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RESEARCH REGARDING THE WEAR LEVEL FOR A NEW CONSTRUCTIVE SOLUTION OF A CUTTING TOOL

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ABSTRACT

The paper presents a study of wear made to implement a constructive solution for a new cutting tool. The design of the cutting tool can be checked from a functional perspective, as well as reliability during the cutting process (process simulation). The purpose of the cutting process simulation is to check the new solution using the finite element analysis method. The criterion to assess the effectiveness of the constructive solution is the study of the tool wear level depending on cutting regime parameters. The implementation of the wear model in the DEFORM software was used to establish the wear level.

KEYWORDS: cutting tool, simulation, DEFORM Machining software

1. Introduction

The research literature revealed that Deform 2D software is effective in both research and industrial applications.

Machining 2D software developed by Scientific Deform Forming Technologies Corporation, Columbus, Ohio has, in addition to the previous embodiments, the predictive model on the basis of the cutting tool wear analytical model of Usui.

$$\frac{dw}{dt} = C_1 \cdot \sigma \cdot v_s \cdot e^{\left(\frac{-C_2}{T}\right)} \qquad (1)$$

where: $\frac{dw}{dt}$ – wear intensity

C_1, C_2 - coefficients that depend on the workpiece and tool material;

v_s - the flow rate of the cut, [m/min];

T - cutting temperature;

σ - normal pressure (specific pressing).

Machining Software Deform shapes and simulates the cutting process using orthogonal cutting assumptions.

2. Simulation of the chamfer process

The purpose of the chamfering process simulation is to check the proposed solution design with the terms of finite element analysis. The assessing criteria for the effectiveness of the solution is the wear of the constructive tool depending on cutting regime parameters: cutting speed, feed and cut depth. The possibility of the wear calculation is given by the implementation of the wearing model in the Deform software.

In the simulation of the chamfer process it has been used metal carbide, type P30, coated with a layer of 5 micron titanium carbonitride (TiCN), with the rake angle γ = 10, the clearance angle α = 8, the attack angle κ = 45. As processed material was used OLC 45 improved steel.

Usui's model coefficients for equivalent material OLC 45 (ANSI 1045) for the boring operation have the values: a = 0.0000002; b = 650.5.

From the finite element calculation point of view, the tool is considered rigid because the program does not calculate the deformations and tensions inside the tool, but only the specific temperature and pressing.

For the workpiece it is chosen the elastic-plastic environment. Cutting conditions (chosen as intensive) shown in Table 1 and the working conditions are introduced in the pre-processor of the program. Here are defined all the initial conditions. The process is finalised with the positioning of the tool and of the workpiece as is shown in Figure 1.

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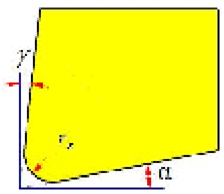
Table 1. *The simulation process parameters*

No.	Tool geometry	feeding, [mm/rot]	Cutting depth, [mm]	Cutting speed, [m/min]
1.	 $\alpha = 6^0$ $\gamma = 6^0$ $r_\varepsilon = 0.05$			75
2.		0.03	1.0	100
3.				200

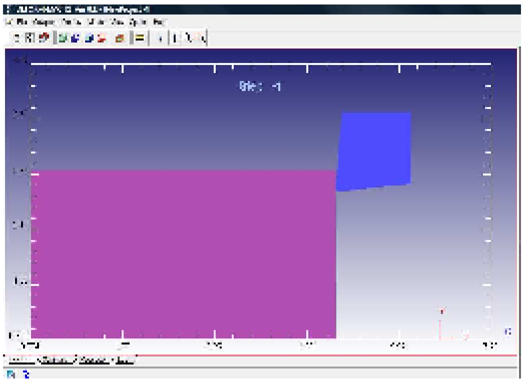


Fig. 1. *The initial position of the simulation*

Note that, for each combination shown in Table 1 the meshing of the tool and of the workpiece was done.

After running the finite element program for chamfering operation (bore processing), the output of the procces is represented by the following sets of parameters values, that are included in the graphs in Figures 2 and 3). The temperature field in the cutting area and in the cutting tool are shown in Figure 2.

