Qualitative Evaluation of Machined Surface of Aluminum Alloy AlCu4Mg1 Depend on Feed Rate

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Aim of the article is evaluation of surface quality parameters Rz and Ra after turning of aluminum alloy. Turning is one of the wide spread manufacturing technologies used in industrial production. Experiment was focused on researching of influence of various cutting conditions on machined surface. Main aim of this article is comparison of surface roughness parameters Ra and Rz depending on feed rate and tool nose radius. Investigation and finding of optimal cutting conditions is necessary for economy of manufacturing organization. Despite extensive research carried out in the area of turning, there is always room for new research.

Keywords: Rate, Roughness, Surface Quality, Lathe

1 Introduciton

Presented article is focused on prediction of machined surface quality depend on feed rate and tool nose radius. Experimental samples were prepared on band saw. Turning operation was realized on CNC Lathe Leadwell Twilight series T-5. This type of turning machine is mainly used to production of rotary parts such as shafts, flanges etc. in small and middle series production. Leadwel T-5 is equipped with control system Fanuc 0i – TC with manual guide [10], [11], [12], [14].

As tool were set four cutting platesTCMW 11 02 04, TCGX 11 02 04 – AL, DCGT 11 T3 02 - PM2, DCGT 11 T3 02 - PF2. First cutting plate (TCMW 11 02 04) is without chip former, other three are equipped with chip former. All plates are designed for machining of allumminium alloys and have positive geometry. [8][6][2]
As experimental material was selected aluminum alloy AlCu4Mg1 (EN: EN 2024 T3). Mechanical properties and chemical composition of experimental material are shown in table below (tab. 1 and tab. 2). [4],[1],[7],[13]

***Tab. 1** Chemical composition of material AlCu4Mg1*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Pb
0.5	0.5	3.8-4.9	0.3-0.9	1.2-1.8	0.1	-	0.25	0.15	-

***Tab. 2** Mechanical properties of material AlCu4Mg1*

Tensile strength [MPa]	Yield strength [MPa]	Elongation A5 [%]	Hardness [HB]
Min. 425	Min. 290	7-9	120

2 Impact of changes of feed rate on quality of machined surface

Experiment was focused on monitoring surface roughness values in dependence on feed rate per revolution. Cutting plates used in tests are for machining of aluminum alloys, with tool nose radius 0.2 and 0.4 mm and different chip formers. All test were performed without lubrication and cooling.
[3][5][6]
Experimental cutting conditions
Coting conditions for experiment were set as follows:

- Cutting sped $v_c = 300\ m.min^{-1}$
- Depth of cut $a_p = 0.5$ mm
- Length of turning 20 mm
- Feed rate 0.05 mm/rev
  0.10 mm/rev
  0.20 mm/rev
  0.40 mm/rev

In the following chart are cutting plate TCMW 11 02 04 marked as 1, TCGX 11 02 04 – AL marked as 2, cutting plate DCGT 11 T3 02 - PM2 marked as 3 and cutting plate DCGT 11 T3 02 - PF2marked as 4 (tab. 3.)(Fig. 1).

***Tab. 3** Cutting plates and feed rate combination*

symbol	**Parameter**	**unit**	**1**	**2**	**3**	**4**
A	Tool nose radius r_ε	mm	0.4	0.4	0.2	0.2
B	Feed rate f	mm	0.05	0.1	0.2	0.4

