Systems in Mechanical Engineering

F.E. [Common to All Branches] Semester - I

Anup Goel
B.E. Mechanical
Post Graduation in Tool Design with CAD/CAM
Managing Director of AG Engineering Study Centre,
Akurdi, Pune
13 Years Teaching Experience

Dr. Virendra K. Bhojwani
Ph.D. (IIT Bombay)
M.E. (Heat Power) (Gold Medalist)
Professor, Mechanical Engineering Department,
MITSOE, MITADT University, Loni, Pune
**Power**
- Power is the rate of doing work or transferring heat. It is the amount of energy transferred or converted per unit time.
- It is a scalar quantity.
- The S.I. unit of power is Joules/sec or watts. It is also expressed in kW, MW, etc.

\[
1 \text{ kW} = 1000 \text{ W} \quad \text{and} \quad 1 \text{ MW} = 1000 \text{ kW}
\]

- Mathematically power is given by,

\[
P = \frac{\text{Energy}}{\text{Time}} = \frac{E}{t}
\]

or

\[
P = \text{Force} \times \text{Velocity} = F \times V
\]

or

\[
P = \text{Torque} \times \text{Angular velocity} = T \times \omega
\]

but

\[
\omega = \frac{2\pi N}{60} \text{ rad/sec}
\]

... (N = No. of rev/sec)

\[
\therefore P = \frac{2\pi NT}{60} \quad ... (T = \text{Torque in N-m})
\]

In electrical, \( P = \text{voltage} \times \text{current} = V \times I \)

**Binary cycle power plant**
- Binary plants, like dry-steam and flash-steam plants, make use of naturally sourced hot steam generated by activity from within the Earth's core.
- All geothermal plants convert thermal energy to mechanical energy, then finally to electrical energy.
- Binary plants specifically use a second working fluid or geothermal fluid (hence, "binary") with a much lower boiling point than water.
- The binary fluid is operated through a conventional Rankine cycle. Generally, the working fluid is a hydrocarbon such as isopentane, or a refrigerant.
- The geothermal fluid (predominantly water vapor) and working fluid pass through a heat exchanger, where the working fluid flashes to vapor and drives the turbines.
- The cooled water vapor is then released back into the underground reservoirs, so the cycle can start again.
- No gas is emitted to the atmosphere, as the binary cycle is a closed system.
- The binary cycle can operate with geothermal fluid temperatures ranging from 85 °C to 170 °C.
- Depending on the temperatures, different working fluids are selected based on appropriate boiling points.

![Fig. 1.1 Binary cycle power plant](image-url)
The upper temperature limit is restricted by the working fluids well, as they are generally organic molecules that become thermally unstable at higher temperatures.

The low temperature limit is restricted by economic and engineering concerns. The heat exchanger size for a given capacity becomes impractical and costly at low temperatures.

A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.

**Advantages**

- Does not use steam directly to spin turbines.
- Only the heat of the underground water is used.
- Vapourized hydrocarbons are used to spin the turbine.
- Hydrocarbons having lower boiling point such as isopentane, isobutane and propane can be used.
- No harmful gas is emitted to the atmosphere because the underground water is never disclosed to outside.

**Note:** For steam power plant input power is,

\[ P_1 = \text{Mass flow rate of fuel (kg/s)} \times \text{calorific value (J/kg)} \]

\[ \therefore P_1 = \dot{m}_f \times C.V \] (watts or J/sec)

For hydraulic power plant input power is,

\[ P_1 = \text{Water power} \]

\[ = \rho g QH \] (watts or J/sec)

where, \( \rho \) = Density of water in kg/m³

\[ = 1000 \text{ kg/m}^3 \]

\( g \) = Gravitational acceleration in m/s²

\[ = 9.81 \text{ m/sec}^2 \]

\( Q \) = Volume flow rate of water in m³/sec

\( H \) = Available head of water (Height) in m

**Numericals**

**Ex. 1.1** The coal consumption of thermal power plant is 100 Tonnes of coal/day. The calorific value of coal is 21000 kJ/kg. If the power generation in one day is 5000 kW find overall efficiency of the power plant.

