AIRCRAFT PRODUCTION TECNOLOGY

III B. Tech V semester (Autonomous IARE R-18)

BY

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<table>
<thead>
<tr>
<th>CO’s</th>
<th>Course outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1</td>
<td>Demonstrate different type of materials used in aircraft industry and study its properties</td>
</tr>
<tr>
<td>CO2</td>
<td>Understand the process of casting and inspection techniques used for production.</td>
</tr>
<tr>
<td>CO3</td>
<td>Explain sheet metal operations and its tooling operations used for aircraft industry.</td>
</tr>
<tr>
<td>CO4</td>
<td>Gain knowledge about the basic convectional and unconventional Machining</td>
</tr>
<tr>
<td>CO5</td>
<td>Understand the importance of composites and its manufacturing process.</td>
</tr>
</tbody>
</table>
MODULE - I

AIRCRAFT ENGINEERING MATERIALS
## MODULE - I

<table>
<thead>
<tr>
<th>CLOs</th>
<th>Course Learning Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLO1</td>
<td>Choose a concept or idea of technical real time problems to form solutions for the same.</td>
</tr>
<tr>
<td>CLO2</td>
<td>Understand, Identify, Study and comprehend processes that lead to solutions to a particular production.</td>
</tr>
<tr>
<td>CLO3</td>
<td>Develop one-self to extend the outputs of research.</td>
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Classification of Engineering Materials

Engineering Materials

Metallic Materials
- Ferrous
  - Steels
    - Plain
    - Carbon
    - Alloy
  - Cast iron
- Non-ferrous
  - Aluminium
  - Copper
  - Magnesium
  - Tin
  - Zinc
  - Lead
  - Nickel and their alloys

Non-metallic Materials
- Organic
  - Plastics
  - Wood
  - Paper
  - Rubber
  - Leather
  - Petroleum
- Inorganic
  - Minerals
  - Cement
  - Glass
  - Ceramic
  - Graphite
Alloy of the Iron-Carbon system include steel and cast iron
Alloys with a carbon content up to 2% are known as steels
Alloys with a carbon content above 2% are called Cast Irons.
The Iron-carbon system provides the most prominent example of heat treatment
Eutectoid steels

- Steels with a carbon content from 0.008 to 0.8% are called hypo eutectoid steels.
- Steels containing carbon from 0.8 to 2% are called hyper eutectoid steels.
- Steel with a carbon content of 0.8% is known as eutectoid steel.
Eutectic Steels

- Iron having carbon in the range of 2 - 4.3% is called Hypoeutectic steels.

- Iron having carbon in the range of 4.3 to 6.67% is called Hyper eutectic steels.
Iron Carbon Equilibrium Diagram
Iron Carbon Equilibrium Diagram

- From 11300 C Carbon precipitates from austenite
- At 7230 C the Austenite and the Austenite in Ledeburite contain 0.8 % C, and pearlite transformation takes place at that temp
- Ledeburite below 7230 C is a mixture of Cementite and Pearlite
- Pearlite is a mixture of ferrite and Cementite
δ Iron

This is a solid solution of carbon in iron and has a BCC crystal structure

- The maximum solubility of C in Fe is 0.09% at 1495°C.
- This has no real practical significance in engineering.
Body Centred Cubic (BCC)

Stick model illustrates the centres of atoms in a BCC structure.

The body centred cubic packing sequence.
BCC Unit Cell

\[ \sqrt{3}a = 4R \]
Austenite ($\gamma$ iron)

- FCC, high formability, high solubility of Carbon, over 2% C can be dissolved in it
- At $1148^\circ$ C most of heat treatments begin with this single phase
FCC Unit Cell
FCC Unit Cell
Pearlite

- Is an intimate mixture of ferrite and cementite.

- It has a distinct lamellar structure and consists of alternate layers of ferrite and cementite.

- It is an eutectoid phase transformation of austenite at 7230°C having 0.83% carbon.
Ledeburite

- Is a mixture of austenite and cementite.
- It is obtained by eutectic phase transformation of liquid alloy containing 4.3% carbon is cooled below 1148°C.
- Below 723°C ledeburite changes to pearlite.
Microstructures of Iron Carbon System at different compositions
Microstructures of Iron Carbon System at different compositions
HEAT TREATMENT can be defined as a process of changing the structure and the properties of the metals and alloys by controlled heating and cooling.

(HEAT TREATMENT is the heating and cooling of metals to change their physical and mechanical properties without letting it change its shape)
HEAT TREATMENT

- To relieve internal stresses.
- To soften the metal.
- To improve hardness of the metal surface.
- To improve machinability.
- To refine grain structure.
- To increase the resistance to wear, tear, heat and corrosion.
Types of HEAT TREATMENT

Annealing
Normalizing
Hardening
Tempering
Annealing

- Annealing in which steels are heated to above the transformation range and holding the steel at the temperature for certain time. Then allow to cool slowly in the furnace.

Purpose
- To soften the steel
- To improve the machinability
- To increase ductility
Non -Ferrous metals and their Alloys

- Non Ferrous metals are those which have no iron in their composition.

- The non ferrous metals are generally used in alloy form.

- Non ferrous alloy consists of two or more materials, one of which must be a non ferrous metal.

