ABRASIVE WEAR OF THERMALLY AGED 6061 Al–SiC COMPOSITES

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1. Introduction

There have been many studies on the abrasive wear properties of metal matrix composites[1–9]. However, only a few of these studies have been concerned with the effect of thermal ageing on wear resistance[7–9]. The effect of ageing temperature has been determined by Wang and Rack[8] in 2124 Al–SiC$_w$ and by Song *et al.*[9] in 2014 Al–SiC$_p$ and 6061 Al–SiC$_p$ composites. In these experiments, it was found that raising the ageing temperature from the under-aged condition to peak aged condition improved the wear resistance. The aim of the present work was to determine the effect of ageing time on the hardness and wear resistance of thermally aged 6061 Al–SiC$_p$ composite.

2. Experimental Materials and Techniques

The abrasive wear characteristics were studied of two metal matrix composites based on the age-hardening aluminium alloy 6061 which had a nominal chemical composition of Al–1.1Mg–0.26Cu. The composites were reinforced with volume fractions of 10 and 20% of 3μm (1200 grit) particulate SiC. Light microscope examination of the microstructures revealed that the particles were reasonably uniformly dispersed throughout the matrix with some tendency toward clustering which was similar in both materials. Unreinforced 6061 aluminium alloy was included in the study as a reference material for comparison purposes.

The materials were heat-treated to the T6 condition, which involved solution treatment at 530 °C for 1 h, quenching in cold water, and then pre-aging at room temperature for 20 h. To study the effect of ageing time on the hardness and wear properties, the materials were then artificially aged at 175 °C for 0.5, 4, 8, 20 and 50 h. The specimens were refrigerated at –10 °C to prevent further ageing prior to wear testing and hardness measurement.

After ageing, Vickers microhardness measurements were carried out using a load of 50 g. This created indentations which were approximately 5 times larger than the interparticle spacing, and the hardness values are thus representative of the matrix and reinforcement. The abrasive wear tests were performed on cylindrical pins 6.35 mm diameter and 30 mm in length, using a pin-on-drum machine according to the method described by Song *et al.*[9]. The tests were performed using 80 μm Al_2O_3 heavy duty cloth with a deadweight load of 66.7 N at a velocity of 4.23×10^{-2} m s^{-1}. The weight loss of each pin was determined to the nearest 0.1 mg from a test run over a path length of 12.84 m. Each pin was tested four times and an average weight loss was taken. The weight loss of a pin of reference material (a quenched and tempered low-alloy steel of hardness HV 265) was also measured between the second and third test runs on each abrasive cloth, and this was used to correct the measured weight losses of the composite material pins to compensate for variability between different abrasive cloths. After wear testing, the surfaces of the wear pins were examined by SEM microscopy.

3. Results and Discussion

Fig. 1 shows the variation of microhardness with ageing time for both composite materials and the 6061 alloy. The materials all exhibit similar ageing characteristics; underaging occurs for times up to 20 h; peak ageing occurs at approximately 20 h, and the overaging occurs at 50 h. The effects of reinforcement volume fraction are also evident in fig. 1. The ageing curves for the three materials are similar in shape, but the general level of the ageing curves increases with increasing volume fraction of SiC reinforcement, with each 10% volume fraction of SiC increasing the hardness by approximately 20 HV points. This pronounced increase in hardness in the presence of SiC particles has been observed previously by other workers and has been attributed[8,10] to the generation of high dislocation densities in the matrix near particles due to differential thermal contraction effects between the SiC reinforcement and Al alloy matrix.

Fig. 2 shows the variation of wear resistance with ageing time for the composite materials and the 6061 alloy. The wear resistance was the reciprocal of the volumetric wear rate (the volume lost per unit distance of sliding in cm^3/cm). The volumetric wear rate was calculated by dividing the average weight loss (g) of each pin by the specific gravity of the material (g cm^{-3}). Despite some scatter in the wear resistance values, it is evident in fig. 2 that the wear resistance increases with ageing time until the maximum wear resistance is reached for an ageing time of approximately 20 h, and that a reduction in wear resistance occurs with longer ageing times. This trend is parallel with the trend in hardness in fig. 1. The decrease in wear resistance is contrary to the effect reported by Wang and Rack[8] that the wear resistance increases in the overaged condition.