**Sol.** Given data:

\[ \dot{m}_f = 100 \text{ tonnes/day} = \frac{100 \times 10^3 \text{ (kg)}}{24 \text{ (hrs)} \times 3600 \text{ (sec)}} \]

\[ = 1.1574 \text{ kg/sec} \]

\[ C.V = 21000 \text{ kJ/kg} = 21000 \times 10^3 \text{ J/kg} \]

Output power \( P_o = 5000 \text{ kW} = 5000 \times 10^3 \text{ W} \)

**To find:** Overall efficiency

Input power \( P_i = \dot{m}_f \times C.V = 1.1574 \times 21000 \times 10^3 \)

\[ \therefore P_i = 24.3054 \times 10^3 \text{ J/sec or watts} \]

Efficiency, \( \eta = \frac{\text{Output power}}{\text{Input power}} \times 100 = \frac{P_o}{P_i} \times 100 \)

\[ \therefore \eta = \frac{5000 \times 10^3}{24.3054 \times 10^6} \times 100 \]

\[ = 20.571 \% \]

...Ans.

**Ex.1.2** A steam power plant has coal consumption of 165 tonnes per hour. The calorific value of coal is 3500 kcal/kg. If the power generation is 250 MW find overall efficiency of the plant. Take 1 kcal = 4.18 kJ.

**Sol.** Given data:

\[ \dot{m}_f = 165 \text{ tonnes/hr} = \frac{165 \times 10^3 \text{ (kg)}}{3600\text{ (sec)}} \]

\[ = 45.8333 \text{ kg/s} \]

\[ C.V = 3500 \text{ kcal/kg} \]

\[ = 3500 \times 4.18 \text{ kJ/kg} \]

\[ \therefore C.V = 14630 \text{ kJ/kg} \]

\[ = 14630 \times 10^3 \text{ J/kg} \]

Output power \( P_o = 250 \text{ MW} = 250 \times 10^6 \text{ W} \)

**To find:** Overall efficiency
Input power \( P_i = \dot{m}_f \times C.V = 45.8333 \times 14630 \times 10^3 \) 
\[ \therefore \quad P_i = 670.5411 \times 10^6 \text{ Watts} \]

Efficiency \( \eta = \frac{P_o}{P_i} \times 100 = \frac{250 \times 10^6}{670.5411 \times 10^6} \times 100 \) 
\[ \therefore \quad \eta = 37.283 \% \quad \cdots \text{Ans.} \]

**Ex.1.3** A steam power plant has coal consumption of 16200 kg/hr with calorific value of coal as 17793.9 kJ/kg. If the speed of turbine is 1000 rpm and generated torque is 477464.8293 N·m. Find a) Input power b) Output power c) Efficiency

**Sol.** Given data:
\[ \dot{m_f} = 16200 \text{ kg/hr} = \frac{16200}{3600} \text{ sec} \]
\[ = 4.5 \text{ kg/sec} \]
\[ C.V. = 17793.9 \text{ kJ/kg} = 17793.9 \times 10^3 \text{ J/kg} \]
\[ N = 1000 \text{ rpm}, \quad T = 477464.8293 \text{ N·m} \]

**To find:** a) \( P_i \)  
  b) \( P_o \)  
  c) \( \eta \)

Input power \( P_i = \dot{m}_f \times C.V. = 4.5 \times 17793.9 \times 10^3 \)
\[ \therefore \quad P_i = 80.0725 \times 10^6 \text{ watts} \quad \cdots \text{Ans.} \]

Output power \( P_o = \text{Torque} \times \text{Angular velocity} = T \times \omega \)
\[ = \frac{T}{60} \times \frac{2\pi N}{60} \]
\[ = 477464.8293 \times \frac{2\pi \times 1000}{60} \]
\[ \therefore \quad P_o = 55 \times 10^6 \text{ Watts} \quad \cdots \text{Ans.} \]

Efficiency \( \eta = \frac{P_o}{P_i} \times 100 = \frac{55 \times 10^6}{80.0725 \times 10^6} \times 100 \)
\[ \therefore \quad \eta = 68.26 \% \quad \cdots \text{Ans.} \]

**Ex.1.4** A steam power plant has coal consumption of 16300 kg/hr with calorific value as 17793.9 kJ/kg. If the speed of steam turbine is 1100 rpm, radial distance is 1.5 m and generated tangential force is 318309.8862 N find:
  a) Generated torque  
  b) Input and output power  
  c) Efficiency

