TYPICAL FLATNESS ERRORS CAUSED BY THE DIFFERENT CUTTING OPERATIONS

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Abstract

Beside the size tolerance the geometrical tolerance (GD&T) has increasing importance in industrial practice. The aim of the work presented in this paper is to analyse the form error dependence of different machining processes. In this project flat machining procedures were investigated. In experiment sevral different processes, diferent machine tools and two materials were machined and the flatness errors were investigated. 3D coordinate measuring machine was used to evaluate the form accuracy. The stiffness and the accuracy level of the machine tool play the highest role in the magnitude of the form errors. The typical shape deviation depends on type of the cutting operation.

Keywords: flat shape machining, flatness measurement, flatness errors

1. Introduction

Increasing demands for precision-machined parts put a greater emphasis on achieving a better understanding of the relationships between manufacturing processes, its parameters, and deviations from perfect geometric forms. There is a lot of factor, which can affect the accuracy of a machined product. We assume every difference from the expected accuracy as a failure. The final shape of the workpiece may bear the imprint of successive operations. Correlations of dimensional, shape, and texture information with process parameters are of interest across the entire manufacturing procedure, including the workpiece, tooling, holding fixture, machine tool, machining methods and parameters, forces, vibrations or thermal effects. We can make 4 main groups to categorize the failure types [1] those are 1) geometric and kinematic; 2) Caused by thermal effects; 3) Caused by manufacturing forces and 4) Other failures (see Fig. 1).

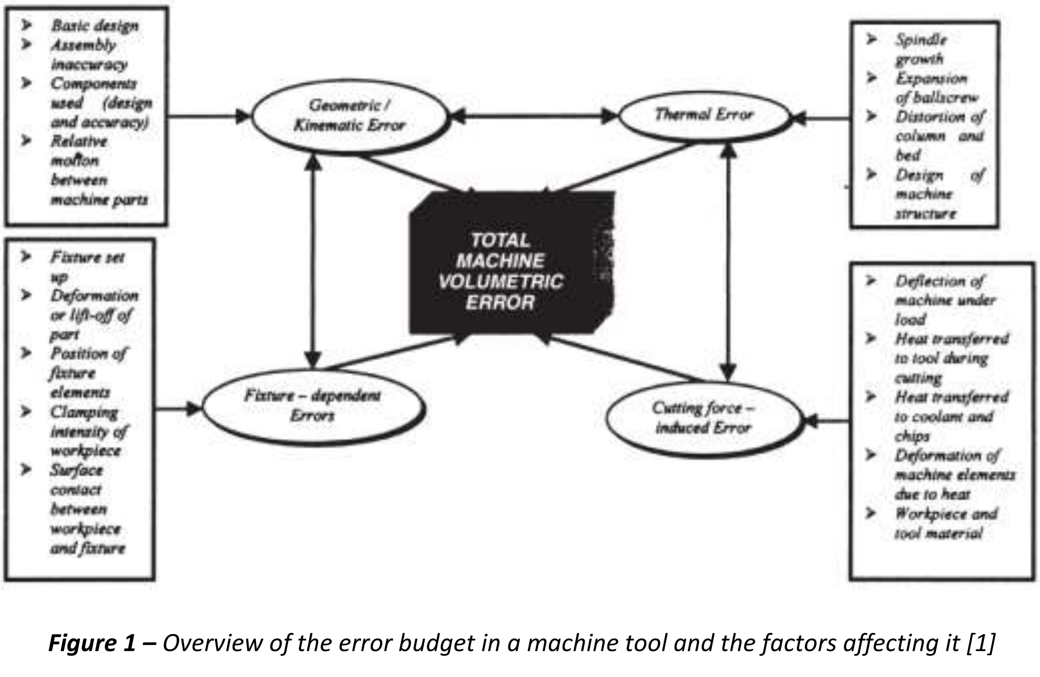

Figure 1 – *Overview of the error budget in a machine tool and the factors affecting it [1]*

The aim of the project introduce in this paper is to analyse the geometry type error dependence of different machining processes. In the experiments we needed to take into consideration the opportunities of the department, however, we tried to use as many machine tool as we can. According to the material we selected the commonly used C45 unalloyed carbon steel and AlMgSi0.1 aluminium workpieces. According to the used literature the influences of the machining parameters such as feed rate or manufacturing speed on the form errors are mostly known, that underline our decision to use only one parameter setting for all the machines. In all cases we used the manufacturing parameters according to the toolmaker company's request, taking into consideration the quality of the materials.

