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The effect of surface roughness on scratch adhesion and tribological behavior of PVD hard coatings with different layer designs

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INTRODUCTION AND AIM

The surfaces of industrial components intended to be coated by wear-resistant coatings are frequently not polished. On the contrary, during the coating development, its properties are always evaluated on highly polished surfaces. These differences in surface conditions may lead to erroneous estimation of the future coated part properties. The contemporary hard coatings used for enhancing tribological performance are produced with different layer designs: single-layer, multi-layer, and nanolayer. However, their performance on surfaces with different roughness is addressed to a minimal extent in literature. Therefore, in this investigation three kinds of coating with different layer designs were evaluated by scratch test and sliding wear test.

METHOD

This investigation concerned coatings deposited by magnetron sputtering, namely **TiAlN (single layer), TiAlN/CNx (dual layer) and AlTiN/TiN (nanolayer) coating**. The coatings were deposited on steel substrates with four degrees of roughness. The coatings' adhesion was evaluated by a **scratch test** performed parallel and perpendicular to the grinding marks. The tribological behavior of the coatings was assessed by **dry reciprocating sliding test** against Al_2O_3 counter ball. All samples were evaluated before and after the experiments by 3D tactile profilometry, confocal optical microscopy, and energy dispersive spectroscopy. The wear volume of the samples was determined from 3D topography images of the wear tracks. For these purposes, a specially developed method was employed that estimates the initial roughness and volume of the tested region of the samples.

RESULTS & DISCUSSIONS

In all cases the surface roughness of samples increased after the coating deposition and these surfaces belong to the range of fine surface finishes, Sa=12–545 nm. Within the investigated range of surface roughness coatings with different layer designs behaved differently with change in surface roughness. In the range of very fine surface finishes (Sa ≈ 10 – 50 nm) TiAlN and TiAlN/CNx coatings show insignificant dependence of scratch adhesion and tribological behavior on surface roughness. For the roughest surface (Sa ≈ 500 nm), a reduction in adhesion and an increase in wear rate were observed. The AlTiN/TiN nanolayer coating displayed the largest sensitivity of adhesion on roughness and scratching direction. The coefficient of friction and wear rate of AlTiN/TiN coating increased when the roughness was larger than Sa ≈ 48 nm. Given that the performance of nanolayer coating exhibited the most pronounced sensitivity on the changes in surface roughness, future investigations should cover a wider range of nanolayer coatings.

TiAlN

t=4.9 µm
3000 HV

Sa [nm]			
Polished	**1500**	**400**	**ground**
11.1	19.3	48.5	525.7

CNx

t=6.3 µm
1350 HV

Sa [nm]			
Polished	**1500**	**400**	**ground**
10.6	18.0	46.2	467.1

nl-AlTiN/TiN

t=6.3 µm
2250 HV

Sa [nm]			
Polished	**1500**	**400**	**ground**
10.6	15.0	41.8	545.2

CONCLUSIONS

- Investigated coatings exhibited different behavior regarding the effect of surface roughness on their adhesion and tribological performance,
- The performance of all investigated coatings is the worst on the coarse ground surfaces,
- The properties of TiAlN/CNx coating are the least sensitive to the changes in roughness,
- The tribo-performance and adhesion of the AlTiN/TiN nanolayer coating is highly dependent on its surface roughness.
- No general rule can be established about the effect of surface roughness on the adhesion and tribological behavior of the coatings with different layer designs.

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