CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO PISTON

The piston is a vital component of a cylindrical engine. It reciprocates inside the cylinder bore. The piston acts as a moveable end of the combustion chamber. The cylinder head is the stationary end of the combustion chamber. The piston head is the top surface (closest to the cylinder head) of the piston which is subjected to pressure fluctuation, thermal stresses and mechanical load during normal engine operation. By the forces of combustion, piston reciprocates inside the cylinder bore.

In order to increase the efficiency of operation and better functionality, the piston material should satisfy the following requirements:

- Light weight
- Good wear resistance
- Good thermal conductivity
- High strength to weight ratio
- Free from rust
- Easy to cast
- Easy to machine
- Non magnetic
- Non toxic

Piston should be designed and fabricated with such features to satisfy the above requirements.
A recessed area located around the circumference of the piston is used to retain piston ring. These rings are expandable and split in type. They are used to provide a seal between piston and cylinder wall. Three such rings employed in a diesel engine are

1. Compression ring
2. Wiper or second compression ring
3. Oil ring

The components of piston are presented in Figure 1.1

![Diagram of piston components]

1. Piston skirt diameter
2. Eccentricity of piston axis
3. Total piston length
4. Piston pin hole
5. Compression height
6. Oil ring groove
7. Piston ring grooves
8. Oil cooling tunnel
9. Valve pocket
10. Combustion chamber
11. Piston crown
12. Crown land
13. Al-Fin reinforcement
14. Ring land
15. Oil slit groove
16. Hidden steel struts
17. Skirt area

Figure 1.1 Components of a piston [72]
Compression ring is used to prevent the leakage from combustion chamber during combustion process. It is located closest to the piston head. The wiper ring is placed between compression ring and oil ring. It further seals the combustion chamber and keeps the cylinder wall clean by wiping out the excess oil. Combustion gases passed through the compression ring are stopped by the wiper ring. Oil ring is located near the crank case which is used to wipe excess oil from the cylinder wall during piston movement.

Piston ring must be provided with a radial fit between the cylinder wall and the running surface of the piston for an efficient seal. Piston ring varies depending upon the size of the engine.

1.2 PISTON MATERIAL AND SELECTION

Piston head is exposed to heavy pressure when the engine is operating under load. The expanding gases of combustion apply forces on the piston head. At the same time, the flame front crosses the piston head also exert forces with higher magnitude. The force differentials caused by the expanding combustion gases and the flame front crossing exert forces the piston head can reach two to three times this force. Due to the reciprocating movement of the piston from Top Dead Centre (TDC) to Bottom Dead Centre (BDC) and high temperature fluctuations during operation, this can be called as thermal cycle loading. The temperature of the initial flame front during combustion exceeds 2200°C. When the piston is subjected to this temperature for a short span of time, the thermal stress and expansion of the piston head are to be considered as serious factors.

In addition to these forces and thermal fluctuations incurred by the piston, the piston changes its direction inside the cylinder bore. Design,
material selection and manufacturing of piston are to be considered to satisfy these operating conditions. Aluminum silicon alloy is used as a piston material. The addition of silicon in aluminum improves the following properties (Rosenthal et al 1997).

(i) Reduces solidification and hot cracking
(ii) Increases fluidity
(iii) Improves corrosion resistance

Typical functional variation of increase in silicon content Al-Si is presented in Figure 1.2. From the figure it can be understood that 12% of silicon improves the durability and strength. If the percentage of silicon exceeds 13% then the alloy exhibits extreme difficulties in machining.

![Figure 1.2 Function of silicon in aluminum alloy [57]](image-url)
According to the phase diagram, (Sydney H. Avner 1994) aluminum silicon alloy exhibits eutectic reaction at 12-12.5% of silicon, below which is referred as hypo and above which is called as hyper eutectic components.

These three basic compositions of aluminum silicon alloys are used for manufacturing of pistons.

**Hypereutectic** - Because of the increased strength, improved wear resistance and improved ring groove wear, aluminum silicon greater than 12.5% is often used in piston manufacturing industries.

**Eutectic** – Aluminum alloy with a silicon content of 12 – 12.5% is termed as eutectic composition. It is very common in industry because of its strength and cost effectiveness.

**Hypoeutectic** - represents silicon content of less than 12%. Due to the reduced wear resistance, this composition is not used in today’s industry.

The presence of silicon in aluminum not only improves the high temperature strength but also reduces the coefficient of thermal expansion. Because of this, pistons are manufactured and installed with minimum clearance.

However, the service requirements dictate the need for a better material. In order to enhance the efficiency of the piston, wear resistance material is reinforced specifically at high load bearing area. This results in reduction of wear of piston as well. To have such bimetallic piston, Fairchild Inc. has developed a process called as Al-Fin process. This is explained in chapter 3 in detail.
1.3 FABRICATION OF BIMETALLIC PISTON

The fabrication sequence of bimetallic piston is presented in Figure 1.3.

