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DESIGNATION OF THE MINIMUM THICKNESS OF MACHINED LAYER FOR THE MILLING PROCESS OF DURALUMIN PA6

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Abstract: *This article is to present the result of experimental research concerning measurements of the minimum thickness of machined layer to initiate the end milling process of duralumin PA6. The research was conducted in two stages at the laboratories of the Kielce University of Technology. The research required performance of machining tests that involved initiation of the milling process. The gradual initiation of the milling process was achieved thanks to a flowing change of machining depth by tilting the working surface of samples at a slight angle (Fig. 1). The designation of the minimum thickness of machined layer was implemented with the use of a 2D profile that represented the initiation zone of the machining process, which was achieved by measuring the working surface of samples with a skidless contact profilometer TOPO 01P. The results of experiments concerning the impact of feed and cutting speed on the value of the minimum thickness of machined layer have been presented in form of charts. Machining tests were conducted at a numerically controlled machining center AVIA VMC 800 with a milling head CoroMill 490 manufactured by Sandvik Coromant.*

Keywords: End milling, Minimum thickness of machined layer, Feed, Cutting speed.

1. Introduction

The parameter determining the beginning of the material separation process is the minimum thickness of the machined layer (h_{min}), which is the smallest possible layer of material that can be removed under particular conditions. Depending on the thickness of machined layer within the machining zone, one may distinguish three stages of impact of the cutting edge on the machined material (Nowakowski et al., 2016):

- I – when $a_p < h_{min}$: there are elastic deflections and malleable pressure of the treated material,
- II – when $a_p \approx h_{min}$: there are elastic and malleable deflections with partial cutting of the treated material,
- III – when $a_p > h_{min}$: beginning of removing the material in form of shavings.

When the minimum thickness of the machined layer is known, it is possible to achieve additional optimization and low vibrations (Błasiak, 2016) of the end milling process conducted with a very high feed on the cutting blade and little depth of cut, resulting in the effect of thinning of chips. The milling process with high cutting speeds would allow more efficient and accurate machining of precision machine parts (Adamczak et al., 2016), i.e. engine parts (Ambrozik et al., 2014), precision valves (Takosoglu, 2016), (Chatys and Polyakov, 2013), non-contact face seals (Blasiak and Zahorulko, 2016), (Blasiak et al., 2014) and water jet machines (Krajcarz, 2014), (Krajcarz and Spadło, 2016). A large impact on the value of the minimum thickness will be caused by the actual geometry of the cutting edge, which is not perfect under realistic conditions (Grzesik et al., 2005), (Depczyński et al., 2016), (Bochnia, 2012) it has some losses and has a rounding with a radius r_n resulting from the method of performance (Miko, 2005), (Nowakowski and Wijas, 2016). The aim of the scientific research was to determine the value of the minimum thickness of the machined layer for the process of end milling of duralumin PA6.

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2. Methods

The subject of the research was to designate the minimum thickness of the machined layer for the milling process of duralumin PA6 in the function of variable feed and cutting speed. On the basis of the literature and the current own research, it was decided that the most relevant programme of experimental research would be the statistical determined and selective univariate programme PS/DS-U. The variable factors were feed pre tooth and cutting speed v_c. Parameters of processing were selected according to instructions of the manufacturer, bearing in mind the machined material. The machining parameters have been presented on the Fig. 3.

The material selected for the tests of machining was a material that is frequently used in industry, duralumin PA6. A cuboid sample was placed on the track at a known angle and it was fixed in a vise Bison Bial 6620 (Fig. 1b). The face surface of the sample, on which the milling process was planned, was grinded on a surface grinder JOTES SPC 20b, with a disc 250 x 25 x 76 mm 99A 60K7 VE01-35 and with a cutting speed of v_c = 30 m/s. Due to the accuracy of the image of the phenomenon, it is advantageous when the face surface of the sample is made with roughness that is smaller by an order of magnitude from the smallest roughness possible to be obtained by machining with the analyzed tool. Before starting the machining test with the subject probe and measurement cycle, the angle of the sample was determined according to Fig. 1a.