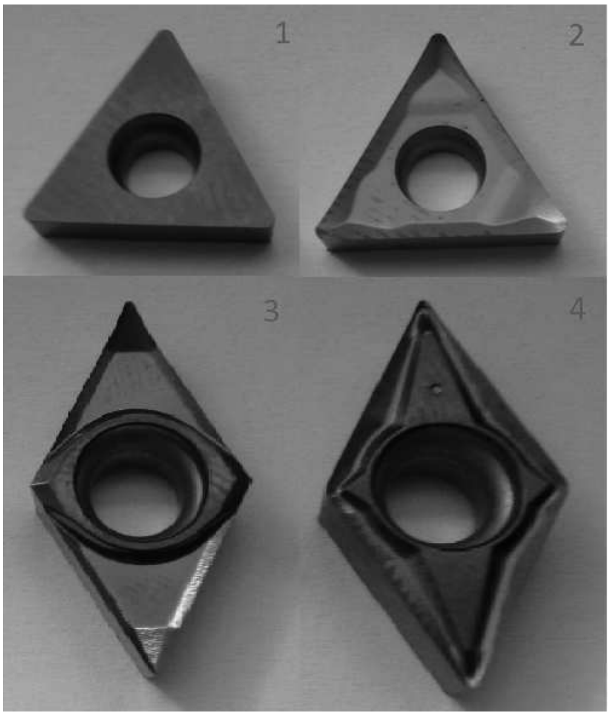


Fig. 1 *Cutting plates used for experiment*

2.1 Measured values

Theoretical values of surface roughness Ra and maximal surface roughness Rz were calculated and are listed in table below (tab.3) . According to calculated values of Ra and Rz can be stated that surface roughness increasing with increased feed rate per revolution more significantly for cutting plates with tool nose radius 0.2 mm.

In the following table (tab. 4.) are listed values of surface roughness Ra and maximal surface roughness Rz obtained with usage of all cutting plates and feed rates. Values of roughness at lowest level Ra = 0.28 μm was reached by cutting plate DCGT 11 T3 02-PM2 (Walter) at feed rate per revolution f = 0.05 mm. Second lowest value of surface roughness Ra = 0.29μm was reached by cutting plate TCGX 11 02 04 – AL . Opposite the highest values of surface roughness were obtained by cutting plates with tool nose radius 0.2 mm at feed rate per revolution 0.4 mm. Difference between TCMW 11 02 04 a DCGT 11 T3 02 - PF2 at feed rate per revolution level 0.4 mm is 15.41 μm. Cuting plates with tool nose radius 0.2 mm caused highest values of surface roughness compared to plates with radius 0.4 at higher feed rates because f > rε.

Tab. 3 *Theoretical values of surface roughness parameters Rz a Ra*

Feed rate [mm/rev]	**Theoretical values of average arithmetical deviation Ra [μm]**		**Theoretica value of maximal height of profile Rz [μm]**	
	$r_ε$ = 0.2 mm	**$r_ε$ = 0.4 mm**	**$r_ε$ = 0.2 mm**	**$r_ε$ = 0.4 mm**
0.05	0.488	0.244	1.562	0.781
0.1	1.953	0.976	6.25	3.125
0.2	7.812	3.906	25	12.2
0.4	31.25	15.625	100	50

Tab. 4 *Measured values of surface roughness parameter Ra*

Surface roughness Ra [μm]				
Feed rate [mm/rev]	**Cutting platte**			
	TCMW 11 02 04	**TCGX 11 02 04 - AL**	**DCGT 11 T3 02 - PM2**	**DCGT 11 T3 02 - PF2**
0.05	0.51	0.29	0.28	0.34
0.1	0.86	0.66	1.7	1.74
0.2	3.25	3.52	8.5	8.01
0.4	14.39	16.88	27.8	29.8

In table 5 are measured values of maximal surface roughness Rz obtained from all cutting plates at all feed rates per revolution. Surface roughness Rz was achieved by cutting plate T3 02-PM2 (Walter) at feed rate per revolution f = 0.05 mm concretely Rz = 1.6 μm. Second lowest value of Rz= 1.8 μm was achieved by DCGT 11 T3 02-PF2 (Walter) in contrast with Ra parameter where second lowest value was achieved by cutting plate TCGX 11 02 04 – AL. Difference between cutting plate DCGT 11 T3 02-PM2 and DCGT 11 T3 02-PF2 at feed rate 0.05mm was in 0.2 μm. Oppositely minimal difference was monitored on surface made by cutting plates with tool nose radius rε= 0.2 mm and rε= 0.4 mm at feed rate 0.05 mm was surface roughness out of range about 0.8μm. Paranormal activity was occurred with cutting plate TCMW 11 02 04, where surface roughness has decreasing character specifically at feed rate 0.05 mm was Rz = 5.3 μm and at feed rate 0.1mm was Rz = 3.6 μm. The highest values of surface roughness were measured on surface after machining with cutting plates DCGT 11 T3 02-PM2 at feed rate 0.4 mm and the most significant difference of surface roughness was monitored at cutting plate TCMW 11 02 04, where maximal dispersion is 52.9 μm.

Graphical dependence (Fig. 2.) of surface roughness parameter Ra and feed rate per revolution with tool nose radius rε = 0.4 mm. From graphical dependences can be state, that cutting plate TCMW obtained higher quality of the surface in comparison with theoretical course of surface roughness. Quality of surface made by cutting plate TCGX in comparison with theoretical values is not approaching the limit of calculated, what is most significant at feed rate 0.4mm.

