Effect of Mechanical Mould Vibration on the Properties of Sand Casting Aluminium (A-1100) Alloy

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***Abstract*—In the present research, the effect of mechanical mould vibrations on properties of sand casting alloys is studied. In A1100 alloy casting, it is an important and readily observable feature which determine the trouble of porosity. This process increases the quality and decreases the porosity and inner defect of moulding alloy or metal. Aluminium alloy A1100 is used for sand casting under the effect of mechanical vibration. The effect of mechanical mould vibration on hot tearing, grain size of cast and on the morphology of eutectic silicon of alloy A1100 are studied. A1100 alloy is tested on UTM machine to check its mechanical and metallurgical properties and note down any increase and improvement in these properties by comparing A1100 sand casted alloy the under effect of mechanical vibration with the A1100 sand casted alloy without mechanical vibration. The results showed improvement in characteristics and properties of alloy A1100 when mechanical vibration is applied during sand casting of the alloy. With this enhancement in quality and properties of A1100 alloy, it can be used more extensively in machinery and automobiles that can also improve cost/benefit ratio of A1100 alloy.**

Keywords— Mechanical mould vibrations, Sand casting, Alloy, Lathe Machine, UTM, Hot tearing, Porosity, and Grain Refining.

I. INTRODUCTION

Aluminium is the third most common element and the most abundant metal in the world. It comprises 8% of the earth's crust. Due to its versatility, aluminium is the most widely used metal after steel. Per year around 29 million tons of aluminium is demanded worldwide. It is commonly alloyed with zinc, silicon, magnesium, copper, lithium and manganese. Aluminium has over 300 wrought alloys in which 50 are used commonly. The various properties of aluminium and its alloys make aluminium most economical, versatile and attractive material to be used for wide range of purposes i.e. from highly ductile and soft foil to the other demanding engineering applications. Some of the properties possessed by aluminium are high thermal conductivity, resistance to corrosion, electrical conductivity, fabrication ease, lightweight and bright colour and texture [1][2].

Aluminium Alloys have a wide range of application in 'marine castings', railway coaches, motor vehicle, aircraft fittings, thin section castings, and control parts, etc. A1100 is a hypereutectic Al-Bronze alloy characterized by high wear resistance wide commercial applications. A1100 alloy is used in various high wear resistance applications such as in ring gears, engine blocks, pistons etc. The peculiar properties of Aluminium A1100 alloy which make it more versatile are-

Properties of A1100 alloy

- Light in weight
- High machinability
- High corrosion resistance
- Good conductivity
- High thermal conductivity
- Workability

Aluminium is among one of the few metals that can be cast by all processes used in casting metals. The important factor for all casting processes is feasibility quality factor and cost factor. The term quality when applied two casting refers to the degree of soundness (free from hot tearing, porosity and surface imperfections) and also the levels of mechanical properties (ductility and strength) [3]. Mostly aluminium is used in alloy form so as to increase its mechanical properties and versatility among engineering and other usages.

Metal casting is one of the most important manufacturing processes in which liquid metal is poured into the mould cavity and allow cooling or solidifying in that cavity. Among all the manufacturing process, the casting process is cheaper due to its simplified procedure. The casting quality depends on the flow behaviour of molten metal and other parameters of the process. More than 80% of products made these days use casting processes [4].

The casting temperature of aluminium alloy ranges between 649ºC – 750ºC. To estimate the corresponding pouring temperature of metal and alloy knowledge of their melting temperature is necessary [5][6]. Also, pouring temperature has a significant effect on quality of cast obtained. Lower pouring temperature than the optimum value, mould cavity will not be filled because of rapid solidification of riser this lead to the interruption in directional solidification. When pouring temperature is higher than the optimum value, it cause casting shrinkage and wrapping of mould [7][8][9] .

Modern methods for production of casting articles is done using sand moulds, die, centrifuge casting and metal mould. Peculiar microstructures are seen in castings produced using sand moulds depend upon the average shape, size and distribution of sand grains and also on alloy's chemical

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

compositions. These factors also affect the permeability, refractoriness and surface finishing of all castings [10].

Sand casting is widely used casting process in which sand moulds are used to form metal parts of complex metals made up of an alloy. Sand casting has typically low production rate because sand mould must be destroyed to obtain the casting. The molten metal is poured into the mould cavity, cooled to room temperature and then solidified and separated from the mould. The six main steps in sand casting are

- Making the pattern and placing in the sand mould.
- Proper gating system made in the mould.
- Pattern removal
- Molten metal pouring into the mould cavity.
- Mould cooling to the room temperature.
- Mould-breaking and obtaining casting.

