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Special Deformation Structures During Machining Plastic Metals, Their Activation And Use

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Abstract - The contribution analyses the possibilities of modification of cutting geometry in order to preserve a protective plastic zone of a material upon a cutting key. Based on the results of model experiment as well as practical verification, considerable increase in tool life has been achieved. The tools durability is dependent on the size of the shortened front face. Optimation of the face size enables to achieve a multiple durability when compared to a classical cutting key. The peculiarity of the processes is the creation of the two chips, one of which is an expelled plastic layer along the edge of the cutting tool. The application of the tool is possible only with the plastic materials cutting. Experimental tests have been carried out with frequently used steels. cutting tool, plastic deformation, wear, hips

I. INTRODUCTION

Following the analysis of recent works dedicated to the cutting tools durability, [1], [3], [4], [5], [6], [8], cutting wedge geometry has considerable influence on the tool durability. The development of trends has reached the optimation of the values of back and face angles for cutting conditions, sort of cut and cutting materials in advance. Great advance has been achieved in the application of rubbing-proof coats on functional tool parts. Other reserves are given in the knowledge and application of the character of plastic deformation in front of the tool cutting wedge. Specific structures of highly deformed material, which do not occur at other technological methods (e.g. at shaping), occur in front of the cutting wedge. Generally known augmentation on the cutting edge is considered a negative fact, because the parts releasing from it cause considerable tool wear and worsening the quality of machined surface. At higher cutting speeds the augmentation disappears. However, a set back layer develops in front of tool face, which moves along it very slowly. The speed of material movement increases into the chip until it reaches the speed of chip movement. This plastic zone of material is the object of our interest.

II EXPERIMENT METHODOLOGY

To observe the changes in the zone of chip creation it is necessary to stop the machining process immediately, it means to interrupt the contact of the tool and the workpiece. A reliable method to stop the machining process immediately has been developed [9].

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It has been based on the observation of the end of the chip, which was created at interrupted cut, e.g. during planing or face milling. When the tool is leaving the mesh, the end of the tool „tears off“, according to *Fig.1*.

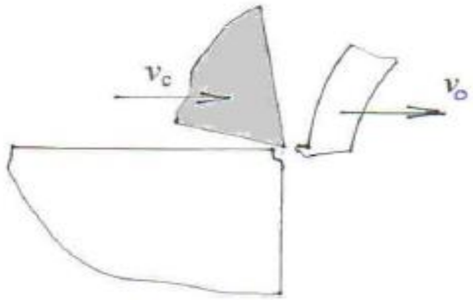

Fig. 1 Creation of the imprint of the cutting wedge on the chip during interrupted cut.

The cut of the chip end has shown that it is possible to observe the texture in the chip, which equals the actual cutting speed (*Fig.2*). The interruption of machining occurse immmediately (cca in the course of 0,02 sec, similarly to the friction test by thrust). This has lead to the design of a method of obtaining the chip roots by the adjustment of the workpiece end according to *Fig.3*.

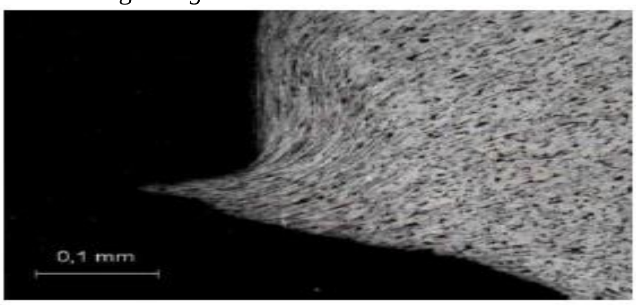

Fig. 2 Metallographic cut of the chip end during interrupted cut, steel (E335)

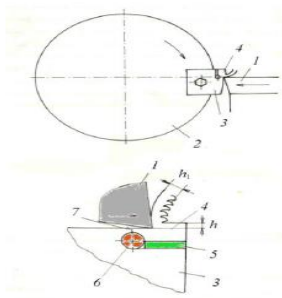

Fig. 3 Principle of the method for immediate interruption of the contact of the tool and workpiece (a)[9], 1- cutting wedge, 2 - disc, 3 – tested material sample, 4 – torn out sample part, 5 – support plate for sample slip, 6 – metal bar, 7 – sample herniation place

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In the place where the tool leaves the mesh *1* there is a groove with inserted plate *5*, which prevents the deformation of the sample during the herniation. Behind the groove there is a drilled hole *6* and in it there is an inserted pole, which prevents the hole deformation. When the tool passes above the hole, the cross cut contracts *7* and the material tears off, similarly to the test by thrust. From the oscillographic record of the cutting force it can be seen that the interruption of machining occurs immediately. The sample *4* is swiftly thorwn along the course of the tool movement and it happens in higher speed than the cutting speed is. On the sample there is recorded state of plastic deformation equal to actual cutting speed.

