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MACHINING PROCESS MODELING

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Abstract: *In the first part of the article on modeling of machining process with the finite element method (FEM) as a modern approach in investigating the processes of cutting, is presented the current state of research on thermo-mechanical materials used for modeling the cutting process, breaking criteria and fracture modeling methods, meshing and remeshing strategies of the finite element (FE) networks, modeling friction processes between piece and tool, modeling heat transfer between tool and chip and the tool wear model. The second part of the article presents the results of the research, performed during an internship in the Machining Institute at Stuttgart University, Germany.*

Key words: *modeling, finite element method (FEM), breaking criteria , FE networks*

1. INTRODUCTION

The role of modeling manufacturing processes becomes universally recognized in the industry, with increasing of the competition in the area of product and process design. To achieve high productivity in the cutting processes there is important, besides the selection of the machine, tool, cutting conditions and process sequence, a complete analysis of all the requirements and parameters needed to develop and optimize the processes and the cutting tools which can be made only by modern methods of simulation.

The modeling is mainly based on the finite element method, for which there is a wide range of software on the market. These programs provide the calculation and simulation of the cutting process both 2D and 3D in a satisfying time. However, so far some did not succeeded in developing a comprehensive calculation model, generally valid, for the cutting process cutting, given the complexity of the cutting process.

2. MODELING WITH THE FINITE ELEMENT METHOD (FEM)

2.1 Overview of the cutting process

The plastic deformation process for the orthogonal cutting is complex, on an extended temperature range and high levels of plastic deformation coeficients, creating special modeling difficulties in establishing a viable model. At first, the cutting layer suffers strong plastic shear deformations in the primary deformation zone I (Fig. 1) around the OC shear plan, additional shear occurs in the smaller dimension area II, at the tool-chip interface OE. The finite element method (FEM) allows the modeling of the chip forming mechanism with complex problems relating the temperature distribution, strain distribution and the field of plastic deformation produced by thermo-elasto-plastic loads specific to the orthogonal cutting.

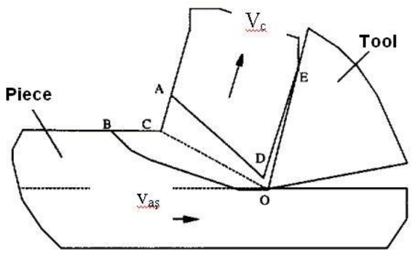

Fig.1. Orthogonal cutting model with continuos chip forming

The temperatures are very different in the primary and secondary cutting areas. The temperature field is the result of the thermal conductivity process, started from heat sources formed in the deformation process and friction on the contact surface (isothermal deformation) or adiabatic heating (adiabatic deformation). At the breaking forming proces witch generates the chip at small and medium cutting speeds, the temperature in the primary cutting area is relatively low (for steel AISI 1045-DIN 1.1191, is about 200°C). This is also characteristic for other materials. At high cutting speeds, the heat generated in the deformation process will not disperse, resulting in a considerable increase of the temperature in the primary cutting area, and a considerable drop of the material strengh. The result is a chip forming characteristic to the adiabatic deformation. The secondary cutting area temperature is higher then in the primary area due to heat generated by friction in the tool-chip interface. In this area the temperature can reach, during the cutting process, the melting temperature of the processed material T_m .

In general, we can confirm that during the cutting process, the materials to be processed go through visible changes. These changes differ very much in the cutting areas and lead to a mechanical qualities change of the material. The mathematical description methods of flow curves can be classified into: tabular, with neural networks, empirical and semiempirical.

2.2 Thermo-mechanical models of materials used in the cutting process modeling [3]

Stress and deformation fields describe separatly one dynamic and one cinematic state of the particles of a continuous environment. So far, however, there is no universal theory that would merge tensions, deformations, time and temperature to achieve a complex charging scheme to reach a specific concordance between calculations and experiments.

