3D Topography for Environmentally Friendly Machined Surfaces

I Dudás¹, G Varga²

¹ Head of Department, ¹,² Department of Production Engineering, University of Miskolc, Egyetemvaros, Miskolc, H-3515, Hungary

E-mail: gyulavarga@uni-miskolc.hu

Abstract. Nowadays more and more scientific paper deals with drilling. In recent years there have been limited changes to the drill design but considerable improvements have been made in the selection of drill materials, drill coatings, flute design and the cutting fluid guiding methods. All of these improvements have been introduced to improve the surface finish of the drilled hole, reduce the energy during drilling process and to reduce ecological damage to the cutting fluids, which carry away heat and debris from the cutting zone. The paper briefly describes the development of surface characterization to its current 3D capability. It shows how selected parameters can assist with drill process analysis and how this can be supported through the introduction of the planned new ISO International Standard for 3D Surface characterization. The paper is supported by a sample-drilling test to demonstrate the power of the proposed analysis.

1. Introduction
Production in the engineering industry can have harmful effects on the environment. As the engineering industry has a significant role in the economy we have to deal with its environment impairing effects and with the possibilities of prevention. In a developing economy the increasing production can be resulted - for lack of an appropriate environmental policy - with more and more increasing damage to the environment.

2. Environmentally conscious machining
The basic aim of environment protection is to ensure - by means of the quality of the environment - the protection of human health and life, the biological diversity and the conditions for economic and social development.

2.1. Dry machining
Neglecting the lubrication or selecting lubricant with minimal volumes for a machining process and particular workpiece material involves taking into account several factors. These factors have effects on the different type of wear of the cutting tool as well. In dry machining, the functions of coolants-lubricants must be substituted. For the cutting process, these functions are cooling, lubricating and swarf disposal, and for the machine they include cooling and flushing.

2.2. Near Dry Machining
Near Dry Machining is defined as the dispensing of cutting fluids at optimal flow rates, tiny quantities
of cutting fluid are sprayed to the cutting zone directly [1]. Near Dry Machining offers the following advantages: decreased use of metal working fluids, reduced costs as compared to flood applications, reduced industrial hygiene hazard, opportunity to employ more benign fluids and improved process performance as compared to dry machining.

3. Surface finish and integrity

3.1. Characterisation of surface finish
Surface finish influences not only the dimensional accuracy of machined parts, but their properties as well. In drilling, as in other operations, the tool leaves a spiral profile - feed marks - on the machined surface as it moves across the work piece. For definite experiments will be shown later. Surface integrity describes not only the topological aspects of surfaces and their physical and chemical properties but also their mechanical and metallurgical properties and characteristics [2].

3.2. Development of 3D surface characterisation
At present, 3D surface texture measurement is not yet covered by international standards, but it is the object of on-going research projects in Europe and abroad; standards concerning this area are expected to appear in the future. In the research carried out within the European Program a set of fourteen 3D parameters has been proposed [3], [4].

The primary 3D parameter set proposed in [4] Amplitude parameters (Sq Root mean square deviation, Sz Ten point height, Ssq Skewness of height distribution, Sku Kurtosis of height distribution) Spatial parameters (Sds Density of summits, Str Texture aspect ratio, Sal Fastest decay autocorrelation length, Std Texture direction) Hybrid parameters (Sdq Root mean square slope, Ssc Arithmetic mean summit curvature, Sdr Developed surface area ratio) Functional parameters (Sbi Surface bearing index, Sci Core fluid retention index, Svi Valley fluid retention index).

4. Environmentally-friendly drilling experiments
The main goal of the researches was to examine how the different environmentally friendly technological solutions such as: different type of cutting tools, type and material of coating of the tool, type and quantity of coolants and lubricants, different technological parameters have effect on the state of cutting edges, quality of the machined surfaces, load of the machine tool and effectiveness of the machining as well.

4.1. Experimental conditions
The environment friendly drilling experiments were performed by a program elaborated on the base of preliminary experiments. The technological parameters and values to be adjusted were determined using the method of Factorial Experiment Design [5].

Manufacturing experiments: Drilling of holes of diameter 10 mm, the length of the machined hole was l=30 mm.
Material of workpiece: GG200 grey cast iron

4.2. 3D surface analysis of drilled specimen
By using of Factorial Experiment Design a great number of experiments were elaborated. We have chosen 8 experiments among them in order to show the results of 3D surface analysis. The codes and the technological data are given in Table 1.

The measured area was 2 mm x 2 mm on the drilled surface. In this paper let us consider how the cutting speed (vₖ) has effect on drilling process related the 3D surface characters.

