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The Research of the Surface Profile after Profiling of Inconel 738LC

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Abstract

Production of so-called superalloys is increasing in the present. This paper is about Inconel 738 LC. There are main mechanical properties as well as chemical composition of Inconel 738 LC in this paper. Special properties of superalloys cause, that they are very hard machining materials, mainly thanks to their high thermal stability during machining. For this reason it was necessary to measure the surface roughness after machining turbine blades made of Inconel 738LC depending on profiling. Roughing and finishing of Inconel 738 LC was used to get nearly the best parameters of the surface roughness.

Keywords: inconel 738 lc; superalloy; milling; machining; roughness

1. Introduction

In the present, as well as in the future is expected to increase production of products made of so-called superalloys. Among the superalloys can be sorted materials such as Inconel, Hastelloy, Waspaloy, Nimonic or Titat. The main advantages of these materials are used in the air industry, in the manufacture of turbines, in the space industry and in manufacturing of components that are working in high temperature. Thanks to its special properties are superalloys very hard machining materials, mainly thanks to their high thermal stability during machining. There is a lot of requests for products made of superalloys. One of the most common request is for surface integrity, mainly for roughness. For this reason it was necessary to design machining experiment and measure the surface

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roughness after machining turbine blades made of Inconel 738LC depending on profiling.

2. Inconel 738 LC

Inconel 738 LC is a high-strength, corrosion-resistant polycrystalline Ni-based superalloy, which is stabilized by coherent precipitates on the basis of A_3B (Ni_3Al, Ni_3AlTi).

It is a modification of a low-carbon alloy Inconel 738. This superalloy is used for the production of high-temperature stressed components in the aerospace and energy industries, mainly thanks to its excellent mechanical properties and structural stability at high temperatures and resistance to oxidation and corrosion. Products made of Inconel 738LC are can operate in temperature up to 750 ° C.

Mechanical properties (at 20°C) are $R_m \geq 927$ MPa, $R_{p0,2} \geq 772$ MPa, $A_5 > 4$ %. Furthermore, the creep characteristics are measured at the temperature of 870 °C. ($R_{mT} \geq 309$ MPa with minimal time to fracture 50 hours). [5]

There is chemical composition of Inconel 738 LC in the table 1.

Table 1. Chemical composition of Inconel 738 LC [7].

Element	C	Mn	Si	Cr	Ti	Al	Fe	B	Zr	Nb	Ta	Mo	W	Co	Cu	P	S	Ni
Min.(%)	0,09			15,7	3,2	3,2		0,007	0,03	0,6	1,5	1,5	2,4	8,0				
Max.(%)	0,13	0,2	0,3	16,3	3,7	3,7	0,35	0,012	0,08	1,1	2,0	2,0	2,8	9,0	0,1	0,01	0,015	rest

Machining of Inconel 738 LC is difficult, technically demanding, especially because of the high temperature of cutting at the edge of the tool, that cause deformation during machining and also increasing wear of tool. Another negative phenomenon in machining of this material is hardening during the mechanical deformation, which makes the vibrations, which also affect the quantity of the tool wear.

3. Experiment

The aim of the experiment is to verify the influence of cutting conditions on the surface roughness of turbine blades made of Inconel 738 LC.

For this experiment was chosen blade marked as BTS-500-085, which contains the geometry of the complex shaped and planar surfaces. The technology used for the production of blades is to produce cast parts using the investment casting and finish this part by machining technologies.

In this experiment it was necessary to define the part of the area to be machined, because of the working range of the instrument is not unlimited. Selected area for machining is irregular quadrangle which is shown in figure 3. The defined area for the experiment is machinable by 3 axes milling [15], where the slope of the surface in the field reaches values of -45 ° to +55 °.

