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MODELING MANUFACTURING PROCESSES OF CUTTING

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Abstract: *In the second part of the article about modeling manufacturing processes of cutting, is prezented a numerical 2D simulation for the modeling of orthogonal cutting processes by using the commercial software SFTC DEFORM-2D ® V 9.1 for AISI 1045 steel (DIN 1.1191). At the same time it will be shown the experimental determinations for selecting an appropiate friction coefficient, that minimize errors in predicting the cutting force. For the chosen friction coefficient, it will be determined the maximal chip temperature with the help of the created model, whici will be compared with the experimental values presented in the literature. The researches have been conducted in an intership at the Institut for Machining Tool, University Stuttgart, Germany.*
Key words: *cutting force, friction, temperature chip*

1. INTRODUCTION

The purpose of the research is focussed on achieving a 2D numerical simulations to model the orthogonal cutting process using commercial software SFTC deform-2D ® V 9.1 [11] for AISI 1045 steel (DIN 1.1191), and experimental detering of the cutting force in different cutting conditions. In this context, theoretical and experimental research concerning the orthogonal cutting process have been directed towards the following objectives :

1. the development of a model for the numerical 2D simulation of the orthogonal cutting process ;
2. the experimental determination of the cutting force in diferent cutting conditions and the selection of frictin coefficient for the developed model, in order to minimize errors in the prediction of the cutting force value;
3. the determination of the maximal chip temperature for the friction coefficient obtained under paragraph 2, and the comparison with the experimentally determined value reported in the literature.

2. THE DEVELOPMENT OF A MODEL FOR THE NUMERICAL 2D SIMULATION OF THE ORTHOGONAL CUTTING PROCESS

Thaking into account the previous theoretical considerations, with the help of the commercial software SFTC DEFORM-2D ® V 9.1 [11], there has been created a model in whici the tool is considered as a rigid body made of the hardened material TiC and the part as a body whici undergoes elasto-plastic derformations and is made of the material AISI 1045. These materials come from the database of the software SFTC DEFORM-2D ® V 9.1.

The mesh network of the tool contains initialy 875 quadrilateral elements and that of the part contains 1917 quadrilateral elements (as shown in fig. 1 and fig. 2). This networks are in the contact area tool-part more refined than in other areas.

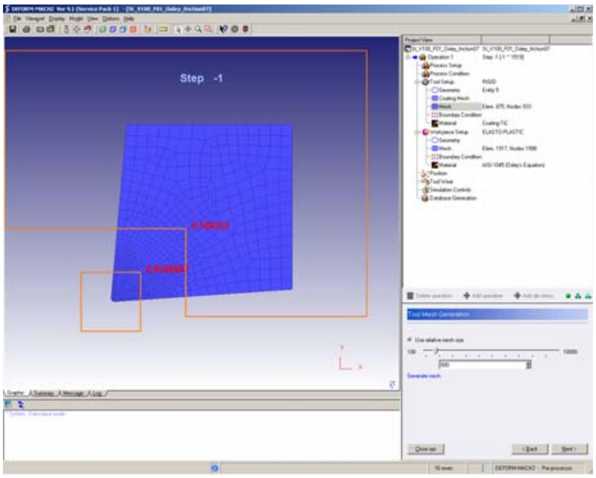


Fig.1. The mesh network of the tool

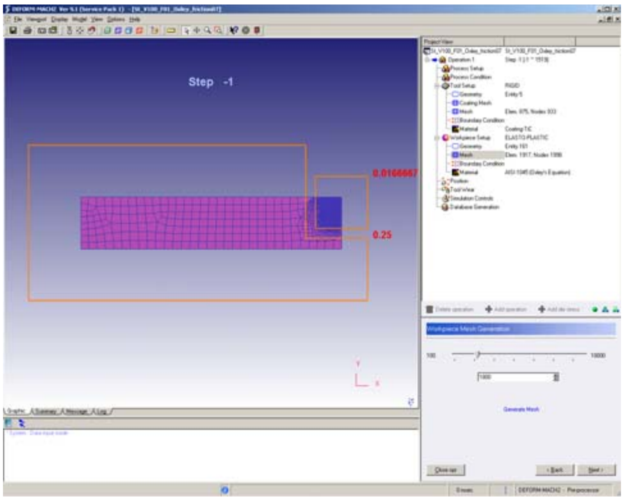


Fig.2. The mesh network of the part

The constitutive equatuions for the part are in accordance with the law of Oxley, which was implemented to describe the flow of material as a function of strain, strain rate and temperature. The termical parameters of the parts material have been defined as a function of temperature, and come from the database of the software SFTC DEFORM-2D ® V 9.1. [11] (as shown in fig. 3).

