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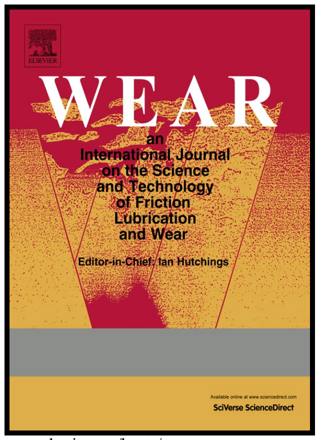

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Assessment of wear behaviour of copper-based nanocomposite at the nanoscale

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Abstract: Nanoscale wear behaviour of copper-based nanocomposite with Al_2O_3 nanoparticles have been investigated with the help of the circular mode atomic force microscopy (CM-AFM). The occurrence of running-in and steady-state wear regimes is similar to macroscopic behaviour described by Barwell. Archard's macroscopic wear equation, which states that the wear value is proportional to the applied load and independent on the sliding speed, is also valid at the nanoscale, with the limitation that the normal load should reach a threshold value to generate wear. Eventually, it is shown that the wear value at the nanoscale is highly dependent on the nature of the counter-body (AFM tip) material.

Keywords: circular mode AFM, nanowear, metal matrix nanocomposite, wear laws.

1. Introduction

Wear at nanoscale is a field of growing interest, due to the nanotechnology developments and their increasing applications in micro-electromechanical and others systems. Experimental and theoretical studies of wear behaviour on macroscale are numerous, while the experimental difficulties hinder noticeably experimental studies on nanoscale. For instance, many friction experiments at nanoscale are described as operating in a ''wearless'' regime, i.e. with a wear rate considered below the detection limit of the experiment. Such low wear rates make it difficult to quantify wear [1]. In addition, there is a problem connected with the atomic force microscope (AFM) tip wear, which exist even when e.g. diamond tip is in contact with softer counter-body [2]. Furthermore, a complete 3D quantification of the wear volume is difficult at the atomic scale. Most of the investigations at the nanoscale reported in the literature are typically based on 2D images analysis of scanning electronic microscope (SEM) AFM tip images [3]. In this latter case, the worn volume is usually calculated by assuming that the tip worn is was cone shaped [4].

Phenomenological laws of dry sliding adhesive and abrasive wear of metals on macroscale were established by Archard, more than 60 years ago [5]. Among other relevant features, he has concluded that the wear rate is proportional to the applied load and is independent on sliding speed. In addition, Burwell and Strang [6] showed that the wear volume is proportional to the sliding distance, while Barwell [7] gave a set of three different empirical wear laws describing respectively the running-in, the steady-state, and the wear-out regimes. Nowadays, these wear regimes are presented through the wear curves, i.e. wear volume dependence on sliding distance [8]. Although broadly applicable for the macroscale wear behaviour, these underlying rules remain unclear at the nanoscale.