The Influence of Strontium On the Hardness and Impact Strength of Eutectic Al-Si+1.0% Manganese Alloy

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ABSTRACT: *This paper studies the effect of strontium on the hardness and impact strength of aluminium-1.0%manganese-12%Si alloy. Aluminum and its alloys are gaining a wider industrial importance because of their physical and mechanical properties which includes high specific strength, high wear resistance, high temperature strength and controlled thermal expansion coefficient. In this research, strontium was added at various compositions to the percentage of silicon present in the alloys (12% of Si; 0.02-0.03% of Sr) and 1.0% manganese which serves as a modifying agent). A calculated mass of the aluminum and silicon were melted and cast as cylindrical ingots. Hardness and impact test were carried out using charpy impact test machine for impact test and Rockwell hardness testing machine (ASTM E18-11) used to measure the hardness test. The results showed that the addition of strontium to eutectic Al-Si alloy modifies the Al-Si eutectic morphology with significant improvement in mechanical properties of the alloy.*

KEY WORDS: strontium, aluminum alloy, eutectic alloy, impact strength, hardness.

INTRODUCTION

Aluminum becomes the common structural material because of following properties: light weight, ease of fabrication and machinability, high resistance to atmospheric corrosion, good thermal as well as electrical conductivities, high metallic luster and its non magnetic and non-sparking in nature[2]. Al-Si alloy is an important class of aluminum die-casting alloys having wide ranging applications especially in the automotive industry, as well as, the aerospace industry. Aluminium is mostly demanded in automobile industry because the thrust of materials research is directed at the design of smaller and/or lighter components which can reduce fuel consumption and running costs though not at the expense of quality and environment [3]. Aluminum alloys are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear and seizure resistance, high stiffness, better high temperature strength, controlled thermal expansion coefficient and improved damping capacity. Aluminum-Silicon alloys are of greater importance to engineering industries as they exhibit high strength to weight ratio, high wear resistance, low density, low coefficient of thermal expansion etc. Al-Si alloys allow complex shapes to be cast; however, the silicon forms brittle needle-like particles which reduce impact strength in cast structures. One of the main reasons for using these alloys to make high-quality castings is eutectic modification, which was accidentally discovered by Aladar Pacz in the 1920's while using an alkali-fluoride treatment in Al-Si melts. This treatment results in a considerable improvement in mechanical properties, especially elongation by altering the form of the silicon which is a major constituent of these alloys and plays a significant role in determining the mechanical properties of the alloys.

The use of cast aluminium alloys is still limited in comparison with wrought alloys, even though casting would be a more economical production method. Apart from the emerging economical processing techniques that combine quality and ease of operations, researchers are, at the same time, turning attention to modifying aluminum-silicon matrix and isotropic properties, especially in the applications not requiring extreme loading or thermal conditions, for example automobile components [4]. Silicon forms brittle needle–like particles which reduce impact strength in cast structures. The finger-like structure formed acts as stress raisers that initiates and propagates cracks thereby reducing the mechanical strength of the alloy. Again, there are many naturally occurring impurities in commercial aluminium which can only be removed at great cost. Iron is probably the most important detrimental impurity in cast aluminium and its alloy degrades mechanical properties such as fracture toughness. A very effective way of enhancing the stability of aluminium-silicon alloy utilization in the industry is to improve the mechanical properties such as structurally sound and dimensionally accurate Al-Si castings and fabricated products at reduced cost. The key to achieving the improvement of properties is to understand the structure-property-application relationship of the aluminium-silicon alloy additives. Also, better quantitative understanding of the microstructure-property relationships in cast Al alloys coupled with improved foundry practice will allow wider application of reliable castings in low mass structures. The essence of adding modifiers to Al-Si alloys is to improve strength, enhance mechanical properties and disperse porosity and shrinkage as they modify the eutectic structure [1]. . Addition of some modifiers in Al-Si cast alloys have been found to improve mechanical properties considerably, especially the ductility [5]. The improvement in mechanical properties generally has been attributed to the variations of the morphology and size of the eutectic silicon phase particles. It is worth noting, however, that at the same time when eutectic silicon particles change from acicular to fiber, the amount, morphology and size of dendritic α-Al phase are varying too

MATERIALS AND METHOD

The materials used for alloy preparation, casting of test bars and testing are: aluminium, silicon, manganese, strontium, Weighing machine, Mild steel pot (fabricated) and laboratory size tungsten-arc electric furnace for melting. Four different compositions of alloys were produced with amounts of strontium varying from 0·02-0.03 wt%.Before casting, sample A which was the control sample was anaylsed chemically to ascertain the composition and after the casting the samples were also analysed chemically to ascertain the effect on the alloys as observed in Table 1. Those compositions were melted in a bailout crucible furnace separately in alumina crucible and thereafter crucible was removed from the furnace and was followed by addition of the modifier.

These crucibles were taken back to the furnace and furnace temperature raised from 750°C to 800°C because the modifiers were not made to melt but to form intermetallic phase in the alloy The techniques to follow for the experiments are:

i. Pattern making/Moulding
ii. Casting/Preparation of samples
iii. Machining
iv. Characterization and testing

Samples	% Si	% Mn	% Sr	% Fe	% Al
Sample A	11.54	1.0	0.02	0.78	Bal
Sample B	11.55	0.92	0.024	0.73	Bal
Sample C	11.55	1.01	0.026	0.60	Bal
Samples D	11.58	1.00	0.028	0.55	Bal
Sample E	11.56	1.00	0.03	0.48	bal

TABLE 1: CHEMICAL ANALYSIS OF THE ALLOYS

RESULTS AND DISCUSSIONS

The table and graph below shows the result of effects of manganese and strontium additions on the hardness and impact strength of Al-12%Si alloy. Table 2 and Figures 1 and 2 showed the hardness and impact strength that was carried out on the treated alloys.