- Various Non- ferous metals are Cu, Al, Mg, Ni, Pb, Zn, etc.
Few Components of Non Ferrous metals
Non-Ferrous Metals and their Alloys are preferred in Engineering Applications because of their

- High electrical conductivity
- High thermal conductivity
- Low specific gravity
• High Corrosion resistance

• High fatigue strength

• Good castability

• Good formability
Role of Non Ferrous metals

A turbofan jet engine for Boeing 757 aircraft contains the following Non ferrous metals and alloy:

- 38% Titanium
- 37% Nickel
- 12% Chromium
- 6% Cobalt's
- 5% Aluminum
- 1% Niobium (columbium)
- 0.02% Tantalum
Copper and its alloys

- Due to their high electrical conductivity used in electrical industries.
- Due to their high thermal conductivity used as house hold utensils, etc.
- Copper possesses good manufacturability
- The cupro - nickel alloy is superior in resisting erosion in high velocity salt water
Aluminium and its Alloys

- Due to their low specific gravity, it is used in manufacturing aircraft parts
- Due to their high resistance to corrosion, it is used in making refrigerator parts
- It possess high strength to weight ratio
- It has good machinability, formability, workability and castability
- Al-Si alloys are the most important Aluminum casting alloys because of high fluidity
Copper and its alloys
Properties of Copper

- High electrical conductivity
- High heat conductivity
- Excellent resistance to corrosion
- High ductility and malleability
- Easily soldered, brazed or welded
Uses of Copper

Due to its electrical conductivity copper is universal adopted for:

I. Electrical conductors
II. Telegraph wires
III. Telephone wires and cables

Used in electroplating and electrotyping

Making coins
Important copper alloys are

- Brass
- Bronze etc.,
Properties of Aluminium Bronze

- Resistance to corrosion
- Malleable
- Machinability (silicon improves)
- Hardness
- High strength (Fe & Ni increase strength)
- Good castability
- Yellowish brown alloy
- Light weight
Properties of Aluminium

- Low specific gravity (Aluminium weighs about one-third that of steel)
- High electrical and heat conductivity
- High resistance to corrosion specially after anodising it
- Becomes hard by cold working and, hence needs frequent annealing
- Low fatigue strength
- High light – reflectivity
Uses of Aluminium

- Unusual combination of lightness and strength, Al is used in aircraft field

- Best electrical conductor on an equal weight basis

- Due to corrosion resistance Aluminium is used
  - I. In chemical apparatus and
  - II. For coating other metal
Corrosion

Corrosion is the deterioration or destruction of metals and alloys in the presence of an environment by chemical or electrochemical means.
- Loss of valuable products: leakage due to corrosion, eg. slight losses of uranium compound or solutions are hazardous and can be very costly.

- Effects on safety and reliability: Corrosion products could make sanitizing of equipment more difficult, eg. milk and dairy product plant.

- Hip joints, screws, heart valves, etc – high reliability is of paramount importance.
Classification of corrosion

- Dry corrosion
- Wet corrosion
Dry corrosion

- Dry corrosion occurs when the metals are exposed to gaseous environment
- Corrosion processes involve reaction of metals with environmental gases.
Wet corrosion occur when a metal or an alloy comes in contact with an aqueous solution of salt, acid or alkali by an electrochemical type of reaction. When a metal is immersed in an aqueous electrolyte, it dissolve/dissociate into metal ion + electron.
Paints

A paint is a cheap and convenient method but poor at wear resistance.

They deteriorate with time and surface will be repainted.

A paint should have following qualities:

(i) It should be spread easily on the surface
(ii) It should form a tough, uniform film
(iii) The coating of paint should not crack after drying
(iv) It should neither be oxidised nor reduced in environment
Enamels are good at higher temperatures but these coatings are brittle in nature.

A commonly adopted method to protect a metal is to cover it with a thin layer of another metal having good corrosion resistance.

Cadmium, Chromium, Nickel, Aluminium, Tin, Zinc, Silver are used for coating Steel.
Electroplating

- Electroplating is the process of coating metals and protects them from corrosion, wear and chemical attack.
- Electroplating is the method of electro-deposition of metal by means electrolysis over surface of metals and alloys.
- The base metal is first subjected to acid pickling to remove any oxides etc.
- The base metal is made as cathode of the electrolytic cell and the coating metal is made as anode.
- Low temperature, medium current density, low metal ion concentration conditions are maintained for better electro-plating.
Copper Cathode is reduced (accepts electrons)

Nickel Anode is oxidized (gives us electrons)

Ni^{2+} ions within solution become attracted to Copper cathode
Microstructures

Unit cells of FCC, BCC, BCT structures

Pearlite

Martensite

99% Martensite
The process is similar to annealing and is carried out to avoid excessive softness in the material.

The material is heated above austenitic phase and then cooled in air. This gives relatively faster cooling and hence enhanced hardness and less ductility.

In this process, austenite is decomposed in ferrite and carbide at relatively lower temperature and fine pearlite is produced.

Normalizing is less expensive than annealing.

In normalization variation in properties of different sections of a part is achieved.

The selection of heat treatment operations is strongly influenced by the carbon content in the steel.
Martensite is very hard and brittle. Tempering is applied to hardened steel to reduce brittleness, increase ductility, and toughness and relieve stresses in martensite structure. In this process, the steel is heated to lower critical temperature keeping it there for about one hour and then cooled slowly at prescribed rate. This process increases ductility and toughness but also reduces hardness, strength and wear resistance marginally. Increase in tempering temperature lowers the hardness.
Heat treatment methods in general change the properties of entire material.

Hardening improves wear resistance of material but lowers impact resistance and fatigue life. Therefore sometimes there is requirement of surface hardening.

Two methods are used, first is heating and cooling to get required phase, and second is thermo-chemical treatment.
- Induction heating
- Flame hardening
- High frequency resistance heating
- Laser
CASTING, WELDING AND INSPECTION TECHNIQUES
### MODULE – II

<table>
<thead>
<tr>
<th>CLOs</th>
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</tr>
</thead>
<tbody>
<tr>
<td>CLO4</td>
<td>Outline performance of the output of research, development or design.</td>
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<tr>
<td>CLO5</td>
<td>Identify, solve new problems and gain new knowledge.</td>
</tr>
<tr>
<td>CLO6</td>
<td>Understand about the turning, milling, grinding and drilling of a specimen.</td>
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Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process.

