Mechanical Tests of Gradient Ti/TiN/TiCN Hard Coating Intended for Tool Production

M. D. Simov
FESTO Production EOOD, Smolyan, Bulgaria
Plovdiv University "Paisii Hilendarski", Faculty of Physics and Technology, Department of Mechanical Engineering and Transport, Smolyan, Bulgaria
V. S. Rupetsov
Plovdiv University "Paisii Hilendarski", Faculty of Physics and Technology, Department of Mechanical Engineering and Transport, Smolyan, Bulgaria
Ch. O. Pashinski
Central Laboratory of Applied Physics, Bulgarian Academy of Sciences, Plovdiv, Bulgaria
Technical University of Sofia, Plovdiv Branch, Faculty of Mechanical Engineering, Dept. of Mechanics, Plovdiv, Bulgaria

INTRODUCTION

At present, the use of plastic products is widespread with increasing trend. New plastics with improved mechanical properties are emerged, often adding fillers or fibers [1]. Such plastics are often difficult to cast using injection molds. On the one hand, there are the classical problems with cyclic temperature changes during the molding, mechanical stress in the mold components, etc. On the other hand, the fillers often increase the friction which makes the article ejection difficult and wears out the surfaces of the injection mold.

One of the most suitable ways to deal with the latter problems is a deposition of a suitable PVD hard coating on the working surfaces of the injection mold. A well-designed coating could significantly increase the wear resistance, respectively the tool's lifespan [1-3].

When properly constructed, TiCN coatings could mix the beneficial properties of TiC and TiN, which is profitable for industrial needs [3, 4]. In this work, one gradient TiCN hard coating was deposited which (in combination with the Stavax ESR steel substrate) shows very good mechanical properties.

EXPERIMENTAL DETAILS

Test samples of commonly used material for injection molds - Stavax ESR (AISI 420 modified) [1] were prepared. The shape of the specimens is a rectangular parallelepiped and their dimensions are: 30 x 10 x 10 mm (Length x Breadth x Height).

The samples were separated into three groups: A (unhardened, ground), B (hardened, ground) and C (hardened, polished).

The coating Ti/TiN/TiCN was created by Vacuum (Cathodic) Arc Deposition (VAD, CAD) using coating unit π80+ (produced by PLATIT, Switzerland and depicted in Fig.1). There was applied LAteral Rotating Cathodes (LARC®) technology with a single Ti cathode, and N_2 and C_2H_2 gases were flowed in a controlled manner into the chamber. The deposition began with a contact gradient Ti/TiN/TiCN structure, followed by the main $TiC_{0.2}N_{0.8}$ layer.

Fig.1. Overall view of coating unit π80+

Thickness, nanohardness, adhesion, roughness and others mechanical properties of the coating were measured, with the greatest attention paid to the wear resistance. The reason is its direct connection with the coating purpose – an increasing in the lifespan of the active elements of one injection mold.

A ball-on-flat (reciprocating) test was used to examine the wear resistance, after the wear volume was calculated for this purpose. The counter-part was pressed by a load F which took values of 1, 2, 3, 4 and 5 N. The other parameters of the tests were constant (average sliding speed: 10 mm/s, passed sliding distance: 50 m, ambient temperature: 20 °C, lubricant: absent). The trace width was controlled at five places along its length, and then the average value of these measurements was taken account. Then, by means of geometric calculations described in [5], the wear volume was determined.

The wear rate I_w (mm³/Nm) is calculated by the known formula [5]:

$$I_w = \frac{V}{F.L} \qquad (1)$$

where V - wear volume, i.e., volume of the removed material (of the trace) (mm³), F – normal load (N), L – sliding distance which is the path passed from the sample to the fixed counter-part (m).

RESULTS AND DISCUSSION

It was found that the coating is ca. 2.00 μm thick, with clear calotte section without tears.

Taking into account this thickness, the coating hardness was studied, and the result of avg. 35 GPa was considered as authoritative (indenter load: 20 mN). The reached indentation depth of avg. 193 nm is less than 10% of the thickness, this minimizes the substrate influence. Simultaneously, an elastic modulus of avg. 434.0 GPa was identified.

The adhesion of the coating is excellent, no adhesion or cohesion faults are observed. The maximal stylus pressure allowed by the equipment was reached: 30 N. At the same adhesion test, a practically constant coefficient of friction (COF) of 0.15 was measured (against diamond indenter).

After coating application, an increase in the roughness of the samples, especially the polished ones (group C), is observed. This is mainly explained by the presence of a droplet phase in the deposition process which condenses on the surface.

Data on the wear volume are shown in Fig.2.