Comparing surface quality at feed rate 0.1 mm and 0.2 mm can be state, that both cutting plate made surface quality on higher level than predicated values of surface roughness but oppositely at feed rate 0.05mm was theoretical surface roughness parameter Ra lower in comparison with real measured values Ra.

***Tab. 5** Measured values of surface roughness parameter Rz*

Surface roughness Rz [µm]				
Feed rate f [mm/ot]	Cutting plate			
	TCMW 11 02 04	TCGX 11 02 04 - AL	DCGT 11 T3 02 - PM2	DCGT 11 T3 02 - PF2
0.05	5.3	2.4	1.6	1.8
0.1	3.6	2.9	5.9	6.7
0.2	11.8	12.6	30.3	29.3
0.4	51.8	61.9	88.9	104.7

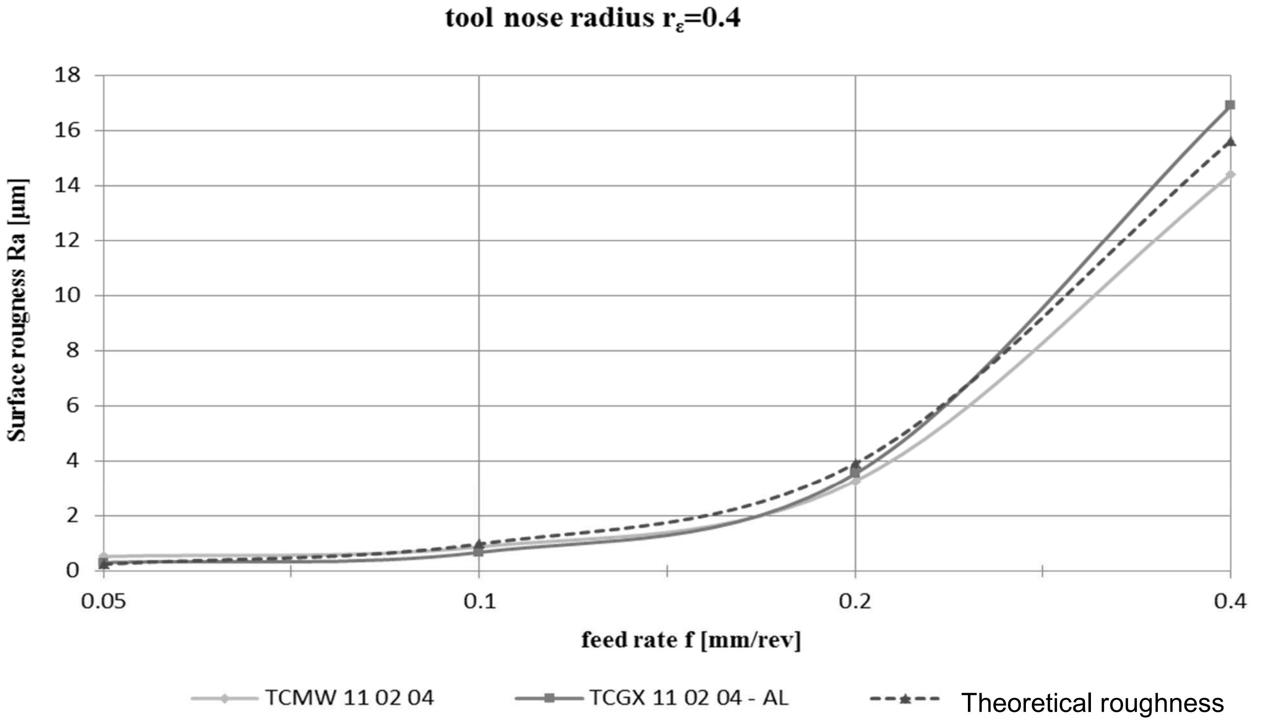


***Fig. 2** Graphical dependence of Ra on feed rate for tool nose radius 0.4 mm*

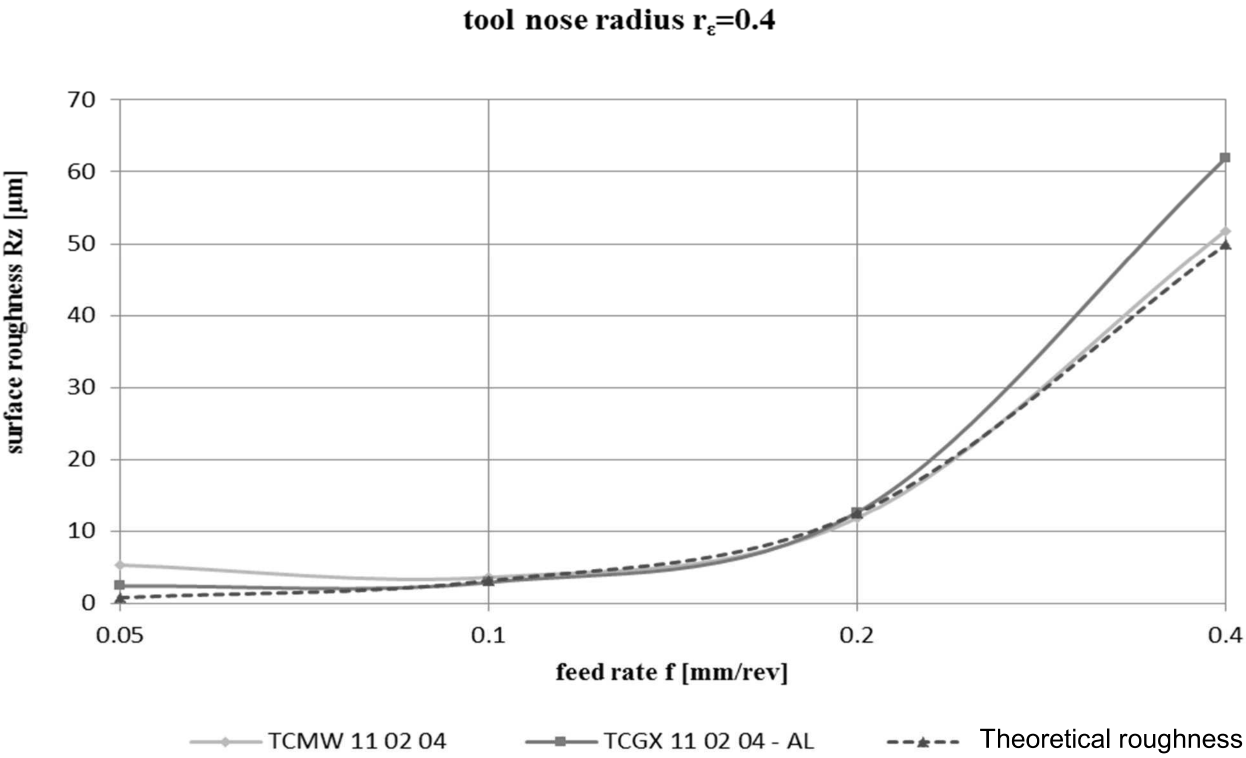


***Fig. 3** Graphical dependence of Rz on feed rate for tool nose radius 0.4 mm*

Graph (Fig. 3) shows dependence of surface roughness parameter Rz on feed rate f for cutting plates with tool nose radius rε = 0.4 mm with theoretical comparison. From mentioned courses can be result, that at feed rate from 0.05mm to 0.1 mm was measured values of selected surface roughness parameter above theoretical course of Rz.