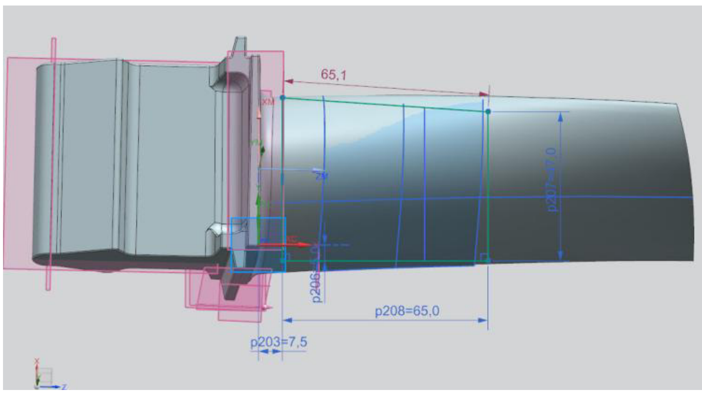
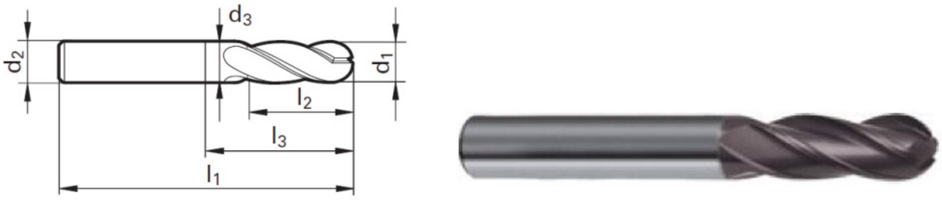


Fig. 1. Machining area.

The experiment was realized on CNC machining center DMG 125 U with the control system Heidenhain TNC 530 at the company PBS Velká Bíteš a.s.. For this experiment the company Gühring recommended tool marked as 6707 CUTTER VHM 4-edges R5 RF100VA 10,000 x72x22 HA10 nanoTiAlN. The tool is equipped with 4 edges with unequal helix with angles of incline 36 ° and 38 ° which improves resistance to vibrations. The tool is created for machining face and perimeter. The tool coat is TiAlN nano-A which is a multilayer coating with increase abrasion resistance.



Size	d1 h10	d2	d3	l1	l2	l3
[mm]	10	10	9.2	72	22	32

Fig. 2. Solid spherical cutter R5 RF100VA.

The experiment was designed by using the methods of designing and evaluation of experiments (DOE) to determine the dependence of the cutting parameters (v_C, f) on the resulting surface roughness parameters. For the whole experiment was selected uniform depth of cut 0,1 mm and a uniform cut direction for all the blades. Each of the blades was marked with the serial number – there were 11 blades used for this experiment. Thanks to the necessary division machining for roughing and finishing were determined cutting parameters for both roughing and finishing. The selected cutting parameters are in the table 2.

Table 2. Cutting parameters of the experiment.

Machining number	Blade number	Roughing			Finishing		
		v_c (m/min)	f_z (mm/zub)	f (mm/min)	v_c (m/min)	f_z (mm/tooth)	f (mm/min)
1	B33206	42,07	0,1	534	42,07	0,1	534
2	B33185	42,07	0,13	700	35	0,1	446
3	B33191	42,07	0,13	700	42,07	0,1	534
4	B33199	42,07	0,13	700	42,07	0,13	696
5	B33200	42,07	0,13	700	37,07	0,12	567
6	B33203	42,07	0,13	700	42,07	0,1	534
7	B33209	42,07	0,13	700	42,07	0,1	534
8	B33210	42,07	0,16	850	42,07	0,1	534
9	B33212	42,07	0,16	850	42,07	0,12	643
10	B33215	42,07	0,16	850	42,07	0,1	534
11	B33217	47,07	0,12	719	37,07	0,08	378
12	B33221	47,07	0,12	719	42,07	0,07	375
13	B33232	47,07	0,12	719	47,07	0,08	479
14	B33237	47,07	0,12	719	49,14	0,1	626

Clamping of the product was carried out by using a clamping device. This setup was partially adjustable by the range of motion clamping screws which is shown in the following picture of the clamping device.