![Flowchart for bimetallic piston fabrication](image-url)

Figure 1.3 Flowchart for bimetallic piston fabrication
1.4 NEED FOR BIMETALLIC PISTON

In order to meet the requirements regarding reduction of noise and reduction of friction losses, the piston should be light in weight, should have a small assembling clearance, an axial contour having only a minimum curvature and the smallest possible thermal expansion. To ensure a maximum life with unchanged riding comfort, the piston must be stiff particularly at its skirt end, so that the skirt will not be deformed to a substantial extent. Generally, diesel engine pistons are made of a high-strength alloy of aluminum containing silicon having a small thermal expansion coefficient and high resistance to abrasion. The piston head is subjected to corrosion from pressurized fuel injected from a fuel injection nozzle. The ring grooves of the piston are subjected to repeated loading by pressure from the piston rings corresponding to the pressure of the burning of fuel. Due to the above mentioned reasons, it is strongly desired to improve the high temperature hardness of these parts, thereby improving resistance to abrasion (resistance to corrosion) and resistance to fatigue. For improved performance of these low weight components, light alloy is reinforced with strong metal based insert especially at high load bearing region. Different techniques can be used to produce such bimetal components from various aluminum alloys with a cast iron insert. Die casting and Squeeze casting are generally used for making bimetallic piston and the associated characteristics of each process are presented in Table 1.1.
Table 1.1 Comparison between Die casting and Squeeze casting

<table>
<thead>
<tr>
<th>SI No</th>
<th>Die Casting</th>
<th>Squeeze casting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Simple in construction, less cost involved in equipment</td>
<td>Complexity in construction and high cost in equipment</td>
</tr>
<tr>
<td>2</td>
<td>Pressure is not required until the part is solidified</td>
<td>Squeeze pressure is required until the part is solidified</td>
</tr>
<tr>
<td>3</td>
<td>High production rate</td>
<td>Rate of production is low</td>
</tr>
</tbody>
</table>

1.5 HEAT TREATMENT

Heat treatment is the controlled heating and cooling of metals and alloys to change their physical, metallurgical and mechanical properties. Heat treatment is often associated with increasing the strength of material, but it can also be used to modify certain manufacturability objectives such as machinability improvement, formability enhancement and restoring ductility. It is a very enabling manufacturing process and also improves the product performance by increasing the strength and other desirable properties without changing the product shape.

The solution heat treatment is applicable to heat treatable aluminum alloys. In this case, the alloy constituents are taken to solution and retained. Subsequent treatment at lower temperature results in precipitation of constituents thereby achieving increased hardness and strength (Rosenthal et al 1997).
Machinability is not a simple property of a material, but it is the result of complex interactions between the work piece and various cutting devices operated at different rates under different lubricating conditions. The increased use of disposable inserts has reduced the cost of tool, along with a greater emphasis on quality. The importance of surface finish, dimensional accuracy and consistency are realized. Machining is essential in order to manufacture the bimetallic pistons towards satisfying the near net shape condition. Bimetallic machining has to be carried out in a careful manner, since it involves machining of both the metals. In one way, it is like machining of composite materials, which comprises of soft and hard phases. However, in this bimetallic machining, the tool will not be subjected to alternate soft and hard phases. Bimetallic pistons are manufactured through gravity die casting, by reinforcing grey cast iron as an insert in the aluminum alloy. The graphite particles in grey, malleable and ductile irons are responsible for the free-machining characteristics of the cast iron and their superior machinability when compared to steels. Within the cast irons, graphite morphology plays an important role in machinability, with the graphite flakes found in grey iron providing superior machining characteristics. While the graphite particles influence cutting force and surface finish, the matrix is the primary determinant of tool life.

Hardness is often used as an indicator of machinability because of the close relationship between hardness and microstructure. However, hardness gives an accurate representation of machinability only for similar microstructures. For example, a tempered martensite matrix will exhibit
superior machinability to a pearlitic matrix of similar hardness. Ferrite is the softest matrix constituent in ductile iron and as a result it exhibits the best machinability. The ferrite in ductile iron gives superior machinability due to the effect of silicon.

Pearlite, which consists of an intimate mixture of soft ferrite and hard lamellar iron carbide, is a common matrix component in all intermediate strength grades of ductile iron. The volume fraction of pearlite and the fineness of the lamellae determine the hardness and the machinability of ductile iron. Machinability decreases with increasing pearlite content. Pearlite irons are considered to have the best combination of machinability and wear resistance. Carbides are the hardest constituents in ductile iron and have the poorest machinability. Martensite is an extremely hard matrix phase produced by quenching of ductile iron. It is too hard and brittle to be machined as quenched, but after tempering, martensite can be machined.

1.7 SUMMARY

This chapter elucidated the importance of piston in automotive system with its terminology. The detailed explanation is given in the history of piston with keen concentration on type of piston materials and the selection of suitable piston materials. Apart from this, the methodology behind the fabrication process of piston by die casting method with a flow chart is explained in detail. The need for such bimetallic piston is revealed.