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MODELING THE FRONTAL TILT ANGLES AND SIDEWAYS IN THE MILLING PROCESS WITH SPHERICAL HEAD USING A 3D GRAPHICS PROGRAM

BY

OVIDIU TOADER RUSU*[1], OCTAVIAN LUPESCU[2] and ADRIAN CIPRIAN BĂLAN[2]

[1]University “Ştefan cel Mare” of Suceava,
Department of Mechanics and Technologies
[2]“Gheorghe Asachi” Technical University of Iaşi,
Department of Machine Manufacturing Technology

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Abstract. Milling process with spherical head is widely used in aeronautical industry for machining of complex shapes and in manufacturing industry for machining complex surfaces of dies and moulds. One reason except the capability of machining more complex surfaces is the possibility to cut material with a tool having the axe different than the normal direction to surface. In this way we can avoid zero cut speed at tool tip and ensure prediction of the cutting tool life and the machined surface higher quality. There are simple relations used to calculate tilt angle frontal and sideways, but for study the effect of these parameters associated to machined surface quality we need a more complex model. Using a 3D CAD software we can find the value and the real position of the contact area between cutting tool and the machined surface material. In same time we get the radius of the point on the cutting edge with the maximum rotational speed, related to the axial depth of cut and tilt angles frontal and sideways.

Key words: tilt; lead; ball end milling.

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*Corresponding author; *e-mail*: rusu.o@fim.usv.ro

1. Introduction

For a milling cutting process with SPHERICAL HEAD using a 3D CAD software, generated model for different frontal tilt angles are presented in Figs. 1,…,6.

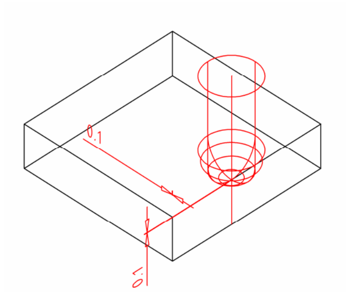

Fig. 1 − 3D CAD model with zero tilt and lead.

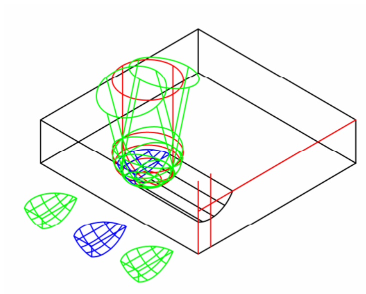

Fig. 2 − Ball end milling with tilt angle (uncut chip).

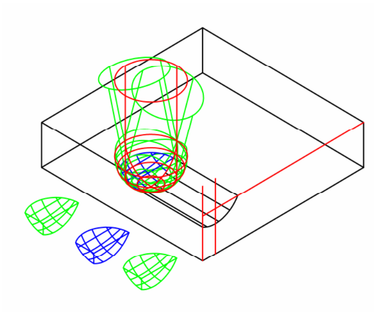

Fig. 3 − Ball end milling with lead angle (uncut chip).

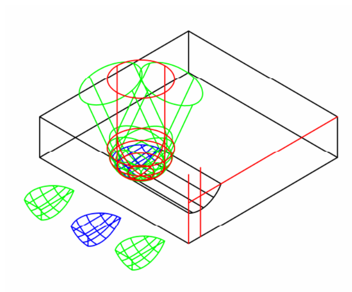

Fig. 4 – Ball end milling with tilt and lead angle (uncut chip).

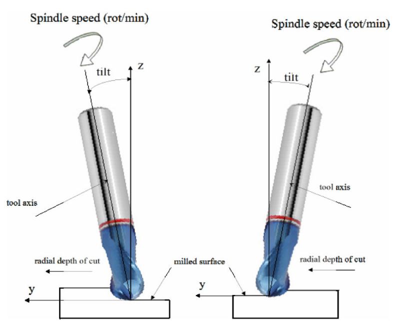

Fig. 5 – Positive and negative tool tilt angle.

