EFFECT OF CUTTING PARAMATERS ON SURFACE ROUGHNESS IN TURNING MILD STEEL

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Abstract: *Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surface. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. Although roughness is often undesirable, being difficult and expensive to control it during the manufacturing process. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.*

Keywords: *Roughness, surface generation, cutting parameters, turning*

1. Introduction

Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth.

In practice, the assessment of surface roughness is according ISO 4287: 2001, based on the following main sizes (see Figure 1):

- the maximum height of irregularities R_t (or R_{max});

- arithmetic average of absolute values R_a, which is the ordinances average y_1, y_2, ... y_n of the points from the effective profile, compared to the average line profile;

- height of irregularities R_z, based on the five highest peaks and lowest valleys over the entire sampling length (l_n).

Based on the above, the following mathematical relations can be written:

$$R_t = \max\left(R_{z_1}, R_{z_2} ... R_{z_n}\right) \qquad (1)$$

$$R_a = \frac{1}{l} \cdot \int_o^l |y(x)| dx \qquad (2)$$

$$R_z = \frac{1}{5} \cdot \sum_{i=1}^{5} R_{zi} \qquad (3)$$

where:
l_r- base length;
l_n- sampling length;
R_{zi}- height of irregularities;
R_{max}- maximum height of irregularities.

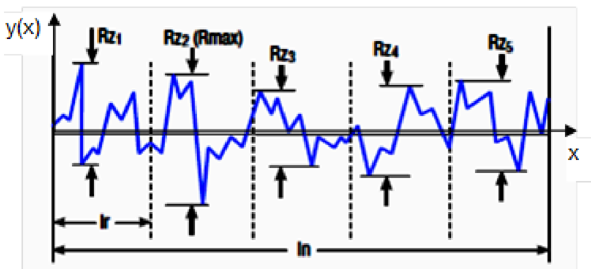

Figure 1: *Surface roughness according to SR ISO 4287: 2001 [3]*

The theoretical value of the maximum height of the irregularities R_t can be determined at turning from geometric conditions, taking into consideration the feed rate s and the tip radius r_ε of the cutter.

With the notations from Figure 2, it can be written the following relations:

$$R_t = r_\varepsilon - \sqrt{r_\varepsilon^2 - \left(\frac{s}{2}\right)^2} \qquad (4)$$

or: $$R_t^2 - 2\cdot R_t \cdot r_\varepsilon + r_\varepsilon^2 = r_\varepsilon^2 - \frac{s^2}{4} \qquad (5)$$

namely: $$2\cdot R_t \cdot r_\varepsilon - R_t^2 = \frac{s^2}{4} \qquad (6)$$

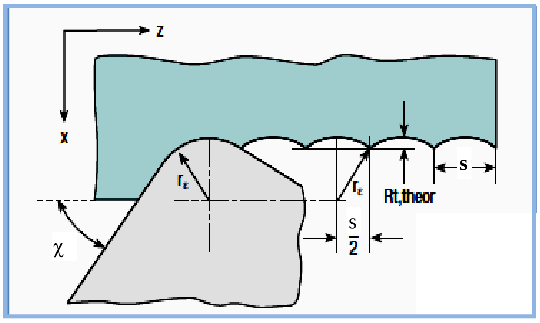

Figure 2: *Theoretical value of the maximum height of the irregularities at turning with cutter having rounded tip [3]*

Taking into consideration that R_t^2 can be neglected compared with the product $2\cdot R_t \cdot r_\varepsilon$ $\left(R_t^2 << 2\cdot R_t \cdot r_\varepsilon\right)$, it is resulting Cebîşev's relationship:

$$R_t \cong \frac{s^2}{8\cdot r_\varepsilon} \qquad (7)$$

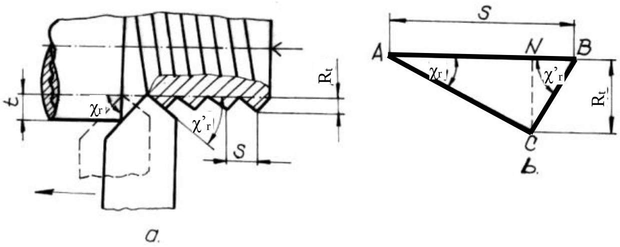

Figure 3: *Theoretical value of the maximum height of the irregularities at turning with straight-edged cutter*

For straight-edged cutters (having tip radius $r_\varepsilon=0$), with the notations from Figure 3, it can be written the following relations for the side cutting-edge angle χ_r, respective for the end cutting-edge angle χ_r':

$$\mathrm{ctg}\,\chi_r = \frac{AN}{NC} \quad \text{respective} \quad \mathrm{ctg}\,\chi_r' = \frac{NB}{NC} \qquad (8)$$

