

# Development of the Micro-Scale Abrasion (Ball Cratering Wear) Test

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*The surface engineering of components for wear resistance is now an established technology and the number of successful applications has increased rapidly. However, one of the problems in making an assessment of wear resistance is the fact that wear rates of hard coatings are very low. The ball cratering or micro-scale abrasion test technique has been found suitable for measuring these low wear rates. The adoption of a fixed ball as opposed to a free ball design offers many advantages. It has also become clear that the contact conditions must be selected to suit the materials being tested.*

## 1 Development of the Technique

The rotation of a ball against a coated plate in the presence of an abrasive slurry results in the production of a circular depression. Eventually the coating is worn through and a "bulls-eye" depression is seen where the substrate shows through. Measurements of the inner and outer diameters of this bulls-eye are easily made and provide an accurate and low cost method of determining coating thickness. This is an established coating thickness measurement technique. A similar technique using a rotating drum is cited in the ASTM Annual Book of Standards [1]. A further related technique is the dimple grinder where a coated sample is rotated under a grinding wheel to produce the crater [2].

Rutherford and Hutchings [3] suggested that the ball on plate technique could be adapted to measure the wear resistance of surface coatings by simple instrumentation.

In order to use this configuration for wear coefficient determination it is necessary to measure precisely ball rotational speed, applied load and number of rotations completed (for sliding distance determination). The aim of such a test is to measure progressive wear over an extended number of cycles and thus determine wear rates and wear coefficients of the coating and substrate material.

## 2 Free Ball Devices

The existing ball cratering devices used for coating thickness measurements use a free ball that rests on the coated surface and at two points on a rotating shaft. The static load on the surface is determined by the size of the ball and the tilt angle of the coated surface (Figure 1). The ball is driven by friction against the shaft and abrasive slurry is fed into the wearing contact. Since the ball is free and the friction conditions variable, the number of rotations (therefore sliding distance) and applied load are both uncertain.

The influence of the friction conditions on load was analysed in detail by Rutherford and Hutchings [4]. The numerical determination of normal load requires a knowledge of the friction coefficient in the contact. This would have to be determined for every material and slurry combination.

Their solution was to introduce a load sensing transducer directly under the mount for the coated sample. However, since variations in the friction force result in variations in the normal load, the load should be continuously monitored during the test. Whether the instantaneous values or an average for the complete test should be used is not clear.

### 3 Fixed Ball Devices

The logical alternative to the free ball configuration is to have the ball fixed in a drive shaft. Such a configuration offers several advantages over the free ball system, making a test device that is valid for a wider range of uses than just for coating wear evaluation.

1. The load can be defined precisely without interaction with the friction force.
2. A wide range of loads (including those greater than the mass of the ball) can be applied precisely and repeatably, without the need for variable ball sizes.
3. The rotational speed of the ball and the number of cycles completed can be measured and controlled precisely.
4. Means can be provided for continuous measurement of the relative displacement of the specimens to indicate wear.
5. The ball material can be changed in order to control abrasive conditions in the contact when testing soft or hard materials.

In the Plint Micro-Scale Abrasion Tester the ball is fixed into the rotating shaft and the test surface is mounted on a counterbalanced beam that hangs vertically from a pivot (Figure 2). The alternative configuration is a horizontally pivoted beam pressing the coated sample against the underside of the ball (Figure 3).

Two disadvantages of the latter configuration are that the mass of the specimen and fluid require counteracting. In the case of massive samples (for instance made from WC), the degree of counterbalance would have to be high. The weight of the liquid held on the sample would also influence the load during the test. A second problem is that there is no path for the slurry to pass in to and then through the contact.

### 4 Issues to Address

The parameters that can be selected for a test on a particular surface are: ball material, applied load, ball speed, abrasive slurry feed rate, abrasive particle size and shape and abrasive concentration. Many of the early publications using the fixed ball technique have focused on gaining an understanding of the relative importance of these parameters [5-10]. A number of these issues will be discussed at this meeting.

Perhaps one of the keys to the success of the development of this technique will be having a clear understanding of the abrasive wear mechanisms at work for any particular material combination.

The wear mechanisms can change from three-body (where the abrasive particle is freely tumbling in the contact) to two-body abrasion (where the particles become embedded in the ball).

For the technique to be more widely applied, careful selection of abrasive type and ball material is required for different counterface (test) materials in order to control the abrasive wear mechanism.

One disadvantage of the fixed ball configuration is that a wear groove can form on the ball. This can under certain circumstances produce non-circular wear scars. This is possibly due to the way the abrasive particles are entrained in the groove on the ball. Again, this is not an effect seen under all conditions. Rotation of the ball between tests and replacement after a series of tests seems to be the best way to address this problem when it arises.

## 5 Future of the Micro-Scale Abrasion Test

The fixed ball version of the micro-scale abrasion test has been proved to be easy to use and applicable to testing a wide range of materials including hard and soft coatings, multi-layer coating systems, ceramics, MMCs, metals and plastics.