- Sand casting is relatively cheap and sufficiently refractory even for steel foundry use.
- In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand.
Plastic Light weight  Easy to make Light in weight Smooth glossary surface.
One half of the pattern

Flask placed over the first pattern

One half the mould (cope)

Other half of the pattern

Flask placed over the second pattern

Other half the mould (drag)

Assembled molds

Casting through the gating system

The solidified casting
Dissembled view of casting
Casting products
Hot-chamber die casting, also known as gooseneck machines, rely upon a pool of molten metal to feed the die.

At the beginning of the cycle the piston of the machine is retracted, which allows the molten metal to fill the "gooseneck".
These are used when the casting alloy cannot be used in hot-chamber machines; these include aluminum, zinc alloys with a large composition of aluminum, magnesium and copper.
ADVANTAGES OF DIE CASTING
1. Very high rate of production is achieved.
2. Close dimensional tolerances.
3. Surface finish of 0.8 microns.
4. Fine details can be produced.
5. Longer die life is obtained.

DISADVANTAGES
1. Not economical for small runs.
2. Only economical for nonferrous alloys.
3. Heavy casting cannot be cast.
4. Cost of die and die casting equipment is high.
Casting products
In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away.
Fig. 3.59. Centrifuge Casting.
Investment casting

- Many Intricate forms with undercuts can be cast.
- A very smooth surface is obtained with no parting line.
- Dimensional accuracy is good.
- Certain un Machin able parts can be cast to preplanned shape.
- It may be used to replace die-casting where short runs are involved.
The Basic Steps in the Investment Casting Process

- Wax Injection
- Assembly
- Shell Building
- Dewax/Burnout
- Gravity Pouring
- Knock Out
- Cut-off
- Finished Castings
ALLOWANCES IN CASTING PROCESS

Patterns are not made the exact same size as desired casting for several reasons. Such patterns would produce castings which are under size. That is why allowance should be present in pattern.

Shrinkage allowance
When a metal solidifies and cools it shrinks and contracts in size.
3. Draft allowance

When a pattern is drawn from the mould there is always some possibility of injuring the edges of the mould. This danger is greatly decreased when the vertical surfaces of the pattern are tapered inward slightly. This taper inward in the vertical surface is called Draft.
Welding is a process of joining similar metals by application of heat with or without application of pressure and addition of the filler material.

Weld ability is the capacity to be welded into inseparable joints and having specified properties such as definite weld strength, proper structure etc.

1. Thermal expansion
2. Thermal conductivity
3. Melting point
4. Surface condition
5. Change in micro structure
Plastic welding or Pressure welding

The metal pieces which are to be joined are heated to plastic state and forced together by using external pressure.

1. Forge welding
2. Thermit welding
3. Resistance welding
4. Gas welding

Presssure Welding

Forge welding
Pressure gas welding
Resistance welding
Friction welding
Diffusion welding
Cold pressure welding
Ultrasonic welding
Arc pressure welding

Resistance butt welding
Flash butt welding
Spot welding
Projection welding
Seam welding
Explosive welding
Arc stud welding
Magnetic arc welding
Fusion welding or non pressure welding the material at the joint is heated to the molten state and allowed to be solidified.
1. Arc welding
2. Thermit welding
<table>
<thead>
<tr>
<th>Square Butt Weld</th>
<th>Single V Butt Weld</th>
<th>Single Bevel Butt Weld</th>
</tr>
</thead>
<tbody>
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<td><img src="image" alt="Square Butt Weld" /></td>
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<td><img src="image" alt="Single Bevel Butt Weld" /></td>
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<tr>
<td>Single-U Butt Weld</td>
<td>Single-J Butt Weld</td>
<td>Backing Run</td>
</tr>
<tr>
<td><img src="image" alt="Single-U Butt Weld" /></td>
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<tr>
<td>Fillet Weld</td>
<td>Plug Weld</td>
<td>Spot Weld</td>
</tr>
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<td><img src="image" alt="Plug Weld" /></td>
<td><img src="image" alt="Spot Weld" /></td>
</tr>
<tr>
<td>Flare V Weld</td>
<td>Flare Bevel Weld</td>
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</tr>
<tr>
<td><img src="image" alt="Flare V Weld" /></td>
<td><img src="image" alt="Flare Bevel Weld" /></td>
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OXY ACETYLENE GAS WELDING

DIAGRAM:

- Welding Torch
- Oxygen Hose Connection
- Acetylene Hose Connection
- Working Pressure Gauge
- Cylinder Pressure Gauge
- Oxygen Regulator
- Oxygen Hose
- Oxygen Cylinder
- Sparklighter
- Apparatus Wrench
- Acetylene Regulator
- Acetylene Hose
- Acetylene Cylinder
- Twin Hose

2000
EDUCATION FOR LIBERATION

80
This type of welding is used to join metal sheets and plates having thickness of 2 to 50 mm.

With metal thicker than 15 mm filler metal is used. The composition of the filler rod is almost same as the part being welded.

