CHAPTER-1

INTRODUCTION

This chapter contains the introduction regarding the casting of aluminum alloys, techniques of grain refining and improvement in properties (mechanical and metallurgical properties) by mold oscillation during solidification of casting. Mold Oscillation is one of the most popular methods to use for degassing of molten metal and reduction of waste due to gas blow hole as compared to stationary casting. D.K.Chernov back in 1868 mentioned this approach for improving the characteristics of cast steel with vibration in the process of solidification. K.M.Korol kov and N.I .Smirnav understood the vibration of iron chill mold under industrial conditions when casting a via pistons from aluminum alloys in 1938.The mold vibration as grain refining method has been briefly described in this chapter, which is also followed by the enhancement in the property of castings, described by the overcoming of surface tension of the molten metal and as a result of promoting the flow of the melt and filling the forms. A study of the structure of metal castings, cast and solidified in a vibrating form showed that the structure is much finer and denser as compared with the structure of an alloy, obtained by casting solidified under stationary conditions. In this way, vibration can eliminate or considerably reduce the primary defects in the structure of steel, cast iron, and non-ferrous metal castings.

1.1 BACKGROUND OF THE RESEARCH STUDY

The mechanical and metallurgical behaviors of aluminum alloys components can reveal large variation even when the identical alloy is used. Best way to get maximum mechanical and metallurgical properties included molten metal quality, metal processing (modification, grain refining), suitable gating methods, filtration, directional solidification, high cooling rates and competent risering. The purpose of used experimental process is to improve mechanical and metallurgical behaviors of cast aluminum alloys.

In the casting and welding process, the as-cast microstructure is formed during the solidification. Since many casted product are used in the as cast state (without any additional mechanical and thermal processing), it follows that microstructure which results from solidification. It also follow that the mechanical properties of casting, which depends on the microstructure and controlled through the solidification process.

There is an ongoing need to reduce the cost and weight along with high strength, high toughness cast aluminum alloys .The aforesaid goal can be obtained by using grain refining technique during the solidification of aluminum casting alloy. Refining of cast structure needs the nucleation at a significant number of sites and that voluminous growth of crystal is avoided. By existing knowledge of grain refinement it may be categorized into three types such as a mechanical, chemical and thermal method.

Mechanical Method: It involves stirring of the molten metal during solidification by using mechanical, electro-magnetic and ultrasonic means. Most techniques need detailed processing. They are generally employed to semi-solid metal processing due to long processing time and high processing cost.

Chemical Method: Grain refinements by chemical method involve addition of some element improving nucleation and controlling the growth of grains. Inoculation is a common example of this method. Al-Ti-B ternary master alloys are used for to obtain fine equiaxed grain in aluminum and aluminum alloy casting. However TiB_2 agglomerates can lead to problems including damage to production of aluminum foil.

Thermal Method: Grain refinements by thermal method involve high cooling rate and variation of process parameters. We know that in both cold molds and at low superheating conditions equiaxed fine grains are obtained.

For better understanding of casting quality and properties researcher continue to develop new casting methods such as Sand, shell mold, expandable mold, and investment casting permanent mold, die and centrifugal casting. These are commonly used in industrial settings.

With high strength, cast aluminum alloys can have exceptionally high strength but suffer from a lack of ductility (very low % tensile elongation). It is hypothesized that the lack of ductility is caused by the combination of two micro-structural features; an interdendritic network of intermetallic particles and randomly dispersed microporosity. These microstructural features are caused by the solidification characteristics of these alloys.

Development of shape castings produce high strength hypo- and hyper-eutectic aluminum (Al)-silicon (Si) alloys with silicon content in the range of 6-9% and that possess nano-sized fibrous silicon morphology in the microstructure. In an Al-Si binary system, hypo-eutectic is formed with a silicon composition lower than 12.2 at% (12.7 wt%) of silicon. In the microstructure of hypo-eutectic Al-Si alloys, two major components coexist, the primary and the eutectic phase. The primary phase consists of Al containing about 1.67% Si as solid solution that exists in the form of dendrites, while the eutectic structure consists of an aluminum-rich solid solution of silicon and virtually pure silicon and that is found in between the arms of the primary Al dendrites. Typical hypo- and hyper-eutectic alloys grown by impurity-modified conventional casting exhibit a microstructure comprising of primary Si that assumes sizes of the order of 10^{-4} m and eutectic silicon with a rather course fibrous morphology of sizes of the order of 10^{-6} m. These properties of the microstructure have not provided ultra-high strength and fracture toughness for such as cast alloys. Recently a new procedure based upon the concept of the solubility of barium (Ba) in the silicon phase has demonstrated that a hypereutectic Al-17wt%-Si alloy can be produced without a primary Si phase being present.

