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Geri Dönüştürülmüş Al – Si Pistonlarda Mikroyapılarının Aşınma Etkisi

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Anahtar Kelimeler
Aşınma Oranı; Mikroyapı; mikrograf; α-alüminyum.

Öz

Aşınma, bir otomobil motor sisteminde olumsuz koşulları başlatma eğilimindedir. Piston, bir motordaki şiddetli termal gerilimlere dayanan önemli bir motor bileşenidir. Çevresel rahatsızlık oluşturan hurda pistonlar geri dönüştürülecek. 1,15 µg / m olarak belirlenen pistonların aşınma oranının azaltılmış bir değerinin, optimum çalışma koşulu için gerekli olan tokluğu ve sertliği koruyan gelişmiş bir mikro yapıya sahip olduğu fark edilmiştir. 6.04 µg / m'lik yüksek aşınma hızı değeri, daha az belirgin iğne şeklinde ötektik silikon parçacıklar üreten pistonların mikrografını vermiştir. Hurda jeneratör pistonlarından üretilen alüminyum alaşımlı döküm pistonun mikrografları. Sonuçlar piston alaşımının yapısal matrisinin arka planında birincil a-alüminyum parçacıklarını göstermektedir. Ayrıca, ötektik silikon partiküllerine yakın iğne şeklindeki partiküllerin ithal edilen piston alaşımlarının mikroyapısında dağıldığı fark edilir.

Effect on Wear of the Microstructure of Recycled Al –Si Pistons

Keywords
Wear rate; Microstructure; micrograph ; α-aluminium.

Summary

Wear has a tendency of initiating adverse conditions in an automobile engine system. The piston is an important engine component which withstands severe thermal stresses in an engine. Scrap pistons which constitute environmental nuisance will be recycled. A reduced value of wear rate of the pistons determined to be 1.15µg/m was noticed to have an improved microstructure which retains toughness and hardness required for optimal working condition. While wear rate high value of 6.04µg/m yielded micrograph of pistons which produced less pronounced needle shaped eutectic silicon paricles. The micrographs of the aluminium alloy cast piston produced from scraps generator pistons. The result shows primary α-aluminium particles at the background of the structural matrix of the piston alloy. Also, needle shaped near eutectic silicon particles are noticed to be dispersed in the microstructure of the imported piston alloys.

1. Introduction

Wear is a major challenge in the automobile industry and its direct cost is estimated to be between 1 and 4% of the gross national product (Agarwal, Parnaik and Sharma, 2013). Its effect can initiate adverse conditions in an automobile engine syste (Ameen, Hassan and Mubarak, 2011). To put forth great resistance to abrasive and sliding wear it will be important to have engine components produced in aluminium-silicon alloys (Hassan et al, 2011). So much effort and techniques has been expended to manufacture more durable materials to reduce the effect of wear on tools and engineering components.

Aluminium silicon alloys are reputed for great advantages like corrosion resistance, high thermal conductivity, good weldability and excellent castability (Dell, 2009). For many decades, engine pistons were manufactured from cast iron which was used for producing other engine components (Heuer, 2015). There is a departure in the usage of cast iron because of the improved mechanical properties of aluminium inherent in modern engineering (Yang, 2003).

Presently, automobile engine pistons are mostly manufactured from aluminium silicon alloys. In the recent past Yamaha generator piston had been produced using a Silumin aluminium alloy material which is chosen on the basis of high fatigue strength, high wear resistance and hardness (Ebhota et al,, 2015). Silumin is usually a term used in most countries for alloys based on Al-Si system. It is a series of lightweight, high-strength aluminium alloys with a silicon content within the range of 3-50%. Some of these aluminium alloys are casting ones which could be produced by rapid solidification processes and powder metallurgy. Putting into perspective the Aluminium Association designation system silumins are corresponding to alloys of two systems:which are 3xxx aluminium-silicon alloys containing magnesium and copper, and 4xxx-Binary aluminium-silicon alloys.One of the greatest advantages of silumin is its resistance to corrosion which makes it very applicable in humid environments(Vengatesvaran et al, 2018). The relevance of silicon and copper elements in eutectic aluminium alloys have been adjudged to be satisfactory in improving mechanical properties (Kumar and Grewal, 2013.

The microstructure of metallic material has the tendency of influencing physical properties such as toughness, strength, ductility, hardness, corrosion resistance and wear resistance(Manchanda, and Narang, 2005). In addition, the mechanical properties of aluminuim alloy such as strength formability, ductility, fatigue strength and surface hardness, amongst others enhances its performance in service. Studies have also shown that failure of aluminium can result from production methods, use of substandard material, poor design, manufacturing errors due to poor machining, or failure from a phenomenon called fatigue (Ajayi, 2013).

