International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3 Issue 4 ǁ April 2014 ǁ PP.20-24

Effect of Molybdenum and Cobalt Addition on Structure and Mechanical Properties of Aluminium-12.5%Silicon Alloy

[1]C. N. Nwambu, [1]E. E. Nnuka, [1]J.U. Odo, [1]C. I. Nwoye, [1]S.O. Nwakpa.
[1]*Department of Metallurgical and Materials Engineering, NnamdiAzikiwe University, Awka, Anambra State, Nigeria*

ABSTRACT: *This paper attempts to investigate the influence of cobalt and molybdenum on the structure and mechanical properties of aluminium-12.5%silicon alloy. Aluminium alloys are very important category of materials used for automotive, aerospace, packaging and construction due to their high mechanical properties and wide range of industrial applications.Cobalt and molybdenum were used as modifying elements during this experiment and these inoculants were added as microadditive at various compositions to the percentage of iron present in the alloys (1% of Fe: 1, 2, 3, & 4% of modifying element). These alloys were produced by melting a calculated mass of the charged aluminium and silicon, and subsequently microadditives of the inoculants were added to the melt, which were cast into rod-like ingots from which mechanical tests and microstructure examination were conducted. The hardness strength and impact strength were measured using Vickers hardness tester and charpy test; while chemical composition analysis was conducted using chemical analyser and microstructure examination was done using metallographic microscope. The results showed that the hardness and impact strength improved as the iron content in the alloy reduced, especially for cobalt while the microstructure result shows areas of fine particle distribution.*

KEYWORDS: *Aluminium, Silicon, Molybdenum, Cobalt, Hardness strength, Impact strength.*

I. INTRODUCTION

In recent times non-ferrous metals and alloys have become so important that technological development without them is unconceivable. Among the most important non-ferrous metals is aluminium with its alloys. Aluminium excels among other non-ferrous metals because of its high specific weight, resistance to corrosion etc [5]. 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. 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]. 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].

Aluminium in its pure state is a soft metal with low tensile strength. Substantial increase in strength can be obtained by alloying and cold working, but higher strength as demanded in various engineering applications can be obtained by suitable alloying elements to impart high fluidity and low shrinkage, necessary for good castings. Eutectic alloy composition of Al+12.5%Si is widely used for casting because of its high fluidity and castability. Iron is the main impurity in eutectic aluminium silicon alloy and efforts should be 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. It is known that cobalt, manganese, sodium chloride and sodium fluoride had been used to modify the structure of Al-Si alloys [5]. 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 increaseor decreasewith 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].

II. EXPERIMENTAL PROCEDURE

Materials used for this research are: high purity aluminium, silicon, cobalt, molybdenum, beakers, and electronic weighting balance and microscope. Nine different compositions of alloys were produced with amounts of Mo and Co varied from 1% of Fe presentat the alloy to 1% of the additives up to 4% of additives, i.e. (1:1, 1:2, 1:3 and 1:4) 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 nine 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 cobalt and molybdenum.These additives were added according to the percentage of iron present in the alloy because the aim is to modify the iron content in the alloys. These crucibles were taken back to the furnace for half an hour and furnace temperature was raised from 750^0C to 800^0C 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 hardness test and impact test specimens and micro structural examination were taken. Table 1 shows the chemical composition of developed alloys.

Mechanical Test

The objectives of mechanical testing are; 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. Hardness refers to a material ability to resist permanent or plastic deformation. Vicker hardness test was carried out by indenting the specimen, 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.

III. RESULT AND DISCUSSIONS

Results

The results of the effect of Mo and Co additions on the structure and mechanical properties of Al-12.5%Si alloy were presented in tabular and graphical form. Tables 2 and Figures 1&2 shows the variation of hardness strength, impact strength to percentage of Co and Mo addition to alloys.

Table 2; Result of hardness value of the Alloys

Samples	Hardness VHN	Impact energy (Joules)
Sample A	206	1.5
Sample B	216	1.7
Sample C	221	1.9
Sample D	229	2.2
Sample E	234	2.4
Sample F	209	1.58
Sample G	212	1.64
Sample H	216	1.72
Sample I	222	1.87