The main objective of this study is to determine the dominant key parameters combination (Frequency, Amplitude) of the oscillatory casting experiments. Due to mold oscillation by changing frequency and amplitude can help the manufacturing industry in the scale up of the oscillatory casting technique for commercial applications. During solidification puncher of creation of huge number of nucleation site (more than stationary casting) is due to oscillation. During the solidification of castings, mold oscillation can be used for degassing and microstructure refinement and modification. The main effects of the mold oscillation processing are discussed below:

1. Mold oscillation induced degassing: During the solidification, very small tiny bubbles are created and then fracture of alloying element due to oscillation within the melt occurs. These bubbles and fracture element can act as nuclei for the formation of hydrogen and vapor bubbles. Hydrogen will escape from the liquid. So that the degassing efficiency is proportional to the frequency of oscillation.

2. Mold oscillation applied during solidification is effective in reducing the particle size of a large number of substances, and has been widely used for producing small,

uniform crystals. The insinuation of solidifying metals produces ingots that are fine-grained, dense, and homogeneous.

3. The use of Mold oscillation during the crystallization of supercooled melts results in an increased rate of crystallization, smaller crystals and an increased number of nuclei.

4. Grain nucleation: There are several ways that mold oscillation can alter grain nucleation. Since the oscillations exist in a melt during solidification, the liquidus temperature for the melt is changed. Thus, some part of the melt is superheated and the other part is under cooled. This phenomenon occurs at high frequencies and causes increase in the amount of nuclei into the melt **[9-10]**

5. Dendrite fragmentation: Dendrites usually start melting at the root due to local temperature rise and segregation. In the melt, mold oscillation produces strong convection and shock waves which may promote dendrite fragmentation. Convection can promote dendrite fragmentation because it causes local temperature and composition variations and promotes diffusion of solute. Shock waves will induce the fracture of the melting root **[11-12].**

1.2 Merits of Aluminum Alloys:

Aluminum alloys possess the advantage of opening new intricate, space-efficient design possibilities in many markets. Some of the notable advantages of the Aluminum alloys are listed below:-

i. Generally, majority of the aluminum alloy components are one-third lighter than steel

ii. All the Aluminum alloy parts & components can be recycled completely.

iii. Aluminum alloys are widely used in aerospace and automotive applications where weight savings are needed for better fuel efficiency and performance.

iv. Al-Li alloys are lightest among all Al alloys and find wide applications in the aerospace industry.

v. Aluminum can be riveted, welded, brazed, or resin bonded.

vi. Corrosion resistant - no protective coating needed, however it is often anodized to improve surface finish, appearance.

vii. Al and its alloys - high strength-to-weight ratio (high specific strength) owing to low density.

1.3 Castability of Aluminum Alloys:

Castability is the ability of an alloy to be cast without formation of defects such as cracks, segregations, pores or misruns. Alloys have fluidity, macrosegregation, hot tearing and porosity.

The most frequently used alloying element in aluminum, silicon, actually owes some of its popularity due to improvements in castability. Silicon has a maximum solubility of about 1.5wt% in aluminum and since concentrations in aluminum foundry alloys exceeds that concentrations by far (typical concentrations range between 5 and 17wt% in the 300 and 400 series alloys), silicon is normally present in its elemental form. The heat of fusion of silicon is about five times that of aluminum, therefore, it improves fluidity significantly. Moreover, silicon expands on solidification and the solidification shrinkage of aluminum; pure aluminum shrinks by 6.7% which is reduced to about 4.5% in a eutectic Al-Si alloy with 12wt% of silicon.[8].

1.4 Application of Aluminum Alloys Specially A356 and A319:

Aluminum alloy castings are economical in many applications. They are used in the automotive industry, in construction of machines, appliances, and structures, as cooking utensils, as covers and housings for electronic equipment, and in innumerable other areas. Typical applications of some aluminum casting alloys such as A356 and A319 are as under**:**

A319: Engine crankcases; gasoline and oil tanks; oil pans; typewriter frames; engine parts.

A356: Structural parts requiring high strength; machine parts; truck chassis parts, flywheel castings; automotive transmission cases; oil pans; pump bodies. Permanent: machine tool parts; aircraft wheels; airframe castings; bridge railings etc.