

# DEVELOPMENT OF GEOMETRY OF CARBIDE MULTIFACE PLATES FOR SUPERFINISH PROCESSING

## РАЗРАБОТКА ГЕОМЕТРИИ МНОГОГРАННЫХ ТВЕРДОСПЛАВНЫХ ДЛЯ СУПЕРФИНИШНОЙ ОБРАБОТКИ

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Protective coatings are widely used for carbide tools stabilization and functionality. Surface hardening of carbide tools by coatings which are based on titanium nitride is allowed to stabilize them for 3-5 times. But they are not available in cases of affinity of chemical elements with composition of worked stock. Multilayered coating provides sufficient toughness of the coating and high durability by the front coating allows to process different constructional materials efficiently [1].

Superfinish and finish edge cutting machining can be only with usage of high-quality tools but with an ideal wedge which has edge less than  $1 \mu\text{m}$  affects to have optimum shapes during the work. At start time of shake-down period this edge assumes the rounding and its dimensions are depended on cut depth, approach, tooling and worked material which assign intensity of production process.

Generally accepted finish machining is characterized by the production mode: approach  $S = 0,1 \dots 0,3 \text{ mm/turn}$  and cut depth is  $a_p = 0,5 \dots 2,0 \text{ mm}$ . Superfinish -  $S = 0,05 \dots 0,15 \text{ mm/turn}$  and  $a_c = 0,25 \dots 2,0 \text{ mm}$ . Even with the lowest process rates, edge (conditional inscribed radius of rounding edge) of standard metal-cutting tool ( $\rho = 15 \dots 25 \mu\text{m}$ ) is enough for stable operation. With process rates: approach  $S < 0,05 \text{ mm/turn}$  and cut depth is  $a_p < 0,1 \text{ mm}$ , for example,  $S = 0,01 \text{ mm/turn}$  and  $a_c = 0,010 \text{ mm}$ , the edge of modern tool does not provide the stable operation (Fig. 1)

Cutting process will be accompanied with deformation and hardening of surface layer of the work piece. It is necessary to provide the correspondent edge and the application of a harden negative chamfer is allowed to stabilize the tool for the normal operation of the cutting tool. In Figure 2 there is a dependence of kinematic chip thickness on lead angle  $\varphi$  and approach  $S$ . It is seen from the dependence that with the decreasing of lead angle  $\varphi$  and approach  $S$  kinematic chip thickness  $h_m$  decreases.

The creation of edge (with short conventional inscribed radius) strictly defined form of the cutting edge of the tool increases the quality of finish, but the carbides do not bear the load increasing and fail rather quickly and in the result the quality of processing coating decreases and tools can be failed. Solving of this issue is to apply a hardening coating but nowadays a lot of traditional coatings are developed but not all of them are suitable. With the covering of the coat the circle radius and as consequence the processing accuracy and quality decreases. Moreover they are quite fragile. With the cutting edge of  $1 \mu\text{m}$  the coating thickness must have commensurable dimensions (traditional coatings have optimal thickness  $5 \mu\text{m}$ ).

Consequently, the coatings which can bear a high load and provide a long-term usage of tools at shallow thicknesses are necessary. At inserted carbide cutting with the coatings should not be seizure with the work materials. The last one is essential at hard-to-cut materials processing on basis of titanium, nickel, aluminium and etc. Coatings must possess a small friction ratio combined with the work material, possess damping properties and not be subjected to brittle failure.

For the purpose of finding out of influence of the light coatings on the tool cutting characteristics the study of tool with coating operation Al-Si-N and into the part of coatings are additionally implemented ions Mo has been made.

