EFFECT OF THE Al_2O_3 PARTICLE ON THE WEAR RATE AND MICROSTRUCTURE OF HYPO AND HYPER AL-SI ALLOYS

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Abstract: In the present work wear performance and hardness of as cast Al-Si alloys before and after the addition of Al_2O_3 were investigated. Wear specimens of cylindrical shape were prepared from cast ingot. Wear test were conducted on the samples by using pin on disk wear type. The test variable were load and time. It was observed that when Silicon content increased the hardness increased while the wear rate decreased. When the load and time increased the wear rate also increased. By the addition of Al_2O_3 particles the wear rate decreased while the hardness increased

Keywords: Aluminum silicon alloy; wear; hardness; Al_2O_3

1. Introduction

Universal attempt to decrease emissions of dangerous exhaust, coast reducing and improve fuel of vehicle, so aluminum alloys is the best choice because of their lightweight they used in piston, bearing etc [1]. Aluminum silicon composite consist from two or more materials the purpose of composite is to give the material the desired properties[2]. Depending on silicon percentage aluminum silicon alloy divided into three main group: first group if silicon content between 5% and 10% the alloy was called hypoeutectic, second group if silicon content between 11.5-12 % the alloy called eutectic, third

group if silicon content between 14%-20% the alloy called hypereutectic [3]. Aluminum silicon casting widely used in industrial because their premium mechanical properties, corrosion resistance and good casting properties [4], they were used in marine application, aerospace, etc. [5]. The properties of aluminum silicon alloys were influenced by silicon particles distribution and shape [6]. The strength of aluminum silicon alloys increased when silicon content decreased but the hardness of these alloys will decreased [7, 8]. Also the silicon addition result in increased wear resistance of aluminum silicon alloys [9]. When the surface of aluminum silicon alloy was loaded and subjected to sliding motion wear was occurred. Wear result in substance loss from the surface of materials [10]. The strength of aluminum matrix composite increased by reinforcement by Al_2O_3 , B_4C and SiC etc. this additive result in wear enhancement and increase ratio of weight to strength [11, 12]. Stir casting method was widely used to produce aluminum silicon composite alloy [13]. In this process the metal melted in furnace then vortex was formed by stirring the metal. Oxide formation is prohibit

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By adding inert gas. When particles were added string stopped. Then the molten poured in die. Speed of stirring, time of stirring, melt temperature and mold temperature are critical parameters in stir casting process.

In the present work aluminum silicon alloy reinforced by addition the Al_2O_3 particles by using stir casting method and study the effect of these additive on the wear performance, hardness and microstructure of aluminum silicon alloy.

2. Experimental work

2.1. Preparation of aluminum - silicon alloy

Aluminum silicon alloy with chemical composition that shown in "Table 1". Was prepared for this work by used metal mold casting. This process was done by place Al wires in clay bonded graphite crucible, and after that, this crucible will be put in a gas furnace to the point of aluminum melting. Then Fe and cu were added to Al molt and mixing with molten. . After that, the pure Si of the commercial bulk will be added and mixed with the use of the graphite mixer to the point where all quantities of the Si will be dissolved in molten of Al. Then Mg and Zn will be added as well into the molten and mixed. Afterwards, slag remover aqueous aluminum chloride add to the molten of Al in the ratio of 1 gram. And after that, the slag was removed from the molten. The cast iron mold pre heated at the temperature of 200°C and the molten was poured inside the mold. The poured process is re held with different silicon percentage. Cast rod was obtained with diameter of 14 mm and length of 22 cm. The homogenous process was held to cast rod through the placing of cast rod into the electrical furnace at a 500°C temperature for five hours and left them to cool in a furnace air for the purpose of obtaining homogenous grain.

After obtaining alloys with two different concentrations of silicon, the plumbing process was carried out again and with the same work steps mentioned above where Al_2O_3 added at a concentration of 7% by stir casting Technique, knowing that the material was wrapped in aluminum foil and heated to a temperature of 200°C to get rid of moisture before putting it to the molten.

