Roghness of Machined Surfaces in the Technology of Broaching Inner Shaped Contours

Jozef Martinovič[1], Jozef Peterka[2,*]

Abstract: *This paer provides information on research on the technology of broaching of the internal shaped surfaces. This paper provides information on the research on the technology of stretching of internal shaped surfaces. It is a technology that is used in mass production. Our research was focused on machining of internal surfaces. The difficulty of the research was that it involved internal shaped complex surfaces called grooves. At the same time, the research was carried out under mass production conditions. Another problem is that in broaching, low cutting speed is used and therefore oil is commonly used as the cutting medium. The test specimens were intended for further use in assembly. The effect of changing the cutting medium on the roughness of the machined surface of the newly formed grooves was investigated. The experimental conditions consisted of obtaining data directly from a real production broaching process. Real production conditions were used and the type of cutting medium was varied. So far, oil has been used. Our intervention was to replace the oil with an emulsion. The research hypothesis was based on the fact that if, with sufficient lubricating properties of the emulsion used, the machining process will be satisfactory in terms of the prescribed surface roughness, then considerable financial costs will be saved for this process. The paper documents the occurrences for the roughness of machined grooves as a function of the change in cutting fluids.*

Keywords: *broaching, broaching tool, surface, roughness*

1 INTRODUCTION

Broaching machines perform a rectilinear movement. The tool for broaching is a mandrel. The broaching mandrels have more teeth, the last teeth are shaped to the desired shape of the machined area. Broaching mandrels are manufactured with high precision and quality of cutting surfaces and therefore also ensure high accuracy of machined surfaces. The force required for the broaching operation, i.e. the force on the broaching mandrel is the sum of the forces of all the teeth [1].

The workpiece is centred with the broaching tool directly on the broaching machine. The broaching machine performs a straight line movement with the broaching mandrel. When broaching, we have only this one movement and its speed is the main cutting speed, which we call "v_c". We do not have secondary movements during broaching or the secondary movements - feed and feed - are determined by the design of the broaching mandrel [2]. Overstretching usually produces surfaces of the desired final shapes, dimensions, tolerances and roughness. This is because the cutting teeth gradually remove a small chip and each tooth creates a new intermediate shape until the final desired shape of the workpiece surface is achieved. But often different workpieces after broaching technology go for further processing usually heat treatment or induction hardening operations [3]. Broaching mandrels, because of the large number of cutting teeth, are rod-shaped and tend to be sufficiently long. The cutting teeth represent [4] a cutting tool with multiple cutting edges [5]. The advantage with this technology is that the desired final shape of the workpiece can be created with only one movement of the broaching mandrel through the blank [6].

The materials used for the production of broaching mandrels are mainly high-speed steel, or sometimes also sintered carbides. It is common practice to use coated broaching mandrels. The choice of material and coating directly influences the lifetime of the broaching tools and thus the efficiency of the broaching process.

Knowledge from tribology and tribotechnics is generally used in broaching processes [7]. The illustration of the principle of the technology of broaching of internal contoured surfaces is shown in Figure 1.

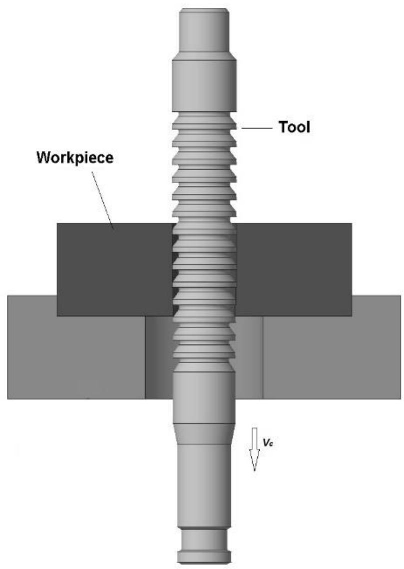

Fig. 1. Representation of the principle of broaching internal contoured surfaces
v_c – vektor of the main cutting speed

2 THEORETICAL ANALYSIS

There are currently two directions in which new surfaces are emerging in production technologies. The new technologies are the so-called additive technologies [8] and the older well-known and tested ones are the take-off technologies - (machining) [1, 2, 3]. In our paper we will focus on machining technology. This technology, in terms of the precise mathematical definition of the cutting edge(s), can be divided into defined cutting edge and undefined cutting edge machining methods. The methods with a defined cutting edge include milling [9], turning, boring [10], drilling but also broaching. Methods with an undefined cutting edge include polishing, grinding [11], honing, superfinishing.