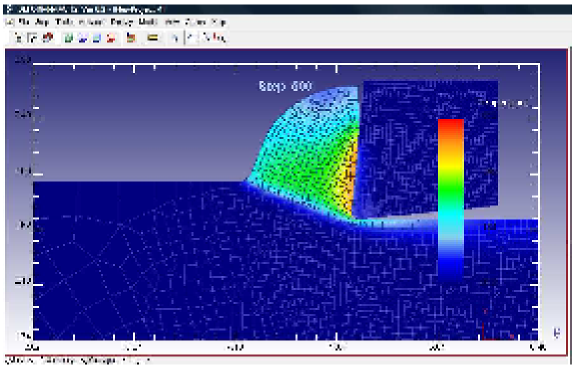


Fig. 2. *Map temperature into the piece and cutting tool*

The isotherms of the thermal field in the cutting tool and the workpiece, by means of which it is possible to predict the wear of the tool, are shown in Figure 4 a and b.

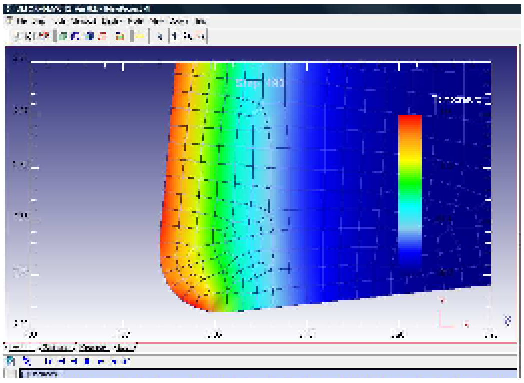
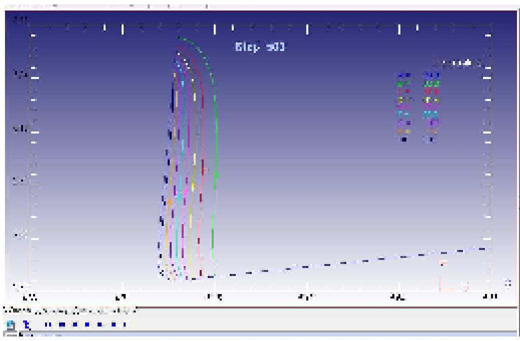
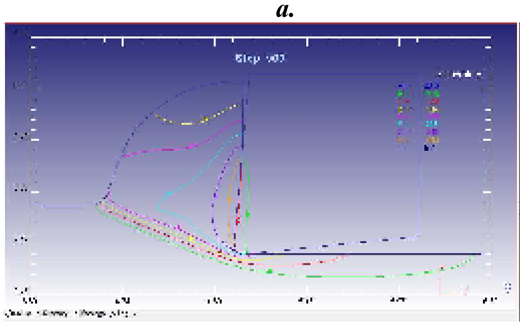


Fig. 3. *Temperature map inside the piece and cutting tool*



a.



b.

Fig. 4. *Isotherms of the thermal field*

The chart of Loading splinter elements in [N] (X axis) is shown in Figure 5, and Figure 6 shows the plane stress state in the workpiece and chip highlighting actual voltage, $\overline{\sigma}$ [N/mm^2].