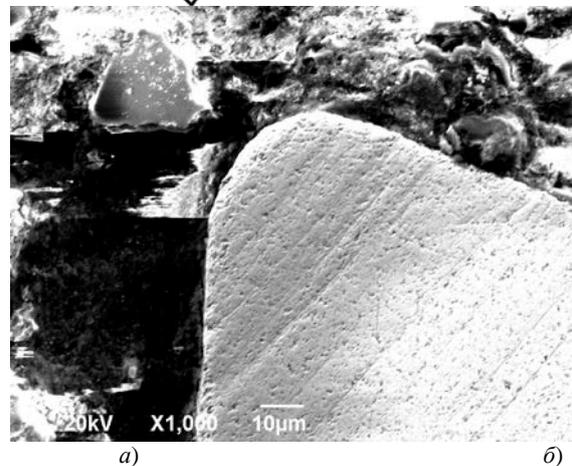
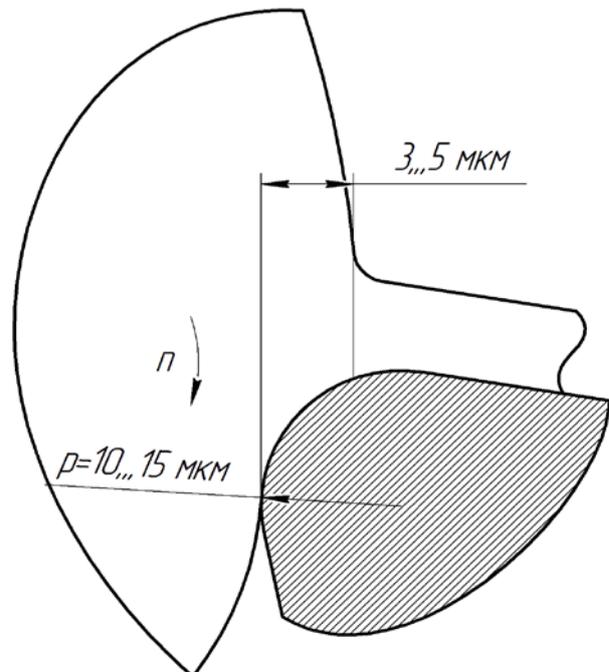


Figure 1 – Edge of modern metal-cutting tool: a) cutting pattern; b) picture of the edge in cross-section

From the tests of cutting edge tool made by the authors it is stated that negative chamfer must have an angle  $\gamma = -5^\circ \dots -15^\circ$  and width chamfer is fixed by the forming width of cutting which depends on depth of cut and approach. The realization of superfinish processing with the light feed and depth of cutting is possible only with high edge of the tool. From the tests it is stated that the stable cutting is observed in the ratio of layer cut thickness and the edge.

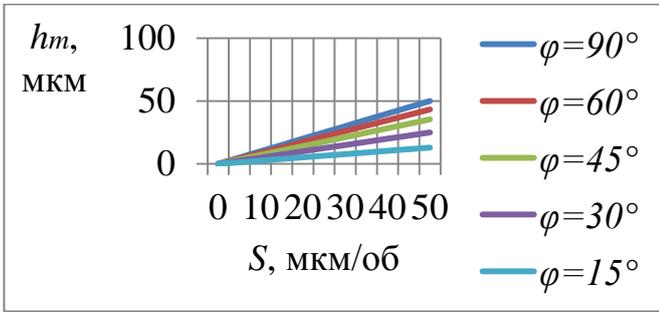


Figure 2 – Graph of kinematic chip thickness from lead angle  $\varphi$  and approach  $S$

In operation research of the edge’s keenness influence on the cutting process in processing heat-resistant alloy was carried out. The high-quality edge was obtained through the high-speed sharpening (grinding speed is 350...400 m/s).

On the basis of research results of the stable cutting were obtained. Figure 3 shows recommended ratio of layer cut thickness and the edge’s keenness.

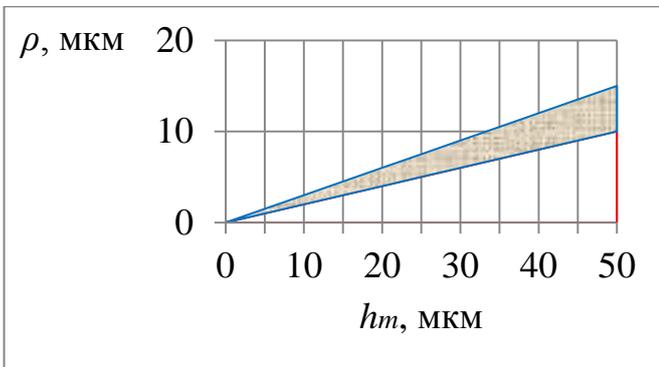


Figure 3 – Graph of recommended edge  $\rho$  from kinematic chip thickness  $h_m$  in the area of the stable cutting

The graph makes possible to identify required edge’s keenness of carbide tool in the ratio  $5 < R_{c.a.} \leq 10$ , where  $R_{c.a.}$  is the ratio of the cutting ability, which has a dependence, defined as  $R_{c.a.} = h_m / \rho$ . That is the ratio of the cutting ability depends on kinematic chip thickness  $h_m$  and edge’s keenness  $\rho$ . From the above ratio of the cutting ability it’s possibly to define the area of stable cutting.