Making the substitution $R_t = NC$, the relationships (7) becomes:

$$AN = R_t \cdot \mathrm{ctg}\,\chi_r \quad \text{and} \quad NB = R_t \cdot \mathrm{ctg}\,\chi_r' \qquad (9)$$

Further:

$$s = AN + NB \qquad (11)$$

namely:

$$s = R_t \cdot (\mathrm{ctg}\,\chi_r + \mathrm{ctg}\,\chi_r') \qquad (12)$$

and therefore:

$$R_t = \frac{s}{\mathrm{ctg}\,\chi_r + \mathrm{ctg}\,\chi_r'} \qquad (12)$$

Examining the relations (7) and (12), it can be concluded that the machined surface roughness can improved by decreasing the feed rate *s*.

2. Set-up of the experimental study

This research was primarily focuses on turning of mild steel of grade C45, using HSS made tools, due to their lower cost, ready availability and a wide range of applications.

Turning was performed on a usual lathe (type SN 560), by using standard high speed steel tools, without the use of cutting fluid.

The experiments were carried out on a mild steel round bar having an initial diameter of 70 mm and a length of 600 mm, previously prepared according to Figure 4.

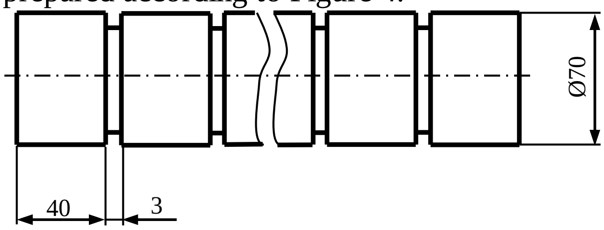

Figure 4: *Steel bar prepared for the experiments*

Details of the experiment, respective the used cutting parameters are listed in Table 1.

Table 1

Details of the experiment	
Machine tool	**Turning lathe SN 560**
Tool specification	
Material grade	HS6-5-2C (1.3343), acc. to SR EN ISO 4957
Work piece material	
Steel grade	C45 (1.0503), acc. to SR EN 10.083-2
Hardness	Brinell 200
Cutting conditions	
Turning speed n [rev/ min]	200; 315; 400; 500; 630 and 800
Cutting speed v [m/min]	43,96; 69,24; 87,92; 109,9; 138,47 and 175,84
Feed rate s [mm/ rev]	0,1; 0,2; 0,315; 0,4; 0,63 and 0,8
Depth of cut t [mm]	0,5; 0,75; 1 and 1,5
Cutting fluid	none

For measuring the surface roughness it was used the portable device shown in Figure 5. The device has a modular design which includes a tester and a unit of measurement and display.

Figure 5: *Portable surface roughness measuring device*

3 Experimental results and discussion

The cutting parameters and the measured surface roughness's are shown in Table 2.

Table 2

No.	Turning speed n [rev/min]	Cutting speed v [m/min]	Feed rate s [mm/rev]	Depth t [mm]	Roughness R_a [µm]
1	315	69,24	0,1	1	3,24
2			0,2		6,38
3			0,315		7,42
4			0,4		9,15
5			0,63		10,24
6			0,8		13,27
7	315	69,24	0,2	0,5	6,32
8				0,75	6,43
9				1	6,38
10				1,5	6,61
11	200	43,96	0,2	0,5	7,34
12	315	69,24			6,32
13	400	87,92			6,26
14	500	109,9			5,95
15	630	138,47			4,2
16	800	175,84			3,86

3.1 Effect of feed rate on surface roughness

The results presented in Figure 6 are showing the effect of the feed rate on the surface roughness. It can be observed that an increase of the feed rate leads to an increase of the surface roughness.

Based on experimental data, obtained by maintaining a constant depth of cut t= 1 mm, respective a constant cutting speed of v= 69,24 m/ min, it have been deducted following mathematical formula which is showing the variation of the surface roughness for a feed rate average s= 0,1 - 0,8 m/rev.