In *Fig. 4* there is an oscillographic record of the cutting force at the moment of machining interruption.

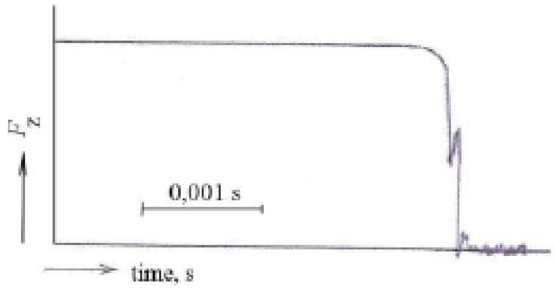
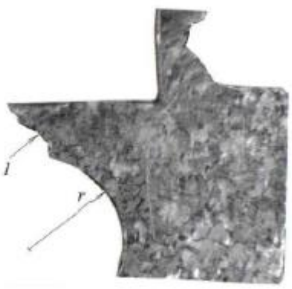


Fig. 4 Oscillographic record of the change in cutting force when machining is interrupted

The view of taken samples is shown in Fig. 5. In figure b there is the metallographic cut of the sample, where there is a visible plastic deformation of the grain s in the chip, the field of plastic deformation immediately in front of the cutting wedge and not deformed grains of the basic material of the workpiece.

(a)



(b)

Fig. 5 Metallographic cut of the sample with creating chip . a – taken samples, b – linear cut of the sample. 1- place of sample herniation, r – hole radius .

III. ESSENCE OF CREATION OF CHÁP CREATION AND ITS CHANGES WITH CUTTING SPEED

As it is known, when using small cutting speeds, an augmentation is created on the cutting wedgem, caused by adhesive ties between the cutting and cut materials. After crossing certain values of cutting speed (and temperature of cutting), it disappears. Typical shapes of those augmentations can be seen in *Fig. 6*.

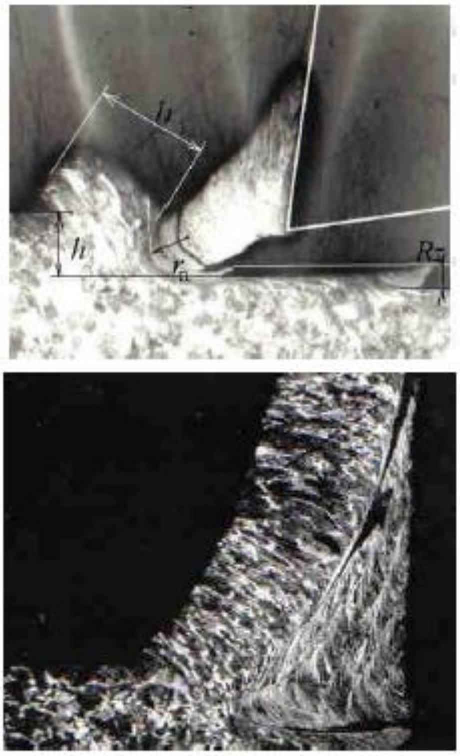


Fig. 6 The typical shape of augmentation on a cutting wedge during finishing. Workpiece: steel C45, tool: P20, f = 0,05 mm, v_c = 30 m.min^{-1}, h-chip thickness, r_n – radius of augmentation edge Rz – surface roughness

In the picture on the left it can be seen that the augmentation worsens the quality of machined surface. Therefore it is undesirable during finishing. Its parts are released onto the machined surface and create uneveness. During roughing, when the quality of machined surface is not so important, the augmentation is not so harmful. However, it changes the tool geometry as it takes over its function and causes oscillation in technological system.

