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Microstructure and Static Microhardness of as cast Al-Si-Fe-B alloy by the addition of Ni

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ABSTRACT: *This investigation sheds a light on the effect of Ni addition to the conventional cast Al-Si-Fe-B alloy. The mentioned alloy was prepared with a nominal composition Al- 20 wt% Si- 9 wt% Fe- 1.2 wt% B by means of normal casting process once. Through the same process Al-20 wt% Si- 9 wt% Fe- 1.2 wt% B- 6 wt% Ni was also prepared in order to study the influence of Ni addition on the morphology and mechanical properties of as-cast Al-Si-Fe-B alloy. The microstructure of tested samples was synthesised using optical microscopy (OM), and the mechanical properties were analysed by Vickers microhardness test technique. It is observed that the resulted phase constitutions of Al-Si-Fe-B alloy are primary Si, δ-Al_4 (Fe,B)Si_2 intermetallic compounds and α-Al matrix, while the four phases structure of Al-Si-Fe-B-Ni alloy is composed of β-Al_5 (Fe,Ni,B)Si, δ-Al_4 (Fe,Ni,B)Si_2 , primary Si and α-Al. The higher value of measured hardness for Al-Si-Fe-B alloy is 179 Hv, which is significantly larger than that of Al-Si-Fe-B-Ni alloy (161Hv).*
KEYWORDS : *Al-Si alloy, morphology, Fe-containing intermetallic, microhardness*

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I. INTRODUCTION

Aluminium alloys are the second most used materials in the world according to their eligible strength to weight rate, machinability, workability and good withstand to the corrosion. However, it is known over the world the demands for reducing energy consumption and contamination, aluminium alloys are widely used in airplanes, automotive and bicycles industries [1,2,3,4]. The most substantial characteristics of aluminium is its light density (2.7 g/cm^3) that is approximately one third of those for steel, in addition to one more important property is its good quality of electrical and thermal conductivity which is about two-third of that for copper. Generally aluminium alloys categorised as casting alloys and wrought alloys, however, cast alloys have a low melting point and even tending to have low tensile strength, the major part of available aluminium is utilized in wrought alloys [5,6]. Therefore, the most used alloying elements in aluminium alloy are copper, magnesium, nickel, manganese, zinc, zirconium, silicon and iron, alloying element selection is based on their effectiveness and suitability, accordingly they are classified as a minor and major elements, where the major elements assumed to be the microstructure modifiers or impurities [7,8]. However, increasing the amount of alloying elements is proportionally improve the strength of aluminium alloy, certain concentration of elements may resulted in grain boundary segregations accordingly lead to form extra eutectic phases and coarse ingredients at the boundaries of grains, which have a negative influences on mechanical properties[9,10]. In order to obtain the optimum combination property many ways can be selected to avoid the possible coarse constituents, such as composition of elements in the alloy, effect of different additives and effects of cooling rates [9,11]. Now a days the aluminium-silicon alloys are used in many industrial application such as automotive (cylinder heads, cylinder blocks, valve filters and piston) and electronics, in respect of their optimum abrasion and resistance of corrosion, high strength to weight ratio and low coefficient of thermal expansion [12,13,14]. Different research papers have investigated Aluminium- Silicon based alloy it is reported that the mechanical properties depend not only on the chemical compositions, it is even remarkably affected by microstructural characteristics. It has been notified that iron is the most employed element as a modifier (impurity) for Al-Si alloy [13,15]. It is reported that the primary particles of Al-Si-Fe alloy is agglomerated as intermetallic compounds according to iron contents in the alloy[16]. The coarse plate-like and acicular Fe-bearing intermetallic compounds such as δ-Al_4 $FeSi_2$ and β-Al_5 FeSi phases which are very brittle and hard are crucial parameters in the mechanical characteristics of resulted Al-Si alloy [17,18]. In last decades , concerning about modifying harmful Fe-containing intermetallic attracted many investigation to this field, Osawa [16] in order to control the morphology (Fe-bearing intermetallic) of Al-18Si-4Fe alloy applied the (USV) ultrasonic vibration on the melt of alloy during solidification , results exhibited that the coarse columnar morphology of Al-(18 wt.%) Si-(4 wt.%) Fe alloy was improved to be a fine grained microstructure. Zhang [19] examined the influence of solidification rate on the type and microstructure of Fe-containing intermetallic of Al- 14 wt% Fe- 2 wt% Si alloy, by using an extensive range of cooling rates it is observed that the morphology of Al-14Fe-2Si alloy is definitely depends upon the rate of cooling, it is also indicated that the higher cooling rates resulted in α-phase intermetallic while the faceted Al_3 Fe performed at lower cooling rates. Hou[20] studied the effect of (2.0Mn and 1.0Cr, wt%) on the microstructure and thermal stability of Al-25Si-5Fe-3Cu (wt%) alloy using spray-forming (SF) technique, results exhibited that both Fe-containing intermetallic and primary Si phases were refined (< 10μm), it is also observed that the thermal stability was drastically improved due to the formation of fine α-Al(Fe,Mn,Vr)Si. In the same way, KILIÇASLAN [21] investigated the effect of Ni addition on the morphology and mechanical characteristics of as-cast Al-20Si-9Fe-1.2Nb (wt%) alloy, it is observed that Si particles were relatively coarsened, β-phase intermetallic was reduced with a significant increasing in δ-phase after Ni addition, while the hardness of alloy was improved by a relatively increment from 101Hv in Al-20Si-9Fe-1.2Nb alloy to 114 Hv in Al-20Si-9Fe-1.2Nb-6Ni alloy.

