ADVANCED ADHESION EVALUATION FOR BRITTLE COATING MATERIALS USING THE SCRATCH TEST METHOD

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Surfaces in tribological applications like milling tools or combustion engines components (i.e. pistons and valve trains) are commonly coated with hard PVD coatings to increase their wear resistance. An adequate adhesion of the coating to the substrate material is necessary to ensure its specific function. Therefore, reliable adhesion testing is essential. Typically, the scratch test method is used to assess a coating's adhesion. The critical loads that are used for evaluation indicate the first occurrence of certain types of failure. However, they are strongly influenced by several parameters of the investigated material, such as coating thickness, hardness and ductility of coating and substrate material, internal stress distribution, surface topography, and others, as well as parameters of the test setup, such as diamond tip geometry and loading rate. Thus, they have to be kept constant for a comparison of different coatings, which is an extensive impairment of the scratch test method. Additionally, the critical loads alone do not contain information on the specific failure mechanism, which needs to be studies separately.

As a combination of phenomenological and quantitative analysis, the concept of determining the relative area of delamination was established by our group [1]. This approach of comparing the size of delaminations in a standardized area (relative area of delamination) was found to be correlating with the stress state and less depending on the coating thickness than the critical loads.

In this work, the evolution of two typical failure scenarios of hard and brittle coatings under scratching conditions is described. Furthermore, an extension of the concept of determining the delaminated area is introduced that enables the evaluation of scratch tests with different failure mechanisms and ratios of indenter radius to coating thickness (R/h ratio). Based on that, the relation of R/h ratio, failure mechanism, relative area of delamination, and indenter wear are studied in detail. It is discussed if the relative area of delamination can be used to directly compare scratch tests with different indenter radii and/or different failure mechanisms.

For this purpose, hydrogen-free tetrahedral amorphous carbon coatings (ta-C) are investigated by the scratch test method with different R/h ratios to study their scratch behavior with respect to the loading conditions. In total, 40 different ta-C coatings with hardness between 50 GPa and more than 70 GPa and thickness in a range of 1 µm to 4.4 µm are investigated.

[1] M. Zawischa, S. Makowski, N. Schwarzer, V. Weihnacht, Surface and Coatings Technology 308 (2016), p. 341–348.