Study of the Mechanical Properties of Aluminium-Silicon-Iron Alloy

B. N. Pathak*, Anant Kuchhal, Shubham Aggrawal and Mukesh
Department of Mechanical Engineering
IMS Engineering College, Ghaziabad, India.
* bnpathak2007@rediffmail.com

Received: *02.04.2018,* ***Accepted:*** *05.05.2018*

Abstract

The paper deals with the manufacturing process through gravity casting which leads to a better grain size and good quality of casting. Generally, the silicon are not evenly distributed in the casting. Therefore, stirring casting were used for uniformly distribution of the grain. In the present investigation, gravity die casting were made for different composition of Al, Si and Fe in Sand, steel and copper mould and then their microstructure, strength, hardness & % elongation were studies. It was found from the experiment that grain size was finer in copper mould casting whereas the grain size was found coarser in sand mould casting when compared with copper mould casting. It may be due to fast cooling rate of casting in copper mould. When the percentage of silicon increases, the hardness of the alloys improves and it was again further improved by the variation of mould system from sand moulding to copper moulding. Therefore, the hardness of the aluminium alloys depends on percentage of silicon and the types of moulding used. As the cooling rate increases in copper moulding, hardness also improves. The strength of the alloys increases with increasing of silicon percentage and the value of the percentage elongation is comparatively lower when the percentage of Silicon is increased. Therefore, ductility properties of the alloy is gradually decreased when Silicon % increased.

Keywords – Al-Si-Fe alloys, Sand & Copper Mould, Grain Structure, Strength, Hardness, Ductility.

Introduction

Al-Si alloys are attractive as a substitute for cast iron in automobile and engineering applications due to their light weight, good strength-to-weight ratio, and high strength at higher temperature. These alloys also possess good thermal conductivity, excellent castability, good corrosion and wear resistance properties. Further, cold working and alloying can increase their strength. Thererefore, these alloys have best suitable application in the field of aerospace, military and automotive industry. Some authors has developed 12% silicon & used 6 to 10 % silicon alloys in thier studies through the spray casting method (Ojha *et al.*, 2008). The uniformity of the mixture may be increases as the silicon percentage increases. Thus the result of the properties of the aluminium alloys increases. The grain size of silicon may be refined in hypereutectic aluminum-silicon alloys by addition with phosphorus-bearing element in the melt but this is not effective when silicon percent increases more than 25% (Krishtal *et al.*, 2004). One another approach for refining of silicon particle size is spray forming process which gives uniform, finer structure and less segregation of grains. Al-Si eutectic alloys have low thermal expansion properties therefore these alloys are used for piston hence it is referred as piston alloy (Haque *et al.*, 2001). The alloys can be considered to be metal matrix composites, with the silicon essentially a particulate reinforcing phase in the metal matrix. Mechanical properties can also increase by modification treatment of Al-Si alloys by adding antimony, sodium and strontium. On modification, the silicon phase changes into fine and fibrous structure which gives good result and mechanical properties improves (Kara *et al.*, 2007). In composites materials, the secondary phases are distributed in the metal matrix as reinforcement materials. Mostly the metal matrix composite materials are used which possesses higher strength, hardness. The reinforcement metal matrix offers potential for improvement in efficiency, mechanical performance and reliability over the new generation alloys (Mary *et al.*, 2009). Aluminium metal matrix composites (MMCs) are attractive materials in the mechanical, automotive and aerospace industry, mainly for their light weight, thermal conductivity, energy efficiency, wear-resistant properties. Wear properties and friction of these materials are very important (Nikolaev *et al.*, 1977). It was also observed that higher amount of reinforcements increased the transition load for severe wear. It has been observed by many researchers that the volume fraction of reinforcement has more effect on wear properties. The properties of metal matrix composite material for modified Al–12% Si alloy had been studied by many researchers. Antimony were used as a modifier to change the properties of Al-Si alloys.

Since there is lot of data on traditional alloys & composite materials are available in the literature therefore, researchers are seeking for new materials to be used (Nikolev *et al.*, 1977). Magnesium were used as a modifier in aluminium alloys to change the grain structure from coarser size to finer size and favourable compact forms of phases and there by improves the mechanical properties which can be used for higher temperature application (Sahoo *et al.*, 2001).

Aluminium-silicon alloys possess several advantages on other systems. At the same time Al–Si alloys can have appreciably high strength characteristics at good parameters of crack and corrosion resistance. Despite these positive qualities Al–Si alloys have a limited practical use because of the low thermal stability. Owing to better properties of the aluminium alloys, it is most demanding materials to use for different application in recently. Aluminum alloys are second most available material used only to steel in terms of volume of production over other nonferrous metals in this regard.