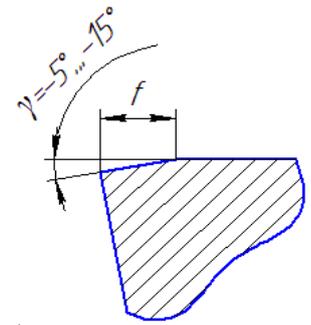
Analysis of industrial experience and literary data allowed to define that the usage of negative chamfer increases durability and can have different dimensions and shape. Negative chamfer serves as strengthening edge’s element.

For comparison of the cutting process the analysis of existing microgeometry carbide tools was conducted. The analysis showed that sharpening of high-quality carbide tool with the formation of negative chamfer and additional chamfers (Fig. 4, a – 4, d) changes the mechanism of their wear and increases the life.

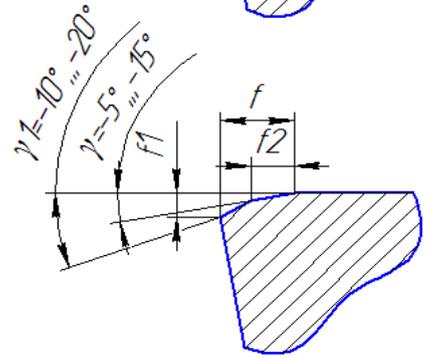
There are several types of chamfers [2]. The size of the negative chamfer along the contour and on front surface depending on specifications should be 30...50% of the kinematic chip thickness  $h_m$ .

For approvement of the influence of the chamfer on the cutting process of hardmachining materials geometry with negative chamfer  $f = 3...5 \mu\text{m}$  and an angle  $\gamma = -10^\circ$  (Fig. 4, a) and geometry of edge tool free from edge’s defects with the sharpness  $\rho = 1...2 \mu\text{m}$ , while all plates were covered by Al-Si-N.

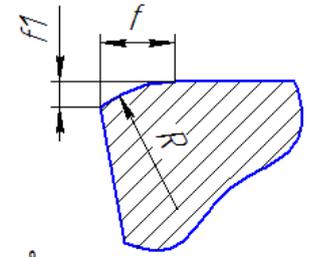
a) Negative chamfer  
 $f = (0,3...0,5) \cdot h_m$   
 $\gamma = -5^\circ...-15^\circ$



b) Double negative chamfer  
 $f = (0,3...0,5) \cdot h_m$   
 $f_2 = 0,5 \cdot f$   
 $\gamma = -5^\circ...-15^\circ$   
 $\gamma_1 = -10^\circ...-20^\circ$



c) Rounding negative chamfer  
 $f = (0,3...0,5) \cdot h_m$   
 $R = (2...3) \cdot h_m$



d) Negative chamfer with rounding  
 $f = (0,3...0,5) \cdot h_m$   
 $\gamma = -5^\circ...-15^\circ$   
 $R = (1...2) \cdot h_m$

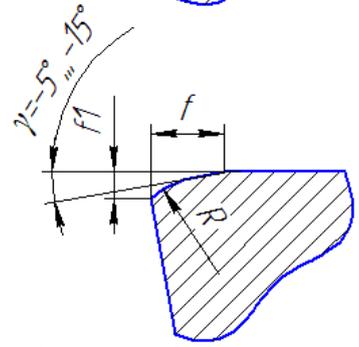


Figure 4 – Types of negative chamfers

Tests of different bars were conducted for comparison of influence of abrasive material on production of the chamfer. Meanwhile chamfer on the edge was produced experimentally with the use of different abrasive materials (Fig. 5).