To remove the oxides and impurities present on the surfaces of the metal and to obtain satisfactory bonding FLUX is employed during the welding.
GAS WELDING
RESISTANCE WELDING
Resistance welding is one of the oldest of electric welding processes in use by industry today. The weld is made by a combination of heat, pressure, and time. As the name implies, it is the resistance of the material to be welded that causes current to flow and localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during, and after the welding current time cycle. The required amount of time for current to flow in the joint is determined by material thickness and type, the amount of current flowing, and the cross-section area of the welding tip contact surfaces.
Spot welding
Schematic diagram of LBW
Principle of TIG Welding

- Contact (for current)
- Shielding-Gas
- Shielding-Gas Nozzle
- Tungsten Electrode
- Welding Power Source
- Filler Metal
- Arc
- Weld Seam
- Work-Place
MIG Welding

- Wire Electrode
- Wire Transport Rolls
- Contact Nozzle (for current)
- Shielding Gas
- Nozzle
- Weld Seam
- Arc
- Workplace
- Welding Power Source
PLASMA ARC WELDING
Resistance Spot Welding (RSW)

![Resistance Spot Welding Diagram](http://www.substech.com)
Seam Welding (RSEW)

AC Power Supply

Sliding contact

Upper electrode wheel

Welded metal sheets

Weld

Lower electrode wheel

www.substech.com
Butt Welding (UW)

Movable clamp  Welded parts  Stationary clamp

AC Power Supply

Force

Weld

www.substech.com
Figure 5-40. Projection welding.
Figure R-7—Simplified Diagrams Showing the Basic Processes of Spot, Seam, and Projection Welding
Figure 6-12. Steps in making a thermit weld.
OXY ACETYLENE GAS WELDING
Introduction to Nondestructive Testing
Outline

- Introduction to NDT
- Overview of Six Most Common NDT Methods
- Selected Applications
Six Most Common NDT Methods

- Visual
- Liquid Penetrant
- Magnetic
- Ultrasonic
- Eddy Current
- X-ray
Most basic and common inspection method.

Tools include fiberscopes, borescopes, magnifying glasses and mirrors.
A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.

The excess liquid is removed from the surface of the part.

A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.

Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.
The part is magnetized. Finely milled iron particles coated with a dye pigment are then applied to the specimen. These particles are attracted to magnetic flux leakage fields and will cluster to form an indication directly over the discontinuity. This indication can be visually detected under proper lighting conditions.
Magnetic Particle Crack Indications
The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.
Film Radiography

Top view of developed film

- X-ray film

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

- More exposure
- Less exposure

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.
Eddy Current Testing

Coil

Coil's magnetic field

Eddy current's magnetic field

Conductive material

Eddy currents
Eddy Current Testing
High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.
Ultrasonic Imaging

Gray scale image produced using the sound reflected from the front surface of the coin.

Gray scale image produced using the sound reflected from the back surface of the coin (inspected from “heads” side).

High resolution images can be produced by plotting signal strength or time of flight using a computer-controlled scanning system.
Common Application of NDT

- Inspection of Raw Products
- Inspection Following Secondary Processing
- In-Services Damage Inspection
Inspection of Raw Products

- Forgings,
- Castings,
- Extrusions,
- etc.
Special Measurements

Boeing employees in Philadelphia were given the privilege of evaluating the Liberty Bell for damage using NDT techniques. Eddy current methods were used to measure the electrical conductivity of the Bell's bronze casing at various points to evaluate its uniformity.
SHEET METAL PROCESSES IN AIRCRAFT INDUSTRY
<table>
<thead>
<tr>
<th>CLOs</th>
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</tr>
</thead>
<tbody>
<tr>
<td>CLO7</td>
<td>Getting knowledge about the techniques to produce a safe, effective, economic final product.</td>
</tr>
<tr>
<td>CLO8</td>
<td>Understand the theoretical knowledge behind the design and development of aircraft components.</td>
</tr>
<tr>
<td>CLO9</td>
<td>Gain knowledge about the basic convectional, unconventional riveting and welding for knowledge based exams.</td>
</tr>
</tbody>
</table>
Introduction

- Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes.

- Countless everyday objects are constructed of the material.

- Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.
The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size.

If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized ‘blank’ from larger sheet.
Sheet Metal Forming processes
Introduction

1. Sheet metal processes involve plane stress loadings and lower forces than bulk forming
2. Almost all sheet metal forming is considered to be secondary processing
3. The main categories of sheet metal forming are
   - Shearing
   - Bending
   - Drawing
Shearing

Shearing is a sheet metal cutting operation along a straight line between two cutting edges by means of a power shear.
Shearing by two sharp cutting edges.
Plastic deformation to penetration to fracture
Blanking and punching

Blanking and punching are similar sheet metal cutting operations that involve cutting the sheet metal along a closed outline. If the part that is cut out is the desired product, the operation is called blanking and the product is called blank. If the remaining stock is the desired part, the operation is called punching.

Steps in production of washer
Fine blanking - close tolerances and smooth edges in one step.

Trimming - Cutting operation to remove excess metal.

Shaving - Shearing with very small clearance to obtain accurate dimensions.

Secondary or finishing operation.
Bending

Bending is defined as the straining of the sheet metal around a straight edge.
V-Bending

- For low production
- Performed on a press brake
- V-dies are simple and inexpensive
Edge Bending

- For high production
- Pressure pad required
- Dies are more complicated and costly
Bending Operations

- Straight flanging
- Stretch flanging
- Shrink flanging
- Hemming
- Seaming
- Curling
Drawing

Drawing is a sheet-metal operation to make hollow-shaped parts from a sheet blank.
**Drawing**

- $c$ = Clearance
- $D_b$ = Blank diameter
- $D_p$ = Punch diameter
- $R_d$ = Die corner radius
- $R_p$ = Punch corner radius
- $F_h$ = Drawing force
- $F$ = Holding force

![Diagram with labeled parts](image-url)
Deep Drawing

Initial step: bending of edge, straightening of side wall.

Thinning and drawing to form the final cup shape.