**Sol.** Given data:
\[ \dot{m_f} = 16300 \text{ kg/hr} = \frac{16300}{3600} \text{ Kg/sec} = 4.5277 \text{ kg/sec} \]
\[ C.V. = 17793.9 \text{ kJ/kg} = 17793.9 \times 10^3 \text{ J/kg} \]

\[ N = 1100 \text{ rpm}, \quad \text{Radial distance} \; l = 1.5 \text{ m} \]
\[ \text{Force} \; F = 318309.8862 \text{ N} \]

**To Find:** a) \( T \)  
  b) \( P_i \) and \( P_o \)  
  c) \( \eta \)

Torque \( T = \text{Tangential force} \times \text{Radial distance} = F \times l \)
\[ \therefore \quad T = 318309.8862 \times 1.5 \]
\[ \therefore \quad T = 477.4648 \times 10^3 \text{ N·m} \quad \cdots \text{Ans.} \]

Input power \( P_i = \dot{m}_f \times C.V. = 4.5277 \times 17793.9 \times 10^3 \)
\[ \therefore \quad P_i = 80.565 \times 10^6 \text{ Watts} \quad \cdots \text{Ans.} \]

Output power \( P_o = \text{Torque} \times \text{Angular velocity} = T \times \omega \)
\[ = \frac{T}{60} \times \frac{2\pi N}{60} \]
\[ = 477464.8293 \times \frac{2\pi \times 1100}{60} \]
\[ \therefore \quad P_o = 55 \times 10^6 \text{ Watts} \quad \cdots \text{Ans.} \]

Efficiency \( \eta = \frac{P_o}{P_i} \times 100 = \frac{55 \times 10^6}{80.565 \times 10^6} \times 100 \)
\[ \therefore \quad \eta = 68.26 \% \quad \cdots \text{Ans.} \]

**Ex.1.5** A small generating plant of 100 kW capacity uses gas of a calorific value of 4000 kJ/m³. The volume of gas required per hour when the plant is running at full load condition is 450 m³/hr. Find a) Input power  
  b) Overall efficiency of the plant.

**Sol.** Given data:
\[ P_o = 100 \text{ kW} = 100 \times 10^3 \text{ W}, \quad \text{C.V.} = 4000 \text{ kJ/m}^3 \]
\[ = 4000 \times 10^3 \text{ J/m}^3 \]

Volume flow rate \( \dot{V}_f = 450 \text{ m}^3 / \text{hr} = \frac{450}{3600} \text{ m}^3 / \text{sec} \]
\[ = 0.125 \text{ m}^3 / \text{sec} \]

**To Find:** a) \( P_i \)  
  b) \( \eta \)

Input power \( P_i = \dot{V}_f \times \text{C.V.} \)
\[ = 0.125 \left( \text{m}^3 / \text{sec} \right) \times 4000 \times 10^3 \left( \text{J/m}^3 \right) \]
\[ P_1 = 500 \times 10^3 \text{ J/sec or Watts} \quad \text{...Ans.} \]

\[ \eta = \frac{P_0}{P_1} \times 100 = \frac{500 \times 10^3}{500 \times 10^3} \times 100 \]

\[ \therefore \eta = 20\% \quad \text{...Ans.} \]

Ex. 1.6 Determine power developed by wind mill if the wind speed is 20 m/s and length of blade (radius) is 50 m. Take density of air as 1.23 kg/m\(^3\) and efficiency as 40%.

Sol. : Given data:
V = 20 m/s, r = 50 m, \( \rho \) = 1.23 kg/m\(^3\), \( \eta \) = 40% 

**To Find:** Power developed

Input power of wind mill is,
\[ P_1 = \frac{\pi r^2 V^2 \rho}{2} \]
\[ P_1 = \frac{\pi}{2} \times 50^2 \times 20 \times 1.23 \]
\[ \therefore P_1 = 38.6415 \times 10^6 \text{ Watts} \]

Efficiency:
\[ \eta = \frac{P_0}{P_1} \times 100 \]
\[ \therefore P_0 = \eta \times P_1 \]

\[ P_0 = \frac{40 \times 38.6415 \times 10^6}{100} \]
\[ \therefore P_0 = 15.4566 \times 10^6 \text{ Watts} \]
\[ P_0 = 15.4566 \text{ MW} \quad \text{...Ans.} \]

\[ P_1 = 1.1772 \text{ MW} \quad \text{...Ans.} \]