In consideration to the previous investigation this work is assumed to be a part of these projects which is conducted to provide greater understanding of the influence of alloying element addition. Therefore, 6 wt% Ni has been added to Al-20Si-9Fe-1.2B alloy in order to analyse the effect of Ni addition on morphology and mechanical properties of motioned alloy.

II. MATERIAL AND METHODS

Alloys Al-Si-Fe-B and Al-Si-Fe-B-Ni with nominal compositions as given in Table (1) (at wt%), are prepared as follow, bulk ingots of suitable compositions are produced by Induction Furnace(IF), the mixture of high purity elements (Al, 99.99%; Si, 99.99%; B, 99.99%; Ni, 99.99%; Fe,99.99%) are prepared and melted in graphite crucible many times to ensure chemical homogeneity. Some additive materials melted prior to alloy melting to react with residual oxygen and nitrogen in the chamber. In this investigation the as-casts Al-Si-Fe-B and Al-Si-Fe-B-Ni alloys are denoted as AlCC3 and AlCC4 respectively. The microstructure of the as casts was graphically characterized by optical microscopy (OM, Leica). In order to view a metal specimen under an optical microscope samples of mentioned compositions were embedded in epoxy resin then the samples were polished using polishing machine, utilizing finer and finer grits as well as polishing slurry, and eventually samples were etched using Keller's reagent (2 ml HF+3 ml HCI+5 ml HNO_3 +190 ml H_2O, special for aluminium alloys) in order to be completely flat and scratch samples free when viewed with the aid of a microscope devices. The mechanical properties of the samples were measured using Vickers micro-hardness testing machine with applied load Hv 200gf and holding time 16s at different points. Where the all mentioned experimental work and tests were prepared in the laboratories of Kastamonu University.

Table 1: Chemical composition of studied alloys (wt. %).

samples	Al	Si	Fe	B	Ni
AlCC3	69.8	20	9	1.2	-
AlCC4	63.8	20	9	1.2	6

III. RESULTS AND DISCUSION

The optical micrograph image of prepared as-cast AlCC3 alloy is displayed in Figure 1. It is obviously visible that the microstructure of high silicon AlCC3 alloy composed of three constitution phases (i) primary Si,(ii) δ-Al_4 (Fe,B)Si_2 intermetallic, (iii) α-Al matrix. However, the iron has a low solubility in aluminium during normal solidification process, approximately all the added iron to an Al-Si alloy tends to form intermetallic compounds [16]. Consequently, once the δ-Al_4 (Fe,B)Si_2 was formed simultaneously Si and Fe elements would be relocated to the edges of δ-Al_4 (Fe,B)Si_2 phase due to the decreasing solubility of mentioned elements in dendritic aluminium [20]. Generally, the primary Si particles revealed as a (light gray) coarse plates larger than 2.0μm x 2.0μm. Meanwhile, the white δ-Al_4 (Fe,B)Si_2 particles randomly distributed with a large size more than 3.0μm x 3.0μm.