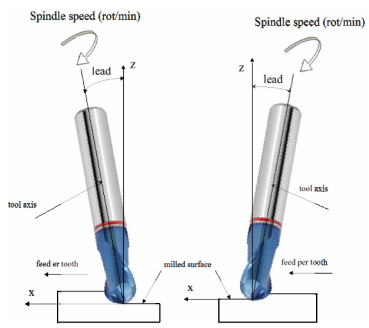

Fig. 6 – Positive and negative tool lead angle.

As we see in Figs. 2,…,4, for different tilt and lead angles uncut chip volume is identical, for identical axial depth of cut and feed per tooth. In 3D modelling uncut chip area doesn't depend on technological parameters such as: spindle speed, cutting direction (up or down milling), lead and tilt tool angles.

Instead changing tool lead and tilt angle will vary entrance and exit angles in cutting zone related to axial position of point on the cutting edge. As is known due to changing value of lag angle with the axial depth of cut not all the points on the cutting edge will enter in cutting zone at the same time. Related to tool axis points on the cutting edge with same elevation on tool axis, have different cutting speeds for different lead and tilt angles (Yamada *et al.*, 2007; Ozturk *et al.*, 2009).

2. Radius and Speed for Points on the Cutting Edge

A change of position radius of different points on cutting edge for milling with constant feed per tooth and constant radial and axial depth of cut is presented in Figs. 7,…,13 (axial depth of cut = 0.5 mm, cutting tool radius = 8 mm, tilt (left/right) = (-15°…+15°), lead (front/back) = (-15°…+15°) and cumulated in Fig. 14:

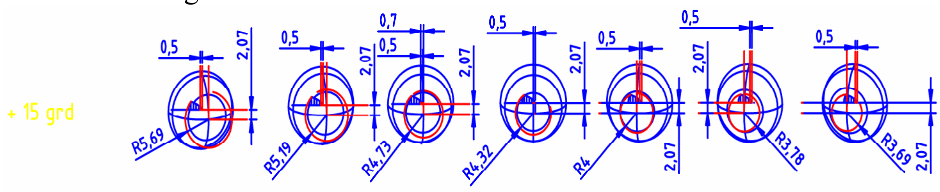

Fig. 7 – Lead angle front 15°, tilt (left/right = -15°,-10°,-5°, 0°, +5°, +10°, +15°).

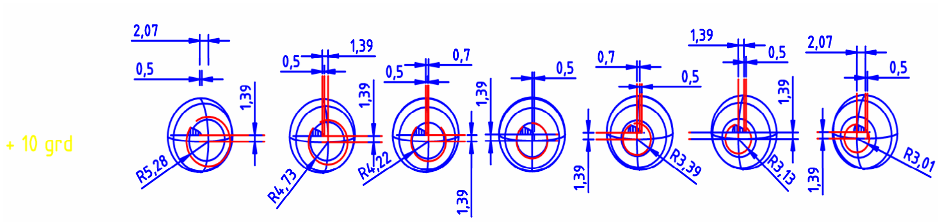

Fig. 8 – Lead angle front 10°, tilt (left/right = -15°,-10°,-5°, 0°, +5°, +10°, +15°).

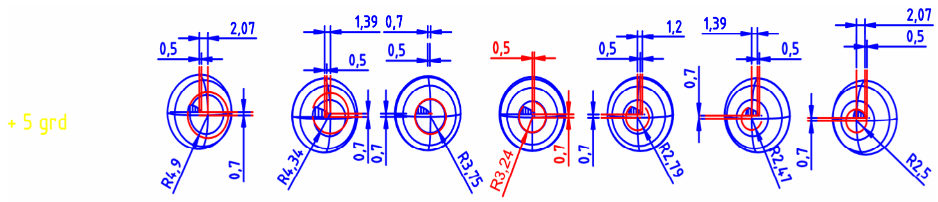

Fig. 9 – Lead angle front 5°, tilt (left/right = -15°, -10°, -5°, 0°, +5°, +10°, +15°).