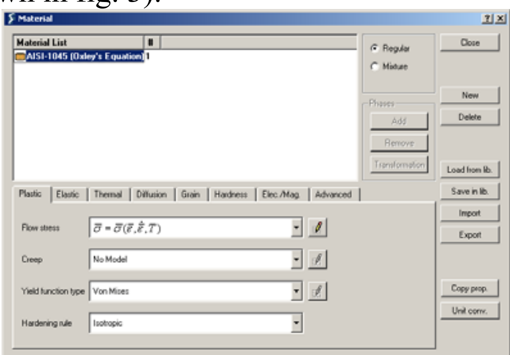


Fig.3. Modeling of the parts material (AISI-1045) using the Oxley equation

The constitutive equatuions for the tool are in accordance with the law of power, this beeing considered rigid. The termical parameters of the tool material have been defined as a function of temperature, and come from the database of the software SFTC DEFORM-2D ® V 9.1 [11]. The angle of approach of the tool is α=5°.

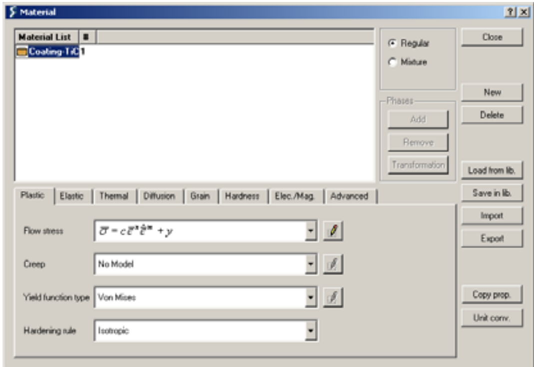


Fig.4. Modeling of the tool material (TiC)

3. EXPERIMENTAL RESEARCHES

3.1 Description of the experimental equipment (fig.5)

The simulation does not take into consideration several phenomena such as: cutting edge wear, residual internal stresses in the material and machine oscillations and also the simulation model containes certain simplifications whici had to be introduced in the experimental model as well.

The influence of the cutting edge wear was reduced by changing the cutting edge of the tool for every test and by using tools with very high hardness. The used tool is a square cutting plate of the type Walter Tiger Tec WKP 35, cod ISO SEHW1504AFN.

The tested parts are rectangular plates 170/50/5 of AISI 45 steel. In order to avoid residual stresses, the tested parts were subjected to the annealing process for stress relief.

The effect of oscillatory behavior of the machine were studied using a prototype testing equipment. The testing equipment was designed to study the cutting process and the structure. Its ability of controlled flexibility is useful when it is wanted to reduce the influence of oscillations on the cutiting process.

The simplification consistes of the assumption that the tool is a rigid body without deformation. This is achieved by using a special tool holder and through the hardness difference between the tool and the workpiece.

User interface

Its role is to create a user-friendly interface with the Siemens control panel. The connection with the control panel is based on PROFIBUS technology. The user interface is build using Visual Basic. The interface is used to control the machine position and the speed of the machine table.

The Siemens command

The Siemens comand provides the actual control of the linear motor. It descibes the interference of motion and alerts the user about the unacceptable discrepancies for the movement of the machine table.

In accordance with the given commands, for example when, during the cutting process, the speed of the table is slown under the influence of acceptable interferences, the table is stopped and a failure display announces the failure of the experiment.

The testing equipment

The cutting process whici is submited to the simulation is planing, in whici the tool is stationary, and the part performs a translation movement on the x direction. The framework of the testing equipment consistes of solid concrete with polymers. To support the tool there is used the method of a portal construction. The resistance is controled by adjustable massive traction anchors, whici link the portal to the framework. The liniar motor is used for the motion of the table. This allows a continuous change without steps of the speed, from 0 to 200 m/min.

Piezoelectric sensors

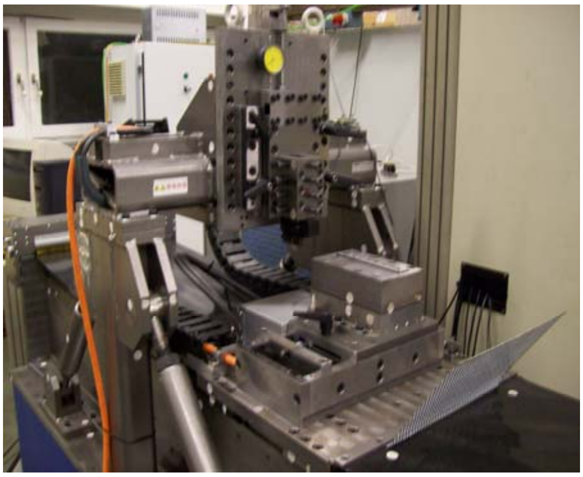
The sensors are displayed as follows:two on the tool holder and two on the measuring plate from underneath the table. There role is to measure two main forces of the planing process: the cutting force and the passive force. These forces are compared with the FEM simulation data. Before the start of the experiment, a calibration of the sensors is performed.

