Spatially-distributed Impact Test – a revolutionary nano-impact test for simulating erosive wear in coatings and bulk materials

Introduction

The fully-instrumented, high strain rate impact test was developed by Micro Materials to expand the range of tests possible on the NanoTest system and is proving an effective tool in simulating intermittent contact situations such as in interrupted cutting, automotive and aero-engines.

Studies have reported a strong correlation between coating performance in the nano-impact test and the real application, e.g. wear resistance and lifetime of coated tools in high-speed machining of hard-to-cut materials [1-3], and in solid particle erosion testing of EB-PVD TBCs [4]. In all of these studies, the cyclic impacts occur at the same position on the sample.

Micro Materials have extended the repetitive impact technique to allow a programmed number of impacts to be distributed within a specified region of the sample in order to directly study how damage from one impact affects subsequent damage, therefore providing a more realistic analogue for simulating the 'random' nature of erosive wear.

Development tests on BK7 and fused silica

Two glass materials were selected for the development of the technique, fused silica and a borosilicate glass (BK7), due to their smooth, transparent and homogenous nature.

500 mN applied load impacts using a 25 µm end-radius diamond conical probe were performed in a rectangular distribution over a 500 µm x 500 µm area. Four tests were carried out with a varying number of total impacts (50, 150, 250 and 500).

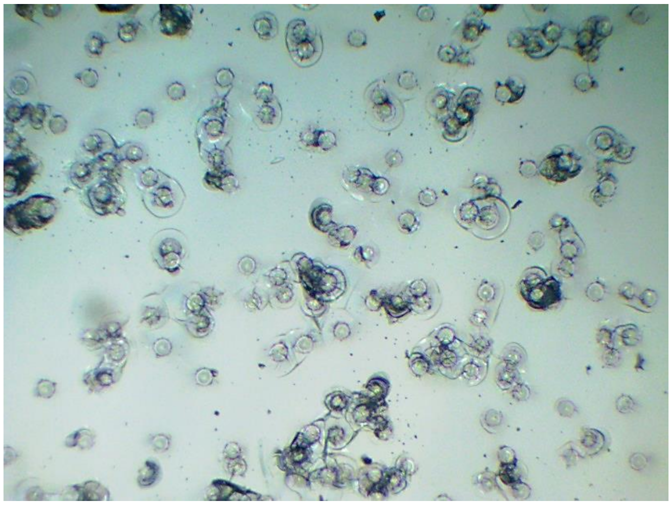


Figure 1 – fused silica after 250 impacts

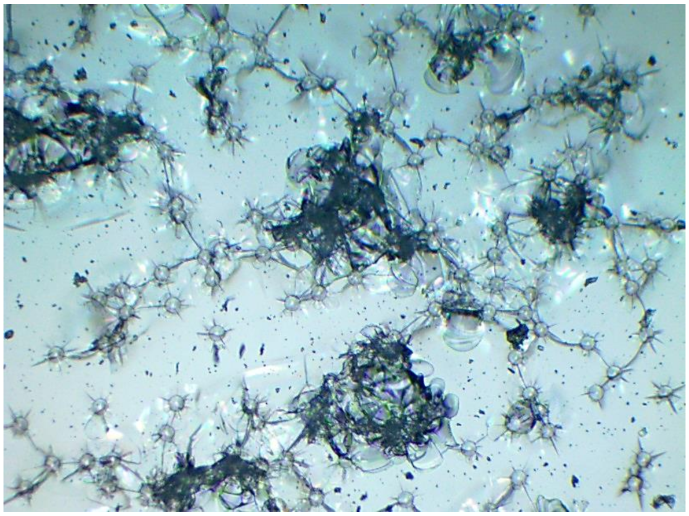


Figure 2 – BK7 after 250 impacts

Optical microscopy clearly shows greater damage on the BK7 sample, particularly after 250 impacts (Figure 2) and 500 impacts (Figure 3). This correlates with greater erosion rate reported in literature.

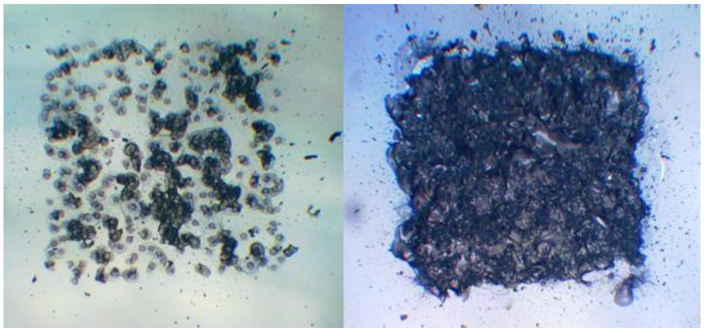
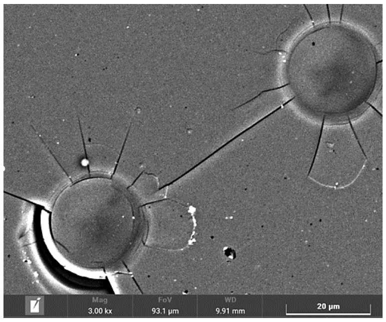


