Chapter 1

Introduction

1.1 Introduction

Can you think of metal white as silver, strong as iron, and lighter than glass that is malleable, ductile, and unalterable like gold? That is what the renowned **British author Charles Dickens wrote in 1857**. Dickens was known for his social sensibilities. On the earth's surface, there are significant amounts of this metal. A metal with such characteristics is readily understandable in terms of its benefits. Its importance as a raw material is undeniable, and its application will likely increase significantly soon. We can expect to use it in a variety of manners [1].

Aluminium has played a vital role in developing lightweight, fuel-efficient transportation systems due to its lightweight. New cars in North America often contain more than 300 lbs (136 kg) of aluminium. More than 40 cars, in the shape of different structural and gearbox parts, weigh more than 500 lbs (227 kg). Compared to today's cars, less than a fourth of the weight of aluminium was present in cars in 1973 [1]. A rising cost-benefit ratio will continue to make aluminium a key material in safer, cleaner, and lighter cars. Stronger, more formable aluminium alloys are required for high-performance applications like the automotive and aerospace industries. The aerospace, automotive, packaging, and transportation industries all depend on structural components composed of aluminium and its alloys [1].

1.1.1 Introduction of aluminium Alloy

Aluminium is the third most prevalent element on the earth after silicon and oxygen, with an abundance of 8.3% by weight. It is extracted from the bauxite ore. About 4 kg of bauxite is needed to produce 1 kg of Aluminium. It is accessible in various forms, including oxides, sulphates, and silicates.

Aluminium is a very light metal, about one-third the weight of steel at 2.7 g/cm^3. Structural components made from Al and its alloys are vital to the aerospace and automotive industries and are important to the packaging and transportation industries. Vehicles using Al lower their dead weight and energy consumption while increasing their capacity to transport more weight [2].

1.1.2 Application of aluminium alloy in the automotive sector

- Aluminium is the second most used material in automobiles.
- It has the potential to become the most used, as new aluminium alloys are made to deliver more value than steel.
- At the end of a vehicle's life, nearly 90% of the aluminium is recycled.
- Over the past few decades, the automotive and aerospace industries have increased the use of Al-Si alloys due to the increasing demand for weight reduction to achieve higher performance efficiency.
- This material can replace cast iron and steel structural components [2].

1.1.3 Merits of aluminium alloy

Aluminium reduces CO_2 emissions and raises fuel economy by improving vehicle performance. Aluminium can be resin-bonded, brazed, welded, or riveted. The properties of aluminium alloys are listed below: -

- **Highly corrosion resistant:** The passivation process naturally creates a protective oxide covering.
- **Excellent heat and electricity conductor:** Al is the material most frequently used in large transmission lines because it is almost twice as good a conductor.
- **Highly ductile and malleable:** Al has a low melting point, is ductile, and has low density. Due to its ductility, products made of aluminium can be manufactured near the end of the product's design.

- **High strength-to-weight ratio:** To attain the necessary strength and rigidity of the same level, aluminium sections are typically deeper and thinner than corresponding steel sections.
- **Completely impermeable and odourless:** This makes it ideal for packaging food or pharmaceuticals.
- **Recyclability:** High scrap value, 100% recyclable, and just 5% of the energy required to produce the primary metal initially [2].

1.2 Research background

Complicated and narrow-shape aluminium alloy components are usually applied in the automotive and aerospace industries. Al-Si alloys show several advantages, such as formability, conductivity, corrosion resistance, strength-to-weight ratio, and a density of about one-third that of steel. Appropriately, these alloys are preferred to make engine blocks and cylinder heads, pipe fittings, military applications, and aviation parts [3, 4].

The key problem for the foundry is controlling grain structure, such as α-Al particle size, the morphology of metallic and non-metallic secondary phases, and the casting's porosities (gas and shrinkage). Optimising foundry practices such as proper degassing compound, melting, pouring, die temperatures, and economic variables can result in quality castings. Chemical, physical, and post-processing techniques may further improve the quality [5].

Small amounts of Na, Sr, B, and Ti are added to the melt during chemical treatment to improve the microstructure by transforming the eutectic silicon from a plate-like shape to a branching fibrous form [4]. Besides, chemical treatment needs a large-scale addition to be successful, making it a polluting practice. Physical approaches have emerged to avoid the drawbacks of chemical treatment. Friction stir casting, rheocasting, electromagnetic and ultrasonic castings involve different levels of a shearing action.

However, these approaches are not practised more often due to the complexity of the process and the equipment's high cost, i.e., superconducting magnet, magnetic coil, ultrasonic coil etc. Furthermore, they limit the shape and size of the castings [4, 5].
On the contrary, the mechanical mould vibration treatment offers a simple, practical, economic, and eco-friendly approach towards grain refinement. Therefore, it can suit industrial requirements more suitably than any other physical treatment. In 1878, Chernov was probably the first one to introduce reciprocal rocking action during steel solidification [1, 4].

Mechanical vibration can be used in two different ways: vertically and horizontally. The vertical vibration approach is more popular because it detaches columnar grains from the mould wall. Correspondingly researchers have used it for alloys and pure metals. Compared to vertical vibration, horizontal mould vibration is a less explored, robust and safe method that can also be applied to extensive castings. Therefore, for this study, the horizontal mould vibration approach was chosen to refine the morphology of eutectic silicon to enhance the mechanical properties of the alloy [5, 6].

1.3 Aim and objective

The present investigation aims to refine the microstructure of A 308 alloy *via* an indegenious horizontal mould vibration casting setup coupled with a digital power amplifier (Spranktronics Bengaluru) at three different intensity levels.

i. Low-frequency range at (2 - 10) Hz at 2.5 ± 0.5 mm.
ii. Medium frequency range at (20 - 50) Hz at 39 ± 5 µm.
iii. High-frequency range at (75 - 150) Hz at 31 ± 5 µm.

The refinement of the microstructure of A 308 alloy was achieved using horizontal vibration to fracture the dendrite structure so that a uniformly distributed structure could be achieved. Various testing techniques were applied to the cast as well as vibratory cast samples to judge their performance. The vibrated cast samples were characterized for physical, metallurgical and mechanical behaviour. For optimization purposes, the results of the low, medium, and high-frequency range vibrations were compared.