LABORATORY MANUAL

TA211 MANUFACTURING PROCESSES-I

2024-2025, Semester-II

Indian Institute of Technology, Kanpur

Department of Materials Science and Engineering

INSTRUCTOR	**TUTOR**	**LAB IN-CHARGE**
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Laboratory	**Monday & Wednesday: 14:00 - 17:00** **(As per one of the assigned days of your section)** **Venue: TA211, Diamond Jubilee Academic Complex (Engineering Metallurgy Laboratory)**	

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TA211: Introduction of Manufacturing Processes-I

Engineering Metallurgy Lab (DJAC 101H)

2024-2025, Semester-II, Laboratory Schedule

Time: 02:00 pm to 05:00 pm

Experiment Turns / Day	1st E1	2nd E2	3rd E3	4th E4	5th D5	6th Lab Exam (LE6) + Drawing Submission	7th P1	8th P2	9th P3	10th P4	11th P5	12th P6	13th Project Evaluation (PE)
Monday	6/1	13/1	20/1	27/1	3/2	10/2	17/2	3/3	17/3	24/3	5/4	7/4	21/4
Wednesday	8/1	15/1	22/1	29/1	5/2	12/2	19/2	5/3	19/3	26/3	2/4	9/4	16/4

Mid and End Examination & Recess	Date	Saturday Make-up Lab
Mid Semester Examination	Feb 21 – 28, 2025 (Fri-Fri)	**Makeup lab on 05/04/2025 @ 2:00 PM. to 5:00PM.**
Mid Semester Recess (Holi)	Mar 8 – 16, 2025 (Sat – Sun)	
End Semester Examination	Apr 26- May 6, 2025 (Sat-Tue)	

Lab In-Charge:	**Tutor**	**Course Instructor:**
Mr. Anil Kumar Verma	Prof. Rajiv Shekhar	Prof. Kallol Mondal
Contact:7978/akumarv@	Contact: 7016/vidtan@	Contact:6156/kallol@

Tutors, TAs & staff members contact:

Tutors:

Day	Tutor	Email	Phone
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	241060612	Adam Musa	madam24@iitk.ac.in	9129118493
	241060610	Shakshi Jain	shakshi24@iitk.ac.in	7023566047
Wednesday	20106290	Aman Kumar	amanphd20@iitk.ac.in	8373845366
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Staff members:

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1.	Mr. Anil Kumar Verma	akumarv@iitk.ac.in	7978
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5.	Mr. Gyanendra Singh	gyans@iitk.ac.in	7920
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7.	Mr. Rajdipta Samadder	rajdipta@iitk.ac.in	7920
8.	Mr. Pappu	--	7978

General Information

- **Grading policy**

  Laboratory (100%):

  - *Weekly lab quiz and attendance (E1-E5): 10 %*
  - *Weekly job (E1 – E4): 10 %*
  - *Lab exam (LE6): 20 %,*
  - *Weekly Project Design Progress (E2-E5): 10%*
  - *Weekly Project Progress and attendance (P1 – P6): 10 %*
  - *Project report (6th turn): 10 %*
  - *Final Project Evaluation (PE) + Video on making of the project: 30 %*
  - *Minimum 40% required for passing the course.*
    - There will be a total of 12 labs starting from **6th Jan 2025 (for Monday batch) and 8 Jan 2025 (for Wednesday batch)**. All the lab turns are mandatory. The only exception is medical emergencies which must be approved by SUGC. 13th Turn is reserved for Project Evaluation.
    - Contribution to the group project by every member of a group is mandatory.

- **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 and leather hand gloves will be issued to each student during Welding and Brazing exercises. Students not wearing the apron will not be permitted to work in the laboratory.
  - At the end of each experiment, students must clear off all tools and materials from the work area.
  - During Sheet Metal forming, wearing cotton hand gloves is compulsory.
  - Students must come to the laboratory wearing (i) Trousers, (ii) Preferably cotton cloth (especially forwelding/brazing) and (iii) Closed shoes.
  - Project report must be submitted on the 12th turn. Not submitting the project report by the deadline will result in deduction of marks.

- **Rules:**

  - Strictly follow the lab timing (2:00 pm – 5:00 pm). There will be two attendances: Initial attendance will be based on Weekly Quiz, and final one consists of filling the job submission form.

- **Mobile phones are prohibited during the initial 6 turns**. **However, one person in a group can operate the mobile phone while recording the job progress during project turns. Each group will designate one person for that. S/He has to take permission from the TAs or Tutor for doing so. Every group needs to prepare a video of 10-15 min to showcase "Making of the Project".**
- **Half pants, loosely hanging garments, slippers and sandals are not allowed. It is safer to wear cotton cloths (especially for welding/brazing).**
- Before commencement of the experiment, there will be a **weekly lab quiz** on questions related to theprevious lab. On the 6^{th} turn, there will be lab quiz first and after that lab exam will be held.
- Every student should obtain a copy of the Manufacturing Processes Laboratory manual. You are required to bring your lab manual every day. Lab manual will also be available online.
- **Absent without SUGC approval or health certificate from IITK health center in case of illness would invite heavy deduction of marks.**

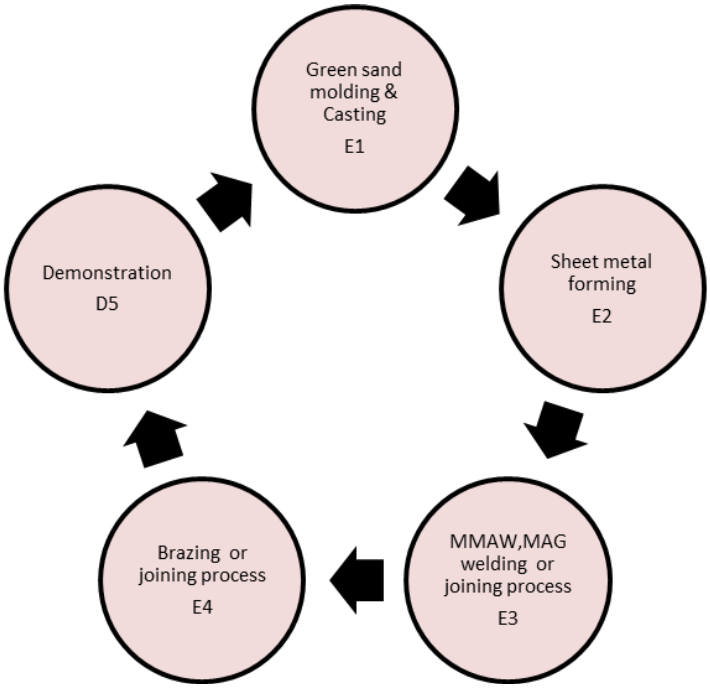
- **Suggested Reading Materials:**

- **Preferred:** Fundamentals of Modern 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. Kalpakian
- E. P. DeGarmo: Materials & Processes in Manufacturing, Macmillan.

➢ Lab turns distribution:

S No	Lab Turn	Experiments	Staff members
1	E1	Sand Moulding , Casting and Forging	Mr. G. Singh, Mr. A. Prasad and Mr. R. Samadder
2	E2	Sheet Metal Forming	Mr. R. Kumar
3	E3	Welding Processes, Powder Metallurgy and Plasma Cutting Process	Mr. G. Mishra
4	E4	Brazing Process, Drilling/Cutting/Grinding Operations, Object Fabrication	Mr. B. R. Singh
5	D5	Demonstration of Rolling, Swaging, Tape Casting, 3 D Printer and Plastic moulding Exp.	Mr. A. K. Verma
6	LE6	Lab Exam and Project Report Submission	Respective staff member
7	P1	Project	Staff supervisor
8	P2	Project	Staff supervisor
9	P3	Project	Staff supervisor
10	P4	Project	Staff supervisor
11	P5	Project	Staff supervisor
12	P6	Project	Staff supervisor
13	PE	Project Evaluation	Respective members

➢ Rotation of experimental turns:



- **Project schedule:**

1st Turn	Project group formation
2nd Turn	Bring a minimum of three project ideas along with the rough sketch – Discussion with tutor and lab incharge
3rd Turn	One project idea will be finalized.
4th Turn	Discussion on a finalized project with proper drawing as per engineering norms, including parts drawing (with numbering and requirement of specific materials from the list of materials provided to you)
5th Turn	A final discussion on drawing and process (Pre-final draft of report)
6th Turn	Final report submission (including drawings).
7th - 12th Turns	Projects
13th Turn	Project Evaluation

- **Outline of project report:**

<table>
<tr><th>S. No.</th><th colspan="4">Description</th><th>Page no.</th></tr>
<tr><td>1</td><td colspan="4">Project name</td><td rowspan="5">1</td></tr>
<tr><td>2</td><td colspan="4">Tutor name</td></tr>
<tr><td>3</td><td colspan="4">Course In-charge and Lab In-charge names</td></tr>
<tr><td>4</td><td colspan="4">Section:</td></tr>
<tr><td>5</td><td>S No.</td><td>Roll no.</td><td>Name</td><td>Signatures</td></tr>
<tr><td>6</td><td colspan="4">Contents</td><td>2</td></tr>
<tr><td>7</td><td colspan="4">Certificate about plagiarism</td><td>3</td></tr>
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<tr><td>12</td><td colspan="4">Materials List</td><td>8</td></tr>
<tr><td>13</td><td colspan="4">Isometric Drawing with numbering</td><td>9</td></tr>
<tr><td>14</td><td colspan="4">Part Drawing (in mm) and page number should be provided</td><td>10</td></tr>
</table>

- **Points to be used in the project report:**
  - The manufacturing process involving in each component needs to be mentioned.
  - Proper drawing should be made and submitted in consultation with the tutor and lab incharge.
  - The part drawing should be made with appropriate dimensions in mm.
  - You should make isometric and part drawing with appropriate dimensions on A-4 sheet.
- **Restrictions:**
  - Maximum size of the project: 40 cm x 40 cm x 40 cm (**to be followed strictly**) and total weight for casting objects should not exceed 1 kg of aluminum per project. Oversize/overweight projects will invite deduction of marks.
  - Do not grind the aluminum parts of the project.
  - Total project weight should not exceed 5 Kg.
  - External color /paint should not be used.
- **About the project:**
  - Plan your project carefully. Do not make it unnecessarily complicated. The project is to be made by each project group. Laboratory staff will only guide you.
  - Your tutor, course In-charge and the technical staffs will advise on the projects.
  - There will be no extra lab turn for the project.
  - The project groups will be formed and informed to you by the end of the first lab turn.
  - You should come with at least three ideas with the rough sketch on the second lab turn for thediscussion. On the third lab turn, one idea will be frozen.
  - 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.
  - The copy of the final project drawing with material list and process plan (pre-final draft 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). The draft report will be useful for guidance during project execution stages. Final report will have to be submitted on 12th turn.
  - The exact responsibilities of each group member should be specified in the final report.
  - Maximum size of the project: 40 cm x 40 cm x 40 cm (to be followed strictly) and total weight for casting objects should not exceed 1 kg of aluminum per project.
  - Do not grind the aluminum parts of the project.
  - Moving parts in your project will result in extra credit during evaluation.
  - External colour/paint cannot be used.