The alternating current amplifier

The current coming from piezoelectric sensors is too small for the accurate measurement value. The amplifiers role is to provide a controlled increase of the signal, so that an accurate reading can be accieved. From here, the loaded signal is sent to a National Instruments data registration system.

Data registration computer

With the help of the data registration system and the Labview 7 program, data from the 4 sensors is saved and analyzed. The data flow of the sensors passes 2 Labview modules. The first module saves the signal from the sensor in .txt format and connect it with the information from the amplifier and the calibration test.



.**Fig.5**. Experimental equipment

The forces have been measured using the SlimLine type 9133B on the Z axis and 9134B on the X axis, both sensors are produced by Kistler Instrumente AG. These sensors are made of quartz with an extremly flat design and are used to measure dynamic and quasi-static forces. The sensors have a welded frame, where the embedded connexion cable is integrated in the body with a non-detachable connection socket.

Table 1

SlimLine Sensor techincal data

Type	Domain F_z [kN]	Over-load F_z [kN]	Sensitivity [pC/N]	Rigidity [kN/μm]
9133 B	14,0	17,0	-3,8	2,5
9134 B	26,0	30,0	-3,8	5,6

Table 2

SlimLine Sensor techincal data

Type	External diameter D [mm]	Internal diameter d [mm]	Height H [mm]	Mass m [g]
9133B	16,0	6,1	3,5	6,0
9134B	20,0	8,1	3,5	6,0

The force can be measured by the sensors through an assembly or through the preloading elements. When the sensor is loaded, this produces an electrical charge proportional to the applied force. This load conducted to the exterior by an electrod or an integrated cable. The cable is integrated in the body and this assembly is shielded.

The cutting parameters and the results obtained for the cutting force and the passive force are summarized in table 3.

Table 3

The cutting parameters an the results obtained from the determinations

No. test	Cutting speed [m/min]	Feed rate [mm/rot]	Cutting force F_x [N]	Tan gential force F_z [N]
1	50	0,1	849	417
2	100	0,1	886	468
3	150	0,1	745	433

3.2 The simulation results

The simulation started with the entering of the tool in the workpiece at the specified speed. The chip is detached from the machined surface when the surface connections are unfolded and a contact with the placement surface of the tool is achieved. To avoid the numerical instability caused by the imbalance of forces from the surface nods, that are being separated, a distribution was specified that allows the gradual decrease of their value to zero. Due to the strong deformations of the elements around the tip of the tool, a further remesh of the model was needed for a more advanance analysis.

For the friction between tool and chip there has been selected a friction coefficient μ so that the errors in obtaining the cutting force F_x are minimized. It was concluded that the values 0,7 and 0,8 for the friction coefficient are the more satisfying.

Table 4

The cutting parameters an the results obtained from the simulation

No test	Cutting speed [m/min]	Feed rate [mm/rot]	Cutting force F_x [N]	Tan gential force F_z [N]	Maximal tem perature [°C]	Fric tion coeffici ent μ
1	50	0,1	895,13	358,68	476,17	0,8
			817,76	290,80	460,41	0,7
2	100	0,1	871,96	343,26	586,13	0,8
			811,15	285,04	559,38	0,7
3	150	0,1	847,40	314,24	646,09	0,8
			787,16	267,02	620,46	0,7

In Fig. 6 the experimentaly determined results were represented graphically and those obtained from the simulation for the cutting force F_x [N] according to the feed rate [mm/min] for a feed of 0,1 mm/rot, using the value 0,8 for the friction coefficient μ.

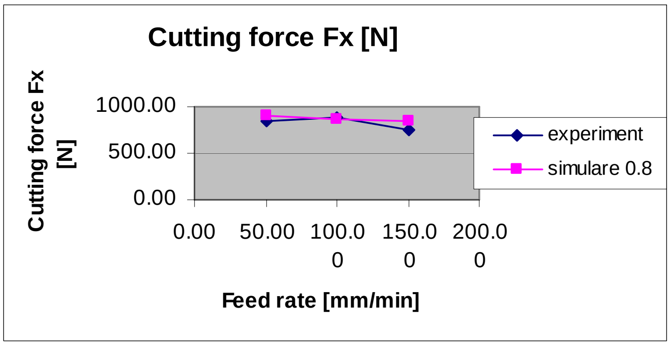


Fig.6. Cutting force Fx [N] according to the feed rate [mm/min] for a feed of 0,1 mm/rot

For the obtained model regarding the above, there has been studied how temperature varies across the three areas when using the value 0,8 for the friction coefficient μ:

I – the primary shear plane;

II – the area where fiction occurs between the chip and tool rake face;

III – the area where friction occurs between the cutting surface and the tool placement surface

