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New Frontiers in Hard Materials Testing

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Abstract

Significant advances in mechanical testing for hard materials are discussed in this paper. There are three specific areas that are covered. In the measurement of fracture toughness factors such as the control of slow crack growth to produce strating cracks, and evaluating reproducibility and repeatability of tests have been recently examined. The miniaturization of tests reduces the amount of material that is used in testing, improves the throughput of tests, and also improves cost effectiveness. New techniques such as stepwise testing and micro scratch testing have contributed to significant additions to the knowledge of the wear mechanisms that operate in these materials.

Keywords : hard Materials, PM materials, mechanical property evaluation, wear, fracture toughness, miniaturised testing

1. Introduction

With recent advances in computing power and in the technologies that underlie modern actuators and sensors, many new opportunities have been opened for the testing of hard materials such as WC hardmetals, ceramics and PM tool steels. This allows for more effective testing to be carried out in terms of efficiency, cost effectiveness and the ability to address previously intractable problems. These new developments are being put into practice in a number of laboratories around the world, including NPL.

Three different aspects of mechanical testing are discussed specifically in this paper.

As hard materials, particularly ceramics, have a tendency to brittle behaviour, the evaluation of the fracture properties of these materials is particularly important. One of the areas that has proved difficult is the measurement of the fracture toughness. There has been recent progress in several centres on developing slow crack growth procedures to produce the starting cracks that enable accurate determination of KIc using cost effective methods. Extensive work under VAMAS has evaluated reproducibility and repeatability of fracture toughness testing methods. There has also been progress in the development of methods for the measurement of the fatigue performance of hard materials both at ambient and elevated temperatures.

2. Results

A VAMAS interlaboratory exercise was conducted [1] to generate underpinning technical information on toughness tests for hardmetals. Eight organisations were able to complete Palmqvist tests and two completed short rod chevron notch tests; however, only three organisations were able to provide single edge beam data. Good statistics were obtained on the Palmqvist data that have enabled a quantitative assessment of uncertainties to be performed for this relatively simple test (Fig 1). Single edge precracked beam data was thought to be closest to the “true” value [2] and most of the short rod chevron notch test data compared reasonably well with these results. However, care was needed in testpiece preparation to ensure a good correlation between data from the Palmqvist tests and the single edge precracked beam results.

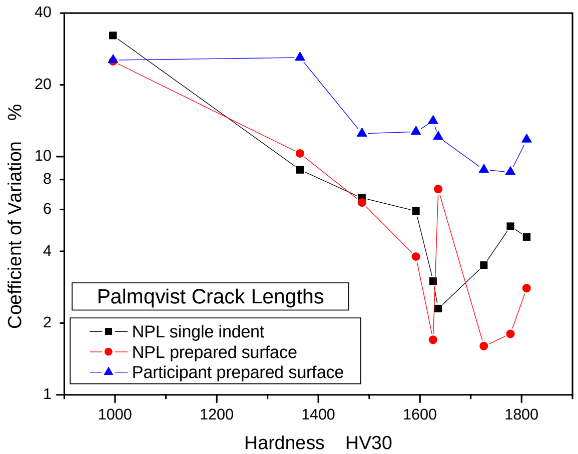


Fig. 1. Palmqvist toughness uncertainties

The failure of hardmetals and hard PM materials can be dictated by occasional defects, and therefore a large scatter is typically found in both strength and fatigue testing. Previous work on hardmetals has shown that flexural strength is determined by one of two factors; the distribution of large defects (pores, large WC clusters, etc) with a size greater than approximately 20 μm and the intrinsic strength of the average microstructure. In order to minimise the risk of failure in testing from such defects, and to promote failure from 'normal' microstructure, at NPL we have investigated a simple test geometry through the use of V-notched test pieces to obtain S-N data in $R > 0$ flexural tests.

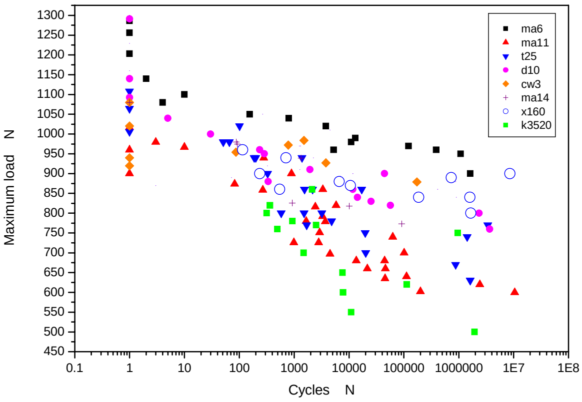
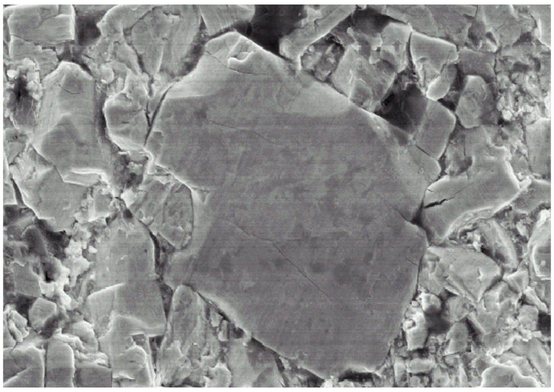
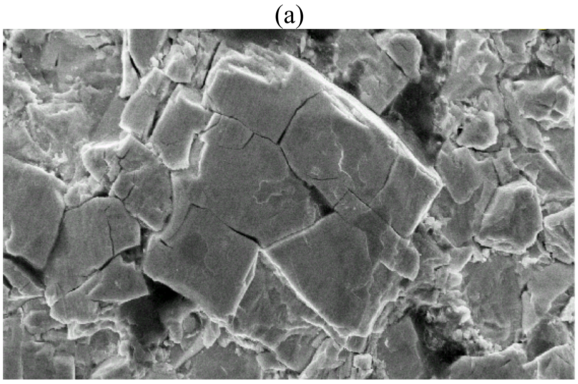


Fig. 2. S-N fatigue curves for hardmetals



(a)



(b)

Fig. 3. Surface of medium grained hardmetal exposed to a) 0.1 g of erodent, b) 27.4 g of erodent.

A particularly promising avenue is the minaturisation of tests. Not only does this entail the use of less test material, but there are also dividends in terms of the throughput of testing and the cost effectiveness of the test systems. A particular example of this approach is the ETMT, originally developed by NPL but now marketed by Instron, which has been used for the measurement of the thermal fatigue and other high temperature performance attributes of hard materials.

Hardmetals are important in wear resistant applications. Recent progress in the development of techniques such as stepwise testing and micro scratch testing have contributed to significant additions to the knowledge of the wear mechanisms that operate in these materials. In stepwise erosion testing [3], for example, a sample is exposed to small increments of sand erodent blasted against the surface. After each brief exposure, a specific area is examined in a high resolution scanning electron microscope. In Figure 3 the additional cracking to the large grain in the center of the micrograph due to an additional exposure of 27.3g of erodant can be clearly seen.

4. References

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