Materials List for Project

S. No.	Descriptions	Size	Approx. Rate
1	Mild Steel Flat	25 mm x 3 mm	Rs.85/kg
2	Mild Steel Flat	25 mm x 5 mm	Rs.83/kg
3	Mild Steel Round Rod	25 mm dia	Rs.85/kg
4	Mild Steel Round Rod	10 mm dia	Rs.88/kg
5	Mild Steel Round Rod	8 mm dia	Rs.88/kg
6	Mild Steel Round Rod	6 mm dia	Rs.90/kg
7	Mild Steel Round Rod	5 mm dia	Rs.90/kg
8	Mild Steel Round Rod	4 mm dia	Rs.90/kg
9	Mild Steel Round Rod	3 mm dia	Rs.90/kg
10	Mild Steel Square Rod	10 mm x 10 mm	Rs.83/kg
11	Mild Steel Square Rod	6mm x 6 mm	Rs.85/kg
12	Mild Steel Round Pipe	1-inch dia	Rs 550/20 ft length pipe
13	Mild Steel Round Pipe	3/4-inch dia	Rs 475/20 ft length pipe
14	Mild Steel Round Pipe	12 mm dia	Rs 400/20 ft length pipe
15	Mild Steel Square Pipe	25 mm x 25 mm	Rs 550/20 ft length pipe
16	Mild Steel Square Pipe	15 mm x 15 mm	Rs 400/20 ft length pipe
17	Mild Steel Angle	25 mm x 25 mm	Rs 550/20 ft length pipe
18	Mild Steel Discs	20-50 mm dia x 10 mm thick	Avg ~ Rs 20-25/disc
19	Galvanized Iron Sheet	3 ft x 8 ft x 0.35 mm	Rs 1256/sheet
20	Galvanized Iron Sheet	3 ft x 8 ft x 0.5 mm	Rs 1620/sheet
21	Mild Steel Sheet	4 ft x 8 ft x 0.5 mm	Rs 1745/sheet
22	Mild Steel Sheet	4 ft x 8 ft x 0.7 mm	Rs 1958/sheet
23	Mild Steel Sheet	4 ft x 8 ft x 1.0 mm	Rs 2878/sheet
24	Mild Steel Sheet	4 ft x 8 ft x 2.0 mm	Rs 4500/sheet
25	Thermocol	1000 cm x 500 cm x 12 mm	Rs 90/sheet
26	Thermocol	1000 cm x 500 cm x 24 mm	Rs 85/sheet
27	Thermocol	1000 cm x 500 cm x 36 mm	Rs 140/sheet
28	Thermocol	1000 cm x 500 cm x 48 mm	Rs 232/sheet
29	Thermocol	1000 cm x 500 cm x 74 mm	Rs 4320/sheet
30	Fevicol	small size tube	Rs 5/tube
31	Sandpaper for thermocol	(9X11 inch), No. 80	Rs 7/sheet
32	Nut-Bolt Mild steel Washer	all sizes	Avg ~ Rs 10/piece
33	Thin Galvanized Wire	1 mm and 2 mm Dia	Rs 20/ meter
34	Aluminum products	ingots	Rs 480/kg

Experiment 1 (E1)

Sand Moulding & Casting and Forging

- **Theory**
- **Sand Moulding and Casting**
  - **Introduction to Casting Process:**

Casting is one of the oldest and the most popular processes of converting materials into useful shapes. The casting process is primarily used for shaping metallic materials. Although it can be adopted for shaping other materials, such asceramic, polymeric and glassy materials. In casting, a metal is melted, treated at the proper temperature and then poured into a cavity called mould, whose shape is similar to final desired shape in which molten metal spreads completely before solidification starts. Simple as well as complex shapes can be made from any metal that can be melted. The resulting product can have virtually any configuration the designer desires.

Casting products range in weight and size from few grams (few centimeter) to many tons (few meters). Moreover, casting has marked advantages in the production of complex shapes, like having hollow sections or internal cavities, irregular curved surfaces and 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. These various processes differ primarily in mould material (whether sand, metal or other material) and pouring method (gravity, pressure or vacuum). All the processes share the requirement that the material solidifies in a manner that would avoid potential defects, such as shrinkage voids, gas porosity and trapped inclusions. The casting process involves three necessary steps, i.e., mould making, melting and pouring of melt into the mould cavity, and removal and finishing of cast product after complete solidification. One of the significant classifications of casting is based on whether the mould is used repeatedly, or it is prepared fresh every time. Sand casting is an example of an expendable mould process or where the mould is broken after every casting to remove the component. In this lab, students will practice this process by making the mould and then pouring the liquid metal into the mould to form a final component.

- **Sand Casting Processes:**

Sand is one of the cheaper and moderate refractory materials, and hence is commonly used for making mould. Sand contains grains of silica (SiO_2) along with few impurities. For mould making, sand is mixed with a binder materials, such as clay, molasses, oil, resin, etc.

- **Green Sand Moulding**

In the green sand moulding process, clay (a silicate material) along with water as activating agent is used as a binder. The mould-making mainly 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 mould, and in this demonstration, you will learn to make it using wooden 'pattern' and 'green-sand' as the mould 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 of wood, metal or plastic. Wood is the most common material. Green sand refers to an intimate mixture of sand (usually river sand), bentonite clay (3-7% by weight of sand, to provide bonding or adhesion between sand grains), and water (3-6% by weight of sand, necessary to activate the bonding action of the clay).

Mixing the above ingredients in a sand muller provides an intimate mixing. In practice, a significant 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 mould. Moulding flasks are rectangular frames with open ends, which serve as containers in which the mould is prepared. Usually, a pair of flasks are used. The upper flask is referred to as 'Cope' and the lower one as 'Drag' (Fig. 1.1). A riddle is a relatively coarse sieve which is used to break the lumps in the green sand and its aeration.

Sometimes the cast 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 mould. A 'core' is used to block off portions of the mould from being filled by the liquid metal. A core is normally made using sand with a suitable binder like molasses. The core is prepared by filling the core-box with core sand to get the desired shape and baking this sand core in an oven at a suitable temperature. During mould making, a suitable 'gating system' and a riser' are also provided. The gating system is the network of channels used to deliver the molten metal from outside the mould into the mould cavity. 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 and ideally should be last to freeze. Fig. 1 shows the various parts of a typical sand mould. Several hand tools, such as rammer, trowel, sprue pin, draw spike, slick, vent wire, gate cutter, strike-off bar, etc. are used as aids to making a mould.

- **Melting and Pouring of Metals**

Next important step is the melting of metal. A melting process must be capable of providing molten metal not only at the proper temperature, but greater than melting point and also in the desired quantity with acceptable quality at a reasonable cost. In transfer the metal from the furnace into the mould, some 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 mould without slag or oxide. The operations involved in the melting of metal in induction furnace and pouring of liquid metal into the mould cavity will be shown in the lab.

- **Removal and Finishing of Castings**

After complete solidification, the cast is removed from the mould. Most casts 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. The process of casting is schematically shown in Fig. 1.2.

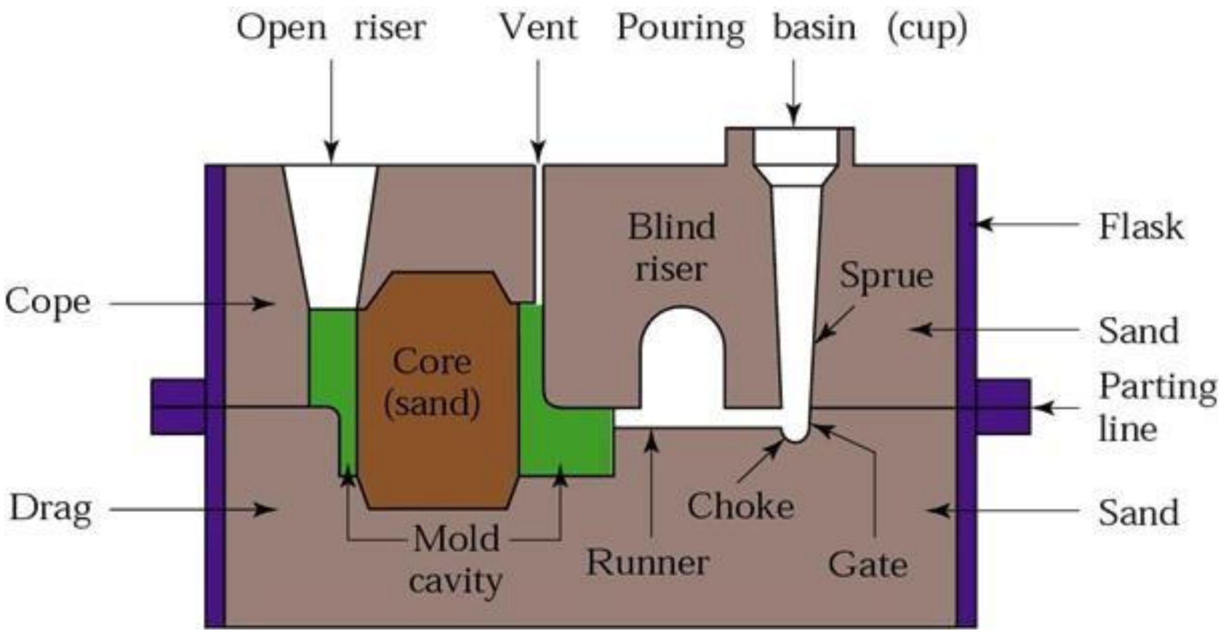


Fig. 1.1. *Schematic of a typical two-part sand mould, indicating various mould components and terminology [https://www.iqsdirectory.com/articles/sand-casting.html].*

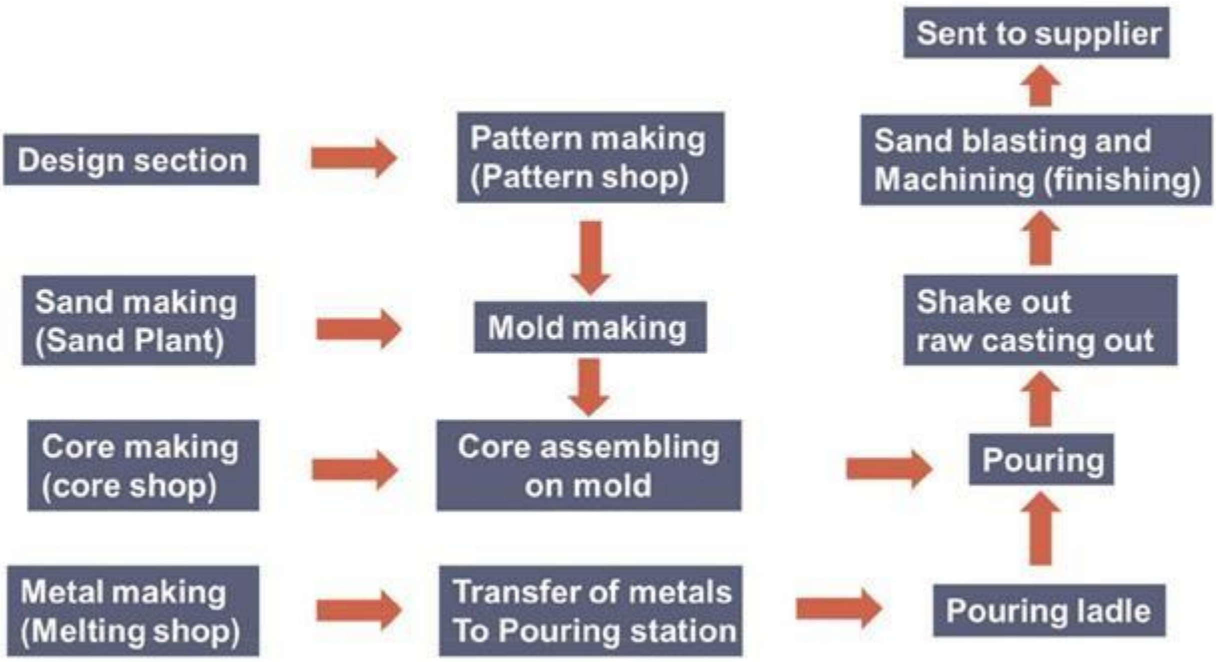


Fig. 1.2. *Process of casting, including pre-processing and post-processing operations.*

- **Exercise**

The exercise will consist of moulding and casting (Part-1) along with the demonstration of aluminium forging (Part-2).

Part 1: Mould making & casting

- **Objectives**
  - ❖ To prepare a green sand mould from wooden pattern.
  - ❖ To melt and pour Aluminum metal into the mold.
  - ❖ To prepare a pattern for a given object for lost foam casting (demonstration).
  - ❖ To prepare a molasses sand mold from the prepared Thermocol pattern (demonstration).

