THE EFFECT OF THE DIFFERENT CUTTING TOOLS ON THE MICRO-GEOMETRICAL SURFACE OF ENGINEERING PLASTICS

Gabriella Farkas[**]

[**]Bánki Donát Faculty of Mechanical and Safety Engineering,
Institute of Material Science and Manufacturing Engineering, Universitas Budensis

Gábor Kalácska[*]

[*]Institute for Mechanical Engineering Technology,
Faculty of Mechanical Engineering, Szent István University

Abstract We would like to present in this article the results of the microgeometrical study of the engineering polymer surfaces and the applied cutting tools. We compare the effects of different technological parameters (cutting speed, cutting feed, depth of cut) having on the microgeometrical characteristics (R_a, R_z) and we summarise the results and conclusions from the practical engineering life.

Keywords Engineering plastics, parameters of cutting, cutting tools, parameters of the surfaces roughness.

1. INTRODUCTION

In the machining circumstances and data should be chosen in the cutting process so that the work piece machined is in accordance with the accuracy to gage, geometrical trueness and surface quality given by design engineer. Several researchers dealt with the cutting of metals and the study of effect of cutting features [1]. The aim of my research work is mainly the analysis of the roughness parameters of cutting surfaces in case of different circumstances. Other important task is the elaboration of surface planning criterions in accordance with the expected functional behaviour. The most important aspect was that the results of tests would be useful for the technical practice. That's why we chose several thermoplastic polymers which are important in the technical practice but their behaviour isn't known in case of cutting.

2. EXPERIMENT OF CUTTING

The technical literature provides cutting parameters generally [2,3,4,5]. Cutting speed can be average and high rate between 200 and 600 m/min. Feed rate can be low and average rate is between 0,05 and 0,4 mm. The optimal cutting parameters are not exactly determined for certain polymers with regard to surface roughness. We performed the cutting tests in the machine shop of the Institute by NCT EUROTURN 12B CNC controlled HSC lathe. We fixed the work pieces into the chuck. The turning was made with 80 mm length and 40 mm diameter. We chose several polymers in accordance with technical application: PA6, POMC, PET, PEEK.

We cut the work pieces always without cooling with different parameters given below:

- cutting speed, v_c [m/min]: 200–250–315–400
- cutting feed, f [mm/rev.]: 0,05–0,08–0,12–0,16–0,2–0,25– 0,315–0,4
- depth of cut, a [mm]: 0,5
- parameters of workpieses: ø40x80 mm,
- we don't used cooling.

We used three different tools for experiment. Figure 1. contains the parameters of tools.

parameters	A tool	B tool
κ_r	93 °	93 °
ε_r	35 °	55 °
α_0	5 °	7 °
λ_s	0 °	0 °
r_ε	0.4 mm	0.4 mm
r_n	14,1 ± 5,6 μm	6,75 ± 0,96 μm
R_a (tool)	1,29 ± 0,15 μm	0,58 ± 0,03 μm
R_z (tool)	6,43 ± 0,62 μm	2,66 ± 0,18 μm

Figure 1. Edge-geometry of"A", "B" tools

Before cutting I measured the edge radius (r_n) and the edge of roughness (r_ε) of the tools as well as the arithmetic mean deviation of the roughness profile (R_a) and the maximum height of roughness profile (R_z) of tools. In case of "A" tool the value of r_n has got large standard deviation and roughness parameters differed differing. It was typical of "B" tool the small edge radius (r_n) and the little surface roughness (R_a, R_z) with small standard deviation in this way it was the better quality tool.

3. STUDY OF MICROGEOMETRY

During machining typical microgeometrical unevenness is arousing on the surface which depends on applied technological parameters, geometrical features of tool and machinig circumstances.

Regarding micro-geometric characteristics, the roughness and waviness parameters are applied which have been worked out for decades and are still subject of research at present, and provide information about divergences and characteristics of the surface. Several measuring processes have evolved for the examination of surface texture by today.

2D Stylus instruments are generally used for measuring and evaluation; however, there is an increasing demand for 3D topographic scanning in order to learn more about the characteristics of surface texture (random, periodical, isotropic, anisotropic, etc.) and its stereoscopic position [6,7].

The examinations were performed on surfaces with Perthometer-Concept type stylus scanning instruments. The surfaces were evaluated on an evaluation length (LM=4 mm) complying with the ISO standard with the standard filter (LC=0.8 mm) and a one grade smaller filter (LC=0.25 mm). Considering the possibilities of measuring techniques during the tests, the following data were taken: unfiltered profile (P), filtered roughness profiles (R), as well as 8 roughness (R), 4 waviness (W) and 5 unfiltered (P) parameters. 2 figures were included in the precise comparison, which are also generally used in industrial practice: parameters of height (R_a, P_a, R_t, P_t), one spacing parameter (R_{sm}, P_{sm}), and two characteristics of shape (R_{sk},P_{sk}, R_{dq},P_{dq}).