Steps:
1. **Bending**
   - Force applied: $F_h$
   - Movement: $v$

2. **Compression and thickening of flange**
   - Force applied: $F_h$
   - Movement: $v, F$

3. **Straightening**
   - Force applied: $F_h$
   - Movement: $v, F$
Dies

Components of a punch and die for blanking operation:

- Attached to press ram
- Punch holder
- Punch
- Stripper
- Strip stock
- Die
- Die holder
- Press base
- Blank
- Bushing
- Guide pins
- Stop
Sheet metal forming processes

Sheet metal processes can be broken down into two major classifications and one minor classification

• Shearing processes
  processes which apply shearing forces to cut, fracture, or separate the material.
Shearing Process

1. Punching: shearing process using a die and punch where the interior portion of the sheared sheet is to be discarded.
Blanking:
the shearing process using a die and punch where the exterior portion of the shearing operation is to be discarded
Components made with blanking and punching
Perforating:

- punching a number of holes in a
Parting: shearing the sheet into two or more pieces

Notching: removing pieces from the edges

Lancing: leaving a tab without removing any material
SHEET METAL BENDING WITH A V DIE

1. Punch
   Work
   Die

2. Punch
   Force
   Work
   Die
STRETCH BENDING

TUBE

FORM BLOCK

FORCE

FORCE

FORCE

FORCE
(a) Air bending

(b) Bending in a 4-slide machine

(c) Sheet

(d) Polyurethane roll

Adjustable roll

Driven rolls

Roll bending
Dies

(a) Upper shoe
Punches (4)
Stripper
Strip stock
Die
Lower shoe

(b) Strip stock
Finished part
Seminotch
Square punch
Parting
Punch
Stretch Forming

Stretching and forming with a die at the same time.
Spinning

- Tube spinning: Similar to shear spinning but working on a tube.
Spinning

Conventional spinning - thinning and bending occur at the same time.
MODULE-IV

CONVENTIONAL AND UNCONVENTIONAL MACHINING PROCESSES
### MODULE-IV

<table>
<thead>
<tr>
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</tr>
</thead>
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<td>CLO10</td>
<td>Discuss the principle of advanced materials and what factors drive to develop the composite materials.</td>
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<tr>
<td>CLO11</td>
<td>Extend the outputs of earlier research and discover good ideas for new products or improving current products.</td>
</tr>
<tr>
<td>CLO12</td>
<td>Memorize procedure and steps to keep the products working effectively.</td>
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</table>
**LATHE MACHINE**

- **Bed:** Usually made of cast iron. Provides a heavy rigid frame on which all the main components are mounted.
• Headstock: mounted in a fixed position on the inner ways, usually at the left end. Using a chuck, it rotates the work.
• Spindle: Hole through the headstock to which bar stock can be fed, which allows shafts that are up to 2 times the length between lathe centers to be worked on one end at a time.
• Chuck: 3-jaw (self centering) or 4-jaw (independent) to clamp part being machined.
• Tailstock: Fits on the inner ways of the bed and can slide towards any position the headstock to fit the length of the work piece. An optional taper turning attachment would be mounted to it.
• Compound Rest: Mounted to the cross slide, it pivots around the tool post.
• Apron: Attached to the front of the carriage, it has the mechanism and controls for moving the carriage and cross slide.
• Feed Rod: Has a keyway, with two reversing pinion gears, either of which can be meshed with the mating bevel gear to forward or reverse the carriage using a clutch.
• Lead Screw: For cutting threads.
• deflection.
The basic function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution,
Cutting motion

Conventional, or up milling

Depth of cut

Climb, or down milling

Feed
(a) parallel facing by two side (single) cutter

(b) slotting by side (double sided) milling cutter

(c) Parting by slitting saw
Conventional Machining  VS  NonConventional Machining

- The cutting tool and workpiece are always in physical contact, with a relative motion against each other, which results in friction and a significant tool wear.

- In non-traditional processes, there is no physical contact between the tool and workpiece. Although in some non-traditional processes tool wear exists, it rarely is a significant problem.

- Material removal rate of the traditional processes is limited by the mechanical properties of the work material. Non-traditional processes easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fiber reinforced materials, carbides, titanium-based alloys.
In traditional processes, the relative motion between the tool and work piece is typically rotary or reciprocating. Thus, the shape of the work surfaces is limited to circular or flat shapes. In spite of widely used CNC systems, machining of three-dimensional surfaces is still a difficult task. Most non-traditional processes were develop just to solve this problem.

Machining of small cavities, slits, blind or through holes is difficult with traditional processes, whereas it is a simple work for some non-traditional processes.

Traditional processes are well established, use relatively simple and inexpensive machinery and readily available cutting tools. Non-traditional processes require expensive equipment and tooling as well as skilled labor, which increases significantly the production cost.
Classification OF Processes

- Mechanical Metal removal Processes
- It is characterized by the fact that the material removal is due to the application of mechanical energy in the form of high frequency vibrations or kinetic energy of an abrasive jet.

1. Ultra sonic Machining (USM).
2. Abrasive Jet Machining (AJM).
3. Water Jet Machining (WJM).
Electro-Chemical

It is based on electro-chemical dissolution of materials by an electrolyte under the influence of an externally applied electrical potential.

1. Electro-Chemical Machining (ECM).
2. ECG
3. ECD
Thermal Method

The material is removed due to controlled, localized heating of the work piece. It results into material removal by melting and evaporation. The source of heat generation in such cases can be widely different.

1. Electric Discharge Machining (EDM).
2. Plasma Arc Machining (PAM).
3. EBM
4. LBM
A stream of fine grain abrasives mixed with air or suitable carrier gas, at high pressure, is directed by means of a nozzle on the work surface to be machined.

The material removal is due to erosive action of a high pressure jet.

