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Multi-mode scratch testing—a European standards, measurements and testing study

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Abstract

This paper presents results of the final state of the art of an E.C. sponsored R and D project of reference coatings (i.e.: 3μm thick carbon doped chromium) deposited on HSS substrates.

Instrumentation upgrade has led to the integration of an interactive video microscope with a 10^6 pixel resolution, as the sole reliable diagnostic tool for coating damage assessment. Optical resolution allows for post-synchronised off-line crack identification. In addition, highly enhanced acoustic emission sensitivity is implemented. This way post-synchronisation, via online triggering of data storage related to specific (cohesive and/or adhesive) failure events, is achieved.

A multi-mode operation software menu comprises instrumented depth sensing macro-indentation, as well as fatigue modes like "multi-pass scratching" in the same track (or in parallel tracks in the scanning mode) both in unidirectional and reciprocating sliding—in addition to standard modes like constant and progressive load operation. These additional operation modes bridge the gap between single cycle, high contact pressure, accelerated testing and more realistic, low cycle, macro-elastic fatigue testing closer to industrial friction and wear situations.

Triboscopic presentation of the on-line friction and AE data as a function of sliding distance and cycle number is introduced as a means of user-friendly data analysis and damage mechanism identification.

Keywords: Scratch testing; Brittleness; Surface fatigue

1. Introduction

The development of hard, wear resistant coatings requires pertinent mechanical testing for process optimisation. Since the pioneering work by H. Hintermann and coworkers [1] scratch testing has become one of the major techniques for the assessment of the "practical adhesion" [2] of coatings. A series of round robin studies [3,4] has shown the potential of using the critical loads for L_{c1}, L_{c2}, and L_{c3} corresponding to first cracking, spallation on the scratch track borders and final coating delamination in the centre of the track as criteria for ranking coatings. There is a general agreement that the only valid technique for surface damage diagnosis is inspection by microscopy, AE and FF being often useful online parameters, which need to be validated under all circumstances by associated micrographs. For coatings with mediocre adhesion ($L_{c3} < 15$ N) this technique is fairly adequate to eliminate bad products.

In various EC funded Measurement and Testing programmes [5,6] it has been reported that extreme precautions are required concerning identical experimental conditions (substrate hardness, coating thickness, indenter tip integrity and cleanliness etc.). The state of the art of such standard scratch testing under progressive loading can be found in a European standard [7]. However, coaters generally agree that prediction of wear resistance, based on results of critical loads for coating spallation (L_{c3}), are often misleading.

Various attempts have been made to extend both the instrumentation and the operation modes of scratch testers in order to achieve more reliable rankings with respect to their

