

## Dependence of Surface Roughness on Depth of Cut for Aluminum Alloy AlCu4Mg1

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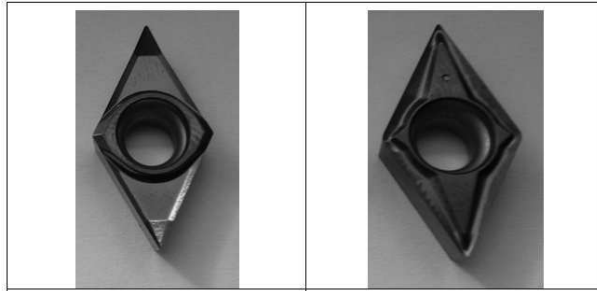
**Presented article is focused on evaluating surface quality parameters Rz and Ra after turning made by various cutting conditions. Monitored parameters in experimental part were feed rate, cutting speed and depth of cut. Researching optimal cutting conditions, which sets often affect and increase productivity, quality and precision of manufactured products. Aim of the article is to increase quality of current state, what require long time testing and experiences. Article also presents individual comparing of two selected cutting plates in various cutting conditions, when in conclusion are clearly define results of experiment and requirement for practical using in industry.**

**Keywords:** Lathe, Roughness, Surface Quality, Cutting Plates

### 1 Theoretical background and experimental part Open this template and delete all texts,

Experimental procedure was realized on CNC lathe Leadwell Twilight series T-5 (Fig. 1), which is intended for manufacturing shafts, flanges and other rotary parts. Control system of used CNC lathe is Fanuc 0i – TC with manual guide. Leadwell Twilight series T-5 is applicable from small series to large series production. Cutting plates, DCGT 11 T3 02 - PM2, DCGT 11 T3 02 - PF2 with adequate holder was set as tool (Tab. 1.). Both of cutting plates has positive geometry [8], [6], [2], [10].

**Tab. 1** Cutting plates used for experimental procedure



**Tab. 2** Chemical composition of the material

%	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Pb
min	-	-	3.8	0.3	1.2	-	-	-	-	-
max	0.5	0.4	4.9	0.9	1.8	0.1	-	0.25	0.1	-

**Tab. 3** Mechanical properties of the material

Rm [MPa]		Rp0.2 [MPa]		A [%]	A50[%]	Hardness [HB]
min	max	min	max			
420	-	270	-	10	8	120

### 2 Dependence of surface quality on depth of cut

Experiment was aimed to observe and evaluate dependence of surface roughness on depth of cut.

Cutting plates used for experiment was with 0.4 mm corner radius. Cutting plates are intended to manufacture



**Fig. 1** CNC lathe Leadwell T-5

Experimental part was realized with chosen material AlCu4Mg1 (EN 2024 T3) also called super Dural (Tab. 2.). Super Dural is structural material used for manufacturing middle and high strained components, which are intended to long lifecycle for various loads or short time heat exposition. Main usage is in area of aircraft industry, railway industry and in automotive industry and in other industries, where technologies of machining are used [1], [3], [5], [9].

aluminum alloys and dispose with two types of chip former. Experimental parts were realized without additional lubricating or cooling [4], [7], [6], [11].

Cutting conditions for experimental procedure were set on values as follows:

- cutting speed  $v_c = 300 \text{ m} \cdot \text{min}^{-1}$

- feed rate per revolution  $f = 0.8$  mm
- depth of cut-  $a_p = 0.5$  mm
  - $a_p = 1$  mm,
  - $a_p = 2$  mm,
  - $a_p = 3$  mm.

Cutting plate used in turning process was used in continual cut process with length 20 mm for each plate individually.

#### Results and analysis of experiment

Values of surface roughness  $R_a$  and  $R_z$  obtained from roughness meter Mitutoyo SJ-400 (Fig. 2.) are in table below (Tab. 4).