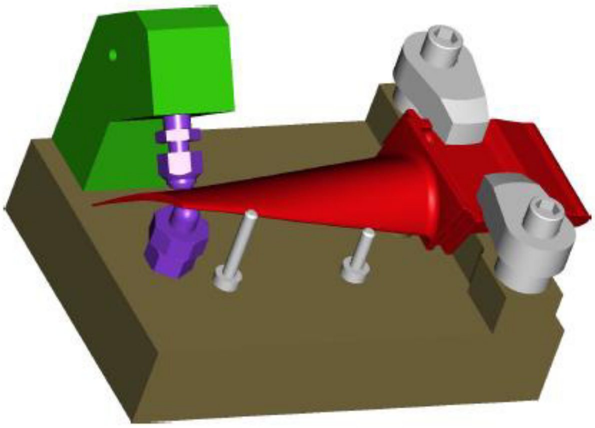


Fig. 3. Model of the clamping device.

There was appeared that the strength of clamping blades is insufficient, during the machining. During the clamping the deformation had appeared. This fact caused that the blade was distorted by clamping forces and that is why its dimensions were again changed against to the theoretical model and the measured values. It was also necessary to create a high clamping force that caused deformation of the clamping device of the blade in the place of the clamping screw. At this point, due to the deformation of the blades occur that a force in the clamping screw did not operate directly against the contact screw. So there was the overturning moment, which is responsible for the deformation. Despite the efforts to solid clamp there appeared vibrations and also occasional judder of the tool mainly during the roughing with a variable depth of cut. Vibrations also appeared during the machining in the areas with a high gradient of the tool to the surface, which formed chipping and damaged surface on the surface of the workpiece. This problem is shown in the following figure 4.

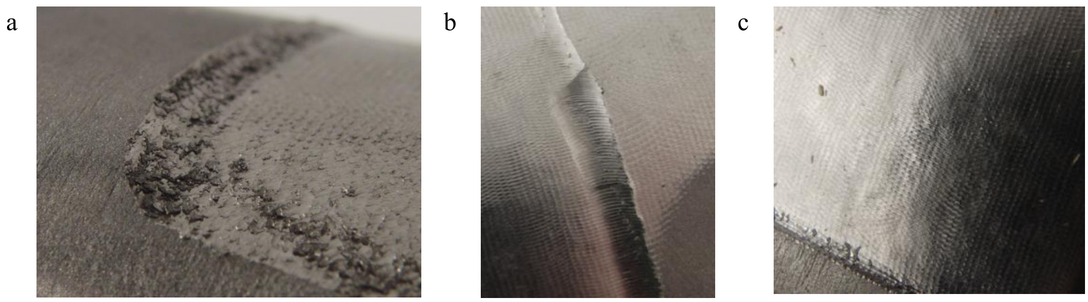


Fig. 4. (a) Surface defects, (b) Imperfect surface structure, (c) Surface structure.

For clamping of the solid spherical cutter Guhring R5 RF100VA were used collet chuck with collet type ER made by company Seco. Machining showed that these clamps are unsatisfied for its strength of clamping, because it caused slippage of the tool in the clamping tool and gradually inserting of the tool into the chuck. This insertion was demonstrated by step changes in depth of cut and so the steps after machining on the blades. But thanks to the possibility of tool movement may also the tool moved into the material. Changing the depth of cut is shown in the following figure 4.

Large cutting forces and possible imperfections in the tool clamping is also reflected in the smoothness of the surface. There is finished surface of the blade in the figure 4, where you can see the structure of imperfect machining. This structure was evident on all machined blades.

