Wear 271 (2011) 1804–1812

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Effect of abrasive size on wear of metallic materials and its relationship with microchips morphology and wear micromechanisms: Part 2

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ARTICLE INFO

Article history:
Accepted 12 January 2011
Available online 30 May 2011

Keywords:
Abrasive particle size
Wear debris
Wear micromechanisms
Metallic materials

ABSTRACT

In this paper, the effect of abrasive particle size on the wear of three different metallic materials (AISI 1045 steel, aluminum alloy and gray cast iron) was investigated. Abrasive wear tests using a pin on alumina paper were carried out using abrasive sizes between 16 μm and 192 μm. The wear surface of the specimens was examined by SEM for identifying the wear micromechanism and the type of microchips (wear debris) formed on the abrasive paper. The results show that the mass loss for the AISI 1045 steel and for the aluminum alloy increases linearly with the increase of particle size until the critical particle size is reached. After the critical particle size is reached, the rate of mass loss of the aluminum alloy increases at a lower linear rate, and for the AISI 1045 steel the curve of mass loss is non-linear and flattens when the critical particle size is reached. The abrasive paper in contact with the AISI 1045 steel presents continuous microchips before reaching the critical particle size (about 116 μm) and after it, it presents deformed discontinuous microchips and abrasive fracture. The abrasive paper in contact with aluminum presents clogging and continuous microchips before the critical particle size (about 36 μm) and after it, it presents discontinuous microchips. The wear surfaces of the AISI 1045 steel and the aluminum alloy present microcutting as the main wear mechanism before reaching critical particle size, and after that, it presents microploughing as the main wear mechanism. The gray cast iron did not show a transition in the curve of abrasive size against mass loss. The morphology of the microchips was similar for the different sizes of abrasive (discontinuous). However, at smaller abrasive sizes, some thin continuous microchips and clogging were formed. The main abrasive wear micromechanism was microcutting for the different abrasives sizes tested. The results show that the effect of critical abrasive size on wear in metallic materials can be related with the wear micromechanisms and the microchips morphology.

1. Introduction

The effect of abrasive particle size on wear has been studied extensively for homogeneous materials [1–18]. Anvient et al. [1] abraded a series of pure metals: Ag, Cu, Pt, Fe, Mo and W, with emery paper, a mixture of Al_2O_3 and Fe_3O_4. Fig. 1(a) shows that the wear rate increases with abrasive size in the range of 5–70 μm and becomes independent when the grit size is in the range of 70–140 μm. Anvient et al. [1] and Goddard and Wilman [3] established that the critical particle size (CPS) value is controlled by clogging of the small sized abrasive. Rabinowicz et al. [2] found that the wear produced by loose Al_2O_3 abrasive is affected by the abrasive size in the same way observed by Anvient et al. [1] using emery paper. Rabinowicz et al. [2] claimed that the position of the bend in the curve is essentially the same found by those authors [1] (Fig. 1(b)). However, a close examination on Anvient et al. [1] and Rabinowicz et al. [2] results (Fig. 1) show that for iron and steel the CPS may be estimated in about 50 μm, whereas for other metals and alloys the CPS is close to 70 μm.

Further studies where metals and polymers were studied led Rabinowicz and Mutis [4] to the conclusion that the change in wear curves after CPS is due to interference between the abrasives and adhesive wear fragments. The author proposed that the adhesive wear may occur when abrasive particles are small, and when the adhesive fragments are larger than the abrasive size the cutting action can be prevented. In a broad sense this explanation encompasses the clogging effect expressed by Anvient et al. [1]. Nathan and Jones [5] studied the particle size effect of a silicon carbide on different materials (aluminum, brass, copper, bronze, iron and steel) using two-body abrasive wear equipment. The authors found that the wear volume increases linearly up to 70 μm and the gradient continuously decreases between the values of 70 μm and 150 μm, and above 150 μm the linear relationship is again

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doi:10.1016/j.wear.2011.05.036