2.2. The Microstructure test

The alloys were prepared for microstructure test by cut these with length 10 mm , and samples grinding by using emery papers with different grade (220, 400, 600, 800, 1000, 1200, 1500, and 2000). Water was used as coolant to avoid heat rising. The specimens was polished by using alumina. The samples washed by using water and alcohol and dried by using air. Then (99.5 water and 0.5 HF) used as etching solution.

2.3. The Hardness test

Vickers hardness test was utilized in the present work to measure the hardness of samples. By using load of 1 kg for 15 sec. then the penetration diagonal was calculated by using equation (1).

$$\text{H.V} = 1.854 \times P / d_{(\text{AV})}^2 \quad (1)$$

Where HV: Vickers hardness

P: load

$d_{(\text{AV})}$: penetration diagonal

2.4. The Wear test

For wear messurment pin on disk device was utilized in the present work. The samples were cut in the length of 30mm and diameter of 10 mm. in the present work two loads were utilized (5 and 10 N) and sliding volicty of (490 m/s) at different time (5, 10, 15 and 20 min).

The wear rate of the samples were calculated according to equiton (2)

$$\text{Wear rate (w.r)} = \Delta w / \pi \text{DNt} \quad (2)$$

Where $\Delta w : W_0 - W_1$

D: sliding distance (14 cm)

t= time (min)

N= velocity (rpm)

Table 1. The chemical composition of Al-Si alloys

element	Si%	Fe%	Cu%	Mn%	Mg%	Cr%	Ni%	Zn%	Ti%	Pb%	Al%
Sample1	5.7	0.546	3.45	0.0310	0.404	0.0227	0.054	0.50	0.0291	0.0063	Bal
Sample2	13.11	0.811	2.35	0.0827	0.603	0.011	0.031	0.720	0.058	0.003	Bal

3. Results and dissuaction

3.1. Effect of Al_2O_3 and Si additions on the microstructure of AL-Si alloy

"Fig. 1", show the microstructre of Al-Si alloy, Figure a and b show the microstructre of alloy with different precentage of Si. The microstructure relive that alpha aluminum and Si etuctic. When the precentage of sillicon increased rod of si eutectic will increasing and plate of Si appearance as shown in figure b. after the addition of Al_2O_3 it was shown that the microstrucuter become more refined and become more homogenous as shown in c and d .

Figure 1. the microstructre of Al-Si alloys before and after the adding of 7% alumina: a) Al-5%Si alloy ; b) Al-13%Si alloy ; c) Al-5%Si after addition alumina ; d) Al-13%Si after addition alumina .

3.2. XRD test results

It was obsserved that from the XRD test befor the addition of Al_2O_3 ,the major peaks were Al and Si, and the mainor peakes are Al_2Cu and $Al_{3.21}Si_{0.47}$.

Figure 2. the XRD analysis of aluminum silicon alloy; a) Al with 5% of Silicon , b) Al with 13% of Silicon , c) Al with 5% of Silicon after addition alumina , d) Al with 13% of Silicon after addition alumina .

Table 2. the intensities (I) and the angle of diffraction

Alloy	Phase	2θ	I/I ₁
Al-5%Si	Al	44.35,38.12,77.94	100,13,7
Al-5%Si	Si	64.76,46.94	11,5
Al-5%Si	Al ₂ Cu	77.97,98.75	7,10
Al-13%Si	Al	44.76,38.51,99.08	100,76,6
Al-13%Si	Si	65.04,78.22,116.50	39,34,22
Al-13%Si	Al _{3.21} Si _{0.47}	28.44	19

Table 3. the intensities (I) and the angle of diffraction after the addition of Al_2O_3