AJM differ from the conventional sand blasting process in the way that the abrasive is much finer and effective control over the process parameters and cutting. Used mainly to cut hard and brittle materials, which are thin and sensitive to heat.
Abrasive Jet Machining Setup
Ultrasonic Machining (USM)

Ultrasonic Machine Parts

Principal components of an ultrasonic machine.
Ultrasonic machining (USM) is the removal of hard and brittle materials using an axially oscillating tool at ultrasonic frequencies [18–20 kHz]. During that oscillation, the abrasive slurry of B₄C or SiC is continuously fed into the machining zone between a soft tool (brass or steel) and the workpiece. The abrasive particles are, therefore, hammered into the workpiece surface and cause chipping of fine particles from it. The oscillating tool, at amplitudes ranging from 10 to 40 μm, imposes a static pressure on the abrasive grains and feeds down as the material is removed to form the required tool shape. USM is characterized by the absence of any deleterious effect on the metallic structure of the workpiece material.
Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion.

In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape.

In the EDM process an electric spark is used to cut the workpiece, which takes the shape opposite to that of the cutting tool or electrode.

Generally the workpiece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal.
Electro discharge machining (EDM) Diagram
Electric Discharge Machining (EDM)

FIGURE 26.7
Electric discharge machining (EDM): (a) overall setup, and (b) close-up view of gap, showing discharge and metal removal.
“light amplification by stimulated emission of radiation.”

Electrons are atomic particles that exist at specific energy levels. These energy levels are unique and are different for every atom or molecule.

Electrons in outer rings are at higher energy levels than those in the inner rings. A flash of light can bump electrons to higher energy levels by the injection of energy. When an electron drops from an outer ring to an inner ring or level, the excess of energy is given off as light.

The wavelength or the color emitted is related to the amount of energy released.
Laser Beam Machining
Laser Beam Machining

Schematic diagram of LBW

- Supply
- Capacitor
- Mirror
- Cooling system
- Xenon Flash tube
- Laser crystal
- Focusing lens
- Laser beam
- Concentrated beam
- Work piece
Electron Beam Welding (EBW)

- Cathode
- Anode
- Electron beam
- Focusing coil
- Deflection coil
- Workpiece
- Vacuum pump
AIRCRAFT COMPOSITES
<table>
<thead>
<tr>
<th>CLOs</th>
<th>Course Learning Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLO13</td>
<td>Gain knowledge about what materials used to manufacture for each component in an aircraft.</td>
</tr>
<tr>
<td>CLO14</td>
<td>Ability to summarize the efficiency of the product development in achieving the mission goal.</td>
</tr>
<tr>
<td>CLO15</td>
<td>Ability to summarize the efficiency of the safety of flight</td>
</tr>
</tbody>
</table>
In the 1940s, the aircraft industry began to develop synthetic fibers to enhance aircraft design. Since that time, composite materials have been used more and more. A “composite” material is defined as a mixture of different materials or things. This definition is so general that it could refer to metal alloys made from several different metals to enhance the strength, ductility, conductivity or whatever characteristics are desired.
- Wrought aluminum alloys
- Cast aluminum alloys
Aluminum and Its Alloys

- Aluminum is the most abundant metal in the Earth's crust, and the third most abundant element therein, after oxygen and silicon.
- It is a silvery-white metal.
- It is light-weight, non-toxic, and can be easily machined or cast.
- Pure aluminum is soft and ductile, but can be strengthened by alloying with small amounts of copper, magnesium, and silicon.
Aluminum

- Aluminum is strong, corrosion resistant,
- It also conducts electricity and heat well, and is readily weldable by MIG or TIG processes.
- In terms of ease of construction, aluminum is excellent.
- Aluminum provides the option to make use of much greater plate thickness within a given weight budget, so that strength can be greater than with steel.
Wrought aluminum

- Those aluminum products that have been subjected to plastic deformation by hot- and cold working mill processes (such as rolling, extruding, and drawing, either singly or in combination), so as to transform cast aluminum ingot into the desired product form.

- One significant change being implemented by designers of automobiles and military vehicles today is converting driveshafts, radiators, cylinder heads, suspension members, and other structural components to aluminum.
Aluminum can be cast by all common casting processes. Aluminum casting alloys are identified with a unified, four-digit (xxx.x) system.

Commercial casting alloys include heat-treatable and non-heat-treatable compositions. Alloys that are heat treated carry the temper designations 0, T4, T5, T6, and T7. Die castings are not usually solution heat treated because the temperature can cause blistering.
Aluminum Castings

- Good fluidity for filling thin sections
- Low melting point relative to those required for many other metals
- Rapid heat transfer from the molten aluminum to the mold, providing shorter casting cycles
- Hydrogen is the only gas with appreciable solubility in aluminum and its alloys, and hydrogen solubility in aluminum can be readily controlled by processing methods
- Many aluminum alloys are relatively free from hot-short
Selection of Casting Alloys

- Casting process considerations: fluidity, resistance to hot tearing, solidification range
- Casting design considerations: solidification range, resistance to hot tearing, fluidity, die soldering (die casting)
- Mechanical-property requirements: strength and ductility, heat treatability, hardness
- Service requirements: pressure tightness characteristic, corrosion resistance, surface treatments, dimensional stability, thermal stability
- Economics: machinability, weldability, ingot and melting costs, heat treatment
Aluminum Castings

- Castings are usually moderately good enough to be used for welding & machining purposes. They can offer better corrosion resistance than wrought products.
- Aluminum automotive pistons generally are permanent mold castings. This design usually is superior in economy and design flexibility.
- The alloy most commonly used for passenger car pistons has a good combination of foundry, mechanical, and physical characteristics, including low thermal expansion.
- Heat treatment improves hardness for improved machinability.
Use of aluminum-lithium alloys in commercial aircraft
Alloys of Al–Cu system