Tools and Equipment: Wooden pattern, core box, molding box, screw, spoke lifter, vent wire, rammer, leveler, sand muller, core, baking oven, melting furnace, pouring ladle, pyrometer, hacksaw, etc.

Materials: Thermocol, River sand, bentonite clay, coal dust, molasses, aluminum, flux, etc.

- **Procedure of Green Sand Casting**

Mixing: Green sand and molasses sand will be prepared by mixing the ingredients in sand muller (Fig. 1.3).

Fig. 1.3. *Sand Muller for green sand preparation.*

Mould making

- ❖ Place the drag part of the molding flask and fill molding green sand.
- ❖ Place the wooden pattern at the center of the drag (flask)
- ❖ Pack the sand carefully around the pattern. Heap more molding sand in the drag and ramwith rammer carefully.
- ❖ Place the other half of the pattern over the pattern (already placed on the drag) matching the guide pins. Then, place the gating system with sprue and riser in proper positions.
- ❖ Repeat step 3 to complete the mould box. Remove the sprue and riser pins and make a pouring basin.
- ❖ Open the mould and remove the wooden pattern. Now, make runner of the gating system. Place the core and then close cope and drag.

Overall process is shown in Fig. 1.4.

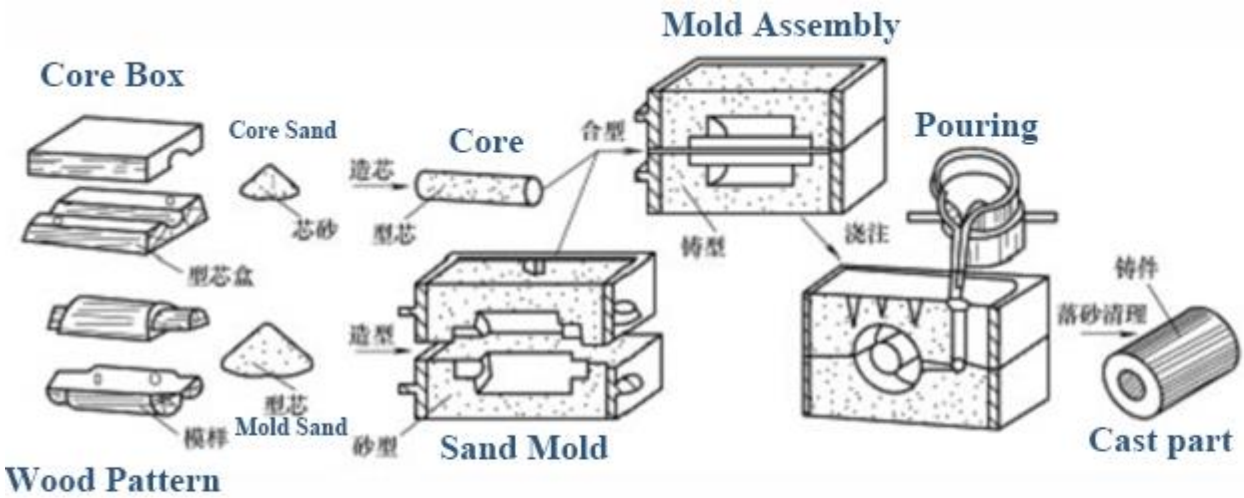


__Fig. 1.4.__ Sequence of sand mould making and subsequent casting process
[https://sinowayindustry.com/8-main-steps-in-sand-casting/]

- **Melting and Pouring**
    - Melt the metal in the furnace (Fig. 1.5a). Use appropriate fluxes at proper stages to prevent the oxidation of the metal. Measure metal temperature from time to time.
    - Pour the molten metal into the pouring ladle kept at a higher temperature (say 100^{o}C higher) than the pouring temperature. As soon as the desired pouring temperature is achieved, pour the liquid metal into the mould in a steady stream with ladle close to the pouring basin of the mould. Do not allow any dross or slag from the surface to go in the ladle.
    - Allow sufficient time for the metal to solidify in the mould.

- **Removal of cast from mould**
    - After the melt has solidified, break the mould carefully and remove the cast (Fig. 1.5b).
    - Cut-off the riser and gating system from the cast and remove sand (if any).
    - Inspect the cast visually and record surface and dimensional defects (if any).

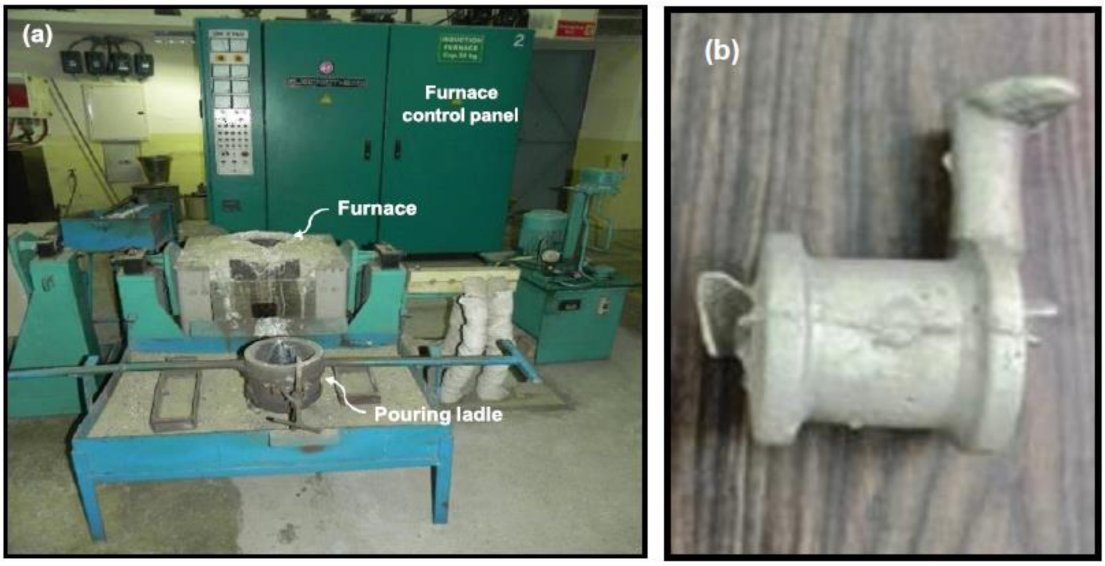


Fig. 1.5. *(a) Furnace to melt metal and pouring ladle and (b) cast.*

- **<u>Demonstration of Lost Foam Casting using Molasses Sand</u>**

Lost foam casting process will be demonstrated. The process of mixing and moulding/casting/Melting and Pouring are same as that of green sand casting. However, the pattern will be made of thermocol (Fig. 1.6). The final product after casting is shown in Fig. 1.6.

Fig. 1.6. *Foam pattern and the corresponding cast object.*

Part 2: Forging Process (It is for demonstration)

- **Introduction to Forging Process:**

Metal forging is a process of shaping and forming metal through the application of heat and pressure in the solid form in general. It involves heating the metal to a specific temperature and then applying force to shape it into the desired form. Open die forging uses dies that leave the metal open, but closed die forging encases the metal, allowing for more precise forged shapes. During forging, several defects can occur, including ‘Barreling’ and ‘Buckling’. Barreling is when the sample starts to form a barrel shape as it's being compressed in an open die forging process. Buckling is the sudden change in shape (deformation) of a structural component under load, suchas the bowing of a column under compression.

Objectives: Demonstration of forging of aluminum using press forging

Tools and Equipment: Vernier caliper, Forging machine

Materials: Aluminum

Procedure: Take aluminum cylinders (one large and one small height) and compress those using forging machine (Fig. 1.7a). The forging process is shown in Fig. 1.7b. The samples show barreling and buckling during forging (Fig. 1.7c).

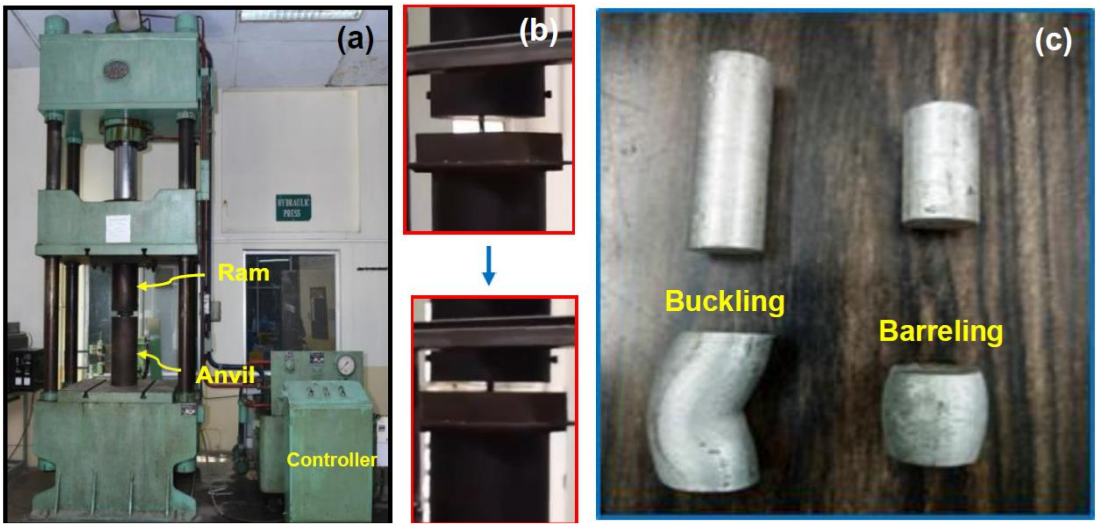


Fig. 1.7. *(a) Forging machine, (b) Forging of cylinder, and (c) Buckling and barreling during forging*

Experiment 2 (E2)

Sheet Metal Forming

- **Theory**
- **Introduction to Sheet Metal Forming:**

Products made of sheet metals are all around us. They include a very wide range of consumer and industrial products, such as beverage cans, cookware, file cabinets, metal desks, appliances, car bodies. The term press working or press forming is used commonly in industry to describe general sheet-forming operations because they typically are performed on presses.

Many products are manufactured from sheet metal involving a combination of processes, such as shearing, bending, deep drawing, stretch forming, etc. (Fig. 2.1). These processes are characterized by localized deformation and configuration changes and are together called “Sheet Metal Forming”. These processes do not result in a bulk shape change of the parts but lead to configurational changes. Sheets have large surface area to volume ratio of starting metal which distinguishes these from bulk deformation. Sheet metal forming is often called ‘press working’ as presses are required to perform these operations. It is also called stamping, where usual tools involve punches and dies. Sheet metal operations can involve a combination of stresses, for example,

- Stretching of the metal (tensile stresses)
- Bending of the metal (tensile and compressive stresses)
- Cutting of the metal (shear stresses)

Shearing, bending and folding machines for sheet metal are shown in Fig. 2.2.

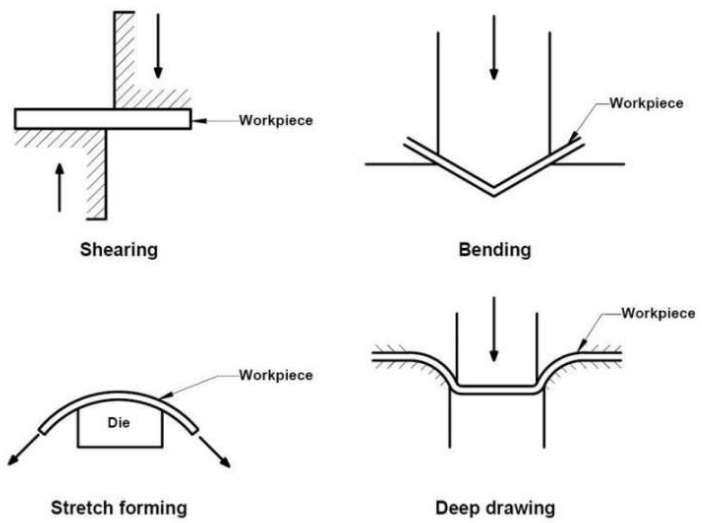


Fig. 2.1. *Schematic of a few sheet metal working operations [https://www.enggwave.com/sheet-metal-forming]*

Fig. 2.2. *Some of the apparatus available in TA211 lab for sheet metal forming (a) shearing equipment, (b) bending equipment and (c) folding equipment.*

- **Exercise**

The exercise will consist of making a sheet metal product (funnel) (Part - 1) and self-secured sheet metal joints (Part - 2).