Efficiency:
\[ \eta = \frac{P_0}{P_1} \times 100 = \frac{950 \times 10^3}{1.1772 \times 10^6} \times 100 \]
\[ \therefore \eta = 80.7\% \quad \text{...Ans.} \]

**System Ench Plumbing**

**Chapter - 6 : Vehicle Systems**

**Steering Mechanism**
- The steering gear mechanism is used in the automobiles for changing the direction of two or more of the wheel axles with respect to chassis, so as to move the automobile in any desired path.
- Generally, steering is done by means of the front wheels, because the back or rear wheels are mounted on a common axle which is fixed in direction with reference to the chassis.
- In automobiles, the front wheels are mounted on the front axle, which are pivoted at the points A and B. Refer Fig. 6.1.

\[ \text{Fig. 6.1 : Steering gear mechanism} \]

- The rear wheels are mounted over the rear axle, at two ends of the differential.
- When the vehicle takes a turn, the front wheels along with the respective axles turn about the respective pivoted points, but the back wheels remain straight and do not turn.
It is important to note that, to avoid skidding or slipping of the wheels, both the front wheels must turn about the same instantaneous centre I which lies on the axis of the rear wheels.

There are two main types of steering gear mechanism:

- Ackermann steering gear mechanism
- Davis steering gear mechanism.

If vehicle is taking right turn then,

\[ AC \text{ and } BD = \text{Stub axles} \]
\[ A \text{ and } B = \text{Fixed pivots} \]
\[ E \text{ and } F = \text{Rear or back wheels} \]
\[ C = \text{Outer front wheel} \]
\[ D = \text{Inner front wheel} \]

In order to turn the vehicle towards one side, its front wheels are mounted on short axles called as stub axles pivoted to the chasis of the vehicle.

The condition for correct steering is that, all the four wheels must turn about the same instantaneous centre I as shown in Fig. 6.1.

Note that, the axis of the inner wheel makes a larger turning angle \( \theta \) than the angle \( \phi \) subtended by the axis of outer wheel.

For correct steering,

\[ \frac{b}{I} = (\cot \phi - \cot \theta) \]

**Ackermann Steering Gear Mechanism**

- Fig. 6.2 shows an Ackermann steering gear mechanism.

  This mechanism consists of cross link KL (parallel to AB) connected to stub axles AC and BD of the front wheels with the help of short links AK and BL.

  These short links form bell crank levers CAK and DBL and they are pivoted at A and B respectively. Refer Fig. 6.2 (a).

  When the vehicle is moving along a straight path, the longer links AB and KL are parallel to each other.

  At that time, each of the shorter link i.e. AK and BL is inclined at an angle \( \alpha \) with the longitudinal axis of the vehicle.

  - When vehicle is taking right turn (steer to the right), the short link BL is turned so as to increase angle \( \alpha \) whereas, another short link AK turns to reduce angle \( \alpha \).

  - From Fig. 6.2 (b) it is clear that, the angle \( \phi \) through which AC turns is less than angle \( \theta \) through which BD turns, hence the left front axle turns through a smaller angle than the right front axle.

  Ackermann steering mechanism gives correct steering for following three positions:

  1. When vehicle is moving along a straight path \( (\theta = 0) \).

  2. When the vehicle takes right turn and turning angle \( \theta \) is such that the wheel axes AC and BD intersect on the axis of back axle.

  3. When the vehicle takes left turn and similar condition is obtained as above.

  It consists of all turning pairs and it is based on the four bar mechanism.

**Fig. 6.2 : Ackermann steering gear mechanism**
- Because of turning pairs, its manufacturing cost is less and less wear and tear of the parts.
- Hence, Ackermann steering gear mechanism is the most widely used steering mechanism in automobiles.

**Telescopic suspension system (Hydraulic shock absorber)**

Telescopic Type Hydraulic Shock Absorber
It works on the principle that when a piston forces the fluid in a cylinder to pass through a small hole, then the fluid offers high resistance to the piston movement.
- The damping is proportional to the amplitude of vibration.
- So for small vibrations, the damping is also small.
- Refer Fig. 6.3 for cut-section of a hydraulic type telescopic shock absorber.