The properties of sand used for moulding should be checked before making the mould. Different types of moulding sand are used according to cast material and its application. Mostly, natural and synthetic sands are used. According to recent techniques, mechanical mould vibration during still solidification and pouring is the important methods used to produce casting for good surface finish, decreased shrinkage and better morphology [11].Factors such as pouring temperature, mould conditions, vibration frequency and other variables of the process have the particular effect on properties and microstructure of castings [12].

Vibrations are mainly of three types- mechanical vibration, ultrasonic vibration and electromagnetic vibration. Mechanical vibration is simple one due to its easier control over its parameters. Many research employs electromagnetic and ultrasonic vibration and studies their effect on casting material and product [13-16].

Sokoloff [17] studied and mechanical vibration use for grain refinement. Cambell [18] studied that improvement in corrosion and mechanical properties of an alloy is caused by mechanical vibration. Dommaschk [19] investigate and reported the effect of vibration on pure aluminium, Alwt%SiMg alloys along with other non-ferrous alloys. He focused on the study grain refinement process and reported that the casting wall thickness dependency on characteristics of casting could be minimized using mechanical vibration. Pillai [20] used very low-frequency vibration to the study the effect on A356 and Al12Si alloy. He concluded that mechanical vibrations improve the density and elongation of the cast component

In this research, the effect of mechanical mould vibration on sand casting alloy A1100 is evaluated. The A1100 alloy is cast in the sand mould. The mechanical vibration is produced while solidification of the cast. After that, the resulted alloy is dimensionally cut and surface smoothening is done on a lathe machine. UTM machine is used to test the ultimate tensile strength and ductility. Hardness and rigidity are tested by Rockwell and Brinell test. The results of tests are noted down to check any increase in mechanical properties and characteristics of A1100 alloy when mechanical mould vibration is used during casting.

II. LITERATURE REVIEW

Aluminium is widely used engineering metal after steel and iron. It is the most commonly found metal on earth's crust [2][21]. Some of the properties of aluminium which made it widely use metal are- electrical conductivity, high light and heat reflectivity, thermal conductivity, high corrosion resistant and non-toxic. The alloys of aluminium were not available for casting purposes in any significant quantity the discovery in 1886 of the electrolytic process of reduction of aluminium oxide by Charles Martin Hall in USA and Paul Heroult in France [22]. A combination of tribological and mechanical properties and low density are offered by aluminium alloys made them highly appropriate for complex metal manufacturing. Aluminium alloys can be used for packaging purposes in food industries, pistons production, making sumps of internal combusting engines, heads of the cylinder and electrical cables [23][9]. One of the alloy of aluminium is 1100. A1100 is a hypereutectic Al-Bronze alloy characterized by high wear resistance wide commercial applications. It is also brittle in nature.

In recent times, the ability to improve and alter the properties and quality of aluminium through modern techniques have developed tremendously. These techniques include- casting, drawing, forging, welding, extrusion etc. [24].

Metal casting is processes in which liquid metal is poured into the mould cavity and allow cooling or solidifying in that cavity. Metal casting processes can be classified either by the type of mould or pattern or by the pressure or force used to fill the mould with molten metal. Often, a permanent pattern is utilized by conventional plaster, shell and sand moulds, but the mould is used only once. Permanent moulds or else known as dies are machined in metal, graphite or other specially selected die matrix material and are used for large volume production castings. Investment casting and the lost foam process involve an expendable mould as well as an expendable pattern [25].

Sand casting is the most versatile method among casting. Almost any pattern can be constrained into a fine sand mixture to form a mould into which the aluminium can be poured. This is by far the highest productivity of any casting process, and highly economical. Modifications of the process are also appropriate for small quantities, one-off and large castings and intricate designs. Some of the main advantages of the casting process can be given as follows-

- Most intricate shapes both internal and external may be cast.
- Some metals can only be cast since they cannot be shaped by other methods because of their nature.
- Construction may be simplified. A number of separate items in an assembly can sometimes be integrated to be cast as a single piece.
- Highly adaptable to mass production.
- Even very large, heavyweight metal objects may be cast that would be difficult and/or economically impossible to produce otherwise.
- Generally low cost.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

It is observed that prominent grain refinement can be obtained when the solidifying melt should be kept under the mechanical mould vibration influence for a long time ranging from 1-5 minutes [26]. During solidification of the cast, different methods have been applied to use create vibration. Electromagnetic vibration is among one of the non-contact methods used for inducing vibration in the solidifying metal [27-33]. Several other researchers have investigated the effect of vibration on the microstructure of castings [34-37]. The effects include – reduced porosity, grain refinement, fragmentation of the dendrite structure and degassing.