Part-1: Sheet metal forming

Objectives: To fabricate a sheet metal product (Funnel).

Tools and Equipment: Mallet, hand snip, bench vice, grooving tool, scriber, scale, marker, light weight hammer, divider, power and manual shearing machines, three rolls bending machines, folding machine.

Materials: Galvanized iron (GI) sheet and rivets. The dimension of the funnel is shown in Fig. 2.3.

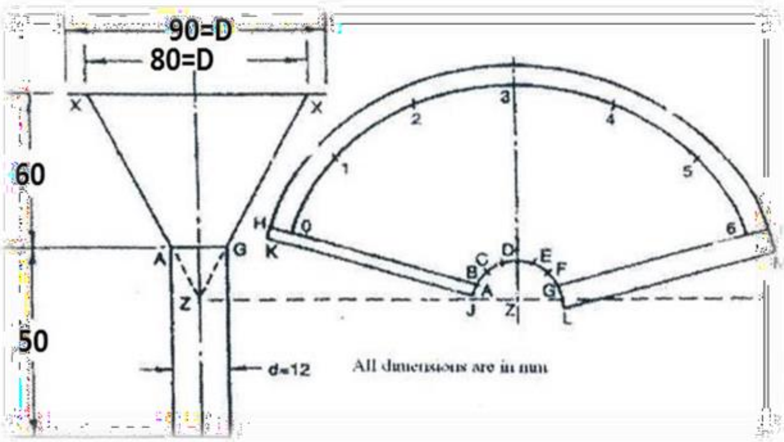


Fig. 2.3. *Approximate dimensions of the funnel to be fabricated.*

- **Procedure for making 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 a 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 length equal to $\pi d/6$.
  - ❖ Again, starting from point 3-mark length 3-2, 2-1, 1-0, 3-4, 4-5 and 5-6, each equal to $\pi d/6$.(D and d are major and minor diameters, respectively)
  - ❖ Draw another curve with Z as a center and ZX+5 mm as a 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. 2.4. *The final form of funnel to be fabricated in the lab.*

Part-2: Self-secured sheet metal joints (Fig. 2.5)

(a) Internal (Single) grooved joint

- ❖ Mark out portions of given sheets near edges to be joined with a marker.
- ❖ Fold the sheets at edges in the portion marked, first at right angles to the plane of the sheetand then at 180° to the plane.
- ❖ Insert one folded sheet into the other.
- ❖ Groove the seam using grooving die.

(b) Double grooved joint

- ❖ Fold sheets as per the instructions given.
- ❖ Cut a piece of a sheet (called strap) of required width.
- ❖ Strap width = (4 x size of marked edges) + (4 x thickness of sheet).
- ❖ Close the edges of the strap slightly.
- ❖ Slip the strap on the curved edges of the sheets.

(c) Knocked-up joint

- ❖ Fold one sheet and close the edges slightly.
- ❖ Bend one sheet to form a right-angle bend.
- ❖ Slip the second sheet in the folded one.
- ❖ Close the right-angled sheet using a mallet.

(d) Rivet joints

- ❖ To make a rivet having both fixed and movable joints using GI Sheet.

(e) Hemisphere

- ❖ To make a hemisphere using GI Sheet with the help of anvil and ball peen hammer.

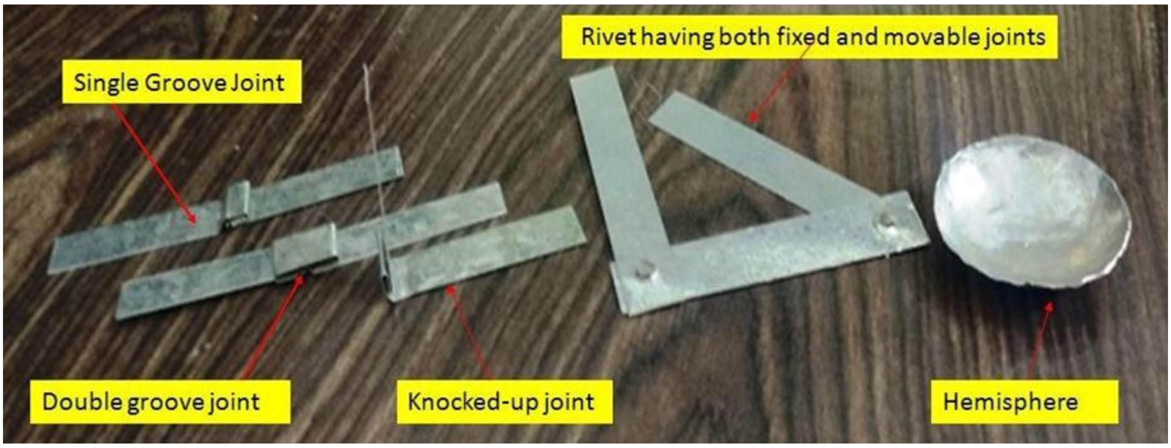


Fig. 2.5. *Different joints and hemisphere.*

Experiment 3 (E3)

Welding Processes, Powder Metallurgy and Plasma Cutting Process

- **Theory**
  - **Introduction to Welding**

Solid materials need to be joined together 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 extensivelyused for joining metals.

Welding is a process in which two materials, usually metals, are 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. Thus, welding can be achieved under a wide varieties of conditions, and numerous welding processes have been developed and are routinely used in manufacturing.

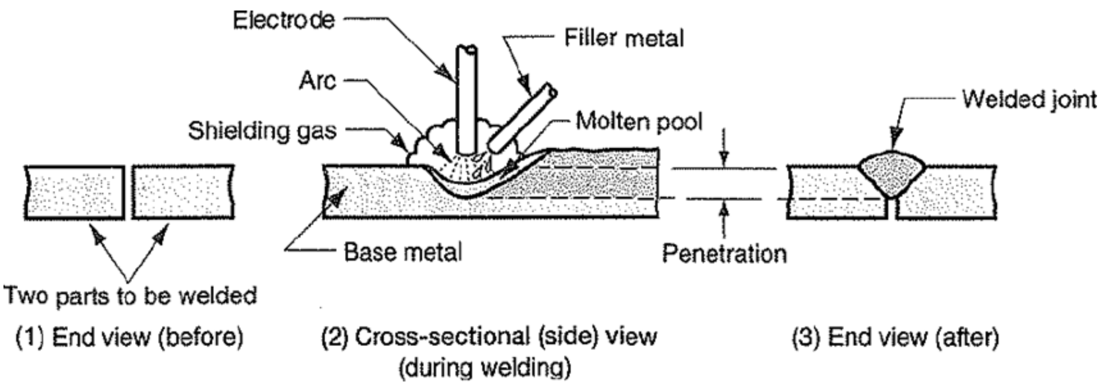
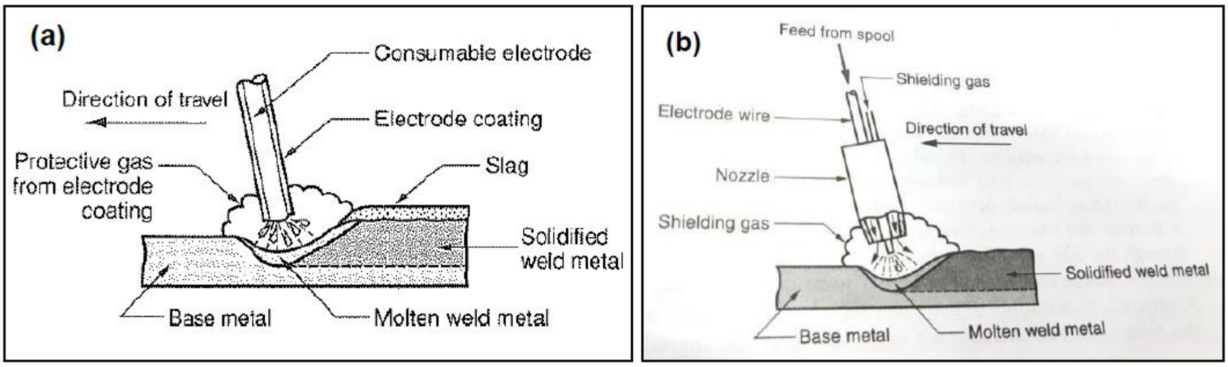


Fig. 3.1. *Schematic of a welding process [Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover].*

To obtain coalescence between two metals the following requirements need to be met: (1) perfectly smooth, flat or matching surfaces, (2) clean surfaces, i.e., free from oxides, absorbed gases, grease and other contaminants. Surface roughness is overcome by pressure or by melting two surfaces so that fusion occurs. Contaminants are removed by mechanical or chemical cleaning before welding or by causing sufficient metal flow along the interface so that they are removed away from the weld zone. 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 a 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 maximum temperature of approximately more than 3000°C. The electrode held externally may act as a filler rod (consumable electrode) or it is fed independently of the electrode (non-consumable 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 many types of the basic arc welding processes, such as Manual Metal Arc Welding (MMAW), Metal Active Gas Welding (MAG), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW). Please note that MAG is also known as Gas Metal Arc Welding (GMAW) and Metal Inert Gas Welding (MIG). MMAW is also known as Shielded Metal Arc Welding (SMAW). GTAW is also known as Tungsten Inert Gas (TIG) welding and W Inert Gas (WIG) welding. Also, it should be noted that GMAW, SMAW, SAW processes use consumable electrode, whereas, GTAW uses non-consumable electrode. Schematic diagrams of SMAW and GMAW processes are shown in Fig. 3.2.



- ***Fig. 3.2.*** *Schematic of a (a) shielded metal arc welding process (SMAW) and (b) gas metal arc welding (GMAW) [Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover]*

- **Introduction to Powder Metallurgy:**

Powder metallurgical (P/M) processing of the metals and alloys plays an important role in manufacturing various engineering components for several applications. The conventional P/M technology for making components starts with metal powders as the raw material, which is pressed in dies of suitable shape to produce green compacts. These green compacts are subsequently sintered at high temperature under protective atmosphere with following objective: (i) to develop proper bonds between higher to mechanically pressed powder particles comprising the green compacts and (ii) to reduce the porosity level in the sintered compact so that it has still higher relative density. However, parts produced by the conventional P/M approach always contain some residual porosity. Non-conventional P/M technologies have been developed with the objective of eliminating the porosity from the manufactured part.

Metal powders are produced by various methods, such as (i) atomization, (ii) solid-state reduction of metal oxides or other compounds, (iii) chemical precipitation from organic or inorganic solutions, (iv) electrolysis, (v) mechanical alloying, etc. Each of these generic processes may have several specific variants for metal powder preparation. The shape, size and their distribution of as-synthesized metal powders depend on the specific method of production and variables associated with the process and their control. The tapping of a powder stock in the die and its behavior during compaction and sintering is substantially influenced by its size and shape characteristics. It can be mentioned here that the spherical powder particles with uniform size distribution is usually preferred from the point of view of good flowability during compaction as well as for good sinter ability.

The density of loose powder is known as the apparent density. It is measured by allowing the loose powder to flow through the Hall flow meter. Very often, the loose powder is mechanically vibrated and/or tapped so that the particles in the loose mass further settle andoccupy a smaller volume.

