Effect of Modification on the Structure and Mechanical Properties of Aluminium-12% Silicon Alloy

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Abstract - This paper examines the influence of cobalt, magnesium and sodium fluoride on the mechanical properties of aluminium-12%silicon alloy. In this research, cobalt and magnesium were used as modifying elements at three different ratio while sodium fluoride was used as a refining element, 1.0%, 2.0%, and 3.0% of cobalt and magnesium were added in the melt while sodium fluoride was added at a compositions to the percentage of silicon present in the alloys (1% of Si: 4% of NaF). These alloys were produced by melting a calculated mass of the charged aluminium and silicon, and subsequently the additives were added to the melt, which were cast into cylindrical ingots from which mechanical and microstructure examination were conducted. The Tensile, hardness and impact strength test were determined using universal testing machine and microstructure examination was done using metallographic microscope. The results of the mechanical properties test were analyzed using analysis of variance (ANOVA), which confirms that these additives are significant and improves the mechanical properties of this alloy.

Keyword - Effects, structure and mechanical properties, Aluminium-Silicon Alloy.

1 INTRODUCTION

Aluminium-Silicon alloys are the most commonly used alloys in the automotive, defence and aerospace industries mainly because of their high strength to weight ratios, better castability and good surface finish [10]. They also present good wear resistance and high welding characteristics. The alloys are also less prone to shrinkage, hot cracking and porosity when compared to other aluminium casting alloys such as Al-Cu alloys. Structural components made from aluminium and its alloys are vital to the areas of transportation and structural buildings [1]. Eutectic alloy composition of Al-12%Si is widely used for casting because of its high fluidity and castability [7]. Iron is the main impurity in eutectic aluminium silicon alloy and efforts should be made to keep it as low as tolerable, because of its deleterious effect on strength, ductility and corrosion resistance. Structural modification can be achieved using various additives [4]. It is known that cobalt, manganese, molybdenum, sodium chloride and sodium fluoride had been used to modify the structure of Al-Si alloys [16]. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. Corrosion resistance is also often greatly reduced by aqueous salts, particularly in the presence of dissimilar metals [8]. Castings are the main use of aluminium-silicon alloys, although some sheet or wires are made for welding and brazing. The low thermal expansion coefficient is exploited for pistons and the high hardness of the silicon particles for wear resistance. The maximum amount of silicon in cast alloys is within of 22-24%Si, but alloys made by powder metallurgy may go as high as 40-50%Si [11]. Earlier work on aluminium-silicon alloys states that sodium or strontium produces the refinement and phosphorus nucleates the silicon to enhance a fine distribution of the primary crystals [2]. In sand castings and permanent mould castings the upper limit is usually 0.6-0.7%Fe. In some piston alloys, iron may be added deliberately and in die-casting up to 3%Fe may be tolerated. Cobalt, chromium, manganese, molybdenum copper and nickel are sometimes added as correctives for iron thereby improving strength at high temperature [5]. Copper is added also to increase the strength and fatigue resistance without loss of castability, but at the expense of corrosion resistance. Magnesium, especially after heat treatment, increases substantially the strength, but at the expense of ductility. Zinc is a tolerated impurity in many alloys, often up to 1.5-2% because it has no substantial effect on room temperature properties [3]. Titanium and boron are sometimes added as grain refiners, although grain size in these alloys is not too important because the properties are mainly controlled by the amount and structure of the silicon, as affected by refinement produced by sodium calcium or phosphorus additions [9]. A distinction between dissolved and graphitic silicon is sometimes made by dissolving the alloy in acids, in which case the dissolved silicon transforms into SiO_2 whereas the graphitic remains uncombined [14]. Prolonged or repeated heating tends to spherodise faster in modified alloys and results in a coarsening of the silicon to a size very close to that of non modified material. Castings are the main use of aluminum-silicon alloys, although some sheet or wires are made for welding and brazing. Magnesium and manganese when added to Al-12.5%Si alloy improve the strength, fluidity and resistance to corrosion [15]. An improved fluidity enhances the surface finish of the casting [14].