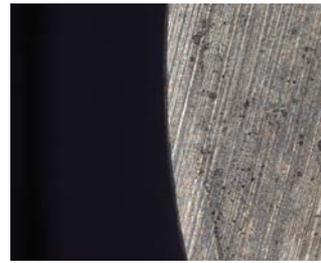


Grinding bar 47 F2500 (main fraction 8,4 μm) Norton (Brazil)  
a)

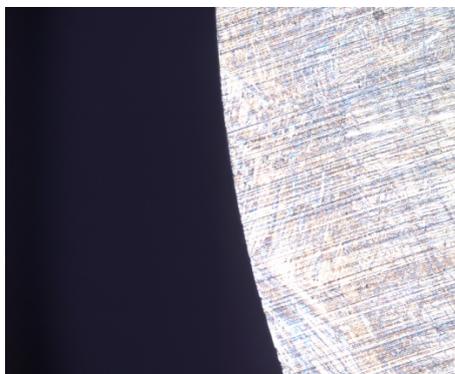
Grinding bar ACM 28\20 B2-01 (main fraction 23 μm) (Russia)  
b)



Grinding bar on volcanicite bundle 95 32ГТ (corresponds to the mark of abrasive material 14A) (main fraction 348 μm) Luga (Russia)  
c)



Grinding bar ACH 7/5 4 B2-01 (main fraction 5,5 μm) Inrost (Инрост) (Russia)  
d)



Grinding bar with suspension of submicropowder Masaper prep polishing suspension 0,05 μm (USA)  
e)

**Figure 5** – Edge of carbide tool, produced after blunting by different abrasive materials

Analysis of the results showed that the best result was obtained using the grinding bar ACH 7/5 4 B2-01 (main fraction 5,5 μm) Inrost (Инрост) (Russia) (Fig. 5,d), chamfer in the range 3...5 μm. Usage other abrasive materials doesn't allow to get a stable result. Grinding bar 47 F2500 (main fraction 8,4 μm) Norton (Brazil) (Fig. 5,a) makes defects on the edge in form of microchips. Grinding bars ACM 28/20 B2-01 (main fraction 23 μm) (Russia) (Fig. 5,b) and on volcanicite bundle 95 32ГТ (corresponds to the mark of abrasive material 14A) (main fraction 348 μm) Luga (Russia) (Fig. 5,c) make obstructions on the edge, and grinding bar with suspension of submicropowder Masaper prep polishing suspension 0,05 μm (USA) (Fig. 5,e) allows to make a chamfer and to produce any processing at all. In the last case the result can be supposedly explained by the fact that abrasive material has a low hardness and it can't make processing.

Selected the best in terms of cutting geometries of the tool were covered with *Al-Si-N*. Except various geometries coating *Al-Si-N* was used in the work, the thickness of which amounted to 2,3 μm on the front side. The coating was formed with much worse adhesion with a thickness 0,26 μm at the back side because of the spraying (Fig. 6).

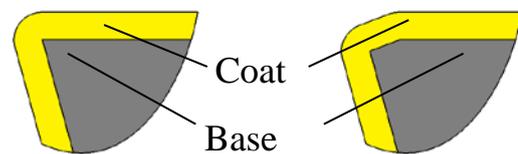


**Figure 6** – The scheme of coating

Small thickness and actually one-sided covering of coatings preserve edge's keenness. Because of the significant difference in coating hardness and base the back side will wear more quickly, which would lead to the realization of the self-sharpening condition and longer tool operation.

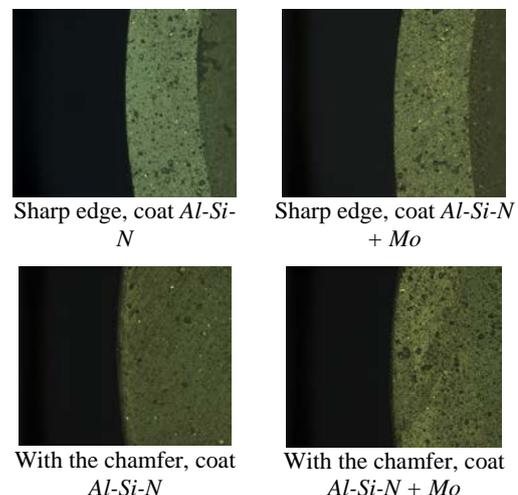
Coatings, that is ~2...2,5 μm thick, were settled on the vacuum unit YBH-05МД «КБАКТ» in argon-nitrogen gas mixture at a total pressure 0,3 Pa and the ratio of partial pressures  $Ar: N = 3 : 1$  by the method of the bipolar impulsive magnetron sputtering of mosaic target based on aluminum with silicon inserts. The discharge power of the magnetron was 1,2 kW; frequency of current impulse was 50 kHz. Heating sublayers and maintaining their constant temperature in the settling process of coatings were carried out by molybdenum resistive heater power of 10 kW. The chemical composition of coatings *Al-Si-N* included: *Al* – 34 at.%, *Si* – 13 at.%, *N* – 53 at.%. Figure 7 shows a sketch of carbide plates which used in the work. Also in the same way plates implanted with molybdenum *Mo* in the coating *Al-Si-N* were tested.