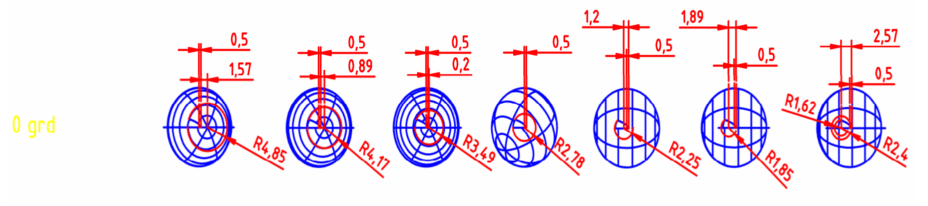

Fig. 10 – Lead angle = 0°, tilt (left/right = -15°, -10°, -5°, 0°, +5°, +10°, +15°).

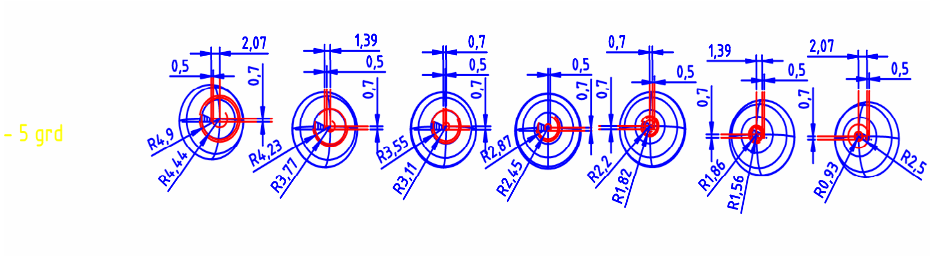

Fig. 11 – Lead angle back -5°, tilt (left/right = -15°,-10°,-5°, 0°, +5°, +10°, +15°).

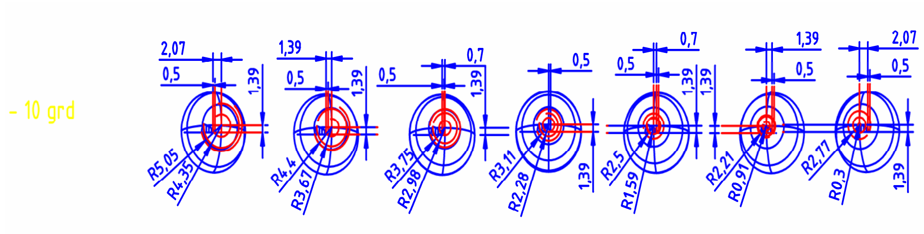

Fig. 12 – Lead angle back -10°, tilt (left/right = -15°, -10°, -5°, 0°, +5°, +10°, +15°).

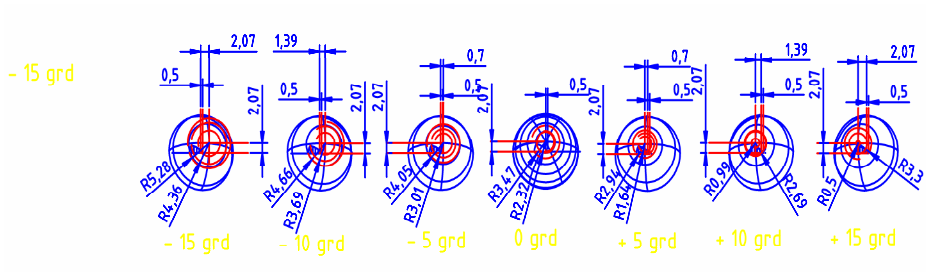

Fig. 13 – Lead angle back -15°, tilt (left/right = -15°, -10°, -5°, 0°, +5°, +10°, +15°).

