ASSESSMENT OF PLASTIC DEFORMATION IN THE CUTTING ZONE AND CORRELATION WITH ROUGHNESS, AT PLAIN TURNING WITH SMALL CUTTING FEEDS

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Abstract: This paper describes a study concerning the influence of plastic deformations on the cutting zone at the plain turning with small cutting feeds. It notes that in the field of cutting feeds, the real roughness is much greater than the geometric roughness because of high plastic deformations that appear in the cutting zone. The determined coefficients are parameters which evaluate the deformability in the cutting area, therefore allow the establishment of material machinability in the small cutting feeds.

1. INTRODUCTION.

Usually, from cutting theory, it knows that in cutting metals and alloys considered like soft, deformation phenomena from the cutting area have a great influence on the resulting roughness.
In [3] six parameters from turning and boring are taken into account and roughness is studied using Taguchi method for determining the optimal values of parameters that ensure a minimum roughness. Small feeds between 0,08 mm/rot and 0,16 mm/rot are used.
In [4] it is established the roughness of steel turning, on small cutting feeds, tacking into account the depth of cut and vibrations.
At turning, the cutting tool generates on the cylindrical surface a kind of very fine thread pitch.
If plastic deformation does not occur in the cutting, the piece would still geometric marks of cutting tool point (peak), namely theoretical or geometric roughness. Triangles formed are H height, respectively Rz of geometric roughness:

$$H = r_\varepsilon - \sqrt{r_\varepsilon^2 - \frac{f^2}{4}} \tag{1}$$

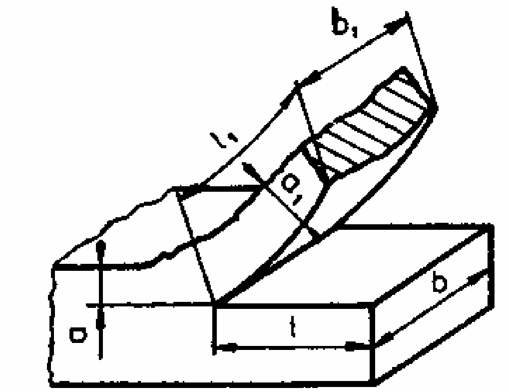
for f<r_ε .
Next, in this paper, the influence of these deformations to the plain turning in small cutting range where deformation phenomena are more pronounced than in the field of normal field are studied.

2. PLASTIC COMPRESSION OF CHIPS.

Theoretical thickness of chips, "a" and its theoretical width, "b" are given by following relations:

$$a = f \cdot \sin \aleph_r \tag{2}$$

$$b = \frac{a_p}{\sin \aleph_r} \tag{3}$$



The effective chip is thicker because of plastic deformation from the cutting zone, and its width increases while its length is reduced (fig.1).

Followings coefficients are known: thickening chip factor ‘k_a” and widening chip factor “k_b”:

$$k_a = \frac{a_1}{a} \quad (4)$$

$$k_b = \frac{b_1}{b} \quad (5)$$

Fig.1. Aspect of the chip

where subscript "1" refers to the chip parts.

2. THE PERFORMED EXPERIMENT

The turning has been made on a centre lathe type SNB 400, on to a bushing with internal diameter of 60 mm, with a rate of cutting of 53,4 m/min and cutting depth of 0,3mm. Carbide-tipped tools type P10 was used. The part was made by OL37 steel. It was used cutting feeds range. Thus, in table 1 is presented the cutting feeds range used.

Table 1. The cutting feeds range used.

Number of step	1	2	3	4	5	6
Cutting feed mm/rot	0,053	0,059	0,075	0,083	0,088	0,096

In table 2 the geometry of cutting tools used for turning are presented.

Table 2. The geometry of cutting tools used for turning.

Geometrical elements of cutting tool	Cutting tool for shaft
χ_r	90^0
χ_r'	18^0
ε	72^0
bevel	4 mm
γ_n	8^0
α_n	10^0
r_ε	1,1 mm
r_n	0,04 mm
λ_T	4^0

Turning was done by holding the shaft between lathe chuck and running centre, figure 2.