**Construction :**
- The assembly consists of a sheet-metal body which covers the piston rod and cylinder unit.
- The cylinder 'C' houses the valve (plunger) 'A' and 'B'.

![Fig. 6.3 : Cut-section of telescopic type hydraulic shock absorber](image3)

![Fig. 6.4 : Telescopic shock absorber](image4)
• Cylinder 'C' is surrounded by outer tube 'D'.
• Valves 'A' and 'B' have small orifices passing through it.
• Upper eye is connected to vehicle frame while the lower eye is connected to the axle.
• Cylinder 'C' is closed on top with a head 'H' and a small gland 'I' is provided to return any fluid back to the outer tube 'D'.
• Fluid used in shock absorbers is a mixture of 60% transformer oil and 40% turbine oil.

**Working:**
• When the vehicle comes across a bump, the lower eye pushes the cylinder 'C' upwards.
• This causes fluid in between valve 'A' and 'B' to move out and enter in the chamber above valve 'A'.
• Since the volume holding capacity of chamber above valve 'A' is less due to presence of piston rod, the upward movement of cylinder 'C' is resisted.
• Thus fluid from chamber below valve 'B' is forced out through the small orifice into the annular tube 'D'.
• The resistance offered by fluid to flow through the small openings provide the damping effect.

• During downward movement of lower eye, the small quantity of fluid will get accumulated between valve 'A' and 'B'.
• In case of gas absorbers, the hydraulic fluid is replaced by gas.

**Advantages:**
• Shock absorbers can be made in varying sizes based on damping requirements.
• The operation of shock absorber is noise free as against that in friction damping.
• It requires limited service care.
• No wear and tear of moving parts.
• Low initial and running cost.

**Constant Mesh Gearbox**
• As the name indicates, in this type, all the gears are in continuous (constant) mesh with each other.
• Selection of gears take place by additional sliding dog clutches provided on the main shaft.
• Refer Fig. 6.5 for construction and working of a constant mesh gearbox.
• It shows a typical 3-forward and 1-reverse gear configuration.

![Fig. 6.5 : Constant mesh gearbox](image)
Construction:

(i) Clutch shaft
- It is the input shaft to the gearbox.
- Its outer end is connected to the clutch disc.
- It has a gear machined at its inner end (gear 'A') that meshes with respective gear on the lay shaft (in this case, it is gear 'B').

(ii) Lay shaft
- The lay shaft is freely suspended in bearing mounted on the transmission case.
- It has gears rigidly mounted / machined on it (gears 'B', 'E', 'C' and 'G').

(iii) Main shaft
- It is the output shaft of the gearbox.
- It has splines cut across its length to accommodate axial movement of sliding dog clutches on it.
- Its outer end is connected to the propeller shaft through a universal joint.

(iv) Bearings
- Generally, taper roller bearings are used.
- These bearings are required to take radial and thrust loads during gear engagement.

(v) Reverse idler shaft
- It is a short shaft that supports the reverse idler gear.

(vi) Transmission gears
- In sliding mesh gearboxes, generally spur gears are used.
  - These gears can be grouped into:
    Gears on clutch shaft - rigidly attached / machined
    Gears on lay shaft - rigidly attached / machined
    Gears on main shaft - free to rotate on main shaft
    Gear on reverse idler shaft - rigidly attached / machined

(vii) Sliding dog clutches
- These are special couplings with dog teeth provided on its either side.
- They can slide on the splined main shaft.
- They engage with respective gears on the main shaft and transmit the drive.

(viii) Selector mechanism
- The selector mechanism employed is similar to that used on sliding mesh gearbox.

(ix) Transmission case
- It provides support for the bearings and shafts.
- It also provides an enclosure for lubricating oil.
- It is generally made up of aluminium to reduce weight.
- It has a vent on its top surface to ensure atmospheric pressure inside the gearbox.

Working:
Refer Fig. 6.5 for working and power flow across various gears in constant mesh gearbox.

