

Influence of Wear-Resistant Coating on the Reliability of Replaceable Inserts in Cutting Steel

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Abstract. Results of cutting tool life research of replaceable inserts (replaceable polyhedral plates) with wear-resistant coating and stressed-deformed condition of their cutting wedge are presented. Investigations have been executed in steel (0.40 % C, 1 % Cr) machining. Components of cutting force were measured by means of the dynamometer Kistler, magnitude and distribution of contact stresses have been defined according to earlier executed research in this area with use of a method of a sectional (split) cutting tool. Calculation of stresses in a cutting insert has been executed with use of program ANSYS which has displayed reduction of internal stresses in a base material of the insert with an antiwear coating in comparison with the insert without it. In the antiwear coating equivalent stresses more than in the insert without a coating and rich 1821 MPa. Experimental data on influence of various kinds of coats on cutting tool life and strength of replaceable inserts are presented.

1. Introduction

One of methods of working ability increasing of cutting tools is to use of wear-resistant coatings. Application of replaceable polyhedral cutting plates or replaceable inserts has allowed to reduce the cost price of deposition of high-quality coatings in a vacuum chamber and to improve their quality. To increase in reliability of work and durability of coatings they are applied multilayered [1-11].

Each layer of such composite coatings has own functionality. Properties of a composite cutting material with a coating can be steered due to a variation of a chemical compound of coatings, their structure and type of link with a base cutting material.

2. Materials and condition of experiments execution

Influence of cutting speed on tool life of inserts with three types of coating TiN, AlTiN, TiCN and without a coat was examined in turning steel (0.40 % C, 1 % Cr). The wear chamfer on a flank surface with the greatest its maximum permissible length $h_f = 0.2$ mm was accepted as criterion of wear of a cutting insert, corresponding for semifinish turning.

The cutting mode also corresponded to semifinish turning: feed rate $f = 0.13$ mm/r, depth of cut $t = 1$ mm, cutting speed $v = 360$ m/min. At execution of researches the change of a chamfer length h_f on a flank surface during of cutting (figure 1) was investigated.



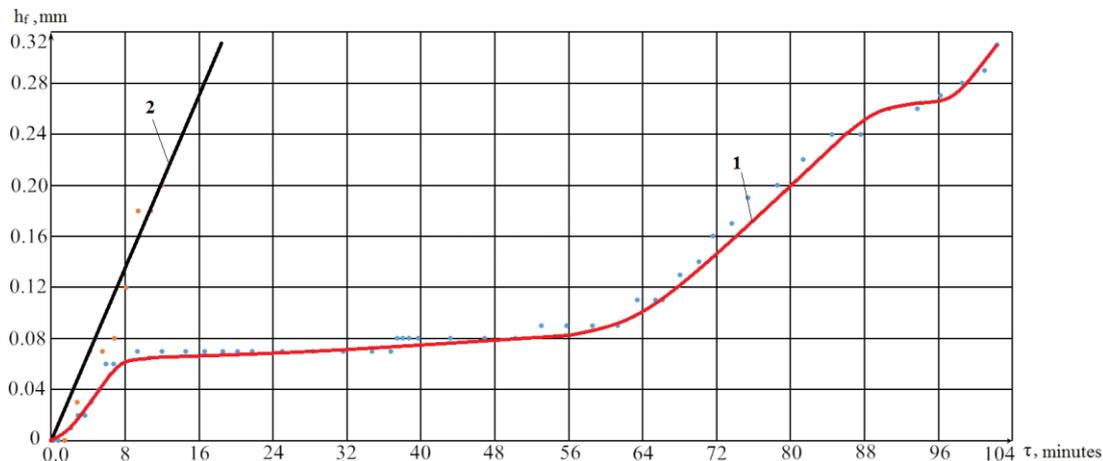


Figure 1. Dependence of length of the wear chamfer on the flank surface h_f (mm) from a time of cutting τ (minutes) in steel (0.40 % C, 1 % Cr) machining.

Steel (0.40 % C, 1 % Cr) – insert WNMG080404-TM with the coating TiN. $f = 0.13$ mm/r;
 $t = 1$ mm. 1 – $v = 180$ m/min; 2 – $v = 360$ m/min.