For a point A on the cutting edge with elevation related to tool tip $z_A = a_p$, $n\ (rot/\min)$, $\omega\ (rad/s)$, $AD = diameter\ of\ tool\ for\ z_A (mm)$, $R_b = ball\ radius$ we define cutting speed with relation (1):

$$V_A = V_D = \omega \cdot \frac{AD}{2} = \frac{\pi \cdot n}{30} \cdot \frac{AD}{2} = \\ = \frac{\pi \cdot n}{30} \cdot R_b \sin\left[a\cos\left(1 - \frac{a_p}{R_b}\right)\right] \cdot \frac{1}{1000} \left(\frac{m}{s}\right) \tag{1}$$

If we rotate tool axis related to tool tip with lead (l) or tilt (t) angle radius for point A turn into AE (from AD/2) and cutting speed for point A is given by relation (2).

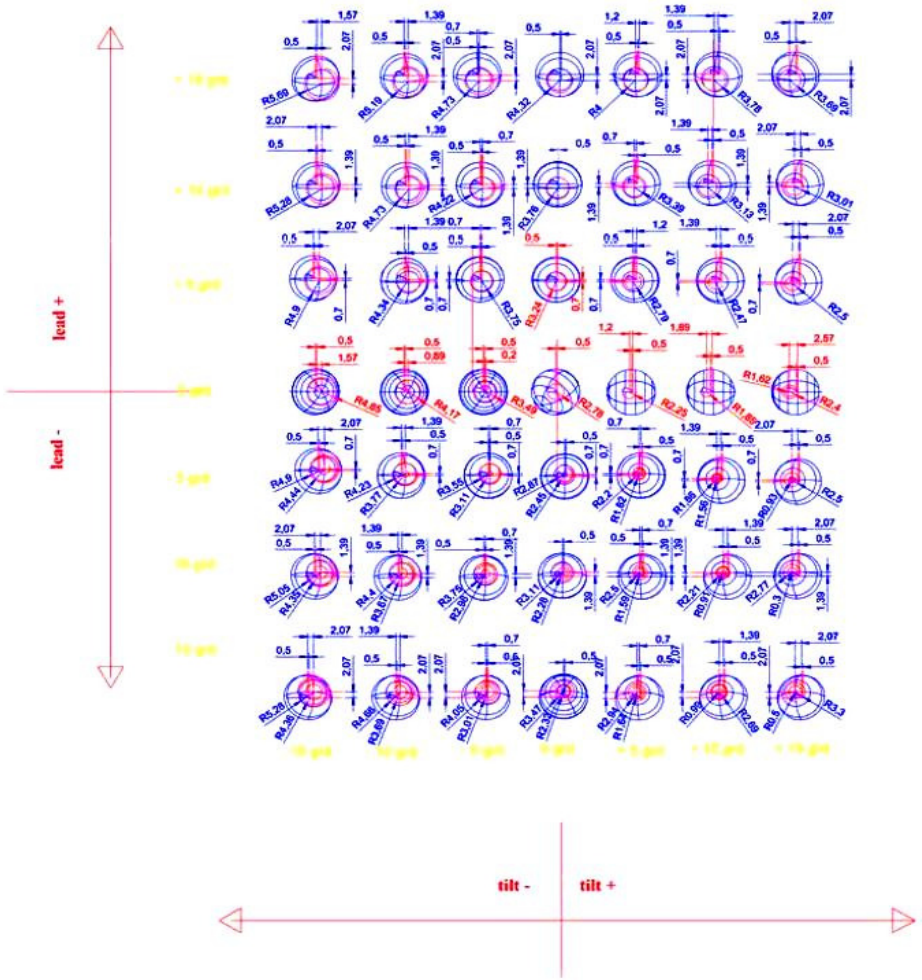

Fig. 14 − Changing of position radius for axial depth of cut = 0.5 mm, cutting tool radius = 8 mm, tool tilt (left/right) = (-15°…+15°), lead (front/back) = (-5°…+15°).