(i) 1\textsuperscript{st} gear
- To engage 1\textsuperscript{st} gear, dog clutch 'P' is shifted towards left such that it engages with gear 'D'.
- Refer Fig. 6.5 (a) for power flow in 1\textsuperscript{st} gear.
  Gear 'A' → 'B' → 'C' → 'D' → Dog clutch 'P' → Main shaft
  Gear Ratio \( G_1 \) = \( \frac{N_A}{N_D} = \frac{Z_D}{Z_C} \times \frac{Z_B}{Z_A} \)

(ii) 2\textsuperscript{nd} gear
- To engage the 2\textsuperscript{nd} gear, dog clutch 'P' is disengaged.
- Then dog clutch 'Q' is shifted towards right such that it engages with gear 'F'.
- Refer Fig. 6.5 (b) for power flow in 2\textsuperscript{nd} gear.
  Gear 'A' → 'B' → 'E' → 'F' → Dog clutch 'Q' → Main shaft
  Gear Ratio \( G_2 \) = \( \frac{N_A}{N_F} = \frac{Z_E}{Z_C} \times \frac{Z_B}{Z_A} \)
(iii) IIIrd gear
- To engage the IIIrd gear, dog clutch 'Q' is shifted towards left.
- It is made to engage directly with gear 'A'.
- Refer Fig. 2.11 (c) for power flow in IIIrd gear.
- It is also referred to as direct gear.
  Gear 'A' → Dog clutch 'Q' → Main shaft

(iv) Reverse Gear
- To engage the reverse gear, all other dog clutches are disengaged.
- Then dog clutch 'P' is shifted towards right to engage with gear 'T'.
- Because of reverse idler 'H', the gear 'T' rotates in opposite direction.
- Refer Fig. 6.5 (d) for power flow in reverse gear.
  Gear 'A' → 'B' → 'G' → 'H' → 'T' → Dog clutch 'P' → Main shaft

Reverse Gear Ratio \( G_R = \frac{N_A}{N_D} = \frac{T_D}{T_H} \times \frac{T_H}{T_G} \times \frac{T_B}{T_A} \)

Advantages of constant mesh gearbox:
- Since gears are in constant engagement, helical gears can be used.
- With use of helical gears, the noise produced during operation is reduced.
- Wear and tear of dog teeth is reduced because all its teeth are in contact during power transmission as against 2-3 teeth in case of sliding mesh type.

Limitations of constant mesh gearbox:
- For smooth engagement of dog clutches, it is necessary that the speed of sliding dog clutch and main shaft are equal. Hence to engage low gears, speed of clutch shaft should be increased.
- This is called double declutching.
- Since all the gears are in continuous mesh, some amount of power is wasted in overcoming friction across all engaged gear pairs.
- This gearbox is costly due to addition of sliding dog clutches in the system.

Fig. 6.5: Various gear positions in a constant mesh gearbox
Open-die forging

- It is the simplest and important forging process.
- The shapes generated by this process are simple like shafts, disks, rings, etc.
- An example of open-die forging in the steel industry is the shaping of a large square cast ingot into a round cross-section.
- Open-die forging operations produce rough forms of workpiece hence, subsequent operations are required to refine the parts to final shape.
- Open-die forging process can be depicted by a solid workpiece placed between the two flat dies (lower die is fixed and upper die is moving) and reduced in height by compressing it. This process is called as upsetting or flat-die forging. Refer Fig. 7.1.
- The deformation of the workpiece is shown in Fig. 7.1. Due to constancy of volume, any reduction in height of the workpiece increases its diameter.
- In Fig. 7.1 (b) the workpiece is deformed uniformly but practically the workpiece develops a barrel shape which is called as pancaking or barreling.
- It is caused by the frictional forces at the die-workpiece interfaces and it can be minimised by using an effective lubricant.

![Fig. 7.1 : Open-die forging](image1)

Closed-die forging

- Impression-die or closed-die forging is performed with dies which contain the inverse of the required shape of the component. Refer Fig. 7.2.

![Fig. 7.2 : Closed or impression die forging](image2)
Initially the cast ingot is placed between the two impressed dies. As the die closes to its final position, flash is formed by the metal.

This flash flows beyond the die cavity and into the small gap between the die plates.

The formed flash must be cut away from the final component in a subsequent trimming operation but it performs an important function that, it increases the resistance to the deformation of the metal.

