3D deformation modeling of CrAlN coated tool steel compound during nanoindentation

Kirsten Bobzin¹, Siegfried Schmauder², Christian Kalscheuer¹, Marco Carlet¹, Wolfgang Verestek², Muhammad Tayyab¹

¹Surface Engineering Institute, RWTH Aachen University, Aachen
²Institute for Materials Testing, Materials Science and Strength of Materials, University of Stuttgart, Stuttgart

tayyab@iot.rwth-aachen.de

The comprehensive study on the deformation of physical vapor deposition (PVD) coated compounds under application of relevant loads, such as bending or impact loads, requires both experimental and simulative methods. However, the simulation models presented in the literature either consider only 2D deformation behaviour of the coating or ignore the substrate influence in 3D deformation modeling, which presents a rather limited approach. Therefore, the current work aims to develop a robust finite element (FE) model based on 3D deformation behavior of a CrAlN coated tool steel compound during nanoindentation.

The elastic-plastic properties of a CrAlN coating deposited on HS-6-5-2C substrate were determined by nanoindentation. Moreover, the deformation behavior of the coated compound was investigated through additional nanoindentations at higher loads. The Scanning electron microscopy (SEM) images of the coating surface were analysed with a machine learning (ML)-based algorithm to determine the size distribution of the columnar morphology. This information allowed to set up a 3D FE model containing a digital clone of the coating morphology. A linear elastic-plastic behavior based on the Johnson-Cook model was considered for the coating, substrate and the interface. Finally, the material parameters such as yield and flow stress were determined by fitting the simulated force-indentation curves to the experimental ones.

An overall good agreement between the simulated and experimental force-indentation curves was achieved. Moreover, a 3D FE model of the coated compound containing a ML-based digital clone of the coating morphology was successfully developed and implemented.