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# EXPERIMENTAL EXAMINATIONS OF THE FLOW DIRECTION ANGLE AND THE CHIP BURST ANGLE AS FUNCTION OF METAL CUTTING TOOL GEOMETRY

**Abstract:** *The paper presents the results of experimental measurements of the flow direction angle and the chip burst angle as a function of the basic parameters of tool geometry - $\lambda$, $\gamma$, $\kappa$ and r. The materials examined were duraluminum, bronze, brass and grey iron. A direct method of measuring the chip flow angle (photo-method) has been used. The obtained results have been processed and shown on diagrams with appropriate comments.*

**Key words:** metal cutting, chip burst angle, tool geometry

## 1. INTRODUCTION

Observing the cutting process in a large number of brittle materials during production, as well as a series of experiments, show that the burst angle and chip flow direction depend on numerous factors. The following factors should be taken into account: the type of processing (milling, drilling, grinding etc.), physical and mechanical properties of the work-piece material, cutting data, tool geometry parameters and others.

There is little research about the chip burst and the influence of certain factors in the cutting process on the flow direction angle. In the papers by Merchant, Rosenberg and Eremin [8], Zorev [13], J. Stanic [10] and others, there are certain elements of tool geometry. Also, some of them have provided analytical relations for calculating the chip flow angle in the horizontal or the rake (chest) surface, in which some of the parameters of tool geometry are present.

The author of this paper carried out the experimental research at longitudinal chipping of duraliminium, brass, bronze and grey iron [3, 5, 6].

Cutting properties and geometry parameters of cutting tools have been adopted in accordance with the recommendations and on the basis of experience of brittle metal cutting in production.

The aim of the experiment was to determine:

1. Chip flow direction,
2. The influence of tool geometry parameters ($\lambda$, $\gamma$, $\kappa$, $r$) on the flow direction and the chip flow angle.

The results of this study should serve as a basis for determining the method and the manner of the most effective technical solution to the problem of continuous chip and dust removal from cutting tools.

## 2. APPLIED METHOD

To investigate the shape of chip flow and its direction of movement at longitudinal treatment of brittle materials on a lathe, a direct process of measuring the angles $\rho_{H}$., $\rho_F$ and $\rho_{P}$. was used. The process was recorded by a photo camera (photo-method). Chip flow direction was observed from three points (Fig. 1). The cutting tool was fixed to the right side of the holder, so that the chip could burst freely. Displays with measurement scales were attached to the cutting tool holder, or support, and they moved together during the treatment. Photo cameras were adjusted perpendicular to the screen at the moment of recording.

Photographic images of chip flow together with measuring scales help us accurately determine the geometric shape of chip flow and its position in space during brittle materials cutting (Fig. 2).

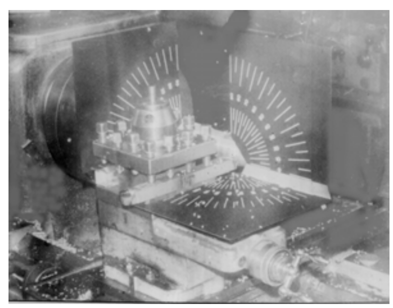
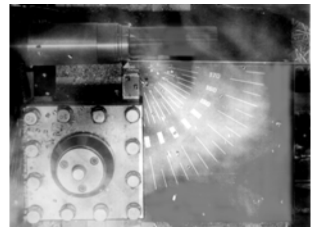


**Figure 1.**. *Chip flow angle registering and registering the chip burst angle at horizontal, frontal and profile plane – description of a work-place*

During this process, the angles of the beginning $\rho_i'$ and ending of chip bursting $\rho_i''$ (Fig.2) were defined, while the mean values, i.e. angles $\rho_H$, $\rho_F$ and $\rho_P$ were calculated afterwards (Fig.3). On the basis of the measured values, the diagrams for each variable were obtained (Fig. 4.1÷ 4.16).