3. Research of wear

Character of change of a chamfer length during of experiments depends on cutting speed: at cutting speed 360 m/min it is rectilinear dependence on a time of cutting τ (min), but at cutting speed twice smaller (180 m/min) it is more complex dependence (figure 1). At cutting speed 180 m/min during 8 minutes the length of wear chamfer h_f is increased to 0.06 mm, after that the intensity of wear is sharply diminished that is connected, in our opinion, with the finish of wear-in time.

After 56 minutes of cutting the intensity of wear is sharply increased and becomes almost the same, as during the wear-in time.

After reaching of wear chamfer length $h_f = 0.3$ mm the chip is badly broken, is got confused round the workpiece and a cutting tool, and, having got on cams of a turning chuck, is scattered every which way, therefore trials should be stopped because of danger of deriving of a trauma of the human controller and aggravation of observation of the cutting process. Therefore the maximum permissible length of the wear chamfer is limited by not due to increasing of a cutting force and an elastic deformation (strain) of technological system, but due to aggravation of the chip shape.

Results of research of influence of machining time on the length of the wear chamfer h_f for inserts made from cemented carbide (15% TiC, 6% Co, 79% WC) with coat TiCN and without it are shown

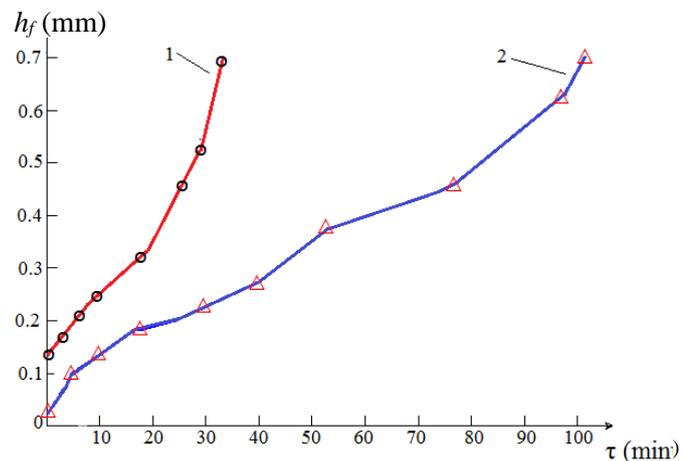


Figure 2. Change of length of the wear chamfer on the flank surface h_f (mm) of inserts made from cemented carbide (15%TiC, 6%Co, 79%WC) from a time of cutting τ (min) in steel (0.40 % C, 1 % Cr) machining. $s = 0.13$ mm/r; $t = 1$ mm; $v = 300$ m/min;
 1 – inserts without a coat; 2 – inserts with the coat TiN.

in figure 2. For inserts without coating at cutting speed $v = 300$ m/min the length of the wear chamfer $h_f = 0.3$ mm occur through 18 minutes. For inserts with coating TiCN the same wear occurs through 45 minutes that is 2.5 times longer.

More prolonged machining has allowed to augment the length of the wear chamfer h_f to 0.7 mm that corresponds to recommended maximum permissible wear for rough machining. Tool life without a coating and with the coating TiCN is 30 and 105 minutes accordingly, i.e. differ already more than 3 times.

In spite of the fact that after occurrence of the wear chamfer on the flank surface on this chamfer already there is no covering, all the same there is a protective action from a covering on a front surface which hangs over the chamfer a little and diminishes contact of transient surface with not already protected chamfer. This protective effect is more significant with the account of a sag of a transient surface in machining of the materials forming a continuous chip [1, 2, 3].

In machining with the cutting speed $v = 360$ m/min intensive local wear is observed on the surface which is positioned far from the working top (figure 3). It is explained by friction of the chip quenched after cooling on air.

Wear of a tool holder surfaces was not observed which is explained, in our opinion, by more essential reducing of temperature of the chip after cooling on a distance far from a cutting zone, thus smaller degree of effect.

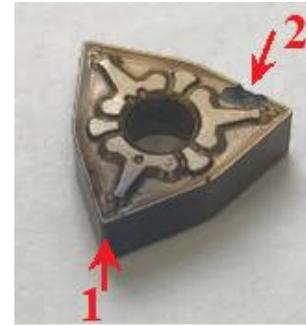


Figure 3. Wear of surface of the insert from a chip; 1 – working top of the insert, 2 – wear from the chip quenched on the air.