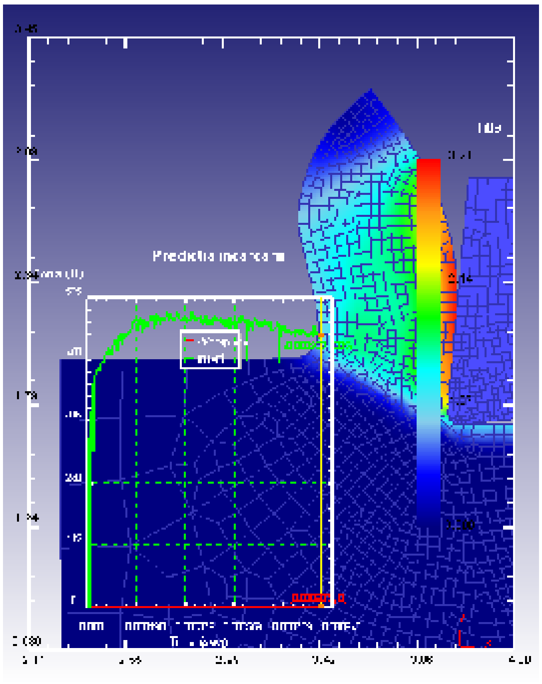


***Fig. 5.** Prediction loading in the workpiece and in the tool*

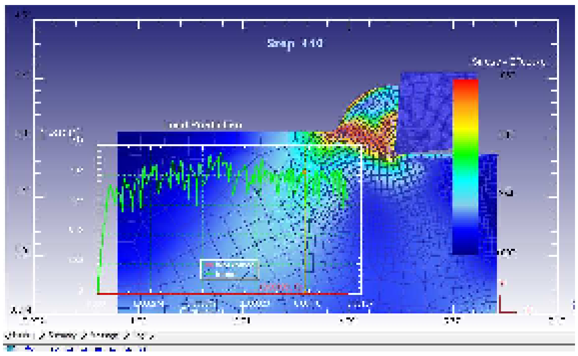


***Fig. 6.** Plane stress condition,* $\overline{\sigma}$

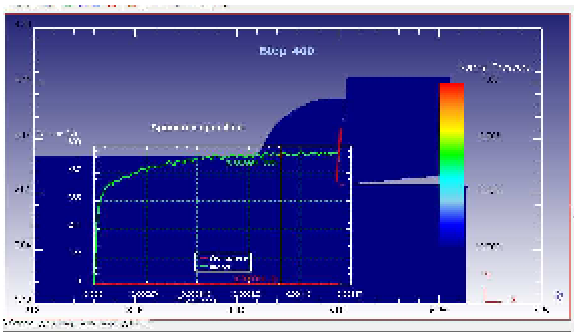


***Fig. 7.** The specific pressing on the clearance face*

The specific pressing on the direction X and P, [N/mm^2] is shown in Figure 7.

3. Interpretation of results

The variables states provided by the simulation of cutting software are very useful in establishing a model based on the mechanical wear of specific cutting. Also, the cutting forces can be calculated on the X, Y direction, highlighting indirectly the state of wear of the cutting tool.

From the temperature state, we can see that the position of the center of wear on the rake face is located at a certain distance from the cutting edge of the tool, which coincides with the maximum depth of crater wear. Isotherms representation are highlighting exactly the shape of the crater wear on the rake face and the wear of the settlement surface. Temperature values will be used in the calculation of the tool wear, based on Usui model.

The database generated by simulating the cutting process can be transferred to the analysis of the tool state of stress and strain, using another finite element program (ANSYS). For this analysis, the initial load status parameters on contour (Boundary Condition) are already stored in the database.

In-depth analysis of the program simulation results and other elements of the cutting process can be identified, which are not directly related to the phenomenon of wear, such as:

Figure 4 presents the maximum stress state of contact between tool and chip to an intermediate position tool (Step 500), as the chip shear zone is very distinctly evidenced.

Also, in this Figure, there is an uneven stress distribution on the contact surface between the tool and the part (the effective sectional area of the chip).

The size of the area affected by the tension in the piece can be observed. The tool wear can be estimated for the same cutting conditions. The estimation of tool wear is brought to an end after three cycles of tool wear calculations.

Machining Deform 2D program is controling the chip formation, and the analysis of heat transfer is watching the analysis process, and the result is then stored in a database. These values are required to estimate the tool wear.

Estimation of tool wear can be simplified assuming that the wear is only created by the cutting process steady state and neglecting the effect of entry or exit phase.

Integrating the mathematical model of tool wear with finite element analysis of steady-state cutting tool wear, the estimation of the tool wear can be implemented.

This will be done using a computer program to calculate the tool wear.

3.1. Calculation algorithm of the tool wear at chamfering

To calculate the tool wear in the boring process it was created in Matlab program the program called "The tool wear after simulation. m". The program is designed to perform the calculation of tool wear based on the results of finite element simulations. Thus, after a certain number of steps (Step increments to save = 10) of the simulation data are taken calculated data on the specific pressing, temperature and flow rate of the chip.

After each calculation cycle, the data on chip formation and heat transfer are exported as Matlab files matrices, in order to obtain the input values of variables needed to calculate the wear. The values of these measurements are then processed by the Usui's analytical wear model (equation 1). The procedure for estimating the wear of the tool is shown in Figure 8.

