FEM TEMPERATURE MODELLING IN DRILLING PROCESS

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ABSTRACT
Paper presents a three dimension finite element method modeling of drilling process. It is the attempt of making of a model containing all important elements taking part in this complex process. The paper presents an geometric model, boundary conditions, material models (Johnson-Cook model for workpiece and rigid for the drill), material properties of workpiece and tool etc. The model includes heat generation due to friction and plastic deformation. A main goal of the presented research is getting of the temperature of edge of drill while drilling in steel plate. Obtained result were verified.
Keywords: Drilling, FEM modelling, temperature

1. FEM MODEL

In presented simulation *Abaqus* code was applied . The thickness of drilled slab carries is 10 mm, and the diameter of the tool 8 mm. The geometrical model applied for purpose of simulation is shown in figure 1.

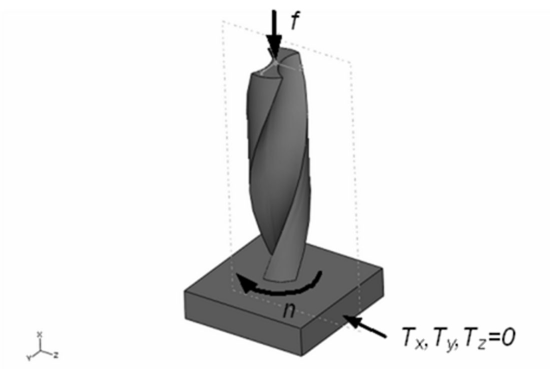

Figure 1. Scheme of FEM model

In figure 1 T_x,T_y,T_z=0 marks stiff support of workpiece. Furthermore, drilled plate is supported from bottom, what is not shown in this figure. This way of modeling corresponds to stiff supporting of workpiece on table of machine tool. The scheme on figure 1 shows also kinematical parameters: the rotary speed of tool the *n* as well as the feed *f* = 0,156 mm / rev.. The cutting speed applied in simulation v_c = 25 [m / min].

1.1. Material model of material of workpiece

During cutting process material undergoes considerable deformations, which rate achieves considerable values. In result of work of friction and the plastic deformation heat is generated. All these factors influence on value of yield stress of material. The yield stress can be determined from Johnson-Cook formula [1, 2]:

$$\sigma_p = [528{,}7 + 383{,}6(\bar{\varepsilon}^p)^{0,23}]\left[1 + 0{,}031\ln\left(\frac{\dot{\bar{\varepsilon}}^p}{\dot{\varepsilon}_0}\right)\right]\left[1 - \left(\frac{T-293}{1723-293}\right)^{1,01}\right] \tag{1}$$

where: $\bar{\varepsilon}_p$ – equivalent plastic strain,

$\dot{\bar{\varepsilon}}_p$ – equivalent plastic strain rate [1/s],

$\dot{\varepsilon}_0$ – reference strain rate [1/s], assumed to be equal 1,

T – transition temperature [K].

Similarly to the case of mechanical properties, it is important an introducing to the code of proper parameters having the influence on heat flow. It is important to carry out in a right way. The influence of temperature in this case is observed on value of suitable coefficients too. The specific heat as well as the thermal conductivity were introducing as a function of temperature [3]. As an example, the changes of the thermal conductivity λ with growth of temperature illustrates the graph on figure 2.

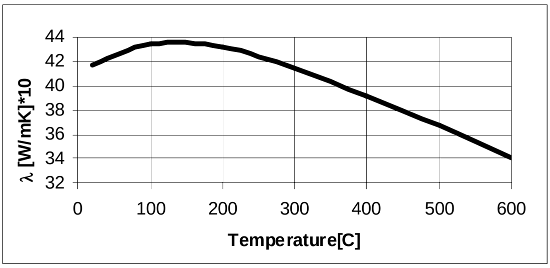

Figure 2. Changes of thermal conductivity λ as function of temperature

Similarly, the changes of the specific heat c_p with temperature growth are shown in figure 3.

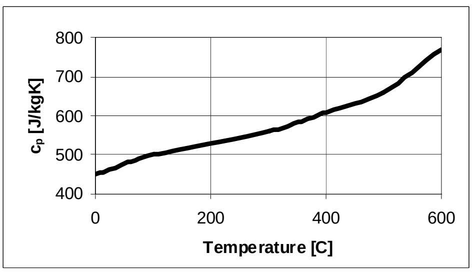

Figure 3. Changes of specific heat c_p with temperature changes

1.2. Tool material properties

During cutting the tool edge is not subject to the plastic deformations. The tool is modeled as rigid body with heat transfer. So the material properties set of the material of the tool are restricted. A list of the parameters of the tool material (high speed steel) is as follows: thermal conductivity (60 W/(mK)), density (15000 kg/m^3), Young modulus (550 GPa), Poisson ratio (0,22) and specific heat (450 J/(kgK)) entered according to [4].

1.3. Modeling of friction

The experimental investigations on phenomena of friction occurring when cutting has shown, that the coefficient of friction depends on normal stress acting on rake face. Grzesik states [5], that with growth of normal stress at rake face the coefficient of friction decreases.