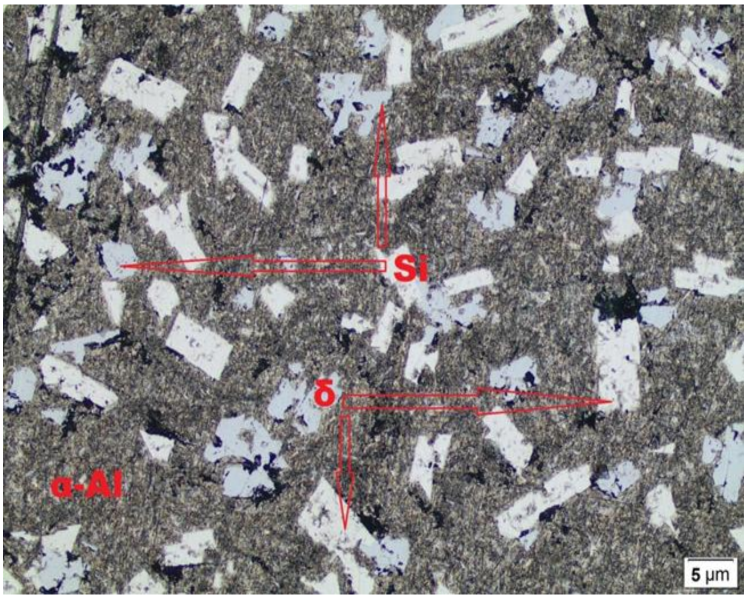

Figure 1: Optical microscopy micrograph of as cast AlCC3 (Al-Si-Fe-B) alloy.

On the basis of the observations after Ni addition as presented in Fig.2, it is clearly seen that the morphology of a conventional cast AlCC4 alloy is completely different from that of AlCC3 alloy. One can notice that the constitution phases are totally refined and homogeneously distributed in α-Al matrix with Ni addition. The microstructure of AlCC4 alloy is mainly composed of α-Al matrix, light gray primary Si particulates(with size >0.5µm x 0.5µm), needle-like β-Al_5 (Fe,Ni,B)Si_2 phase and fine block δ-Al_4 (Fe,Ni,B)Si_2 phase [15,22]. With a peritectic reactions the earlier formed δ-phase transforms into β-phase through L + δ-Al_4 (Fe,Ni,B)Si_2 → β-Al_5 (Fe,Ni,B)Si +Si at lower temperature[15].

Even though, both of primary Si and Fe-bearing intermetallic compounds were fully refined in the microstructure of as cast AlCC4 alloy after Ni addition, the measured micro-hardness value of AlCC3 alloy is 156.9 Hv which is relatively higher than that of AlCC4 alloy (114 Hv). Which is may attributed to the noticeable formation of a harmful acicular β-phase that resulted in inferior mechanical properties [18, 20] after Ni addition.

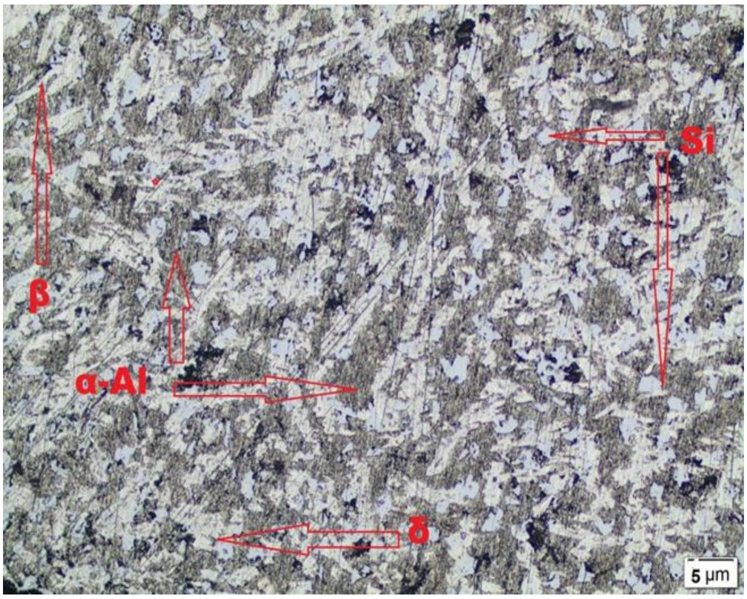

Figure 2: Optical microscopy micrograph of as cast AlCC4 (Al-Si-Fe-B-Ni) alloy.

IV. CONCLUSION

1- Both of δ-phase (fine blocks) and β-phase (needle-like) intermetallic compounds are co-existed in the microstructure of alloy after the addition of Ni.

2- With the addition of Ni alloying element, both of primary Si particles and Fe-containing

phases have been fully refined and homogeneously distributed through the α-Al matrix.
3- After Ni addition the measured micro-hardness was decreased from 156.9 Hv in as cast Al-Si-Fe-B alloy to 114 Hv in as cast Al-Si-Fe-B-Ni alloy.

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