- ### Introduction to Plasma Cutting:

Plasma cutting, also referred to as plasma fusion cutting or plasma arc cutting, is a fabrication process which employs superheated, ionized gas funneled through a plasma torch to heat, melt and ultimately, cut electrically conductive material into custom shapes and designs. This process is suitable for a wide range of metals and alloys, including structural steel, alloy steel, aluminum, and copper, and can cut a wide range of thicknesses. When the plasma jet hits the workpiece, recombination takes place and the gas reverts to its normal state, emitting intense heat. This heat melts the metal, and the gas flow ejects it from the cut. Plasma gases are usually argon, argon/hydrogen or nitrogen. Plasma arc can cut a very wide range of electrically conductive alloys including plain carbon and stainless steels, aluminum and its alloys, nickel alloys and titanium. The method was originally developed to cut materials which could not be satisfactorily cut by the oxy-fuel process. Normally, the component or sheet tobe cut remains stationary and the plasma torch is moved.

- **Introduction to Spot Welding:**

It is a form of resistance welding, where two or more sheets of metal are welded together without the use of any filler material. The process involves applying pressure and heat to the weld area using shaped alloy copper electrodes which convey an electrical current through the weld pieces. The material melts, fusing the parts together at which point the current is turned off, pressure from the electrodes is maintained and the molten "nugget" solidifies to form the joint (Fig. 3.3).

The welding heat is generated by the electric current, which is transferred to the workpiece through copper alloy electrodes. Copper is used for the electrodes as it has a high thermalconductivity and low electrical resistance compared to most other metals, ensuring that the heat is generated preferentially in the work pieces rather than the electrodes. The amount of heat dependson the thermal conductivity and electrical resistance of the metal as well as the amount of time the current is applied. This heat can be expressed by the equation:

$Q = I^2Rt$, where 'Q' is heating energy, 'I' is current, 'R' is electrical resistance and 't' is the time for which the current is applied.

Spot welding has applications in a number of industries, including automotive, aerospace, rail, metal furniture, electronics, medical, construction, etc. Given the ease with which spot welding can be automated when combined with robots and manipulation systems, it is the most common joining process joining process in the construction of steel cars.

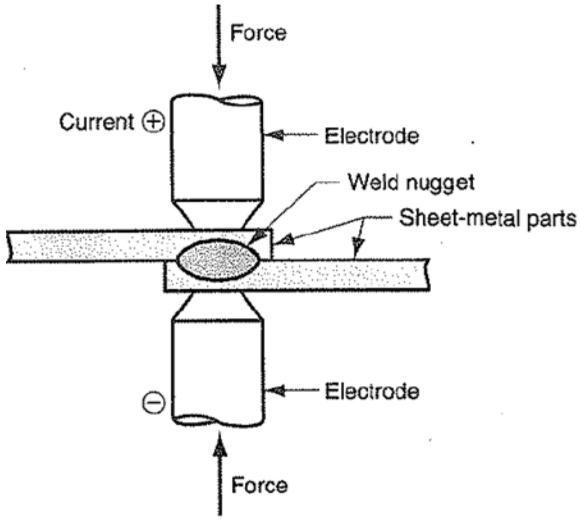


Fig. 3.3. *Process of spot welding [Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover]*

- **Exercise**

The exercise will consist of making a joint by arc welding process (Part - 1). Demonstration of P/M process, spot welding and plasma cutting process (Part - 2).

Part-1: Arc welding process

Objectives: To prepare a butt joint with mild steel flat using Metal Active Gas Welding (MAG) and Manual Metal Arc Welding (MMAW) technique.

Tools and Equipment: Welding unit, Protecting gas, Wire Brush, Tongs, etc.

Materials: Mild steel flats (100 x 25 x 5 mm), Consumable mild steel wire

Procedure

- Clean the mild steel flats with a wire brush.
- Arrange the flat pieces properly providing the gap for full penetration for butt joint (gapto be ½ of the thickness 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 andmake tacks at both ends to hold the metal pieces together during welding process.
- Lay beads along the joint maintaining proper speed and arc length (Speed 100-150 mm/min).
- Clean the welded zone and submit the job.

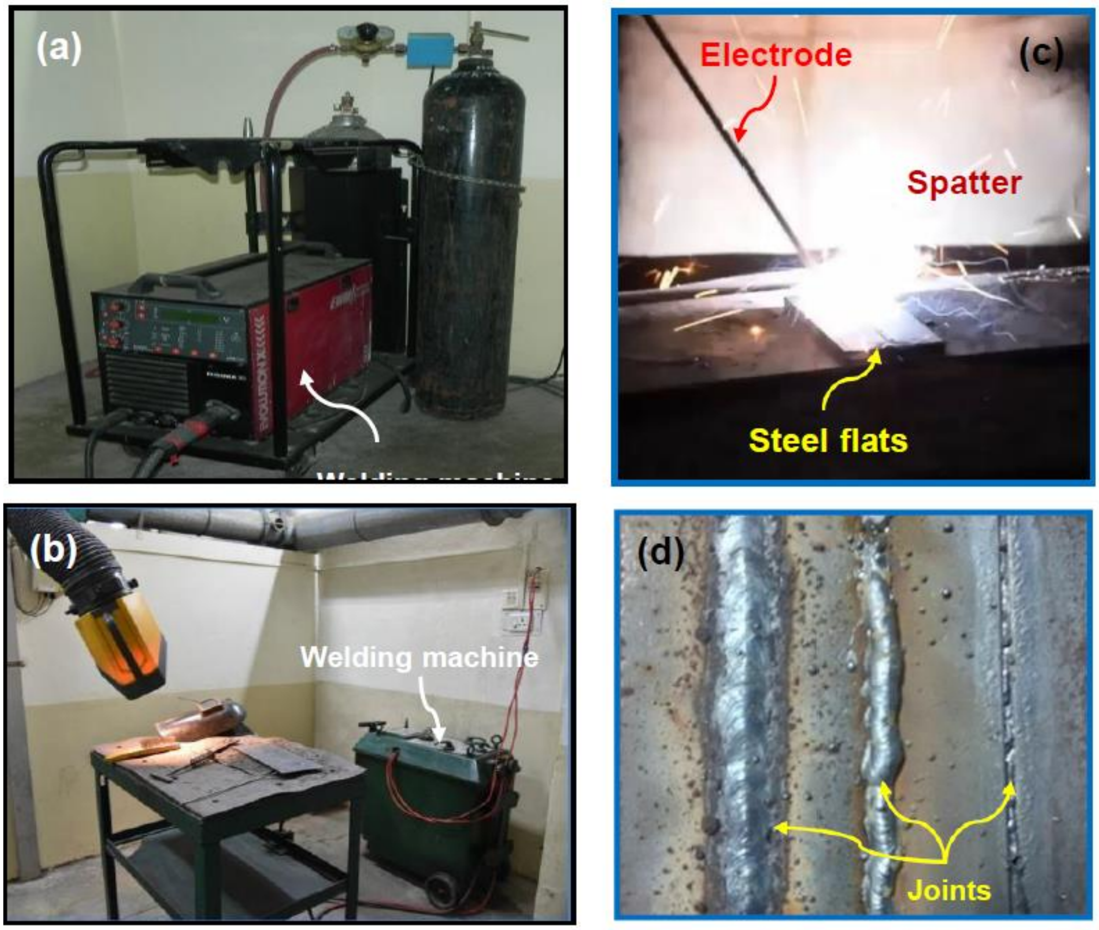


Fig. 3.4. *Welding machines in TA211 lab: (a) MAG and (b) MMAW. (c) Welding process, (d) Joints using MMAW and MAG.*

Part-2: Demonstration of powder metallurgy, spot welding and plasma cuttingprocesses

Objectives:

- To fabricate samples using P/M process.
- To cut a 2 mm thick mild steel sheet using a plasma cutting process.
- To create a joint between mild steel sheet (0.35 mm) using spot welding process.

Tools and Equipment: Spot welding machine, Hydraulic press machine, Furnace, Plasma cutting set up.

Materials: Copper powders and Mild steel sheets

Procedure:

(a) Powder Metallurgy Process:

- Take copper powders and measure apparent density and tap density.
- Place the powders inside the die and prepare green pellet using hydraulic press.
- Place the green pellet inside the furnace to obtain the final sintered compact.

The overall process is shown in Fig. 3.5.

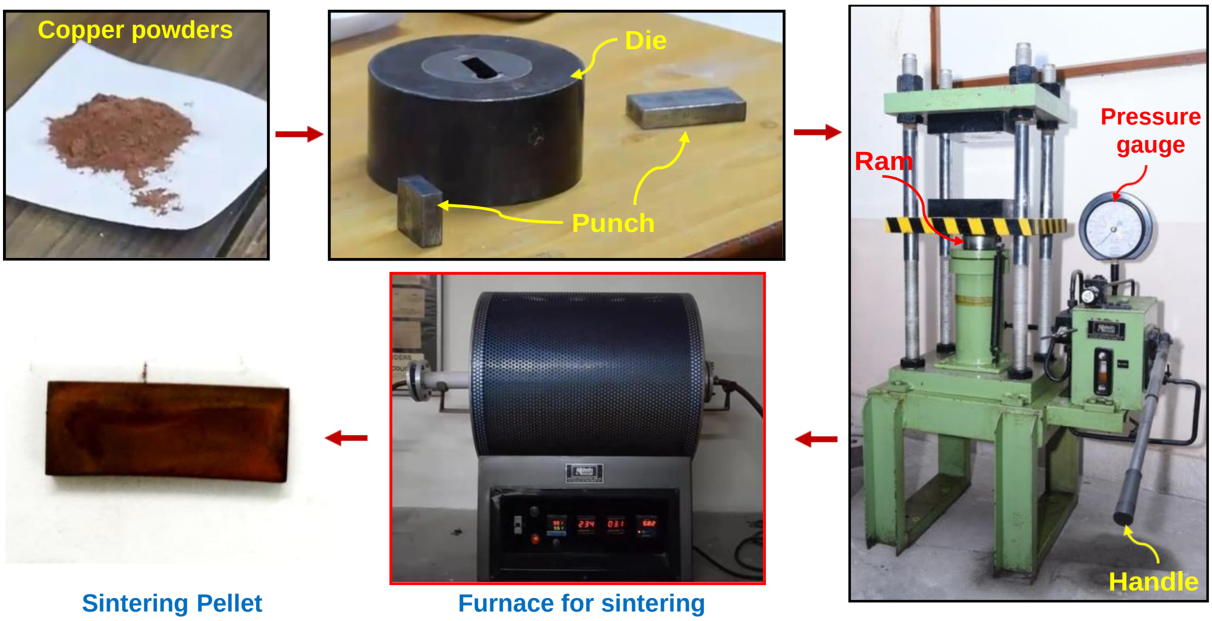


Fig. 3.5. *Overall P/M process for fabricating samples.*

(b) Plasma Cutting Process:

Please take 2 mm thick mild steel sheet and cut the sheet using plasma cutting machine. Fig. 3.6 shows the plasma cutting set-up along with process.