The material model for metals is typically determined by the additive decomposition of elastic and plastic deformations having an associative law. The law imposes the requirement of orthogonality of the vector that refers to the plastic deformation growth into the flowing area. This requirement is achieved by the flow condition by v. Mises and by two scalar ecuations, that connect the strains and deformations of the material.

The first of the two scalar equations, called the equation of state, connects the hydrostatic presure:

$$p = -1/3 tr(\sigma) \qquad (1)$$

with relative volume change:

$$p = p(\varepsilon, T) \qquad (2)$$

The second scalar equation, called the equation of determination or flow curve, contains a part of the material flowing conditions. It connects the yield point σ_S with the hardening parameters q, the deformation speed intensity $\dot{\varepsilon}^p$, temperature T and time τ :

$$\sigma_S = \sigma_S(q, \dot{\varepsilon}^p, T, \tau) \qquad (3)$$

To establish the determination equation, are enough experimental data that can be obtained from a simple charging scheme, such as tensile testing on a single axis. The obtained curves in the coordinates $\sigma - \varepsilon$, can be used as determination equation at the cutting process modeling. In practice, though, this requires a large computing effort. For a reduction of computing time and ease of use, the curves will be approximated through analytical equations. The mechanical deformation complexity and the visible differences in the shape of the curves $\sigma - \varepsilon$ for different materials, hinder the decisive choice of the approximation equation. The use of tables became known, as in [7] neural networks in [1]. The empirical and semiempirical methods have the biggest spreading. The analyses made for developing and empirical and semiempirical use for de flow curves can be found in Table 1.

The semiempirical ecuations can be presented with the following equations, based on research and considering the thermally activated plastic deformation method:

$$\sigma_S = \sigma_{aterm} + \sigma_{term} \quad (4)$$
$$\sigma_S = (\sigma_{Sa}(\bar{\varepsilon}^p).U(\dot{\bar{\varepsilon}}^p) + \sigma_{term}(T, \dot{\bar{\varepsilon}}^p)).\varphi(T)$$

in which $\sigma_{Sa}(\bar{\varepsilon}^p)$ is a rigid-plastic model of the plastic deformation considering the hardening process and the speed effect, $\sigma_{term}(T, \dot{\bar{\varepsilon}}^p)$ considers the ductile resistance of the material deformation, $\varphi(T)$ considers the temperature effects.

The analysis of the table 1 shows that the evolution of the flowing curve is based on very simple models: the rigid-plastic model of v. Mises and Newton´s linear-ductil model. A continuous development of the models was produced considering the gardening processes, deformation speed and thermal resi stance decrease.

