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Department of Mechanical Engineering

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TRIBOLOGY TESTING OF SUPERHARD MULTILAYERED DLC COATINGS ON TOOL STEELS**FÜLÖP Fruzsina, MAROSNÉ BERKES Mária PhD***Institute of Materials Science and Technology University of Miskolc**E-mail: fulop.fruzsina@uni-miskolc.hu, maria.maros@uni-miskolc.hu***Keywords:** DLC coating, PACVD, wear resistance, friction coefficient, tribology testing**INTRODUCTION**

Nowadays the automobile industry is one of the most dynamically developing industries. The requirements, relating both mechanical loadability, informatics, aesthetic and convenience services are continuously increasing with the demand of reduced material, fuel consumption, and more and more stringent environmental protection. These changes initiated using higher strength materials for the components, consequently tools with increased loadability and lifetime. However, if we use stronger bulk materials, which have at the same time appropriate toughness, and wear resistance, the costs will be significantly increased. It is much favourable to improve only the surface layer properties of the tools – that is put to the most critical loads – using heat treatment or coating technologies. For metal forming tools superhard ceramic coatings are widely applied, among which DLC (Diamond Like Carbon) are so called self-lubricating coatings and stand out with their great hardness (1500-3200 HV) and very good wear resistance. The most common method of characterizing the tribological behaviour of these coatings are the standardized wear tests, and scratch tests.

OBJECTIVE AND EXPERIMENTAL PROCEDURE

The basic objective of the research work was to compare the friction and wear behaviour of DLC coatings produced by PACVD process on a substrate material made of a widely used cold work tool steel. The applied test methods were pin-on-disc wear test and scratch test. The thickness and operational suitability of the coatings was characterized by Calotest and Mercedes test. During the research work we compared two different types of coatings. One of them was a DLC coating on a Si-underlayer (henceforth SiCH/DLC coatings), the other one was a multi-layered coating system consisting of Cr+CrN+WC layers under the top DLC layer (henceforth Cr+CrN+WC/DLC). The substrate material was a high alloy, precipitation hardened Böhler K110 steel, (1.2379; X153CrMoV12). Test samples were disc shaped specimens with diameter of $d=20.8$ mm, and heights of $h=5$ mm. Surface preparation involved grinding before the bulk heat treatment, and two different finishing procedures – i.e. glass bead blasting (GBB) and polishing (P) – after heat treatment prior to coating. The examined coating systems were prepared by PACVD (Plasma-Assisted Chemical Vapor Deposition) process which combines the advantages of PVD (Plasma-Vapor-Deposition) and CVD (Chemical-Vapor-Deposition). [1]

During Calotest we applied steel ball of $\phi 30$ mm in diameter, and two different test times, since the two kinds of coatings had very different behaviour: the SiCH/DLC coatings were tested for 4 minutes, while the Cr+CrN+WC/DLC coating needed 10 minutes to see the coating thickness properly. The average layer thickness for the SiCH/DLC coating was $2.194\ \mu\text{m}$ and $4.248\ \mu\text{m}$ for the multilayer coating. It is supposed that in case of the Cr+CrN+WC/DLC multilayer coating, the combination of the ceramic underlayers provides a stronger support for the DLC upper layer.

To evaluate the tribological performance of the coating systems pin-on-disc tests were accomplished by an UNMT-1 (CETR) multifunctional modular surface tester. The applied test parameters were as follows: normal load $F=5, 10$, and 30 N; sliding rate $v=10$ and 30 mm/s; frictional counterpart was a SiC ball, diameter of $\phi 6$ mm; the tests were executed at room temperature in unlubricated sliding conditions. Altogether 24 tribo-systems were studied, and 3 measurements for each system were accomplished.

TEST RESULTS AND EVALUATION

Analysing the friction coefficient diagrams obtained for the different tribo-systems representing one-one combination of the normal load, sliding rates and surface finish, the following establishments can be made. In case of the uncoated samples the friction coefficient showed mostly an increasing character almost during the whole test and reached a value close to 0.6, while for the coated systems the friction coefficient value stabilized already at 50-70 m sliding distance, getting extremely low value close to 0.02. This friction coefficient is generally characteristic for the DLC coatings at low loadings. Figure 1. illustrates an example of the obtained friction coefficient diagrams for an uncoated and SiCH/DLC coated sample having GBB surface finish below the DLC top layer.