The theory of machining knows four physical causes of the formation of the machined surface. They are: 1. the shape of the cutting edge, 2. the roughness of the cutting edge, 3. BUE (Built Upo Edge) and 4. the vibrationsr. All four causes contribute their share to the resulting roughness of the machined surface. This shape is copied into the surface of the workpiece and creates a new roughness profile of the machined surface. In various literature sources, e.g. [1, 2, 3] and many others, equations for calculating the theoretical roughness of the machined surfaces can be found. Mostly these are equations for turning technology, where this topic is most elaborated. Applying the broaching technique, Figure 1, and considering the four causes of roughness of the machined surface mentioned above, it is evident that the cutting edge roughness and possibly the occurrence of BUE have the greatest influence on the occurrence of roughness in this case.

Based on this reasoning, we can write that:

$$Rz_{surface} = Rz_{cutting\ edge} \quad (1)$$

where

$Rz_{surface}$ is the roughness of the machined surface,
$Rz_{cutting\ edge}$ is the roughness of the cutting edge.

The broaching technology is characterised by the use of very low cutting speeds of the broaching mandrel. At low cutting speeds, BUEs are likely to occur. In order to prevent the formation of BUE, intensive lubrication of the broaching mandrel is necessary. Intensive lubrication between the cutting wedges and the cutting surfaces of the workpiece will cause a reduction in friction. By reducing friction, less heat is generated and thus no BUE is generated. Lubrication in this case is provided by cutting oils. In contrast, cutting oils represent a high cost item in broaching technology. Our intervention was to replace the oil with an emulsion. The research hypothesis was that if, with sufficient lubricating properties of the emulsion used, the machining process will be satisfactory in terms of the prescribed surface roughness, then considerable financial costs will be saved for this process.

3 EXPERIMENTS

3.1 'In situ' Experiments

The experiments were carried out under the conditions of real production of internal shape-complexed surfaces. The cutting medium was varied and the achieved roughness of the machined internal groove surfaces was carefully measured. The cutting fluid has the task, among other things, to prolong the life of the cutting tool [12], the broaching mandrel. The cutting fluid also contributes to the preservation of the machined surface and thus prevents its corrosion. A very important positive benefit of using cutting fluid is the reduction of the thermal load on the machined surface as well. The experimental conditions took into account the production process in a real production plant. Production production machines, tools and real workpieces were used. The experimental conditions were based on the definition of the machine tool, the broaching mandrel, the cutting speed and the three types of cutting fluids.

The workpiece chosen was the so-called idler ring Fig. 2. This is housed in a stator. The workpiece material used is C45 steel. The prescribed surface roughness after broaching is Rz25.

Fig. 2. Test workpiece before broaching of internal contoured surfaces

The broaching machine works in automated mode, it has hydraulic movements. Example of broaching tools is shown in the Figure 3.

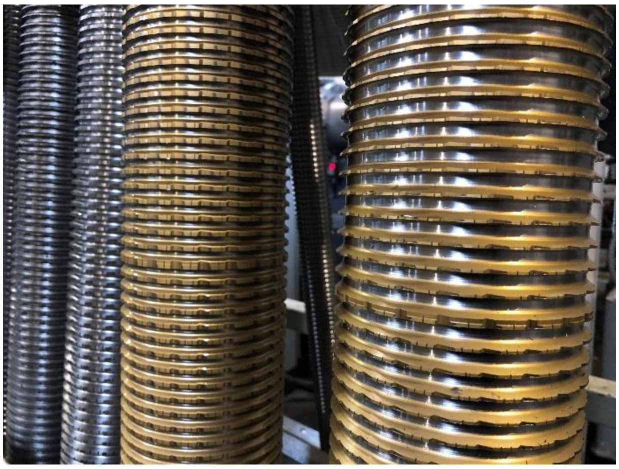

Fig. 3. Broaching tools

Table 1. Cutting conditions for broaching tests

Broaching machine	7B66
Length of the broaching mandrel - L_{bm}	1100 mm
Main cutting speed - v_c	2,5 m/min
Workpiece material	C45
Measuring device	MarSurf XCR20

Figure 4 shows the situation of measuring the roughness of machined grooves.