2. SIMULATION RESULTS

Drawing (fig. 4a) shows the field of temperatures of the drill bit after about 3 seconds of drilling. The extreme observed values of the temperature is visible at the edge of the drill (about 660°C). Lower values of the temperatures, about 400°C, span the rest of the tip, including the chisel edge. The temperature of the tool and workpiece at 1 second after realization of drilling is shown in figure 4b. The maximum temperature of the tip comes to about 220°C.

a) *b)*

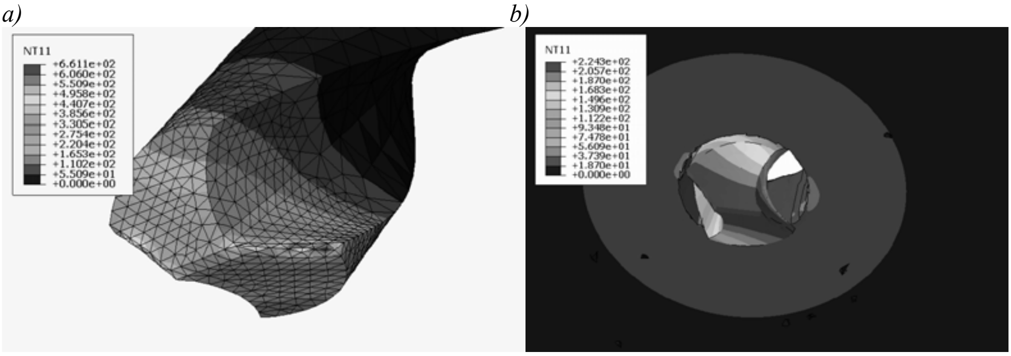

Figure 4. a) Temperature of drill at the last stage of drilling, b) temperature of the drill and workpiece about 1 second after realization of drilling.

The next figure (fig. 5) presents changes of temperature changes in time for the corner of the drill and for the chisel edge (average values taken from several nodes in the vicinity of the drill corner).

a) *b)*

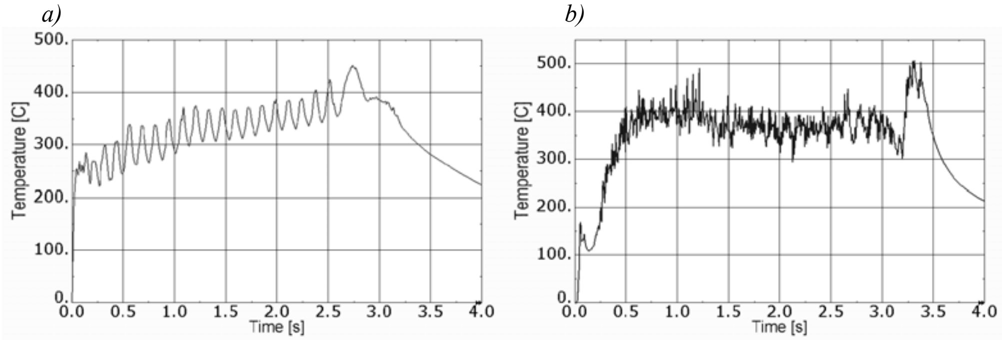

Figure 5. Charts of temperature changing in time for a) chisel edge, b) corner of the drill

3. VERIFICATION INVESTIGATIONS OF TEMPERATURES OF THE TOOL

Measurements were conducted indirectly. Radiation hits to a photoelement of an IR camera after reflection in a reflector (fig. 6). The IR radiation emitted by the tool at the moment of going out from the drilling plate. The IR camera was placed in distance of 1300mm from workpiece on a tripod and the reflector was positioned under workpiece. The angle of inclination of the reflector was wellmatched to make the angles of incidence and reflection to be as approximate as possible to a normal of the reflector surface.

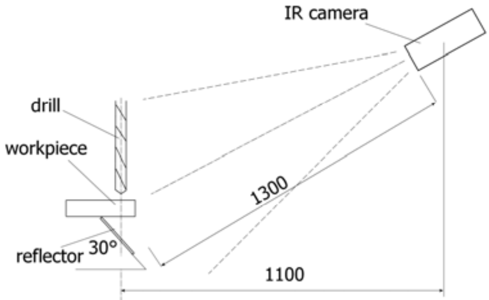

Figure 6. Scheme of the test bench

The analysis of received fields of temperature is concentrated on the point in time when the drill is going out from the drilled plate making wholes. Results for 5 holes are collected in table 1.

Table1. Values of received temperatures

T [°C]					$T_{average}$ [°C]	Stand. deviation T[°C]
1	2	3	4	5		
428	435	407	441	429	428	13

A difference between value of the average temperature obtained from experiment and the temperature obtained from the modeling is formulated as a relative error η:

$$\eta = \frac{428 - 418,5}{428} \cdot 100\% \approx 2,22\% \qquad (2)$$

4. SUMMARY

The maximum temperature of the tool can be observed in neighborhood the drill corners, slightly nearer the axis of the tool than the corner is placed. Rieznikow presented similar results [6]. The lower temperatures are visible near chisel edge even though large negative values of rake angle are present there. Presented simulations suggest that the cutting speed stronger influences growth of temperature than the negative angles.

The temperature of the bit drill in time of simulation of drilling stabilizes in some areas only. The results presented in charts suggest that the time (approximately 3 seconds) of drilling through the plate is not sufficient for a settlement of the temperature of the chisel edge. A different state can be observed in the vicinity of the corners of the cutting edges - the temperature stabilizes there already after about 1,5 sec. of cutting. Obtained results stay with good agreement with verification tests.

5. REFERENCES

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