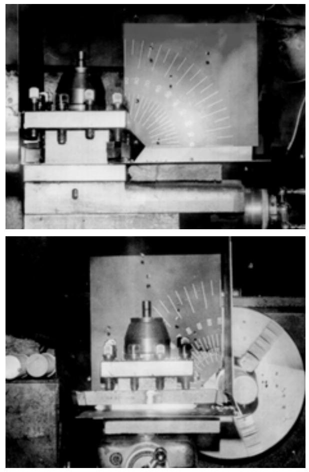


**Figure 2.** *Photographic images of chip flow at duraluminium treatment D5*

*a) at horizontal plane, b) at frontal plane, c) at profile plane*

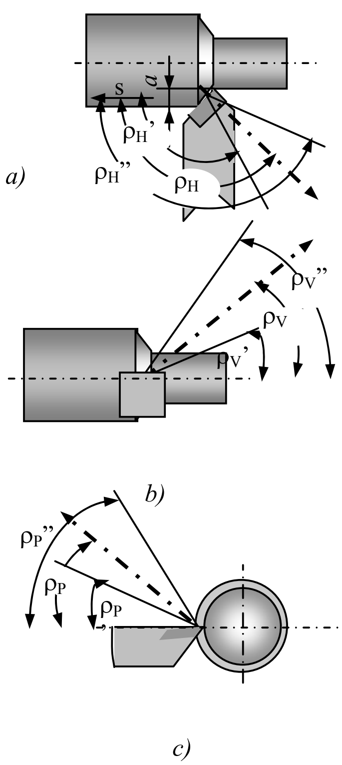



**Figure 3.** *Parameters which determine chip flow direction and angle of chip bursting according to M.Jovanović*

*a) at horizontal plane, b) at frontal plane, c) at profile plane*

## 3. EXPERIMENTAL CONDITIONS

Experimental tests (carried out by the author of this paper) were performed at longitudinal chipping of aluminum alloy D5 (duralumin of HB > 100 hardness), brass CuZn39Pb2 (duralumin of HB > 120 hardness), centrifuged bronze CuSn14 (hardness HB = 100) and grey iron SL 18 (hardness HB = 200). Diameter of work-piece was D = 50 mm for all tests*.

Brazed carbide tipped lathe tools (K10) were used in the experiments. The knives were sharpened by a diamond grinding disc under the same conditions, with the final fine rake surface grinding. The angular geometry varied and it included real cutting data [24].

Control of the angular geometry was carried out on a Mitutoyo coordinate measuring machine. The maximum deviation from the desired geometry of tools was $\pm 0{,}3\%$.

When conducting the experiment, the following parameters of angular tool geometry varied:

- $\lambda$ - blade inclination angle, from - $4^\circ \div 12^\circ$ at $4^\circ$
- $\kappa$. - angle of attack, from $30^\circ \div 90^\circ$ at $15^\circ$
- $\gamma$ - rake angle, from $0^\circ \div 12^\circ$ at $4^\circ$
- $r$ - radius of the rounded knife–edge, from 0,5÷3[mm].

Some experiments were repeated several times, and chips for further analysis of elementary particles were collected after each measurement.

After a series of previous tests and after determining the range of parameters, there were three independent measurements for each varied value. Mean values were calculated later, and they were used to create the diagrams (Fig.4.1÷ 4.16).

The experiments were conducted on a universal lathe ADA POTISJE PA P 631, in the factory of non-ferrous metals NISSAL in Niš, the pump factory "Jastrebac" FAM and MIN Niš (Metal Industry Nis).

Additional conditions of the experiment were given for each image.

## 4. MEASUREMENT RESULTS

Points on the graphs were obtained from the mean values of three independent measurements. A second-order polynomial was tunneled through the points:

$$y = A + Bx + Cx^2$$

Note: dependence of the chip burst angle:

$$\psi_i = \rho_i^{''} - \rho_i^{'} = f(v, s, a, \lambda, \kappa, \gamma, r)$$

- ● $\rho_H$,' - beginning of chip bursting in horizontal plane,
- ○ $\rho_H$, '' - ending of chip bursting in horizontal plane
- ● $\rho_F$,' - beginning of chip bursting in frontal plane,
- ▲ $\rho_F$, '' - ending of chip bursting in frontal plane,
- ○ $\rho_P$,' - beginning of chip bursting in profile plane,
- △ $\rho_P$, '' - ending of chip bursting in profile plane,

dependence of the chip flow direction angle:

$$\rho_i^{'} = f(v, s, a, \lambda, \kappa, \gamma, r)$$

- \+ $\rho_H$, - chip flow direction angle in horizontal plane,
- \+ $\rho_F$ - chip flow direction angle in frontal plane,
- x $\rho_P$ - chip flow direction angle in profile plane.

