INVESTIGATE THE EFFECT OF ADDITIVES ON MECHANICAL PROPERTIES DURING CASTING OF 6351 ALUMINIUM

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Abstract. Aluminum is one of the significant and widely used metals in the manufacturing industries. The effectiveness of casting processes depends upon various process parameters like type of sand, moulding process and additive used. However, the additive in the sand plays important roles to make a perfect casting. Hence, in this research work the experiment were performed to investigate the effect of additives like Tamarind Powder, Starch Powder and Coal dust on the Mechanical Properties namely during casting of aluminium alloys.

Keywords:- Coal dust, Tamarind Powder, Starch Powder, Tensile Strength, Hardness

1 Introduction

Every product which presents in this universe is going through some manufacturing process. Casting is one of the most important manufacturing processes. While casting liquid material is usually poured into the mold cavity of the desired form and then allowed to solidify. The thickened section is also known as a casting. Casting materials are metals or various cold setting materials that cure after mixing two or more components together. Casting is mainly used for making intricate shapes that would be otherwise difficult or too expensive to make by other methods.

The casting process is carried out on almost every metal, but aluminium is widely used metal during casting due to its wide range of applications in the manufacturing industries. Many of the household products made of aluminium. The aluminium alloys are used to produced in hundreds of compositions by all commercial casting processes while the casting such as green sand, dry sand, composite mold, plaster mold, Investment Casting, Permanent Mold, counter-gravity, low-pressure casting, and pressure dies casting.

Aluminium metal in the real stage is too soft for such uses, and it does not have the high tensile strength. The pure aluminium is mixed some other metal to made alloys. The aluminium alloys have excellent mechanical properties such as high strength, low density, durability, machinability, which is required in the manufacturing industries. Aluminium alloys are used in advanced applications due to their combination of availability and relatively lower cost as compared to other competing materials.

Aluminum alloys are used in numerous applications in which the blend of high strength and low weight is attractive in airframe in which the small weight can be a significant value. Many from of aluminium alloys are used in the manufacturing industries, But aluminium 6351 is widely used because of light weight and superior oxidization resistance. Its thermal and electrical conductivity is four times greater than steels. It has superior strength amongst the 6000 series alloys. Alloy 6351 is also known as a structural alloy and is most frequently used for manufacturing purpose. There is much application of Aluminium 6351 i.e. used for the construction of the ship, rail & road transport, column, rod, mould, pipe, tube, vehicle, bridge, crane and roof. It used because of its excellent surface finish. One of the major applications of Al 6351 in the aircraft industries to make aircraft structures due to its high strength to weight ratio and outstanding corrosion resistance.

Aluminium is going through the different manufacturing process, but casting is the main manufacturing process. There are many process parameters which affect the properties of final casted products. But the additives presents in the sand are significantly impact the final casted products. Therefore, in this research work, an effect of different additives in the sand was investigated during casting of aluminium 6351 alloys.

2 Previous Works

The casting of aluminum alloys was carried out by the different process. But the properties of final casted products are affected by many process parameters. Some researchers have tried to improve the properties aluminium by the addition of metals different metals like magnesium, zinc. In this research, the detailed study is carried on the effect of magnesium and zinc on