Fig. 4. Surface roughness measurement on the Mahr MahrSurf XCR 20

Type of cutting fluid - oil

The production itself used the original ECOCUT 715 cutting oil [13]. We kept the same one for the first experiment.

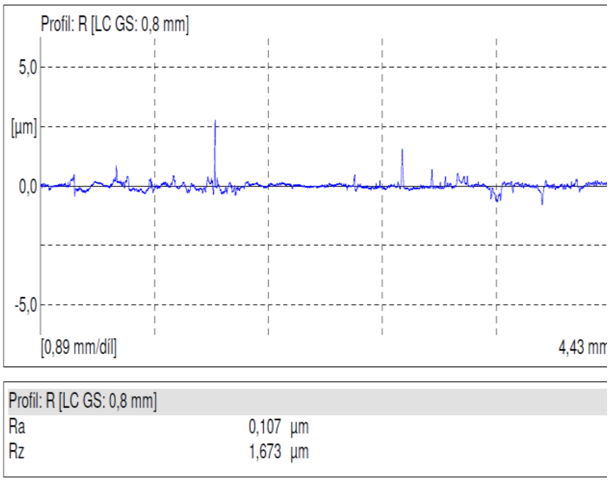

Fig. 5. Graphical representation of roghness measurement in experiment No.1

Conclusion for cutting fluid - oil

The use of cutting oil had an effect on achieving the desired roughness values of the machined surface, Figure 5 – graphical representation of roughness.

Type of cutting fluid – 5% emulsion

The cutting fluid used in this test was an emulsion cutting fluid with a concentration of 5%. Such concentrations are commonly used in machining methods such as turning. Such a concentration will ensure sufficient cooling. Our ambition was to see if it would also provide sufficient lubrication. The type of emulsion was Blaser BLASOCUT 4000 Strong [14].

Conclusion for cutting fluid - 5% emulsion

If a cutting fluid - emulsion with 5% concentration was used, then we could observe a very fast wear of the cutting wedge of the broaching mandrel. The broaching mandrel itself was damaged very quickly, so it was necessary to stop this experiment and re-sharpen the broaching mandrel.. Example of grinding of broaching tool on a grinding machine is shown in the Figure 6.

Fig. 6. Grinding of broaching tool on the sharpener

Type of cutting fluid - 15% emulsion

The cutting fluid used in this test was an emulsion cutting fluid with a concentration of 15%. Such concentrations are used in machining methods where more lubrication is required, such as tapping. Such a concentration will ensure sufficient lubrication. Our ambition was to see if it would also provide sufficient lubrication for broaching technology. The type of emulsion was Blaser BLASOCUT 4000 Strong [14].

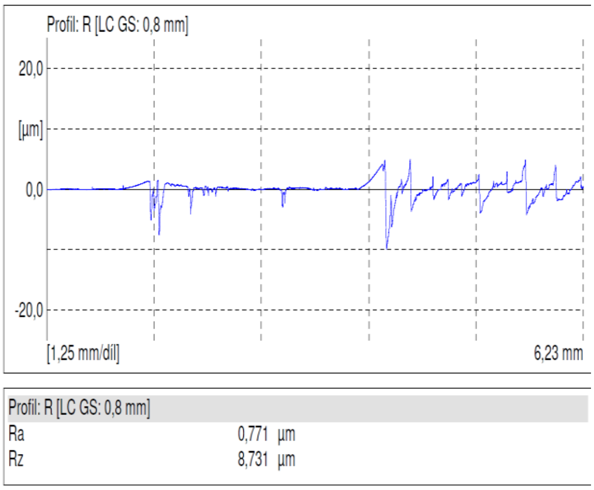

Fig. 7. Graphical representation of roghness measurement in experiment No.3

Conclusion for cutting fluid - 15% emulsion

The use of this cutting fluid - cutting emulsion with 15% concentration had an effect on achieving the desired roughness values of the machined surface, Figure 7 – graphical representation of roughness.

CONCLUSION

In conclusion, it can be stated that it is possible to reload workpieces after changing the cutting oil to an emulsion fluid and thus achieve the desired surface roughness quality.

The results of the experiments using emulsion showed the importance of the size of the concentration of the emulsion liquid on the broaching process. In the next step, it is recommended to map the range of emulsion fluids, analyze the parameters and compare them with the test and perform new tests.