Measuring results were given in the following diagrams:

*Duraluminium sign is D5 which is Al Cu Mg Pb, according to DIN
Brass Cu Zn39Pb2 (JUS) is marked as MS 58, according to DIN
Bronze CuSn14 (JUS) is marked as G-Sn Bz14, according to DIN
Grey iron SL 18 is marked as GG-18, according to DIN

Dependence of the angle of chip bursting and chip flow angle on **blade inclination angle** at longitudinal processing ($\kappa$=45$^o$; $\gamma$=4$^o$; $\alpha$=8$^o$; r=0.5mm; v=208m/min; s=0.16mm/o and a=2mm):

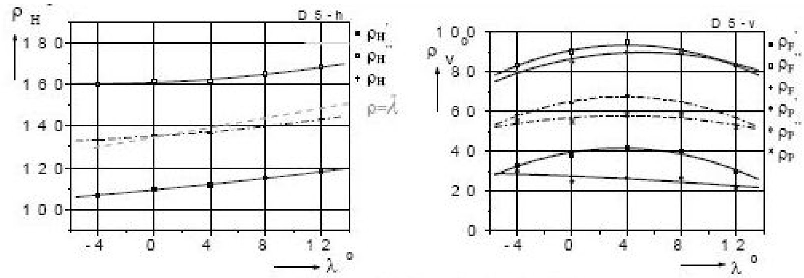



**Figure** *4.1. Duraluminium D5*

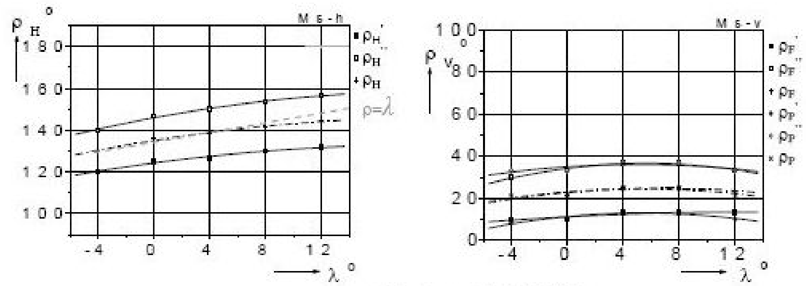



**Figure**.*4.2. Brass CuZn39Pb2*

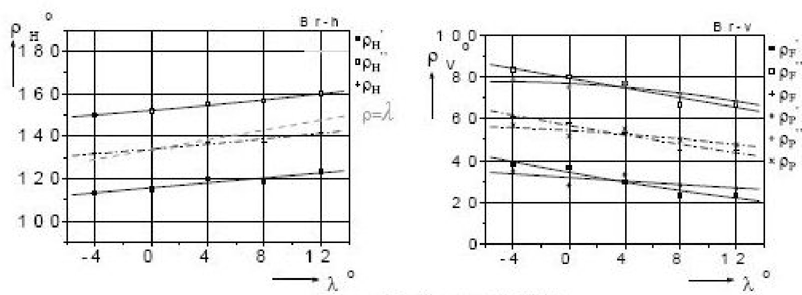



**Figure**.*4.3. Bronze CuSn14*

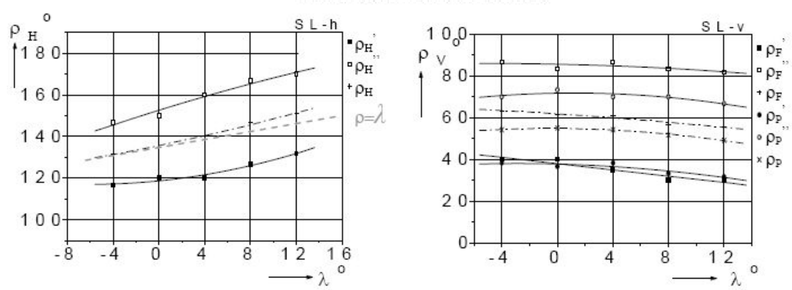



***Figure.*** *4.4. Grey iron SL 18*

Dependence of the angle of chip bursting and chip flow angle on **the angle of attack** at longitudinal processing ($\gamma$=4$^o$; $\lambda$=0$^o$; $\alpha$=8$^o$; r=0.5mm; v=208m/min; s=0.16mm/o and a=2mm):