Alloy	phase	2Theta	I/I1
Al-5%Si	Al	38.4,66.9,44.6,78.1	100,49,44,38
Al-5%Si	Si	28.7	8
Al-5%Si	Al_2Cu	60.2	6
Al-5%Si	Al_2O_3	67.2,42.2,37.4	59,16,10
Al-13%Si	Al	38.4,44.7,65.78.1	100,42,29,24
Al-13%Si	Si	28.4,47.2,58.1	43,16,3
Al-13%Si	Al_2O_3	67.1,42.5,37.6	22,7,5

3.3. Hardness test Results

As shown in the “Table 4”, the hardness of AL-Si alloy increased when the percentage of silicon was increased, due to plate of Si precipitation during the solidification process, and this can be attributed to the presence of fine intermetallic compound such as aluminum silicon ($Al_{13}Si_{0.47}$). When Al_2O_3 was added, the hardness also increased because Al_2O_3 act as barriers for alloy distortion due to, their high hardness. Also it act as barriers for dislocation movement.

Table 4. vicker Hardness (kg/mm^2) for alloy before and after addition Al_2O_3 .

Alloy	As received	After addition Al_2O_3
Al-5%Si	47	59
Al-13%Si	65	78

3.4. Wear test results

"Fig. 3" and "Fig. 4", show the relationship between the wear rate and time at different load for AL-Si alloys before and after the addition of Al_2O_3 . it was shown that wear rate increase as result of sliding reaction that occur between the two slipping metal surface [14]. It also observed that when the silicon content increased the hardness increased so the wear rate will decrease due to primary silicon particles and fine intermetallic compound ($Al_{13}Si_{0.47}$) may be result in decreased rate of wear. at low values of the load wear lost which are discovered as fine particles and protective oxide layer will be formed, and the area of the contact between the disc and the samples will be decreased, which is why, wear rate will be decreased. While at load of 10 N severe wear will occur. in this load wear lost found in the form of large metallic particles. The oxide layer will break out thus result in increased wear rate. The contact area between the burrs will increased. This burrs will break out and Separate from the surface. When the load increased the silicon particles will Break up and the break silicon will become spheroidis as result of high temperature that occur between the two slipping surface. After the addition of ceramic particles, (Al_2O_3) phase were appeared and this will result in increase the wear resistance.

(a)

(b)

Figure 3. the wear rate of Al-Si alloy before the addition of Al_2O_3 ; a) Al-5% Si alloy ; b) Al-13% Si alloy

(b)

Figure 4. the wear rate of Al-Si alloy after the addition of Al_2O_3 ; a) Al-5% Si alloy with addition Al_2O_3 ;b)Al-13% Si alloy with addition Al_2O_3 .

(a)

4. Conclutions

- 1- Hardness increased by the increased in Si content from (47-65) HV.
- 2- When added alumina, the hardness value in Al-5%Si alloy increased from (47-59)HV, and in Al-13%Si alloy increased from (65-78)HV.
- 3- When Si content increased the wear rate decreased.
- 4- The wear rate of Al-5%Si increased from (3.06×10^{-8} – 3.71×10^{-8}) at load 5 N and at load 10 N increased from (3.24×10^{-8} – 4.06×10^{-8}), in Al-13%Si wear rate increased from (1.39×10^{-8} – 2.22×10^{-8}) gm/cm at load 5N and increased from (1.67×10^{-8} – 2.36×10^{-8}) gm/cm at load 10N.
- 5- The addition of alumina to the alloy lead to wear rate decreased.

Acknowledgements

The authors would be like to thank the staff of Mustansiriya University (www.upomustansiriyah.edu.iq) Bagdad-Iraq, for their support in the present work.

Conflict of interest

The author confirm that there's no conflict of interest.

Abbreviations

Al	aluminum
Si	silicon
Al ₂ O ₃	alumina
Fe	iron
Cu	copper
Zn	zinc
Mg	Magnesium
B ₄ C	Boron carbide

5. References

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