Comparison of fig. 2 with fig. 1 indicates that the level of the wear resistance curves is not as widely separated between materials as the hardness values, particularly at short ageing times. This suggests that the wear behaviour is governed by the matrix properties to a greater extent than hardness.

The typical particle size and interparticle spacing of the SiC in the composite materials were 3 and 5–10 μm respectively The alumina abrasive particle size was larger at 80 μm, and the width of abrasive grooves was typically 20–30 μm. Thus it is likely that many of the small SiC particles are removed relatively easily in larger particles of wear debris.

SEM examination of the worn surfaces showed that the wear mechanisms in the unreinforced 6061 alloy were predominantly microploughing and microcutting. It was observed that the proportion of microcutting increased at the expense of microploughing with increasing ageing time. The same wear mechanisms were also predominant in the case of the composite materials, but it was also observed that significant pull-out of reinforcing particles by the larger abrasive particles occurred. The latter effect appeared occur more frequently in the 20% SiC composite than in the 10% SiC material. Such pull-out of reinforcing particles could be expected to increase the wear rate and thus reduce wear resistance.

4. Conclusions

The abrasive wear resistance and hardness of 6061/SiC composites both increase with ageing time, and reach a maximum value when the composites are in the peak-aged condition. At any particular ageing time, the hardness and wear resistance increase with increasing volume fraction of SiC particle reinforcement. However, the increase in wear resistance associated with SiC reinforcement is less than the corresponding increase in hardness. This is attributed to pull-out of reinforcing particles in the micro-mechanism of wear, which could be expected to increase the wear rate. In the over-aged condition, both hardness and wear resistance decrease below the peak values.

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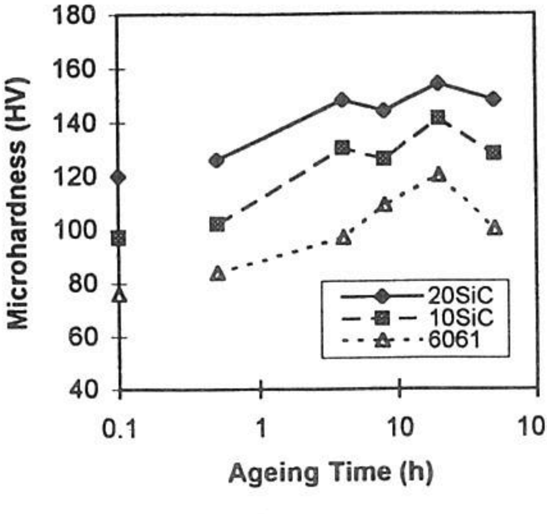

Figure 1. Effect of ageing time at 175 °C on Vickers microhardness. The values at 0.1 h are for the solution treated and unaged condition.

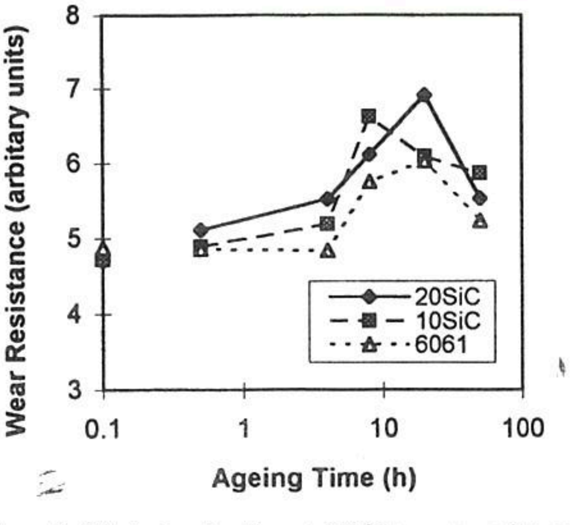

Figure 2. Effect of ageing time at 175 °C on wear resistance. See text for method of calculating wear resistance. The values at 0.1 h are for the solution treated and unaged condition.

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