Table 1

Development analysis of the semiempirical equations of flow curves

Author, Publication years		**Equation de stare**
0		**1**
Mises		$\sigma_S = \sigma_T$
Newton		$\sigma_S = \mu\dot{\bar{\varepsilon}}^p$
Ludwik P., 1909		$\sigma_S = \sigma_T + A\bar{\varepsilon}^p$
Perzyna P., 1966		$\sigma_S = \sigma_T(1 + \dot{\bar{\varepsilon}}^{p*})^n$
Sellars C.M., Tegart W.J., 1972		$\dot{\bar{\varepsilon}}^p = A(\sinh(a.\sigma_{mepM}))^m e^{\frac{Q}{RT^*}}$
Litonski J., 1997		$\sigma_S = \sigma_T(\bar{\varepsilon}_0^{\,p} + \bar{\varepsilon}^p)^n(1 + B\dot{\bar{\varepsilon}}^{p*})^m(1 + C\theta)$
Vinh T. U.a., 1979		$\sigma_S = \sigma_T(\bar{\varepsilon}^p)^n(\dot{\bar{\varepsilon}}^{p*})^m e^{-mT^*}$
Johnson G.R. Cook W.H.	Forma inițială, 1983	$\sigma_S = (A + B(\bar{\varepsilon}^p)^n)(1 + C\ln(\dot{\bar{\varepsilon}}^{p*}))(1 - (T^*)^m)$
	Altan T., 2000	$\sigma_S = (A + B(\bar{\varepsilon}^p)^n)(1 + C\ln(\dot{\bar{\varepsilon}}^{p*}))(1 - (T^*)^m + a.e^{-m_o(T^* - T_0^*)^2})$
	Ee K.C. 2004	$\sigma_S = (A + B(\bar{\varepsilon}^p)^n)(1 + C\ln(\dot{\bar{\varepsilon}}^{p*} + a.e^{-m_o\dot{\bar{\varepsilon}}^{p*}}))(1 - (T^*)^m)$
Usui E., 1987, Maekawa K. u.a., 1991		$\sigma_S = \sigma_T.\left[\int_{T,\bar{\varepsilon}\equiv(\dot{\bar{\varepsilon}})} e^{\frac{k.T}{N}}.(\dot{\bar{\varepsilon}}^{p*})^{\frac{m}{N}} d\bar{\varepsilon}\right].(\dot{\bar{\varepsilon}}^{p*})^{m_1}.\left(\sum_{i=1}^{n} A_i.e^{k_i.T} + B.e^{k(T-T_0)^2}\right)$
Klopp, R. W.; Clifton, R.J., 1985		$\sigma_S = \sigma_T\bar{\varepsilon}^n(\dot{\bar{\varepsilon}}^{p*})^m T^{-m_i}$
Zerilli F.J., Armstrong R.W., 1987		$\sigma_S = \sigma_T + A(\bar{\varepsilon}^p)^n + B_0 e^{\left(-\beta_0 + \beta_1\ln(\bar{\varepsilon}^p)\right)T}$
Follansbee P.S., Kocks U.F., 1988		$\sigma_S = \sigma_T + A(\bar{\varepsilon}^p)^n + \sigma_0^*.\left(1 - \left(\frac{-T.k_B\ln\left(\dot{\bar{\varepsilon}}^{p*}\right)}{\Delta G_0}\right)^{m_1}\right)^m$ k_B-constanta Bolzmann

Oxley P. L. B., 1989	$\sigma_S = \sigma_T(T_m)(\bar{\varepsilon}^p)^{m(T_m)}$, $T_m = (1 - A\ln(\dot{\bar{\varepsilon}}^{p*}))T$
Hensel A., u.a., 1990	$\sigma_{xx} = \sigma_T(\bar{\varepsilon}^p)^{n_1} e^{n_2 \bar{\varepsilon}^p} (\dot{\bar{\varepsilon}}^{p*})^m e^{-mT^*}$
Childs T.H.S., 2000	$\sigma_S = \sigma_T(\bar{\varepsilon}^p)^{n(T)} (\dot{\bar{\varepsilon}}^{p*})^{m(T)} \sum_{i=1}^{n} c_i T^i$
0	**1**
Marusich T.D., 1995	$\sigma_S = \sigma_T(A + \bar{\varepsilon}^p)^n (1 + B\dot{\bar{\varepsilon}}^{p*})^m \sum_{i=1}^{5} c_i T^i$
El-Magd E., Treppman C., 2000	$\sigma_S = (\sigma_T(A + \bar{\varepsilon}^p)^n + \eta\dot{\bar{\varepsilon}}^p)e^{-mT^*}$
El-Magd E., 2001	$\sigma_S = \sigma_T(\bar{\varepsilon}^p)^{m(T)}(1 + A\ln(\dot{\bar{\varepsilon}}^{p*}))e^{-\left(\frac{T}{T_2}\right)^m}$
El-Magd E., 2003	$\sigma_S = \dfrac{\sigma_0}{\left(1 + \left(\dfrac{\sigma_0}{\sigma^*}\right)^{\nu} e^{\frac{T}{T^0}} \dfrac{\dot{\varepsilon}^*}{\dot{\varepsilon}} \varepsilon\right)^{1/\nu}}$, $\sigma_0 = ((\sigma_T + A(\bar{\varepsilon}^p)^n)(\dot{\bar{\varepsilon}}^{p*})^m + \eta\dot{\varepsilon})\left(e^{\frac{T}{T_1}} + Be^{-\left(\frac{T}{T_2}\right)^{m_1}}\right)$

2.3.Breaking criteria and fracture modeling methods [4]

From experimental investigations it was concluded that the cutting process has a cyclic character, which is based on the formation of chip elements and finally the formation of the flowing chip. In this case the occurrence stages and crack development are repeated continuously. Because of this the breaking model should foresee the continuity interruption moment as well as the crack propagation direction.