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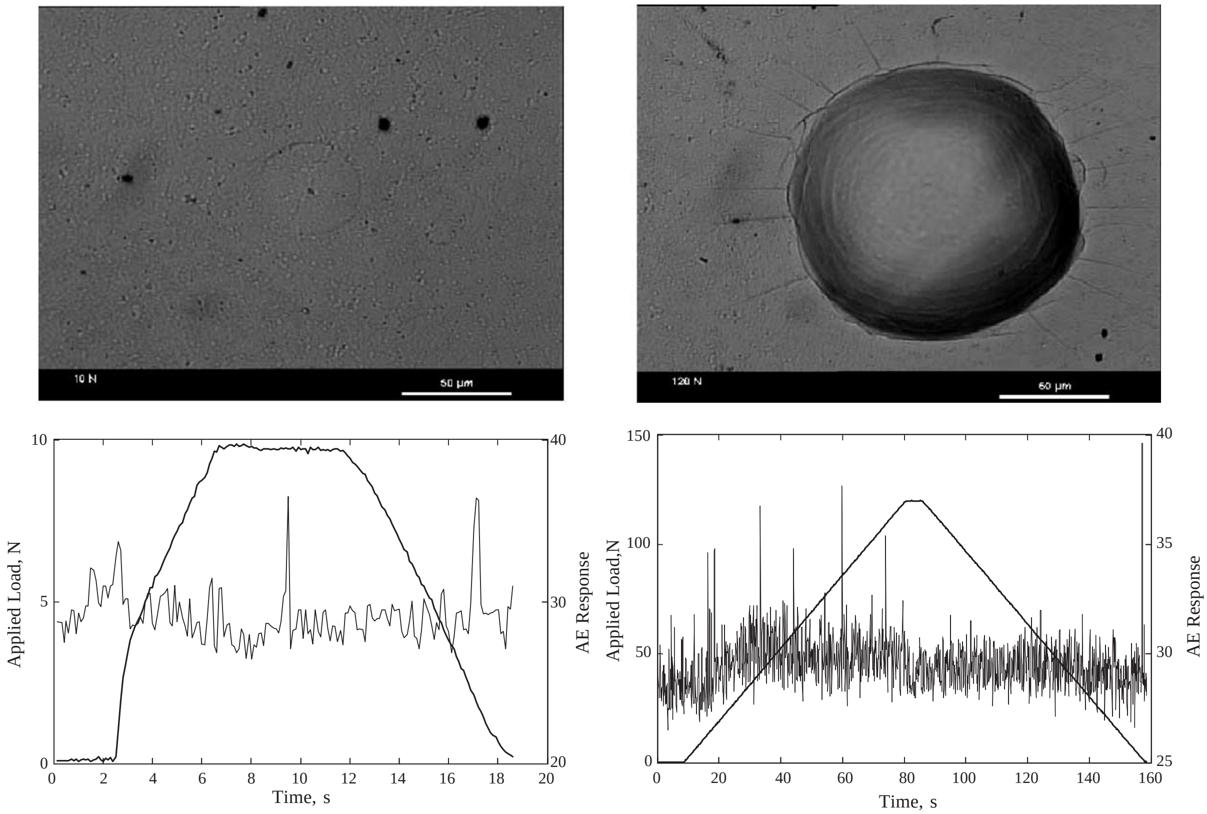

Fig. 1. Static, instrumented Rockwell indentation (holding time 5 s) of a well adhered carbon-doped PVD chromium coating. Upper line: post-test micrographs, lower line: online contact load and AE. Left column: 10 N maximum load, right column: 120 N maximum load.

wear resistance especially via multipass operation [8–10] requiring in particular high precision and rugged displacement stages for cyclic operation. This strive has led to the present EC-sponsored research programme [11].

2. Experimental

2.1. Scratch testing instruments

Two scratch testers were used in the present study: the Revetest by CSM Instruments[1] and the ST-3001 Scratch and wear tester by Teer Coatings[2]. For reasons of limited space available for this paper the experimental results shown below are limited to the latter instrument as it implements all of the recommendations of the present study. Both instruments were equipped with Rockwell C diamond indenters[3] as well as video microscopes for post synchronised failure diagnosis. Unless otherwise specified the calibration and operation procedures are identical with those specified in the European standard [7].

2.2. Instrumentation upgrade

- Interactive video microscope with at least 10^6 pixel resolution, as a reliable diagnostic tool for coating damage assessment with re-positioning displacement stages for post-synchronised off-line crack identification.
- In addition to standard contact load and friction force (FF), highly enhanced acoustic emission (AE) with a newly developed AE module ASCO P[4]: for online event triggering of data storage related to specific (cohesive and/or adhesive) failure with bursts of cracking energy release.
- Depth sensing operation both in high-load indentation and standard scratch testing.

2.3. Multi-mode operation software with automatic scanning facilities

- Instrumented high-load indentation in single indent with data monitoring during the entire load–unload cycle as well as multi-indent fatigue (in the same indent).
- Standard single pass scratch testing under progressive loading and at constant load.
- Low cycle friction fatigue operation via multi pass

[1] http://www.csm-instruments.com/.
[2] http://www.teercoatings.co.uk/.
[3] Supplier: Moessner GmbH, http://www.moessner-gmbh.de/.

[4] Supplier: Vallen SystemeGmbH, http://www.vallen.de/products.