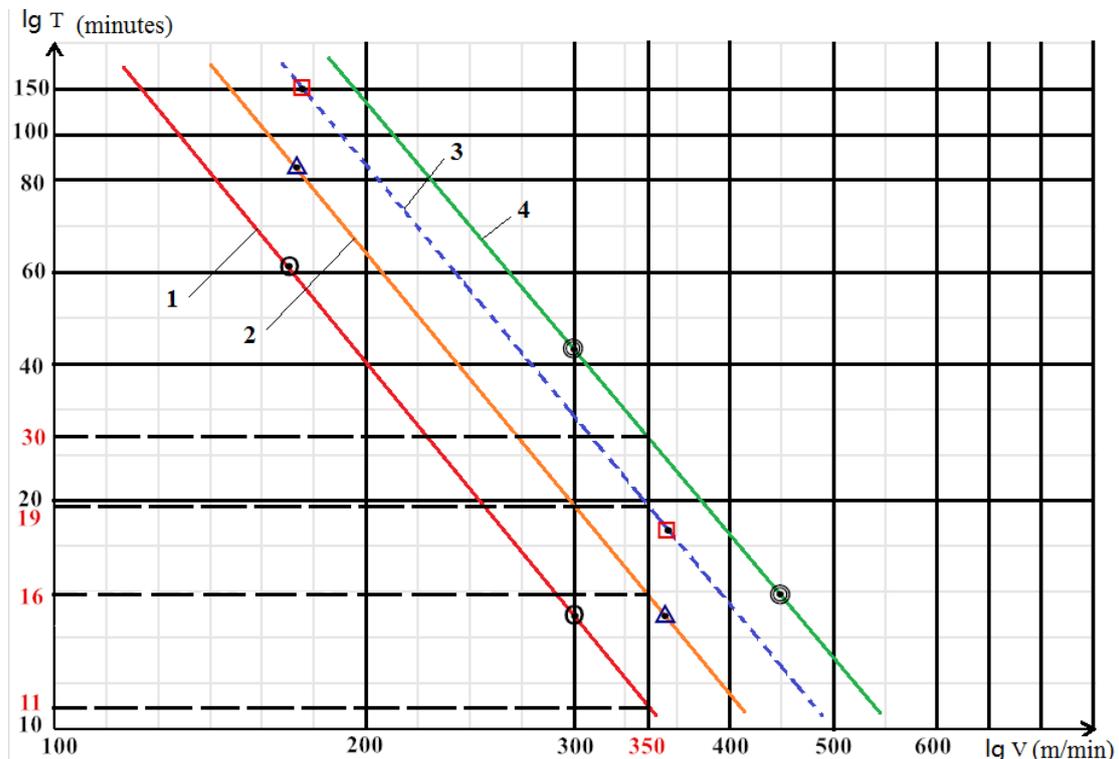


Figure 4. Dependence of the cutting tool life T (minutes) of inserts with wear-resistance coatings from cutting speed v (m/min) in steel (0.40 % C, 1 % Cr) machining and at $h_f \max = 0.2$ mm: 1 – without a coat, 2 – with the coat TiN, 3 – with the coat AlTiN, 4 – with the coat TiCN.

Intensive local wear is observed in a zone of contact of the principal cutting edge with a work (raw) surface in spite of the fact that the workpiece before the experiment has been machined. It confirms position about essential influence of air on chemical wear at high temperature.

Such local wear, so-called "moustache", leads to formation of confused continuous chip which is twisted (is being confused) around a shank of the cutting tool and the workpiece, therefore it is very much trauma-danger and difficult for removing. In a greater degree it is appeared at rather small rate of cutting $v = 180$ m/min.

The maximum permissible length of the wear chamfer on the flank surface $h_f = 0.2$ mm has been selected for construction of tool life graphs $T = f(v)$ because at cutting speed $v = 180$ m/min the action from "moustache" leads to aggravation of observation of the cutting process. The experiments have displayed that the greatest tool life have inserts with covering TiCN (figure 4).

Tool life comparisons were executed also at cutting speed 360 m/min which corresponds to usually recommended cutting speed in semifinish machining, and at 180 m/min (corresponds to usually recommended cutting speed in rough machining with inserts).