After crossing certain cutting speed, the augmentation ceases to exist and changes into a hindered layer which has fibre-like structure, it is firmly attached to the tool face and has a gradient of speed. Above the cutting wedge the material speed increases until it reaches the speed of chip movement:

$$v_t = \frac{v_c}{k} \qquad (1)$$

where v_c is cutting speed, m.min^{-1},

k – chip compression: $k = \dfrac{h_1}{h}$,

h_1 – chip thickness, mm,

h – removed layer thickness, mm.

The photography of the zone of chip creation without an augmentation is shown in *Fig. 7*.

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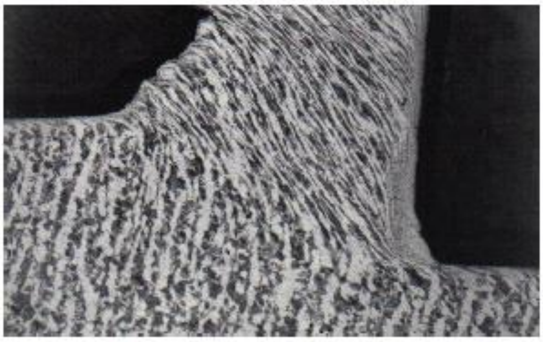

Fig. 7. The photograph of a zone of chip creation with a hinedered zone. Workpiece, Fe70-2FN, Tool: P20, v_c= 120 m.min^{-1}

Hindered zone of material, as it can be seen from *Fig. 7* is too small to protect the cutting wedge against wear. Therefore it is necessary to create conditions for the enlargment of the cutting wedge by the adjustment of its geometry. This is the basis of suggested solution.

IV DESIGN OF RATIONAL GEOMETRY OF CUTTING WEDGE

For the design of rational geometry of the cutting wedge it is necessary to start with the requirement of maintaining the rigidity of cutting wedge and sufficient size and inclination of teh area, which keeps the plastic zone. The experiments devoted to the influence of the face angle on the size of plastic zone so far lead to the values of the face angle: $\gamma_{0f} = -6^0$. Other experiments have shown that the limit angle of another face, which is still suitable from the viewpoint of rigidity and secure that the chip does not touch the face is the angle $\gamma_n = 45^0$.

Supposing that the optimal value of the length of shortened face is determined, it would be possible to obtain the situation according to *Fig. 8*.

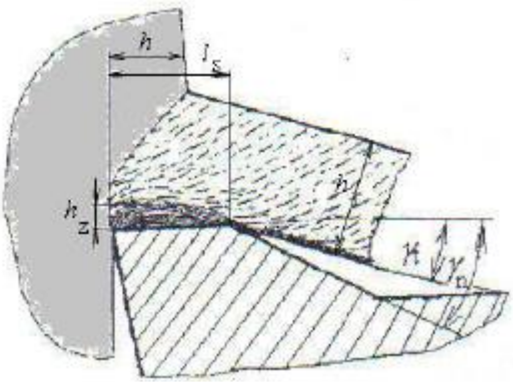

Fig. 8 The scheme of the course of secondary deformation in a chip with cutting performed by a tool with a shortened face

Tests of machining by the tools with different size l_s have been performed. The result is shown in *Fig. 9*. The left curve equals the tool with classical geometry and straight face. On the right there are the curves equaling different values of shortened face. From the diagram it can be seen that this parameter has considerable influence on the tool durability. For the given case, the optimal value is l_s = 0,4 mm.

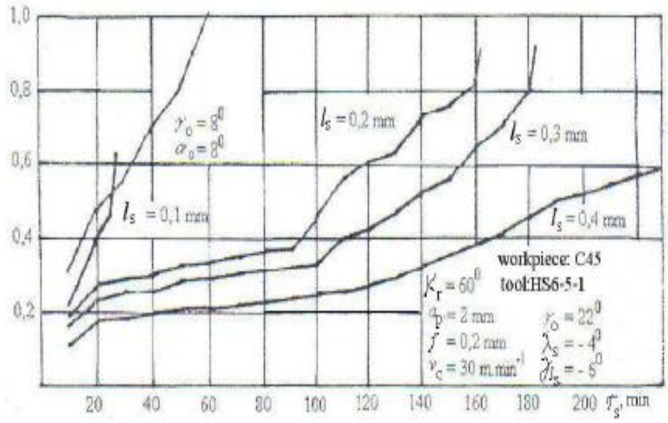

Fig. 9 Experimental dependence VB = f(τ_s), with varions l_s

To prove the function of plastic zone, cuts of thezone of chip creation, obtained by the above mentioned method to stop the machining process immediately, have been performed. In *Fig. 10* there is a typical „chip root“ with increased hindered layer. In the picture there is also the part of the tool, which has broken open during the test. It can be seen that the tool face uneveness is copied in the chip, which proves that the plastic layer has really been hindered.