- Composition 4 – 6 % Cu

- Copper substantially improves strength and hardness in the as-cast and heat-treated conditions

- Copper generally reduces corrosion resistance and, in specific compositions stress corrosion susceptibility

- Copper also reduces hot tear resistance and decreases castability
Nonmetallic Aircraft Materials

- Plastics
- Rubber
- Glass
- Carbon Composites
- Fibers
- Resins
Plastics

- Plastics are used in many applications throughout modern aircraft.
- These applications range from structural components of thermosetting plastics reinforced with fiberglass to decorative trim of thermoplastic materials to windows.
Rubber

- Rubber is used to prevent the entrance of dirt, water, or air, and to prevent the loss of fluids, gases, or air.
- It is also used to absorb vibration, reduce noise and cushion impact loads.
- It is used to include not only natural rubber, but all synthetic and silicone rubbers.
Glass fiber is a material consisting of numerous extremely fine fibers of glass.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber.

Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites.
Carbon Composites

- A composite is basically a material that contains both a reinforcing material to provide strength and stiffness and a matrix material to surround and hold the reinforcement together.
- Carbon-Carbon (C/C) Composites may be manufactured with different orientation of the reinforcing phase (carbon fibers).
- Unidirectional structure, bi-directional structure (cloth made of multiple carbon fiber yarns), multi-directional structure (3D, 4D, 5D, etc.).
C/C composites are lightweight, high-strength composite materials capable of withstanding temperatures over 3000°C.

C/C composites use the strength and modulus of carbon fibers to reinforce a carbon matrix to resist the rigors of extreme environments.
Properties of Carbon-Carbon Composites

- Excellent thermal shock resistance;
- High Thermal Conductivity
- Low density
- High strength
Applications of Carbon-Carbon Composites

- High performance braking systems (eg. brake discs for high speed aircrafts)
- Refractory material (eg. protection tubes and grids)
- Hot-pressed dies
- Heating elements
- Turbojet engine components (eg. rocket nozzles).
Fibers are a class of materials that are continuous filaments or discrete elongated pieces.
They are crystalline, present in both plants & animals.
They are used for making textiles, ropes, utilities, strings etc.
These are of two types
(1) Natural Fibers
(2) Synthetic fibers
ROLE OF RESINS IN FRP COMPOSITES

Composite:
- A heterogeneous combination of two or more materials
  • reinforcing elements such as fibers, fillers
  • binders such as resins or polymers
- These materials differ in form or composition on a macroscale.
- There exists interface between these materials - compatibility

Fiber:
• Load-bearing component.

Resin:
• Dissipate loads to the fiber network
• Maintain fiber orientation
• Protect the fiber network from damaging environmental conditions such as humidity and high temperature
• Dictates the process and processing conditions
Production of semi Fabricated Forms
Purpose of Alloying

- To retain physical properties at high temperature
- To improve corrosion and wear resistance
- To obtain fine grain size
Advantages of Alloy

- Harder and tougher
- High hardenability
- High corrosion and oxidation resistance
- Stronger
Super Alloys

- Nickel Alloys
- Titanium Alloys
NICKEL
Properties of Nickel

- Good resistance to action of both acids and alkalis
- Hard, malleable and magnetic
- More corrosion resistance to salt water and atmosphere
- High tensile strength
Thermocouples
Nickel coated components
Advantages of titanium

- Good strength
- Low density
- Excellent corrosion resistance to many aggressive media
- Non-magnetism
- Resistance to erosion and erosion-corrosion
- Most of its alloys have high mechanical properties in a wide temperature range
Fig. 3: Japanese suppliers for A380 (©AIRBUS)
Titanium Applications

- In the petroleum and chemical industries
- Car suspension springs

Heat Exchanger materials
Die-cast parts for automobiles, luggage, and electronic devices
Biomedical implants such as hip prostheses
Titanium Alloys

The alloys of titanium can be classified into three main groups as follows:

- Alpha and Near Alpha alloys (α-alloys and Near α-alloys)
- Alpha-beta alloys (α+β alloys)
- Beta alloys (β alloy)
α- alloys and Near α- alloys

- They Contain 5% of Aluminum and 2.5 % of Tin.
- Which improves mechanical properties like creep resistance.
- Reasonably good ductility and have excellent properties at cryogenic temperatures.
α+β alloys

- They Contain 6% of Aluminum and 4% of Vanadium which improves the good formability.
- Alpha-beta alloys have higher strength and respond to heat treatment.
- Fusion weld efficiencies up to 100% are attainable.
- This class of titanium alloys account for more than 70% of all commercially available titanium alloys.
β alloys

- They Contain 3% of Aluminum, 10% of Vanadium which improves the good forging capabilities.
- Beta alloys are readily heat treatable to improve.
- Generally weldable and offer high strength up to intermediate temperature levels.
- Cold formability is generally excellent.
Emerging trends in aerospace
Individual Effects of Following Elements

- Tungsten
- Chromium
- Molybdenum
- Vanadium
- Nickel
- Sulphur
Individual Effects of Following Elements

- Manganese
- Silicon
- Copper
- Cobalt
- Aluminium
- Lead
MAGNESIUM
Properties of Magnesium

- Lightest of all metals (weighing two third of aluminium).
- It burns when heated in air with a dazzling bluish white light extremely rich in ultra-violet rays.
- May be sand cast, gravity cast or die cast.
- Ductile and malleable.
Properties of Magnesium

- Carries away heat easily
- Its thermal coefficient of expansion is high
- Not responsive to heat treatment and mechanical working
- Soft, sliver white metal
- Good machinability
- Possess strength to weight ratio
Magnesia bricks
LEAD
Properties of Lead