Lowest value of surface roughness was achieved with

**Tab. 4** Measured values of  $R_a$  and  $R_z$

	Ra [μm]		Rz [μm]	
Depth of cut ap [mm]	Cutting plate			
	DCGT 11 T3 02 - PM2	DCGT 11 T3 02 - PF2	DCGT 11 T3 02 - PM2	DCGT 11 T3 02 - PF2
0.5	1.12	1.07	4.4	4.7
1	1.17	1.04	4.3	4.4
2	1.09	0.93	4.3	5.5
3	1.03	4.78	4.2	29.8

Graphical dependence (Fig. 3.) of surface roughness on depth of cut is basis for the claim, that cutting plate DCGT 11 T3 02 - PM2 with increasing depth of cut the surface roughness is continually decrease except one occasion in depth of cut  $a_p = 1$  mm was surface roughness measured was more about  $0.05\mu\text{m}$  than at depth of cut  $a_p$

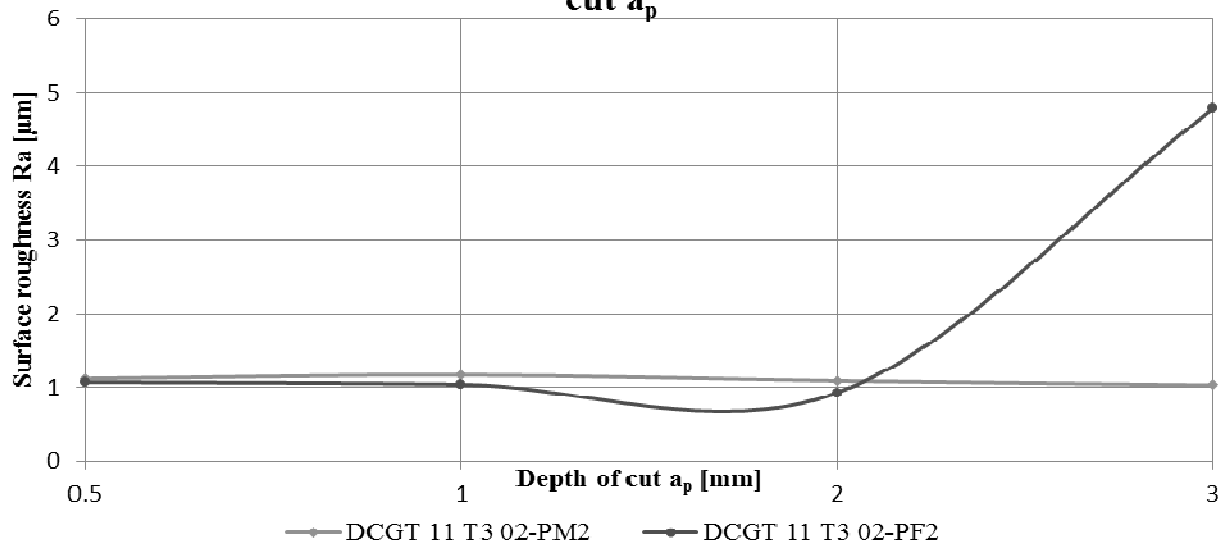
cutting plate provided with chip former PF2 and at depth of cut  $a_p = 2$  mm specifically  $R_a = 0.93\mu\text{m}$ . Oppositely the same plate at depth of cut 3 mm create surface with roughness parameter  $R_a$  on values  $4.78\mu\text{m}$ . Maximum height of surface roughness  $R_z$  was obtained with cutting plate with chip formation PM2, where was obtained lower values with increasing depth of cut (Tab.4.).



**Fig. 2** Measuring experimental parts using Mitutoyo SJ-400

$= 0.5$  mm and more about  $0.07\mu\text{m}$  at depth of cut  $a_p = 2$  mm. Cutting plate, which is designed for finishing operation, obtained at depth of cut  $a_p = 2$  lower values with increasing depth of cut in comparison to cutting plate with chip formation PM2.