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mechanical properties of aluminium.There is massive information available on the theoretical and experimental work related to the effect of magnesium and zinc on mechanical properties of aluminium which is discussed as under. Davis et al. (1999) investigated that Magnesium provides substantial strengthening and improvement of the work-hardening characteristics of aluminium and can impart good corrosion resistance, weldability, extremely high Strength. Silicon combines with magnesium forms the hardening phase Mg2Si that provide the strengthening. Aluminium alloys are significant due to a combination of high strength to low weight property (Krishna et al. 2013). Al 6351 castings have light weight and good corrosion resistance to air, water, oils and many chemicals. The thermal as well as the electrical conductivity of Al 6351is also four times greater than steel (Kishore et al. 2010). Mechanical properties of the material can be easily calculated with tensile tests, with high accuracy (Reddy et al. 2014). The aluminium alloys are used in the manufacturing of boats, columns, chimney, rods mould, pipes roofs due to ease of workability and weldability (Ibrahim et al. 1997). Gas Cylinder made of Al 6351 investigated for crack phenomena and often found prone to crack at various tensile residual stresses (Prince and Ibrahim, 2003). A metallurgical anomaly known as Sustained load cracking, develops in 6351 aluminum alloy high-pressure cylinders (Durmus et al. 2006). Zalticonin et al. (2003) studied the effect of magnesium content on the properties of Al-Cu-Mg alloys. The changes in chemical composition cause changes in the structure and properties of hardness, tensile with increased amount of magnesium for the same content of titanium in the alloy. Compression and hardness increase with the content of magnesium and titanium. Gubicza et al. (2004) studied the effect of Mg addition in the microstructural evolution, and mechanical properties of high-purity aluminium were investigated over a broad range of strain, up to ~8. The high strains were achieved by applying the equal-channel angular pressing technique.In the early stages of plastic deformation, the interaction between the dislocations and the Mg solute atoms results in an increase in the flow stress with temperature. The stable microstructure is developed at higher strains owing to the Mg addition resulting in the saturation of the proof stress at higher strains in Al–Mg alloys. Dobrzański et al. (2007) published the effect of cooling rate on the size of the grains, SDAS, the size of the β precipitation and characteristic thermal results of AC AlSi9Cu cast alloy. According to the X–ray phase analysis, the investigated AC AlSi9Cu alloy cooled wit solidification rate: 0,16, 0.48 and 1.04 ºC composed of two phases. The diffraction lines of the Si-phases do not reveal such intensity. Based on the X–ray phase analysis was found, that change of solidification rate do not influence the phases composition of investigated alloy. The X-ray phase analysis does not reveal occurring of Al2Cu, AlFe5Si and Al8FeMg3Si6 phases, what suggested that the fraction volume of these phase is below 3%. Dong-yan et al. (2010) investigated the effect of Zn content on tensile and electrochemical properties of 3003 Al alloy. The effect of Zn addition on the microstructure, tensile properties and electrochemical properties of as-annealed 3003 Al alloy was investigated. Authors found that high-density precipitates are observed in the Zn-containing alloys and the alloy with 1.8% Zn addition also has rod-like precipitates. The alloy with 1.5% Zn addition has the maximum ultimate tensile strength. Adeosun et al. (2011) presented the effect of separately adding Cu and Zn on the mechanical properties of 6063 aluminium alloy has been examined

Sand cast samples of an an aluminium alloy containing Cu/Zn (0-20 vol %) and homogenized at 5100C for 1hr are analyzed for ultimate tensile strength (UTS), hardness, elongation and impact energy. The addition of more than 15 vol % Zn to structural aluminum alloy raised its hardness and elongation. Copper additions above 4 vol % lowered the UTS, elongation and impact energy. However, the hardness increases with percent addition of Cu. The addition of zinc to structural aluminum will improve the homogeneity of the matrix. The impact energy and hardness of the matrix are enhanced when Cu addition is within 2-4 vol %. Agraval et al. (2012) aimed at studying the effect of varying the composition of Magnesium on the mechanical properties like strength and hardness in an Aluminium-Zinc-Magnesium alloy. Sand casting was used for the purpose of the project and testing was done on the samples for determining the resultant mechanical properties. Girisha and Sharma (2012) investigated the influence of magnesium on microstrructural changes and mechanical properties such as tensile strength and hardness of the Al4Cu alloys. The modifications of Al4Cu by adding Mg of 0.5 to 2 % in the interval of 0.5% mixing with stirrer and casted by gravity die casting, subsequently the specimens were subjected T6 type heat treatment for 5 hr at 175oC. The effect of Mg and ageing on microstructure was studied by using optical microscope with image analysis software for measuring grain size and dendrite arm spacing. The mechanical properties such as tensile strength and hardness were investigated using universal testing machine and Brinell hardness tester respectively. The micro-structural analysis result shows the 2 % addition of Mg reduces the 20% grain size and 21.52% dendrite structure. The tensile strength and hardness increasing with % of Mg. The addition of 2% Mg increases tensile strength 57.9% and hardness of 25%. Aging specimens showed that 1% of Mg influence more on grain refinement and mechanical properties due to smaller the grain size[8]. Rana et al. (2012) reviewed on the influence of alloying elements on microstructure and mechanical properties of aluminum alloys . Alloying elements are selected based on their effect and Suitability. Silicon lowers the melting point and increase the fluidity(improve casting characteristics) of Aluminum. Magnesium provides substantial strengthening and improvement of work harding characteristic of aluminium alloy. It can impart good corrosion resistance and weldability or extremely high strength. Copper has a greatest impact on the mechanical strength and hardness of aluminum casting alloys, both heat treated and not heat treated and at both ambient and elevated service temperature. It improve the machinability of alloys by increasing matrix hardness. Nickel (Ni) enhances the elevated temperature strength and hardness .It is concluded that selection of alloying element depends on the use of materials requirement. Qiaoling et al. (2012) solved the problems which are encountered in the process of experiment study of materials under tensile impact, and its influence factors are discussed in detail. So the issues in the test have been summarized for the purpose of increasing the ability to analyze and solve and improving the exploring spirit of scientific experiments. The article takes the example of yield strength, and the yield point marks the resistance of trace plastic deformation of metal materials which make the ability of the materials express adequately. The materials tensile mechanical properties of the influence factors were acquired in the article from some reference material and analysing the problems in practical work experience. Atanda et al. (2012) investigated the effects of bentonite and starch binders on foundry moulding sand. The two binders were binders were applied separately to silica sand in different proportions and also as a mixture in various proportions as well. Tataram and Nanjundaswamy (2013) studied the evaluation of green sand mold properties has been carried out using various additives. Additives are plays critical role on the green sand mold is to enhance specific mold properties. Here Olivine sand has been used for mold purpose. The properties such as compression strength, permeability and collapsibility have been studied, comparison has made with different additives. By conducting a number of iterations finally, the 7% by volume of water was found the optimal value for the bonding sand and 8% of clay by weight it gives the real bonding strength for the mold.In varying the percentages of additions at 1% of additives the maximum strength was found. Thomas et al. (2014) performed the comparative study of the properties of Aluminium alloy (LM6-12%Si) castings in sand casting and Evaporative pattern casting (EPC) process. Thermocouples are used to measure the temperature of the casting during solidification.The comparative examination was performed, and it is concluded that there is no significant change in mechanical properties. It is possible to assure the viability of adopting the EPC process to an existing conventional acting process to produce Al-Si alloys. The EPC process has advantages of other casting methods, for high production of complex sharp parts he patterns are cheap and easy to manufacture. These are free of lines and extra angled. It is possible to reuse the sand nature.

