`BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi,
Tomul LX (LXIV), Fasc. 1, 2014
Secţia
CONSTRUCŢII DE MAŞINI

NEW APPROACH ON GEOMETRY TOOLS WITH INDEXABLE INSERTS

I. THEORETICAL APPROACH

BY

CRISTIAN CROITORU* **and MIHAI SEVERINCU**

"Gheorghe Asachi" Technical University of Iaşi,
Department of Machine Tools

Received: September 25, 2013
Accepted for publication: October 2, 2013

Abstract. In this paper a new approach for the problem of cutting tools geometry is presented, in relation to the insert shape and geometry of the tool holder. Starting from the constructive geometry of a general shaped insert, a theoretical investigation establishes the constructive geometry of an assembled cutting tool. The first part of the paper offers a useful instrument for cutting tools designers and engineers working in cutting domain.

Key words: cutting tool, geometry, indexable insert.

1. Introduction

As is known, the geometry of a cutting tool fitted with indexable inserts or inserted blades is the result of orientation of insert or blade in relation with the tool holder (Arshinov, 1976), (Boothroyd, 1989), (Stephenson, 1996). The shape and the constructive geometry of the insert is resulting through a sintering process and sometimes one of abrasion, as it can be seen in Fig. 1 (Sandvik, 2011). The direct problem of the simple shaped inserts, i. e. the geometry of the cutting tool resulted from their orientation jn relation to the tool holder (tool body) is already solved (Croitoru *et al.*, 1996). Sintering technology development currently allows the final shape of the insert to be more complex,

* Corresponding author; *email*: ccroitoru@tuiasi.ro

as it can be seen in Fig. 1 (Iscar, 2000). As a result the previous theory (Croitoru *et al.*, 1996) became insufficient to solve the direct problem.

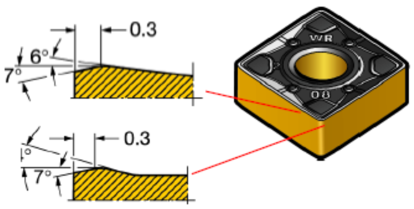

Fig. 1– Simple shaped insert (Sandvik, 2011).

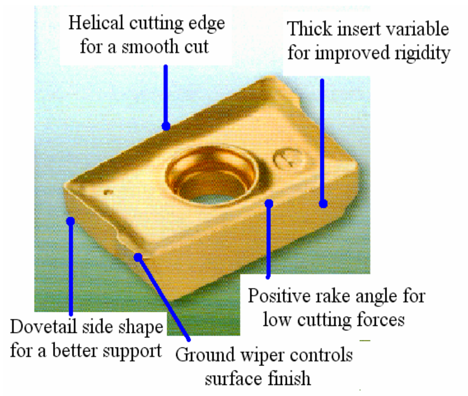

Fig. 2– Complex shaped insert (Iscar, 2000).

2. Insert and Tool Geometry

Considering an indexable insert illustrated in Fig. 2, the following independent parameters can be defined, as against the coordinate system $Vx_{pc}y_{pc}z_{pc}$, according to Fig. 3:

