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# DETERMINATION OF TRANSIENT WEAR DISTANCE IN THE ADHESIVE WEAR OF A6061 ALUMINIUM ALLOY REINFORCED WITH ALUMINA PARTICLES

L.J. Yang
School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798,
Republic of Singapore. e-mail: mljyang@ntu.edu.sg

## ABSTRACT

An integrated adhesive wear model was proposed to determine the transient wear and steady-state wear of aluminium alloy matrix composites. The transient wear volume was described by an exponential equation, while the steady-state wear was governed by a revised Archard equation, in which both the transient wear volume and transient sliding distance were excluded. A mathematical method was developed to determine both the transient distance and the net steady-state wear coefficient. Experimental wear tests were carried out on three types of commercial A6061 aluminum alloy matrix composites reinforced with 10%, 15% and 20% alumina particles. More accurate wear coefficient values were obtained with the proposed model. The average standard wear coefficient, as determined by the original Archard equation, was found to be about 51% higher.

**Keywords:** Transient wear distance, A6061 aluminum alloy matrix composites, adhesive wear, transient wear, steady-state wear, wear coefficient.

## 1. INTRODUCTION

Wear coefficient is an important wear parameter (1,2). However, nearly all the wear tests were carried out arbitrary to determine their values without taking into account their transient wear and steady-state wear separately. Recently Zhang et al. [3] postulated a mathematical model for the transient wear volume of a steel/Al-SiC(P) composite system. However, this equation was found difficult to use, as the distribution of particles and their sizes in MMC materials are usually non-uniform. A simpler exponential transient wear equation, together with an integrated adhesion wear model to cover both the transient wear and the steady-state wear, were proposed in this study. A mathematical method was also developed to facilitate the determination of the transient distance.

Figure 1 shows that a wear volume versus distance curve can be divided into two regimes, the transient wear regime and the steady-state wear regime. The volume (or weight) loss is initially curvilinear and the rate of volume loss per unit sliding distance decreases until at P where it joins smoothly with the straight line PQ. The amount of volume loss in the regime given by OP is the transient wear and PQ is the steady-state wear.

The standard method to calculate the wear coefficient is to make use of the total volume loss and the total sliding distance covered [4]. Hence the standard wear coefficient value obtained from a volume loss versus distance curve is a function of the sliding distance. Due to the higher initial running-in wear rates, it has a higher value initially and will reach a steady-state value as shown in Fig.3. This practice would therefore give a higher steady-state wear coefficient value since the higher wear rate from the transient wear is included in its computation. Hence in the integrated wear model proposed, the original Archard equation [5] was modified to enable the net steady-state wear coefficient to be determined more precisely, by excluding both the transient wear volume and transient sliding distance in its computation.

## 2. THE INTEGRATED ADHESIVE WEAR MODEL

In this integrated mathematical wear model, two different equations are used to describe them: an exponential equation to model the transient wear (Eq.1); while a revised Archard equation to model the steady-state wear (Eq.2). The transient distance ($L_t$) is determined by Eq.3; and the original Archard equation is shown in Eq.4.

$$V_t = A[1-\exp^{-BL_t}] ........(Eq.1) \qquad V_S = K_N \frac{PL_S}{3H} ........(Eq.2)$$

$$L_t = \frac{-\ln[V_S / ABL_S]}{B} .....(Eq.3) \qquad V = K_S \frac{PL}{3H} ........(Eq.4)$$

where $V_t$ is the transient wear volume, $L_t$ is the transient distance, A and B are experimental constants, $V_S$ is the steady-state wear volume, $K_S$ is the standard wear coefficient, P is the applied load, H is the hardness of the softer material, $L_S$ is the steady-state sliding distance, $K_N$ is the net steady-state wear coefficient, while V and L are respectively the total wear volume and total sliding distance used in the original Archard equation.

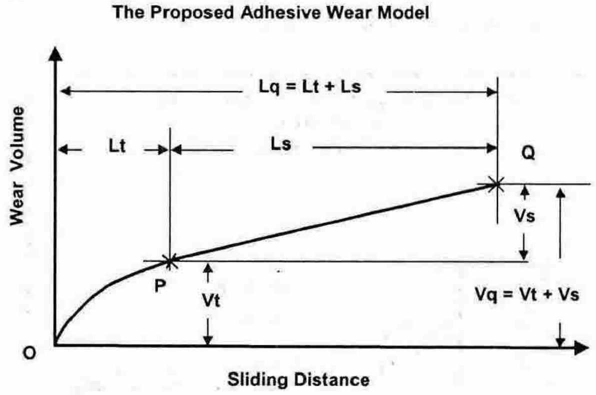

Figure 1. The proposed integrated adhesive wear model.

