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MEASUREMENT OF FORCE COMPONENTS AND Ra SURFACE ROUGHNESS PARAMETER DURING GRINDING TITANIUM ALLOY

ABSTRACT

The paper deals with the measurements of selected parameters during grinding process of aerospace industry alloy. Grinding is one of the most important methods of shaping machine elements. As a result of grinding with high dimensional and shape accuracy as well as with the expected parameters describing the state of the surface layer (SL) should be obtained. Grinding difficult to machine materials used in the aerospace industry is an issue currently being examined by various research centres. An excellent example is the analysis of the grinding process of titanium alloys, as these materials have very poor machinability due to the tendency to adherence to abrasive materials, low thermal conductivity, high strength and compliance at elevated temperatures, which may adversely impact on the quality of SL. A number of factors influence on shaping SL. Worth mentioning are mechanical and thermal phenomena, as well as the type of cutting fluid and abrasive materials.

Keywords: grinding, titanium alloys, grinding forces, roughness parameter, abrasive materials

INTRODUCTION

Grinding process of titanium alloys was carried out with the usage of bonded abrasive tools. Among the grinding wheels used for machining difficult-to-machine alloys, inter alia wheels made of the following materials should be mentioned: aloxite, microcrystalline sintered aloxite, cBN or grinding wheels with Quantum grains. Other parameters defining the abrasive materials, including grain size, its hardness, structure or the type of binder are also important [1-6]. Grinding without cutting fluid carries with it negative consequences such as the increased cutting forces, higher grinding temperatures and shortening sustainability of the grinding wheel. The problem of high temperature generated in the contact zone between the grinding wheel and the sample, can be reduced by applying suitable cooling methods. Selection of abrasive materials, machining parameters and cooling methods is essential due to the temperatures generated in the treatment zone [7,8].

MATERIAL

Titanium alloy Tigr5 was selected for the experiments. It has good tensile properties at ambient temperature and a useful creep resistance up to 300°C. Its resistance to fatigue and crack propagation is excellent. Like most titanium alloys, Tigr 5 has outstanding resistance to corrosion in most natural and many industrial process environments. Chemical composition of workpiece material is presented in Table 1.

Table 1. Chemical composition of titanium alloy Tigr 5, wt. %

H	N	C	O	Fe	V	Al	Ti
0.015	0.05	0.08	0.20	0.40	3.5-4.5	5.50-6.75	bal.

MACHINING ARRANGEMENTS

Conducted research aimed to determine the effect of the abrasive on the state of the surface layer (surface roughness parameter Ra and the grinding force components F_n and F_t) during dry grinding and with the use of cutting liquids (Emulgol ES-12 and BioCut) of flat samples made of titanium alloy Tigr 5.

Investigations were held by means of experimental stand with the basic devices presented schematically in Fig. 1.

Fig. 1. Test bench model

The research was carried out on a grinding machine type SPD-30, with the use of two types of grinding wheels having the following designations: 99A 46J 8VTE10 and 5NQ 54K VQN.

The scope of study attempts consisted of grinding flat samples made of titanium alloy with dimensions 100x10x10 mm using the above-mentioned grinding wheels. The grinding process was carried out at a constant cutting $v_s = 20$ m/s, a constant feed rate $v_w = 0.2$ m/s, and a constant grinding depth $a_p = 0.02$ mm. To assess the grinding process, F_n , F_t forces and the Ra surface roughness parameter were measured. After each grinding process the grinding wheel was dressed with the following parameters: a dresser- single grainy diamond, depth of dressing- $a_d = 0,02$ mm, and feed speed dressing $f_d = 0,18$ mm/rot. The exceptions were the studies presented in the Fig. 4. During the eight trials of grinding process the grinding wheel

was not subjected to the process of regeneration. The study were aimed in order to examine the possibility of self-sharpening grinding wheels made of different abrasive materials and the impact of the self-sharpening process on the selected properties of the surface layer.

Measurement of grinding force components was performed using piezoelectric dynamometer produced by Kistler, wherein the measurement of the force is based on the piezoelectric effect. Registration of the results was held with a sampling frequency of 1000 Hz.

Measurement of 2D surface roughness parameters were carried out using surface roughness tester produced by Hommel Company, model T500. Due to its small size and mobility, it was applied directly on the machine immediately after the grinding process.