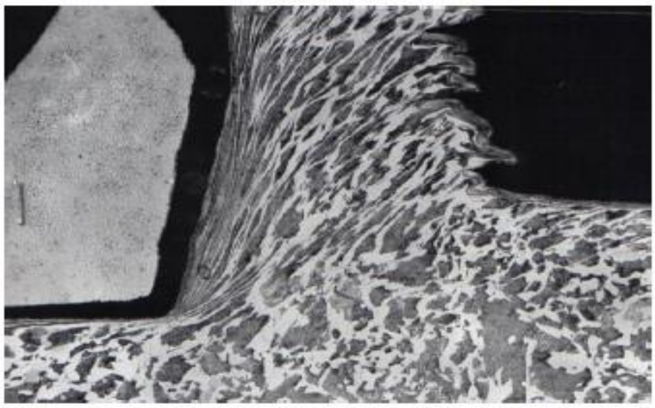

Fig. 10 The fotograph of metalografical section of a chip creation area at turning steel under the conditions shown in Fig. 9 when l_s = 0,4 mm, v_c = 80 m.min^{-1}, workpiece: C45

In *Fig. 11* there is a detailed view of the plastic zone from other experiment.

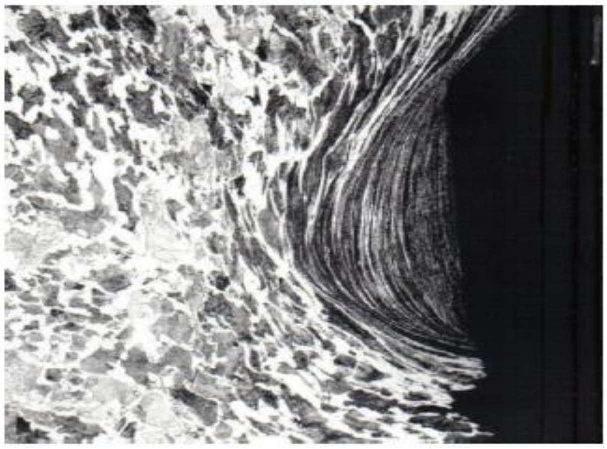

Fig. 11 Photography of metallographic cut of chip creation for steel with l_s = 0,3 mm.

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Plastic zone is continually completed by cut material. Because it does not grow, the question is, where the material leaves. The answer can be seen in Fig. 12. Plastic zone leaves along the cutting edge in the form of a ribbon.

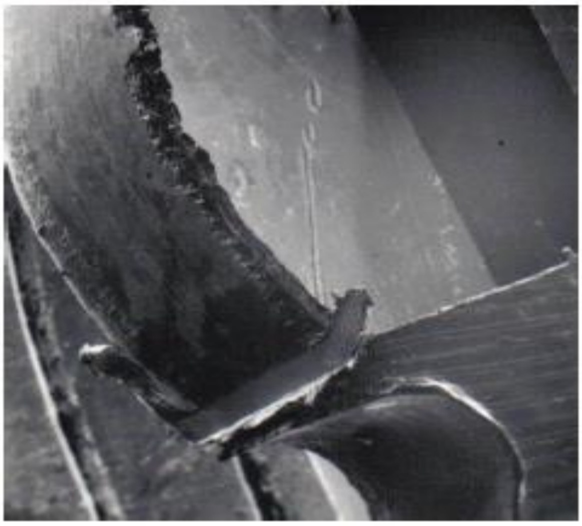

Fig. 12. View of the process of chip creation from the tool side

The ribbon has fibre-like structure and visually it reminds of an amorph. Another view is in Fig. 13.