## 3. EXPERIMENTAL TECHNIQUE

Wear tests for MMC-A, MMC-B and MMC-C, with 10%, 15% and 20% of alumina particles respectively, were carried out at distances of 250m, 500m, 1000m, 1500m, 2000m, 2500m, 3000m, 6000m, 9000m and 12000m by using the

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moving-pin technique developed at Nanyang Technological University. This technique was found particularly useful for testing hard pin materials [2]. It was again used in the current study as the aluminum alloy matrix composites containing alumina could be abrasive to cause a rapid wear of the disc which was made of Assab tool steel (equivalent to AISI-01) and hardened to 60HRC. The disc had a surface finish of 0.3μm ($R_a$). A constant load of 7.5kgf, with a linear velocity of 4.58m/s and a feed of 0.05mm/rev, was used. Three repetitions were carried out for each experimental treatment. A stopwatch was used for timing the sliding distance. Weight loss data were collected, and the constants A and B were determined by using a standard commercial software. The standard wear coefficients of the specimens were calculated by using Eq.4 for both the transient wear and the steady-state wear. The proposed Eq.3 and Eq.2 were then used to calculate the transient distance values and the net steady-state wear coefficient values.

## 4. RESULTS

Figures 2, 3 and 4 show respectively the wear volume versus distance curves, the standard wear coefficient versus distance curves; and the net-steady-state wear coefficient versus sliding distance for the three materials.

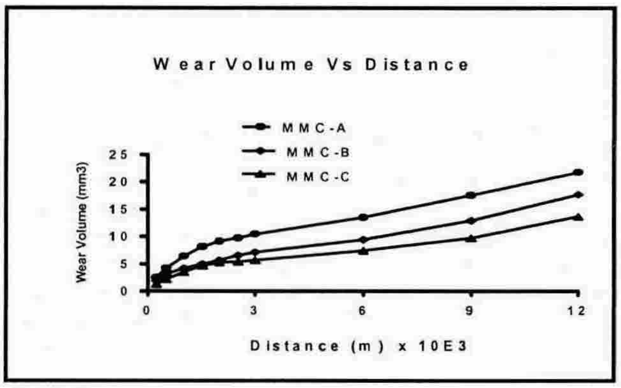

Figure 2. The wear volume versus distance curves

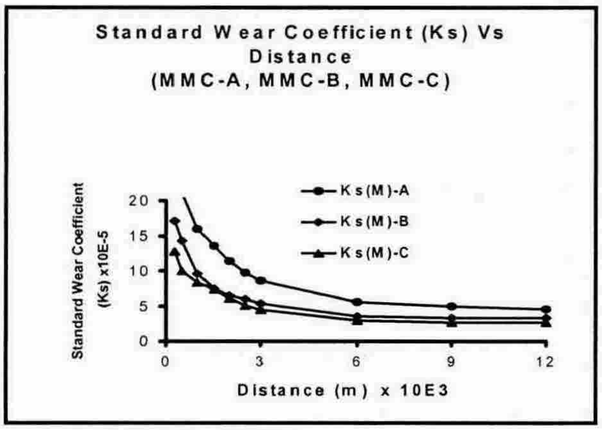

Figure 3. Standard wear coefficient versus distance curves

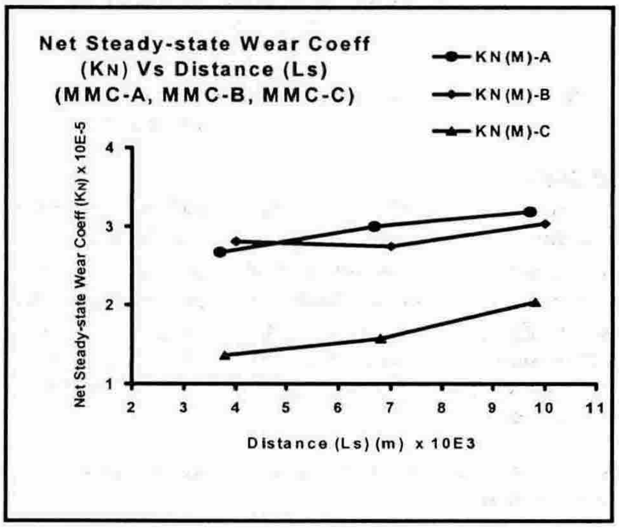

Figure 4. Net steady-state wear coefficient versus distance.

By comparing Fig.3 with Fig.4, it is obvious that the standard coefficient values vary considerably while more consistent values were obtained with the net steady-state wear coefficients. On the average, the standard wear coefficient, as determined by the original Archard equation, was found to be about 51% higher.

## 5. CONCLUSION

i) An integrated wear model was proposed in this study to determine the transient distance and the net steady-state wear coefficient from a volume loss versus distance curve.
ii) The transient distances (Lt) determined for MMC-A, MMC-B and MMC-C were found to be 2311m, 1999m and 2228m respectively.
iii) The net steady-state wear coefficients for the same three materials were determined to be 2.95 x $10^{-5}$, 2.86 x$10^{-5}$ and 1.66 x $10^{-5}$ respectively.
iv) The average standard wear coefficient, as determined from the original Archard equation, was about 51% higher than that obtained from the present model.
v) The proposed model is capable of obtaining more accurate and consistent wear coefficient values, with the potential of saving considerable amount of wear testing time.

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