Hence, from above past work, it is observed that the addition of magnesium and zinc to aluminum can enhance the properties of aluminum. However, still there is a need to investigate the effect of some additives in moulding sand on the mechanical properties during casting of aluminium alloys.

3 Experimental Detail

Use For the casting aluminium, 6351 is selected as materials. Sand used for casting having silica 78-80%, bentonite –14-15%, moisture – 6-7%. For making moulds for casting a split pattern of cylindrical shape, runner, riser of taper shape are used as shown in Figure 1.

Figure 1. Split type pattern

During the experimentation tamarind powder, starch powder and coal dust are used as additives. To prepare moulds for casting, 25 kg of sand for each mould is taken with additions of different additives in various proportions. Mixing of various additives with sand takes place in mixture sand machine. The different percentage of additive used in mold making process as shown in

Table 1 Proportion of additives is on weight of sand.

Additives	Percentage	Total weight of sand
Tamarind powder	1%,3%,5%	25kg
Starch powder	1%,3%,5%	25kg
Coal dust	1%,3%,5%	25kg

10 moulds are made i.e 3 moulds each of 3 different additives and 1 normal mould without any additives .Equal ramming is applied on every mould. Moisture content in each mould is same.only the additives percentage changes in every mould.

3.1 CASTING

Aluminium alloy has been melted in oil fired tilting furnance who can each upto maximum temperature of 1000 degree Celsius. Aluminium whose melting point is 700 degree Celsius can easily melted in it.we took 15 kg of aluminium alloy and being melted in this furnace and it take 2 hr for complete melting.

Melted aluminium is poured in different moulds and being left for cooling for about 2-3 hr.Solidified casted specimen are taken out of moulds and are being aged for 3 weeks before being taken for testing.

Figure 2. Oil fired tilted furnance

4 Results and Discussions

The casting of the aluminium 6051 alloys is carried out with different percentage of additives. The effects of different additives during casting were analysed in terms of mechanical properties namely hardness and tensile strength of the casted specimen.

4.1 Analysis of Hardness

The Rockwell hardness tester was used for measuring the hardness of casted specimen. The variation of hardness with different percentage of additive is as shown in Figure 2.

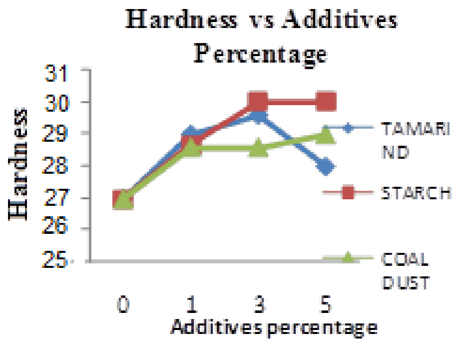

Figure3. Variation of hardness with percentage of additives

Starch additives having finer grain size gives lesser strong bond between sand particles but with increase in starch percentage, its sand holding ability increases i.e give strong bonding which ultimately increases the hardness of aluminium alloy. Tamarind additive due to its lesser fine grain particle bond making capacity increases from 1% to 3% and it gives increase in hardness of aluminium alloy but when percentage increases to 5% its holding capcity increase on the other hand permeability decreases which decreases the hardness of aluminium alloy. Coal dust also follows the same sequence but give less hardness of aluminium alloy as compared to other additives in sand.

4.2 Analysis of Tensile Strength

The Universal testing machine was used for measuring the tensile strength of casted specimen. The variation of tensile strength with different percentage of additive is as shown in Figure 4.

