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Structural Modification of Aluminium-Manganese-Silicon Alloy with Sodium Fluoride

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ABSTRACT: *This paper examines the effect of sodium fluoride on the structure and mechanical properties of aluminium-3.6%manganese-12%silicon alloy. Aluminium and its alloys have been identified as an important and useful engineering material. It is attracted by its various unique properties; such as appearance, strength-to-weight ratio, excellent thermal properties, workability properties and good mechanical behaviour. In this research ,manganese was used as modifying element while sodium fluoride was used as a refining element and 3.6% of manganese was added in the melt while sodium fluoride was added at various compositions to the percentage of silicon present in the alloys (1% of Si: 0.5, 1.0, & 1.5% 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 strength and percentage elongation were determined using TUE-C- 100 Model universal tensile machine while chemical composition analysis was conducted using chemical analyser and microstructure examination was done using metallographic microscope. The results showed that the mechanical properties like tensile strength and ductility improved with fine distribution of silicon particles in the alloys results from the increase concentration of sodium fluoride.*

KEY WORDS: *aluminium, silicon, manganese, sodium fluoride, tensile strength, elongation.*

I. 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 [1, 6]. They also present good wear resistance and high welding characteristics. These alloys are also less prone to shrinkage, hot cracking and porosity defects 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 materials [13].In addition to chemical composition, the structural and mechanical properties of alloys depend on many factors that act during solidification. Important factors are the structure of the melt, the crystallization rate, and the temperature gradient at the liquid–solid interface [10]. As a rule these factors are varied simultaneously, giving rise to contradictory information on the structure and mechanical properties of Al–Si alloys. Thus, for example, the yield stress was published to increase or decrease with increasing content of Si. In order to investigate the influence of the Si content on structure and mechanical properties, it is necessary to prevent contamination by impurities from the crucible and the environment, to maintain constant the superheating of the melt, to have a constant and rather high cooling rate, and effective mixing of the molten alloy [8]. The size and shape of eutectic Si in hypoeutectic Al–Si alloys and of primary Si in hypereutectic Al-Si alloys have a great effect on the final mechanical properties of the manufactured parts. The modification of the Si morphology from flake-like to fibrous form was believed to greatly improve the mechanical properties. Therefore, the modification of eutectic Si in Al–Si alloys has been widely investigated since the first modification phenomenon was discovered by Pacz in 1920, Al–15 wt-%Si alloy was stirred in a sodium fluoride flux and a remarkable increase in the mechanical properties was achieved [7]. The modification of the eutectic Si in hypoeutectic Al–Si alloys is normally achieved in two different ways: by addition of certain modified elements (chemical modification) or by rapid solidification (quench modification) although ultrasonic vibration and electromagnetic field were also reported to refine the eutectic Si [12].Aluminium and its alloys have been identified as an important and useful engineering material. It is attracted by its various unique properties; such as appearance, strength-to-weight ratio, excellent thermal properties, workability properties and good mechanical behaviour [3]. However, to obtain special mechanical properties of aluminium product, some nucleants are essential in a melt. From reviews, it is evidenced that proper casting is aimed at yielding sound and defect –free products.

The soundness of every cast product can be achieved by grain refining agent (chemical grain refinement) and vibration of melt [2]. High solidification rate occurs when the rate of heat extraction exceeds the latent heat of solidification and this is considered to refine grains and enhance the material's strength and other mechanical properties [11]. Cast aluminium alloys are mostly grain refined by adding mixtures of some essential elements to enhance and impact some important characteristics, [9]. Aluminium is non-combustible, non-toxic and non-absorbent. At present the output of aluminium by volume is greater than that of other non-ferrous metals [4]. The ductility of aluminium in hot state enables almost any cross-sectional shape to be extruded easily. Addition of some elements to aluminium improves its properties, for example aluminium is most commonly extruded in the alloyed form. The resistance of aluminium to corrosion is influenced by some elements and their percentages by weight alloyed to aluminium. Silicon is added to improve liquid fluidity in aluminium while copper improves its mechanical properties. Structural modification can be achieved using various additives. It is known that cobalt, manganese, sodium chloride and sodium fluoride had been used to modify the structure of Al-Si alloys [5].