On the basis of the literature survey 12% silicon alloys was studied through the spray casting method. Therefore, in the present study Aluminium alloys were developed with different percentage of Silicon through the stirring casting and conducted their microstructure & mechanical properties for Sand Mould Casting, Steel Mould Casting & Copper Mould casting. It was also compared the properties of Aluminium alloys with each other's and existing alloys.

Preparation of Alloys

Aluminium, Silicon & Iron element were used for the experiment; three different compositions of Aluminium and Silicon has mixed for three different stage of casting. Aluminium and Silicon percentage are (a) 80% Al & 20% Si (b) 85% Al & 15% Si & (c) 90% Al & 10% Si. The percentage of iron was kept fixed (0.2%) for all experiment. Due to the higher melting point of Silicon and lower melting point of Aluminium both alloys are not directly melt in one furnace, thus Silicon & Aluminium were melted in separate furnace, then both molten material added together to maintaining fluidity of the Silicon at high temperature. The molten metal is properly mixed with steel rod due to that temperature losses are occurred so for maintaining the fluidity and viscosity of mixture and casted on three different stages. After solidifying the casting material, samples were prepared for the investigation of mechanical properties.

There were three set of molds used for experiment. They are as follows

a. Sand Mould
b. Steel Mould
c. Copper Mould

Sand Mold: After the preparations of the green sand, Sand mould was formed with help of Cope, Drag, Riser, Runner, and Wooden pattern of size 205 mm length and 38 mm diameter in the foundry shop, three molds was made for each experiment.

Steel Mould & Copper Mould were prepared with plain steel and Copper for the size of 205 mm in length and 25 mm in diameter and mould was kept in the green sand bed and formed gating system with green sand for pouring of alloys. For melting Aluminium and Silicon alloys, crucible furnace were used and then the molten materials were poured into three different mould to prepare the samples. At first, aluminium were cut into small pieces and then it was charged to furnace for melting and then it was kept into holding furnace where degassing was done using argon gas.

Table 1: Percent of alloying elements of Test Specimen

Type of Casting	Silicon %	Iron %	Aluminium %
Sand Casting	(20 % Silicon)	0.20	Rest
	(15 % Silicon)	0.20	Rest
	(10 % Silicon)	0.20	Rest
Steel Casting	(20 % Silicon)	0.20	Rest
	(15 % Silicon)	0.20	Rest
	(10 % Silicon)	0.20	Rest
Copper Casting	(20 % Silicon)	0.20	Rest
	(15 % Silicon)	0.20	Rest
	(10 % Silicon)	0.20	Rest

After the casting of the all grade it was observed that the finishing of the copper mould alloys was better than among all. Different samples were prepared from all the castings for different test. The entire tests were conducted to examine of microstructure and mechanical properties.

Microstructure Examination

The specimen was cut into small sample for microstructure examination. Initially the samples were polished with an emery paper from coarser range to finer one. It was then followed by cloth polishing with alumina powder. Finally, samples were etched using kellers reagents which contains HCl and HNO_3 in distilled water. Now the samples were examined under optical microscope. The microscopic structures of the samples are shown in figure 1,2 &3.