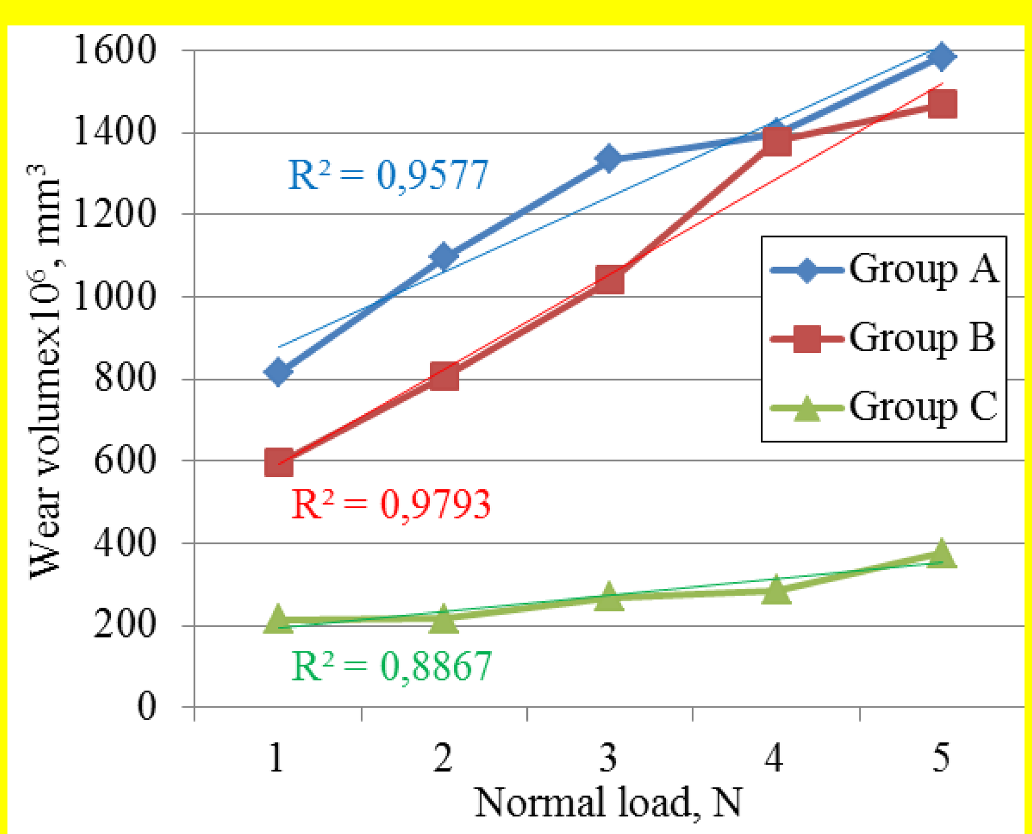

Fig.2. Wear volume under different normal load

As expected, as the normal load F increases, the value of wear volume V does the same. It turns out that the dependence $V = f(F)$ is practically linear, since the coefficient of determination R^2 is much higher than 0.7.

The obtained wear rate data are figured in Fig.3.

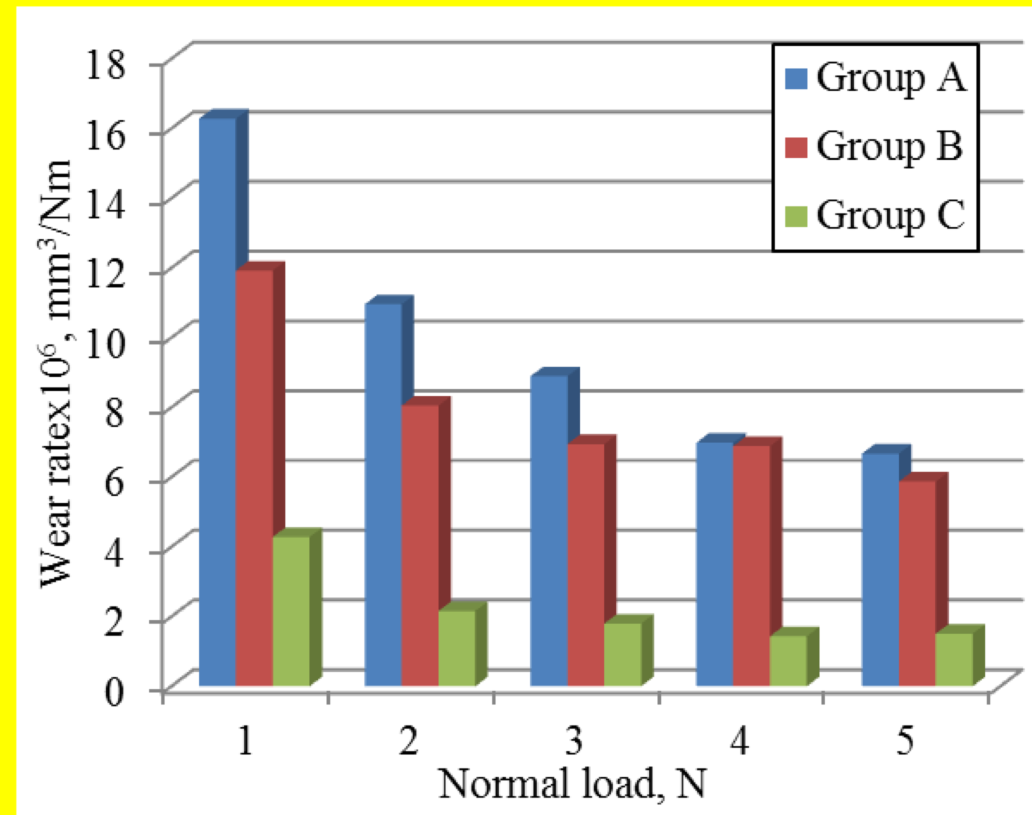

Fig.3. Wear rate under different normal load

Could be noticed that the wear rate decreases with a load increasing which is conducive for the coating purpose.

CONCLUSIONS

A slight increase in the roughness of the samples was found because of the presence of droplets in the coating. However, the measured COF is low enough. Some of the droplets would be extricated at the beginning of the operation with the injection mold – this could further reduce the COF.

The wear volume increases being linearly dependent on the applied load. The wear rate decreases at higher load. Such behavior is favorable for the supposed function of the coating - to protect the active elements of the injection mold.

The initial roughness clearly affects the wear intensity. The polished samples are the least worn (Fig.2 and 3). Thus, it is recommended to polish the surfaces where this is possible prior the deposition.

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