II. EXPERIMENTAL

Materials used for this research are: high purity aluminium, silicon, manganese, sodium fluoride, beakers, electronic weighting balance and microscope. Four different compositions of alloys were produced with amounts of NaF varied from 1% of Si present at the alloy to 0.5% of the NaF up to 1.5% of additives, i.e. (1:0.5, 1:1, and 1:1.5) and before the casting the control sample (sample A) were chemically analyzed to ascertain the composition and after the casting the samples were also chemically analyzed to ascertain the effect on the alloys as observed in Table 1. These four compositions were melted in a bailout crucible furnace separately in Alumina crucible and a thereafter crucibles were removed from the furnace and was followed by addition of manganese and sodium fluoride. The manganese was added according to the percentage of iron present in the alloy while sodium fluoride was added according to the concentration of silicon in the alloys. These crucibles were taken back to the furnace for half an hour and furnace temperature was raised from 750^{o}C to 800^{o}C because these additives were not made to melt but to form intermetallic phase in the alloy. These cast samples were machined according to ASM standard for tensile strength and percentage elongation and micro structural examination were taken. Table 1 shows the chemical composition of treated alloys.

Table 1: Chemical composition of the treated alloys

Samples	% Si	% Mn	% NaF	% Fe	% Al
Sample A	11.94	3.57	-	0.36	Bal
Sample B	11.74	3.48	6.23	0.31	Bal
Sample C	11.21	3.41	12.43	0.28	Bal
Sample D	10.79	3.37	18.76	0.25	Bal

III. MECHANICAL TEST

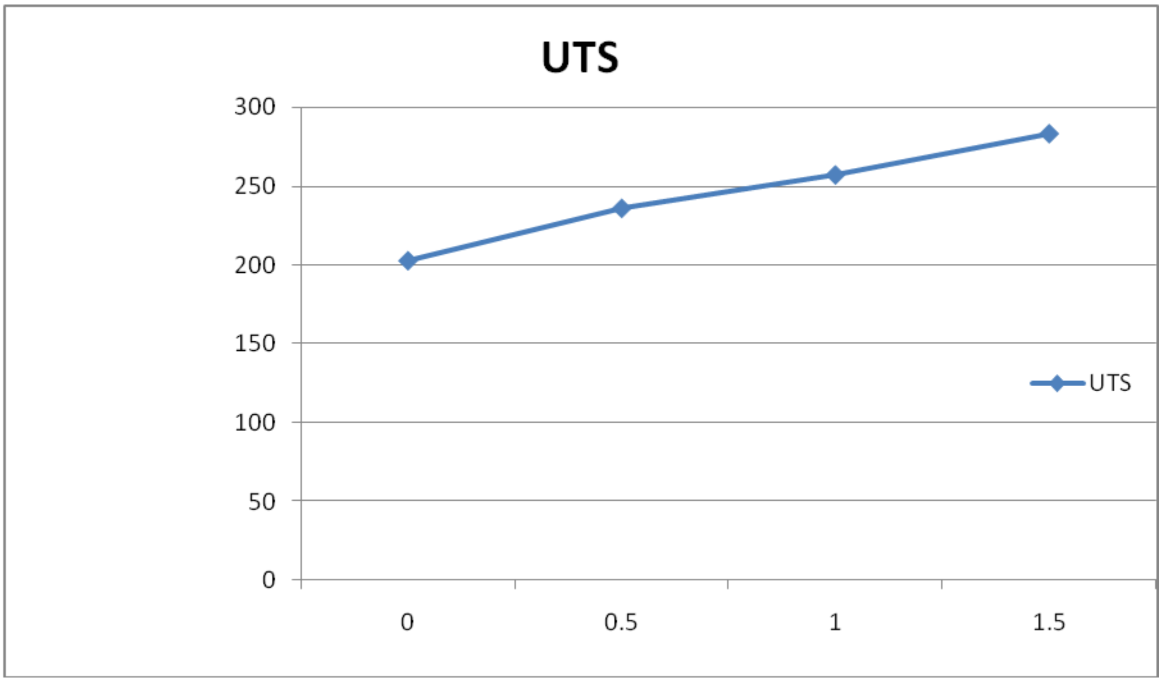
Mechanical testing was done to examine the effects of these additives on the mechanical properties of these treated alloys; to provide data for use in the design of engineering structures, to determine whether a particular sample conforms to the properties assumed in its design and to determine the responds of materials to forces and loads.

