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INVESTIGATION THE CORRELATION BETWEEN TECHNOLOGICAL PARAMETERS AND THE WEAR IN CASE OF DRILLING WITH MINIMAL LUBRICATION

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Abstract: College of Nyíregyháza and University of Miskolc has a common research project on environmentally conscious technologies. In the work published in this paper our purpose was to investigate the effects of technological parameters on the process of drilling and tool wear under outer minimal lubrication conditions. Method of factorial experiment planning was applied for evaluation of experimental results. Relationships were determined between technological parameters and measured tool wears. Physical model of twist drill was developed for calculating stress state and compare results with experimental wear measurements. This model shows good agreement with experiments and gives account of places of highest strain. In this paper we demonstrate a formula describing the corner wear (VB_{Corner}) and flank wear (VB_{Flank}) as function of three quantity: feed (f), length of drilling (L_0) and volume of the lubricant (V_{oil}).
Keywords: environmentally technologies, parameters, drilling, tool wear, minimal lubrication conditions

Introduction

The stress and temperature distribution in the tool during the drilling process basically influences the lifetime of the drill and the rentability of machining by its effect to wear and vibrational state. That's why complex investigation of drill by experimental way and modelling is reasonable for it allows of determining relationship between tool wear, thermal state and stress state.

Finite element modelling of the twist drill was performed assuming minimal volume lubrication circumstances. We took into account that practical realization the principle of minimizing the environmental pollution in the European Union gradually got into the foreground even in production engineering [1, 2, 3, 9].

Aim Of Experiments

Aim of our investigations was to develop a model for relationship between the wear and stress state of the twist drill, being suited for determining most loaded areas during the drilling process. We used factorial experiment design for evaluating our experimental results on minimal lubrication drilling, so that we determine relationship between technological parameters of drilling and wear values. In the modelling experimental data were used as input parameters. We applied experiences of Department of Production Engineering at University of Miskolc when designing our experiments [4].

Circumstances Of Experiments

At our experiments we used the following circumstances:

Machine tool: Universal milling machine, type: MU-250

Adjusted parameters: Revolution number of main spindle: $n = 2250 rev/\min$,
Feeds: $f = 0{,}18 mm/rev$ and $f = 0{,}35 mm/rev$
Cutting speed: $v_c = 72{,}06 m/\min$

Cutting tool: twist drill (with right hand side flute) having inner cooling channels (Ø 10,2 K20 Gühring WRDG DIN 6537)
diameter: Ø10,2 mm,
material and coating: K20 carbide (monolith) twist drill with TiAlN coating.

Specimen material: cast iron, (EN-GJL-200 (MSZ EN 1561))
length of the holes: 30 mm,

Lubrication equipment: „NOGA MINI COOL"

Adjusted volumes: $\dot{V}_{oil} = 0cm^3/h$, $\dot{V}_{oil} = 10cm^3/h$, and $\dot{V}_{oil} = 28cm^3/h$.

Oil: OMV cut XU (without chlorine).

Realization of minimum volume of lubrication was done by outer admission of the lubricants to the superficies of the twist drill by vaporizer type „NOGA MINI COOL" (we controlled two different volume per hour values: $\dot{V}_{oil} = 10cm^3/h$ and $\dot{V}_{oil} = 28cm^3/h$). Furthermore we have elaborated our experiments without using any coolants or lubricants. This was the dry machining, that is the dry drilling.

❖ EVALUATION OF MEASURED WEAR RESULTS

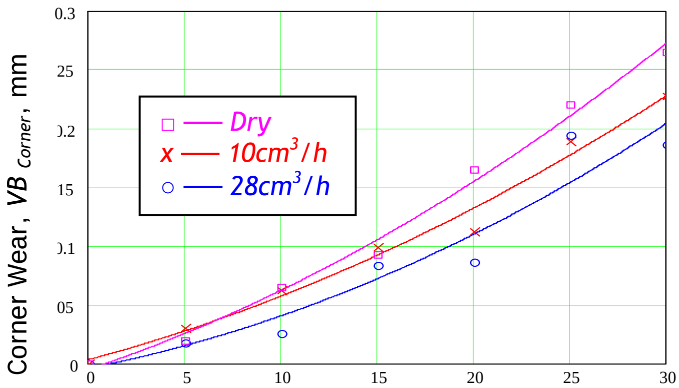
Each measurement was repeated at least three times when the same parameter setup during executing our experiments. The evaluation was done by using mathematic statistics.