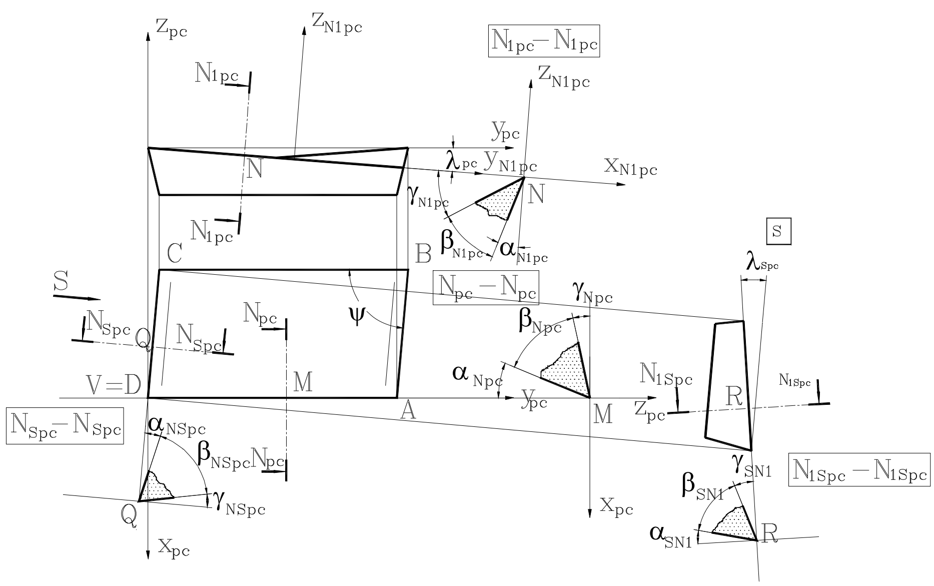

Fig.3 – The independent parameters of a shaped complex insert.

a) insert normal rake angle γ_{Npc} (> 0°), insert norme angle α_{Npc}, insert normal wedge angle β_{Npc}, measured in N_{pc}- N_{pc} plane, normal to the main apparent cutting edge, linked together by relationship:

$$\alpha_{NPc} + \gamma_{Npc} + \beta_{Npc} = \frac{\pi}{2} \quad (1)$$

b) insert main cutting edge inclination, λ_{pc};
c) γ_{Nspc}, α_{Nspc}, β_{Nspc}, measured in the N_{spc}- N_{spc} plane, normal to the main apparent cutting edge, linked by relationship (2);

$$\alpha_{NsPc} + \gamma_{Nspc} + \beta_{Nspc} = \frac{\pi}{2} \quad (2)$$

d) insert minor cutting edge inclination, λ_{spc}.

For the main insert cutting edge may be also defined the angles γ_{N1pc}, α_{N1pc}, β_{N1pc}, în the plane N_{1pc}- N_{1pc}, perpendicular to the real main cutting edge *VA* (see Fig. 3). The links between the insert main cutting edge angles are described by eqs. (3), (4) and (5) (Croitoru, 2005):

$$\mathrm{tg}\,\gamma_{N1pc} = \mathrm{tg}\,\gamma_{Npc} \cdot \cos\lambda_{pc} \quad (3)$$

$$\mathrm{cotg}\,\alpha_{N1pc} = \mathrm{cot}\,g\,\alpha_{Npc} \cdot \cos\lambda_{pc} \quad (4)$$

$$\alpha_{N1Pc} + \gamma_{N1pc} + \beta_{N1pc} = \frac{\pi}{2} \quad (5)$$

The location of the insert in the tool holder (body) is achieved by means of a recess practiced in the body that restricts all the six degrees of freedom of the exchangeable element.

The recess location is identified as against the coordinate system *Vxyz* by means of following parameters (see Fig. 4):

a) K_c, having the same size with the main cutting angle K of the assembled cutting tool, measured in the tool reference plan;

b) recess normal rake angle γ_{Nc}, insert normal rake angle γ_{Npc} (> 0°), measured in the plane perpendicular to the main apparent cutting edge of the assembled cutting tool;

c) recess inclination angle λ_c, measured in the tangential plane T of the cutting tool.

As a result of the orientation of the insert to the tool holder, the geometry of the assembled cutting tool may be defined by the following parameters (see fig. 4):