4.2.1. Characterized 3D views of measured surfaces. For each groups a featuring 3D view of surfaces are summarized on Table 4. The measurements were done at School of Engineering at the University of Huddersfield, England [6].
Table 1. Codes of specimen and technological data applied

| Number | Feed rate (mm/rev) | Cutting speed (m/min) | Volume of oil (cm³/h) | Drilled length (m) | Number of holes drilled |
|--------|-------------------|-----------------------|-----------------------|-------------------|------------------------|
| 1      | 0,2               | 80,0                  | “dry” (0,0001)        | 0,03              | 1                      |
| 2      | 0,2               | 80,0                  | “dry” (0,0001)        | 10,03             | 333                    |
| 3      | 0,2               | 80,0                  | 10,0                  | 0,03              | 1                      |
| 4      | 0,2               | 80,0                  | 10,0                  | 10,03             | 333                    |
| 5      | 0,2               | 120,0                 | “dry” (0,0001)        | 0,03              | 1                      |
| 6      | 0,2               | 120,0                 | “dry” (0,0001)        | 10,03             | 333                    |
| 7      | 0,2               | 120,0                 | 10,0                  | 0,03              | 1                      |
| 8      | 0,2               | 120,0                 | 10,0                  | 10,03             | 333                    |

4.2.2. Featuring 3D parameters of measured surfaces. In previous papers [6], [7], we have presented the features of the amplitude and spatial parameters. Now we concentrate on the hybrid parameters: which parameters make approximately equal use of the information contained in the elevations and in their position.

- Sdq (Root mean square slope) for assessing contact or optical properties,
- Ssc (Arithmetic mean summit curvature) for measuring the openness or closeness of the texture,
- Sdr (Developed interfacial area ratio) for understanding of deformability of materials.

The goals of the study are to quantify the parameters characterising the 3D surfaces due to distinct cutting speeds, drill wears, and different types of cooling and lubrication. Results of the measurements for examining of effect of the cutting speed can be found on figure 1, figure 2 and figure 5. Similar type of diagrams can be created to the other characterising 3D surface parameters as well.

![Figure 1. Sdq - Root mean square slope of the surface](image1)

![Figure 2. Ssc - Arithmetic mean summit curvature](image2)

Sdq and Ssc
Slope Sdq (Fig. 1) and curvature (Fig 2) show that the slope is higher when height of the profile has significant changes (at lower cutting speeds) (Fig. 3, Fig. 4.)

- vc1=80 m/min
  - High profile
  - Large slope

- vc2=120 m/min
  - Low profile
  - Small slope

![Figure 3. Illustration for the results of slope](image3)
vc1 = 80 m/min
High profile
Small curvature

vc2 = 120 m/min
Low profile
Large curvature

Figure 4. Illustration for the results of curvature

Sdr
The Sdr ratio is featured similarly as the previous twoparameters, that is Sdr is larger when the profile is higher. Furthermore the drilled surfaces are marked with furrows due to the operation of the twist drill. This phenomenon causes significant waves that explain the high value of this ratio.

Figure 5. Sdr - Developed interfacial area ratio

Formulas can be created for the examined Hybrid parameters by the use of Factorial Experiment Design. Here can be found how the Sdq parameter depends on the cutting speed $v_c$, volume of coolants $V_{oil}$ and the drilled length $L_0$.

$$Sdq = k_0 + k_1 \cdot v_c + k_2 \cdot V_{oil} + k_3 \cdot L_0 + k_{12} \cdot v_c \cdot V_{oil} + k_{13} \cdot v_c \cdot L_0 + k_{23} \cdot V_{oil} \cdot L_0 + k_{123} \cdot v_c \cdot V_{oil} \cdot L_0$$

Where: $k_0 = 0.4793442$; $k_1 = -3.494 \cdot 10^{-3}$; $k_2 = -0.04213785$; $k_3 = 0.0219994$; $k_{12} = 5.271 \cdot 10^{-4}$; $k_{13} = -2.0 \cdot 10^{-4}$; $k_{23} = 5.95 \cdot 10^{-3}$; $k_{123} = -6.875 \cdot 10^{-5}$;

5. Summary
This paper gave some remarks of successful implementation of dry machining and minimal quality lubrication for different workpiece materials.

Acknowledgements
This work was supported by OTKA project. titled “Modelling and Examination of Machine Industrial Environmentally Conscious Manufacturing Procedures”

References
[1] Dudas I 2001 Production Engineering III, Manufacturing Procedures and its Tools, Production of Toothed Components and its Tools, Miskolc University Press, (In Hungarian)
[2] De Chiffre L, Lonardo P, Trumppold H, Lucca D A, Goch, G, Brown, C A, Raja J and Hansen H N 2000 Quantitative characterisation of surface texture Annals of the CIRP 49/2
[3] Stout K J 1994 The three dimensions surface topography: measurement, interpretation and applications Penton Press London,
[4] Stout K J, Sullivan P J, Dong W P, Mainsah E, Luo N, Mathia T and Zahyouani H 1993 The development of methods for the characterisation of roughness in three dimensions, Commission of the European Communities
[5] Varga G 2000 Examination of environmentally conscious manufacturing technologies, Proc. of ICT-2000 September 6-8 Miskolc, Hungary 377-82.
[6] Dudás I, Varga G and Stout K J 2002 3D Surface Topography of Surfaces Machined by Environmentally Conscious Way Production Processes and Systems, Publ. of the University of Miskolc, 1, Miskolc University Press 185–94
[7] Dudas I, Varga G 2004 Examination of environmentally clean machinings, Proc. of ICT-2004 September 9-11 Miskolc, Hungary 185-97.