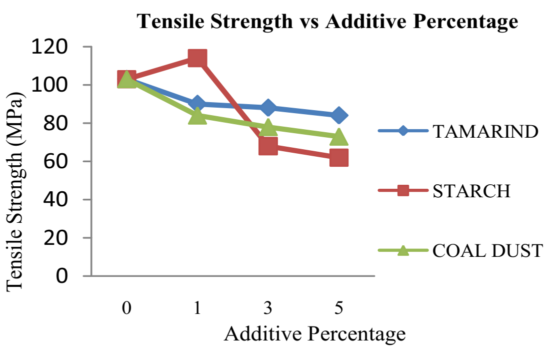

Figure4. Variation of Tensile Strength with percentage of additives

Starch additive at its 1% content in sand increases the compressive strength of mould which increases the tensile stress of aluminium alloy but when starch content increases compressive strength or permeability decreases which reduce tensile strength of aluminium alloy to lower value. Tamarind and coal dust additive in sand result in enough compressive strength of mould but drops the aluminium alloy tensile strength. This may be due to the less fine grain size of tamarind powder or coal dust ability to trap the produce gases during pouring of aluminium alloy.

Conclusions

- The addition of additives in the sand during casting enhanced the hardness of aluminum alloy. Starch powder affects the hardness of aluminum alloy to a great extent as compared to other additives.
- On the other hand additives, addition in sand decreases the tensile tension of the aluminum alloy. Only the starch having a percentage of 1% in sand mould gives the highest value of tensile tension according to the test reports.

References

1. G G Krishna, P R Reddy, and M. M., Hussain Experimental Investigation of Tensile Strength and Deflection Characteristics of Friction Stir Welded Aluminum AA 6351 Alloy Joint, IOSR Journal of Mechanical and Civil Engineering, **7** (5) 2013.
2. K Kishore, P V G, Krishna K Veladri, and G K Kumar., Analysis of Defects in Gas Shielded Arc Welding of AA 6351 Using Taguchi Methods, International Journal of Applied Engineering Research, **5** (3) 2010.
3. M V N Reddy, M N Reddy, K V Kumar, P Garre., Experimental Investigation of Tensile Strength on Al 6351 to The Aerospace Structural Applications, International Journal of Mechanical Engineering and Technology (IJMET), **5** (2) 2014.
4. H K Durmus, E O Zkaya, C Meri, The Use of Neural Networks for The Prediction of Wear Loss and Surface Roughness Of AA 6351 Aluminium Alloy, Materials and Design **27**, 2006.
5. R N Ibrahim, Y C Lam and D Ischenko, Predictions of Residual Stresses Caused by Quenching Process in Aluminium 6351- T6 Gas Cylinder, International Conference on Fracture, ICF 9-Sydney, Australia 1997.
6. J.W.H. Price and R.N. Ibrahim. Cracking in Aluminum Gas Cylinders: A Review of Causes and Protection Measures, Practical Failure Analysis, ASM International, PFANF8, **3**(6) 2003.
7. J. R Davis, Corrosion of Aluminum and Aluminum alloys, Ohio, Internatinal. ASM 1999.
8. B Zlaticanin , S Duric , B Jordonic, B.Radojic, Journal of mining and metallurgy , **39**(3- 4),2003.
9. J Gubicza, N Q Chinh, Z Horita, T.G. Langdon, Material Science and Engineering 387-389,2004.
10. L.A. Dobrzañski, R. Maniara, J.H. Sokolowski , Archives Of Material Science and Engineering **28** 2,2007.
11. ZHU Mei-jun, DING Dong-yan Effect of Zn content on tensile and electrochemical properties of 3003 Al alloy Transition of non ferrous metal society china 20,2010.
12. S.O Adeosun , S.A. Balogun , L.O. Osoba , W.A. Ayoola , A.M. Oladoye , Journal of modern manufacturing technology **3**(1) 2011.
13. H.N Girisha., K.V. Sharma , International Journal of Scintific and Engineering Reasearch, **3**(2) 2012.
14. R.S. Rana, R Purohit, S Das, International Journal of Scientific and Reaserch Publications , **2** (6) 2012.
15. L. agrawal, R. yadav and A. Sexena, Effect of magnesium content on the mechanical properties of al-zn-mg alloys, International journal on emerging technologies **3**(1) 2012.
16. L. F. Mondolfo, Aluminum alloys: Structure and Properties, London, Butterforts ,1976.
17. M. Qiaoling, Y. Yong, Wang Qianfeng, International Conference on Education Technology and

Management Engineering Lecture Notes in information Technology, **16-17,** 2012.
18. Atanda, Olorunniwo, Alonge, Oluwole, International Journal of materials and chemistry **2**(4) 2012.
19. K. Tataram, H.M.Chavan, N. Swamy, International Journal of Research in Engineering & Advanced Technology, **1** (4)