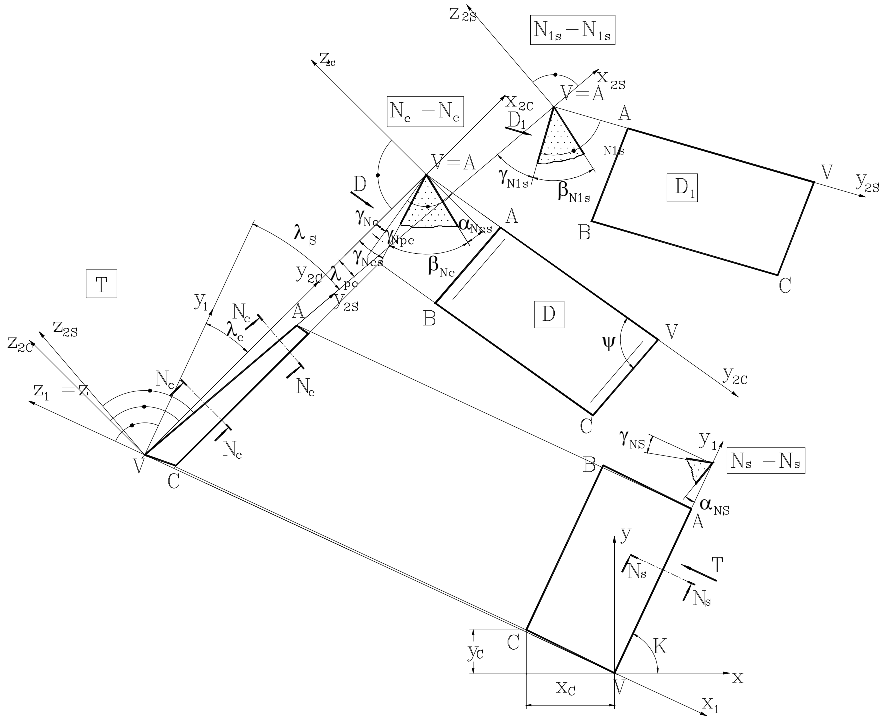

Fig.4 − The independent parameters of a shaped complex insert.

a) tool normal clearance angle α_{Ns} and tool normal rake angle γ_{Ns}, measured in the plane normal to the main apparent cutting edge (see section N_s- N_s);

b) main cutting angle K and minor cutting angle K' measured in the tool reference tool;

c) tool main cutting edge inclination λ_s, measured in the T plane of the assembled cutting tool;

d) α_{N1s}, tool normal clearance angle and γ_{N1s}, tool normal rake angle measured in the plane normal to the real main cutting edge of the assembled cutting tool (see section N_{1s}- N_{1s});

Given the way of defining, it follows that the angles measured in the sections N_s- N_s.şi N_{1s}- N_{1s} are connected through the following relations:

$$\mathrm{tg}\,\gamma_{N1s} = \mathrm{tg}\,\gamma_{Ns} \cdot \cos\lambda_s \tag{6}$$

$$\mathrm{cotg}\,\alpha_{N1s} = \cot g\,\alpha_{Ns} \cdot \cos\lambda_s \tag{7}$$

Solving the direct problem of these tools is finding the relationships between assembled cutting tool angles (K', α_{Ns}, γ_{Ns}, β_{Ns}, λ_s), insert angles (α_{Npc}, γ_{Npc}, β_{Npc}, λ_{pc}) and those of the recess (K_c, γ_{Nc}, λ_c).

The direct problem of these tools may be summed up as following: considering as known the constructive geometry of the insert presented in fig. 3 (α_{Npc}, γ_{Npc}, β_{Npc}, λ_{pc}), the recess orientation formed in the tool holder (K_c, γ_{Nc}, λ_c), the geometry of the assembled tool (K', α_{Ns}, γ_{Ns}, β_{Ns}, λ_s) must be determined.

3. The Minor Cutting Angle Expression *K'* of the Assembled Tool

Consider a parallelogram shaped insert presented in Fig.1, characterized by parameters (α_{Npc}, γ_{Npc}, β_{Npc}, λ_{pc}), located in the tool holder by means of a recess having the parameters K_c, $\gamma_{Nc}>0°$, $\lambda_c>0°$ (see *T* view from Fig. 4).