4. Results

Measurement of surface roughness parameters was carried out on Profilemeter MAHR MarSurf XCR 20 equipped with a drive unit PGK and sensor MFW-250 tracing arm 6851805 (Figure 5). Calibration was carried out by using the caliber MAHR W-Nr: 11416/03 with the filter selected λC = 0.8 μm with a deviation of 4.8% (Figure 5).

a b

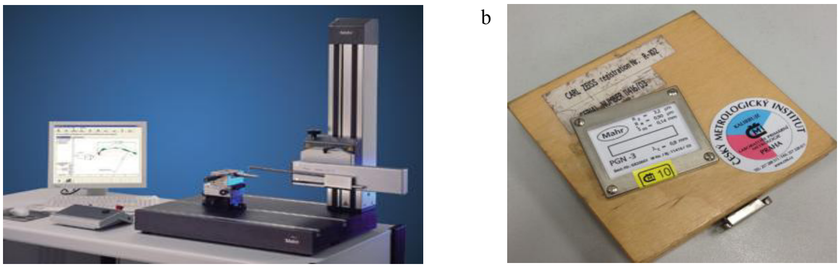


Fig. 5. (a) MAHR MarSurf XCR 20, (b) Caliber MAHR W-Nr: 11416/03.

There were measured parameters of surface roughness [14] on a total of 11 blades cast from Inconel 738 LC, which were then machined by different cutting parameters (table 2), in this experiment. Parameters of surface roughness were measured on each of the blades in three section in the cutting direction (Figure 6).

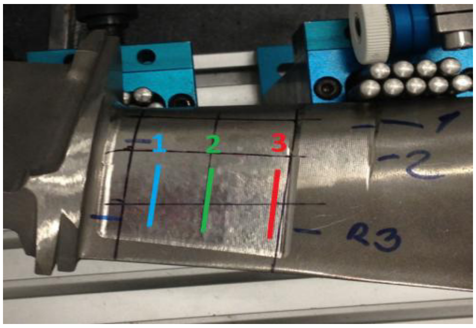


Fig. 6. Sections of the measurement.

Results of measurement of the parameters of surface roughness on machined blades are shown in table 4.

Table 4. Results of measurement.

Blade	Number	Ra [μm]		
		Section 1	Section 2	Section 3
1	B33206	0,917	0,668	0,449
3	B33191	0,876	0,972	0,372
4	B33199	1,126	1,144	1,502
5	B33200	1,335	1,454	0,599
6	B33203	1,32	0,963	0,542
7	B33209	2,433	2,415	2,341
8	B33210	0,712	1,174	0,818
9	B33212	1,279	1,451	1,121
10	B33215	1,427	1,084	1,336
11	B33217	0,782	1,145	1,391
14	B33237	1,375	2,861	2,082

5. Conclusion

Superalloys are used for their special mechanical properties in the air industry, in the manufacture of turbines, in the space industry and for production components working in high temperature. Thanks to increasing production of superalloys components there have appeared a lot of requests for these products. The most common request is for surface integrity, mainly for roughness. For this reason it was necessary to design machining experiment and measure the surface roughness after machining turbine blades made of Inconel 738LC depending on profiling. There were 11 measurements made after designed machining experiment. Thanks to measurement of surface roughness parameters of experimental blades we appeared that, there is not clear relation between cutting parameters and surface roughness. This fact may be caused by both improper clamping of the experimental samples and insufficient clamping of the tool.

Although there was made a device for clamping samples its rigidity was insufficient. For further experiments I would like to suggest suitable rigid fixture. Insufficiently rigid clamping of the tool with collets can be removed using hydraulic clamping tools or using a thermal chuck tools.

Despite the great variability of the results, it was possible to identify the impact of the angle of the tool to the workpiece. The most appropriate angle seems to be an angle of 27 °, which has been observed thanks to the used 3-axes machining of the experimental blades.

For the next research it is necessary to ensure enough strong clamping of the experimental samples and enough rigid clamping of the machining tool. After determining relation between cutting parameters and surface roughness will be machined prototype of the turbine blade (achieve with the best surface properties). The research of stress inside the turbine blade after machining will be realized.

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