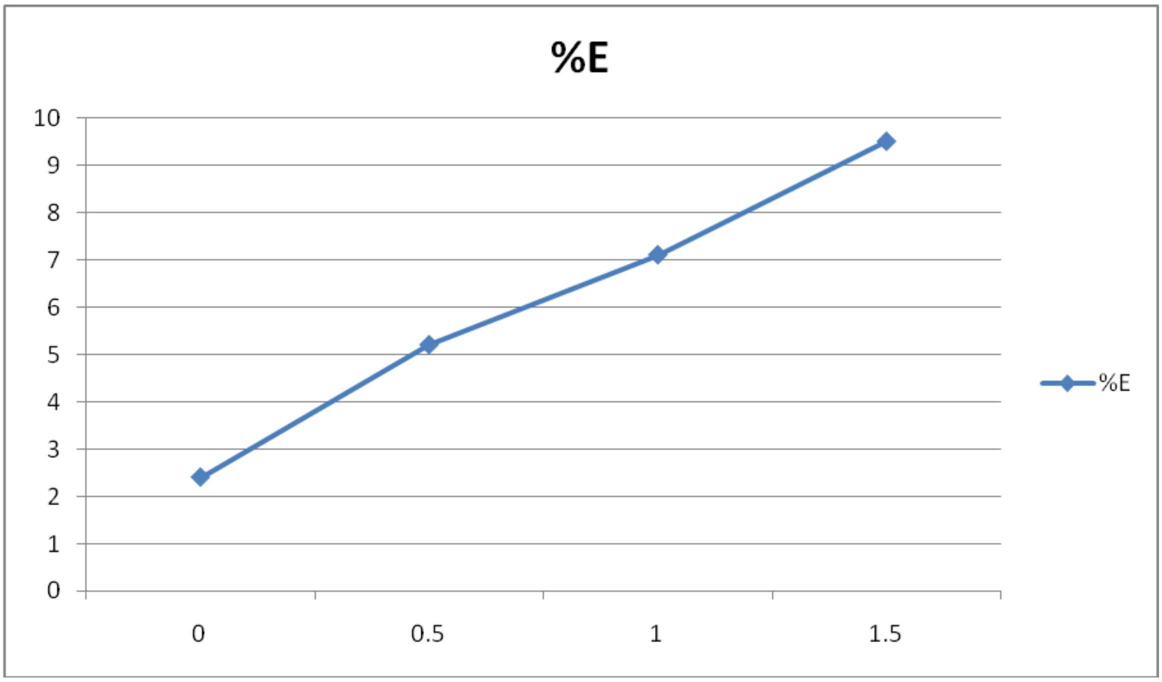
IV. RESULTS

The results of the effect of manganese and sodium fluoride additions on the structure and mechanical properties of Al-12%Si alloy were presented in tabular and graphical form. Table 2 and Figures 1&2 shows the mechanical testing that was carried out on the treated alloys.

Table 2; Result of the mechanical test on the Alloys

S/N	Tensile strength	% elongation
Sample A	203	2.4
Sample B	236	5.2
Sample C	257	7.1
Sample D	283	9.5





V. DISCUSSION

It was observed from the results that were obtained in this study that tensile strength values increased as concentration of sodium fluoride increased and also the values of percentage elongation increased as well. Sample D which has the highest concentration of sodium fluoride posses' better mechanical properties than other samples and it was made possible because at this level silicon particles were distributed homogenously. The results showed that the mechanical properties improved in comparison with the control sample of alloy and these agree with the report of [27] that when eutectic Al-Si alloys were modified with sodium, there will be an improvement in its mechanical properties. These observations confirm a research work on mechanical properties of aluminium alloy where it was reported that the effects of alloying elements on the mechanical properties are generally an increase of hardness, tensile strength and a decrease in plasticity [23].Manganese, if present in the alloy (with Fe) above 0.8%, it forms a compound $Al_{15}(Fe\ Mn)_3\ Si_2$whose primary crystals appear as hexagonal globules that reduce embrittlement in Al-Si alloy [25].

