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THE IMPACT OF HIGH-SPEED MILLING ON 3D SURFACE ROUGHNESS PARAMETERS

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Abstract: *High-speed machining is a highly effective production method to achieve the following goals: increased machining productivity, enhanced quality of the machined surface, improved machining economy, improved ecological impact of machining. The objective of this research was to study the technological factors which influence the 3D surface roughness parameters in high-speed milling of two different types of die steel. The factors analysed were the feed rate, overlap and strategy. The depth of cut and cutting speed were kept constant. This article is based on the technological experiment performed in the Department of Mechanical and Materials Engineering of the Polytechnic University of Valencia and measurements of the 3D surface topography in the Mechanical Engineering Institute of Riga Technical University.*

Key words: machining, high-speed machining, cutting, milling, 3D roughness, surface quality.

1. INTRODUCTION

High-speed milling (HSM) is being increasingly used in various production processes and has particular advantages in die production. However, publicly available scientific publications are not providing in-depth studies on the correlation between HSM and surface topography. In particular, the influence of the technological parameters of high-speed milling on the 3D roughness parameters is currently uncharted territory. In fact, much research has been conducted into the area of 2D roughness, but 3D roughness measuring methods and equipment is relatively new.

The overall aim of this research is to improve technological processes (provide recommendations) in order to obtain optimal surface roughness.

The research was conducted in cooperation between the Polytechnic University of Valencia and Riga Technical University.

2. HIGH-SPEED MILLING

High-speed milling has found its way out of the laboratory and is becoming an industrial practice. However, it is generally considered to be a new manufacturing technology. This method has many benefits

Fig. 1. Gentiger GT-66V-T16B

compared to conventional milling. Very often, high-speed milling is considered solely as a way to improve productivity resulting from faster cutting speeds than those used conventionally. Seldom is it emphasised that the product quality can be improved as a consequence of increased accuracy and better surface finish [1].

This research has been conducted on a Gentiger GT-66V-T16B high-speed milling machine (see Fig. 1.). The machine is located in the Department of Mechanical and Materials Engineering of the Polytechnic University of Valencia.

The main technical specifications of the machine are shown in Table 1.

Table 1. Technical specifications of the Gentiger GT-66V-T16B

Spindle speed	16,000 rpm
Spindle motor	26 kW
Rapid feed rate	30 m/min
X/Y/Z-axis servo motor	Each 4.7 kW

3. MEASURING ROUGHNESS IN 3D

Existing surface roughness standards comprise only two dimensions. However, the real roughness of the surface is three-dimensional (3D). Roughness parameters of the 3D surface are also important in analysing the mechanics of contact surfaces. Problems in the mechanics of contact surfaces arise owing to a lack of accuracy in defining 3D surface roughness characteristics. One of the most important factors in determining 3D characteristics is the number of data points per x and y axes. The number of data points helps us to define the cut-off length. The number of data points has a significant influence on the accuracy of measurement results, measuring time and size of the output data file (especially along the y-axis, where the number of data points is the number of parallel profiles). The number of data points must be optimal. Too few data points lead to inaccurate results and increased distribution amplitude; but too many data points substantially increase measuring time without broadening the range of fundamental information. The aim is therefore to find the optimal number of data points for each surface processing method [2].

For the practical 3D roughness measuring, Riga Technical University is using the Taylor Hobson Form Talysurf Intra 50 measuring device with TalyMap Expert data software.

The technical specifications of Talysurf are listed in Table 2.