The TE 66 Micro-Scale Abrasion Tester is manufactured by Plint and Partners under license to Dr. I. M. Hutchings and Dr. K. L. Rutherford of Cambridge University, Department of Materials Science and Metallurgy.

## 6. References

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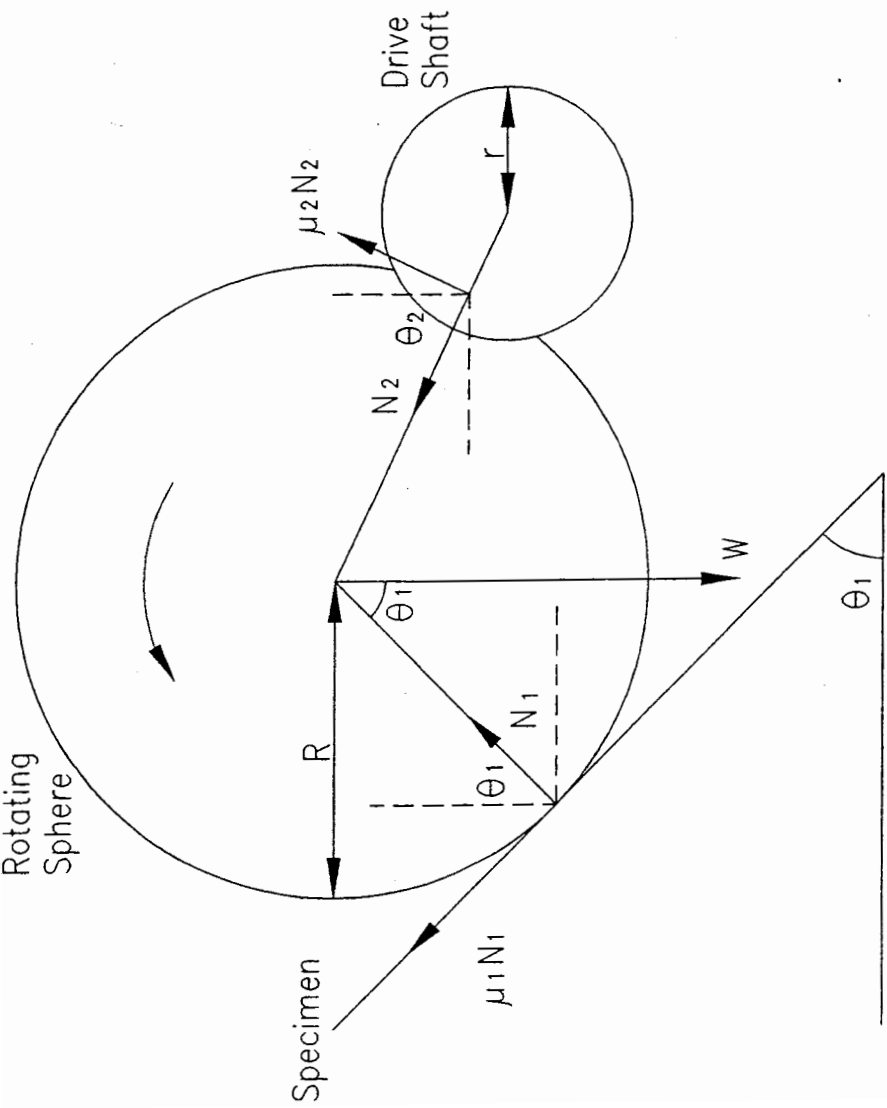


Figure 1: Force Diagram for Free Ball Device  
 (after Rutherford and Hutchings [4])