Micro-structural examination

Figure (3-6) show photomicrographs of eutectic alloy. Figure one shows the eutectic composition of the alloy without sodium fluoride, the distribution of silicon needles are not uniform over entire sample and the sizes of silicon needles are not refined. Also the primary silicon coarse particles are present in the sample. Figure two had the presence of primary silicon particles distributed over the sample, however the distribution is not so uniform and α-Al was also present. Figure three shows that silicon particles are distributed homogenously and the sizes of silicon needles are refined in the structure and in figure four, it was observed that the silicon needles were uniformly distributed and the primary silicon particles are refined and the morphology of silicon changes from needle like structure to the fine structure and because of this improved structure, the mechanical properties of these alloys improved as well.

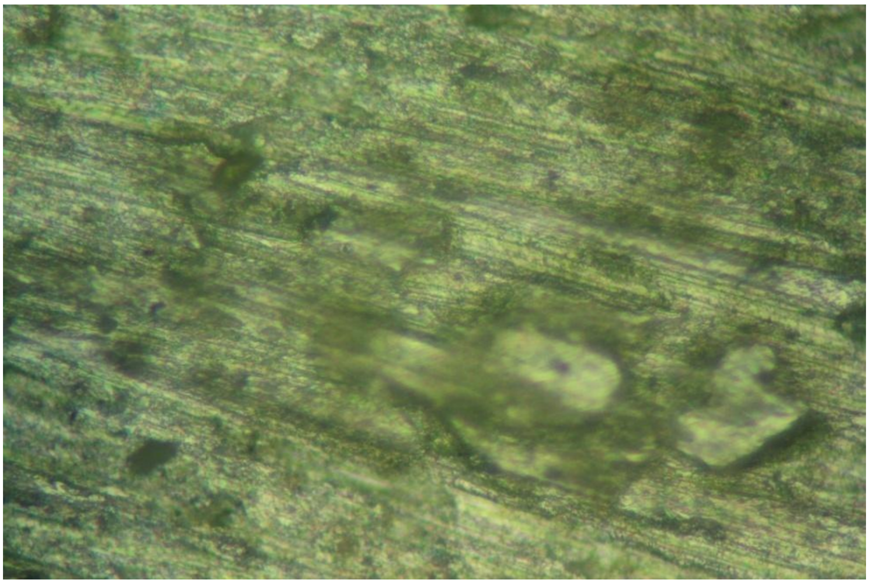


Figure 3 Al-3.6%Mn-12%Si alloy X800

