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SIMULATING THE INFLUENCE OF THERMAL EXPOSURE ON THE MAIN ELEMENTS OF A CUTTING TOOL IN SOLIDWORKS

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The results of experimental studies of the effect of thermal action on the main elements of the cutting tool in the SolidWorks software environment are presented.

Introduction. In the process of cutting, the cutting tool heats up; therefore, it is required to predict its behavior at different temperature operating conditions. Experimental theoretical studies were carried out. Experimental studies consist of real heating of a 3D model of a cutting tool, and theoretical studies consist of simulating the heating of cutting tools using the SolidWorks software environment. The main structural components of the block-modular end mill were investigated: the screw, the block and the body [1]. The reliability of the developed system for fixing the cutting plate in the cutting block and the cutting block in the housing modules is considered in [2].

Basic information on the materials and tools used. During the experiment, a hot air gun "Stern HG2000ACN" was used for heating. Table 1 shows its technical characteristics.

Table 1. – Technical characteristics of a hot air gun «Stern HG2000ACN»

Power	2000 W
Number of temperature modes	2
Temperature range	350 – 550°C
Airflow	300 – 500 lpm
Number of air flow rates	2
Overheat protection	+

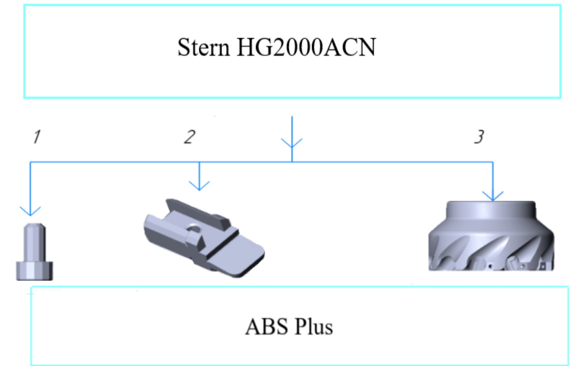
The temperature in the first position reaches 350 °C. In the second position - 550 °C.

The 3D models of the screw, the block and the cutter were 3D printed on the Mass Portal Pharaoh XD 30. They were made of ABS Plus plastic. The characteristics of the plastic are shown in table 2.

Table 2. – ABS Plus Plastic Specifications

Density	1,05 g/cm^3
Tensile strength	30 MPa (2400MPa (23°C))
Impact strength	130 (at 23°C), 100 (at 130°C) kJ/m^2
Tensile modulus	1627 MPa
Tensile modulus at 23 °C	1700 – 2930 MPa
Flexural modulus	1834 MPa
Elongation ratio	6%
Electrical strength	12-15 MV/m
Moisture absorption	0,2-0,4 %
Softening point	~ 100°C
The melting temperature	~ 220°C
Autoignition temperature	~ 395°C
Flame classification	HB

Investigation of the thermal effect on the main elements of the cutting tool. In the laboratory the screw, the block and the cutter body were heated to the melting temperature and their behavior under the influence of temperature was investigated. Figure 1 shows the order of the experiment.



1 – screw; 2 – block body; 3 – end milling cutter body

Fig. 1. – Experiment layout

The calculated formula for the temperature from a heat point source is presented below [3]:

$$\theta(x,y,z,\tau)=\frac{q_T}{\lambda\sqrt{\omega}(4\pi\tau)\frac{3}{2}}\exp\frac{-(x_u-x)^2+(y_u-y)^2+(z_u-z)^2}{4\omega\tau}=$$

$$=\frac{20}{0,2\times\sqrt{1,1}\times(4\times\pi\times20)\times\frac{3}{2}}\times\exp\frac{-(0-0)^2+(24-0)^2+(0-0)^2}{4\times1,1\times20}=175,96°C \quad (1)$$

where: Θ(x,y,z,τ) – temperature of any point of the body;
x, y, z – body point coordinates;
$x_и$, $y_и$, $z_и$ – heat source coordinates;
τ – source time;
λ and ω – coefficients of thermal conductivity and thermal conductivity of the body material respectively;

Next, the heating of the screw, the block and the cutter body was simulated in the SolidWorks environment program.

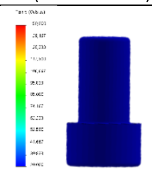
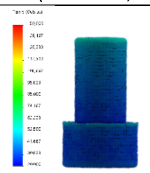
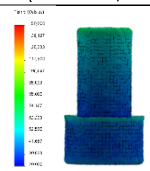
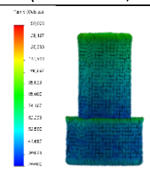
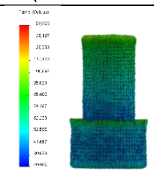
Ambient temperature is 20 °C. The screw, the block and the cutter body were heated to a temperature of 150 °C, since further heating is not advisable and leads to spontaneous ignition (see Table 2). The simulation parameters are presented in Table 3.

Table 3. – SolidWorks Modeling Options

Model material	ABS plastic Plus
Ambient temperature	20°C
Final temperature	150°C
Heating time	3 sec (screw), 5 sec (block bode and end milling cutter body)

The results of the study are presented in Table 4.