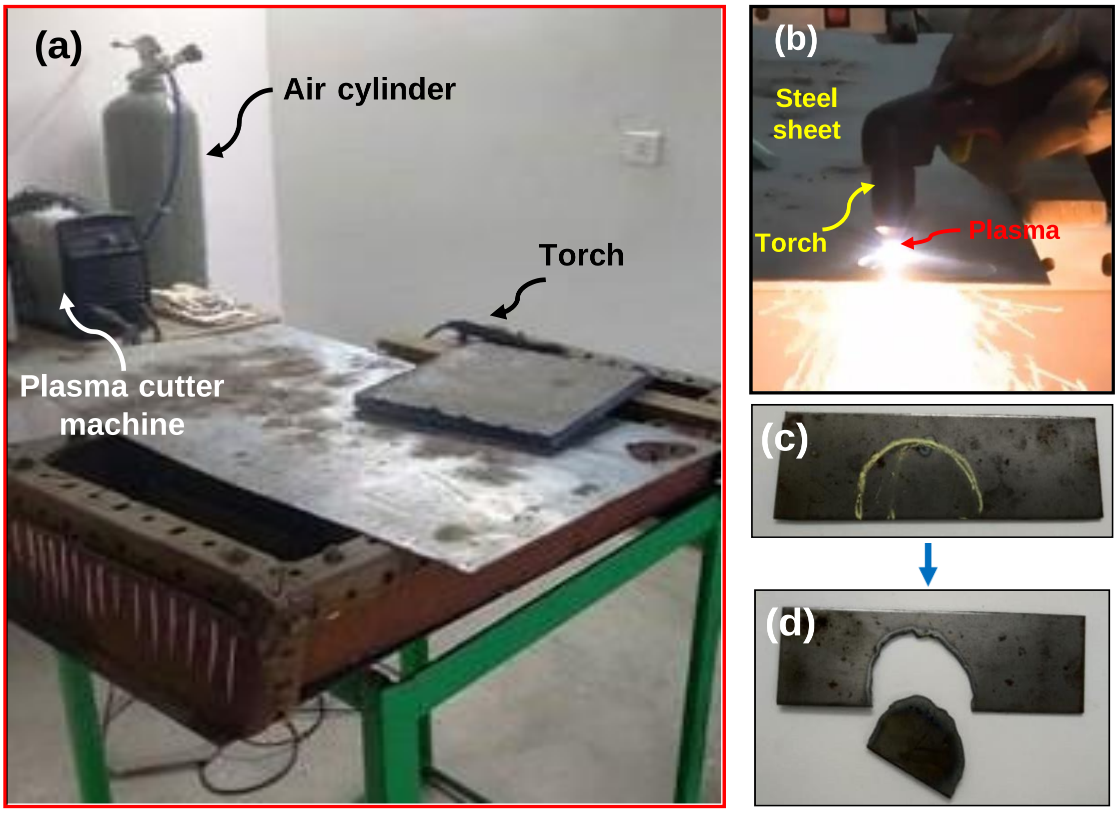


Fig. 3.6. *Plasma cutting (a) setup and (b) process. (c) and (d) are sheets before and after plasma cutting.*

(c) Spot Welding Process:

Please take two steel sheets (0.35 mm thick each) and place their ends one above another. Then, place this configuration between the two electrodes. Now, set up the voltage, current and time in the spot-welding machine to join the two sheets (Fig. 3.7).

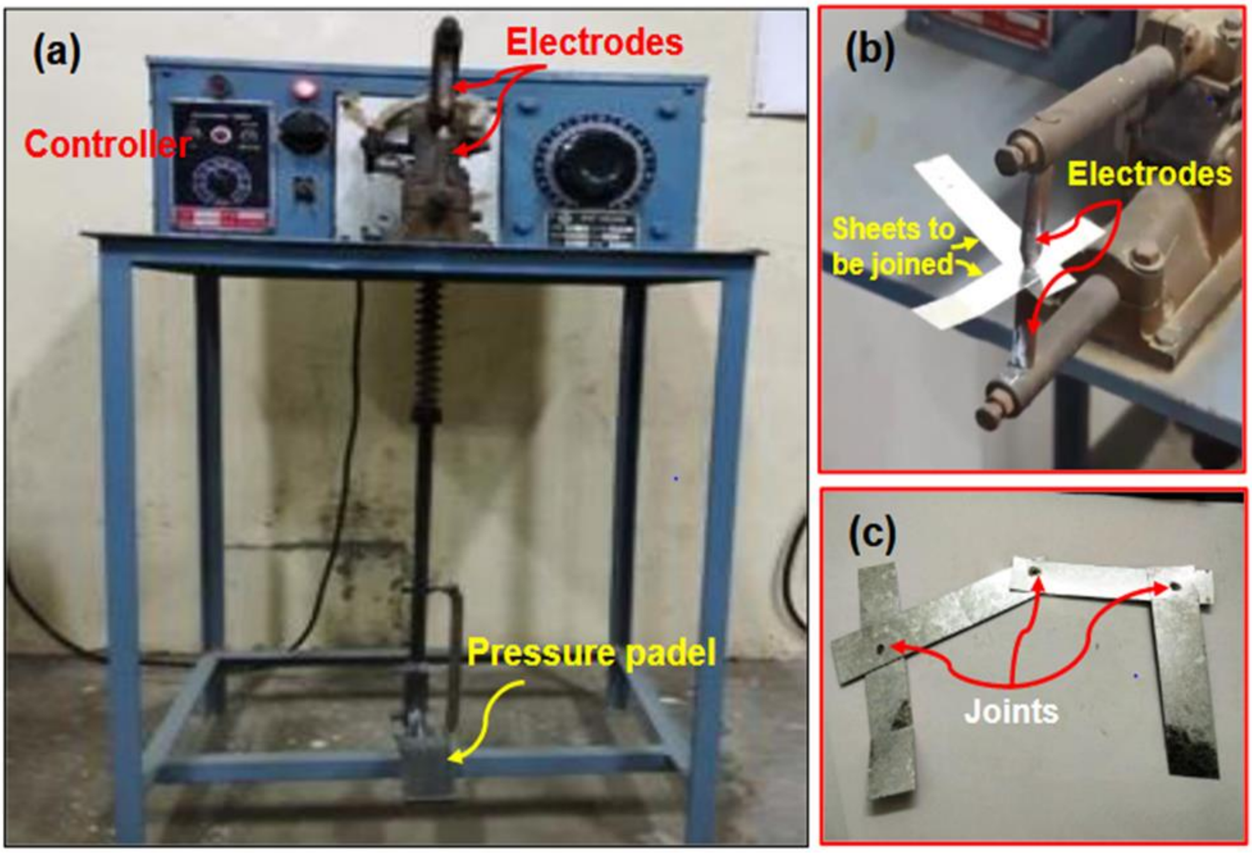


Fig. 3.7. Spot welding (a) setup and (b) process. (c) sheets after spot welding.

<u>**Experiment 4 (E4)**</u>

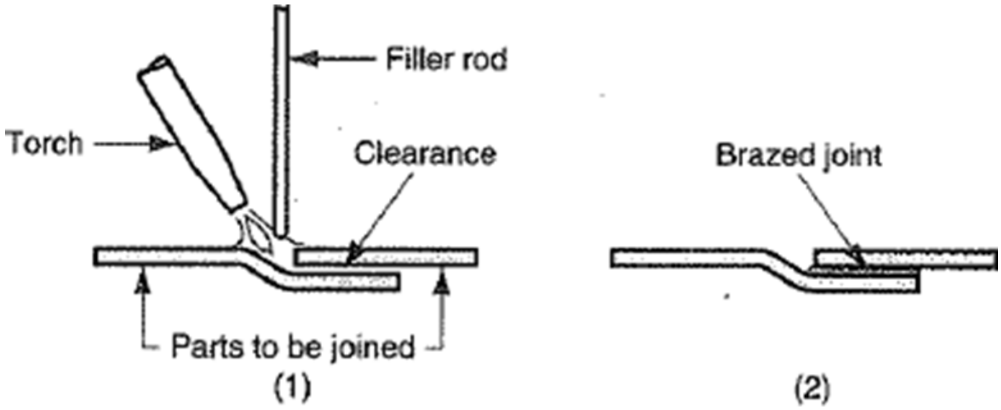
Brazing Process, Drilling/Cutting/Grinding Operations, ObjectFabrication

- **Theory**

- **Introduction to Brazing Process:**

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 filler material, which is used to fill the gap at the joint and establish a bond between the edges. The filler metal is drawn through the joint through the capillary action to create a joint between the two pieces (Fig. 4.1).

In this process, the base metal does not melt, and hence the metallurgy of the base metal is not disturbed much. This also suggests that the joints made by this process are not as strong as those made by welding processes. The advantage of brazing is that it can establish a joint between two dissimilar metals, through a proper choice of filler material. Unlike in welding, the filler rod differs widely in composition from the parent material in brazing. Gas (oxy-acetylene mixture) is usually used for brazing.



o *Fig. 4.1. (1) Schematic of a brazing process and (2) brazed joint [Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover]*

- **Exercise**

The exercise will consist of making a joint by brazing process (Part - 1) and object fabrication (Part 2).Demonstration of drilling/cutting/grinding (Part - 3).

Part-1: Brazing process

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

Tools and Equipment: Oxy-Acetylene set, wire brush, tongs, safety gloves, safety goggles etc.

Materials: Brazing wire, flux, mild steel strips (100 x 25 x 3 mm)

Procedure:

- Clean the mild steel sheets by removing the oxide layer and flatten it.
- Keep the metal sheet in lap position (see Fig. 4.2).
- Start the brazing process and maintain proper speed and feed.
- After the brazing process is complete, clean the joint using brush.

The overall brazing process is shown in Fig. 4.2.

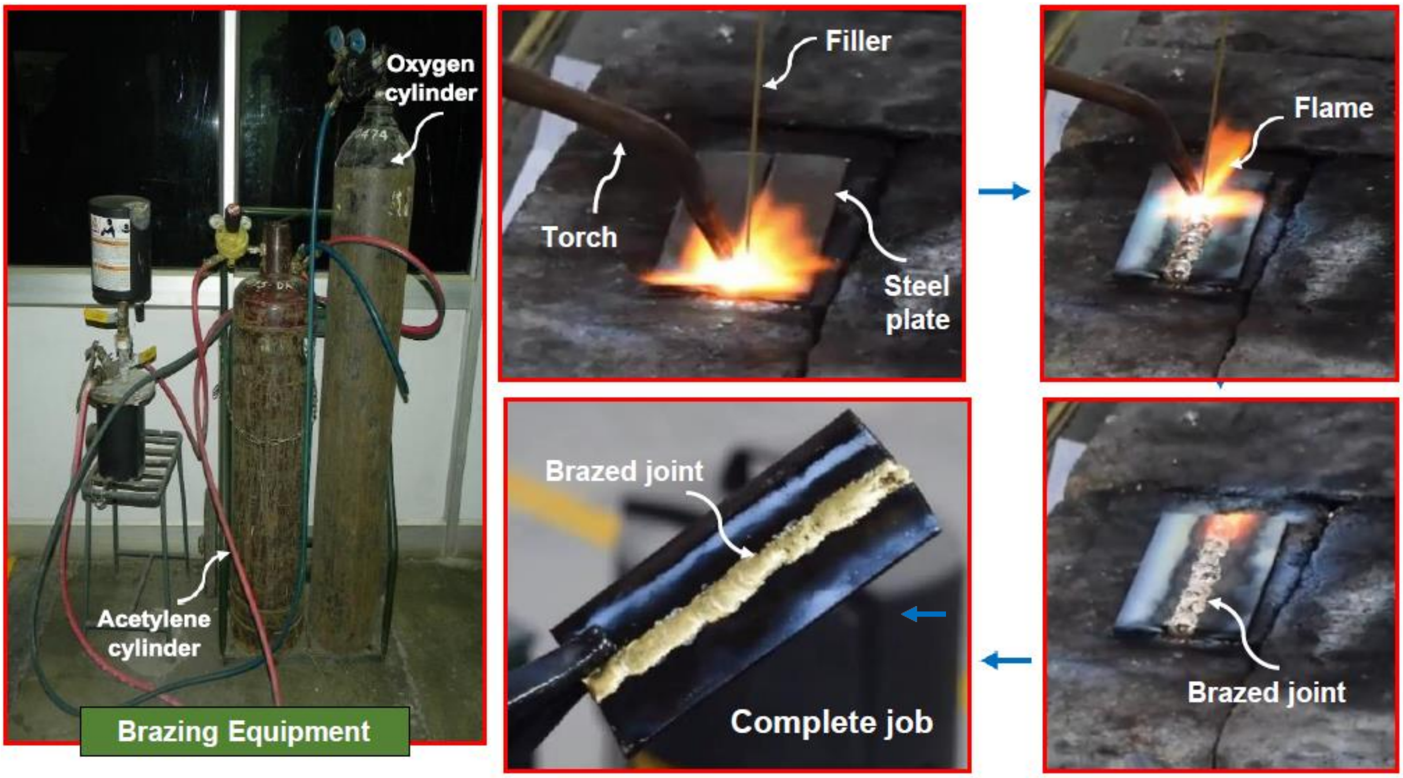


Fig. 4.2. *Overall process of brazing process*

Part - 2: Object fabrication

Objectives: To prepare a (1) spring, (2) square frame and (3) ring.