4. Research of stresses in inserts

Loss of form of the cutting wedge may occur due to wear of the wedge on the face and flank, and also due to destruction: brittle destruction or plastic deformation. For definition of probability of destruction of cutting material and the covering the 3-D sample pieces (the model) of the insert have been created with the covering and without it (figure 4). External loads were set by the application of the contact stresses received from earlier executed experiments [1, 2, 3].

The stressed-deformed condition (SDC) of a cutting wedge has been analyzed by a finite element method (FEM) with use of program ANSYS.

Distribution of internal equivalent stresses in the cutting insert is presented in figures 6 and 7.

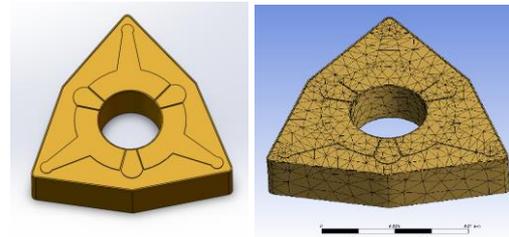


Figure 5. An example of the 3-D sample pieces of the cutting plate for calculation with a finite element method for the stressed-deformed assaying.

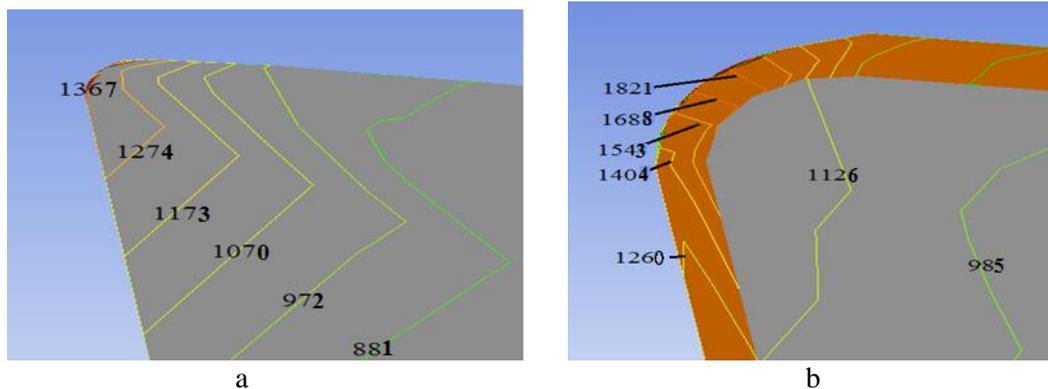


Figure 6. Distribution of equivalent stresses σ_e [MPa] in the cutting wedge of an acute cutting tool in turning steel. $v = 180$ m/min, $f = 0,13$ mm/r, $t = 1$ mm, $h_f = 0$ mm
a – the insert made from cemented carbide T15K6 without covering; b – the insert made from cemented carbide T15K6 with covering TiN.

The SDC analysis has displayed that the cutting plate with the coating has smaller internal equivalent stresses ($\sigma_{e \text{ max wedge with coat}} = 1126$ MPa) in comparison with the cutting plate without coating ($\sigma_{e \text{ max wedge without coat}} = 1367$ MPa), though in the coat layer equivalent stresses more than in a plate without a covering ($\sigma_{e \text{ max in coat}} = 1821$ MPa against $\sigma_{e \text{ max wedge without coat}} = 1367$ MPa). This result is

explained by us due to increased Young coefficient of elasticity E of the coat TiN. In the coat at its depositing by the method PVD and consequently its heightened strength due to small amount of imperfections even at its small depth allow to withstand even big stresses.

At length of wear chamfer $h_f = 0.11$ mm the plate with the coat has 1.4 times more the greatest stress ($\sigma_{e \max \text{ wedge with coat}} = 2508$ MPa) in comparison with the insert without wear on the flank surface ($h_f = 0$ mm) ($\sigma_{e \max \text{ wedge with coat}} = 1821$ MPa).

However at rather large wear ($h_f = 0.2$ mm) the insert with the coat has the greatest internal stress ($\sigma_{e \max \text{ coat}} = 1888$ MPa) close to the insert without wear ($h_f = 0$ mm) ($\sigma_{e \max \text{ wedge with coat}} = 1821$ MPa). Therefore the antiwear coating executes protective function on the flank surface even at rather large wear $h_f = 0.2$ mm.