$$R_a = 3{,}4126 \cdot s^{0{,}7486} \qquad (13)$$

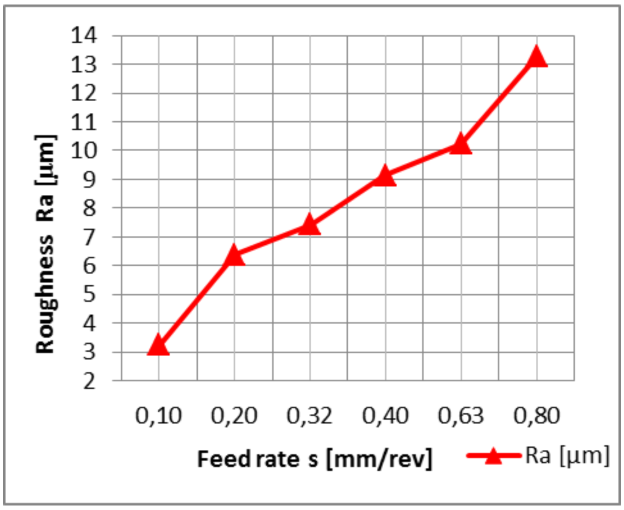

Figure 6: *Roughness R_a vs. feed rate at t=1 mm and v= 69,24 m/min*

3.2 Effect of depth of cut on surface roughness

The obtained values (Figure 7) are illustrating the evolution of the surface roughness depending on the depth of cut at turning with a constant cutting speed of v= 69,24 m/ min, respective a constant feed rate of s= 0,2 mm/. It can be observed that the depth of cut doesn't have a significant influence on the surface roughness.

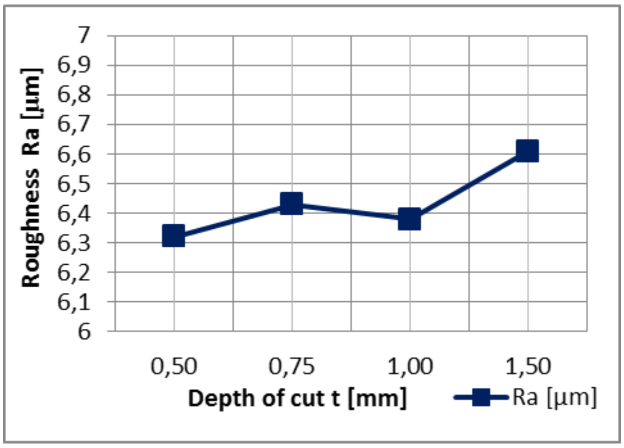

Figure 7: *Roughness R_a vs. depth of cut at v= 69,24 m/ min and s= 0,2 mm/rev*

3.3 Effect of cutting speed on surface roughness

The results presented in Figure 8 are showing the effect of the cutting speed on the evolution of the surface roughness It can be observed that by increasing the cutting speed, the roughness of the machined surface is decreasing.

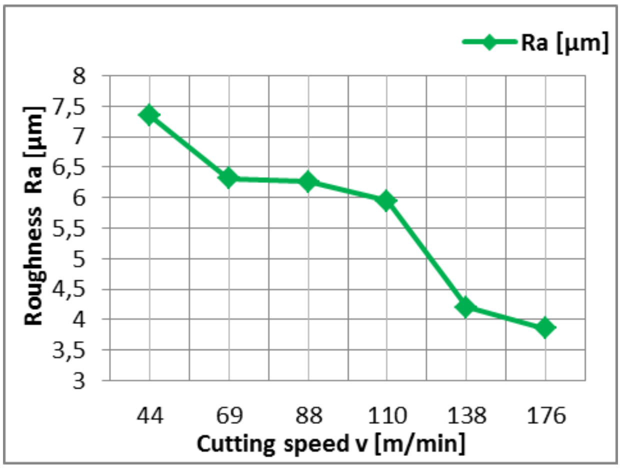

Figure 8: *Surface roughness vs. cutting speed at t= 0,5 mm and s= 0,2 mm/ rev.*

Based on experimental data, obtained by maintaining a constant, by maintaining a constant cutting depth of t= 0,5 mm, respective a constant feed rate of s= 0,2 mm/ rev, it have been deducted following mathematical formula which is showing the variation of the surface roughness for the cutting speed average v= 43,96, – 175,84 m/ min:

$$R_a = 8{,}062 - 0{,}6877 \cdot v \quad (14)$$

5. Conclusions

The tests of longitudinal turning, carried out on C45 steel grade, using HSS made tools, without the use of cutting fluid, enabled us to study the influence of the cutting parameters on the surface roughness.

It could be drawn following conclusions:

- by raising the cutting speed (v) and lowering the feed rate (s), the roughness of the machined surfaces is improved (decreased);

- the variation of the depth of cut (t) doesn't have a significant influence on the roughness of the machined surfaces by turning.

The established mathematical formulas (13) and (14) have defined the degree of influence of the feed rate, respective the cutting speed on the surface roughness.

While the results declared through this experimental work may be generalized to a considerable extend, until working on Mild Steel and using HSS tool, the mathematical models are limited to the extreme range of the specified cutting parameters values.

5. References

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