Figure 2 – *Zeiss 3D UC 850-001 U type CCM what we used*

In case of milling 3 different machine tools (Kondia 630B, Topper TMV 510, TOS FN20) represented three different kinematics were used. Two cutting strategies (up milling and down milling were performed. After the milling procedure we used grinding as finishing method to check the deviation of the reached surface. In case of face turning we also performed the manufacturing process using 3 different machines, traditional lathe, NC machine tool and precision machine tool. Additionally, EDM machined flat surface was also analyzed. Table 1 shows the details about the investigated machining processes.

Table 1 – *Machining processes executed to produce flat surfaces*

Machining mode	Material	Machine tool	Machining strategy
Face milling	Steel	Kondia 640B	Down-milling
			Up-milling
		Topper TMV 510	Down-milling
			Up-milling
		TOS FN20	Down-milling
			Up-milling
	Aluminium	Kondia 640B	Down-milling
			Up-milling
		Topper TMV 510	Down-milling
			Up-milling
Face turning	Steel	POTISJE USA 250	-
		Okuma	-
	Aluminium	Csepel Ultraturn 1	-
Surface grinding	Steel	TOS BPH 300/1000	-
EDM		-	-

2. Measuring the geometry

The measurement was executed on a Zeiss 3D UC 850-001 U type CMM. The machine has a 3D portal with Descartes coordinate system (x,y,z), its load capacity is 850x1200x600 mm and its accuracy is 0,003 mm. It is shown in Figure 2. We executed the measurement in the measuring room with the required temperature range and humidity.

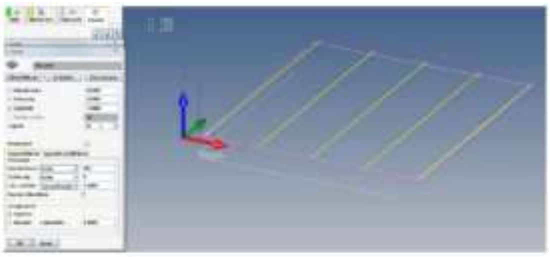

Figure 3 – *Measurement setup of the flat milling technology*

The inspection program that realized the measurement strategy for the milled surfaces were made by Zeiss Calypso measurement software. Only one flatness error was measured according to the instruction book issued by Zeiss. It recommends to use Z400 G-F or Z400 GC-F strategy. The G-F said to measure 4 lines and the other said to sense 3 circle path (small, medium, large). For the evaluation Chebysev method was used (see Fig. 3). In the case of face turning technology we built up the measurement in circle paths as figure 4 shows.

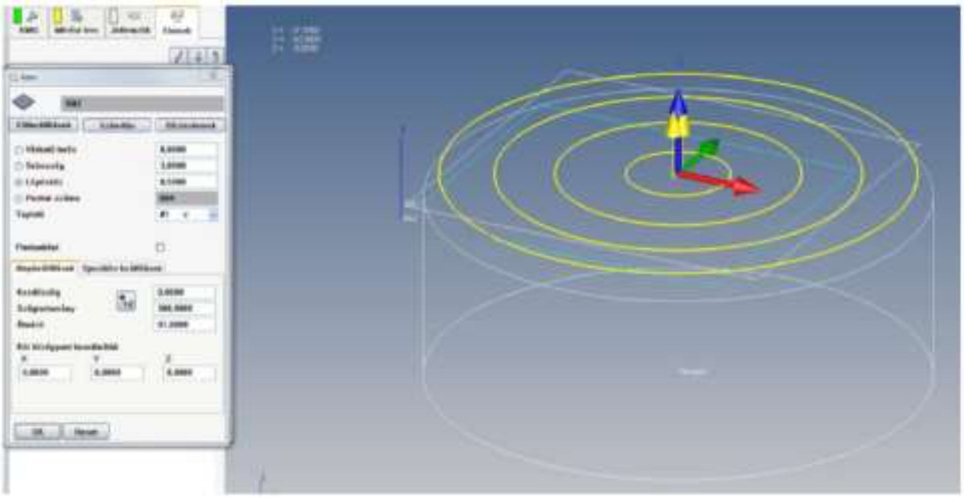

Figure 4 – *Measurement strategy of the face turning technology*

3. Shape errors of flat surfaces

Comparing the machining methods, we can make the conclusion that the precision machine tool has the smallest shape error. However, if this machine tool is not available for us, then the surface grinding is the most adequate method to achieve the required accuracy. Comparing the milling and turning technologies both in case of NC machine tools or traditional lathe, the face milling is favourable.