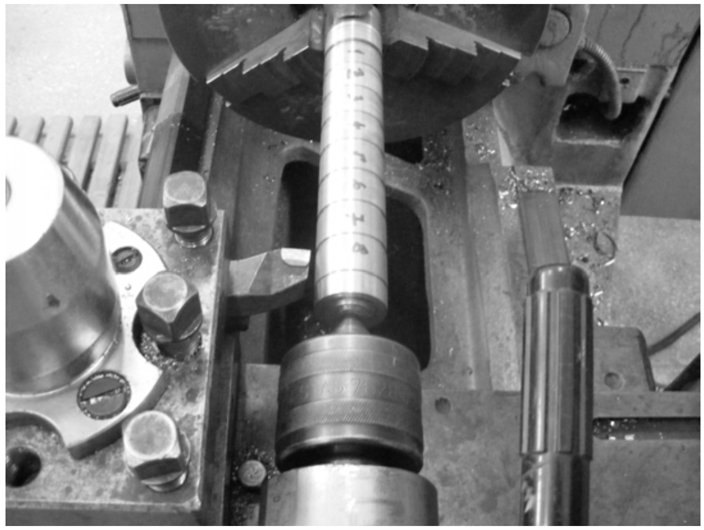


Fig.2. Assembly for shaft processing

4. EXPERIMENTAL RESULTS

The geometrical roughness H was calculated. It was used an electronic roughness tester Mitutoyo, Japan, SJ-201 P model for measuring the roughness on each step of shaft. Also, the theoretical dimensions of chips were established, achieving the following values:

f= .053 H= 3.192425E-04 Rz= .02853 a= .053 b= .3 (6)
f= .059 H= 3.956556E-04 Rz= .02794 a= .059 b= .3 (7)
f= .075 H= 6.393194E-04 Rz= .02915 a= .075 b= .3 (8)
f= .083 H= 7.832051E-04 Rz= .03229 a= .083 b= .3 (9)
f= .088 H= 8.803606E- 04 Rz= .03586 a= .088 b= .3 (10)
f= .096 H= 1.04785E - 03 Rz= .03616 a= .096 b= .3 (11)

It can be noticed that for different values of cutting feed varies the roughness H and „a” , but "b" remains constant.
Also, it can be observed that a=f, because plan approach angle is 90^0 (table 2).
Because of these values and from diagram presents in figure 3 is found that surface roughness (Rz) is much larger than the theoretical (H), so that explains by the great plastic deformations from the cutting zone.
Geometric roughness increases to increasing the cutting feed, but nonlinear.

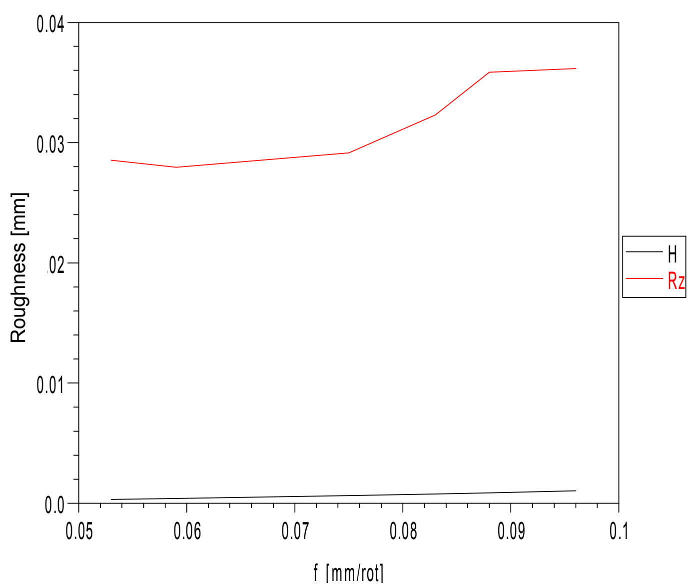
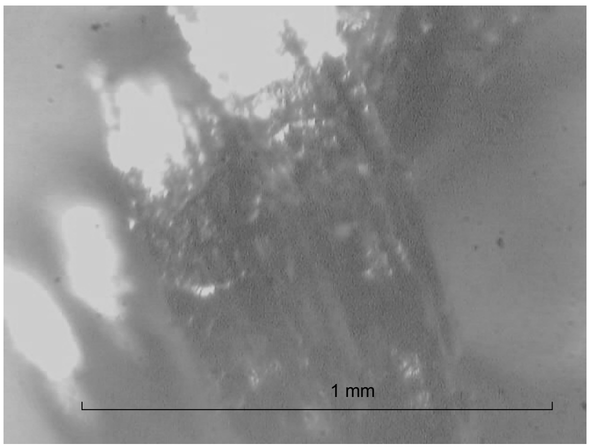