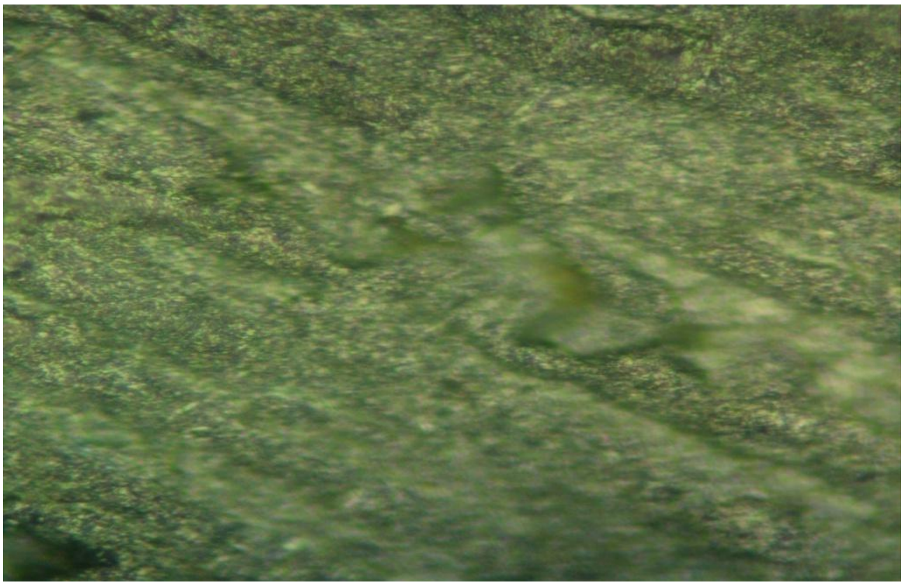


Figure 4 Al-3.6%Mn-12%Si alloy + 6%NaF X800

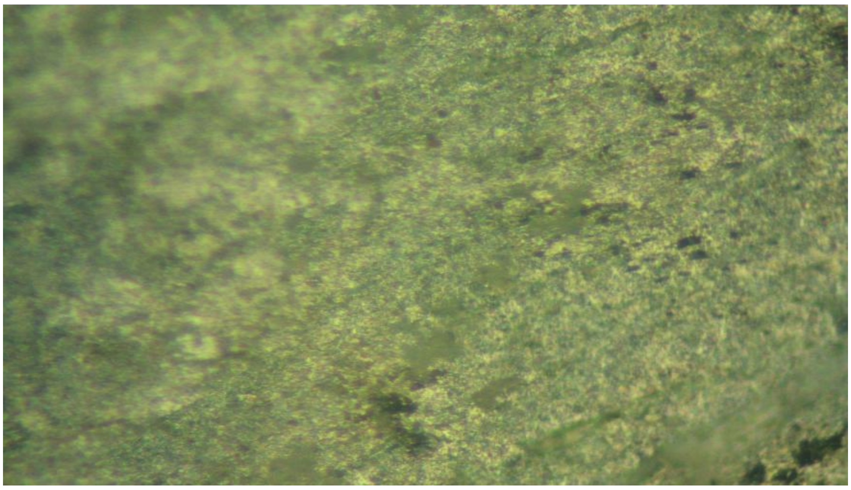


Figure 5 Al-3.6%Mn-12%Si alloy + 12%NaF X800

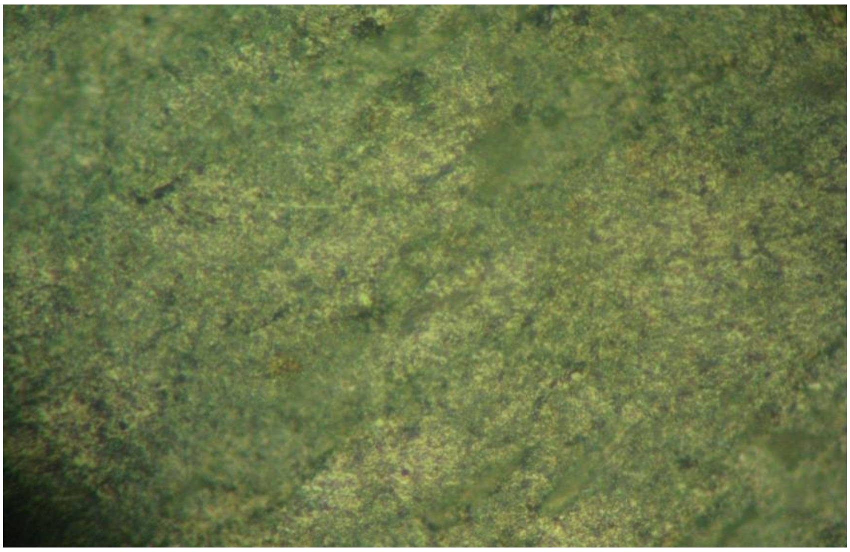


Figure 6 Al-3.6%Mn-12%Si alloy + 18%NaF X800

VI. CONCLUSION

The results from this work have clearly explained the following facts**:**

There was an improvement of mechanical properties with increase of sodium fluoride in the Al-Si alloys.

That the silicon particles were homogenously distributed in the alloys as the concentration of sodium fluoride increased in the alloys. It was also established that fine distribution of silicon particles in the alloys improves the structural and mechanical properties of Al-Si alloys and final this paper has established the mechanism of structural modification of eutectic alloys with sodium fluoride.

REFERENCES

[1] Agbo, U. J, (2004) Effect of modification of the structure of iron and silicon on the mechanical properties of eutectic aluminum-silicon alloy PGD Thesis, University of Agriculture Makurdi.

