Low-cycle static and dynamic fatigue of Cr/CrN coatings in point contact

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The main goal of this study is to examine the way of thin, anti-wear coatings failure exposed to multicycle micro-impacts. The appearance of the first crack is a predictor of the formation of subsequent crumbling and chipping of the coating, so it is crucial to recognize this phenomenon in detail. The low-cycle tests were used to observe and describe the places of disclosure of the first cracks and their propagations. Detailed analysis of coating wear with the use of 3D profilometer and microscope technique is the solid basis for characterize and numerical modeling of micro-impact wear.

Keywords (from 3 to 5 max): micro-impact test, surface fatigue, coatings

1. Introduction

The phenomenon of micro-impact surface cracking can be observed in many machines' parts that are exposed to multi-cycle loads e.g. cold working forming tools. In order to extend the life of such parts, manufacturers are increasingly willing to use coatings that reduce their wear.The subject of the investigation is a determination of the place and form of cracks appearance after static and dynamic fatigue tests on anti-wear coatings.

2. Methods

Three specimens with different coatings were chosen for the experiment – (Cr/CrN), CrN and Cr coating. Each of them had the same thickness of 1 μm and were applied by PLD (Pulsed Laser Deposition) method on ferrite steel. The first step was to determine the nano-hardness and elastic modulus of the prepared samples. Then specimens have been exposed to static and dynamic tests by pressing a spherical ceramic indenter with a radius of 500 μm under a load of 4 N. In the static test, the indenter was pressed at a set constant loading rate by the use of Micro Combi Tester. Dynamic tests were carried out by micro-impact using a laboratory stand called "Impact Tester" [1] presented in Fig. 1.

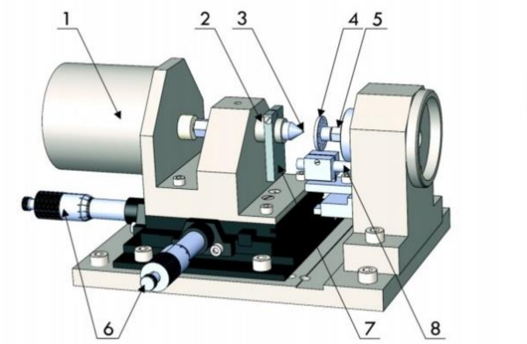
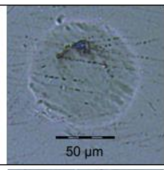
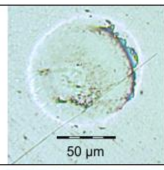
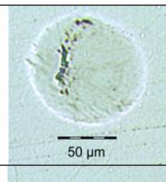
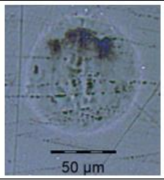
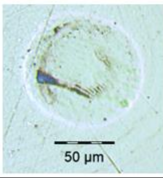
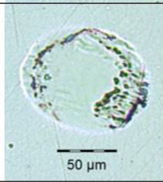


Figure 1: Figure 1: Impact Tester scheme: 1- inductor, 2- head, 3-indenter, 4- holder of sample, 5- force sensor, 6- micrometer screws, 7- mirror, 8- displacement sensor.

Each of the samples has been subjected to 1-, 10-, 50-100-, 500- and 1000-cycles tests. After experiments, the surfaces of the specimens have been observed using a light microscope. Specific craters observed after each test in the place of indentations are shown in Table 1. The most important aspect of this study was to identify the places where the first coating's cracks appeared and how these cracks propagated in subsequent static and dynamic tests. The craters were also examined with the Profilm 3D profilometer device which performed three-dimensional scans of the after-test sample surface and the cross-sectional profile of imprints. Additionally, selected samples were examined under the SEM microscope.

Table 1: Images of surfaces with craters formed in coatings after fatigue tests

	Cr	CrN	Cr/CrN
100 cycles			
1000 cycles			

3. Discussion

The applied research methods allowed to determine the radius of the damaged area on each coating, as well as the size of the cracks, which were the most important factor in the description of the wear mechanism. In both types of tests, a characteristic shape of the craters in the form of spherical craters was observed with different sizes determined by their geometry measurement. It was observed, that the craters formed during static tests had a smaller volume than the corresponding craters formed during dynamic tests, despite the use of the same indenter radius and the same load value. It was also important to indicate the places where the first cracks appeared on the coatings and the direction of their propagation [2]. The results of these observations are an introduction to the development of a numerical simulation model describing the micro-impact fatigue of thin composite coatings.

4. References

[1] Rakowski W., et al., Micro-impact cracking of tribological coatings, Tribologia (2015) 145–157

[2] Zha X., et al., "Investigating the high frequency fatigue failure mechanisms of mono and multilayer PVD coatings by the cyclic impact tests", Surface & Coatings Technology, 344, 2018, 689-701.