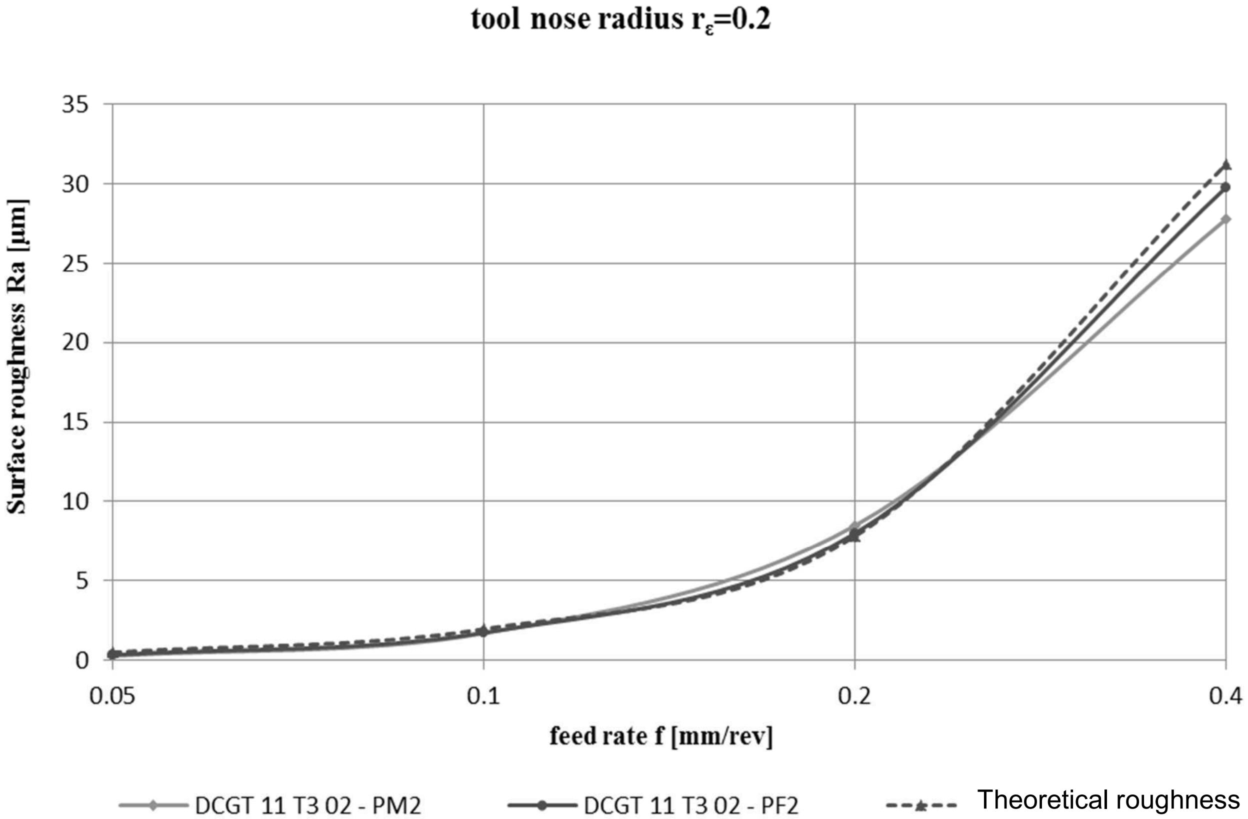


Fig. 4 *Graphical dependence of Ra on feed rate for tool nose radius 0.2 mm*

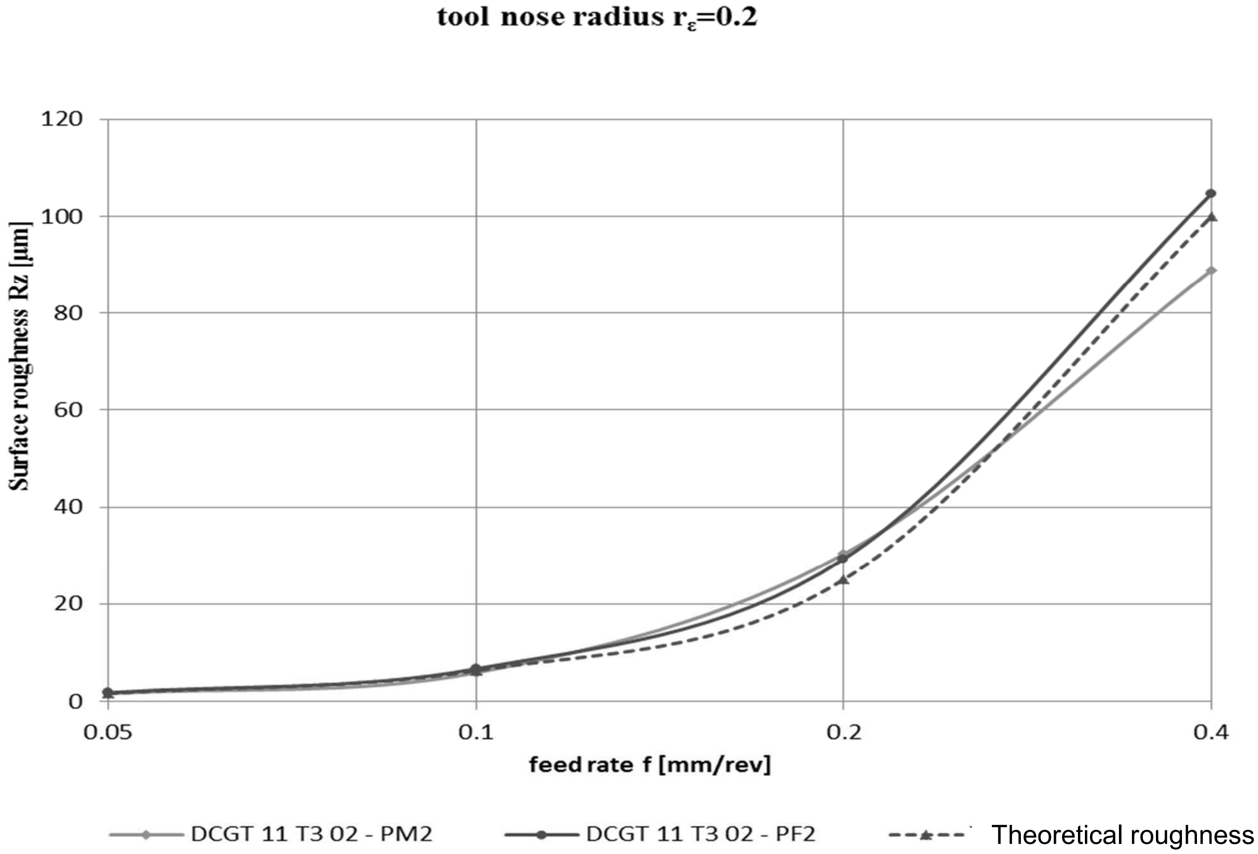


Fig. 5 *Graphical dependence of Rz on feed rate for tool nose radius 0.2 mm*

Graphical dependence (Fig. 4.) of surface roughness parameter Ra on feed rate for tool nose radius rε= 0.2 mm give information about similarity of courses for calculated/theoretical and measured values of surface roughness Ra till 0.1mm. Feed rate 0.1 mm can be consider as bound, because with increasing feed rate were detected that theoretical / expected course of surface roughness Ra than real measured values.

Following graph represent dependence of surface roughness Rz and feed rate f, where theoretical course from the feed rate 0.1 mm to 0.27mm is in lower slope than measured course for both cutting plates, but at feed rate 0.4mm theoretical values of Ra rise more obliquely than course of cutting plate DCGT 11 T3 02-PM2.

Result graph (Fig. 6.) is aimed to comparison of surface roughness parameter Ra for all experimental cutting plates. Comparing feed rates used in experimental part and tool nose radius rε can be state, that both parameters directly influence surface quality. Surface roughness is increasing with rising feed rate, what means quality of surface roughness of machined surface is declining, but set the same cutting conditions the surface quality is higher using cutting tool with bigger tool nose radius. Feed rate 0.1 mm in interaction with used cutting tool with tool nose radius rε = 0.2 mm occur lower quality of machined surface in comparison with cutting plates with radius rε = 0.4 mm for the equal cutting conditions.