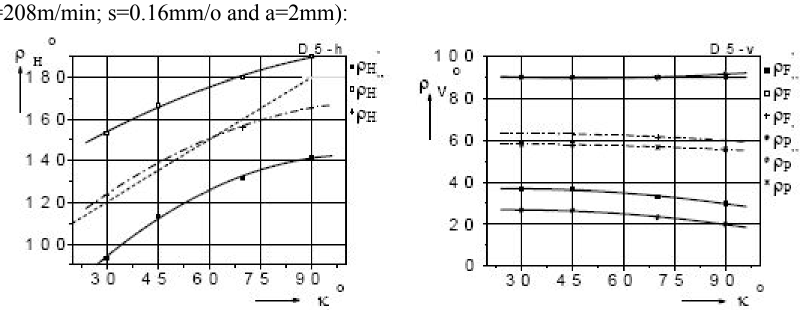



**Figure**.*4.5. Duraluminium D5*

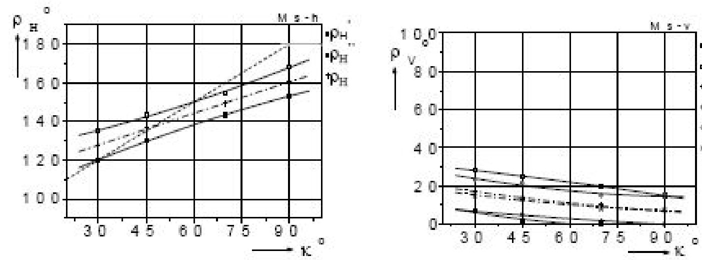



**Figure**.*4.6. Brass CuZn39Pb2*

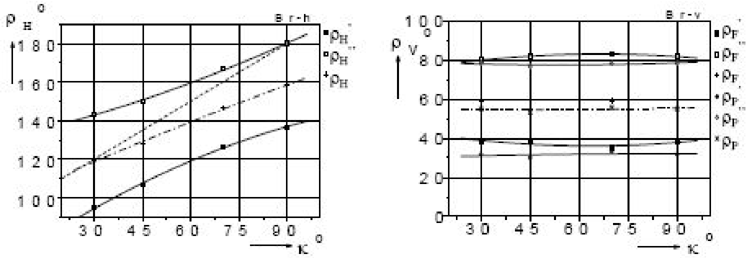



**Figure**.*4.7. Bronze CuSn14*

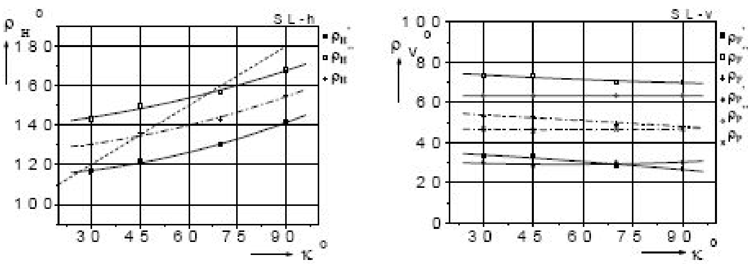



**Figure**.*4.8. Grey iron SL 18*

Dependence of the angle of chip bursting and chip flow angle o n **the rake angle** at longitudinal processing ($\kappa$=45°; $\lambda$=0°; $\alpha$=8°; r=0.5mm; v=208m/min;; v=208m/min; s=0.16mm/o i a=2mm):