The initial steps in the process are used to redistribute the metal in the workpart to achieve a uniform deformation and required metallurgical structure in the subsequent steps.

The final steps bring the component to its final geometry. Also, when drop forging is used, number of blows of the hammer may be used for each step.

As the flash is formed during the process, this process is used to produce more complex components by using dies.

### Comparison between Open-die and Closed-die Forging

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Open-die forging</th>
<th>Closed-die forging</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>In this method, the workpiece is compressed between the two flat dies.</td>
<td>In this method, the workpiece is compressed between the two impressed dies.</td>
</tr>
<tr>
<td>2.</td>
<td>The cost of dies is low.</td>
<td>The cost of dies is high.</td>
</tr>
<tr>
<td>3.</td>
<td>The process is simple.</td>
<td>The process is complex.</td>
</tr>
<tr>
<td>4.</td>
<td>During the process there is poor utilization of the material.</td>
<td>During the process there is better utilization of the material.</td>
</tr>
<tr>
<td>5.</td>
<td>After the process, machining of components is required.</td>
<td>After the process, machining of components is not required.</td>
</tr>
<tr>
<td>6.</td>
<td>The dimensional accuracy of obtained products is not good.</td>
<td>The dimensional accuracy of obtained products is good.</td>
</tr>
<tr>
<td>7.</td>
<td>This process is used for low quantity production.</td>
<td>This process is used for high quantity production.</td>
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### Introduction to G-codes and M-codes for CNC machine

- G-codes are preparatory function which changes the control mode of the machine. It is used to perform various operations or functions during machining process. G-codes are followed by two digit number. For example: G00, G01, G02, etc. It is used for movement of the tool.

- M-codes are miscellaneous function which are used to perform some auxiliary operations. It is followed by two digit number. For example: M00, M01, M03, etc.

- It is mainly used to perform machine operations like spindle start/stop, coolant ON/OFF, tool change, etc.

### Need of specifications

- The technical specifications of an equipment or product is a document that explains what a product or equipment will perform.

- It gives complete information about the product and its performance.

- Because of the following reasons technical specifications are required:
  - It gives detail information about the product.
  - It indicates material to be used while manufacturing the product.
  - With the help of technical specifications customer can compare similar products available in the market.
  - It gives idea about the installation of the product (Assembly of component).
  - It also indicates quality of the product.

For example: Specifications of vehical or specifications of engine. (Refer section 5.5)
Specifications of pump
- The specifications of a centrifugal pump may be given as follows:
  
  Model : IWAKI RD  
  Manufacturer : IWAKI  
  Motor type : D.C. Motor  
  Max. capacity : 10 lit/min  
  Max. head : 10 m  
  Material : Polycarbonate  
  Max. pump speed : 3000 Rev/min  
  Max. outlet pressure : 800 mm of Hg (107 kPa)  
  Max. power : 1200 W  
  Max. voltage : 108 Volts  
  Max. current : 10 A

Specifications of compressor
- The specifications of a reciprocating compressor may be given as follows:
  
  Type : semi-hermetic  
  Power supply : 400 V, 50 Hz.  
  Displacement : 3.86 m³/hr  
  No. of cylinder : 2  
  Max. outlet pressure : 122 bar  
  Max. outlet temperature : 125°C  
  Stroke length : 20 mm  
  Bore diameter : 16 mm  
  Crankshaft speed : 1500 rpm

Specifications of refrigerator
- The specifications of refrigerator may be as follows:
  
  Brand : Godrej  
  Freezer capacity : 60 lit  
  Fresh food capacity : 178 lit  
  Current rating : 0.8 A  
  Voltage : 220 to 240 Volts  
  Frequency : 50 Hz

Types of refrigerant : R 134 a  
Defrost system : Auto defrosting  
Compressor : Hemetically sealed type  
Colour : Grey  
Annual energy consumption : 210 kW-hr  
Installation type : Free standing  
Material : Plastic

Specifications of split A/C
- The specifications of a split air conditioner may be as follows:
  
  Brand : LG  
  Model : KS - Q18 YNZA  
  Capacity : 1.5 Tons  
  Installation type : Split  
  Voltage : 230 V  
  Material components : Plastic  
  Included : 1 Indoor unit, 1 outdoor unit, 1 remote, 2 Batteries, warranty card  
  Battery type : Lead -cadmium  
  Annual energy consumption : 835.5 kW-h  
  Refrigerant : R 32  
  Coil type : Copper condenser coil  
  Compressor : Dual inverter compressor

Note : 1 ton capacity is the amount of heat extracted to convert 1 ton of water (1000 lit.) at 0 °C into ice in 24 hours. Mathematically, 1 ton = 3500 Watts.

