ASIATRIB 2002 International Conference
JEJU ISLAND, KOREA

Wear Property of Al_20_3-Particle-Reinforced Aluminium Composite

***Y. Sahin, *A.Riza Motorcu**
***Department of Mechanical Education, Gazi University, Besevler 06500, Ankara/Turkey.**

Abstract
The abrasive wear behaviour of Al_20_3 particle-reinforced aluminium composite was investigated. The wear rate of the composite and the matrix alloy has been expressed in terms of the applied load, sliding distance and particle size using linear factorial design approach.

Key words: Wear. SiCp. Al-Cu alloy. Factorial design.

1. Introduction

Lower cost and isotropy in properties have made particle-reinforced metal matrix composites (MMCs) more attractive for a variety of commercial applications. Emergence of newer technologies have made many sophisticated fabrication processes to be adapted with a greater control and led to several routes for production of MMCs. Clearly. liquid metallurgy is the most economically attractive technique which employs near standart foundary practice amongst all the routes. MMCs have found their usage in aeorspace applications and automotive industry because of its good wear resistance performance [1-3]. This is particularly applicable in the case of Al alloys reinforced with SiC or Al_20_3 particles. However. much of the attention in wear studies has concentarted on the dry sliding wear behaviour of composites including various reinforcements such as SiCp. boron and Al_20_3 particles [4-9]. A limited number of researches on abrasion behaviour of ceramic particle reinforced aluminium alloy composites have been reported [10-15]. The present article focused on particle-reinforced MMCs and to develop a regression equation for assesing the high stress abrasive wear rate of an aluminium-cupper alloy-Al_20_3-reinforced composites.

2. Experimental Details

The composites were fabricated by a molten metal of Al-2014 alloy using an electric induction furnace. For manufacturing the MMCs:10wt%. 20wt% and 30wt%Al_20_3 particles were used. Melting process is carried out in a crucible made from graphite while mixing process is conducted at with the graphite mixer Details of the experimental set-up and production processes are reported in the previous study [14].

A pin on disc type apparatus was employed to evaluate the wear charactersitics of materials. The samples were loaded against the abrasive medium with the help of a cantilever mechanism. The sliding speed was 0.4 $m.s^{-1}$ while the normal loads were 12. 24 and 36 N. A range of abrasive sizes were 130. 36 and 12 µm. A factorial design of experiment of the type P^n was used in the present study where 'n'corresponds to the number of factors and 'P' stands for the number of levels. In this design. n=3 and P=2. Thus the minimum number of trial experiments to be conducted for each material is 8. If wear rate is represented by Y. the linear regresision equaton for these experiments could be written as:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_1x_2 + b_5x_2x_3 + b_6x_1x_3 + b_7x_1x_2x_3 \quad (1)$$

where b_0 is the response variable of wear rate at the base level: b_1. b_2. b_3 are coefficients associated with each variable of sliding distance. applied load. abrasive size and b_4. b_5. b_6. b_7 are interaction coefficients between x_1 and x_2. x_2 and x_3. x_1 and x_3 and x_1. x_2 and x_3 respectively. The paremteres of equation (1) has been estimated by the method of least-squares using a Mathlab computer package. The positive value of "Y" from equation (1) shows weight losss while its negative value indicates weight gain. Further. the positive value of any of the coefficients suggests that the wear rate of material increases with their associated variables while their magnitude indicates the weightage of each of these factors or their interaction towards the wear rate of the material.

2.0 Results and Discussion

The factorial design of experiments and the values of response variables corresponding to each set of trials are represented in Table 1. After calculating each of the coefficients of equation (1). the final linear regression equation for the wear rate of the alloy and composite can be expressed as follows:

$$Y_{alloy} = 0.0741 + 0.0277x_1 + 0.0052x_2 + 0.0219x_3 + 0.0006x_1x_2 + 0.020x_2x_3 + 0.0113x_3x_1 - 0.00046x_1x_2x_3 \quad (2)$$

$$Y_{comp} = 0.0135 + 0.0041x_1 + 0.0018x_2 + 0.0086x_3 + 0.0028x_1x_2 + 0.0008x_2x_3 + 0.0025x_3x_1 - 0.0032x_1x_2x_3 \quad (3)$$