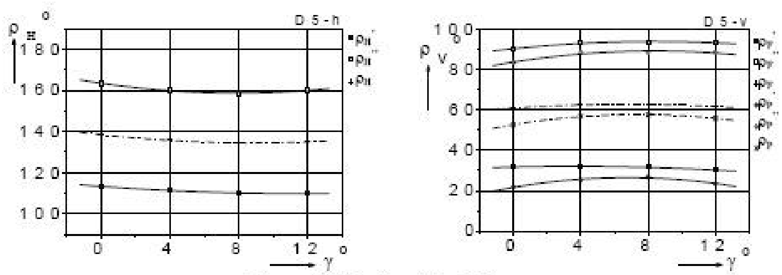



**Figure** *4.9. Duraluminium D5*

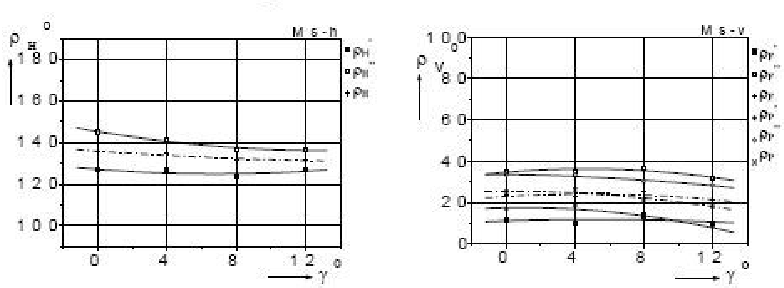



**Figure**.*4.10. Brass CuZn39Pb2*

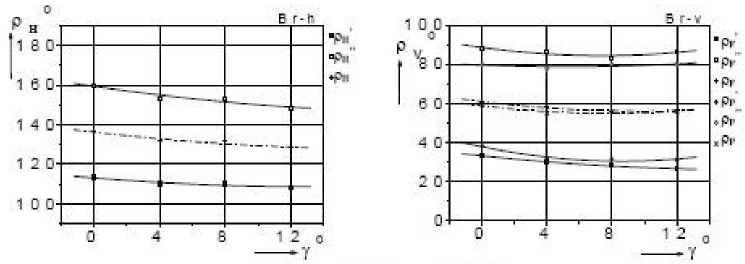


**Figure**.*4.11. Bronze CuSn14*

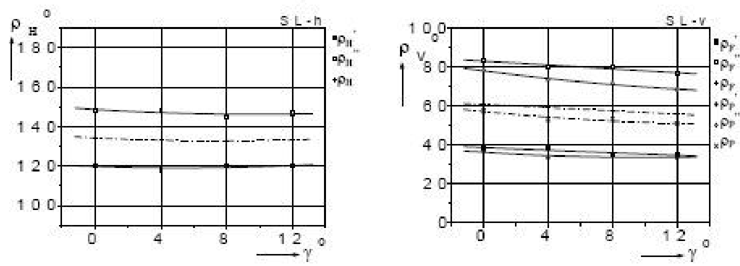


**Figure** *4.12. Grey iron SL 18*

Dependence of the angle of chip bursting and chip flow angle on **the rounded knife edge** at longitudinal processing ($\kappa$=45$^o$; $\gamma$=4$^o$; $\lambda$=0$^o$; $\alpha$=8$^o$; v=208m/min; s=0.16mm/o and a=2mm):