Given the above, the moment of destruction starting is physically correct determined, by comparing the state of stress and deformation with the limit value, and it is used in the so called breaking criteria. To achieve the numerical algorithms using these criteria requires complex resources. Also, these algorithms are not stable enough and require the use of aids, in fact breaking geometric criteria. In a research project J. M. Huang and J.T. Black, show that using breaking geometric criteria leads to stable numerical solutions, altohught they do not contain informations about the physical behaviour of the mechanical breaking. The most known informations about the breaking criteria are presented in the table 2.

If the nature of the crack is known in advance, you can apply simple breaking criteria, based either on the intensity of the plastic deformation or the amount of tension (see criteria 2.1 and 2.5 of table 2). At the modeling of the steel chip formation with the surface separation method, Zahhbani S.A. used the criteria with the tension parameters as follows:

$$f = \sqrt{\left(\frac{\sigma_n}{\sigma_f}\right) + \left(\frac{\tau}{\tau_f}\right)} \qquad (5)$$

$$\sigma_n = \max(\sigma_2, 0) \quad ;$$

where the crack occurs at $f \geq 1$.

Wince used the same method at the aluminium alloys processing modeling. The values σ_f and τ_f were determined from the tension-compresion diagram for a given strain, where the amount of plastic deformation has been defined after the Oxley cutting model.

Table 2

Breaking criteria [4]

Breaking criteria		Conditions
0	**1**	**2**
1. geometric	1.maximum distance from the nod to the cutting edge	$d = d_{cr}$
2. physic	1.Plastic deformation intensity	$I_{cr} = \varepsilon_p$
	2. strain energy density	$I_{cr} = \int \sigma : d\varepsilon$
	3. cumulative work done at breaking	$I_{cr} = \int < \frac{\sigma_1}{\sigma_Y} > d\varepsilon_p$
	4. Cumulative sensitivity to disturbance	$I_{cr} = \int < \varepsilon_p + b_1\sigma_H + b_2 > d\varepsilon_p$
	5. maximum main stress	$\sigma_f = \sigma_I$
	6. resistance to crack generation	$\sigma_f = \frac{K_{IC}}{(2\pi d)^{0,5}}$
	7. cumulative damage $D = \sum \frac{\Delta\bar{\varepsilon}^p}{\bar{\varepsilon}_f^p} \geq 1$	$\bar{\varepsilon}_f^p = (D_1 + D_2.\exp(D_3\sigma^0)).(1 + D_4 \ln \bar{\varepsilon}^0)(1 + D_5 T^0)$; $\sigma^0 = \sigma / \sigma_M$
		$\bar{\varepsilon}_f^p = \varepsilon_0 - \alpha \frac{p}{\sigma} - \beta \frac{\dot{\varepsilon}}{V_c}$
		$\bar{\varepsilon}_f^p = - < 0{,}075 \ln\left(\frac{\dot{\varepsilon}_p}{100}\right) > - \frac{\sigma_H}{37{,}8} + 0{,}09 \exp\left(\frac{T}{293}\right)$
		$\bar{\varepsilon}_f^p = A\left\{\frac{\sigma_Y^2}{2Er}\left[\frac{2}{3}(1+v) + 3(1-2v)\left(\frac{\sigma_H}{\sigma_Y}\right)^2\right]\right\}^{-S} + \frac{\partial \varepsilon_f}{\partial T}(T - T_0)$

As a general criteria for material processing modeling using plastic deformation parameters, can be used the criteria first proposed by Hancock and Mackenzie and later by Johnson and Cook, namely:

$$D = \sum \frac{\Delta\bar{\varepsilon}^p}{\bar{\varepsilon}_f^p} \geq 1 \qquad (6)$$

$$\bar{\varepsilon}_f^p = (D_1 + D_2.\exp(D_3\sigma^0)) \times (1 + D_4 \ln \bar{\varepsilon}^0) \times \times (1 + D_5 T^0)$$

$$\sigma^0 = \sigma / \sigma_M \qquad (6a)$$

where σ is the hydrostatic pressure, σ_M is v. Mises tension, D constants are determined experimentally by the Johnson-Cook method.