A microstrutural examination of wear rate of LM13 using centrifugal casting process was carried out by (Patel,2014). The study reveals that the silicon promotes fluidity during melting, enhances mechanical properties (tensile strength and hardness) and offer resistance to wear. The microstructural characterization of LM13 cast alloy showed presence of rod like shaped structure dispersed within the medium which accounts for toughness of the alloy (Kayser and Svendsen ,2008). The machined samples of the LM13 were tested for tensile strength, hardness, and wear rate. The result showed that the tensile strength, hardness and wear resistance of the LM13 cast alloy increase with silicon. The optimal mechanical properties and wear resistance occurred at 7000C pouring temperature and 1050 rpm mould rotation.

Xi et al. (2020) investigated The microstructure evolution and tribological property of SLM-processed AlSi10Mg/TiB2 composites. The result showed that Al-based composites with high manufacturing quality and uniform dispersion of TiB2 particles were dispersed throughout the structural matrix. Also, the composites showed high microhardness of 126 HV0.2 and wear rate of 5.2 × 10−4 mm3N−1m-1. The aim of this study is to investigate the microstructure and wear behavior of aluminum silicon alloy piston.

2. Material ve Metod

Optical metallurgical microscope of model L2003A having magnification strength of 400X shown in Fig.1 was employed to conduct microstructural analysis on the specimen obtained from the ingot. The specimens were dimensioned 16mm in diameter and 10mm in depth . The specimens were polished with various grade of emery clothe of P-60,P-120,P-220,P-400,P-800 and P-1200.A dry rough and fine polishing operation was carried out using serium oxide. The etching operation was conducted by immersion and swabbing on each specimen for about 30 seconds using the Keller's reagent which constitutes 1% hydrofluoric acid, 1.5% hydrochloric acid, 2.5% trioxonitrate (v) acid and 95% distilled water (Kayser and Svendsen, 2009). The etchant was rinsed off the specimen properly with water and air blower was used to dry it properly before been introduced into the stage of the optical microscope machine. The magnification knob was adjusted to select a proper focal length between the workpiece and the magnification lens (Kayser, 2009). The microstructure of the samples was viewed on the pc screen via connected to the optical microscope.

Fig. 1: Optical Metallurgical Microscope

2.1 Wear Measurement

The wear measurement experiment was performed on the pin on disc machine. The pin on disc machine employs three important parameters during wear test experimentation. The parameters are sliding distance, sliding speed and load.

The specimens from the ingots of cast aluminium alloy prepared in the form of a cylindrical pin with dimension 10.0mm diameter and 20.0mm length. These specimens were utilized as test samples for the experiment. The pin on disc wear machine is made up of steel disc of about 90mm in diameter and a thickness of 10mm.The cylindrical pins and the disc were thoroughly cleaned with water and dried with acetone before the commencement of the test. The steel disc was fixed on a rotating shaft which is connected to the shaft of an electric motor by means of belt and pulley. The test piece was weighed before the commencement of the experiment and properly positioned in the specimen holder of the machine. The positioned specimen is brought in contact to the flat surface disc. The machine is switched on and the shaft is made to rotate for about 50 minutes. In this experiment load of 50N was used. The sliding speed of the cylindrical pin and disc was maintained at 900 revolutions per minute. The weight of the specimen was taken using a weighing balance and the difference or loss in weight was recorded. The specimen test was repeated so as to bring about accuracy of test values gotten. The average weight loss was recorded (M_1-M_2). Wear rate values were determined by equation (1

$$Wear\ rate, W_R = \frac{M_1 - M_2}{2\pi R N_w t} \qquad (1)$$

where sliding distance=$2\pi RN_wt$, R=track radius, t= time taken, N_w=sliding speed, M_1= mass of specimen before wear experiment and M_2= mass of specimen after the wear experiment

Table 1: Chemical composition of Piston alloys

Element	Cast piston(%)	Commercial available piston(%)
Si	10.442	10.800
Mg	0.802	0.804
Al	78.984	83.048
Ti	0.930	1.022
Cr	0.009	0.018
Mn	0.671	0.765
Fe	1.888	1.262
Ni	1.004	1.012
Cu	2.538	2.600
Zn	1.782	1.785
Sr	0.800	0.824
Pb	0.173	0.222
Sn	0.027	0.030
Sb	0.022	0.106

The result from the test shows that the constituents of the local cast piston alloy and the commercially available piston are similar to LM 2 alloy. The local piston showed that its silicon and aluminium content are 10.44% and 79%

respectively while that of the imported piston is approximately 10.84% and 83%. Some aluminium was lost as result of formation of Theta precipitate and metal evaporation. It is apparent from the test result that the developed piston is near eutectic.