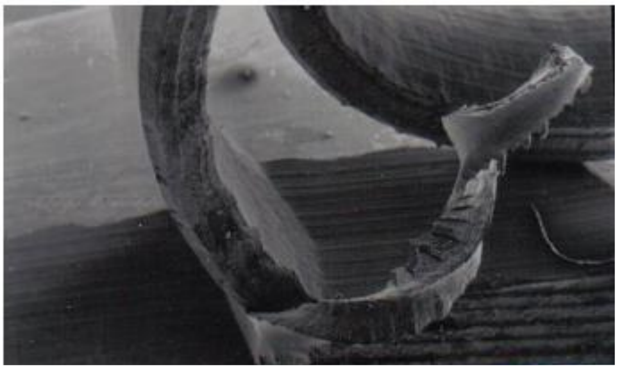

Fig. 13 View of leaving „secondary chip“

Therefore during machining two chips leave along the adjusted tool. In *Fig. 14* there is a photography of recorded secondary chip.

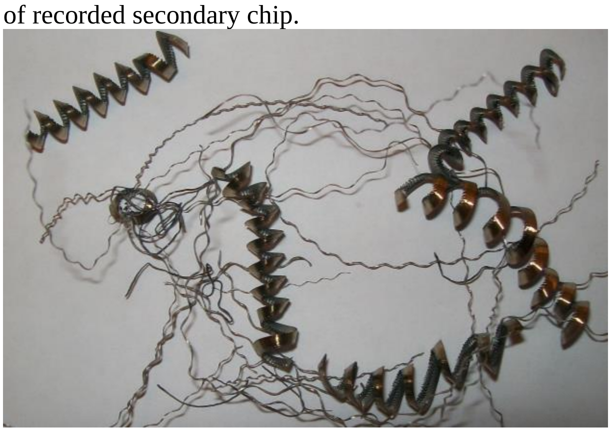

Fig. 14 View of the recorded primary and secondary chip

In *Fig. 15* there is a valuable photograph recording a part of the tool in mesh. It canbe seen that on teh shortened area of the chip there is an imprint of the tool face profile. It canbe inferred that the shortened area of tool face does not wear at all because between it and the tool face there is no mutual movement. Primary chip passes above this zone. It can be seen that the chip slides along the plastic zone. On the chip one can see the traces of friction of the chip and the plastic zone.

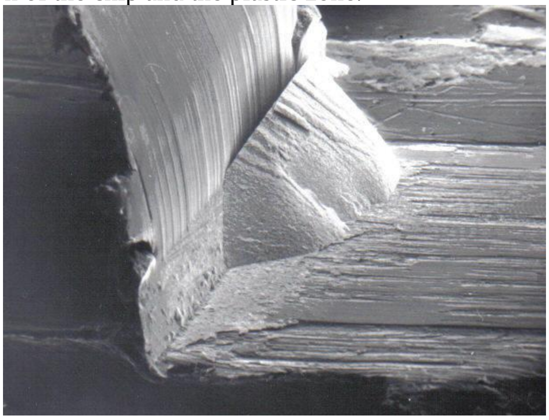

Fig. 15 View of the process of chip creation with adjusted tool

V. DURABILITY TEST

Long-term tests of machining by classical and adjusted tools have been performed to find out their durability. The resulting dependencies of tool durability on cutting speed is shown in *Fig. 16*.

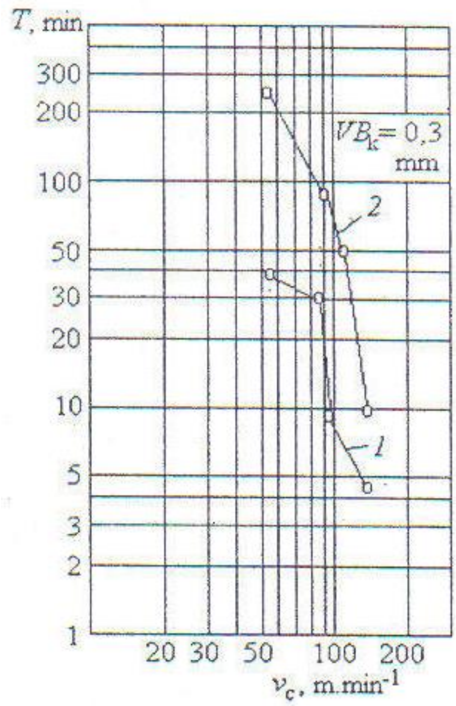

Fig. 16 Experimental dependence of tool durability on cutting speed at application of classical tool (1) and a tool with shortened face (2) with l_s = 0,3 mm

It can be seen that the suggested adjustment has evoked cosiderable tool durability. For example, at cutting speed 50 m.min^{-1} the durabilities of 40 and 250 min. are comparable, which equals six times increased durability. Similarly for v_c= 100 m.min^{-1} the increase of durability from 9 to 60 m.min^{-1} have been recorded.