#### Graphical dependence of surface roughness $R_a$ on depth of cut $a_p$

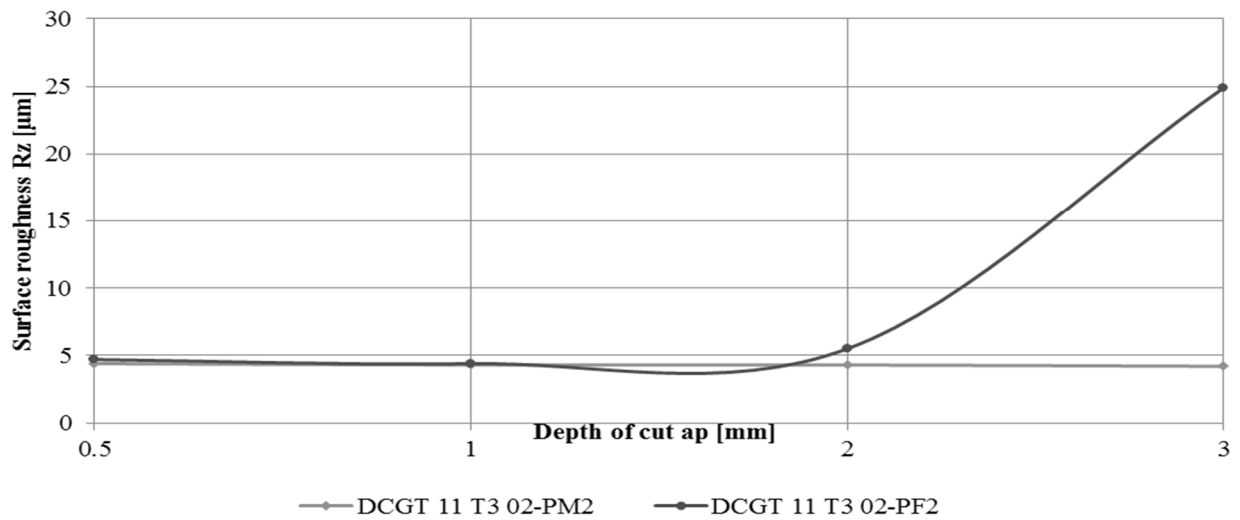


**Fig. 3** Dependence of surface roughness  $R_a$  on depth of cut  $a_p$

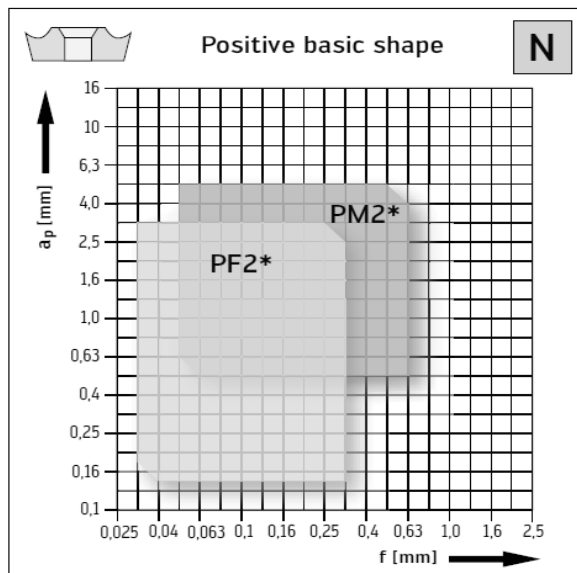
Comparing previous (Fig. 4) occasion with graphical dependence below constructed by measured values of maximal surface roughness of machined surface with cutting tool PF2 obtain higher quality of the monitored surface. Values of maximal height of surface roughness

$R_z$  obtained with cutting plate with chip former PF2 minimally decrease to depth of cut 2 mm on values  $4.7\mu\text{m}$  and depth of cut 2 mm can be consider as boundary condition of qualitative indicator (in this case surface roughness  $R_z$ ).