Sample	hardness	Impact strength
Sample A	53.5	2.3
Sample B	61.3	2.5
Sample C	59.6	2.9
Sample D	62.2	2.6
Sample E	60	3.0

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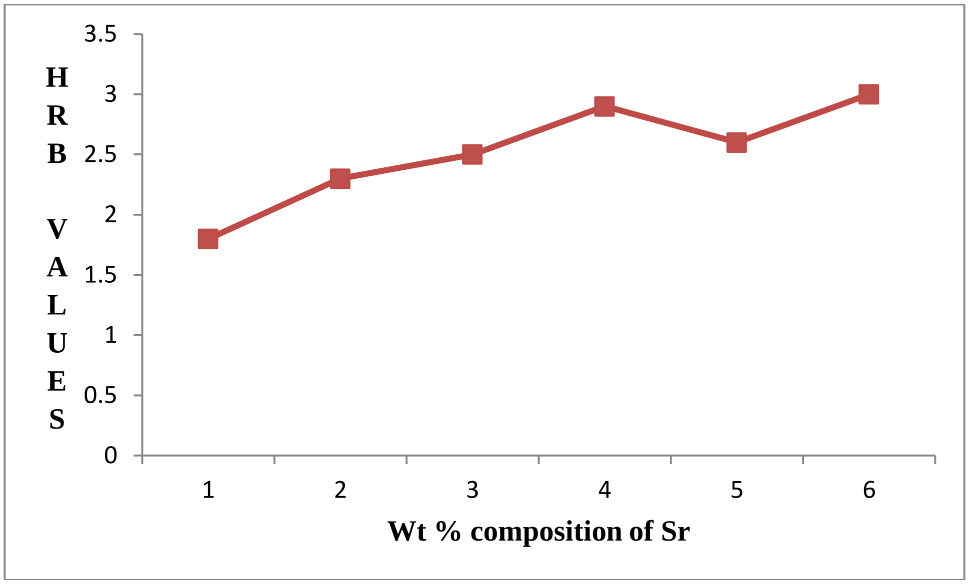

Figure 1: Effect of Sr on the hardness of Al-12%Si alloy

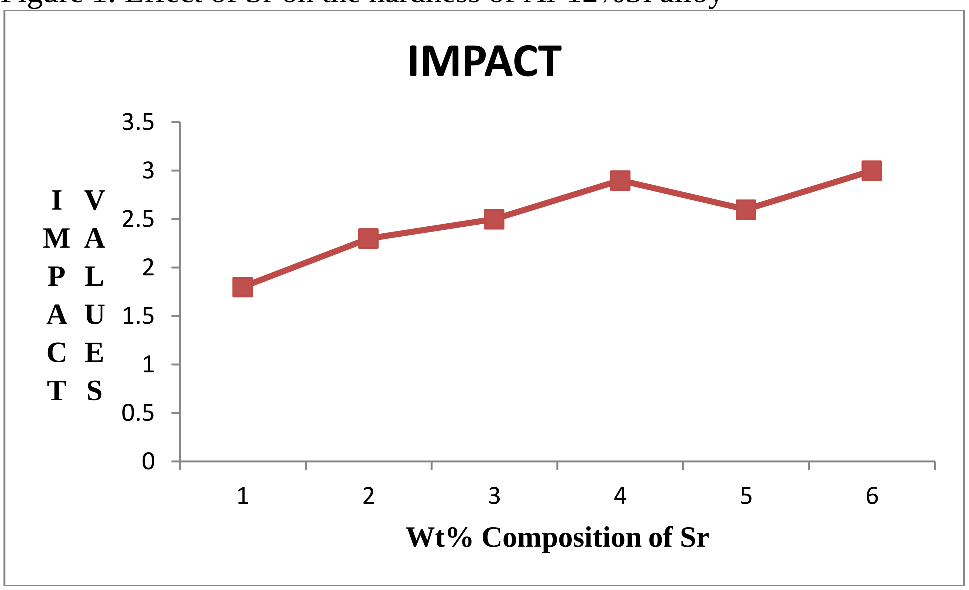

Figure 2: Effect of Sr on the impact strength of Al- 12%Si +1%Mn alloy

DISCUSSION

The addition of Sr increases resilience and durability of the material up to the point 0.028wt% when addition of Sr tends to decrease the material strength in term of impact load. Figure 2 shows the effect of the addition of Sr on the impact strength. The addition of Sr to Al-12%Si alloy increases its fracture energy 2.3 Joule to 2.6 Joule and 3.0 joule. On the other hand, the addition of 0.028Sr tends to decrease the fracture energy of Al-12%Si alloy to 2.1 Joule not withstanding that it equally increased the fracture energy when there was no addition of strontium to the alloy. However, the effect appears to decline as soon as the addition exceeds the 0.026% level which shows negative effect to the mechanical properties because of the presence of some compounds like Al_4SrSi_2 and releases of brittle Al_3SrSi_3 phase are bound to set and coarsening of the eutectic silicon can occur which will reduce the properties of the alloy causing them to revert to values more typical of unmodified material.

CONCLUSION

The results from this research work have clearly explained the following facts; that a low level of strontium addition reduces porosity in the alloy by modifying the eutectic Si morphology from acicular to fine fibrous form with improved hardness and impact strength. It was also established that fine distribution of silicon particles in the alloys improved the structural and mechanical properties of the Al-Si alloys and finally.

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