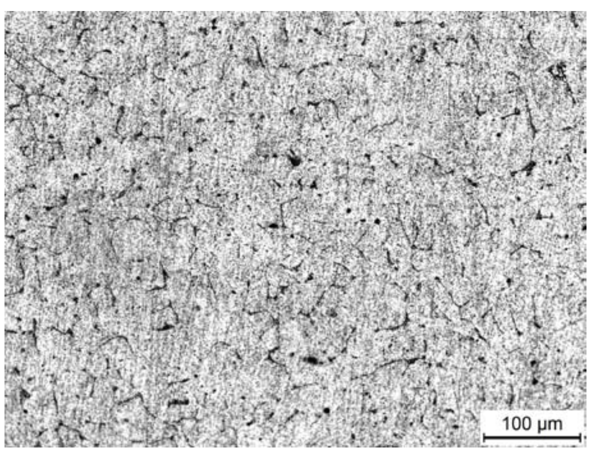

Figure 1: Optical microstructures of Al-Si-Fe alloy of Copper Mould

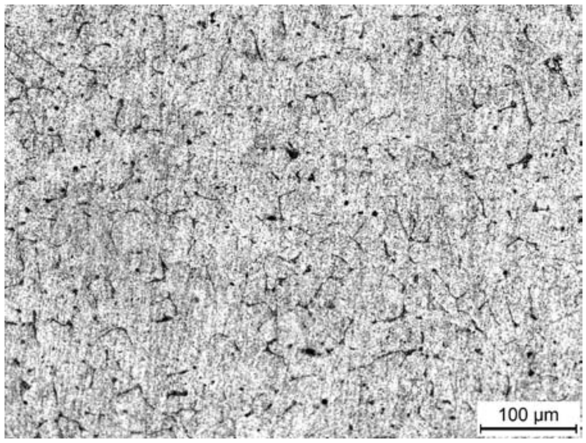

Figure 2: Optical microstructures of Al-Si-Fe alloy of Steel Mould

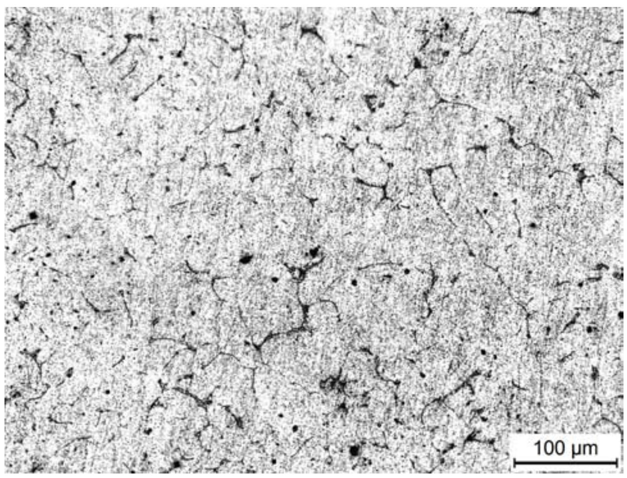

Figure 3: Optical microstructures of Al-Si-Fe alloy of Sand Mould

On the basis of microstructure examination, it was found that grain size was finer in copper mould casting whereas the grain size was found coarser in sand mould casting when compared with copper mould casting. It may be due to fast cooling rate of casting in copper mould.

Hardness Test

Hardness was measurement of the resistance of a metal to plastic deformation. Hardness is the surface property which may be defined as the ability of the material to resist permanent deformation or indentation when it is subjected under external load. The hardness was measured on Brinell Hardness machine for different samples. The observations of hardness on Brinell hardness test of the all specimen are shown in table 2. Indenter size was kept 1.5mm and load was applied 110 Kgf during the testing.

Table 2: Hardness of Test Specimen

Mould Used	Silicon %	Iron %	Hardness(HRB)
Copper	20	0.20	94
Steel	20	0.20	64
Sand	20	0.20	58
Copper	10	0.20	53
Steel	10	0.20	49
Sand	10	0.20	41

It was observed from the above table that when the % of Silicon increases, the hardness of the alloys improves and it is again further improved by the variation of mould system from sand moulding to copper moulding. Therefore, the hardness of the aluminium alloys depends on percentage of silicon and the types of moulding used. As the cooling rate increases in copper moulding, hardness also improves.

Ultimate Tensile Strength Test

The standard specimens were prepared for tensile test. The round specimens were made as shown in figure 4. Universal testing machine (UTM capacity of 1 ton) was used for testing the strength of the materials as shown in figure 5. Testing was performed to find out tensile strength and % elongation on UTM machine. The tested samples of UTM are shown in figure 6.

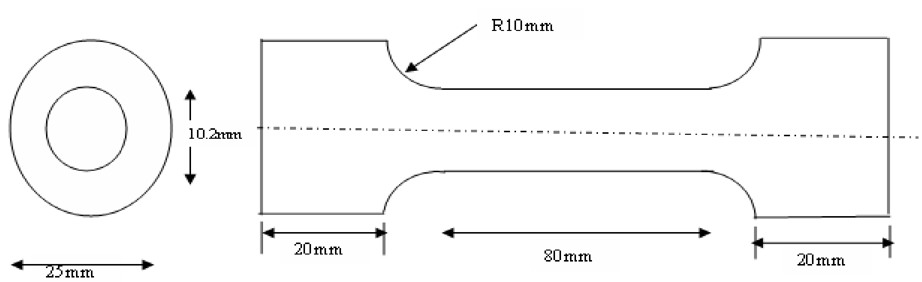

Figure 4: Tensile Test Specimen

Load was gradually increases on the specimen. Throughout the test, control system and its associated software were used to measure the load and elongation of the specimen. The ultimate tensile strength, yield strength and percentage elongation was examined on the UTM Machine.