The following Cartesian coordinate systems are also defined;

a) $Vxyz$ system oriented as shown in Fig. 4 having Vx axis oriented along the feed movement, Vz axis oriented in the direction of main movement of the cutting, and Vy axis completes the Cartesian system;

b) $Vx_1y_1z_1$ system is defined in the main view of Fig. 4 and is oriented with Vy_1 axis along the main apparent cutting edge of the assembled tool; this system is rotated as against $Vxyz$ system around Vz axis ($\equiv Vz_1$) with angle $-\left(\frac{\pi}{2}-K\right)$;

c) $Vx_{2C}y_{2C}z_{2C}$ system is defined in the *T* view of Fig. 4. Its axis Vx_{2C} parallel to Vx_1 axis of the $Vx_1y_1z_1$ system ($Vx_{2C}\equiv Vx_1$), and Vy_{2C} axis oriented along the edge of the recess; this system is rotated as against $Vx_1y_1z_1$ system around Vx_1 axis with the angle - λ_c.

Note that in the *D* view of Fig. 4 (perpendicular to the base of the recess formed in the tool holder) can be found the real size dimensions of the insert, respectively *a, b* and angle Ψ.

Starting from this observation, the coordinates of the *C* point as against the $Vx_{2C}y_{2C}z_{2C}$ coordinate system are given by eqs. (8):

$$\begin{cases} x_{2cC} = -a\cdot\sin\psi\cdot\cos\gamma_{Nc} \\ y_{2cC} = a\cdot\cos\psi \\ z_{2cC} = -a\cdot\sin\psi\cdot\sin\left|\gamma_{Nc}\right| \end{cases}, \tag{8}$$

which are also the projections of the position vector X_{2C} on the previously considered system (9):

$$X_{2C} = \begin{bmatrix} x_{2C} \\ y_{2C} \\ z_{2C} \end{bmatrix} \tag{9}$$

The coordinate transformation from $Vx_{2C}y_{2C}z_{2C}$ to $Vx_1y_1z_1$ system may be written as:

$$X_1 = L_{21} X_{2C1}, \tag{10}$$

where:

$$L_{21} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\lambda_c & -\sin|\lambda_c| \\ 0 & \sin|\lambda_c| & \cos\lambda_c \end{bmatrix} \tag{11}$$

The coordinate transformation from $Vx_1y_1z_1$ in $Vxyz$ system is accomplished through eq. (12):

$$X = L_{10} X_1, \tag{12}$$

where:

$$L_{10} = \begin{bmatrix} \sin K & \cos K & 0 \\ -\cos K & \sin K & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{13}$$

Therefore the coordinate system transformation from $Vx_{2C}y_{2C}z_{2C}$ to $Vxyz$ system is accomplished in two stages, first by rotating around Vx_{2C} axis ($\equiv Vx_1$), with "$-\lambda$", angle, then around Vz_1 axis ($\equiv Vz$) with "$\frac{\pi}{2} - K$" angle by means of eq. (14):

$$X = L_{20} X_2, \tag{14}$$

where:

$$L_{20} = L_{10} L_{21}. \tag{15}$$

After making these transformations, the C point coordinates of the $VABCD$ insert as against $Vxyz$ system are given by the eqs. (16):

$$\begin{cases} x_C = -a \cdot \sin\Psi \cdot \cos\gamma_{Nc} \cdot \sin K + a \cdot \cos K(\cos\psi \cdot \cos\lambda_c - \sin\psi \cdot \sin|\gamma_{Nc}| \cdot \sin|\lambda_c|) \\ y_C = a \cdot \sin\psi \cdot \cos\gamma_{Nc} \cdot \cos K + a \cdot \sin K(\cos\psi \cdot \cos\lambda - \sin\psi \cdot \sin|\gamma_{Nc}| \cdot \sin|\lambda_c|) \\ z_C = a \cdot \cos\psi \cdot \sin|\lambda_c| - a \cdot \sin\psi \cdot \sin|\gamma_{Nc}| \cdot \cos\lambda_c \end{cases} \tag{16}$$