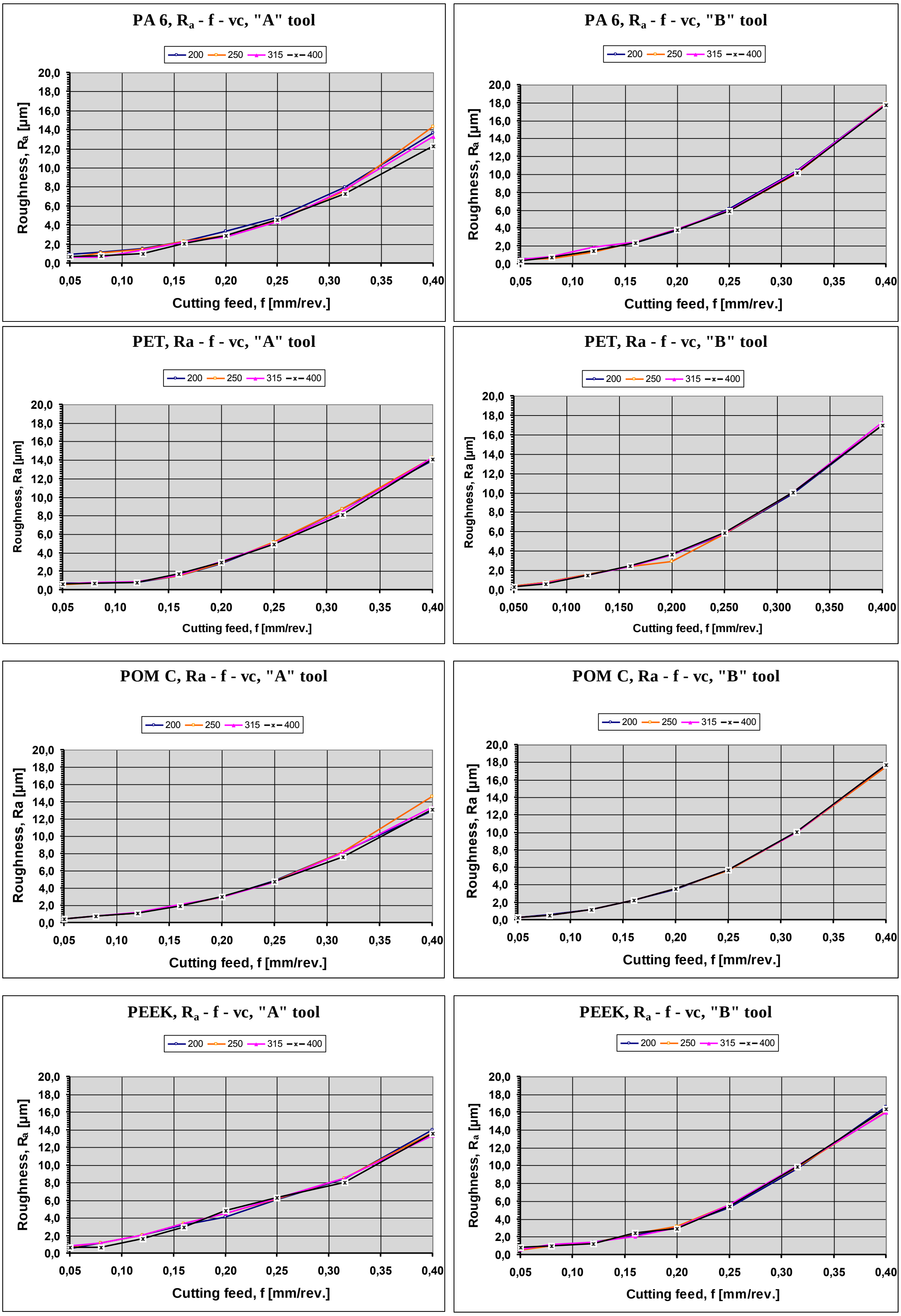

Figure 2. The results of R_a in case of “A”, “B” tools

The results of measurements represent the graphs were include the Figure 2. in case of polyamide 6 (PA 6). It can be see that the results of R_a is more different in case of “A” tool like the other two tools. The behaviour of the polymer studied by different cutting speed and by the same cutting feed is stable the value of arithmetical mean deviation of the assessed profile is about constant. The results of Ra is better in case of „B“ tool, so it has larger angle of tool (ε_r=55°). This is true the all studied polymers (PET, POM C, PEEK) as well.

3. STUDY OF THE THEORETICAL ROUGHNESS (R_E) WITH DOE (DESIGN OF EXPERIMENTS)

I have planned and carried out the tests with method of the Design of Experiments. I have modelled R_a and R_z values measured with power functions.

