BALL CRATERING EXPERIMENTS ON HARDMETALS

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Introduction

Hardmetals are used in many wear resistant applications where slurries of fine sized abrasive are encountered. The recently developed ball cratering (micro-abrasion) test [1-3] is relevant to wear under these conditions, and tests were being performed to explore the suitability of the test for evaluating the response of hardmetals to fine scale abrasion.

A range of hardmetals with Co binder phase contents from 6 % to 25 % and with a variation in hardness from 900 to 2000 HV30 were tested. The samples were all prepared with a polished test surface, and were then annealed at 800 °C to remove residual stresses from the surface of the samples.

The test system used at NPL is shown in Figure 1 and is a lever arm loaded test system which uses a ball fixed in a split shaft. The test-piece is pressed against the rotating ball. Abrasive is drip fed onto the contact interface between the ball and the test-piece.

The abrasive that was used was 4 µm SiC. This was mixed with the appropriate abrasive media (see below) to form a slurry with 20 % abrasive by volume.

Results

The overall results of ball cratering tests on hardmetals are given in Figures 2 and 3. When all the hardmetal results are considered (Figure 2), it was found that there was a considerable scatter in results with no obvious trend in results. With the 6 % Co binder phase hardmetals, there was again considerable scatter in the results (Figure 3), but there was also a suggestion of a slight increase in wear as the hardness increased. To check the scatter in results, some tests were repeated and were found to give a similar but different set of results.

Figures 4 and 5 shows the results of performing tests in a range of different suspension fluids. No effect of the different fluids was seen, but again it was found that there was some evidence for an increase in wear as the hardness of the material increased. This results suggests that corrosion is not involved in the wear of the hardmetal.

The effect of changing the test duration was also examined and it was found that the wear normally increased as the test duration was increased (Figure 6). However, there was again considerable scatter in the results that meant that the results were not clear-cut.

To examine the effect of load on wear a series of experiments was performed at different loads on a hardmetal sample (Figure 7). This showed no variation in wear with increase in test load as the test load was increased from 0.1 to 10N.

Surface Examination

Some optical micrographs of wear scars on hardmetal samples as shown in Figure 8 and confirm that there is not a clear-cut consistent relationship between wear and hardness of the hardmetal. The edge of the scars were not distinct but were feathered and diffuse, potentially one of the reasons for some of the scatter observed in test results for the hardmetals.

Figure 9 shows a scanning electron micrograph of a typical wear scar on a hardmetal. The grooving that is seen across the middle of the scar is visible on many of the hardmetal wear scars. When examined at higher magnification, it can be seen that the grooves are about 15-25 μm wide.

Typical worn surfaces are shown in Figure 10. The binder phase has been completely removed from the microstructure. There is also considerable microfracture damage to the WC grains in the form of "pack-marks" over their surface.

Conclusions

The ball cratering experiments show that wear to the hardmetals took place by a two stage process. Initially the binder phase was removed by mechanical abrasion process, then the WC grains were subjected to fracture damage, causing removal of grains or parts of grains.

It is remarkable that there is little or no change in the magnitude of wear as the hardness of the hardmetals is changed. The reason for this effect is currently not known.

As the abrasion resistance of hardmetals normally increases as the hardness of hardmetals increases, this indicates that the test does not reflect the behaviour of hardmetals in practical applications. Until the reasons behind this discrepancy are understood, the ball cratering test cannot be recommended for the abrasion testing of hardmetals.

References

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2) R Gahlin, M Larssen, P Hedenquist, S Jacobson & S Hogmark. The crater grinder method as a means for coating wear evaluation - state of the art, Surface & Coatings Technology.
3) K L Rutherford, I M Hutchings, Theory and application of a micro-scale abrasive wear test, Journal of Testing and Evaluation, 25(1997)250-260
4) D N Allsop, R I Trezona and I M Hutchings, The effect of ball surface condition in the micro-abrasive wear test, Tribology Letters, 5(1998)259-264