3.2 Wear Rate Test Result

The wear rate test was carried out at the Material Science and Material Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria. The wear test was conducted on a Pin-on-disc machine by keeping normal load of 50N and sliding speed of 900rpm constant. The sliding distance of the specimens were varied and mass loss recorded. The test values are shown in Table 2.

Table 2: Wear Test Values

Experiment No	Random order of exp.	Initial mass(g)	Final mass(g)	Mass loss (mg)	Track diameter(mm)	Sliding distance(m)	Wear rate (µg/m)
1	4	23.011	22.997	13.67	16.00	2262.20	6.04
2	2	22.010	21.998	11.31	15.00	2120.91	5.33
3	5	22.005	21.996	8.53	14.00	1979.50	4.32
4	7	20.004	19.997	7.38	13.50	1908.82	3.90
5	9	21.001	20.993	6.13	13.00	1838.11	3.34
6	1	21.003	20.998	5.03	12.50	1767.38	2.85
7	3	23.002	22.998	3.50	12.00	1696.71	2.06
8	6	22.002	21.999	2.55	11.00	1555.30	1.64
9	8	20.360	20.358	1.63	10.00	1413.91	1.15

The mathematical model obtained by the multilinear regression method using Minitab17 for the wear rate, W_R in terms of pouring temperature A, vibration frequency B, vibration time C and runner size D is given as

$$W_R = 57.29 - 0.07213A - 0.03083B - 0.00922C - 0.000742D \qquad (2)$$

3.3 Significance Test for the Wear Rate, W_R Mathematical Model

A statistical test of significance for the mathematical model developed for wear rate by the multiple linear regression was carried out to ascertain the relevance of the relationship between the response variable, W_R and regressors, A, B, C and D. The test for significance of the wear rate regression model is shown in Table 3 and the probability plot is shown in Fig.2.

Table 3: Result for Significance Test for Wear Rate

Term	Coef	SE Coef	T-value	P-value
Constant	57.290	1.01	56.88	0.000
A	-0.07213	0.00138	-52.27	0.000
B	-0.030830	0.00172	-17.93	0.000
C	-0.009220	0.00229	-4.02	0.016
D	-0.000742	0.00022	-3.34	0.029

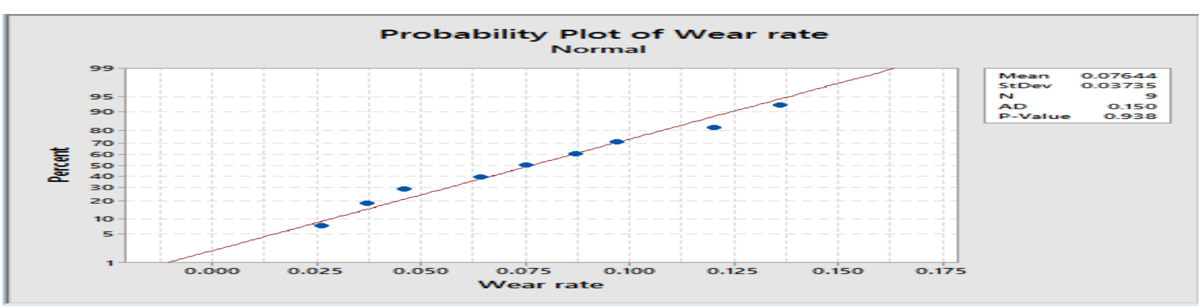


Fig 2: Normal Probability Plot for Wear Test Data

The Normality probability plot shown in Fig. 2 portrays that the residuals lie close to the ideal normal distribution diagonal line which interprets that the data are normally distributed. Also, the Anderson-Daling value and p-value which are 0.150 and 0.938 respectively indicate that there is insufficient evidence for any deviation and as such the normality condition have been satisfied.

3.4 Microstructural Result

The microstructure experiment was conducted for the melted aluminium alloy scrap pistons. The microstructural images of the cast aluminium silicon piston alloys from each experiment are shown in Fig. 3.