Figure 8 presents edges of carbide sharp plates with the chamfer which covered with hardening coating *Al-Si-N* and coating implanted with molybdenum *Mo*.



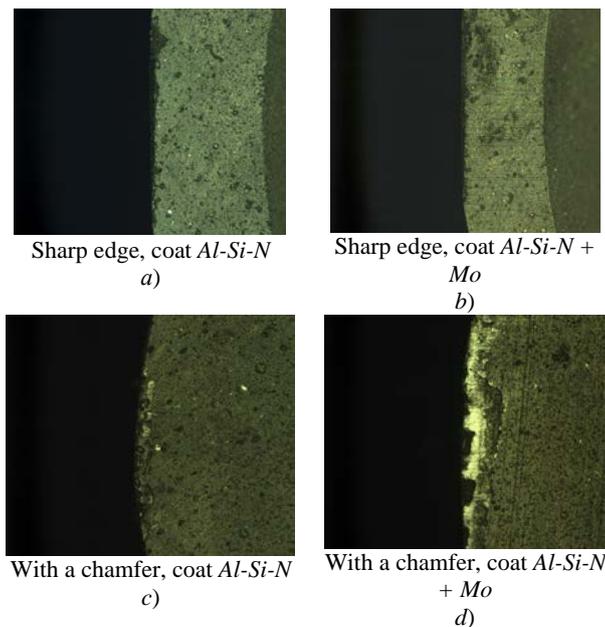
**Figure 7** – Sketch of carbide plates with the coat

Durability tests of carbide plates were carried out in turning steel XH77TIOP on a lathe machine *Okuma ES-L8II*. Cutting fluid *BlasoCut 2000* was used. Processing condition in turning: cutting speed  $V = 40$  m/min, longitudinal feed  $S = 0,05$  mm/Rev and depth of cutting on the diameter  $t_d = 15$  μm.



**Figure 8** – Edges of carbide sharp plates and with the chamfer

The results of tests showed that plates had different wear (Fig. 9).



**Figure 9** – Edges of carbide sharp plates and with the chamfer

Sharp edge plate (Fig. 9,a) has strongly pronounced blaze and classic wear on the back surface. Sharp edge plate with the coat and implanted molybdenum *Mo* (Fig. 9,b) has classic wear on the back surface. Plate with the chamfer and coat *Al-Si-N* (Fig. 9,c) has residual trace of excrescence (stagnant zone), while preserved coat, and the plate with the chamfer and implanted molybdenum *Mo* (Fig. 9,d) has strongly pronounced wear on the front surface with flaking coat and residual trace of excrescence. At the same time this plate has chipping on the edge. The best result for durability and quality of processing was showed by the plate with negative chamfer and coat.

Tool durability was assessed by quality parameters of details' processing. Change of roughness was assessed visually, and was measured by profilometer *MarSurf PS1*. Results for durability compared to the original plate are shown in Table 1.

**Table 1** – Durability carbide sharp plates and with a chamfer

Plate	Durability T, min	Passed way L, m	Treated area S, cm <sup>2</sup>
Sharp edge, coat <i>Al-Si-N</i>	42,4	1696	847,8
Sharp edge, coat <i>Al-Si-N + Mo</i>	59,5	2379	1189,7
With a chamfer, coat <i>Al-Si-N</i>	169,6	6782	3391,2
With a chamfer, coat <i>Al-Si-N + Mo</i>	43,5	1741	870,4
Original	31,3	1252	626,1

Conclusion: In processing of heat-resistant alloy XH77TiOP the best result for durability and quality of processing was given by carbide plate, which has the edge  $\rho = 1...2 \mu\text{m}$  free from edge's defects, original geometry with negative chamfer  $f = 3...5 \mu\text{m}$ , and an angle  $\gamma = -10^\circ$ , with coat *Al-Si-N*.

## References

1. Kornievich M. Cutting theory: textbook / Kornievich M., Feldstein E., Yashcheritsyn P. – Minsk: Novoe znanie, 2007. – 512 p.
2. Catalogue Sandvik Coromant.