- High density
- Malleability
- Resistance to chemical action
- Low melting point
- Low electrical conductivity
- High absorbing power for radiation such as X-rays, γ-rays
Storage batteries

- Positive terminal
- Negative terminal
- Vent caps
- Cell connectors
- Positive electrode (lead dioxide)
- Negative electrode (lead)
- Electrolyte solution (dilute sulfuric acid)
- Protective casing

Right diagram:
- Negative terminal
- Gas vents
- Positive terminal
- Insulating case
- Sulphuric acid
- Lead oxide
- Lead
Lead coated components
CHROMIUM
Properties of Chromium

- Silvery white malleable metal
- Strong and hard
- Resistant to action of air, water and CO2 at ordinary room temperature
- Alloys with iron and nickel
Uses of Chromium

- In electroplating iron articles to resist corrosion and improve appearance
- Important constituent of many alloy steels
- In massive form as a target in x-ray tubes
Chromium coated components
Materials used for aircraft components

Characteristics and applications,
Classification of aircraft materials;
Materials used for aircraft components,
AIRCRAFT MATERIALS

- Basic requirements
- High strength and stiffness
- Low density
  - => high specific properties e.g. strength/density, yield strength/density, E/density
- High corrosion resistance
- Fatigue resistance and damage tolerance
- Good technology properties (formability, machinability, weldability)
- Special aerospace standards and specifications
Development of aircraft materials for airframe structures

<table>
<thead>
<tr>
<th>Year</th>
<th>Wood</th>
<th>AlCuMg alloys</th>
<th>pure AlCuMg alloys</th>
<th>pure AlZnMgCu alloys</th>
<th>other Al alloys</th>
<th>Mg alloys</th>
<th>Ti alloys</th>
<th>composites</th>
<th>other materials</th>
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</table>
Application of composite materials
Use of aluminum-lithium alloys in commercial aircraft
Typical castings in aircraft structures

- Al - front body of engine
  - 32 kg
  - D=700 mm

- Al - steering part
  - 1,1 kg
  - 390 x 180 x 100 mm

- Al - pedal
  - 0,4 kg
  - 180 x 150 x 100 mm

- Al - casing
  - 1,3 kg
  - 470 x 190 x 170 mm
Magnesium Alloys
Basic wrought Mg alloys

Mg-Al-Zn (AZ) alloys

The most common alloys in aircraft industry, applicable up to 150 °C

Composition – 3 to 9 % Al, 0.2 to 1.5 % Zn, 0.15 to 0.5 % Mn

Increasing Al content → strength improvement, but growth of susceptibility to stress corrosion

Zn → ductility improvement

(Cd + Ag) as Zn replacement → high strength up to 430 Mpa

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Composition</th>
<th>Property 1</th>
<th>Property 2</th>
<th>Property 3</th>
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<tbody>
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<td>AZ31B</td>
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<td>220</td>
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</table>
- Mg-Zn-Zr alloys (ZK)

- Zn → strength improvement
- Zr → fine grain → improvement of strength, formability and corrosion resistance
- Better plasticity after heat treatment
- Alloying with RE a Cd → tensile strength up to 390 MPa
- Application up to 150 °C
Titanium Alloys
Characteristics of titanium and titanium alloys

- Pure titanium - 2 modifications
  - $\alpha$Ti – to 882 °C, hexagonal lattice
  - $\beta$Ti – 882 to 1668°C, cubic body centered lattice
  - With alloying elements, titanium forms substitution solid solutions $\alpha$ and $\beta$

- Commercially pure titanium can be used as structural material in many applications, but Ti alloys have better performance.
Composite Materials
Most composites consist of a bulk material (the ‘matrix’), and a reinforcement, added primarily to increase the strength and stiffness of the matrix. This reinforcement is usually in fibre form.

Today, the most common man-made composites can be divided into three main groups:

- **Polymer Matrix Composites (PMC’s)** – These are the most common and will be discussed here. Also known as FRP - Fibre Reinforced Polymers (or Plastics) – these materials use a polymer-based resin as the matrix, and a variety of fibres such as glass, carbon and aramid as the reinforcement.

- **Metal Matrix Composites (MMC’s)** – Increasingly found in the automotive industry, these materials use a metal such as aluminium as the matrix, and reinforce it with fibres such as silicon carbide (SiC).

- **Ceramic Matrix Composites (CMC’s)** – Used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride (BN).
Polymer fibre reinforced composites

- Common fiber reinforced composites are composed of fibers and a matrix.

- Fibers are the reinforcement and the main source of strength while the matrix 'glues' all the fibres together in shape and transfers stresses between the reinforcing fibres.

- Sometimes, fillers or modifiers might be added to smooth manufacturing process, impart special properties, and/or reduce product cost.
Sandwich materials

- Structure – consists of a lightweight core material covered by face sheets on both sides. Although these structures have a low weight, they have high flexural stiffness and high strength.
- Skin (face sheet)
- Metal (aluminium alloy)
- Composite material
- Core
A new structural material having the most influence is carbon fibre reinforced plastic (CFRP).

The Airbus A380 uses some all-CFRP components and has a large proportion of the fuselage manufactured using a unique aluminium/reinforced-plastic sandwich.
CFRP offers durability and is relatively light.
The designers have to exploit the potential weight saving with care.
The fuel efficiency at the maximum payload–range point was shown to be 33% improved on the 777-200LR.
Resin

- In polymer chemistry and materials science
- Resin is a solid or highly viscous substance of plant or synthetic origin that is typically convertible into polymers.
- Resins are usually mixtures of organic compounds.
- Plants secrete resins for their protective benefits in response to injury.
- The resin protects the plant from insects and pathogens.
Thank You