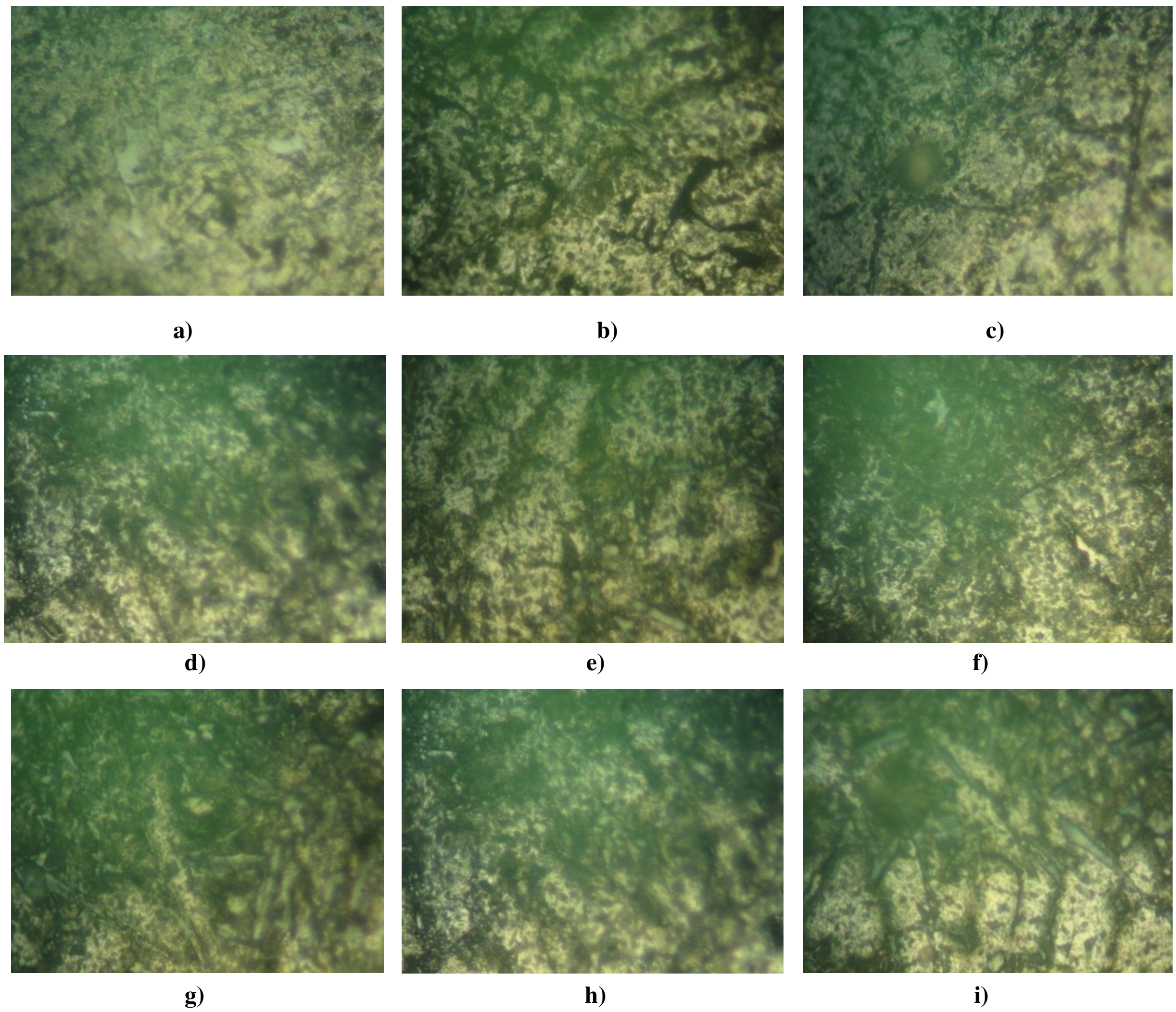
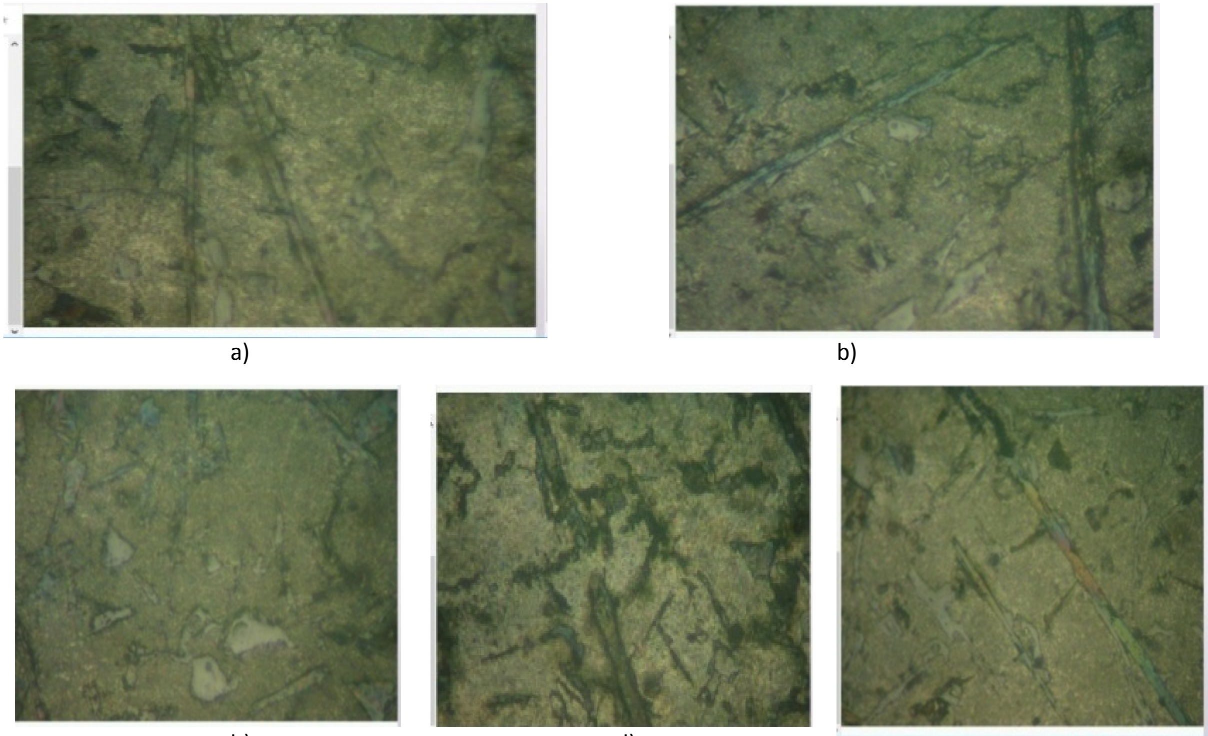