Generally, we achieve smaller error if NC machine tools are used instead of traditional one, because regularly it has better accuracy and stiffness parameters. Independently of the material or the machine tools better error values can be achieved when up-milling strategy is used. The measurement results are shown the diagram in figure 5.

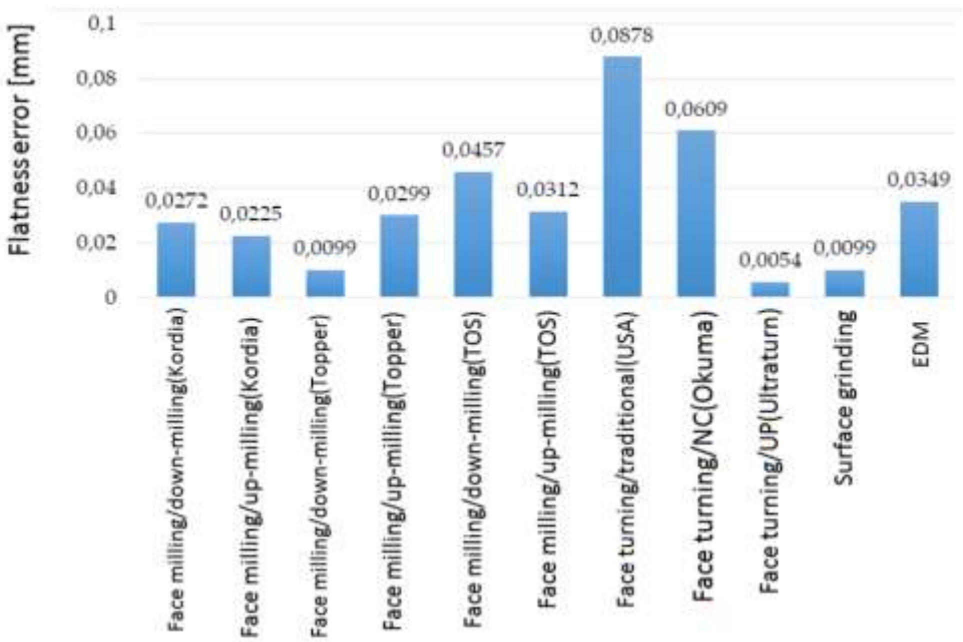

Figure 5 – *Flatness error of the flat surfaces*

As an example figure 6 demonstrate the measured results when the flat surface was produced on Kondia machining center.

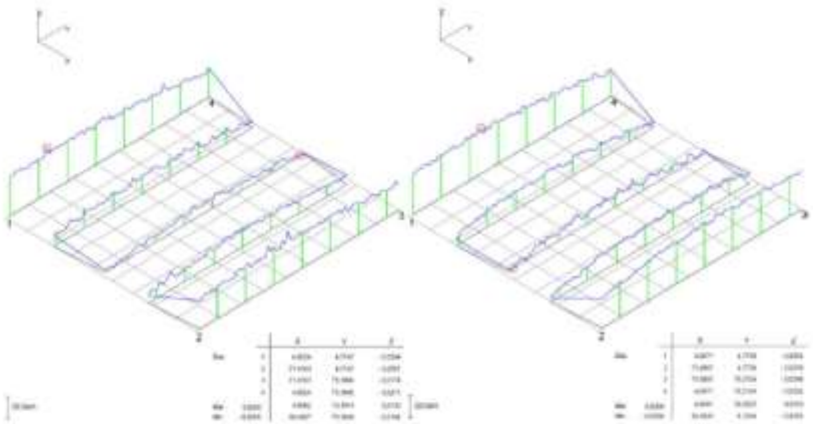

Figure 6 – *Aluminium flat surfaces with down-milling strategy on Kondia machine tool*

In the case of face turning the precision machine tool produced the best error values and the worst error values were achieved using the traditional lathe. The higher accuracy and stiffness parameters may explain this result. As the figure 7 shows each turning machine tool produce taper surface in the direction of the symmetry of the surface.