For characterisation of wear of the twist drill we have chosen the corner wear (VB_{Corner}) and flak wear (VB_{Flank}) [5, 6, 7]. The flank wear was measured on the direction radius at 3,5 mm from centre line on the main cutting edge, wear width into the direction of flank. By using of Factorial Experiment Design 12 experiments were elaborated (Table 1.).

The result of the experiments can be seen on Figure 1 and 2 for the values of corner and flank wear when the volume of coolants and lubricants were $\dot{V}_{oil} = 10cm^3/h$, $\dot{V}_{oil} = 28cm^3/h$, and for dry drilling. On the figures can be seen that the wear of the twist drill was smaller at the case of higher value of coolants and lubricants ($\dot{V}_{oil} = 28cm^3/h$).

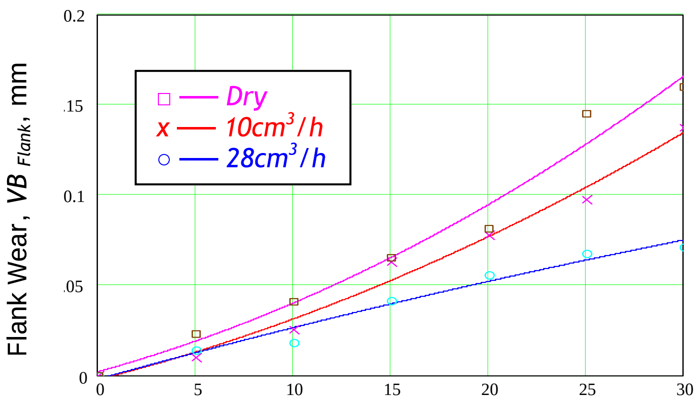
Table 1. Codes of specimen and technological and experimental data applied

Number	Feed, *f*, mm/ford	Length of drilling, L_0, m	Oil volume, $\dot{V}_{oil}$, cm³/h
1	0,18	0,03	0,0
2	0,35	0,03	0,0
3	0,18	30,0	0,0
4	0,35	30,0	0,0
5	0,18	0,03	10,0
6	0,35	0,03	10,0
7	0,18	30,0	10,0
8	0,35	30,0	10,0
9	0,18	0,03	28,0
10	0,35	0,03	28,0
11	0,18	30,0	28,0
12	0,35	30,0	28,0



Length of drilling, L_0,

Figure 1. VB_{Corner} - Measured values ot corner wear,



Length of drilling, L_0, m

Figure 2. VB_{Flank} - Measured values of corner wear,

The evaluations of the experiments were done by the full Factorial Experiment Design.

Equations (2) and (3) valid when the drilling length varies in between $L_0 = 5m$ and $L_0 = 30m$, the volume of coolants and lubricants from $\dot{V}_{oil} = 10\,cm^3/h$ till $\dot{V}_{oil} = 28\,cm^3/h$, and the feed from $f = 0{,}18\,mm/rev$ till $f = 0{,}35\,mm/rev$.

$$VB_{Corner} = k_0^{Corner} + k_1^{Corner} f + k_2^{Corner} L_0 + k_3^{Corner} \dot{V}_{oil} + k_{12}^{Corner} f \cdot L_0 + k_{13}^{Corner} f \cdot \dot{V}_{oil} + k_{23}^{Corner} L_0 \cdot \dot{V}_{oil} + k_{123}^{Corner} f \cdot L_0 \cdot \dot{V}_{oil} \quad (2)$$

$k_0^{Corner} = -0.0146$ $\quad k_1^{Corner} = 0.031$ $\quad k_{12}^{Corner} = 6.85 \cdot 10^{-3}$ $\quad k_{13}^{Corner} = -2.288 \cdot 10^{-3}$