## Graphical dependence of surface roughness $R_z$ on depth of cut $a_p$



**Fig. 4** Dependence of surface roughness  $R_z$  on depth of cut  $a_p$

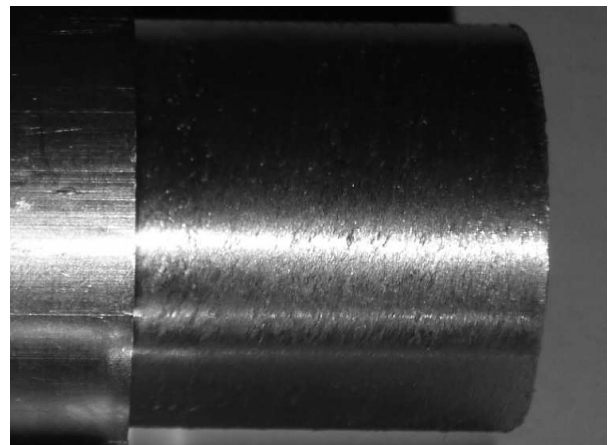


**Fig. 5** Setting of standard cutting conditions

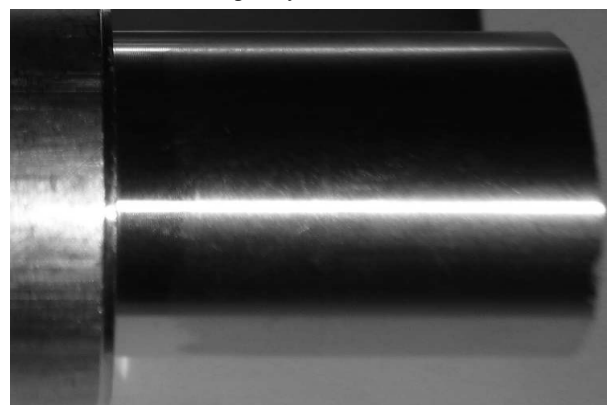
Differences of qualitative character are shown in table follows, where is obvious, that surface roughness at depth of cut  $a_p = 3$  mm is diverse, where can be state, that shape of chip former directly influence surface quality and also possibility of cutting condition sets.

Differences in surface quality can be occurred by experimental conditions (without cooling and lubrication), and also of set of cutting parameters, where cutting plate with chip former PF2 was near to boundary prescribed by producer of plate (Fig. 5).

- Following picture (Fig.6.) shows surface machined with cutting plate DCGT 11 T3 02 - PF2 and cutting conditions as follows:
- Cutting speed  $v_c = 300$  m.min<sup>-1</sup>
- Feed rate  $f = 0.8$  mm/rev
- Depth of cut  $a_p = 3$  mm



**Fig. 6** Surface machined with DCGT 11 T3 02 - PF2 at depth of cut 3 mm



**Fig. 7** Surface machined with DCGT 11 T3 02 - PF2 at depth of cut 3 mm

With listed cutting conditions were obtained values of surface roughness parameters  $R_a = 4.78$  μm and  $R_z = 29.8$  μm. Surface of experimental part is visually scratchy and very rough. Lower surface quality was caused because chip former was not able to remove chip from place

of cutting.

On the other side, as is shown on picture below (Fig. 7.), with same shape of cutting plate equipped with different chip former (DCGT 11 T3 02 - PM2) is surface quality non comparable better. Machined surface is smooth, without visual tracks caused by tool. Surface roughness parameters obtained in this case were  $R_a = 1.03 \mu\text{m}$  and  $R_z = 4.2 \mu\text{m}$ . Experimental sample was machined with cutting conditions which were same as in previous case:

- Cutting speed  $v_c = 300 \text{ m} \cdot \text{min}^{-1}$
- Feed rate  $f = 0.8 \text{ mm/rev}$
- Depth of cut  $a_p = 3 \text{ mm}$

Required prescribed surface roughness was obtained for both plates except of cutting plate DCGT 11 T3 02-PF2 at depth of cut  $a_p = 3 \text{ mm}$ .




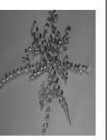

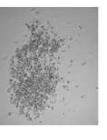
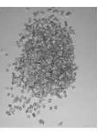

Cutting plate DCGT 11 T3 02-PF2 at depth of cut 0.5 – 1 mm form short helical chip and at higher depth of cut was chip formed into broken chips, what is appropriate and desirable for chip management. Chip management contain unwritten rule, that broken chip point on higher surface quality.