RESULTS

Conducted research aimed to determine the influence of the type of cooling lubricant and the method of its feeding on the grinding forces. Fig. 2 and 3 show the mean values of normal F_n and tangential F_t forces obtained during the subsequent grinding tests without coolant and with the use of the cooling lubricant: Emulgol ES-12 or BioCut. The test results showed that, for the grinding process assumed parameters, the values of tangential force F_t and normal F_n changed in the measurement error (not exceeding 5 %), depending on the applied cutting fluid.

Fig. 2. Mean values of grinding forces depending on the applied cutting fluid; aloxite grain

Fig. 3. Mean values of grinding forces depending on the applied cutting fluid; Quantum grain

In the following experimental studies attention was paid to change in the surface roughness parameter, depending on the type of abrasive and impact of gumming up level of the grinding wheel. Eight grinding tests were carried out with the same grinding parameters conditions. Fig. 4 shows the average values of surface roughness Ra after grinding with abrasive of precious aloxite and Quantum.

Fig. 4. The average value of the parameter Ra measured in 8 consecutive grinding trials

While analyzing the diagram presented in Fig. 4 possible to unambiguously concluded that during grinding titanium alloy Tigr5 with the use of new generation grinding wheel 5NQ54KVQN lower values of the parameter of surface roughness were obtained in comparison to the abrasive tools made of aloxite.

During the research Ra surface roughness parameter was measured. On the basis of the results presented in the Fig.4 it can be clearly stated that after further attempts by means of the grinding wheel made of aloxite grain the surface roughness of the sample was deteriorated. During grinding using the Quantum abrasive self-sharpening process was observed. As a result of that process, a better surface roughness of the sample was observed.

The value of surface roughness parameter differed according to the type of grinding wheel. During grinding with aloxite abrasive Ra parameter ranged between= 0.67 μm to Ra= 0.84 μm. However, for Quantum the Ra range was from = 0.53 μm to Ra = 0.64 μm.

Moreover, during the investigations the impact of the different cutting fluid on surface roughness was verified. Ra parameter was measured according to the type of grain and applied cooling lubricant. Fig. 5 and 6 present the Ra parameter registered during grinding by means of two different grinding wheels. During dry grinding the highest Ra parameter was registered. The best cooling method was flooding. During that tests the lowest Ra parameter was observed. According to the type of the abrasive grains roughness comparison was made. In each case, i.e. by using different cooling methods of the sample surface, a lower surface roughness was obtained during grinding with Quantum abrasive.

Fig. 5. Average values of Ra parameter for aloxite grain

Fig. 6. Average values of Ra parameter for Quantum grain

CONCLUSIONS

Grinding difficult to machine materials applied in the aerospace industry is an issue which now is devoted a lot of attention because these materials due to its characteristics play an increasingly greater role in aeronautics. Depending on the cooling lubricant can get different values of cutting forces. The value of the parameter Ra also depends on the fluid cooling. Examined parameters also vary depending on the used abrasive grains. However, this is subject that needs more investigation. Further research will emerge the most optimum cutting conditions, with the consideration of the best cooling lubricant, the type of the grinding wheel and grinding process input parameters.

REFERENCES

1. Oczó K., Pokrzycki J.: Grinding. Basics and Technique [in Polish], WNT Warszawa 1986.
2. Łaskawiec J., Michalik R.: Theoretical and application backgrounds in implants [in Polish], Gliwice 2002.
3. Melechow R., Tubielewicz K., Błaszczuk W.: Titanium and its alloys: species, properties, applications, processing technology, degradation [in Polish], The monograph, 107, Czestochowa University of Technology, 2004.
4. Grdulska A.: Examination of the temperature distribution in the cutting zone of magnesium and titanium alloys, M.Sc. Thesis, Technical University of Łódź (2012).
5. Oczó K.: Increasing the efficiency of cutting process of titanium alloys [in Polish], *Mechanik*, 10 (2003).
6. Grdulska A., Rosik R.: The influence of the abrasive material on the condition of the surface layer during the grinding titanium alloys [in Polish], *Mechanik*, 8-9, (2013).
7. Sadeghi M. H., Haddad M. J., Tawakoli T., Emami M.: Minimal quantity lubrication-MQL in grinding of Ti-6Al-4V titanium alloy, *Int. J. Adv. Manuf. Technol.* 44 (2009).
8. Ezugwu E.O., Da Silva R.B., Bonney J., Machad A. R.: Evaluation of the performance of CBN tools when turning Ti-6Al-4V alloy with high pressure coolant supplies, *International Journal of Machine Tools & Manufacture* 45 (2005).