$k_2^{Corner} = 5.789 \cdot 10^{-3}$ $\quad k_3^{Corner} = 2.118 \cdot 10^{-4}$ $\quad k_{23}^{Corner} = -1.41 \cdot 10^{-4}$ $\quad k_{123}^{Corner} = 3.268 \cdot 10^{-4}$

$$VB_{Flank} = k_0^{Flank} + k_1^{Flank} f + k_2^{Flank} L_0 + k_3^{Flank} \dot{V}_{oil} + k_{12}^{Flank} f \cdot L_0 + k_{13}^{Flank} f \cdot \dot{V}_{oil} + k_{23}^{Flank} L_0 \cdot \dot{V}_{oil} + k_{123}^{Flank} f \cdot L_0 \cdot \dot{V}_{oil} \quad (3)$$

$k_0^{Flank} = -2.686 \cdot 10^{-3}$ $\quad k_1^{Flank} = -0.04$ $\quad k_{12}^{Flank} = 8.575 \cdot 10^{-3}$ $\quad k_{13}^{Flank} = 8.497 \cdot 10^{-4}$

$k_2^{Flank} = 3.065 \cdot 10^{-3}$ $\quad k_3^{Flank} = 2.804 \cdot 10^{-4}$ $\quad k_{23}^{Flank} = -9.007 \cdot 10^{-5}$ $\quad k_{123}^{Flank} = -1.046 \cdot 10^{-4}$

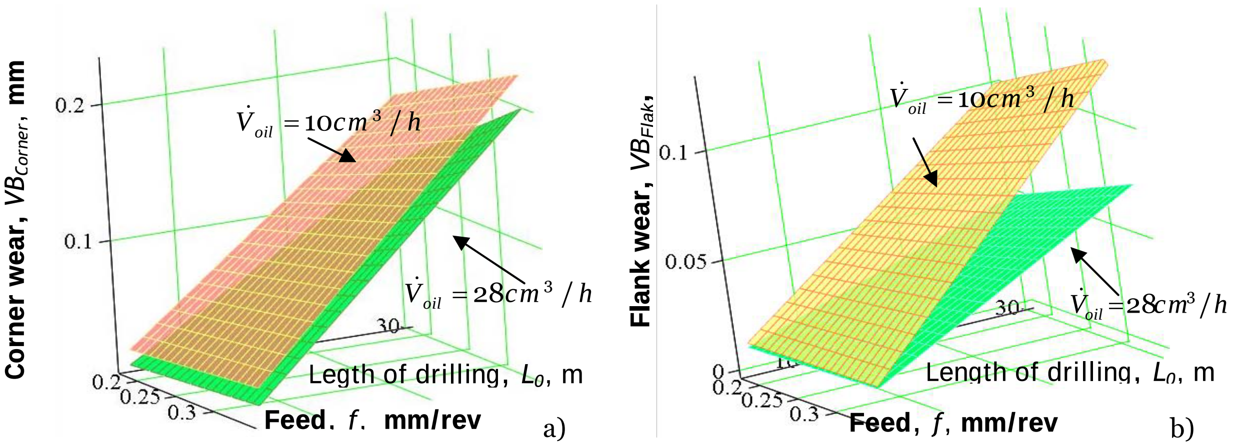


Figure 3. Measured wear values of twist drill, a) corner wear, b) flank wear

❖ MODELING

The thermal- and stress state of the drill was investigated by physical modelling. Our goal was to describe a model, which is simple as much as possible and stands in good accordance with observed wear picture.

The cutting force acting on edges was set as equal to the feed force per edge [8]. Material properties were of the K20 hard metal data.

We performed calculation for the sharp and the partly worn state of the tool. The worn state was modelled by rounding of the edges with 0,1mm and 0,2mm radii. The gradient of the stress far from the top in the drill was negligible, that's why we studied only 20mm long working part of the drill. So we avoided the superfluously large number of finite elements, and we managed to refine the mesh where it was necessary, i.e. where the gradient of physical quantities was large.