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REFERENCES

[1] Vasilko, K., (2009). Theory and practice of chip machining. Prešov: TU, ISBN 978-80-553-0152-5, p. 163 – 165

[2] Lipa, Z., Janáč, A., Bónišová, M., (2007). The geometric, kinematic and dynamic machining analysis. Research papers MTF STU Trnava, ISSN 1336-1589, p. 98

[3] Vasilko, K., (2007). Analyticaltheory of chip machining. Prešov: TU, ISBN 978-80-8073-759-7, p. 96

[4] Karl Klink GmbH., [cit. 2021-10-10], www.karl-klink.de/Produkte/Raeumwerzeuge/Innenraumwerkzeuge/

[5] Wiemers KG., Räumen., [cit. 2021-10-10], internet: wiemers.de/page_id=173

[6] Deutsche Norm DIN 8589-5, (2003). Fertigungsverfahren Spanen Teil 5 Räumen. Beuth Verlag GmbH, Berlin

[7] Peťková, V., et all. (2012). Tribotechnics in theory and practice. Košice: Vienala, ISBN 978-80-8126-057-5, p. 23-37

[8] Milde, J., Jurina, F., Peterka, J., Dobrovzský, P., Hrbál, J., Martinovič, J., (2021). Influence of Part Orientation on the Surface Roughness in the Processof Fused Deposition Modeling. In Key Engineering Materials. Vol. 896, International Conference ob Building Materials and Construction (ICBMC 2021), Nanotechnology and Nanomaterials in Energy (ICNNE 2021), Energy Engineering and Smart Materials (ICEESM 2021), p. 29-37

[9] Peterka, J., Hrbál, J., Buranský, I., Vozár, M., (2020). Design and manufacturing od cutting tools for milling.In MM Science Journal. Vol. 2020, March (2020), p. 3818-3821. ISSN 1803-1269(P)

[10] Kolesnyk, V., Peterka, J., Kuruc, M., Šimna, V., Moravčíková, J., Vopát, T., Lisovenko, D., (2020). Experimental study of drilling temperature, geometrical errors and thermal expansion of drill on hole accuraly when drilling CFRP/Ti alloy stacks. In Materials [electronic source]. Vol. 13, iss. 14 (2020), p. 1-17. ISSN 1996-1944

[11] Peterka, J., Hrbál, J., Buranský, I., Martinovič, J., (2020). Experimental investigation ow wearing grinding wheels after machining sintered carbide. In Research papers MtF STU Trnava. Research papers Faculty of Materials Science and Technology Slovak Universityof Technology in Trnava. Yer 28, no. 47 (2020), p. 11-20. ISSN 1336-1589

[12] Jurina, F., Peterka, J., Božek, P., Repko, A., (2020). Device for automatic data collection on selected properties of cutting fluid: utility model application č.35-2020, Application date: 24.03.2020, Publication date of published application 24.03.2021, Vestnik ÚPV SR č. 06/2021, condition:valid, registered ÚV č. 9240,date of notification of registration ÚV: 28.07.2021, Vestnik ÚPV SR č. 14/2021. Banská Bystrica: Industrial property office SR, 2021. p. 5. Available on the internet: https:indprop.gov.sk/WebRegistre/UzitkovyVzor/Detail/35-2020.

[13] FUCHS, (2019). Cutting oil safety data specifikation ECOCUT 715

[14] BLASER SWISSLUBE, (2017). Fluid safety specification Blasocut 4000 Strong.

[15] Košturiak, J., Boledovič, Ľ., Krišťak, J., marek, M., (2010ň. Kaizen. Brno: Computer Press, ISBN 978-80-251-2349-2, p. 179 – 181

Authors addresses

[1]*Ing. Jozef Martinovic, MEng., Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Production Technologies, Jana Bottu 25, Trnava, 91724, Slovakia, +421335959722 jozef.martinovic@stuba.sk*

[2]*Prof. Dr. Ing. Jozef Peterka, Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Production Technologies, Jana Bottu 25, Trnava, 91724, Slovakia, +421905930245, jozef.peterka@stuba.sk*

Contact person

**Prof. Dr. Ing. Jozef Peterka, Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Production Technologies, Jana Bottu 25, Trnava, 91724, Slovakia, +421905930245, jozef.peterka@stuba.sk*