If the crack nature is not known whether before or at last is known that the crack has a combined character, there have to be used combined breaking criteria. In modern practice the combined criteria are used by the following two assumptions:

-for the tension and strain state a full value is being chosen, which depends on both the size of plastic deformation and the size of maximum tangential tension;

-between two criteria, which independent of each other contain the tension and plastic deformation characteristic, will be a kind of competition. It is assumed that the brake will take place at that point where at least one of the two criteria is met.

Hashemi (1994) used a combination between the equivalent plastic request and the maximum main pressure for the simulation of rapid processing.

The ductile breaking concept was introduced by Itawa. He calculated (in 1984) the braking criteria criteriile de rupere by the time step, based on the state of final demand.

Marusich and Ortiz proposed in 1995 to use the brittle braking criteria, which is based on K_{IC} toughness about breaking the material or ductile breaking criteria:

$$\max_{\theta} \sigma_{\theta}(1,\theta) = \sigma_f \qquad (7)$$

$$\sigma_f = \frac{K_{IC}}{\sqrt{2\pi l}}$$

The criteria is based on pure growth and melting and uses a version of the plastic criteria of Rice and Tracey:

$$\max_{\theta} \varepsilon^p(1,\theta) = \varepsilon_f^p \qquad (8)$$

$$\varepsilon_f^p = 2{,}48 e^{-1{,}5 p/\bar{\sigma}}$$

Owen and Vaz (1999) admitted a chip breaking criteria which was based on considerations of damage related to an adaptive remeshing and element wear.

Important for the working of FE cutting models,in Langrange`s formulation, is the deployment of the method for achieving that break to interrupt the material continuity. The tension values in the primary and secondary deformation areas, chip shape, cutting force components and especially the force at the free surface and other characteristics of the cutting process and cutting model validity are closely related to the properties of the breaking method.Till now there are known four different types to achive the main break:

-division of the nodes on a default border;

-division of the nodes on any border;

-division of the nodes by deleting elements;

-FE network remodeling.

The method of nodes division on a default border consists in dissolving the link between the processing surface nodes and the allready processed surface, when a geometrical or physical breaking criteria is met and the nodes are on the processing surface. Basically this is done either by breaking overlapping nodes or by introducing elasic elements. With such a method a development of a break is beeing modeled, but the direction of propagation of the crack will pe introduced artificially. This leads to errors in determining the tension and makes it impossibile to model the state of tension and strain and implicitly the cutting forces near the cutting edge.

The method of nodes division by any border uses a node division in a point and on one direction in which one of the physical breaking criteria is met. In this case it is necesary to compress the network in the crack tip, and a finit element analysis for choosing the direction of the crack propagation.

The method of nodes division by deleting the elements in the integration point where the breaking criteria is met, consists in losing the material masses with the deletion of elements. At a small size of elements, the mass of material that is lost is small, so that this does not affect experimantal results. In the cutting finite element model can only small elements on one surface be deleted, in this case the method will run similar to the method of nodes division on a default border.

In the last years gained popularity, as a breaking modeling method, the method that does not consits in instantaneous removal of elements to achive predefined criteria, but it reduces the load on the element and the crack changes within certain limits. If the intensity of deformation of a finite element reaces the value ε_0, the development of the crack starts.

When it reaches the value ε_f, the finite element will dissipate, losing its capacity to resist to a load. In mid-1990 network restructuring algorithms have been developed (adapting R), which compensate the need of a limit zone and an continuous finite element network level support introduction. It was shown that using the criteria that uses a permanent renewal of the finite element network, although requiring more resources, it describes better the cutting process than the method that uses the nodes division on an default border criteria.