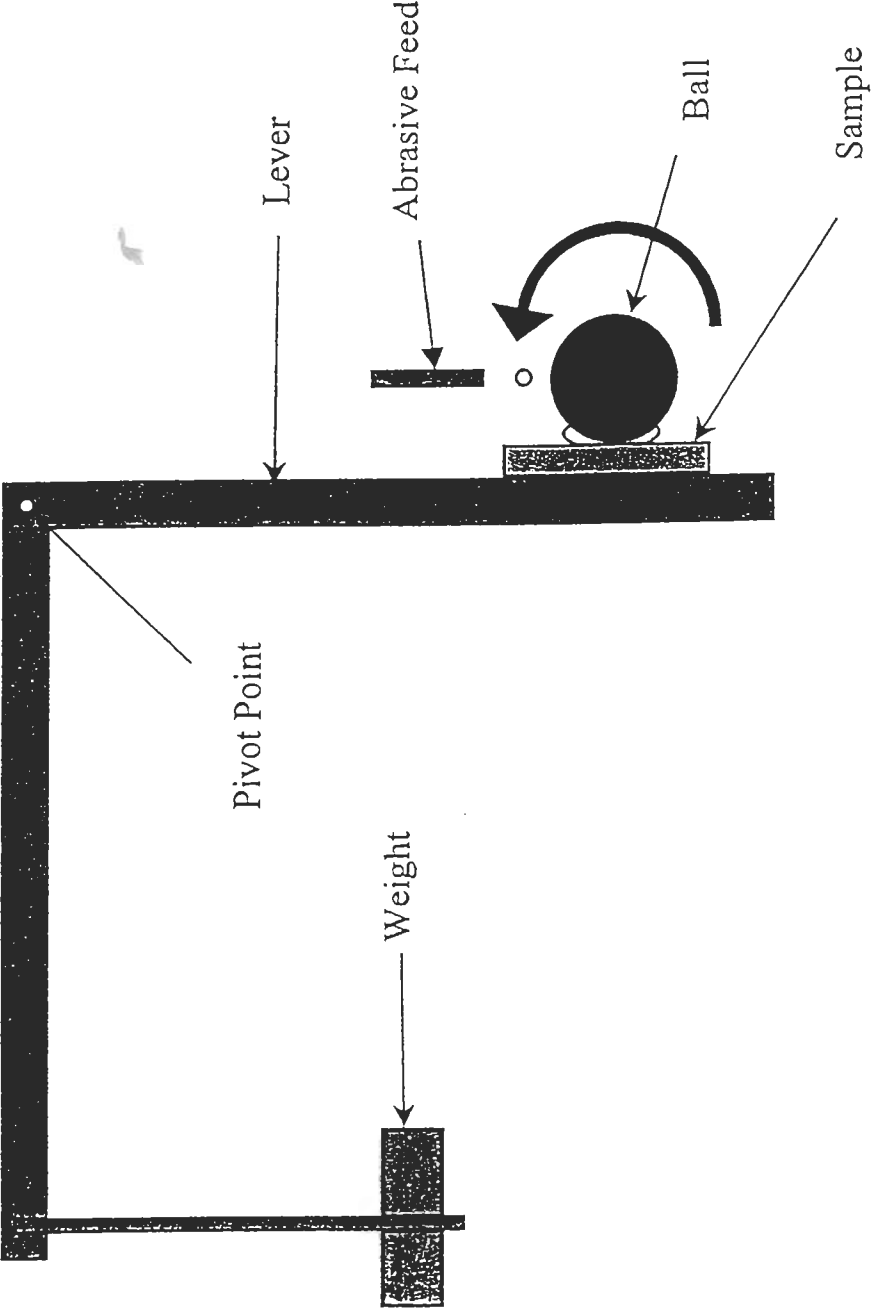


Figure 2: Schematic of Pint Fixed Ball Device  
(courtesy Gee and Gant [5])

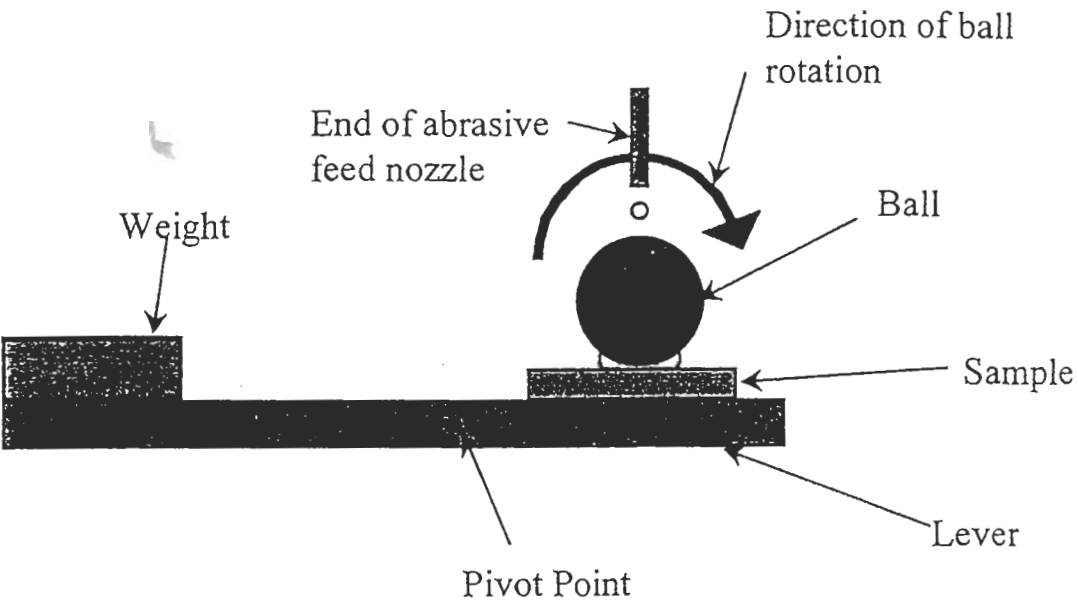


Figure 3: Schematic of Horizontal Beam Type Fixed Ball Device (courtesy Gee and Gant [5])