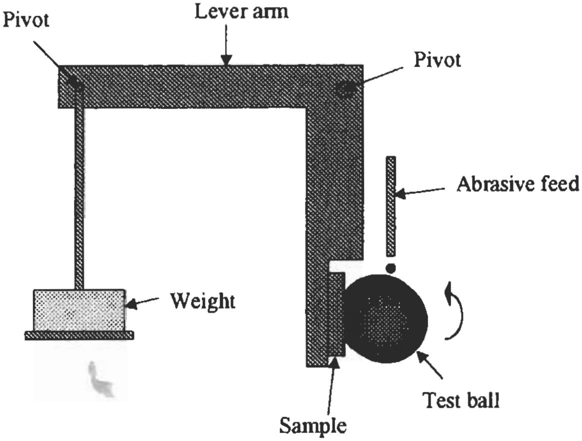


Figure 1, Schematic diagram of ball cratering system

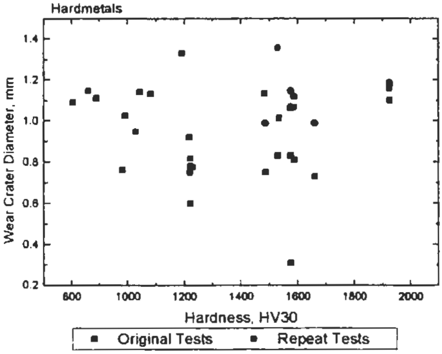
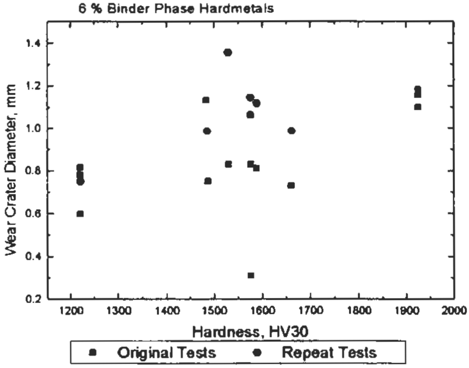


Figure 2, Variation in ball crater diameter with hardness of hardmetals



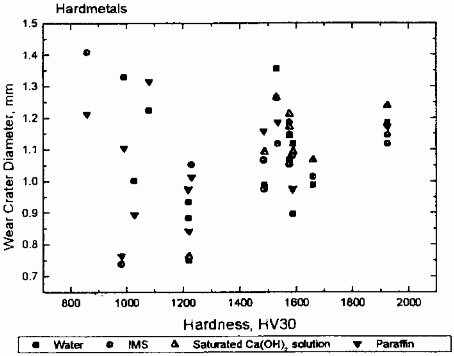


Figure 4, Variation in ball crater diameter for hardmetals with hardness using different abrasive media

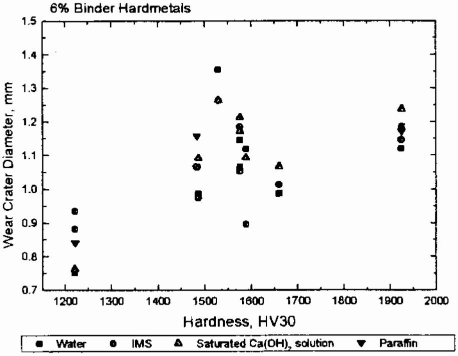


Figure 5, Variation in ball crater diameter for 6 % Co hardmetals with hardness using different abrasive media

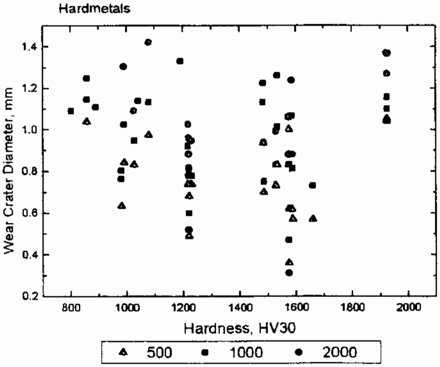


Figure 6, Variation in ball crater diameter with hardness for test durations of 500, 1000 and 2000 revolutions

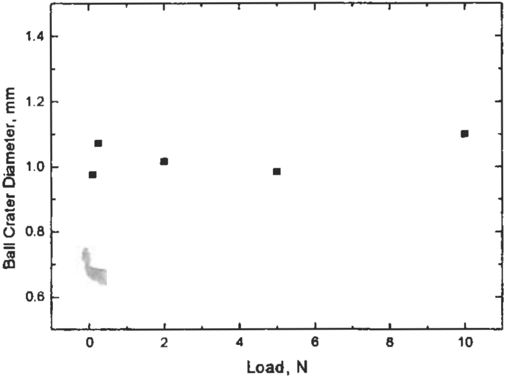


Figure 7, Lack of variation in ball crater diameter with test load.