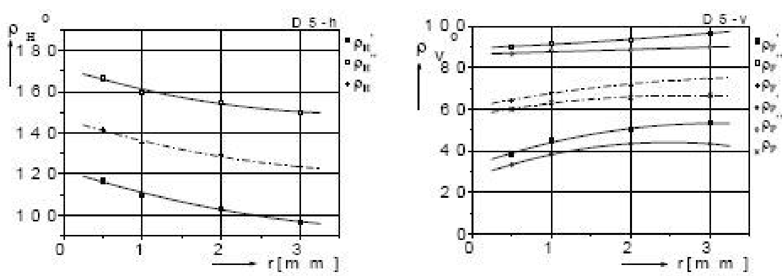


**Figure** *4.13. Duraluminium D5*

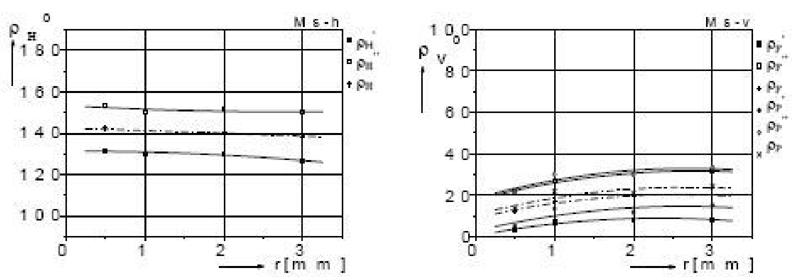


**Figure** *4.14. Brass CuZn39Pb2*

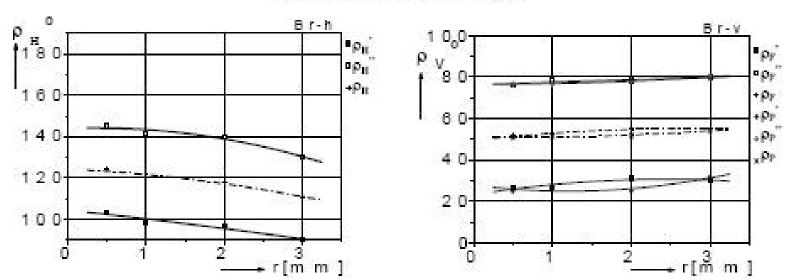


**Figure**.*4.15. Bronze CuSn14*

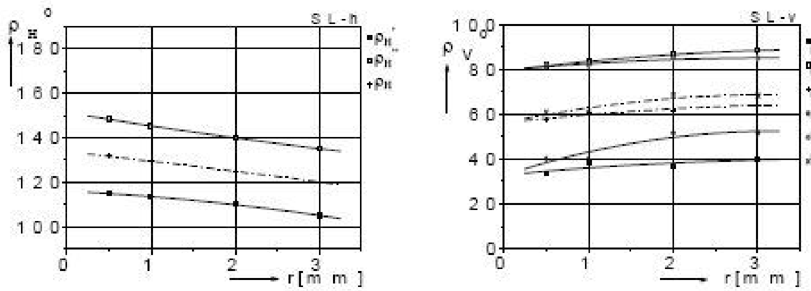



**Figure** *4.16. Grey iron SL 18*

## CONCLUSION

On the basis of these measurements, it can be concluded that the character of the change of chip flow direction and the chip burst angle under the influence of tool geometry parameters is generally the same for all tested materials.

Absolute values of measuring parameters generally differ (which is characteristic for the chip angle).

Therefore, the discussions about the results of measurements relate to all the materials which were treated, while certain characteristics will be pointed out separately.

These tests help us draw up certain general conclusions about the chip bursting .

1) Near the tools, we can see the influence of certain parameters of cutting mode and tool geometry on the chip flow direction and the burst angle.

2) The nature of the change of chip flow angle and burst angle in the function of various parameters of cutting mode and tool geometry is the same for the majority of examined materials.

3) During brass processing, chip flow direction can also be monitored at bigger distance from the cutting edges of tools (even at several meters away from the cutting edge). However, at duraluminium processing, and to some extent during bronze and grey iron processing, the observation of chip flow is meaningful only in the immediate vicinity of the tool (up to 10-15 cm of the tool blade).

4) The effect of environmental factors on the chip duralumin is far more pronounced.

5) Duralumin and brass generally retain the same form of elementary chip particles in all examinations (tubular-helical form), provided that the dimensions, and therefore the mass have been changed for different test conditions; the shape of brass and bronze have changed from the needles and lamells to tubular-shaped spiral.

6) The absolute value of the chip flow angle is primarily the characteristic of work-piece material.

The aim of these experimental researches is to provide complete information to the designers, with the aim to find the better and more efficient systems for continuous chip evacuation (trap receiver) during cutting of the brittle materials

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## ABBREVIATIONS

$r$ - radius of the rounded knife –edge
$s$ - cutting pitch
$v$ - cutting speed
$\alpha$ - clearance angle
$\beta$ - pin angle
$\gamma$ - rake angle
$\kappa$ - the angle od attacke og the main blade
$\lambda$ - blade inclination angle
$\rho$ - friction angle
$\rho_H$ - chip flow direction angle in horizontal plane
$\rho_F$ - chip flow direction angle in frontal plane
$\rho_P$ - chip flow direction angle in profile plane
$\rho_S$ - chip flow direction angle in chest (rake) plane (measured from normal plane to the blade )
$\rho_S'$ - chip flow direction angle in basic plane (measured from normal plane to the blade)
$\rho_H'$ - beginning of chip bursting in horizontal plane
$\rho_F'$ - beginning of chip bursting in frontal plane
$\rho_P'$ - beginning of chip bursting in profile plane
$\rho_H''$ - ending of chip bursting in horizontal plane
$\rho_F''$ - ending of chip bursting in frontal plane
$\rho_P''$ - ending of chip bursting in profile plane
$\rho_{sr}$ - resultant friction force direction at tool surface of the tool

## BIOGRAPHY

**Miodrag Jovanovic** was born in Bela Palanka, Serbia, in 1949. He is Associated Professor at Faculty of Occupational Safety, University of Niš. His main areas of research include Transportation Devices Safety, Machining, Engineering Graphics and Machinery Safety. He is employed at Faculty of Occupational Safety since 1978.

## EKSPERIMENTALNO UTVRĐIVANJE UGLA RASPROSTIRANJA STRUGOTINE U FUNKCIJI PARAMETARA GEOMETRIJE REZNOG ALATA

**Miodrag Jovanović**

**Rezime:** *U radu su predstavljeni rezultati eksperimentalnih merenja ugla pravca prostiranja i ugla rasprskavanja strugotine u funkciji osnovnih parametara geometrije alata - λ, γ, κ, r. Ispitivani su sledeći materijali: duraluminijum, bronza, mesing i sivi liv. Primenjen je direktni metod merenja rasprostiranja strugotine – foto metod. Dobijeni rezultati su obrađeni na računaru i prikazani dijagramima uz odgovarajuće komentare.*

**Ključne reči:** *ugao rasprostiranja strugotine, geometria reznog alata, obrada rezanem*