Fig. 3: (a-i) Micrograph of Cast Al-Si Piston Alloy obtained from melted scrap pistons from Taguchi Design Experiments (1-9) taken on magnification of 400X

The micrographs of the nine specimens show a basic microstructure which consist of primary α-aluminium having even distribution of eutectic silicon grains and intermetallic particles dispersed within the structural matrix. It is noticed that the micrograph of Fig. 3. (a-d) had predominately primary α-aluminium within the matrix. The microstructural view of Fig. 3(g,h and i) showed less pronounced presence of lamellar shaped eutectic silicon in the structure which accounts for toughness of aluminium alloy. The spikes are known to have been made less pronounced because of the action of wear before the metallic piston recycling. Also the micrographs of commercially available pistons are shown in Fig.4.



a) b)

b) d) e)

Fig. 4: Micrograph (400X) of Commercially available Yamaha Generator Pistons (a-e)

The micrograph of the pistons in Figs. 4 (a, b, c, d and e) show that the primary - aluminium particles are embedded in the structure of the aluminium alloy with uniform distribution of the intermetallic particles. The micrograph in Fig. 4 (c) shows globular near eutectic silicon contained in the structural matrix. Also a needle shaped near eutectic silicon particles are noticed to be present in the microstructure shown in Fig. 4(a, b, and d). The micrograph represented by Fig. 4 (e) depicts uniform distribution of long rod shaped eutectic silicon within the aluminium alloy.

4. Conclusion

The study showed that the higher the rate of wear of the piston the less pronounced the lamellar shaped spikes which accounts for the toughness of aluminum alloy. Also, the low wear rate of the piston gives rise to needle shaped eutectic silicon which connotes improved mechanical properties. The eutectic silicon particles also boosted the wear resistance strength of the pistons as seen from the chemical composition of the aluminium alloy. The aluminium metal from the melted scrap pistons was 78.98% while that of the commercially available piston was 83.334%. This occurrence is similar to the findings of Ozioko(2012) in the study of recycling motorcycle piston scraps. Also, the result is similar to that obtained by Mbuya (2010) in which the chemical composition of the melted scrap piston and commercially available pistons yielded little variation among the aluminium and the alloying elements. The result obtained in this study is similar to Kumar et al. (2020) in which the microstructure, mechanical and wear behavior under dry sliding of Silumin with particulate-reinforced Sic and TiB2 Metal matrix developed by stir casting showed excellent mechanical properties for AA6061.

5. Resources

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