In the main view of Fig. 4 it can be written:

$$tgK' = -\frac{y_C}{x_C}, \tag{17}$$

in which, after replacing the eq.(16), results:

$$tgK' = \frac{\sin\psi \cdot \cos\gamma_{Nc} \cdot \cos K + \sin K(\cos\psi \cdot \cos\lambda_c - \sin\left|\gamma_{Nc}\right| \cdot \sin\left|\lambda_c\right|}{\sin\psi \cdot \cos\gamma_{Nc} \cdot \sin K - \cos K(\cos\psi \cdot \cos\lambda_c - \sin\psi \cdot \sin\left|\gamma_{Nc}\right| \cdot \sin\left|\lambda_c\right|}. \tag{18}$$

4. The Tool Main Cutting Inclination Expression λ_S

From the view T of the tool cutting edge of figure 4 it can be written:

$$\lambda_s = \lambda_c + \lambda_{pc}, \tag{19}$$

in which is emphasized that these angles can receive both positive and negative values.

5. The Angles of Assembled Cutting Tool Expressions

According to section N_c- N_c from Fig. 4 it can be written:

$$\gamma_{Nc} + \gamma_{Npc} + \beta_{Nc} + \alpha_{Ncs} = \frac{\pi}{2}, \tag{20}$$

in which it can be noted:

$$\gamma_{Nc} + \gamma_{Npc} = \gamma_{Ncs}, \tag{21}$$

which leads to the conclusion:

$$\gamma_{Ncs} + \beta_{Nc} + \alpha_{Ncs} = \frac{\pi}{2}. \tag{22}$$

Comparing the views N_c- N_c from Fig. 4 and N_{pc}- N_{pc} from Fig. 3, it can be observed that both sectioning planes are identical, which leads to the conclusion:

$$\beta_{Nc} = \beta_{Npc} = \frac{\pi}{2} - \alpha_{Npc} - \gamma_{Npc}. \tag{23}$$

After substitution of eq. (23) into eq. (20) and considering eq. (21), it follows:

$$\alpha_{Ncs} = \alpha_{Npc} - \gamma_{Nc} . \tag{24}$$

Given the relative position of the planes of section N_s- N_s and N_c- N_c, the following relations may be deduced between the angles measured in these planes:

$$\mathrm{tg}\,\gamma_{Ncs} = \mathrm{tg}\,\gamma_{Ns} \cdot \cos\lambda_c , \tag{25}$$

$$\mathrm{cotg}\,\alpha_{Ncs} = \mathrm{cotg}\,\alpha_{Ns} \cdot \cos\lambda_c , \tag{26}$$

hence:

$$\mathrm{tg}\,\gamma_{Ns} = \frac{\mathrm{tg}\,\gamma_{Ncs}}{\cos\lambda_{\mathrm{c}}} , \tag{27}$$

$$\mathrm{tg}\,\alpha_{Ns} = \mathrm{tg}\,\alpha_{Ncs} \cdot \cos\lambda_c , \tag{28}$$

where γ_{Ncs} is given by eq. (21) and α_{Ncs}, by eq. (24).

Given the relative position of the planes of section N_s- N_s and N_{1s}- N_{1s} the next relations result between the measured angles in these planes:

$$\mathrm{tg}\,\gamma_{N1s} = \mathrm{tg}\,\gamma_{Ns} \cdot \cos\lambda_s , \tag{29}$$

$$\mathrm{cotg}\,\alpha_{N1s} = \mathrm{cotg}\,\alpha_{Ns} \cdot \cos\lambda_s , \tag{30}$$

or taking into account relations (27) and (28):

$$\mathrm{tg}\,\gamma_{N1s} = \frac{\mathrm{tg}\,\gamma_{Ncs}}{\cos\lambda_{\mathrm{c}}} \cdot \cos\lambda_s , \tag{31}$$

$$\mathrm{tg}\,\alpha_{N1s} = \frac{\cos\lambda_s}{\cos\lambda_{\mathrm{c}}} \cdot \mathrm{cotg}\,\alpha_{Ncs} , \tag{32}$$

where λ_s is given by eq. (19).