The wear rate of the matrix alloy and composites can be calculated from these equations. By comparing theoritical and experimental values from Table 2. it is also evident from this table that the calculated values are in close proximity with the experimental ones. These facts suggested reasonably good reliability of the equations to predict the wear rate of the samples within the selected experimental domains. The penetration ability increased with increasing abrasive size. rake angle and effective stress on the abrasive. These resulted in increasing cutting efficiency of the abrasive particles. In the case of the presence of hard second phase particles in the matrix alloy. the reinforced hard particles reduced the extent of penetration of the abrasive particles on the specimen surface thereby protecting the softer matrix surrounding the hard second phase. Thus the lower wear rate was obtained for the composites than that of the matrix alloy [13.15]. However this trend is maintained as long as the dispersoid phase is retained by the alloy matrix. The wear resistance of the composites almost increased linearly with increasing load.The depth of penetration is likely to increase with increase in applied load. This is the fact that the abrasive particles are rigidly fixed on paper and the load is effectively transferred from abrasive to the specimen surface. The composite exhibited higher wear resistance than the alloy despite of causing coarser abrasive size than the dispersoid phase even at higher load. Moreover. the hardness of alumina dispersoid is relatively lower than that of the SiC abrasive causing formation of finer alumina fragments which are easily picked up in the matrix portion of the wear surface of the composite.

One of the most important factor affecting the wear behaviour is travel distance. The coefficient (b_1) associated with sliding distance (x_1) is noted to be positive for both types of specimens. This suggests that the wear rate increased with increasing travel distance. Its cutting efficiency did not reduce with increasing the sliding distance due to abrasive comes in contact with the specimen surface and produced new chips.The extent of increase in the wear rate with distance is less in the case of the composite. The more severe degradation of the abrasive medium with sliding distance was not observed when the composite tested. This is not consistent with the previous study carried out by Prasasad et al [15,16] on Al-Zn alloy composite. In their work, wear decreased with sliding distance and explained the decreasing the cutting efficiency of the abrasive particles by the way of capping, clogging and shelling. In our case, a relatively finer microcutting chips are produced and the matrix is plastically constrained, chances of capping and clogging of the abrasive is relatively less for composite. The coefficients b_2 and b_3 associated with the applied load and abrasive size were found to be positive. It indicates that wear rate increased with load, and abrasive size.

The coefficient associated with sliding distance and abrasive size is positive. This suggests sliding distance to be more effective than load and abrasive size in controlling the wear behaviour of the matrix samples, whereas, abrasive size is found to be effective for the composite. The interaction coefficient between load and sliding distance is positive for the composite as well as the matrix alloy. It emerges that processes like the shelling, clogging and work hardening became not more effective at longer sliding distance with increasing combined effect of load and sliding distance. The interaction coefficient between abrasive size and load is positive for both samples. This clearly indicates that the combined action of load and abrasive size caused more damage to the specimen surface. It might be attributed to the fact that under high coarser abrasive size, cutting efficiency of the abrasive increased and caused the formation of wider and deeper wear groves. This effect is relatively high for the matrix alloy and composite although penetration ability is reduced by the ceramic particles which resulted in less damage for alloy. The interaction coefficient between abrasive size and sliding distance is noted to be positive for both materials. This signifies that the effect of sliding distance is more predominant than that of the abrasive size and it is followed by the abrasive size for both cases. Consequently the wear rate increased due to interaction of abrasive size and sliding distance. However, abrasive size is found to be more effective than the distance for the composite due to higher degree of shelling and blunting of abrasive because of the hard dispersoid in it.

3. Conclusions

The wear rate of the matrix and composite samples increased with increasing abrasive size, applied load and sliding distance. However, abrasive size is to be effective than those of the sliding distance and load for MMCs.

References

[1]. Modi, O.P, Prasad, B.K. Yegnewaran, A.H. Vaidya, M.L., Dry sliding wear behaviour of squeez cast aluminium alloy-silicon carbide composites. Mat.Sci.Eng.A 151 (1992) 235

[2]. Sahin,Y., Wear behaviour of planar-random fibre–reinforced metal matrix composites. Wear, 223 (1998) 173-183.

[3] Zhang,Z, Zhang,I, Mai,Y.W.,Wear behaviour of SiCp/Al-Si composites. Wear 176 (1994) 231-237.