2 Experimental Procedure

Materials used for this research are: aluminium, silicon, cobalt, sodium fluoride, magnesium, beakers, electronic weighting balance, and microscope. Seven different compositions of alloys were produced with amount of Co, Mg and NaF varying from 1% of Fe present in the alloy to 1.0% of the additives up to 3.0% of additives, i.e. 1.0%, 2.0%, and 3.0%. The control sample (A) was chemically analyzed to ascertain the composition and after the casting the samples were also chemically analyzed to ascertain the effect on the alloys. The seven compositions were melted in a bailout crucible furnace separately, with the addition of the respective modificator [6]. Thereafter, the crucibles were removed from the furnace and refinement with sodium fluoride followed. The modificators were added according to the percentage of iron present in the eutectic alloy because the aim is to reduce the iron content hence the iron contained phases [12]. The casting then followed after which the cast samples were machined according to ASM standard for tensile, hardness and impact test specimens and micro structural examination were taken.

3 MECHANICAL TEST

This was carried out to assess numerically the fundamental mechanical properties of strength, hardness, impact resistance, ductility etc. To determine the surface or sub- surface defects (flaws) in raw materials or processed parts and the performance of a material for a particular application. These tests were carried out at standard organization of Nigeria (SON), Enugu, Tensile strength test was done using universal tensile testing machine, Brinel hardness test was carried out by indenting the specimen and this method is the best for achieving the bulk or macro-hardness of materials particularly those materials with heterogeneous structure and charpy test for impact strength.

4 RESULT AND DISCUSSIONS

4.1 Results

The results of the chemical composition of the alloy is presented in table one while the results of the modification with Mg, Co and NaF additions on the structure and mechanical properties of Al-12%Si alloy are presented in table 2 and figures 1&2.

Table 1: Chemical composition of the treated alloys

S/N of Samples	% of Si	% of Fe	% of Co	% of Mo	% of NaF	% of Al
AL-12%Si	12.08	2.5	0.23	0.56	0.032	Bal
Al-12%Si+ 1.0%Co	12.02	1.1	2.5	0.34	5.0	Bal
Al-12%Si+ 2.0%Co	12.04	0.8	5.0	0.24	5.0	Bal
Al-12%Si+ 3.0%Co	12.01	0.3	7.5	0.27	5.0	Bal
Al-12%Si+ 1.0%Mg	12.09	1.4	0.02	2.5	5.0	Bal
Al-12%Si+ 2.0%Mg	12.06	0.9	0.06	5.0	5.0	Bal
Al-12%Si+3.0%Mg	12.07	0.6	0.089	7.5	5.0	Bal

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Table 2; Result of Mechanical properties of the Alloys containing Co and Mg

Samples	Tensile	Hardness	Impact	% Elongation
Al-12%Si	106	98	8.5	9.8
Al-12%Si+ 1.0% Co	125	112	9.3	7.8
Al-12%Si+ 2.0%Co	140	121	10.5	6.3
Al-12%Si+ 3.0%Co	161	132	11.9	5.3
Al-12%Si+ 1.0%Mg	112	101	8.8	8.2
Al-12%Si+ 2.0%Mg	121	118	9.4	7.2
Al-12%Si+ 3.0%Mg	136	123	10.5	6.3

Table 3; Result of mechanical properties of the Alloys containing NaF

Samples	Tensile	Hardness	Impact	% Elongation
Al-12%Si+ 1.0%Co + NaF	116	112	8.5	9.8
Al-12%Si+ 2.0%Co +NaF	135	122	10.3	7.8
Al-12%Si+ 1.0%Mg +NaF	110	111	8.5	6.3
Al-12%Si+ 2.0%Mg +NaF	121	118	8.9	5.3