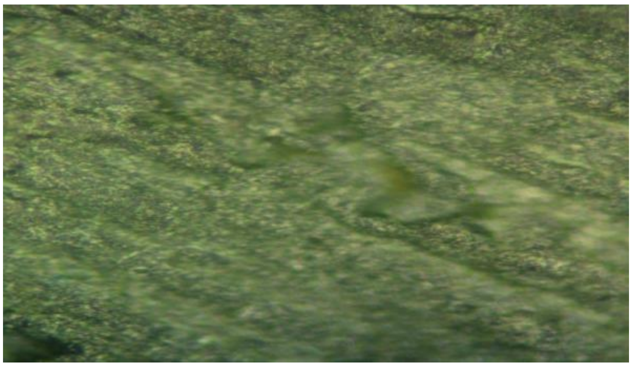
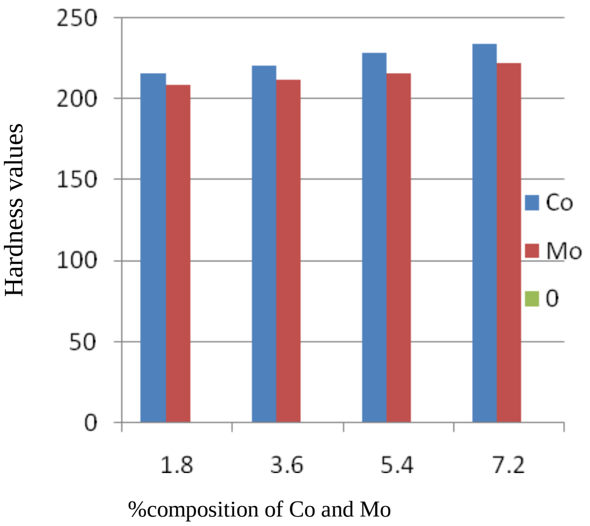


Figure 3: alloy + Co X 400

Table 1: Chemical composition of the developed alloys

s/n	% Si	% Fe	% Co	% Mo	% Al
Sample A	12.5	1.8	-	-	Bal
Sample B	12.57	1.2	1.8	-	Bal
Sample C	12.61	0.7	3.6	-	Bal
Sample D	12.59	0.4	5.4	-	Bal
Sample E	12.63	0.23	7.2	-	Bal
Sample F	12.52	1.4	-	1.8	Bal
Sample G	12.54	1.1	-	3.6	Bal
Sample H	12.58	0.9	-	5.4	Bal
Sample I	12.57	0.8	-	7.2	Bal



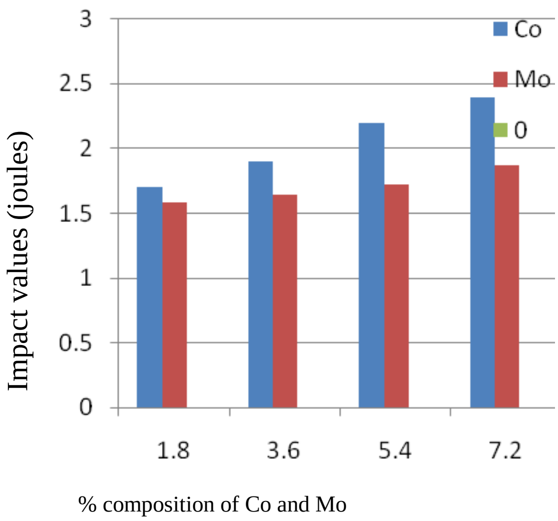


Figure 1: Relationship representing the hardness values Figure 2; Relationship representing impact energy values and % composition of the additives on the alloyand % composition of the additiveson the alloys

IV. DISCUSSIONS

As it has been observed from the results that were obtained in this research work, the hardness values and impact values increases with increase of amount of Mo and Co but the hardness values and impact energy values of cobalt were higher than the values from molybdenum samples, However, samples modified with cobalt possessed better mechanical properties than samples modified with molybdenum. The reason might be due to the precipitation of the intermetallic compounds and the amount of intermetallic precipitates increases with increase of Mo and Co contents. Figures 1&2 have shown that with simultaneous addition of Mo and Co to the alloy system, it improved the mechanical properties of these alloys.

Microstructural Examination

Figure (3-4) show photomicrographs of eutectic alloy. It is observed that the addition of Co and Mo to eutectic alloy significantly refine coarse α-aluminum dendrites to fine equiaxed α-aluminum dendrites. Modification refines the eutectic silicon crystals and changes the morphology of these crystals. The change in microstructure from coarse columnar grain structure to fine equiaxed grain structure and coarse dendritic structure to fine dendritic structure in alloys and with change in plate like eutectic Si to fine particles resulted in high mechanical properties of Al–Si alloys.