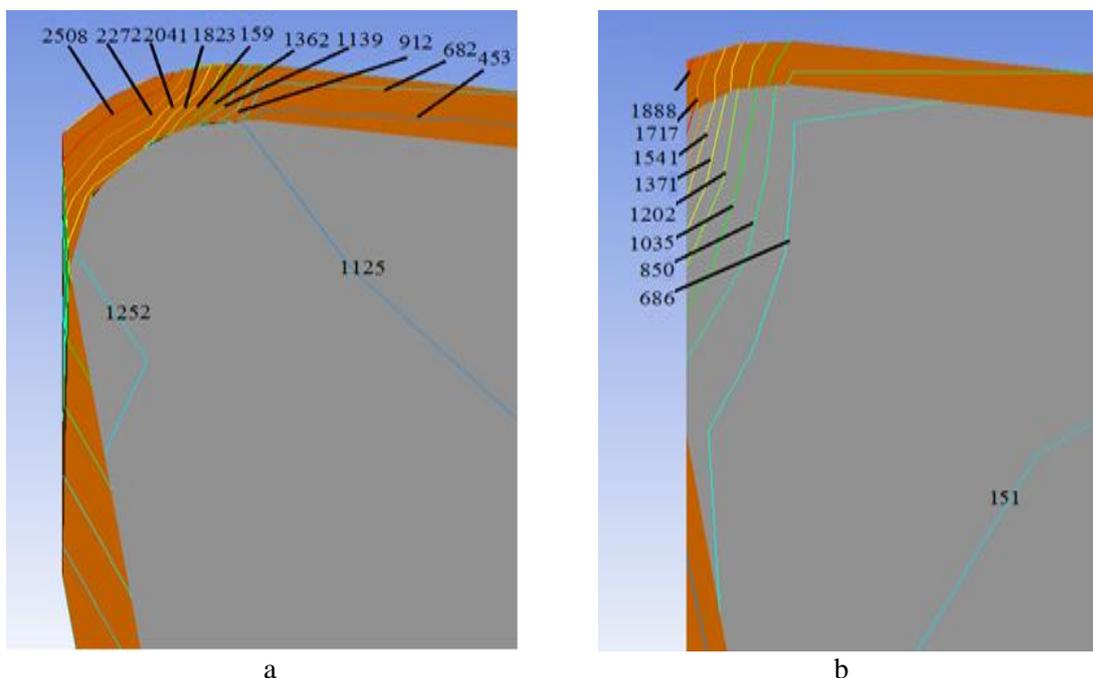


Figure 7. Distribution of equivalent stresses σ_e [MPa] in the cutting wedge of the insert made from cemented carbide T15K6 with covering TiN in turning steel. $v = 180$ m/min, $f = 0,13$ mm/r, $t = 1$ mm. a – $h_f = 0.11$ mm; b – $h_f = 0.2$ mm.

5. Conclusions

1. Character of change of a chamfer length during of experiments depends on cutting speed: at cutting speed 360 m/min it is rectilinear dependence on a time of cutting, but at cutting speed twice smaller (180 m/min) it is more complex dependence.
2. At turning steel with cutting speed 300 m/min and feed rate 0.13 mm/r tool life of inserts made from cemented carbide with the coat TiCN exceeds tool life of inserts without the coat 2.5-2.9 times;
3. Internal stresses in a cutting wedge of the insert with antiwear coat TiN are diminished by 18 % (on 18 %) in comparison with the insert without a coat;
4. At turning steels with cutting speed $v = 350$ m/min, $s = 0.13$ mm/r; $t = 1$ mm cutting tool life of cemented carbide inserts with the coat TiCN exceeds control inserts without a coat 3 times.
5. The greatest internal stress in the coat on 25 % more than in the cemented carbide insert without a coat that is connected with small depth of the coat;

6. Inserts with the coat TiCN has minimal floor price of machining of 1 metre. From economic feasibility point of view application of inserts with the coat TiN it is better, than with the coat AlTiN. Recommendations for choice an antiwear coating for semifinish machining of a steel: inserts with the coat TiCN and inserts with the coat TiN.

Acknowledgments

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