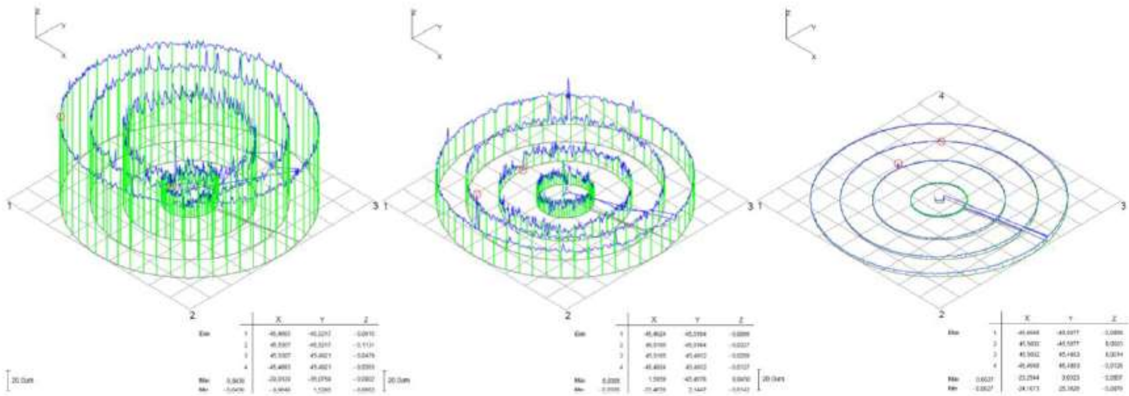

Figure 7 – *Flatness error of face turning in case of Traditional, NC, Ultraprecision machine tools*

The surface machined by EDM has higher error values than the turned or the milled surface. We can see it on the figure 8.

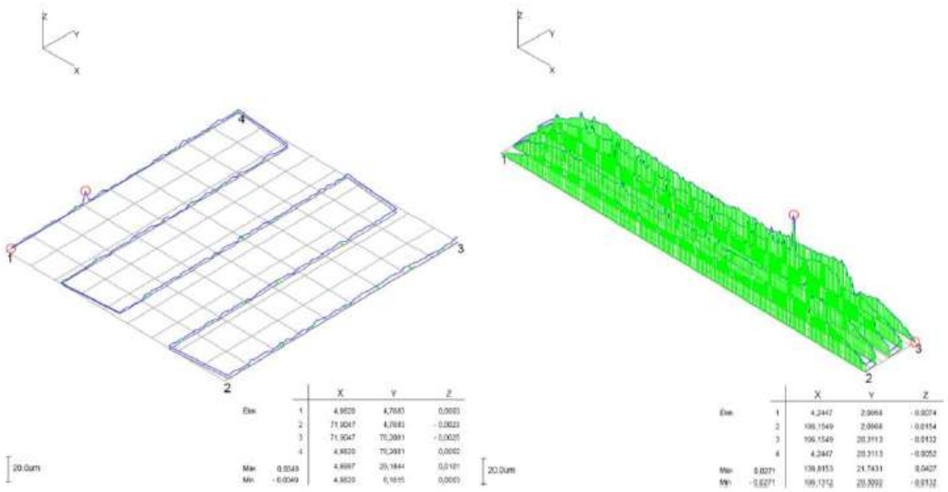

Figure 8 – *Flatness error in case of grinding and EDM procedure*

Conclusion

In order to balance the economical and the quality requirements it is essential to define the tolerances exactly and to determine the adequate technology. The different machining processes result several form deviation on machined parts. The origin of these deviations can be identify as the consequence of the uncertainty comes from the machining environment. The main factors are related to the material, the particular machining operation, the machine tool, the measuring technique etc [2].

Based on the experimental results introduced in this paper the following main conclusions may be deduced:

- the magnitude of the errors are influenced mainly the general accuracy and the stiffness of the machine tool,
- the typical form of the error is generated by the chosen machining process,

In this project the effects of the machining parameters were not investigated because former investigation realized the correlations between the cutting parameters and the geometrical tolerances.

Acknowledgement

The project idea came from the company KOTEM Ltd. This company has proposed to create a program module, which helps for design engineering, early in the design phase of the product. It is able to give us the right information to select the most suitable machining process depends on the expected accuracy or quality requirements. I has also a great advantage to prevent and detect the errors coming from the manufacturing.The authors would like to acknowledge the support provided by the CEEPUS III HR 0108 project. The research reported in this paper and carried out at BME has been supported by the NRDI Fund (TKP2020 IES, Grant No. BME-IE- MISC) based on the charter of bolster issued by the NRDI Office under the auspices of the Ministry for Innovation and Technology.

Bibliography

[1] R.P. HENKE, K.D. SUMMERHAYS, J.M. BALDWIN, R.M. CASSOU, C.W. BROWN (1999): Methods for evaluation of systematic geometric deviations in machined parts and their relationships to process variables. Precision Engineering 23, p. 273–292

[2] B. MIKÓ, G. FARKAS (2017): Comparison of flatness and surface roughness parameters when face milling and turning, Development in Machining Technology, Vol. 7. pp. 18-27