Specifications of iron
- The specifications of an electric iron may be as follows:
  
  Manufacturer : Philips
Model No. : 889102630280
Power : 2000 watts
Soleplate : Scratch resistant type
Rate of steam : 25 gm/min continuous
Warranty : 2 year
Product dimensions : 12 cm × 29 cm × 14 cm
and 1.19 kg

Numericals :

Ex. 8.1 An electric motor of 12 kW running at 1440 rpm is used to drive a machine tool. The diameter of pulley connected to motor is 160 mm and the diameter of machine tool pulley is 320 mm. The torque on the machine shaft is 150 N-m. Calculate:
a) Output power (Power on machine shaft)
b) Efficiency of belt drive c) Belt speed.

Sol. : Given data : \( P_1 = 12 \text{ kW} = 12 \times 10^3 \text{ W}, \)
\( n = 1440 \text{ rpm}, \quad \text{d} = 160 \text{ mm}, \quad \text{D} = 320 \text{ mm}, \quad T_o = 150 \text{ N-m} \)

To find : a) \( P_o \) b) \( \eta \) c) \( V_B \)

![Belt drive diagram]

Speed ratio is,
\[
S.R. = \frac{n}{N} = \frac{D}{d} \quad \therefore \quad \frac{1440}{N} = \frac{320}{160}
\]
\[\therefore \quad N = 720 \text{ rpm}\]

Velocity of belt is,
\[
V_B = \frac{\pi \text{d} \text{n}}{60 \times 10^3} = \frac{\pi \times 160 \times 1440}{60 \times 10^3}
\]
\[\therefore \quad V_B = 12.0637 \text{ m/s} \quad \text{...Ans.}\]

Power transmitted or output power is,
\[
P_o = \frac{2\pi NT_o}{60} = \frac{2\pi \times 720 \times 150}{60}
\]
\[\therefore \quad P_o = 11.3097 \text{ Watts} = 11.3097 \text{ kW} \quad \text{...Ans.}\]

Efficiency of belt drive is,
\[
\eta = \frac{P_o}{P_1} \times 100 = \frac{11.3097}{12} \times 100
\]
\[\therefore \quad \eta = 94.247 \% \quad \text{...Ans.}\]

Note : For more examples on belt drive refer section 8.15.2.

Ex. 8.2 The pitch circle diameter of pinion is 250 mm and for gear 750 mm. The pinion is attached to motor running at 1440 rpm with 6 kW power. The number teeth on pinion are 25 whereas torque on the gear shaft is 100 N-m. Find the power transmitted by gear drive and corresponding efficiency.

Sol. : Given data : \( d_p = 250 \text{ mm} , \quad d_G = 750 \text{ mm} , \quad n_p = 1440 \text{ rpm} , \quad P_1 = 6 \text{ kW} = 6 \times 10^3 \text{ W} , \quad z_p = 25 , \quad T_G = 100 \text{ N-m} \)

To find : \( P_o \) and \( \eta \)

Gear ratio is,
\[
G = \frac{n_p}{n_G} = \frac{d_G}{d_p} \quad \therefore \quad \frac{1440}{n_G} = \frac{750}{250}
\]
\[\therefore \quad n_G = 480 \text{ rpm}\]

Power on gear shaft is,
\[
P_o = \frac{2\pi n_G T_G}{60} = \frac{2\pi \times 480 \times 100}{60}
\]
\[\therefore \quad P_o = 5.026 \times 10^3 \text{ Watts} = 5.026 \text{ kW}\]

Efficiency of gear drive is,
\[
\eta = \frac{P_o}{P_1} \times 100 = \frac{5.026}{6} \times 100
\]
\[\therefore \quad \eta = 83.766 \% \quad \text{... Ans.}\]

Note : • For more examples on gear drive refer section 6.18.
• For examples on COP of refrigerator refer section 3.13.