INTRODUCTION TO THE MICRO-SCALE ABRASION TEST FOR COATINGS AND BULK MATERIALS

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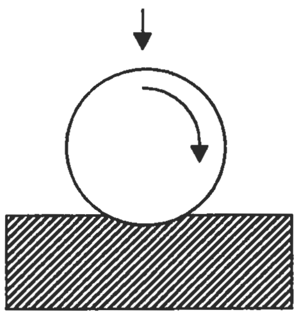
ABSTRACT

There has been considerable interest in the past few years in a simple abrasive wear test which is often called the 'micro-scale abrasion test': two variants of the test are the 'ball-cratering' and 'dimple-grinder' methods. In the first of these, a sphere rotates under a fixed load against the surface of the specimen in the presence of a slurry of abrasive particles, and a wear scar in the shape of a spherical cap is progressively formed in the surface. In order for the test to yield useful results, the test conditions must be closely controlled and the data provided from the test must be analysed in appropriate ways. Significant advances in both these aspects have been made over the past five years. These will be briefly reviewed and some applications of the test method highlighted.



The ball-cratering or dimple-grinder method is an example of a tribological test in which the geometry of the worn surface necessarily conforms to that of the counterbody [1]. Analysis of the progress of wear, as a function of applied normal load and total sliding distance, is trivial for a homogeneous bulk sample if an Archard-type wear law is assumed. However, the fact that the wear scar must conform to the shape of the sphere permitted Kassman et al. in 1991 [2] to analyse the wear of a coated sample, in which the wear coefficients of the coating and substrate are different, even though the coating may be penetrated at an early stage of the test. Their model has been used as the basis for several subsequent methods of analysis, which have been reviewed by Rutherford and Hutchings [3]. In many cases, the need to measure the wear coefficient of the substrate independently, by a separate test on an uncoated region, can be avoided, and the behaviour of both substrate and coating can be deduced by appropriate analysis of measurements made at a single location.

Early studies of the method used either the 'dimple-grinder' geometry, commercially available in devices intended to produce local thinning of specimens for electron microscopy, or a 'ball-cratering' instrument, designed to be used to determine thickness of coatings by radial sectioning. In the latter types of instrument the ball rests under gravity in contact with the surface of the specimen and a grooved driving shaft, which is rotated by a motor; it can be modified by the incorporation of a load cell to monitor the applied load, and such instruments can provide excellent repeatability [4]. For more detailed studies of the mechanics of the test, and of such important aspects as the entrainment of abrasive particles into the contact region, instruments have been designed in which the ball is driven positively, and the specimen is loaded against the ball by a dead weight on a lever arm [5, 6]. Such designs also have significant advantages for routine testing, since there is no need to monitor the normal load during the test, and no danger of the ball slipping against a driving shaft.

Detailed studies of the influence of test conditions on the wear rates and mechanisms in the test have revealed subtle and initially unexpected effects associated with the influence of ball surface condition on the entrainment of particles [5], and transitions between two-body (grooving) and three-body (rolling) motion of the particles in the contact [6]. These aspects, if not appreciated and taken into account in the choice of test conditions, can lead to significant lack of reproducibility of results. Transitions between different regimes of particle motion have been mapped and the test conditions which favour either two- or three-body abrasion can be defined. Test conditions suitable for various types of material can now be recommended [7].

The micro-scale abrasion test has significant advantages over more conventional methods of abrasion testing for certain applications. It involves a very shallow depth of penetration (of the order of micrometres [3]), and also samples small areas of the sample (typically one or two millimetres in lateral extent). It can therefore be applied to samples, and for purposes, where conventional abrasive wear tests could not be used. For example, it can be used for modified surfaces and coatings where the depth of modification or coating is very shallow, especially since the wear rate of the coating can be studied even if the coating is penetrated during the test. Examples include PVD and other types of thin coating [e.g. 3, 8, 9]. Thicker coatings, such as plasma-sprayed coatings or paint films, can be studied as if they were bulk materials since the depth of penetration is so small [10]. The method can be used to study abrasion of very valuable materials, such as precious metals, for which macroscopic wear tests would be prohibitively expensive [11]. The test can be applied to specimens which are unavoidably small: for example, to amorphous metal ribbons [12], or to samples of biomedical implant materials which have been retrieved after implantation in the human body [13].

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