Table 4. – Research Results in SolidWorks

Screw				
0c (T_{max}=20°C)	2,25c (T_{max}=52,5°C)	2,5c (T_{max}=95,83°C)	2,75c (T_{max}=128,33°C)	3c (T_{max}=150°C)
				

The ending of table 4

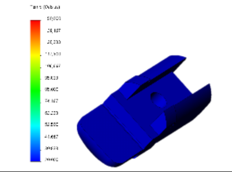
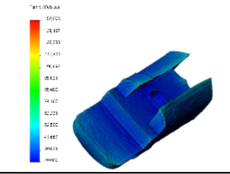
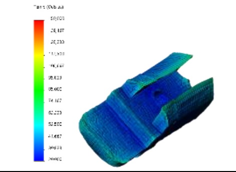
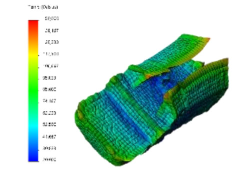
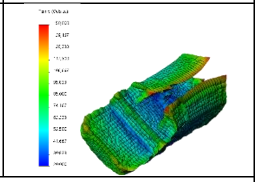
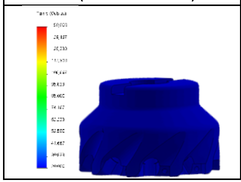
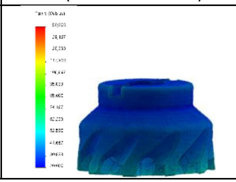
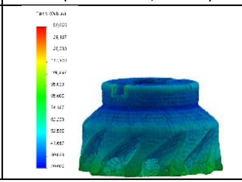
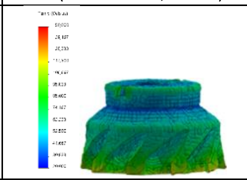
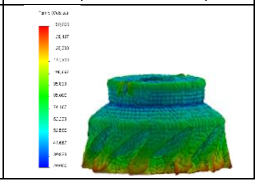
Body block				
0c (T_{max}=20°C)	2c (T_{max}=43,23°C)	3c (T_{max}=84,9°C)	4c (T_{max}=126,42°C)	5c (T_{max}=150°C)
				
End milling cutter body				
0c (T_{max}=20°C)	2c (T_{max}=45.5°C)	3c (T_{max}=89,57°C)	4c (T_{max}=128,33°C)	5c (T_{max}=150°C)
				

Table 1 shows that all models within 1-5 sec began to deform under the influence of temperature, changing the geometric parameters.

Conclusion. If we make a comparison of practical and theoretical studies, it can be seen that they differ in terms of the manifestation of deformations and temperatures. Practical and theoretical experience did not coincide as in real life heating after the heat source is turned off, the temperature continues to rise.

As a result of thermal deformation modeling, the following can be noted [4]:

1. When the fastening screw heats up, it lengthens, which must be taken into account when designing a threaded connection.
2. The cutting tool insert increases in diameter, which must be taken into account when determining the size of the groove for its placement;
3. The body of the tool block increases in size, the side walls of the longitudinal groove for the stuck accommodation are subjected to the greatest thermal deformation, which must be taken into account when assigning tolerances to the width of the groove and the stuck.
4. Thermal deformations of individual structural elements of the cutter block affect the overall deformation of the cutter block assembly - the cutting tool insert enters the body and the grip; the dimensions of the grip change in height, width, and length; the shape of the hole for the pin is deformed; the diameters of the pin and clamping screw increase. These thermal deformations must be taken into account in the dimensional analysis of the tool block assembly.
5. Qualitative changes in the thermal deformations of the end mill indicate their maximum values in the cutting tool insert and the cutting block, however, they cannot be neglected when designing the cutter body, especially in the part of the end key, which the mill is fixed in the shank with.

REFERENCES

1. Попок, Н. Н. 3D-моделирование конструкций блочно-модульных торцовых фрез / Н. Н. Попок, С. А Портянко, Г. И. Гвоздь // Информационно-коммуникационные технологии: достижения, проблемы, инновации (ИКТ-2018) : электронный сборник статей I международной научно-практической конференции, посвященной 50-летию Полоцкого государственного университета, Новополоцк, 14–15 июня 2018 г. / Полоцкий государственный университет ; пред. редкол.: Д. Н. Лазовский. – Новополоцк, 2018. – С. 190.
2. Попок, Н.Н., Максимчук, А.С., Портянко, С.А. Совершенствование системы закрепления пластин режущих и блоков резцовых в блочно-модульных режущих инструментах/ Вестник ПГУ, сер. В – 2015 - №2, с. 16-22.
3. Попок, Н.Н. Теория резания : учебное пособие / Н.Н. Попок. – Минск : ИВЦ, Минфина, 2019 г. – 372 с.
4. Методология исследования работоспособности фрезерных и осевых режущих инструментов на основе 3D прототипирования / Н.Н. Попок, С.А. Портянко – Вестник ПГУ, сер. В. Промышленность. Прикладные науки. 2020 г. – с. 29-39.