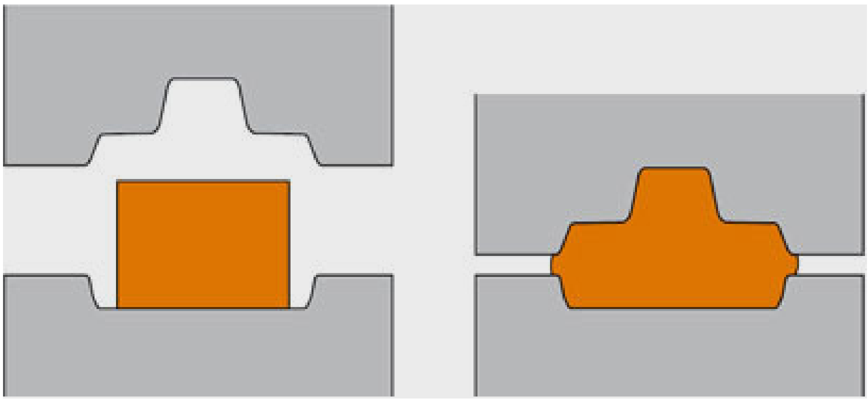
Upsetting

Fundamentally, impression die forgings produced on horizontal forging machines (upsetters) are similar to those produced by hammers or presses. Each is the result of forcing metal into cavities in dies which separate at parting lines.



The impression in the ram-operated "heading tool" is the equivalent of a hammer or press top die. The "grip dies" contain the impressions corresponding to the hammer or press bottom die. Grip dies consist of a stationary die and a moving die which, when closed, act to grip the stock and hold it in position for forging. After each workstroke of the machine, these dies permit the transfer of stock from one cavity to another in the multiple-impression dies.

Die & object View



Rough Work