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Texturing of WC-Co substrate surface to improve the resistance of deposited PVD film to wear and dynamic loads

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Abstract

Use of laser technology for surface preparation of cemented carbide prior to PVD deposition was studied experimentally. Four series of specimens were made, three of which had surfaces prepared by laser and one series had ground surfaces. Some specimens were intended for deposition. Tribological properties and dynamic load-bearing capacity of the substrate under impact load were evaluated. Additional examinations included metallographic observation in a scanning electron microscope, and measurement of residual stresses using X-ray diffraction. The results indicate that adhesion of a PVD film can be improved when a suitable texture is produced on the substrate surface, referred to as the ripple effect. [7] By this means, the effects of residual stresses can be suppressed. In addition, wear resistance can be improved in the substrate beneath the film when subjected to dynamic impact load. This improvement amounts to tens of percent, when compared to specimens coated without laser surface preparation.

Keywords: laser surface preparation, residual stresses, tribological properties, PVD

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1. Introduction

Cemented carbides are used in a multitude of applications. The most common examples are exchangeable cutting inserts; others include special solid-carbide tools. With respect to high cost of the stock, suitable methods must be sought for reducing the cost of manufacture of final products and for extending the life of the cutting parts of tools.

Such methods involve advanced techniques of producing the cutting edge of a tool and subsequent coating with an appropriate surface film. The desired shape of the cutting part of a cemented carbide tool can be obtained progressively by grinding. During grinding, large residual compressive stresses are induced in the substrate. Some studies report these to be beneficial, claiming that they improve resistance to dynamic loads and adhesion of PVD films. [1,5]. In this experimental study, a different approach was chosen in which tensile residual stresses of varying intensity were initiated in the surface layer of the substrate. These strains were due to the ablation of the surface of the WC-Co substrate by pulse laser, which was used to create different types of surface textures. The aim of this study was to verify the tribological behaviour and the dynamic resistance of laser-generated textures and compare these measured values with the measured values of the samples with the ground surface before and after their deposition with the selected PVD layer.

2. Specimens and experimental techniques

As an experimental material was chosen cemented carbide of WC-Co with a 6% of binder and a fine carbide grain fractions. From this material, three series of samples (A-C) were produced by the pulse laser, one series being made by grinding (D). A half of specimens in each series were set aside for PVD deposition. One specimen from each series was selected for analysing the surface stress. Residual stresses were measured in the hexagonal WC carbide phase using X-ray diffraction analysis and the sin2ψ technique. [2]

When the value of macroscopic residual stresses could be determined on the basis of the Bragg equation (1) for the individual components of the voltage tensor.

$$n\lambda = 2d^{hkl} sin\theta^{hkl} \tag{1}$$

After differentiating this equation, it is possible to obtain a relationship for the εhk lattice deformation due to the resulting stresses (2). Based on this, is possible determine the residual stress value at each point of the measured material volume.

$$\varepsilon^{hkl} = \frac{\delta d^{hkl}}{d_0^{hkl}} = \frac{d^{hkl} - d_0^{hkl}}{d_0^{hkl}} = -\delta\theta^{hkl} \cdot cot\theta_0^{hkl} = -(\theta^{hkl} - \theta_0^{hkl}) \cdot cot\theta_0^{hkl} \tag{2}$$

Measurement of residual stress was done in two perpendicular directions in the longitudinal direction (direction of movement of the tool - grinding wheel - laser) and tangential (direction perpendicular to the movement of the tool). Required depth measurements of residual stress measurements were achieved by electrolytic etching of the sample surface. The maximum depth of residual stress measurements was determined on the basis of experience with the residual stress measurement of sintered carbides at KMM UWB workplace in Pilsen and publications dealing with changes in the residual stresses of sintered carbides with surface modified by different technologies [5, 8]. For a series of samples A-C, the maximum depth of measurement was determined on the basis of a metallographic cut, which determined the depth of the sample reaching the laser-affected area, see Fig. 1-3. Measurement of residual stress was then performed to a depth about twice as large as that which occurred after etching the sample with MURAKAMI etchant, to change in contrast to its structure. This occurred for example in sample A at a depth of about 400 μm, see Fig. 1. The residual stress readings are listed in Table 1.