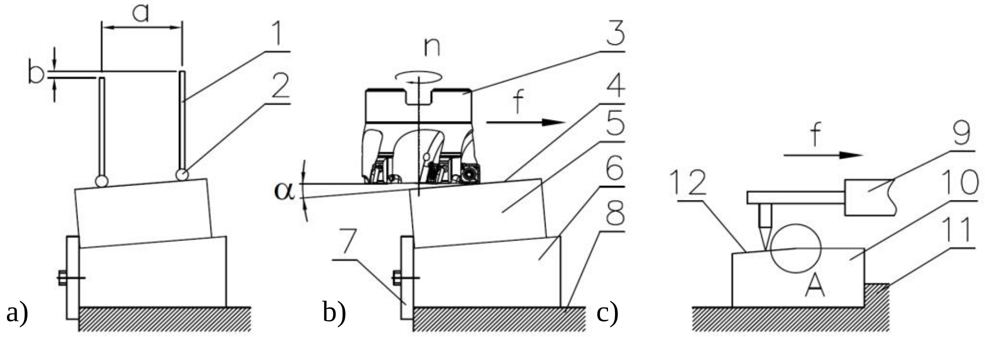

Fig. 1: a) Designation of the angle of sample α; b) Machining test; c) Measurement of the sample with a profilometer. 1 – stylus of the subject probe TS640, 2 – ruby ball with a radius of 5 mm, 3 – tool , 4 – grinded surface of the sample, 5 – sample, 6 – tilted track, 7 – bumper, 8 – vise, 9 – head of the profilometer, 10 – measured sample, 11 – grip of the profilometer, 12 – machined surface, A – initiation zone for the milling process f – feed, n – rotations of the tool, a – distance of measurement points, b – difference in height.

Machining tests were conducted at a CNC machine AVIA VMC800 with end mill CoroMill 490–050Q22–08M with one plate 490–08T308M–PL –1030. Directly after the machining test, the sample was placed at the bench of the profilometer and the head surface was subjected to an analysis within the initiation area of the machining process, as a result of which the profile of the surface, presented in Fig. 2, was obtained.

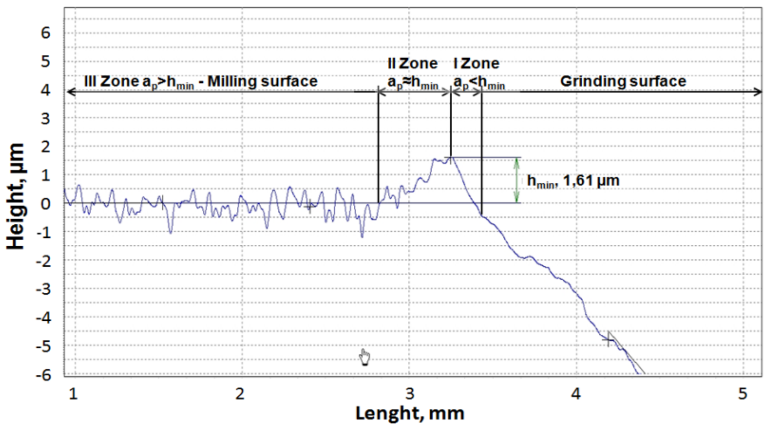

Fig. 2: View of the measured 2D profile of the working surface of the milled sample: v_c = 280 m/min, f_z = 0.1 mm/tooth.

3. Results

As a result of conducted research, the impact of the cutting speed v_c and the feed on the cutting edge f_z on the minimum value of the machined layer h_{min} of duralumin PA6. The results of research have been presented in form of a chart representing the course of changes in h_{min} depending on the feed on the cutting edge and the cutting speed.

Fig. 3 has presented the results of measurements of h_{min} for duralumin PA6. When considering the impact of the feed on the cutting edge f_z on the minimum thickness of the machined layer, it was observed that in the initial stage, along with the increase of the feed (0.02 ÷ 0.08 mm/tooth), the minimum thickness of the machined layer increased gradually. Within the range 0.08 ÷ 0.16 mm/tooth, the parameter h_{min} oscillated around the value of 2 μm and after further increase of cutting speed there was only a gradual decrease of the minimum value of thickness of the machined layer. In order to determine the course of changes of the parameter h_{min}, the chart includes a line of the tendency which shows that along with the increase of the feed on the cutting edge, the value of the parameter h_{min} reflects an increasing tendency.

Fig. 3 has also presented the influence of the cutting speed on the minimum value of thickness of the machined layer h_{min}. When analyzing the chart presented in Fig. 3, it has been determined that in the initial stage, the increase of cutting speed v_c caused a rapid decrease of the value of the parameter h_{min}. Another increase of the parameter h_{min} was observed after exceeding the cutting speed of 220 m/min. The increasing tendency maintained up to the cutting speed of 260 m/min. The further increase of the cutting speed caused, alternately, an increase and decrease of h_{min}, until v_c = 380 m/min, in case of which there was a decrease of h_{min}.