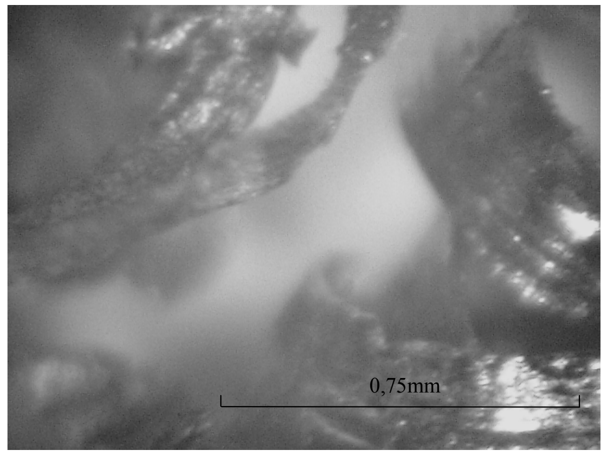
Fig.3. Variation of effective and theoretical roughness

5. THICKENING AND WIDENING COEFFICIENTS OF CHIP

Chips deformations by visualization of some fragments of them on the microscope, measurements made of chips and by calculating of k_a and k_b have been studied.
It was used a microscope Type I.O.R. using a web cam from a digital microscope Type 4 in 1 PC Link E, Eastcolight.
Different scales were used; so on tests were noted standard heights.
In figure 4.a and b the aspect of chips obtained after turning with cutting feed f=0,053 mm/rot is presented.



a.



b.

Fig.4. Shape of chip obtained after turning with cutting feed f=0,053 mm/rot

In fig.4.a. it shows a fragment from resulted chips for a cutting feed of f=0,053 mm/rot. From the fig.4.a it can be observed a constant width, with a slight bend at the bottom. Chip is compact, with parallel flakes. Also, from the fig.4.b it can be observed flakes and breaks of chip components.
In fig.5 a piece from a chip resulted at a cutting feed of 0,059 mm/rot is presented.

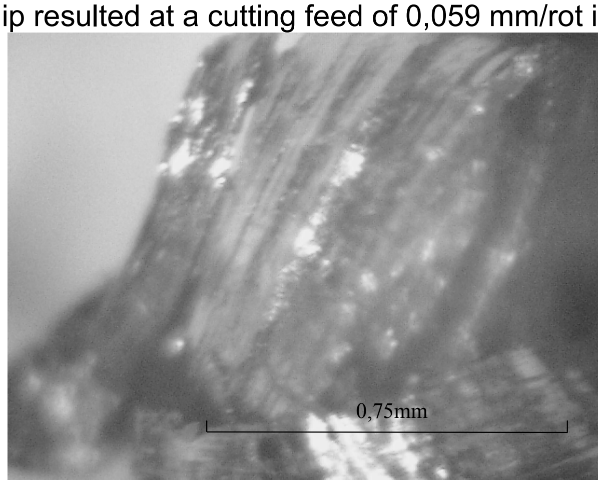
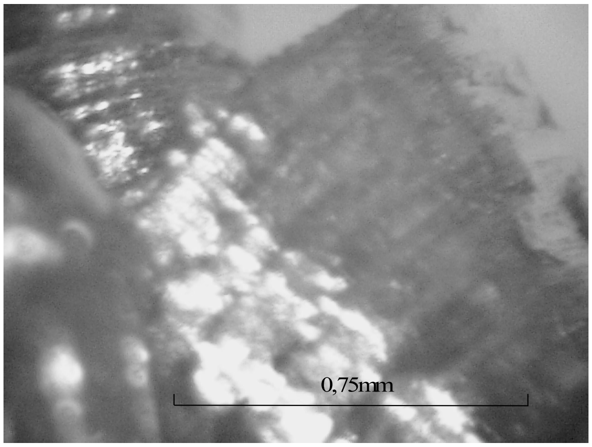