In our calculations both known mesh refinement methods were applied. The adaptive *h* refinement made the mesh denser where the target function changed rapidly, this decreasing the error of the finite element approximation. In our case, this resulted in refinement around edges and corners. The other method for improving the finite element mesh was the p-refinement, which increased the range of polynomial basis functions without changing of the original mesh, so making the approximating function much more flexible where the gradient of the target function was large. The software used realized these two types of refinement in two separate steps. Mechanical stress was used as target function for mesh refinement.

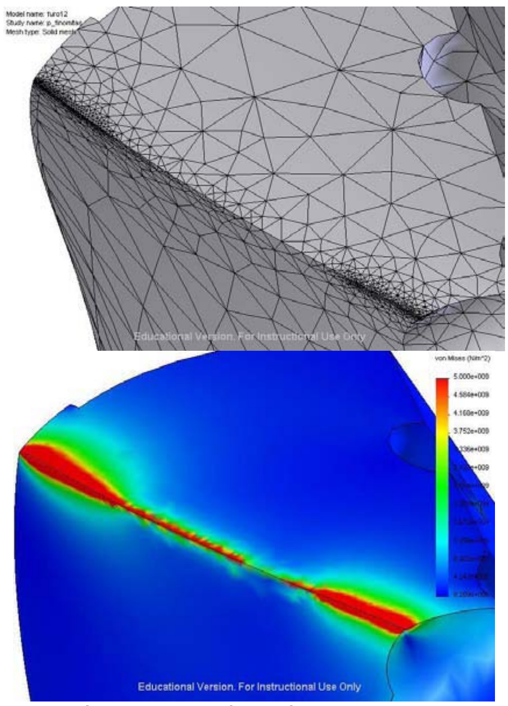


Figure 4. Mesh and stress state of sharp twist drill

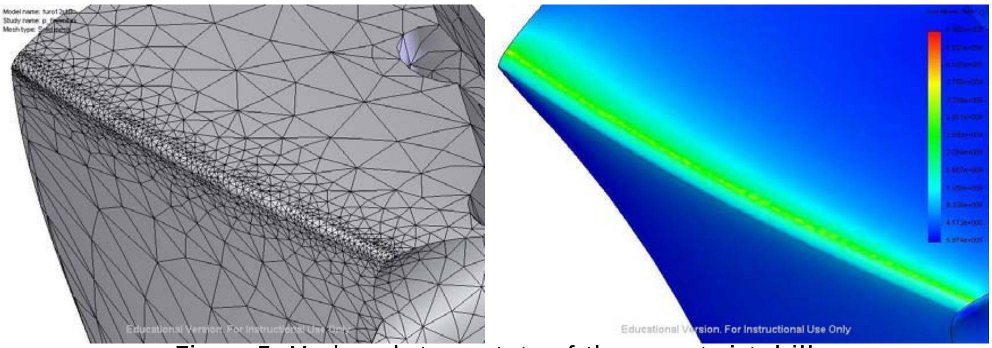


Figure 5. Mesh and stress state of the worn twist drill

Finite element meshes of sharp and two worn drills are shown in Figures 4 and 5. Figure 4 demonstrates the finite element mesh and stress results for the sharp twist drill, Figure 5 shows the shape of a worn twist drill when the effect of the wear is represented by radius 0,1mm.

❖ CONCLUSION

This paper gave some remarks of successful implementation of dry and different near dry machining and for different experimental parameters.

- ❖ Formulas are derived by means of factorial experiment design describing the corner wear (VB_{Corner}) and the flank wear (VB_{Flank}) as function of three quantities: feed (f), length of drilling (L_0) and volume of the lubricant (V_{oil}).
- ❖ The feed of the twist drill and the applied volume of coolants and lubricants have significant effects to the wear of the twist drill.
- ❖ At the case of using similar volumes of coolants and lubricants, the measured values of flank wears (VB_{Flank}) were always smaller than the values of corner wears (VB_{Corner}).
- ❖ Modelling showed that wear changes significantly the stress state.
- ❖ In the first short period of drilling the maximum of the stress is at the chisel edge.
- ❖ Then as the wear increases, the stress distribution has been significantly changed spreading along the edge.

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