The general impact of cutting speed v_c on the value of the minimum thickness of machined layer h_{min} has been represented by the trend line introduced in the chart. It might be noticed that there has been a slight decreasing tendency.

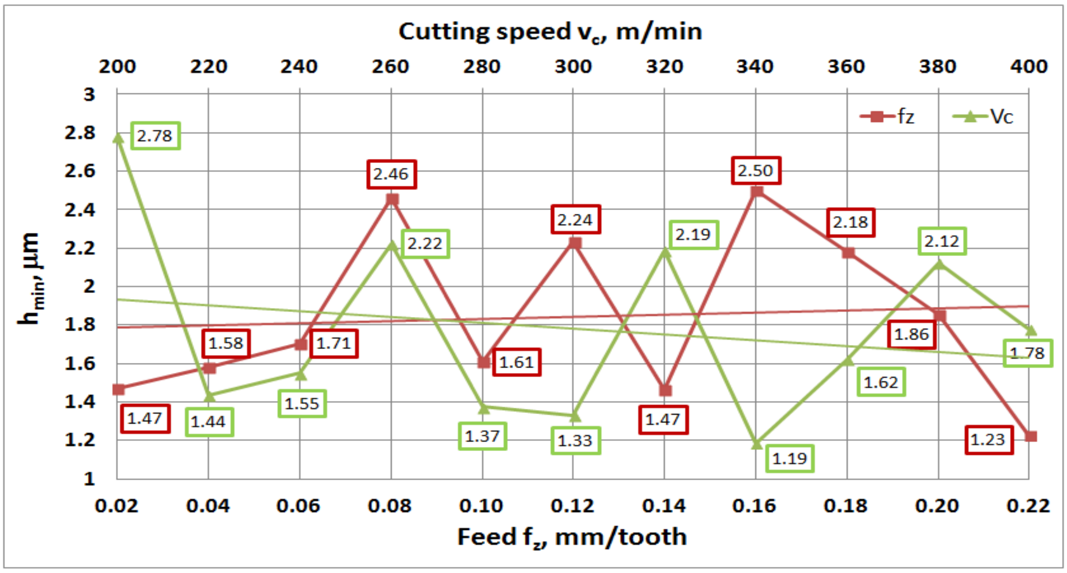

Fig. 3: Results of measurements of the parameter h_{min} for duralumin PA6.

4. Conclusions

The conducted research concerning initiation of the end milling process of duralumin PA6 allowed designation of the impact of feed of the cutting edge and the cutting speed on the minimum value of thickness of the machined layer, as well as allowed formulation of the following conclusions:

1. The use of a skidless profilometer enables a direct and indirect designation of the minimum thickness of the machined layer; it allows measuring of the angle of the working surface of the sample. The high resolution of the measurement system facilitates interpretation and identification of areas where the tool had impact on the surface of the machined sample, which enables an easy measurement of their length.

2. The minimum value of thickness of the machined surface during the milling process of duralumin depends on the value of feed and cutting speed.
3. In the case of small feed values, the increase of the feed value on the cutting edge from 0.02 to 0.08 mm/cutting edge caused an increase of the parameter of the minimum thickness of machined layer from h_{min}=1.147 µm to 2.46 µm. Within the range of feeding rate of 0.08 to 0.16 mm/cutting edge, the increase of the feeding rate caused an oscillation h_{min} within the range 1.47 ÷ 2.5 µm. In the case of feed per tooht above 0.16 mm/cutting edge, the value h_{min} decreased along with the increase of the feed, reaching the lowest value of 1.23 µm for f_z = 0.22 mm/tooth.
4. When taking into consideration the overall impact of feed on the cutting edge on the minimum thickness of the machined layer, a growing tendency has been observed.
5. Cutting speed has an advantageous impact on the parameter h_{min}. Along with the increase of the cutting speed value, it has been observed that there is a decreasing tendency of the minimum thickness parameter of the machined layer. The lowest value of the parameter h_{min} has been noted for the cutting speed equal to 380 m/min, that is the value of 1.19 µm.
6. Equipping the milling head with a cutting plate allowed elimination of axial and radial run-out of the cutting edges, which could have affected the results of measurements. There is a necessity of conducting further research that would include the influence of errors concerning setting of edges in the milling head on the parameter $h_{min.}$
7. The results obtained and presented in the article might be used in models to predict the roughness of milled surfaces.

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