Pandel et al [38] described that when the amplitude of vibration increases from 1-3 mm, the average size of silicon needle reduces, for hyper and hypoeutectic eutectoid Al-Si alloys. Burbure et al [39] have described about grain refinement in aluminium casting solidified under the effect of low-frequency vibration of 50 Hz. The refinement was more noticeable with an increase in casting size and at lower initial mould temperature. Abu Dheir et al [40] have described the increase in elongation percent in the castings exposed to vibration of 100 Hz and changing the amplitude of 18-199 micron. Kadir Kocatepe [41] reported that the size and amount of pores were increased in LM25 and LM6 alloys with increasing frequencies between 15 and 41.7 Hz and amplitudes between 0.125 and 0.5 mm.

It is clear from the above literature review that mechanical mould vibration during solidification of casting material has a significant impact on mechanical and microstructure of castings. It improves the characteristics, microstructure and mechanical properties of castings.

III. EXPERIMENTAL SET UP

A. *A1100 alloy casting:* - The casting of A1100 alloy is done in sand moulds. The sand mould is prepared with the optimum grain size of sand for particular alloy depending on pouring temperature, compositions and physical and chemical properties of alloy has an ultimate effect on the quality of castings produced.

Methodology-

- A1100 alloy is heated in furnace till it changes into liquid form and reaches the temperature of 650ºC. This temperature is maintained as this is the pouring temperature of the alloy.
- The molten alloy is then poured into vibrating sand moulds in which ultrasonic vibration is produced. The vibration is produced using vibration motor in sand moulds. The mould is kept vibrating till solidification of the casted alloy. After solidification, the casted alloy is taken out from the sand mould for further processing and tests.

B. *Dimensional change and surface finishing of casted alloy pieces:-*

The casted alloy pieces are machined i.e dimensional change and surface finishing is done with the help of Lathe machine to the make specimen of A1100 alloy for testing mechanical properties.

C. *Mechanical properties test on UTM:-*

- Ultimate Tensile Strength Test- The specimen of alloy A1100 is fixed into UTM and tensile strength test is done and stress-strain readings are taken until the specimen is broken or rupture. The stress-strain value obtained from load-deformation and the σ-ε curve is plotted.
- Ductility Test- Ductility of the alloy is also tested in UTM and measured during tensile strength test. It is the percentage elongation of alloy until it fracture while doing the tensile test in UTM.

(a) (b)

Fig. 1. (a) UTM machine showing sample specimen of A1100 tested for tensile and ductility. (b) Specimen of alloy A1100 before mechanical test on UTM.

IV. RESULT AND DISCUSSION

A. *Sand mould and vibration effects result analysis:-*

(i). Sand Mould effect- Selection of optimum grain size of sand for preparing sand mould is a critical factor which influence the quality of castings produced. The selection of sand grain size depends upon the composition, pouring temperature, type of metal and required surface finish of casting. Specification of moulding sand for particular casting material avoid casting related problems like permeability, surface roughness, burn in and burn on.

(ii). Vibration Effect- Vibration when applied to sand casting during solidification of alloy played important in improving quality of cast. The results show decrease in porosity, hot tearing, degassing, and reduction in pipe formation and solidification time of the casted alloy.

- It is also observed that dendrite coherency point of alloy tend to shift towards lower temperatures.
- The vibrations applied during sand casting of alloy resulted in reduced equivalent grain diameter D max that lead to increase in grain refinement and compactness of alloy particles that gives more hard and rigid casted A1100 alloy product.

B. UTM test result and analysis:-

(i). Ultimate Tensile Strength Test- The resultant tensile strength for the specimen of casted alloy A1100 after testing on UTM is 0.267 MPa. Also, stress- strain curve is plotted by values of stress-strain obtained during the test.

(ii). Ductility Test- The resultant percentage elongation i.e ductility obtained after testing specimen of casted A1100 alloy in UTM is 1-2%.