Table 2. Technical specifications of the Taylor Hobson Form Talysurf Intra 50

Horizontal Performance	
Traverse length – X Min/Max	0.1 mm to 50 mm
Traverse/ measuring speeds	10 mm/s max / 1 mm/s
Data sampling interval in X	0.5 µm
Straightness error (Pt)	0.4 µm over 50 mm 0.2 µm over any 20 mm
Vertical Performance	
Nominal measuring range (Z)	1 mm
Resolution (Z)	16 nm @ 1 mm range 3 nm @ 0.2 mm range
Range to resolution ratio	65,536:1
Stylus arm length, tip size, force	60 mm arm, 2 µm radius conisphere diamond stylus, 1 mN force

The practical advantages of the 3D roughness measuring device are shown in Figs. 2 and 3. Both pictures are of the same machined sample surface in one case (see Fig. 3) with camera (zoom 50x), in other case with 3D roughness measuring device in 2D View (see Fig. 3).

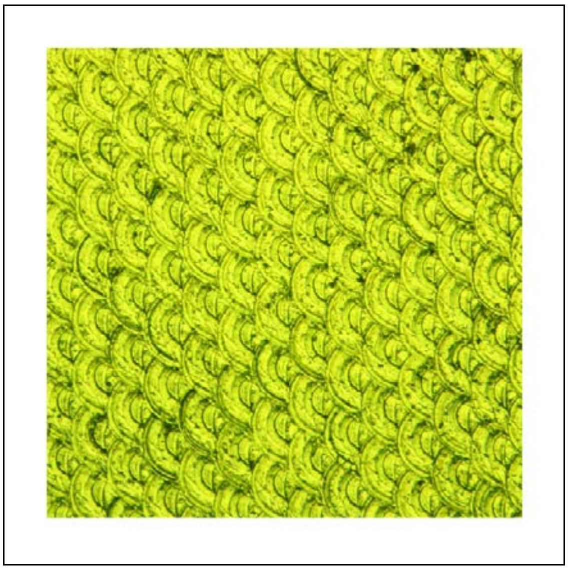

Fig. 2. 2D View from digital camera

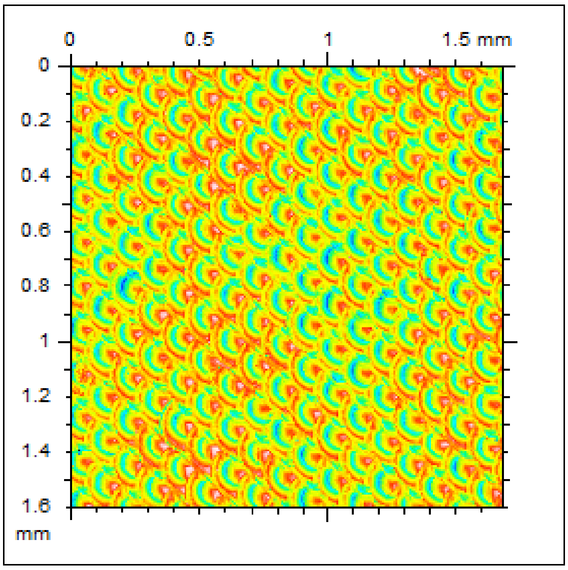

Fig. 3. 2D View from roughness measuring device

4. APPROACH

The experimental research was based on the most popular die steel samples, i.e. 1.2312 (40CrMnMo58-6) and 1.1730 (C45W). Each sample was divided into 16 conditional parts → subsamples (see Fig. 4). Each subsample was machined with a different combination of cutting parameters (feed rate, strategy, pattern and overlap). The depth of cut and cutting speed parameters were kept constant. Also, the same tool was used for all the subsamples.