Fig.5. Shape of chip obtained after turning with cutting feed f=0,059 mm/rot

Chip has an uniform thickness, but, width has slight variations, so on the microscope they can see different plans, with different nuances. It can be observed longitudinal flutes on the chip from the part.
Chip from fig. 6 (resulted after turning with a cutting feed of f = 0,075 mm/rot) is helical, with lots of contour irregularities, as a conglomerate. Elements of particles in the bending of it are observed.

For turning with a cutting feed of f = 0,083 mm/rot chips as in fig. 7 resulted, but with faces quite uniforms. Also, it can be observed flues quite uniforms and with variable sections.



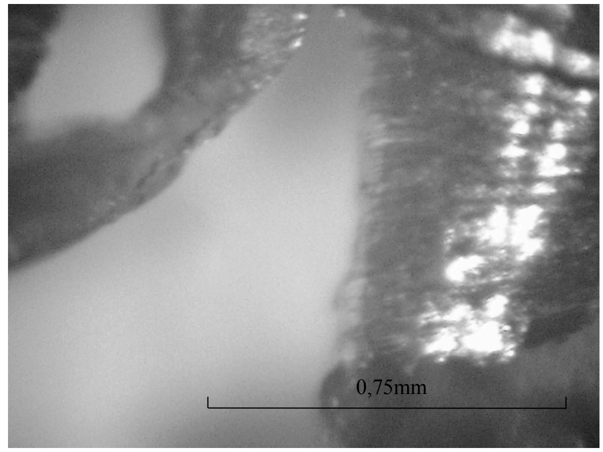
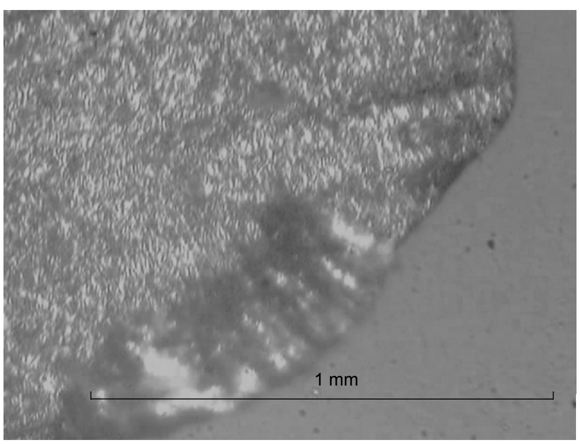


Fig.6. Shape of chip obtained after turning with cutting feed f=0,075 mm/rot

Fig.7. Shape of chip obtained after turning with cutting feed f=0,083 mm/rot

Chip presented in fig. 8, obtained at turning with cutting feed of f = 0,088 mm / rot, has helical shape with constant width, with longitudinal micro-flutes caused by the cutting edge roughness. Also, the blade tip presents irregularities

In fig. 9 chip at turning with cutting feed of f = 0,096 mm/rot seen from the front face of cutting tool is presented. Also, longitudinal micro-flutes and chip rounding are observed.