Cutting plate DCGT 11 T3 02-PM2 form heliacal chip, which increasing character with value of set depth of cut and was broken in periodical interval. Chip with longest character was obtained in machining process with depth of cut 2mm, what could occur to tangle of chip on workpiece or tool, what can negatively affect durability of tool, machine and also quality of machined surface (Tab.5.)

### 3 Conclusion

Depth of cut is one of most significant cutting conditions which can affect quality of machined surface and on the other side manufacturing time. This experiment was focused on determining maximal depth of cut at which is surface quality on acceptable level. As shown in the results most of cutting plates are able to maintain balanced surface quality in whole interval prescribed by producer of plates

**Tab. 5 Shape of chips**

Cutting plate	Shape of a chip Depth of cut $a_p$ [mm]			
	0,5	1	2	3
DCGT 11 T3 02-PM2				
DCGT 11 T3 02-PF2				

### Acknowledgement

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### References

- [1] J. ZAJAC, D. MITAL, P. MICHALIK (2014). Verification of process fluids in mass production, in: J. Kundrat, Z. Maros (Eds.), *Precision Machining VII Book series: Key Engineering Materials*, 2014, pp. 554-559.
- [2] I. VOJTKO, V. SIMKULET, P. BARON, et al. (2014). Microstructural Characteristics Investigation of the Chip-Making Process after Machining, in: S. Fabian, T. Krenicky (Eds.), *Operation and Diagnostics of Machines and Production Systems Operational States II book series: Applied Mechanics and Materials*, 2014, pp. 344-350.
- [3] R. CEP, A. JANASEK, J. PETRU, et al. (2014). Surface Roughness after Machining and Influence of Feed Rate on Process, in: J. Kundrat, Z. Maros (Eds.), *Precision Machining VII Book Series: Key Engineering Materials*, 2014, pp. 341-347.
- [4] BOŽEK P, NIKITIN Y, BEZÁK P, FEDORKO G, FABIAN M. (2015). Increasing the production system productivity using inertial navigation in: *MANUFACTURING TECHNOLOGY*. 2015. Vol. 15, No. 3 s. 396 – 403. ISSN 1213-2489
- [5] J. ZIVCAK, M. PETRIK, R. HUDAK, et al. (2009). Embedded Tensile Strength Test Machine FM1000-An Upgrade of Measurement and Control, in: Z. Gosiewski, Z. Kulesza (Eds.), *Mechatronic systems and materials III., Book Series: Solid State Phenomena*, 2009, pp. 657-662.
- [6] J. ZAJAC, D. MITAL, S. RADCHENKO, et al. (2014). Short-term Testing of Cutting Materials Using the Method of Interrupted Cut, in: S. Fabian, T. Krenicky (Eds.), *Operation and Diagnostics of Machines and Production Systems Operational States II book series: Applied Mechanics and Materials*, 2014, pp. 236-243.
- [7] J. KOVAL. Optimization of Cutting Conditions of Turning (*diploma thesis*), 2015.
- [8] PETRU, J. SCHIFFNER, J. ZLAMAL, T. SADILEK, M. STANCEKOVA, D. (2015). Investigations of Cutting Tool Wear While Machining Inconel 718. In *MANUFACTURING TECHNOLOGY*. 2015. Vol. 15, No. 3 s. 396 – 403. ISSN 1213-2489
- [9] S. F. KRAR, A. R. GILL, A. R. SMID (2011). *Technology of Machine Tools*, 7<sup>th</sup> ed., McGraw-Hill, New York, 2011.
- [10] I. MUKHERJEE, P. K. RAY (2006). A review of Optimization Techniques in *Metal Cutting Processes, Computer and Industrial engineering*. 50 (2006) 15-34.
- [11] KOURIL K., CEP R., JANASEK A., KRIZ A., STANCEKOVA D. (2014). Surface Integrity at Reaming Operation by MT3 Head. In: *Manufacturing technology*, Vol. 14, No. 2, pp. 193 – 199, ISSN 1213-2489