6. Verification of Deduced Equations

Is considered a case of a simple square insert presented in Fig. 5, characterized by angles $\Psi = 90°$, $\lambda_{pc} = 0°$, $\alpha_{Npc} = 0°$, $\gamma_{Npc} = 0°$.

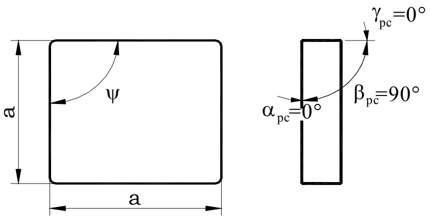

Fig. 5 – Simple square shaped insert.

From eqs. (19), (21) and (24), the successive results are:

$\lambda_s = \lambda_c$; $\gamma_{Nc} = \gamma_{Ncs}$; $\alpha_{Ncs} = -\gamma_{Nc}$,

which substituted in eq. (18) leads to the conclusion:

$$tgK' = \frac{\cos\gamma_{Nc}\cdot\cos K - \sin K\cdot\sin|\gamma_{Nc}|\cdot\sin|\lambda_c|}{\cos\gamma_{Nc}\cdot\sin K - \cos K\cdot\cos\lambda_c + \sin|\gamma_{Nc}|\cdot\sin|\lambda_c|},$$

similar to equation (18) of (Croitoru *et al*., 1996).

After using the same values in eq. (39), it results that:

$$\mathrm{tg}\,\gamma_{N1s} = tg\gamma_{Ncs}\cdot\cos\lambda_c,$$

an equation that is inferred by (Croitoru, 2005).

4. Conclusions

1. The presented case may be interpreted as a generalization of existing theories; the deduced equations may be used in the case of new form of inserts.

2. The deduced equations may be used in the implementation of new tools, which involves both the use of existing inserts but also in the case of inserts with new configuration.

REFERENCES

Arshinov V., Alekseev G., *Metal Cutting Theory and Cutting Tool Design*, Mir. Publishers, 1976.

Boothroyd G., Knight W. A., , *Fundamentals of Machining and Machine Tools,* Marcel Dekker Inc., New York and Basel, 1989..

Stephenson A. D., Agapiou J.S., *Metal Cutting Theory and Practice,* Ed. Marcel Dekker, New York, 1996.

Croitoru C., Severincu M., Dumitraş C., *Particularités de la géométrie des outils équipés de plaquettes indexables,* Buletinul I. P. Iaşi, **XLII (XLVI)**, *1 - 2*, Construcţii de maşini, 101-108 (1996).
Croitoru C., *Scule pentru aşchiere în mecanica fină,* Editura Performantica, Iaşi, 2005.
*** *Metal Cutting Technical Guide, Handbook from Sandvik Coromant*, Sandvik Coromant, 2011.
*** *ISCAR MILL PLUS,* Iscar catalog, 2000.

O NOUĂ ABORDARE A SCULELOR ARMATE
CU PLĂCUŢE AŞCHIETOARE SCHIMBABILE

I. Abordare teoretică

(Rezumat)

Lucrarea prezintă o nouă abordare a problemei geometriei sculelor aşchietoare armate cu plăcuţe aşchietoare schimbabile. Având în vedere formele complicate ale unor plăcuţe schimbabile de ultimă generaţie se deduce că teoria existentă pentru deducerea parametrilor geometrici necesari caracterizării acestor scule este ineficientă. Pornind de la parametrii geometrici care caracterizează plăcuţele aşchietoare şi parametrii corpului sculei se deduce geometria sculelor asamblate. Noile relaţii sunt verificate prin comparare cu fondul bibliografic existent. Prin acestă lucrare se realizează un instrument de lucru util atât pentru studiul sculelor aşchietoare existente, cât şi pentru eventuale scule ce urmează a fi dezvoltate ulterior. Acest instrument de lucru poate fi util atât pentru proiectanţii de scule noi, cât şi pentru tehnologii care proiectează tehnologii de prelucrare prin aşchiere.