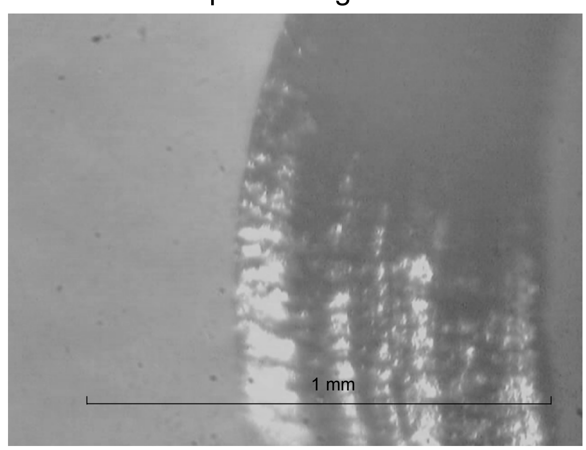


Fig.8. Shape of chip obtained after turning with cutting feed f=0,088 mm/rot

Fig.9. Shape of chip obtained after turning with cutting feed f=0,096 mm/rot

It can be concluded that there is large plastic deformation which changes the chips forms from the theoretical shapes of them. Chip sections are fairly uniform, so it can be measured with sufficient accuracy.

Based on measurements and calculations for chip deformations were established following results:

f= .053 a= .053 a1= .045 b= .3 b1= .062 ka= .8490567 kb= .2066667 (12)

f= .059 a= .059 a1= .09 b= .3 b1= .056 ka= 1.525424 kb= .1866667 (13)

f= .075 a= .075 a1= .01 b= .3 b1= .35 ka= .1333333 kb= 1.166667 (14)

f= .083 a= .083 a1= .11 b= .3 b1= .34 ka= 1.325301 kb= 1.133333 (15)

f= .088 a= .088 a1= .12 b= .3 b1= .35 ka= 1.363636 kb= 1.166667 (16)

f= .096 a= .096 a1= .15 b= .3 b1= .74 ka= 1.5625 kb= 2.466667 (17)

f= .46 a= .46 a1= .41 b= .3 b1= .64 ka= .8913043 kb= 2.133333 (18)
f= .5 a= .5 a1= .43 b= .3 b1= .94 ka= .86 kb= 3.133333 (19)

In fig. 10 theoretical curves for the theoretical thickness "a" of chip (straight-line) and measured thickness "a1" are presented.
From the fig.10 it can be observed that the variations in section measured compared with the theoretical, which shows just the size and unevenness of deformation in the cutting zone.

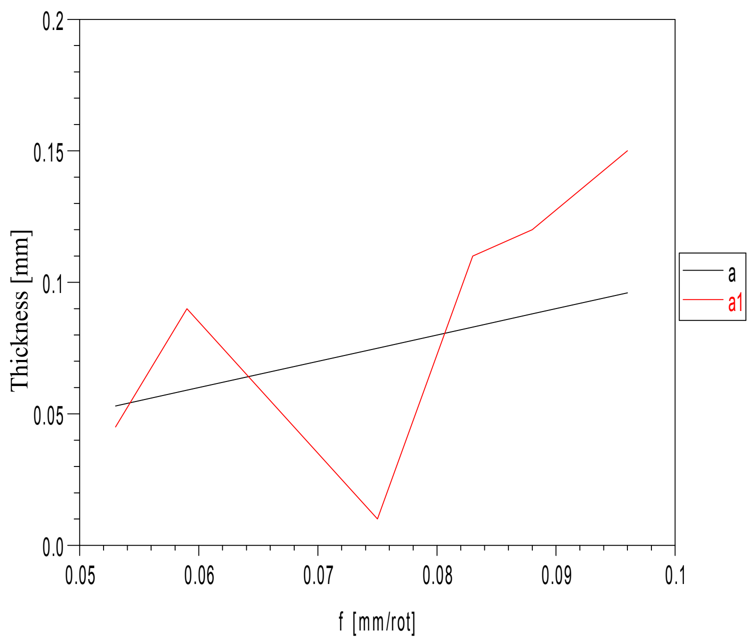


Fig.10. Variation of thickness of chips upon the cutting feed

In the fig.11 the variations of theoretical “b“ and effective “b1” widths of the chip are shown. From the fig.11 can be noticed that theoretical width 'b' is constant because it keeps the main angle and cutting depth and the effective width of chip "b1" is variable, with inrushes, which shows the unevenness of plastic deformations process from the cutting zone.
In fig. 12 the dependencies of the values of chip deformation coefficients ka, kb upon the values of cutting feeds are presented. It can be observed great variations of these coefficients.
It can be concluded that plastic deformation from the cutting area at shaft processing is large and uneven, leading to variations of thickening and width chips coefficients.
All of these are related to those found above about the measured surface roughness for each step of shaft.