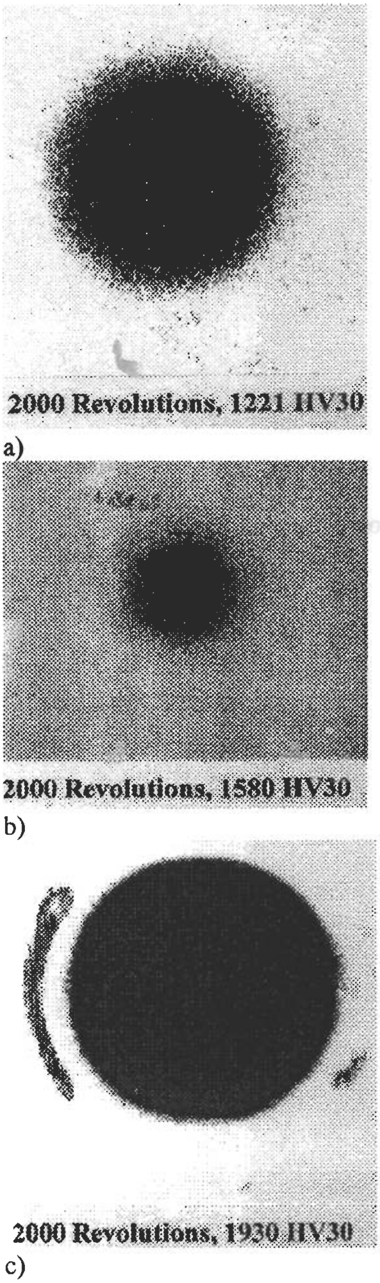
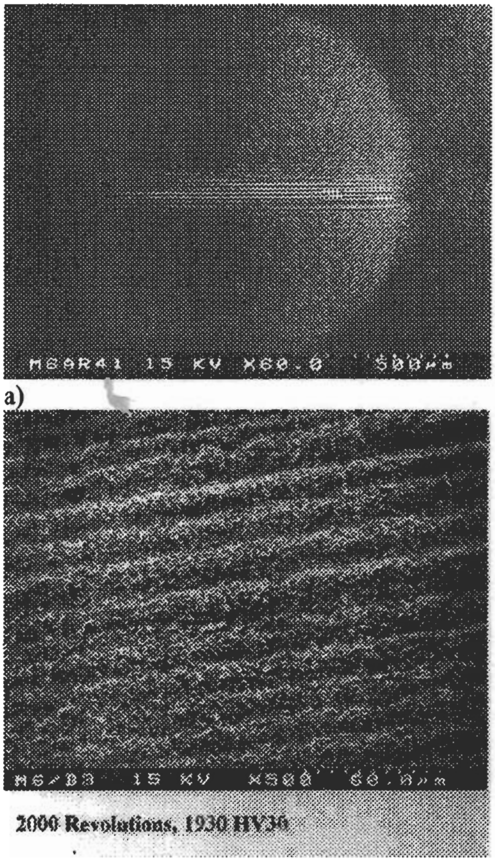


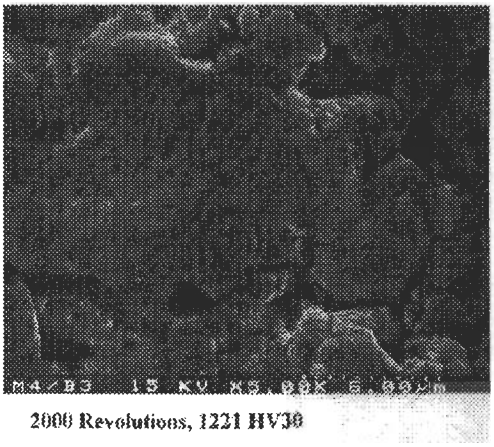
Figure 8, Optical micrographs of ball craters for three different hardmetals,



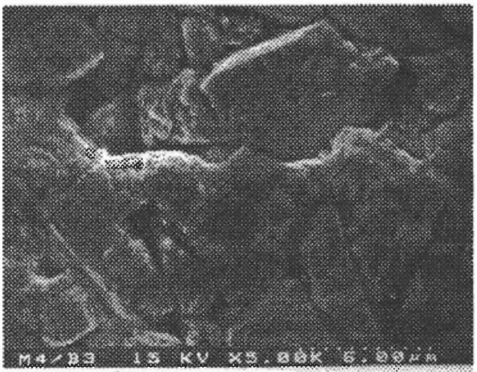
a)

b)

Figure 9, Grooving across centre of ball crater, a) overall view, b) detail of grooving.



a)



2000 Revolutions, 1221 HV30

b)

Figure 10, Typical worn microstructure