Tools and Equipment: Anvil, lightweight ball pein hammer, hand hacksaw, bench vice, pliers, supporting rod and file, etc.

Materials: Mild steel rod (4 mm), Copper coated steel wire (0.8 mm or 1.2 mm).

Procedure:

- ❖ To make a spring from copper coated steel wire (0.8 mm or 1.2 mm) using bench vice andsupporting rod (12 mm).
- ❖ Making a ring from mild steel rod (4.0 mm) using bench vice and supporting rod (40 mm).
- ❖ Bend a mild steel rod (4.0 mm) in a square frame using bench vice and hammer.

Fig. 4.3 shows components to be made in the laboratory.

Fig. 4.3. *Fabricated spring, ring and square frame.*

Part - 3: Demonstration of drilling, cutting and grinding

Objectives: To learn (1) making hole on a plate, (2) cutting a pipe and (3) surface grinding.

Tools and Equipment: Drilling machine, grinding machine, cutting machine.

Materials: Mild steel pipe (25 mm), mild steel flat (5 mm)

Procedure:

- ❖ Use drilling machine (Fig. 4.4a) and make a hole in 5 mm mild steel flat.
- ❖ Cut a mild steel pipe using horizontal cutting machine (Fig. 4.4b).
- ❖ Grind the surface of a steel flat (5 mm) using grinding machine (Fig. 4.4c).

Fig. 4.4. *Equipment available in TA211 lab (a) Drilling machine, (b) Horizontal do ALL cutting machine, and (c) Grinding machine.*

Experiment 5 (E5)

Demonstration of Rolling, Swaging, Injection Moulding and Tape Casting

- **Rolling**

- **Introduction to Rolling:**

Rolling is the process involving plastic deformation of metals by squeezing action as it passes between a pair of rotating rolls. To control the relative positioning of rolls, a roll positioning system is employed on the mill stand, generally through hydraulic pressure. Different configurations of high mills are shown in Fig. 5.1. The most common rolling mill is the 2- high rolling mill and 4-high rolling mill. In 2-high mill, two rolls are usually mounted horizontally in bearings at their ends and vertically above each other rotating in opposite direction. 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. The rolling mills could be either reversing or non-reversing type. In the reversing type, 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 (typically used in industries). The rolling process may be carried out either at room temperature or at higher temperature. Depending on temperature, the rolling process is called cold rolling, warm rolling and hot rolling. Rolling below recrystallization temperature (generally 0.3 Tm, where T is in Kelvin) and above 0.6 Tm (T is in Kelvin) is called cold rolling and hot rolling, respectively. Rolling between 0.3 Tm to 0.6 Tm will come under warm rolling.

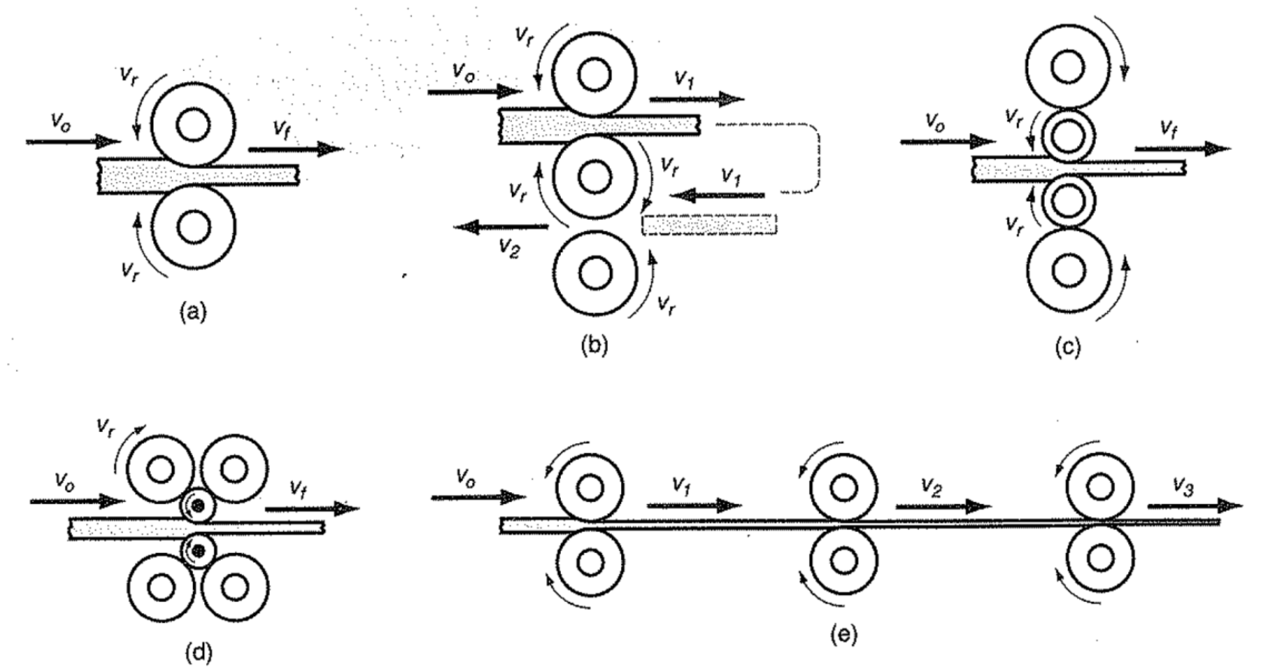


Fig. 5.1. *Different configurations of rolling mills (a) 2-high, (b) 3-high, (c) 4-high, (d) cluster rol and (e) Tandem mill [Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover]*

Objectives: Understanding the rolling process by reducing the thickness of aluminum.

Equipment and Materials: Rolling machine and aluminum sheet.

Observations: Report the various parameters given in the Table below the rolling of the given metal.

- ❖ Roll Diameter:
- ❖ Roll Speed:
- ❖ Lubrication used:

Table format to make

S No.	Initial Dimensions			Lubricant conditions	Roll gap	Final dimensions			Draft	Spring back
	L	**W**	**T**			**L**	**W**	**T**		
1										
2										

Fig. 5.2 shows the different parts of a rolling machine along with the sheet before and after rolling process.

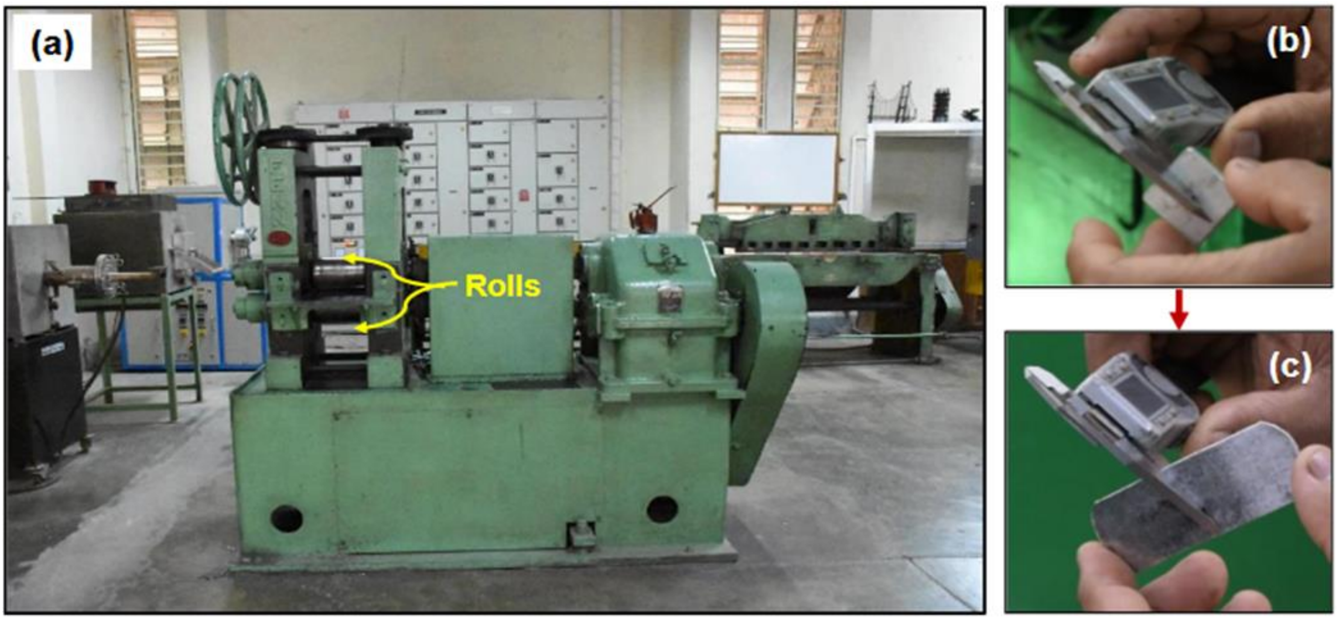


Fig. 5.2. *(a) 2-high rolling machine and (b, c) sample before and after rolling, respectively.*

- ➢ **Swaging**
- ○ **Introduction to Swaging:**

Rotary swaging is a high-performance forging process for hollow and solid parts with an elongated axis. Rotary swaging is used in the manufacturing of various parts for the automotive, aerospace and defense industries. For example, swaging is used in the production of pipes, hollow steering columns, drive and guide shafts as well as various fasteners. The process of rotary swaging utilizes two to six dies for radial forming while the workpiece is moved axially forward and/or backward. The dies may perform up to 10000 strokes per minute and their displacement might be as little as 0.2 mm per stroke.

Rotary swaging significantly reduces the production cost of such components as compared to machining processes and also increases strength properties of the components. Rotary swaging allows higher degrees of deformation compared to conventional metal forming processes without the need for intermediate annealing, consequently reducing the number of operations required for manufacturing finished parts. Furthermore, the overall time is also less.

Objective: To reduce the diameter of a solid rod through the swaging process.

Equipment and Materials: Swaging machine, Aluminum rod etc.

Fig. 5.3 shows the different parts of the swaging machine along with the rod before and after swaging process.

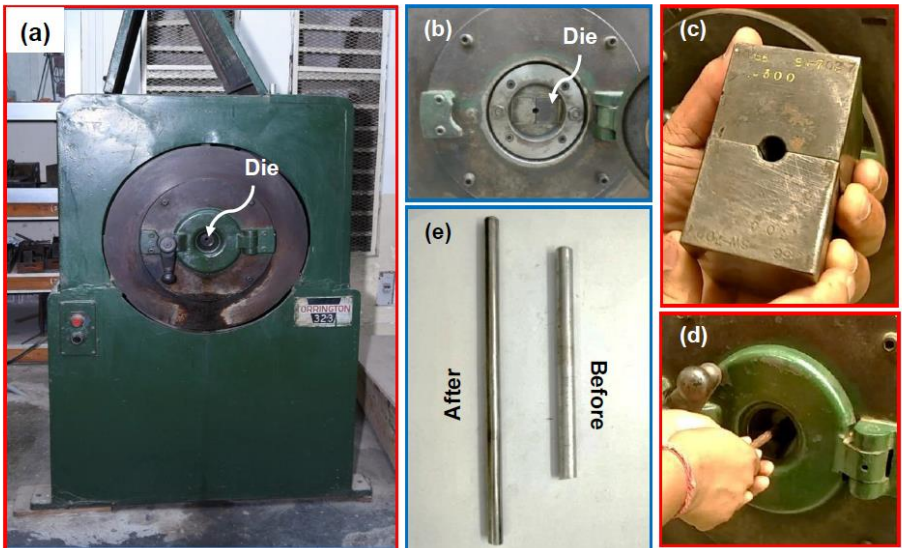


Fig. 5.3. *(a) Swaging machine, (b, c) magnified versions of die, (d) swaging process, and (e) sample before and after swaging process.*

- **Plastic Injection Moulding**
  - **Introduction to Plastic Injection Moulding:**

In injection moulding, objects are formed by forcing molten plastic material under pressure into a mold where it is cooled, solidified and subsequently released by opening the two halves of the mold. Materials, such as polystyrene, nylon, polypropylene and polythene, can be used in a process called injection molding. These are thermoplastics, i.e., when they are heated and pressured in a mould they can be formed into different shapes. Injection molding is used for the formation of intricate plastic parts with excellent dimensional accuracy. Several items associated with our daily life are produced by way of injection molding. Typical product categories include house wares, toys, automotive parts, furniture, rigid packaging items, appliances, medical disposable syringes, etc. You will probably see dozens of injection molded parts in your wallet, kitchen, car and office. Through a schematic, the main parts of injection molding are as shown in Fig. 5.4.