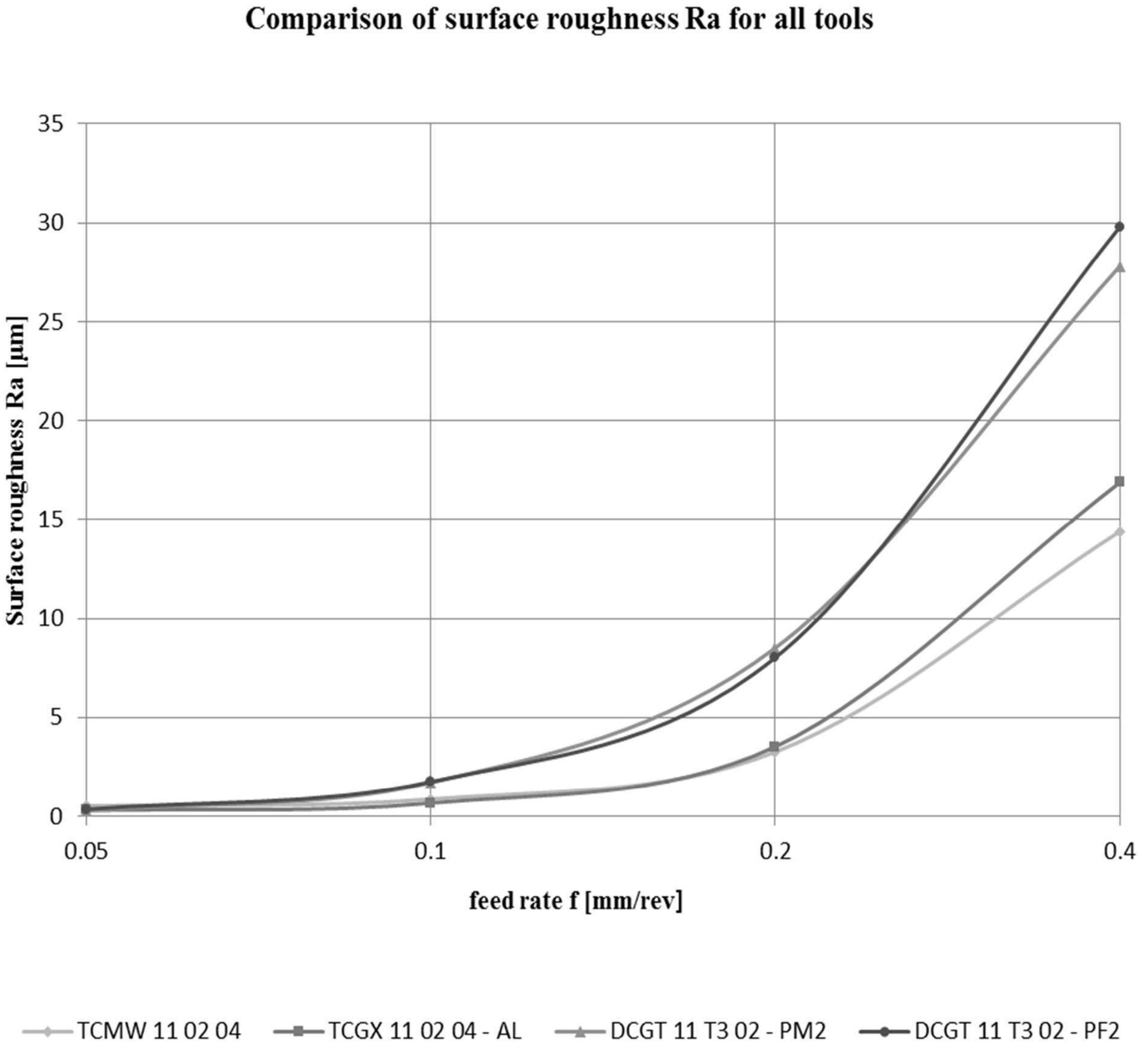


***Fig. 6** Comparison of surface roughness for all used tools*

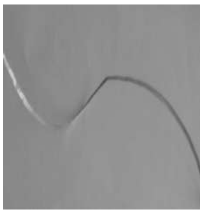
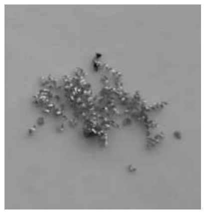
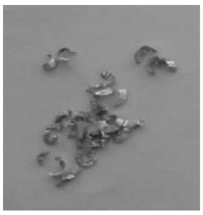
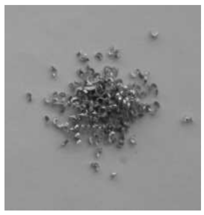
In following table (tab. 6.) are shown shapes of chips at all cutting conditions used in experimental part. As seen on individual pictures almost all kinds of chip shapes were obtained. In general can be stated that small chip refers to better surface quality. It is obvious that shape of chip former is significant for obtained surface quality, not only for shape of chips.

3 Conclusion

Presented article compare different cutting plates used in machining of the same material for various cutting conditions. From the experimental part can be state, that most suitable cutting tool from the sight of surface quality and its selected parameter Ra is cutting plate TCMW 11 04

02 and oppositely cutting plate with worst impact on surface quality was found using plate DCGT 11 T3 02-PF2. Geometry of the cutting plate and tool nose radius are significant factors which affects final surface quality of machined surface.

***Tab. 6** Shape of chips for variable cutting conditions*

Shape of chip				
Feed rate f [mm/rev]	Type of cutting plate			
	TCMW 11 02 04	TCGX 11 02 04 - AL	DCGT 11 T3 02-PM2	DCGT 11 T3 02-PF2
0.05				
0.10				
0.2				
0.4				

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