[4].Sahin, Y., Ph.D. Thesis, The mechanical and wear behaviour of metal matrix composites, Aston University in Birmingham,1994,UK.

[5]. Alpas,A.T, Zhang,T., Wear transition in cast aluminium-silicon alloys reinforced with SiC particles Met.Trans.a 25A (1994) 969-975.

[6]. Akbulut,H, Durman,M,Yılmaz,F., Dry wear and friction properties of δ-Al_2O_3 short fibre-reinforced Al-Si alloy, Wear 215 (1998) 170-176.

[7]. Gürcan, A.B, Baker,T.N., Wear behaviour of AA6061 aluminium alloy and its composites, Wear 188 (1995) 185-190.

[8]. Axen, N, Jacobson, S., A model for the abrasive wear resistance of multiphase materials, *Wear*, **174** (1994), pp.187-199.

[9]. Skolianos,S Kattamis,T.Z.,Tribological property of SiCp- reinforced Al-4.5%Cu-1.5%Mg alloy composites, Mat.Sci.Eng. A 163 (1993) 107-112.

[10]. Sheu,S.-Y, Lin, S-J., Particle size effect on the abrasion wear of 20vol%SiCp/7075 Al composites, Scripta Materialia, 35 (1996) 41-47.

[11].Mondal, D.P, Das,S Jha,A.K Yegnesswaran, A.H., Abrasive wear of Al alloy-Al_2O_3 particle reinforced composite: A study on the combined effect of load and size of abrasive, Wear, 223 (1998) 131-138.

[12]. Deuis,R.L, Subramanian,C,Yellup, J.M., Abrasive wear of aluminium alloy composites-A review, Wear, 201 (1996) 132-144.

[13].Prasad, B.K, Jha,A.K. Modi, O.P., Das, S, Yegneswaran, A.H., Abrasive wear characteristics of Zn-37.2Al-2.5Cu-0.2 Mg alloy dispersed with SiC particles. Mater. Trans., JIM, 36 (1995) 1048-1057.

[14].Sahin,Y, Kok,M, Celik,H., Tool wear and surface roughness of Al_2O_3 reinforced Al alloy composites, J.Mate.Process.Technol. 6060 (2002)1-12.

[15].Prasad,B.K, Jha,A.K. Modi, O.P, Dasgupta,R. Yegneswaran, A.H.,Composites, Part A 28A (1997) 301-308.

[16]. Prasad, B.K.,Wear 252, 3-4 (1996) 250-163.

Table 1. Experimental conditions and their results.

Tri. num	Sliding distance (m)	Applied load (N)	Abra. size (μm)	Wear rate (mm³/m)	
				Matrix	Composite
1	84	36	60	0.14	0.0254
2	84	36	9	0.075	0.0076
3	84	12	9	0.060	0.0518
4	36	12	9	0.0395	0.0028
5	36	36	60	0.070	0.024
6	36	12	60	0.044	0.0070
7	84	12	60	0.130	0.0032
8	36	36	9	0.032	0.0038

Table 2. Random experimental results and their corresponding Theoretical.values.

Tri. num	Sliding distance (m)	Applied load (N)	Abrasive size (μm)	Wear rate (mm³/m)	
				Matrix alloy	Composite
1	72 (0.5)	20 (-0.33)	17 (-0.093)	0.074 (0.0642)	0.0095 (0.0084)
2	72 (0.5)	20 (-0.33)	9 (-0.186)	0.051 (0.0552)	0.0073 (0.0082)
3	24 (-1.5)	20 (-0.33)	17 (-0.093)	0.0470 (0.037)	0.0070 (0.0067)
4	24 (-1.5)	20 (-0.33)	9 (-0.186)	0.0340 (0.036)	0.0056 (0.0062)
5	72 (0.5)	30 (0.5)	17 (-0.093)	0.063 (0.0722)	0.0090 (0.0090)
6	72 (0.5)	30 (0.5)	9 (-0.186)	0.072 (0.0709)	0.0075 (0.0088)
7	24 (-1.5)	30 (0.5)	17 (-0.093)	0.091 (0.0394)	0.0053 (0.0066)
8	24 (-1.5)	30 (0.5)	9 (-0.186)	0.040 (0.0387)	0.0064 (0.0061)