Local Residual Stresses and Thermal Fatigue in CrN Coatings on Steel Characterized by High-Temperature Synchrotron X-ray Diffraction

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Hard coatings are routinely used to protect working tools from abrasion and corrosion. The friction between the coating and the work piece results in local thermal and mechanical stresses which can negatively influence the tool performance and the lifetime. In the case of interrupted services, temperature pulses up to 1000 °C in millisecond range can cause cyclic thermo-mechanical loads in the coating/substrate composite resulting in phenomena like coating cracking, delamination or spalling.

In this contribution, residual stresses in thermally cycled CrN coatings on steel are characterized using high-temperature synchrotron X-ray diffraction. In order to simulate the thermal fatigue, CrN/steel samples were at first thermally cycled using a laser beam in the temperature range of 50-650 °C applying up to 100 000 times in home laboratory. Subsequently, the structures were analysed at the EDDI beamline of BESSY (Berlin, Germany) and G3 beamline of Hasylab (Hamburg, Germany). In both cases, the samples were characterized in-situ in a temperature range of 25-700 °C using a heating chamber DHS1100 (Anton Paar GmbH, Graz, Austria). The measurements at the EDDI beamline using high-energy photons (20-100 keV) were used to evaluate residual stress gradients in the spot irradiated by laser as a function of the penetration depth. In the case of the measurements at the G3 beamline, a lateral distribution of residual stresses in and around the irradiated spot with a resolution of 24 microns was determined.

In this way, it was possible to determine 3D distribution of residual stresses in the irradiated spot as a function of temperature whereby the structures exhibited complex changes in the morphology and in the residual stress state as a result of the thermal fatigue. The laser treatment caused a relaxation of compressive stresses in the coating and a formation of high tensile stresses resulting in a plastic deformation of the steel substrate. This effect was depended on the number of applied cycles.

The presented approach allows a complex characterization of thermo-mechanical processes in coating-substrate composites and opens the possibility to understand phenomena related to the thermal fatigue of coated tools.

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