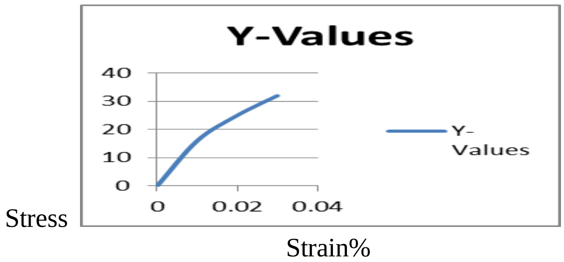

Fig. 2. Stress-Strain Curve obtained from tensile test.

The above results is compared with A1100 alloy which is sand casted without vibration showed increase in tensile strength and ductility of the A1100 alloy when it is casted under mechanical vibration. The increase in elongation percentage showed that brittleness of A110 alloy is decreased. This showed that mechanical vibration while sand casting of A1100 alloy improves its mechanical properties.

C. Hardness analysis:- Vibration during sand casting of alloy A1100 result in grain refinement which lead to compactness and increase in hardness of alloy as compared to A1100 alloy casted without vibration.

*All the results are analysed after comparing the sand casted A1100 alloy under the influence of mechanical vibration with the A1100 alloy, sand casted without mechanical vibration.

V. CONCLUSION

The effect of mechanical mould vibration on casting characteristics of Al-based alloys was evaluated. Aluminium alloy A1100 is chosen to the study the effect of mechanical vibration on hot tearing, grain refinement, and mechanical properties and on the morphology of eutectic silicon of A1100 alloy. It is found from results that mechanical mould vibration has a significant effect on sand casting and in improving the mechanical and chemical properties of A1100 alloy during casting. The following conclusions are drawn from results-

- Mechanical mould vibration during casting of A1100 alloy showed a decrease in porosity, hot tearing, and solidification time and pipe formation.
- Mechanical vibration while solidification of casting showed that dendrite coherency point shift towards lower temperature and increase in the grain refinement and compactness result in improved rigidity and hardness of A1100 alloy.
- The UTM test of A1100 alloy casted under the effect of vibrations showed an increase in tensile strength and ductility of the alloy.
- When A1100 alloy casted in sand mould and vibration is applied, the surface imperfections decreases results in good surface finishing and smoother surface and also decrease in corrosion of alloy.
- Finally, it is concluded that mechanical vibrations during sand casting of A1100 alloy have a significant role in improving the mechanical and metallurgical properties and characteristics of the alloy as compared to the alloy casted without mechanical vibration. This leads to using of this alloy more effectively and readily in machinery and automobiles industries.

VI. FUTURE SCOPE

- Carry out more tensile tests with different alloys and castings conditions to compare bifilm index change with mechanical properties. A valuable target would be the establishment of a map between bifilm index and RPT density, showing the contours of strength and ductility.
- Study on the effects of modifiers (such as Sr, Mg etc) on oxide structure and pore morphology under reduced pressure test.
- Re-processing of the RPT test results obtained from the thesis and with the data that is going to be collected from the future tests, a statistical technique will be used to analyse RPT results in order to find out how many samples should be taken from a melt to get a reliable assessment of the quality of the melt.

VII. ACKNOWLEDGEMENT

I take this opportunity to express my sincere thanks & deep gratitude to all those people who extend their wholehearted co-operation and have helped me in completing this dissertation successfully. The satisfactions that accompany successful completion of this work would be incomplete without mentioning the people who made it possible.

With great honour, I wish to express my sincere appreciation to my HOD, Prof. (Dr.) Ravish Srivastava for his excellent, patient guidance, infinite suggestions and help throughout this research work.

I am also very grateful to my guide Er. Sandeep Katiyar, (Assistant Prof. Mechanical Engineering Department) for his valuable guidance, advice and comments to complete this dissertation.

I would also like to show my gratitude to the Principal, Professor (Dr.) Bikas Prasad, Chhatrapati shahuji subharti Institute of Technology & Engineering for the support and research facilities available in the college.

I also wish to extend thanks to my Co-ordinator Assistant Prof. Kuldeep singh pal & Associate Prof. Anil kumar, and other colleagues for attending my seminars and for their insightful comments and constructive suggestions to improve the quality of this research work.

I am extremely thankful to librarian, lab in charge & workshop member for providing me infrastructural facilities to work in, without which this work would not have been possible.

I would like to wish thanks to the all faculty member of mechanical engineering department & administrative staff and technicians in the college for their valuable help. Sincere thanks are also extended to all the lab assistants for their assistance in handling the equipment in the workshop.

I also would like to record my gratitude to my colleague and others for their support and encouragement. Last but not least, I also would like to express my deepest gratitude to my parents for their unconditional love, patience, and understanding and support through the study.

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