[2] ASM: (1990) 'Properties and selection: nonferrous alloys and special-purpose materials', ASM Handbook, Vol. 2, ASM International, materials park, OH.

[3] Bernersky, L.A (1988) Phase transformation during annealing of rapidly solidified Al- rich Al-Fe-Si alloy. Metallurgical transaction 19a (12) 2893-2900.

[4] Bäckerud, L, Chai, G: (1992) Solidification characteristics of aluminum alloys, Vol. 3, AFS.

[5] Campbell, J. (2001) 'Influence of casting technique and hot isostatic pressing on the fatigue of an Al-7Si-Mg Alloy,'32A, pp. 349-58.

[6] Callister, Jr. (2006) Material Science and Engineering, ISBN; 81-265-0813-2.

[7] Chen,C. I, (2006) Characterization of intermetallic phases in multi-component Al-Si alloys for engineering applications material science forum, J19-52, 359, 64.

[8] Crepau, P. N, (1995) 'Effect of iron in Al-Si casting alloys; a critical review', ASF Transactions, 103, pp-361-366,

[9] Dobrzanski,L.A, K. Labisz, R. Maniara: (2005) Microstructure investigation and hardness measurement in Al-Ti alloy with additions of Mg after heat treatment, Proceedings of the 13th International Scientific Conference, Gliwice-Wisa
[10] Flood, S,C, (1981) Modification in the structure aluminium of Al-Si eutectic alloy with sodium. Metal Science Journal, 15, 287-293.
[11] Green, J R, (1987) A newage of metals; Journal of Advanced Materials and processes, 131, (1) 6-7
[12] Gupta, M, S. Ling, J. (1999) Alloys Compound. Journal of Materials Science, A 287, pp - 284–294.
[13] Haizhi, Ye: (2003) An overview of the development of Al-Si-Alloy based material for engine applications, Journal of Materials Engineering and PerformanceVolume 12, Issue 3 , pp 288-297.
[14] Huo, H and S.C. Tjong, (2007) Corrosion behavior of Al-based composites containing in-situ TiB_2, Al_2O_3 and Al_3Ti reinforcements in aerated 3.5% sodium chloride solution, Advance Engineering Material, Vol 9, pp.588-593.
[15] Kumai,S, and K. Kobayashi: (2006) Journal of Materials Science. JILM 56 21–27.
[16] Kauffman, J. G, Rooy, L.E, (2005)Aluminum Alloy Castings, ASM International, Ohio.
[17] Kobayashi, K.F, (1985). The crystal growth of silicon in Al-Si alloys; Journal of material Science, Chapman and Hall Ltd. 20 (6) 1961-1966.
[18] Li,P. (2000) 'Modification effect and mechanism of Sr, Na in Al-Si alloy.' A 19A, 1365-1372.
[19] Li, P, V.I. Nikitin, E.G. Kandalova, K.V. Nikitin, (2002) Materials Science and Engineering. A 332, 371–374.
[20] Liu, R.P, D.M. Herlach, M. Vandyoussefi, A.L. Greer, (2004)Metallurgiya Material Transaction. A 35 607–612
[21] MacKay, R, M. Djurdjevic, J. H. Sokolowski: (2000) The Effect of cooling rate on the fraction solid of the metallurgical reaction in the 319 Alloy, AFS Transaction.
[22] Mondolfo,L.F (1976) 'Aluminium alloys, structure and properties, Butter-worths', A 19A, 1365-1372. London.
[23] Mbuya, T O, (2003) 'Influence of iron on castability and properties of aluminium silicon alloys; literature review' international journal of cast metals research, 16(5), pp, 451-465.
[24] Massalski, T.B, H. Okamoto, P. R. Subramanian, L. Kacprzak, (1990) Binary Alloy Phase Diagrams–Second edition. ASM International, Materials Park, Ohio, USA.3589 pp, 3 vol.
[25] Nnuka, E.E. (1985) Investigation and design of metallurgical ways of improving the mechanical properties of aluminium alloys Ph,D. Thesis, Minsk BSSR, 250pp.
[26] Nnuka. E.E, (1991)The effects of microadditives on the quantity and distribution patter of the secondary phase in Al-Cu alloy system. The Nigerian Engineer,26(3):30-37