The parameters in the factorial test plan were:

- R_a (arithmetical mean deviation of the assessed profile) [μm]
- R_z (maximum height of profile) [μm]

The factors:

- v_c (cutting speed) [m/min]
- f (cutting feed) [mm/rev.]

The two parameters of surface roughness and the cutting data factors set can be given with the following function:

$$R = C_R \cdot v_c^{x_1} \cdot f^{x_2} \text{ [μm]}$$

I carried it out with Minitab14 statistical software the regression function examination. I have decided with the help of program the coefficient of individual models and exponents (C_R, x_1, x_2), the values of the standard deviation (s) and the correlation (R).

3.1 STUDY OF THE CUTTING TOOL “A”

We executed the cutting tests with “A” tool at first.

The functions write down the measuring results with small standard deviation (s= 0,054-0,16) and relatively large correlation (R= 0,877-0,983). It’s exponents of variables significant in case of “A” tool. Increasing cutting speed causes decreasing of the roughness in the domain examined. Speed is having effect on the surface roughness (x_1= from -0,003 to -0,316). The cutting feed has almost linear connection with R_a, R_z values (x_2= 1,2 - 1,68), it has a smaller effect on the measuring results as the Baurer-formula shows that. This experience is reverse with the measurement outcomes, which at his steels fashioning by machine tool our well versed in our try efforts.

Polyamide 6 (PA6)					
A tool			B tool		
Model	s	R	Model	s	R
$R_a = 191 \cdot v_c^{-0,292} \cdot f^{1,46}$	0,111	0,94	$R_a = 93 \cdot v_c^{-0,036} \cdot f^{1,8}$	0,093	0,971
$R_z = 631 \cdot v_c^{-0,316} \cdot f^{1,2}$	**0,106**	0,921	$R_z = 240 \cdot v_c^{-0,017} \cdot f^{1,58}$	0,105	0,953
Poly(etylen-tereftalat) (PET)					
A tool			B tool		
Model	s	R	Model	s	R
$R_a = 46 \cdot v_c^{-0,008} \cdot f^{1,6}$	0,1606	0,899	$R_a = 120 \cdot v_c^{-0,067} \cdot f^{1,88}$	0,052	0,992
$R_z = 117 \cdot v_c^{-0,026} \cdot f^{1,37}$	**0,154**	0,877	$R_z = 490 \cdot v_c^{-0,105} \cdot f^{1,75}$	0,074	0,98
Poly(oxi-metylen) (POMC)					
A tool			B tool		
Model	s	R	Model	s	R
$R_a = 50 \cdot v_c^{0,003} \cdot f^{1,68}$	0,077	0,977	$R_a = 110 \cdot v_c^{-0,002} \cdot f^{2,1}$	0,035	0,997
$R_z = 234 \cdot v_c^{-0,062} \cdot f^{1,54}$	**0,076**	0,974	$R_z = 288 \cdot v_c^{0,0319} \cdot f^{1,95}$	0,060	0,99

Poly(eter-eterketon) PEEK					
A tool			B tool		
Model	s	R	Model	s	R
$R_a = 63 \cdot v_c^{-0,048} \cdot f^{1,48}$	0,067	0,978	$R_a = 42 \cdot v_c^{0,04} \cdot f^{1,6}$	0,110	0,95
$R_z = 275 \cdot v_c^{-0,089} \cdot f^{1,36}$	**0,054**	0,983	$R_z = 135 \cdot v_c^{0,062} \cdot f^{1,47}$	0,128	0,923

Figure 3. Results of DoE in case of polymers studied

3.2 STUDY OF THE CUTTING TOOL "B"

We carried out the cutting tests with "B" tool for the second time. The exponents of variables are not significant in case of "B" tool because the effect of the cutting speed less than standard deviation of values measured. The values of standard are between (s= 0,035-0,128) and the correlation is larger than in case of "A" tool (R= 0,923-0,997).

Cutting speed is shows almost much smaller effect of the "B" tool (x_1= from -0,002 to 0,062), the cutting feed has a quadratic connection with the roughness (x_2= 1,47 – 2,1), so better this suits better to the theoretical formula used at turning with regular egde-geometrical tool.

According to results found in the microgeometrical study the line of the theoretical roughness (R_e) follows the line of the roughness measured (R_z maximum height of profile) in the domain studied.

4. SUMMARY OF RESULTS

The behaviour of the polymer studied by different cutting speed and by the same cutting feed is stable. That is different from what we have experienced with steel. The result of R_a (arithmetical mean deviation of the assessed profile) is under 2 μm by low cutting feed and by the cutting speed used [8,9].

Overall the effect on the roughness characteristics of the cutting speed examined at plastics can be observed.

This experience is contradictory with those measuring results, which we have experienced in our tests at cutting steels.

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