Figure 3 – Fused silica (left) and BK7 (right) after 500 impacts

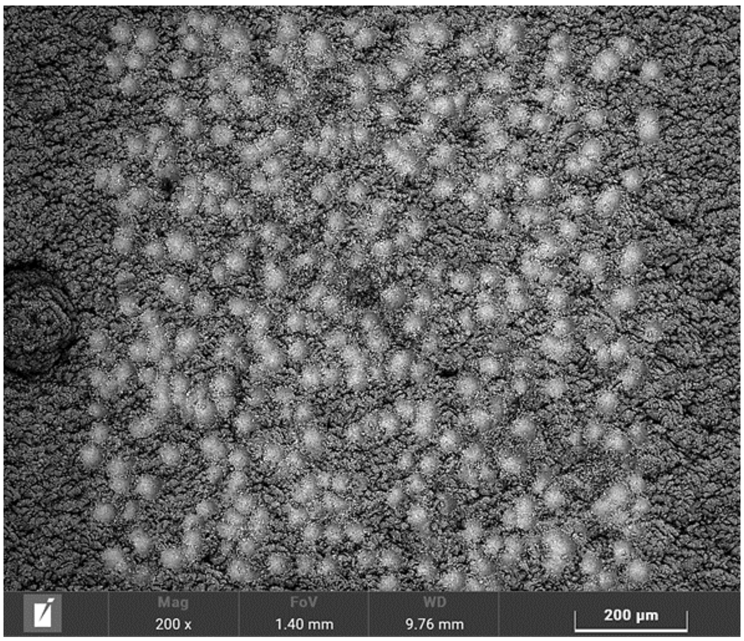


Differences in crack systems are responsible for the differences in behaviour. SEM imaging shows enhanced lateral/ radial cracking between impacts on BK7 (left) and more Hertzian cone cracking on fused silica.

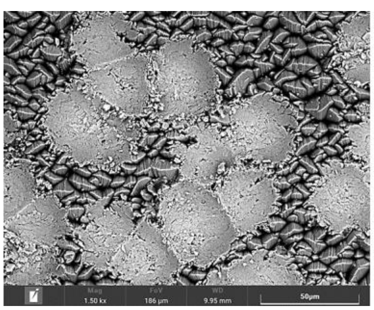
EB-PVD Thermal barrier coating systems

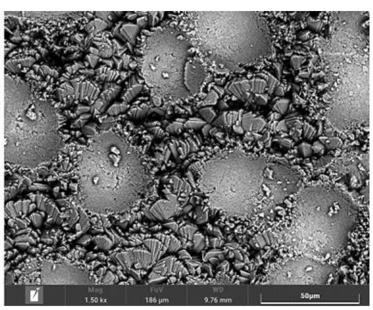
To increase fuel efficiency of gas turbine engines and reduce CO_2 emissions, engines need to operate at higher temperatures. Thermal barrier coatings (TBCs) can effectively protect superalloy turbine blades but can be susceptible to erosion damage which limits the maximum operating temperature. More erosion resistant TBCs are needed to achieve higher operating temperatures. The new randomised impact test is being used to characterise the performance of these coating systems.

Two thermal barrier coating systems, yttria-stabilised zirconia (7YSZ) and gadolinium zirconate (GZO), were subjected to randomised impact tests using a 25 µm end-radius diamond probe. Gaussian and rectangular distributions were explored to simulate different erosion scenarios.



GZO - 500 impacts at 500 mN
rectangular distribution over 1 mm x 1 mm





SEM images (7YSZ – left; GZO – right) show compaction and extensive cracking at impact crater peripheries

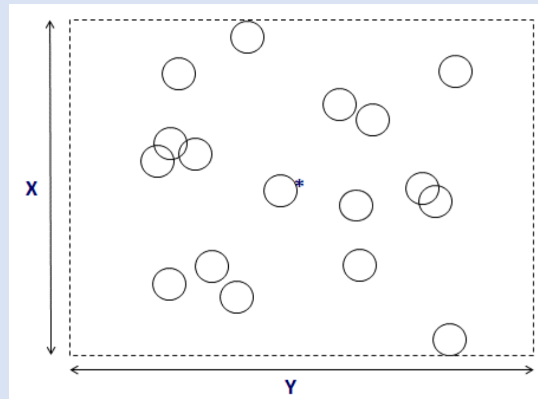
Cross-sectional FIB milling revealed similar sub-surface damage mechanisms in the impact and conventional erosion tests on these thermal barrier coatings.

Differences in volume loss in the randomised impact tests also correlated to the results of the erosion tests.

How it works

A programmed number of random impact sites are set within a specified region X-Y (shown by the dotted area in the figure below) centred around a point marked by the asterisk. Circles mark each impact location and show that overlap with previous impacts varies. Different distributions can be programmed, for example Gaussian, rectangular etc.

The full range of impact parameters (load, acceleration distance, indenter geometry) can be modified as necessary, and the test technique is compatible with the full range of environmental capability of the NanoTest (high and low temperature, liquid, controlled humidity).



Summary

Micro Materials have developed a novel randomised impact technique to simulate erosive wear on the nano and micro-scale. Work carried out so far shows that impact density influences impact wear rate – the number and spacing/ distribution type all are interrelated.

The technique is particularly well suited for studying damage mechanism on thermal barrier coatings and exhibits good correlation to erosion tests, both in terms of damage mechanism and wear rate. The randomised impact test can be extended further by changing load/test probe geometry/test temperature /angle etc, enabling complete characterisation of erosive wear of materials at the relevant in-service conditions.

References

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2. B.D. Beake, G.S. Fox-Rabinovich, Surf Coat Technol 255 (2014) 102.
3. GS Fox-Rabinovich et al, Surf Coat Technol 204 (2009) 489.
4. J. Chen et al, Surf Coat Technol 206 (2012) 4992.

Acknowledgements

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