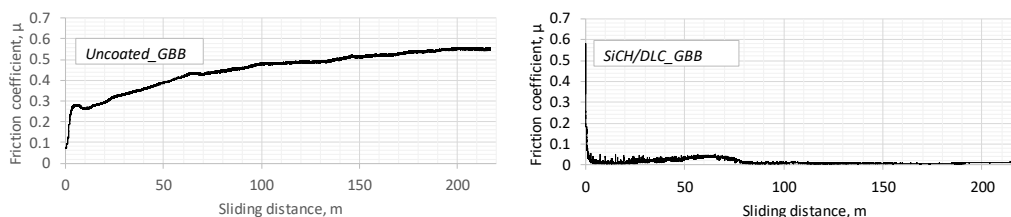


Figure 1 Characteristic friction coefficient vs. sliding distance diagrams recorded during the pin-on-disc test

To compare the friction behaviour of the different tribo-systems we defined the steady state friction coefficients (μ_{ss}) as the average of those obtained at the last 20% of the total sliding distance. The characteristic values are illustrated in Figure 2., based on which we can make the following observations:

- In case of the uncoated and glass bead blasted samples (Uncoated_GBB in Figure 2/a), the friction coefficient value decreased with the increase of the sliding rate. An explanation for this can be that the tribochemical reactions and the formation of the Fe_2O_3 oxid layer, which can serve as a lubricating film, are more enhanced at the higher sliding rates, that results in higher friction heat. The increasing normal load results also in the decrease of the steady state friction coefficient, and a gradually decreasing time up to the stabilization of the μ_{ss} values for these samples (the latter one is not illustrated here).
- For the specimens with multilayer coating and glass bead blasted surface (Cr+CrN+WC/DLC_GBB in Figure 2/b) the μ_{ss} values were systematically lower by one order than those obtained for the Uncoated_GBB samples at the same loading conditions. In Figure 2/b it can be observed that with increasing sliding rate and normal load, the steady state friction coefficient values are increasing, that is an opposite behaviour compared to the Uncoated_GBB materials.
- Comparing the friction behaviour of the samples having SiH/DLC coating and GBB surface finish (SiCH/DLC_GBB in Figure 2/c), with their multilayered counterparts (Cr+CrN+WC/DLC_GBB in Figure 2/b) similar effect of the increasing loading parameters have been observed, and the fluctuation of the friction coefficient values diminished with the increase of the normal load for both sliding rates, i.e. for $v=10$ and 30 mm/s, in case of both types of the coating systems. It is assumed that due to the higher normal loads the wear debris particles are chopped more intensively, and the finer grains will result in weaker abrasive wear, responsible for the variation of the friction coefficient.
- Friction coefficient for samples with polished surface below the top DLC layer were characteristically lower by 30-50% (Figure 2/d) than those measured for DLC coatings deposited in the same way on substrates having GBB finished surface (Figure 2/b).

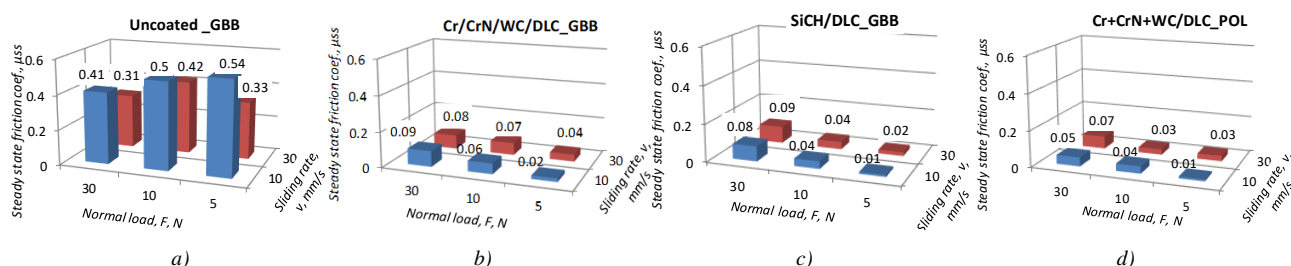


Figure 2. The steady state friction coefficient values for the reference material and the investigated coatings

SUMMARY

Based on the executed tribological study our most important findings can be summarized as follows. Application of DLC coating on the K110 tool steel reduced the friction coefficient significantly – from 0.6 to 0.01 –, comparing to the uncoated state of the tool. Friction coefficients determined during pin-on-disc tests were systematically lower if the underlayer below the DLC coating was made of SiCH, as compared to that of Cr+CrN+WC. Surface finish prior to the PACVD coating may have considerable effect on the friction behaviour of the coating system.

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- [1] Fülöp Fruzsina: *Lemezalkító szerszámok korszerű multiréteges kopásálló bevonatainak vizsgálata*, TDK dolgozat pp.1- 49. TDK Konferencia, Miskolci Egyetem, Anyagszerkezet-tani és Anyagtudományi Szekció, 2017.