2.4. Meshing and remeshing FE networks strategies [5]

One of the biggest disadvantages of breaking criteria for tension parameters is the need for adaptive compression network (H-adaption and/or R-adaption). This occurs in the cutting edges to eliminate errors of the tension gradients in the shear area. As a possible alternative there can be used finite elements with high rank (P-adaption), single elements or a mediation of the stress after a finite element nearby. The remeshing is important for an approximation on an lagrange basis, due to the sensitivity of the method of solving a highly deformation grade gearing.

To resolve this problem there has been addressed two ways, one active and one passive.

A passive approach results in a pre-distorted grid. It must compensate the deformation resulting from cutting simulation.

Such a method has been used by Strenkowski and Carrol in 1985 .

The active approach consists of a statement that triggers a remeshing subroutine. Such a statement may be geometric, like those used by Sekhon and Chenot in 1993.

Marusich and Ortiz used as a statement the plastic energy application rate or an element of estimation based on consideration of material failure like the one used by Vaz, Jr to simulate the rapid processing.

Table 3

Meshing and remeshing statements

Method	Observations
Pre-distorsional network	No remeshing
Element deformation	Geometrical considerations
Plastic energy application rate	$\omega_p = \sigma_Y \dot{\varepsilon}_p$
Failure indicator rate	$\dot{I}_D = \left\{ \frac{\sigma_Y^{\ 2}}{2E} \left[\frac{2}{3}(1+v) + 3(1-2v)\left(\frac{\sigma_H}{\sigma_Y}\right)^2 \right] \right\}^{-s} \dot{\varepsilon}_p$

2.5.Friction at the contact between piece and tool modeling [6]

The friction between tool and piece has an important role in the process of cutting. It is an important source of heat and the most important factor in tool wear.

Table 4

Friction models

Method	Expression
0	**1**
Coulomb`s law	$\tau_f = \mu_c \sigma_n$
Exponential law	$\tau_f = \tau_e \left[1 - \exp\left(-C \frac{\sigma_n}{\tau_e} \right) \right]$
Iwata et. al.	$\tau_f = \frac{H_v}{0{,}07} \tanh\left(\frac{0{,}07 \mu \sigma_n}{H_v} \right)$
Eldrige et al	$\tau_f = \tau_f (T_0) \exp\left(\frac{A}{T} \right)$
Wu et al	$\tau_f = -\Omega \sigma_{eq}$
Sekhon and Chenot	$\tau_f = -\alpha K \left\| v_f \right\|^{p-1} v_f$
Amontons and Coulomb	$\tau_R = \mu \sigma_N \ ; \ \tau_R = m \frac{k_f}{\sqrt{3}}$
Zorev	$\tau_R = \mu \sigma_N \ ; \ \tau = \tau_{\max}$

For friction, generally is used Coulomb´s model, although the model itself does not fully describe the friction phenomenon. This is why many researchers have studied different experimental models.

Shirakashi and Usui used in 1974 an exponential law, which was first developed for non-ferrous materials and was based on the active contact surface concept.

Itawa developed a model that also takes into account the Vickers herdness of the workpiece. It was later considered in the models also the influence of the temperature as was introduced by Eldridge in 1991.

Wu assumed that the friction is proportional to the equivalent pressure.

In 1993, Sekhon and Chenot admitted Norton´s friction law, based on the relative speed of sliding between tool and chip. Newer models tend to improve Coulomb´s law.

Amontons´s and Coulomb´s approximation reports friction at the shear load from the flowing pressure.

Zorev divided the friction area in two: displacement and adherence.

Dudzinski and Molinari paid attention to the influence of friction coefficients of Coulomb´s law and their dependance on cutting speed and temperature.

Tyan used the law of friction factor and analyzed the influences of speed and rate of application of the load on the friction factor m.

Today friction cand be simulated in an acceptable way, but it depends on coeficients very hard to calculate.