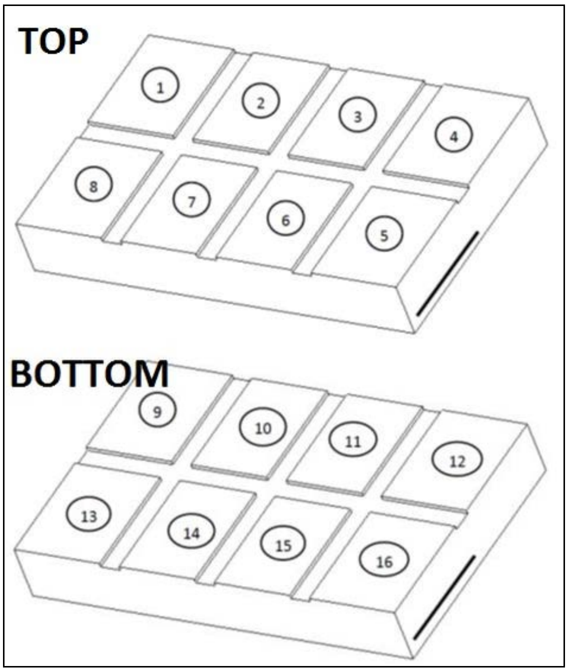

Fig. 4. Subsample numbering

All the cutting conditions and combinations are shown in Table 3.

Table 3. Cutting conditions

Sample	Strategy	Overlap	Feed
1	LP	LO	LF
2	LP	LO	MF
3	LP	LO	HF
4	CP	LO	MF
5	CP	LO	HF
6	LP	HO	HF
7	LP	HO	LF
8	LP	HO	MF
9	CP	HO	LF
10	TLP	LO	MF
11	TLP	LO	HF
12	CP	HO	MF
13	CP	HO	HF
14	TLP	HO	LF
15	TLP	HO	MF
16	TLP	HO	HF

List of abbreviations

LP	Linear Pattern	HO	High Overlap
CP	Circular Pattern	LF	Low Feed
TLP	Two linear Pattern	MF	Medium Feed
LO	Low Overlap	HF	High Feed

The cutter marked VC2E5BR0400 [VC-2E5B.R4] made by Mitsubishi was selected for this experiment. The cutter diameter is 8 mm.

5. RESULTS

The main findings of this experiment were the identification of major factors and the interaction of factors that affect the surface roughness of machined die steel samples. In order to derive definitive conclusions from this research, we have to collect data from all individually machined subsamples. In this case, we have 32 subsamples with their 2D (example see Fig. 6) and 3D (example see Fig. 5) surface roughness parameters and diagrams.

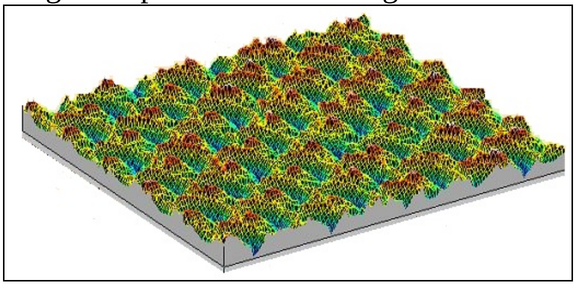

Fig. 5. 3D surface roughness

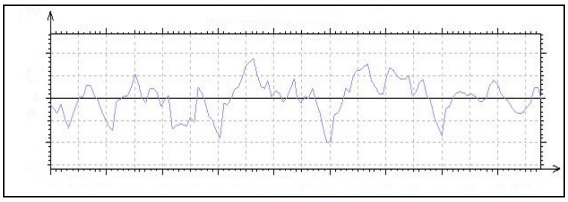

Fig. 6. 2D surface roughness

These results allow us to find the compatibility between the 2D and 3D surface roughness parameters. Analysis of data in ANOVA also provides us with some conclusions.

6. CONCLUSION

Initial results of the research outlined above revealed that:

1) strategy was the main factor affecting the quality of surface finish.
2) the circular pattern strategy provides relatively better surface quality.
3) the interaction of strategy and overlap associated with the feed rate had a direct impact on the 2D and 3D surface roughness.
4) higher feed rate provides better surface roughness quality.

Although these are significant conclusions, the research ought to be developed much further. In-depth, comprehensive data analysis will be carried out.

It is important to note that during this research, several non-conventional and unexpected results appeared. These special cases will be further examined.

7. REFERENCES

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