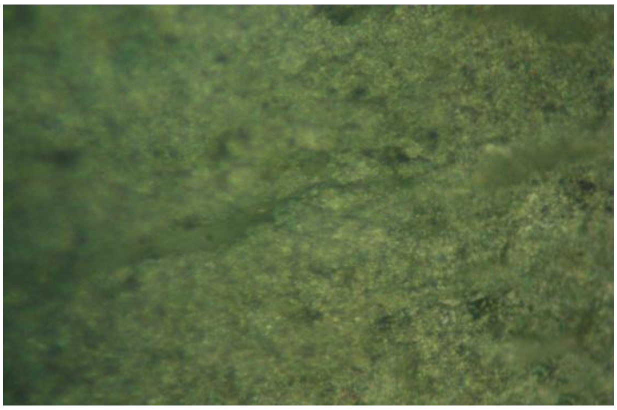


Figure 4: Alloy + Mo X 400

V. CONCLUSION

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

- There was a general increase of mechanical properties with increase of Cobalt and Molybdenum percentages in the alloys.
- Cobalt has a high tendency to reduce the content of iron in the aluminium-12.5%silicon alloy thereby improving the mechanical properties better than molybdenum.
- Additions of Cobalt and Molybdenum to aluminium-12.5%silicon alloy have significantly refines coarse columnar α- aluminum dendrites to fine equiaxed α-aluminum dendrites.

REFERENCES

[1] Roy,N, (1996); 'Porosity Formation in Al-9wt% Si-3wt%Cu Alloy systems: Metallurgraphic Observations' Metall. Mater. Trans. A., 27A, pp. 415-29
[2] Tjong,S.C, (1997); 'Wear Behavior of an Al-12%Si Alloy Reinforced with a low volume fraction of SiC Particles'.
[3] Li,P. (2000); 'Modification Effect and Mechanism of Sr, Na in Al-Si Alloy.'
[4] Samuel,F.H. (1999); 'Effect of Mg on the Ageing Behavior of Al-Si-Cu 319 Type Aluminium Casting Alloys'.
[5] Nnuka, E.E. (1985). 'The Influence of Modificators on the Mechanical and Physical Properties of Alloys. Metallurgia, Minsk, No. 19, pp.62-63.
[6] K. Suzuki, S. Kumai, Y. Saito, A. Sato and T. Haga: Mater. Trans. 45 (2004) 403–406.
[7] S. Kumai, K. Kobayashi, H. Zhu, K. Suzuki and T. Haga: J. JILM 55 (2005) 500–506.
[8] S. Kumai, T. Tanaka, H. Zhu and A. Sato: Mater. Trans. 45 (2004) 1706–1713.
[9] Thompson, R.C, (2006) Characterization of intermetallic phases in multi-component Al-Si alloys for engineering applications Material Science forum, J19-52, 359, 64.
[10] Downs A.J.,(1993); Chemistry of Aluminium, GallionInidiom and Thalliom
[11] Nnuka, E.E., (1985) investigation and design of Metallurgical ways of improving the Mechanical Properties of Aluminium Alloys Ph,D. Thesis, Minsk BSSR, 250pp.
[12] S. Kumai, Y. Nagata and A. Mukaiyama: J. JFS 79 (2007) 717–725.
[13] Agbo, U.J., (2004); PGD Research work on eutectic alloy, Metallurgy University of Agriculture Makurdi.
[14] Stroganov,G.B, et al(1997); ' Aluminium-Silicon Alloys, Metallurgiya,' Moscow.
[15] Gupta, M, (1999); 'Alloys Compound', 287, 284-294.
[16] Mondolfo,L.F,(1976); ' Aluminium Alloys: Structure and properties, Butter-worths', London.
[17] Crepau, P. N, (1995) 'Effect of iron in Al-Si casting alloys; a critical review', ASF Transactions, 103, pp-361-366,.
[18] ASM: (1990); 'Properties and Selection: Nonferrous Alloys and Special-Purpose Materials', ASM Handbook, Vol. 2, ASM International, Materials Park, OH.
[19] Massalski,T.B, et al (1990); 'Binary Alloy Phase Diagrams; 'ASM International, Materials Park, OH.
[20] Hume-Rothery,W. (1962); 'The structure of Metals and Alloys,
[21] Taylor, J A, (2004), 'Porosity formation and eutectic growth in Al-Si-Cu-Mg alloys containing iron and manganese' Proceedings of 9th international conference on Aluminium Alloys, pp. 1016-1021, IMEA, Brisbane.
[22] Taylor, J A. (2003), 'The of manganese and iron in porosity formation in aluminium-silicon foundry alloys', Light metal 2003, proceedings 42nd Annual conference of metallurgists of CIM, pp483-497, Vancouver, Canada.
[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] Vorren O, (1984), 'Microstructure and mechanical properties of AlSi(Mg) casting alloys', AFS Transactions, 92, pp. 459-466.

[25] Green, J R, (1987); A newage of metals; Journal of Advanced Materials and processes, 131, (1) 6-7
[26] Flood, S,C, (1981) Modification in the structure aluminium of Al-Si eutectic alloy with sodium. Metal Science Journal, 15, 287-293.
[27] 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.
[28] Rohatgi, P.K, (1988); Some observations on the matrix-micro structure of aluminium silicon alloy-graphite particles composites. Metallurgical Transactions A 19A, 1365-1372.