Since the full simulation time is much less than the real operation time of the tool till the admissible wear level is reached, by this computer program can be extended the life of the tool to a value close to the actual values. For this, is considered the assumption of achieving the steady state from the "finite element", after which, both temperature and specific pressing are considered relatively constant.

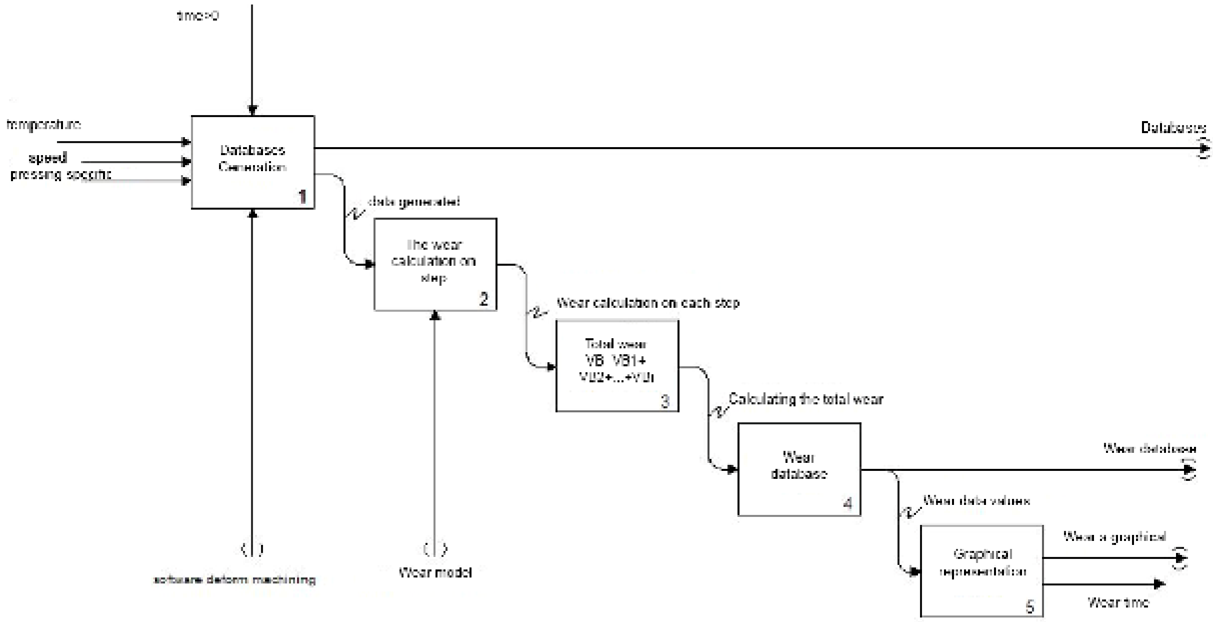


Fig. 8. *The steps for calculating the tool wear*

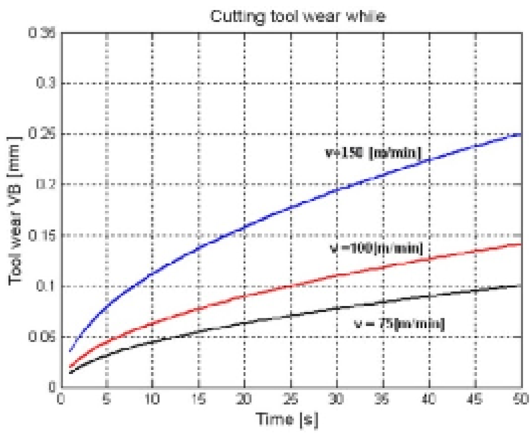


Fig. 9. *Tool wear in time based on simulations from the Deform Software*

This way, by extrapolating the calculation of the wear we are close to reality, considering that we stand on the level of normal wear.

For the wear calculation and for plotting the wear curve of Figure 9, were used the results from the three simulations shown in Table 1.

After the running of the program and considering the time, which now has the real value, the theoretical wear curves were plotted as shown in Figure 9.

4. Conclusions

The results of finite element simulation show that the chosen solution is feasible and the resulting values are within normal limits.

In terms of cutting tool wear estimation, it is shown in Figure 9 that the proposed solution has a high sensitivity to the changes of the cutting speed (it is normal considering that the tip of the cutting tool has a low volume of material).

Acknowledgments

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