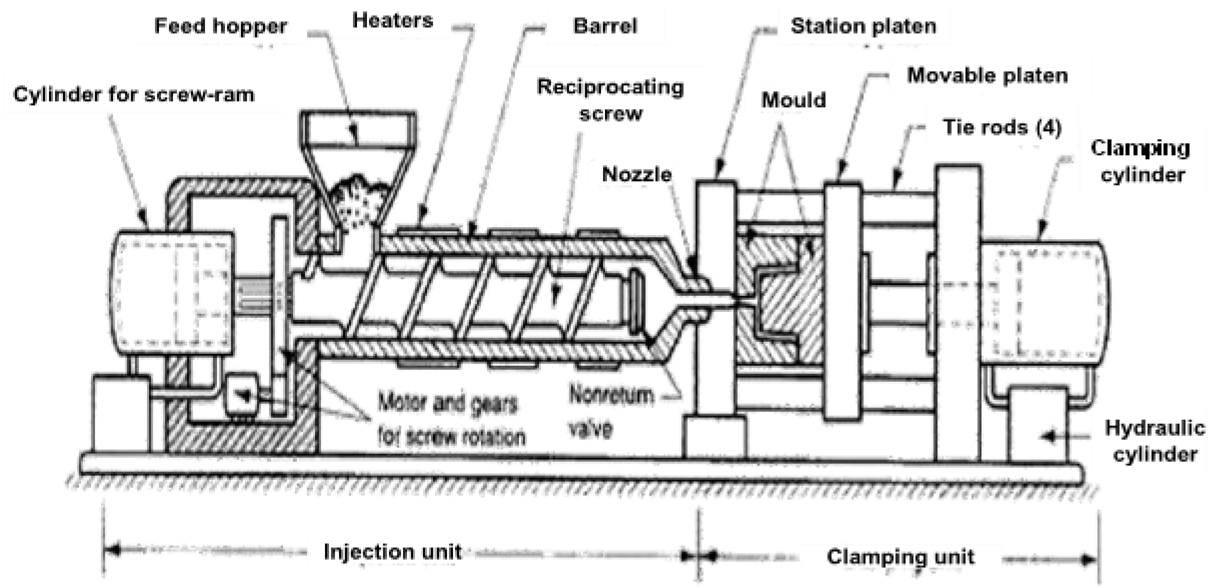


Fig. 5.4. *Schematic of plastic injection molding.*

Some of the advantages of plastic injection moulding include fast production, lower rejection rate, accuracy, choice of desired surface finish, and versatility in processing different raw materials. A fewdisadvantages include the high initial tooling cost and high running cost.

Objective: To fabricate tensile samples using plastic injection moulding process.

Equipment and Materials: plastic injection moulding machine, polypropylene.

Procedure: The process cycle for injection molding is very short, and consists of the following four stages:

- ***Clamping*** - Prior to the injection of the material into the mold, the two halves of the mold must first be securely closed by the clamping unit. Each half of the mold is attached to the injection molding machine and one half is allowed to slide.
- ***Injection*** - The raw plastic material, usually in the form of pellets, is fed into the injection molding machine, and advanced towards the mold by the injection unit. During this process, the material is melted by heat and pressure. The molten plastic is then injected into the mold very quickly and the buildup of pressure packs and holds the material.
- ***Cooling*** - The molten plastic that is inside the mold begins to cool as soon as it makes contact with the interior mold surfaces. As the plastic cools, it will solidify into the shape of the desired part. However, during cooling some shrinkage of the part may occur.
- ***Ejection*** - After sufficient time has passed, the cooled part needs to be removed. In some machines, the process of ejection is automatic.

During cooling, the material in the channels of the mold will solidify attached to the part. This excessmaterial, along with any flash that has occurred, must be trimmed from the part, typically by using cutters. The set-up of injection moulding along with dies and fabricated samples are shown in Fig.5.5.

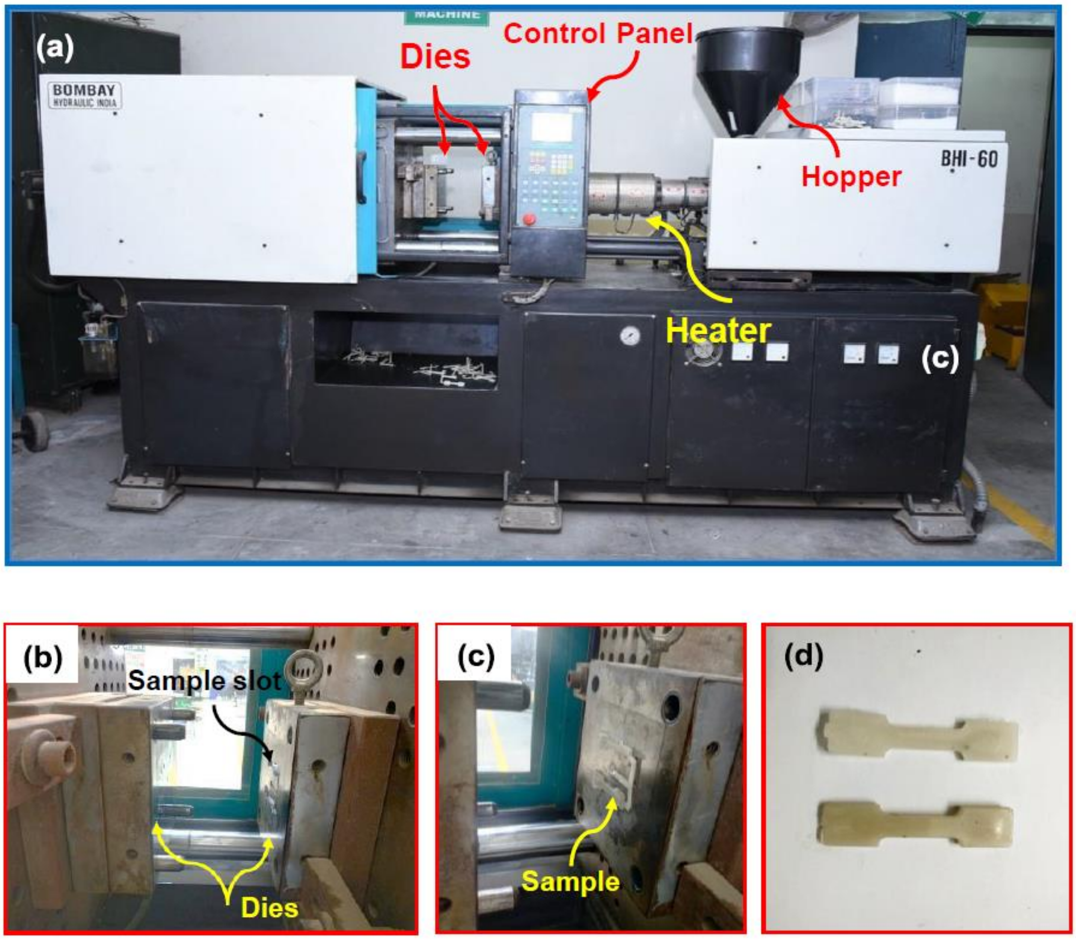


Fig. 5.5. *(a) Injection moulding machine, (b) dies, (c, d) fabricated samples.*

➢ Tape Casting

○ Introduction to Tape Casting:

Tape casting is preferably used for the production of large, thin ceramic layers (wide-flat layers). The ceramic raw powders and a dispersing agent are dispersed in a liquid and mixed with an organic binder system. The homogenous, evacuated slurry is given into the slurry reservoir and flows under an exactly adjusted doctor-blade onto the carrier tape. During the subsequent drying process, the dispersing liquid is evaporated where the tape thickness reduces. Casted tapes range commonly between 20 µm and 1 mm in thickness. Multi-layer tapes withdifferent powders in each layer are prepared by repeating the casting steps or by laminating the single-layer tapes. In this demonstration, Colgate toothpaste will be utilized instead of ceramics etc. (Fig. 5.6)

Tape casting can be used to develop green tapes of ceramic, metal or glass powders. Some of the examples include development of two-layered silicon carbide tapes with coarse-porous support and fine-porous membrane layer and then structuring and joining of these tapes to produce flat multi-channel elements for membrane filtration, thin tapes (≤ 50 µm) for diffusion joining of non-oxide ceramic parts, structured Si-Sic tapes for thermoelectric applications (e.g., heating elements) and development of oxide ceramic tapes for different applications (e.g., dense zirconia, porous alumina).

Objective: To create a layer using tape casting process.

Equipment and Materials: Tape casting machine, Colgate etc.

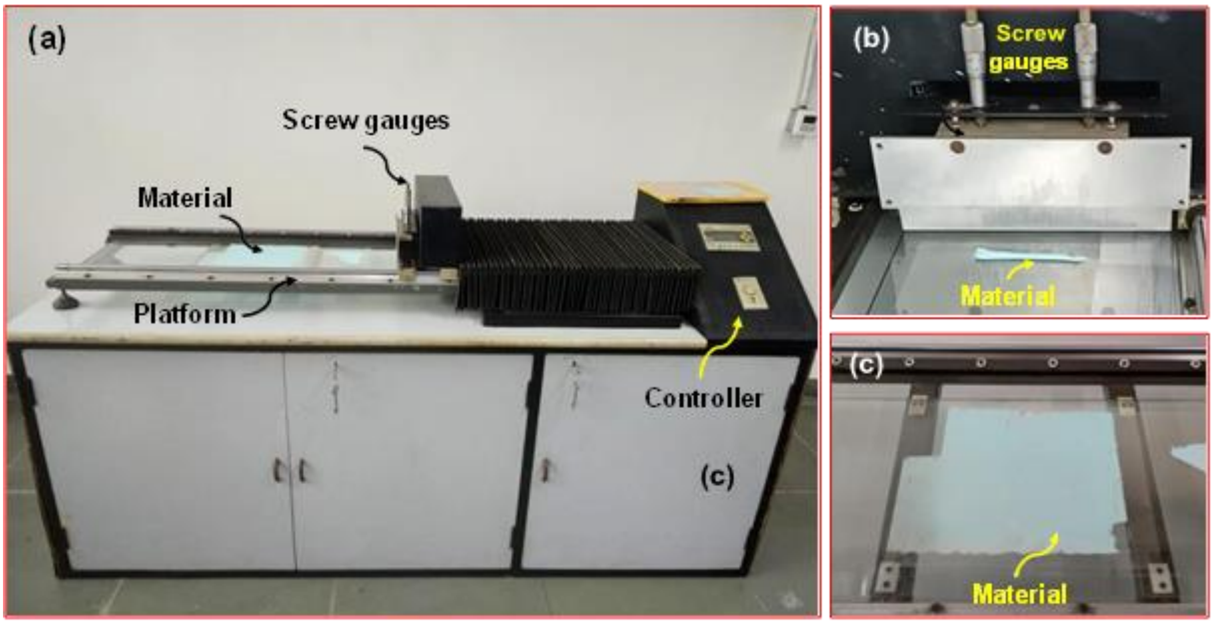


***Fig. 5.6.** (a) Tape casting setup. (b) and (c) are images before and after tape casting process.*