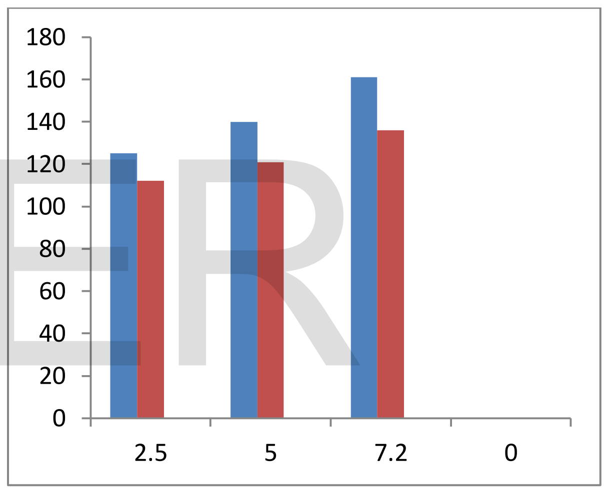

Figure 1.0: Effect of composition on the Tensile strength of Al-Si alloy

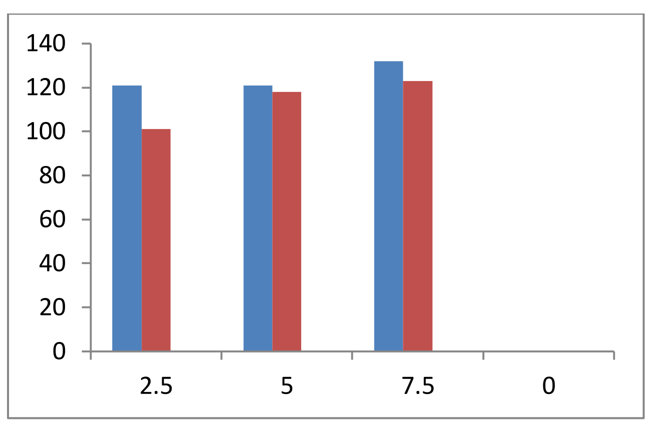

Figure 2.0: Effect of composition on the Tensile strength of Al-Si alloy

4.2 DISCUSSIONS

The mechanical properties like tensile strength, hardness and impact strength improved as the amount of additives increased in the alloy. The same is true for sodium fluoride. The mechanical properties of the alloy improved further when sodium fluoride was added in the alloy. The modifiers modified the structure of the iron-containing compounds while the sodium fluoride refines the structure of the precipitating silicon. Figures 1&2 have shown that with simultaneous addition of Mg, Co and NaF to the Al-Si alloy system, the mechanical property of the alloys improves.

5 MICROSTRUCTURAL EXAMINATION

Figures 3 and 4 show micrographs of treated Al-12%Si alloy. It is observed that the addition of manganese and sodium chloride to the eutectic alloy significantly modified the structure of the iron-containing brittle compounds and refined the plate-like structure of the eutectic silicon crystals thereby improving the morphology of the crystals.

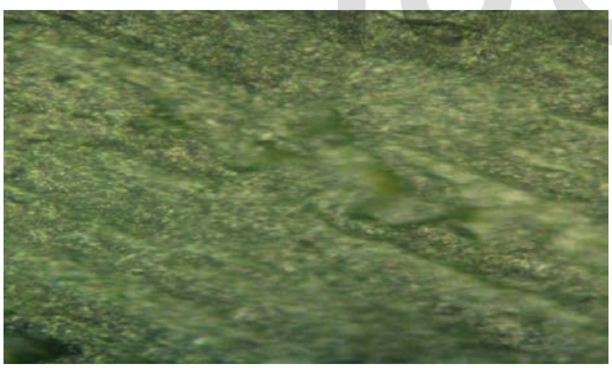

Figure 3: Al-12%Si alloy + Co X 400

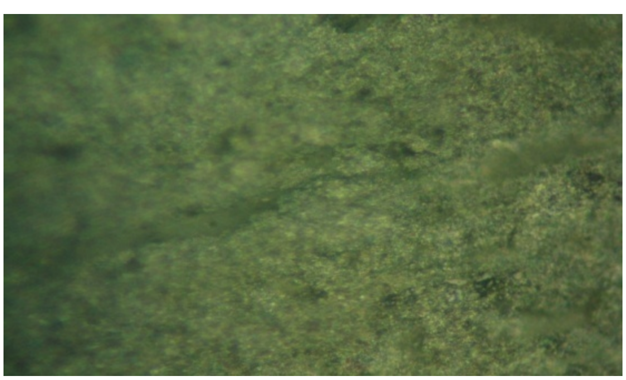

Figure 4: Al-12%Si alloy + Mg X 400

6 CONCLUSION

The effect of additives on the structure and mechanical properties of Al-12%Si alloy has been investigated. The universal tests that were carried out have helped to determine the mechanical and physical properties of th e alloy when modified with different concentrations of magnesium, cobalt, and refined with sodium fluoride. The results from this work have clearly shown that;

- The effect of the modifiers on the mechanical properties depends on the concentration of the modifying elements. This was confirmed by the effects of the variation of the composition of the modifying elements.
- There is a general improvement of mechanical properties with increase of magnesium, cobalt and sodium fluoride percentages in the alloys.
- This set of aluminum alloys can now be applied in production of radiators, air conditioning condensers, evaporators, heat exchangers and associated piping systems.

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