Figure 5: UTM Machine

The following specification was used for the test

Holding Diameter 16mm

Total Length	80mm
Gauge diameter	12mm
Load Scale	0.02 N
Gauge Length	60.00 mm

Figure 6: Tested sample of UTM

The observation were recoded from the testing is given in table 3.

Table 3: Observation of UTM

S.No	1	2	3	4	5	6
Mould Used	Copper	Steel	Sand	Copper	Steel	Sand
% of Silicon	20	20	20	10	10	10
% of Iron	0.20	0.20	0.20	0.20	0.20	0.20
Yield Strength N/mm^2	86	83	48	80	75	41
Ultimate T. strength N/mm^2	158	152	90	139	128	81
%Elongation	1.30	1.50	1.56	1.70	1.95	2.60

It was observed from the above table that when the % of Silicon increase, the strength of the alloys increases and the value of the % elongation is comparatively lower on increasing of silicon percentage. It is also clear from the above table that strength improves much when cooling rate increases as shown in copper moulding compared with sand moulding. Therefore, once again we can say that strength of the aluminium alloys depends on percentage of silicon as well as the types of moulding used. It is evident from the above experiment that ductility properties of the alloy are gradually decreased when Silicon % increased.

Conclusion

The effects of silicon percentage on mechanical properties of Al-20%Si-0.2Fe, Al-15%Si-0.2Fe & Al-10%Si-0.2Fe alloy of copper, steel & sand mould casting have been studied. Based on Mechanical testing & examination conducted of the specimen, the following conclusion can be drawn

1. On the basis of microstructure examination, it was found that grain structure and grain size was better in copper mould casting. It may be due to fast cooling rate of casting in copper mould.
2. Hardness of the specimen was improved as silicon percentages in Aluminium alloy increases while brittleness also increases at higher percentage of silicon.
3. Ultimate tensile strength of all the alloys improved as compared to base aluminium alloys. UTS also increases as silicon percentage increases while % Elongation decreases with increase in silicon %.
4. Hardness and strength are poor in sand mould casting when compared with copper mould casting while the percentage elongation was better in sand mould casting.

References

Fridlyander, I.N., Grushko, O.E., Sheveleva, L.M. 2004. Aluminum alloys heat hardened alloy v1341 for cold pressing of sheets. *Metallovedenie i Termicheskaya Obrabotka Metallov*, 9(1), 3-7.

Haque, M.M., Sharif, A. 2001. Study on wear properties of Al-Si Piston alloy. *Journal of Materials Processing Technology*, 118(1), 69-73.

Karaaslan, A.K., Kaya, I., Atapek, H. 2007. Effect of aging temperature and of retrogression treatment time on the microstructure and mechanical properties of alloy 7075. *Metal Science and Heat Treatment*, 49(1), 9 -10.

Krishtal, M.M. 2004. Effect of structure of aluminum-silicon alloys on the process of formation and characteristics of oxide layer in micro arc oxidizing. *Metal Science and Heat Treatment*, Volume 46(9), 20-25.

Makarov, G.S. 2002. Production of aluminum alloys status and prospects. *Metallurgist*, 46(11-12), 335-339.

Maruyama, K., Suzuki, M., Sato, H. 2002. Creep strength of magnesium-based alloys. *Metallurgical and Materials Transactions A*, 33(3), 875-882.

Mary, C., Mogne, T., Beaugiraud, B., Fouvry, S. 2009. Tribochemistry of a Ti Alloy Under Fretting in Air: Evidence of Titanium Nitride Formation. *Tribo Lett*, 34(1), 2009, 211-222.

Nikolaev, V., Markov, G.A., Pshchevitskii, B I. 1977. A new phenomenon in electrolysis. *Izv. Sib. Otd. Akad. Nauk SSSR, Ser. Khim. Nauk*, 5(12), 22-38.

Ojha, K.V., Tomar, A., Singh, D., Kaushal, G.C. 2008. Shape Microstructure and Wear of Spray formed hypoeutectic Al-Si alloys. *Material Science and Engineering Journal*, 487(1), 591-596.

Sahoo, K.L., Sivaramakrishnan, C.S., Chakrabarti, A.K. 2001. The Effect of Mg Treatment on the Properties of Al-8.3Fe-0.8V-0.9Si Alloy. *Journal of Mater. Processing Tech.*, 112(1), 6-11.