Substantial result can be expected for cutting-off tools, where the cutting speed increases during machining.

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The adjustment of the tool for cutting-off taper roller bearings in *Fig. 17*, by the tool of high-cutting steel, has been performed.

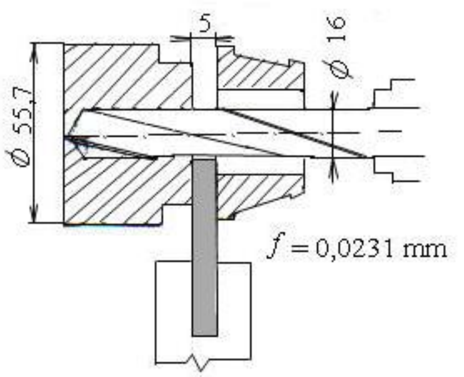

Fig. 17 The scheme of a bearing ring turning

The result of the experiment is shown in *Fig. 18*.

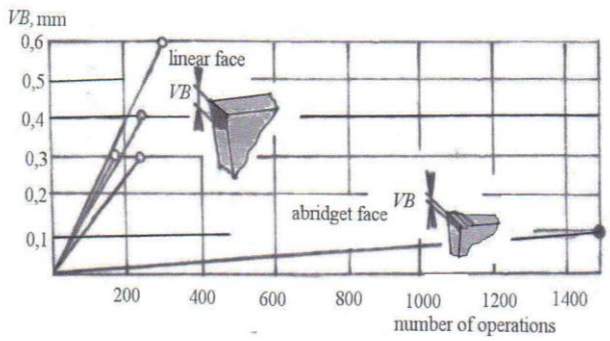

Fig. 18 Experimental dependence of partings number with a classical tool (with a straight face) and a tool with a shortened face

From *Fig. 19* it can be seen that average classical tools durability has been 220 cutting-offs with average wear on the back area VB_k = 0,4 mm. The tool with adjusted face has had durability 1500 cutting-offfs with minimal wear (VB_k = 0,1 mm) and it has been able to continue at work. Therefore it has been seven times increase in durability.

Protective plastic zone of the tool face has remained there during the course of all operation of part cutting. After the tool has left the mesh, it has been firmly attached to the tool.

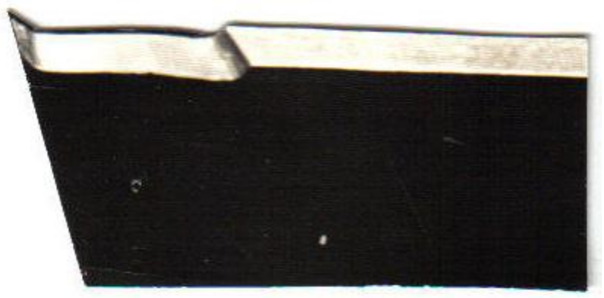

Fig. 19 Photography of the cutting-off tool after finishing the operation with plastic zone on the face

VI. CONSLUSION

The application of the knowledge of the mechanism of plastic deformation in front of the cutting wedge leads to new tool designs, which show noteably higher durability. It is relevant for the tools made of high-speed steel and sintered carbid. It can realistically be presumed that the combination of suggested adjustment and rubbing-proof coatings can lead to further increase in durability. The tool design is suitable for machining of plastic metals, for example carbid steels. Besides high durability there occurs less intensive heating of the cutting tool and the chip because the friction on the tool face is less intensive. The chip compression is smaller as well.

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Professor Karol Vasilko is a prominent academic figure well-known throughout central and Eastern Europe for his academic achievements and scientific contribution in the field of mechanical engineering. During 45 years of his professional career Professor Vasilko published over 300 research papers, 50 patents, 36 books and numerous student textbooks. He founded a new university Faculty, has acted as an expert advisor to many national and international companies, while taught and mentored countless number of students from undergraduate to doctoral level. Professor Vasilko remains very active and continues working at the Faculty of Manufacturing Technologies in Prešov, Technical University of Košice in Slovakia.