$$AE = R_b \cdot \cos\left[90 - (\kappa + l)\right] = R_b \cdot \sin(\kappa + l) \quad (l)\ or\ (t)$$

$$V_A = \omega \cdot AE = \frac{\pi \cdot n}{30} \cdot R_b \cdot \sin\left(a\cos\left(1 - \frac{a_p}{R_b}\right) + l\right) \cdot \frac{1}{1000} \tag{2}$$

$$where\ \kappa\ is\ immersion\ angle\left(\sin\kappa = \frac{AD}{2 \cdot R_b}\right)$$

Relation (2) with values obtained from Fig. 14 can be used to calculate real cutting speed for points on the cutting edge at different tilt and lead angles of tool axis.

3. Conclusions

1) Related to tool tip as we change tools angles:

− lead from 0^o to $+15^o$ in feed per tooth direction, radius of extreme point on the cutting edge increase from 2.78 mm to 4.32 mm;

− lead from 0^o to -15^o opposite to feed per tooth, direction radius of extreme point on the cutting edge decrease from 2.78 mm to 2.32mm.

Geometrically is recommended to change tool angle in feed per tooth direction (front):

− tilt from 0^o to $+15^o$ in radial depth of cut, radius of extreme point on the cutting edge decrease from 2.78 mm to 2.4 mm;

− tilt from 0^o to -15^o opposite from radial depth of cut, radius of extreme point on the cutting edge increase from 2.78 mm to 4.85 mm.

Geometrically is recommended to change tool angle opposite from radial depth of cut direction (left).

2) Analyzing extreme position of cutting area for feed per tooth from -15^o to $+15^o$ and for radial depth of cut from -15^o to $+15^o$ we have graphical presentation in Fig. 15:

$$\left.\begin{matrix} front\,15^o \\ left\,15^o \end{matrix}\right\} R = 5{,}69\,mm \qquad \left.\begin{matrix} front\,15^o \\ right\,15^o \end{matrix}\right\} R = 3{,}69\,mm$$

$$\left.\begin{matrix} front/back\,0^o \\ left/right\,0^o \end{matrix}\right\} R = 2{,}78\,mm$$

$$\left.\begin{matrix} back\,15^o \\ left\,15^o \end{matrix}\right\} R = 5{,}28\,mm \qquad \left.\begin{matrix} back\,15^o \\ right\,15^o \end{matrix}\right\} R = 3{,}30\,mm$$

Fig. 15 − Radial position of a point on the cutting tool edge for different lead and tilt angles.

So strictly from geometrical point of view is recommended to increase cutting speed by changing tool angle forward and left.

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MODELAREA UNGHIURILOR DE ÎNCLINARE FRONTALĂ ŞI LATERALĂ ÎN PROCESUL DE FREZARE CU FREZĂ CU CAP SFERIC FOLOSIND UN PROGRAM DE GRAFICĂ 3D

(Rezumat)

În timpul experimentelor la frezarea cu freză cu cap sferic pe maşinile cu trei axe s-a observat, pentru regimuri de aşchiere normale, o diminuare drastică a durabilității sculei şi o uzură până la dispariție, a stratului de protecție depus, la vârful sculei. Acestea sunt datorate efectului de viteză nulă de la vârful sculei cu transformarea fenomenului de aşchiere în frecare de alunecare. Scopul studiului constă în creşterea durabilității sculei prin înclinarea acesteia şi implicit studiul efectului parametrului înclinare asupra îmbunătățirii calității suprafeței prelucrate. S-a demonstrat strict geometric folosind un program 3D că este recomandat să înclinăm scula în sensul avansului şi înspre stânga pentru a creşte viteza de aşchiere.

Ne propunem să verificăm rezultatele toretice cu cele obținute concret în practică folosind un plan de experiențe.