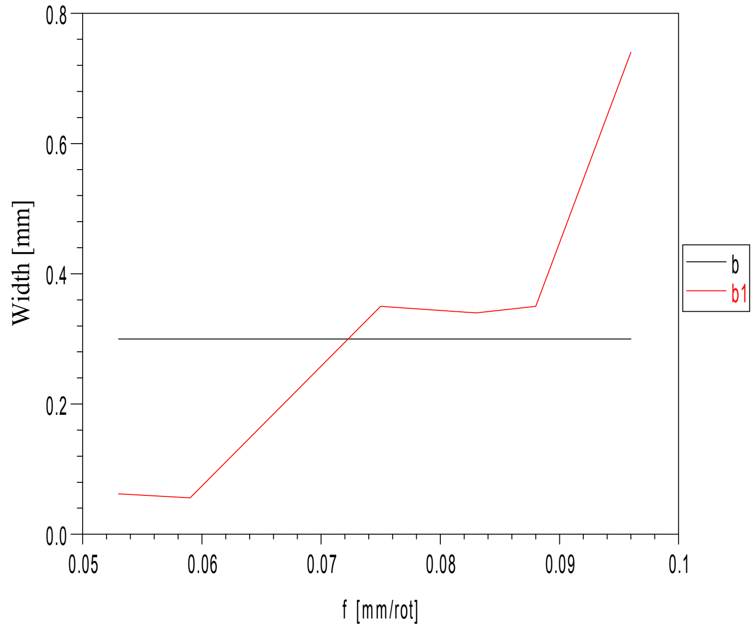


Fig. 11. Variation of width of chips upon the cutting feed

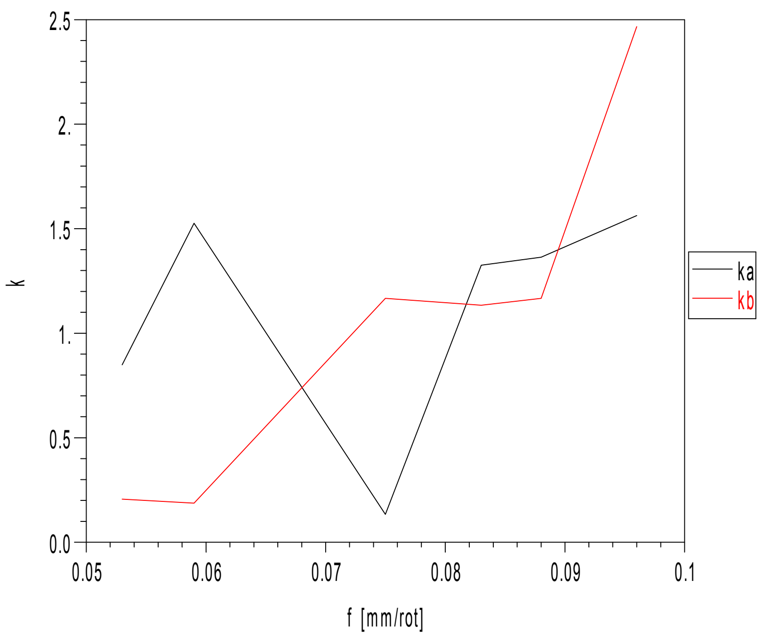


Fig. 12. Variation of chip deformation coefficients ka, kb

6. CONCLUSIONS

- In range of small cutting feeds, the effective roughness is higher than geometrical (theoretical) roughness because of phenomena from plastic deformation in cutting area.
- Plastic deformation in cutting area is higher and non-uniform which lead at variations of thickness and wideness coefficients of chips.

- Very small values of cutting feeds do not offer advantages about roughness, lessening of cutting efficiency, too.
- In range of very small cutting feeds, the plastic deformations have a much higher influence on roughness than for normal or great values of cutting feeds.
- Determined coefficients are parameters that assess the deformability in the cutting zone, thus allow to establishing the material workability of the material in the area of small cutting feeds.

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