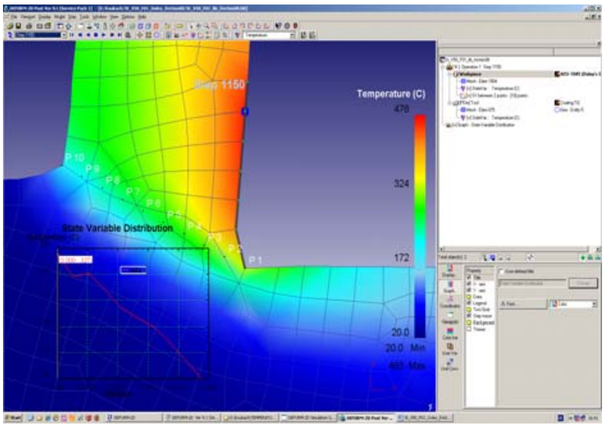


Fig.7. Area I (PAS 1150) ,Cutting speed 50 m/min, feed 0,1 mm/rot, friction coefficient 0,8

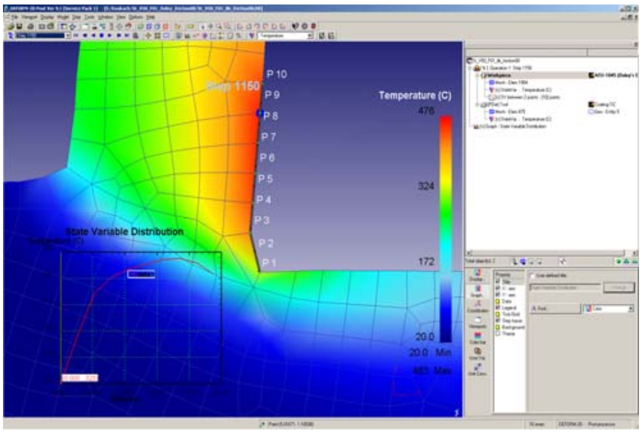


Fig.8. Area II (PAS 1150) , cutting speed 50 m/min, feed 0,1 mm/rot, friction coefficient 0,8

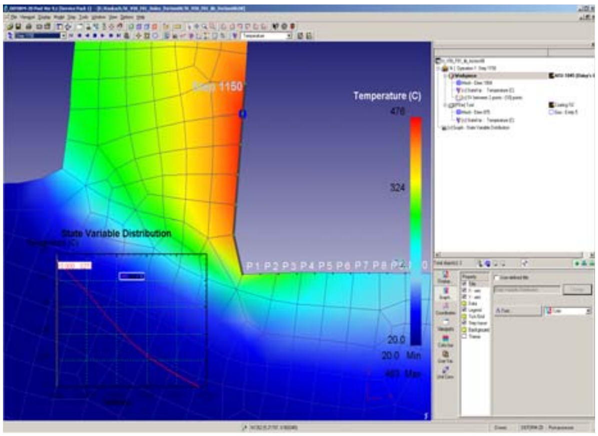


Fig.9. Area III (PAS 1150) , cutting speed 50m/min, feed 0,1 mm/rot, friction coefficient 0,8

The maximum value for the temperature of 476°C obtained in area II was compared with the values experimentaly determined and reported in the literature in the interval of 400...450°C and found that the difference is acceptable (fig.7-9)

4. CONCLUSIONS

The thermo-mechanical model developed to simulate orthogonal cutting, which bounds the thermal-structural effect with the consideration of temperature-dependent material characteristics, is acceptable.

The model calibration regarding the cutting force experimentally determined results, led to obtaining some values for the temperature field according the experimentally determined values presented in the specialty literature [1]. So the application of such an working algorithm where the experimental data is used to calibrate the simulation models, is very usefull.

The research undertaken contrbutited to the foundation of an thermo-mechanical model for the orthogonal cutting that can be calibrated regarding the experimental data of determining the cutting force.

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MODELAREA PROCESELOR DE PRELUCRARE PRIN AŞCHIERE

ABSTRACT: În a doua parte a articolului pe tema modelării proceselor de prelucrare prin aşchiere, se prezintă realizarea unei simulări numerice 2D pentru modelarea unui proces de aşchiere ortogonală, utilizând soft-ul comercial SFTC DEFORM-2D ® V 9.1, pentru oţel AISI 1045 (DIN 1.1191). Totodată, se prezintă determinările experimentale efectuate în vederea alegerii unui coeficient de frecare adecvat, care să minimizeze erorile în prezicerea forţei de aşchiere. Pentru coeficientul de frecare ales, se determină cu ajutorul modelului creat, valoarea maximă a temperaturii aşchiei, care se compară cu valorile determinate experimental prezentate în literatură. Cercetările au fost efectuate în cadrul unui stagiu la Institut fuer Werkzeugmaschinen, Universitatea Stuttgart, Germania.

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