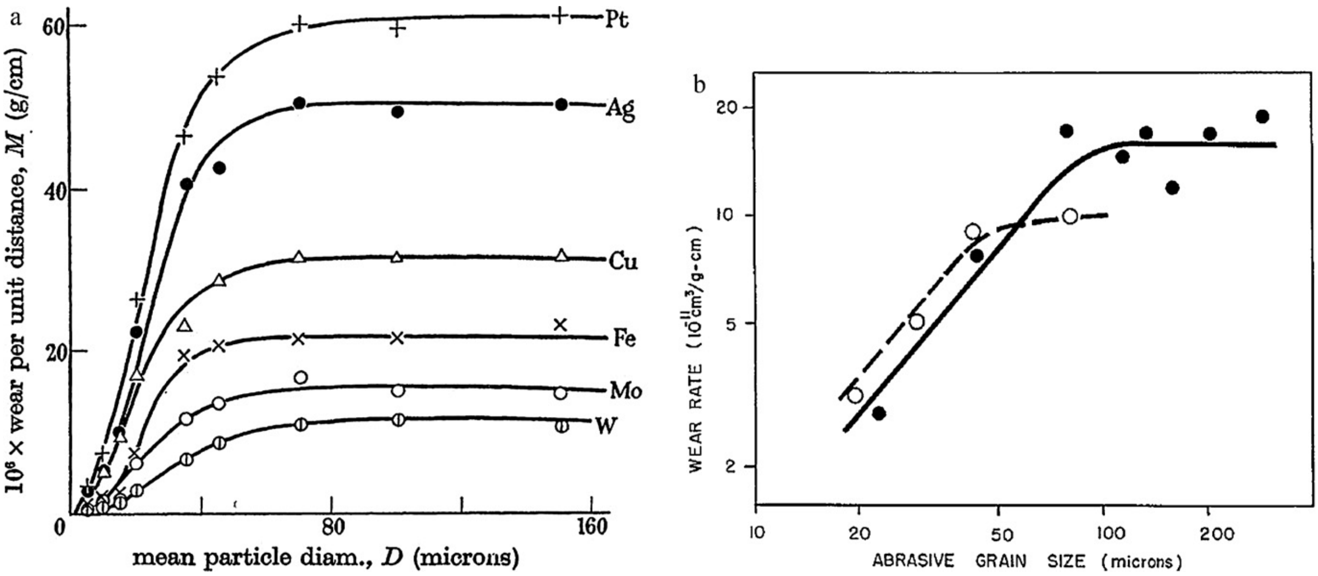

Fig. 1. Relationship between the wear rate and mean abrasive size (a) emery paper and 1 kg load (Anvient et al. [1]), and (b) loose Al_2O_3 and 0.5–1 kg load (Rabinowicz et al. [2]).

established but at a lower wear rate (Fig. 2(a)). For aluminum, the slope is higher, compared with that of the other materials tested. The behavior was the same as that observed in previous papers [1,2] until reaching 70 μm, however, for bigger grit sizes the wear was not independent of the grain size as observed previously in the literature.

Larsen-Badse [6] carried out two-body abrasive wear tests on copper using SiC as abrasive. The author found that the wear rate increases rapidly until the critical grit size is reached (the value of CPS ranging from 40 to 80 μm, depending on the test load). Above the CPS, two things happened: the wear rate was constant for low loads and decreased for higher values of load. The results are shown in Fig. 2(b). The author suggests that the abrasive deterioration was the cause of the decreasing ability of small size abrasives. Larsen-Badse [7] noted that the increase in applied load led to an increased number of scratches; however, the average width of scratch varied little. The author concluded that for smaller sizes of abrasive there exists only elastic contact with the material and therefore it only supports the applied load, with no material being removed.

The literature reported several curves of abrasive particle size versus wear rate for two and three body abrasive and erosion. For abrasive grain sizes below critical particle size the wear increases with abrasive size and, above the CPS one in three curves are found: either the wear rate increases much more slowly with grit size [5,17], or the wear rate becomes independent of further size increases [1,2,8,10–12,14], or the wear rate decreases with grit size [6,12]. For homogeneous materials, many explanations for the abrasive size effect have been reported in the literature: clogging, adhesive wear particles, abrasive damage, elastic contact, abrasive shape, change in material properties, change in strain rate, etc. However, there does not exist a general explanation accepted by the whole scientific community. That is why the particle size effect in abrasive wear is still an interesting topic for investigation and discussion.

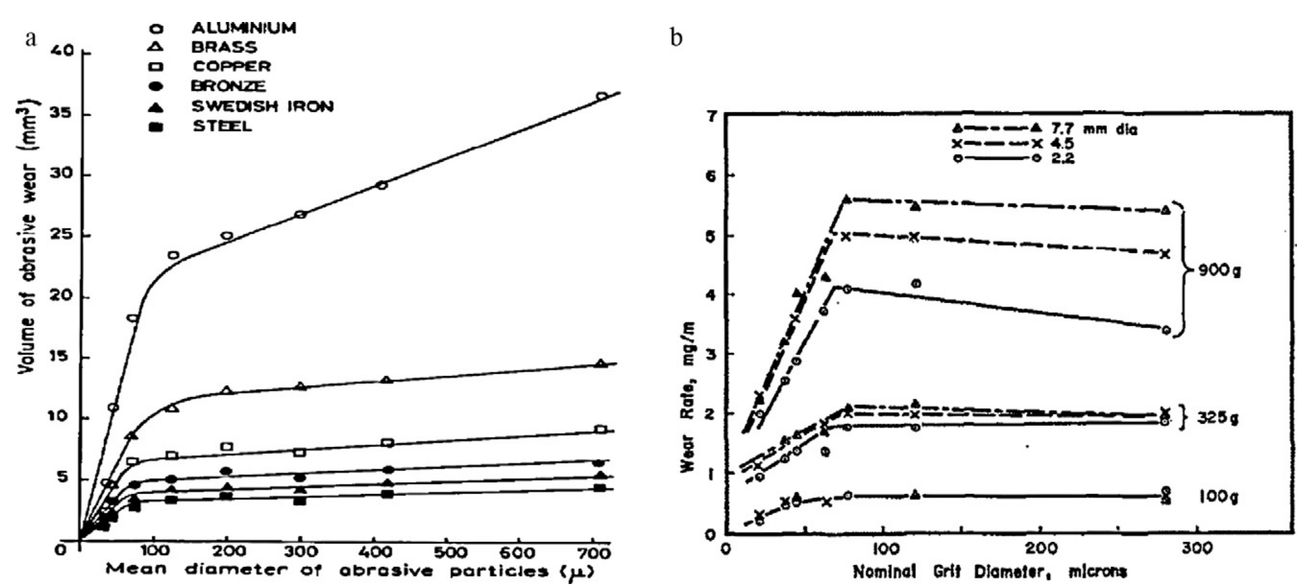

Fig. 2. (a) Relationship between the volume of abrasive wear and the mean diameter of abrasive particles (Nathan and Jones [5]) and effect of grit size on wear rates (Larsen-Badse [6]).