2.6.Heat transfer between tool and chip modeling [8]

Behaviour at different temperatures began to be analyzed with the introduction of high speed cutting. There are several approximations for modeling behaviour at different temperatures. The adiabatic warming assumes that heat from mechanical work of unelastic deformations and from friction inside an element is beeing generated and there is no disposal through heat transfer. This was experimentally verified for the processes of manufacture of materials with low diffusion (spray) and at high cutting speed.

Combining fully consider heat transfer within the workpiece and tool.

Table 5

Heat transfer models

Method	Equation
Transit heat transfer	$-k_w\left(\frac{\partial T}{\partial n}\right)_w = -k_t\left(\frac{\partial T}{\partial n}\right)_t$
Constant factor	$q_w = f_c q_f$
Two infinite half-bodies	$\frac{q_w}{q_t} = \frac{\alpha_t^{0,5}}{\alpha_w^{0,5}}\frac{k_w}{k_t}$; $q_f=q+q_t$
Heat balance	$\int_w q_w c_w \Delta T_w dv = \int_t q_t c_t \Delta T_t dv$

To simulate the heat transfer between tool and chip, Usui and Shirakashi introduced the transit heat transfer concept. It involves a heat flow on the side of the chip and of the tool interface.

The two infinite half-bodies approximate the friction, loaded on the chip and the tool, energy estimation

Another hypothesis to the chip-tool heat transfer problem, based on the first law of termodynamics, named thermal balance method, was introduced in 1996 by Obikawa and Usui.

2.7.Tool wear model [9]

The simulation of the tool wear phenomenon was stimulated by the need to continuously increase the precision of the FEM metal cutting models and their applicability in industry. The main types of tool wear are considered such as abrasion, adhesion and diffusion.

Table 6

Tool wear model

Tool wear model	Equation
Takeyama and Marata	$\frac{dW}{dt} = G(V,f) + D\exp\left(\frac{-E}{RT}\right)$
Usui	$\frac{dW}{dt} = A\sigma_n V_S \exp\left(\frac{-B}{T}\right)$

Takeyama´s and Maratas model consider the wear through abrasion and difussion.

Usui´s model for adhesion wear consider the factors of temperature dependency, normal pressure and the speed on the contact surface.

Mathew showed that the influence of the abrasive wear according to Takeyama and Marata can be neglected.

Molinari and Nouari proposed a model and established a direct temperature control into the diffusion rate.

3. CONCLUSIONS

The cutting process modeling by finite element method (FEM) involves four steps:

1.Model creation

2.Model resolving

3.Simulation results analysis

4.Possible model changing or optimization

The most important step of the four mentioned above, is the model creation. The best way to demonstrate the accuracy of a virtual model is to compare it with experimental data.

Given the above, in the second part of the article on cutting processes modeling, is presented an 2D numerical simulation of a orthogonal cutting process modeling using the commercial software SFTC DEFORM-2D ® V 9.1 [10] for steel SI 1045. The cutting force will pe experimentaly determined for different cutting conditions and the friction coefficient for the developed model will pe chosen in order to minimize errors in the prediction of cutting force value.

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MODELAREA PROCESELOR DE PRELUCRARE

Rezumat: În prima parte a articolului pe tema modelării proceselor de prelucrare prin aşchiere prin metoda elementului finit (FEM), ca şi abordare modernă în cercetarea proceselor de aşchiere, se prezintă stadiul actual al cercetărilor privind modelele termo-mecanice de materiale utilizate la modelarea procesului de aşchiere, criterii de rupere şi metode de modelare a ruperii, strategii de discretizare şi rediscretizare a reţelelor cu elemente finite (FE), modelarea proceselor de frecare la contactul dintre piesă şi sculă, modelarea transferului termic dintre sculă şi aşchie şi modelul de uzură a sculei.În partea a doua a articolului sunt prezentate rezultatele cercetărilor efectuate în cadrul unui stagiu la Institut fuer Werkzeugmaschinen, Universitatea Stuttgart, Germania.

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