Numerical Analysis of the Influence of Cutting Angle on States of Strain and Stress in the Surface Layer of Object

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Abstract. For the experiment needs, the experiment research plan was developed. The researches were carried out to determine the effect of variable cutting angle on the chip's shape. The phenomena on a typical incremental step were described using a step-by-step incremental procedure, with an updated Lagrangian formulation. Then, the finite elements methods (FEM) and the dynamic explicit method (DEM) were used to obtain the solution. Choosen cases were experimentally verified. Conclusions from the experiments were given.

INTRODUCTION

The researches carried out for the purposes of this article is a continuation of the author's researches [1÷8]. It was accepted in the simulations that the abrasive grain is a non-deformable body, while the object is a an elastic/visco-plastic body described with the aid of Cowper-Symonds' model. In the model, Huber-Mises-Hencky's plasticity model is used together with the associated flow right. The model takes into consideration the line-isotropic $(\beta = 1)$, kinematic $(\beta = 0)$ or mixed $(0 < \beta < 1)$ plastic hardening as well as the influence of the intensity of the plastic strain rate, according to the involution dependence:

$$\sigma_Y = (R_e + \beta E_{tan} \varphi_i^{(p)})[1 + (\dot{\varphi}_i^{(p)}/C)]^m \text{, [MPa]} \tag{1}$$

where σ_Y – yield stress, R_e [MPa] – initial yield stress point, $\varphi_i^{(p)}\ [-]$, $\dot{\varphi}_i^{(p)}\ [s^{-1}]$ – intensity of strain and plastic strain rate respectively, $C\ [s^{-1}]$ – material parameter to determine the influence of the intensity of the plastic strain rate, $m = 1/P$ – material constant determining the sensitiveness of material on the plastic strain rate, $E_{tan} = E_T E/(E - E_T)$ – material parameter dependent of the module of plastic hardening $E_T = \partial\sigma_p/\partial\varphi_i^{(p)}$ and of Young's elasticity module E.

The following parameter values were accepted: density of body material $\rho = 7865\ [kg/m^3]$, Poisson's number $\nu = 0{,}27$, limiting damaging strain $\varepsilon_f = 2{,}5$ and $E = 200\ [GPa]$, $R_e = 310\ [MPa]$, $E_{tan} = 763\ [MPa]$, $C = 40\ [s^{-1}]$ and $P = 5$.

Also, constant values were accepted of static $\mu_s = 0{,}1$ and dynamic $\mu_d = 0{,}05$ friction coefficients. The tool cutting edge angle changes in the range of $\gamma = 30 \div 90^0$. The rounding radius of the tool apex was $r = 0{,}001\ [\mu m]$.

RESULTS

Analyzing the obtained results, it was found that when the cutting angle changed γ the values of deformations and stresses may change. Abrupt increases of stresses are the result of the chip creation phenomenon. With the increase of the cut angle of the tool, the shear angle Φ of the material separated from the foundation also increases. It was found that the angle has a significant impact on the shape of the chip (Figure 1). In addition, the shape of the chip depends on the type of material being processed. The greater the hardness of the material, the smaller the chip size. The cutting speed also has a significant impact on the chip formation and shape.

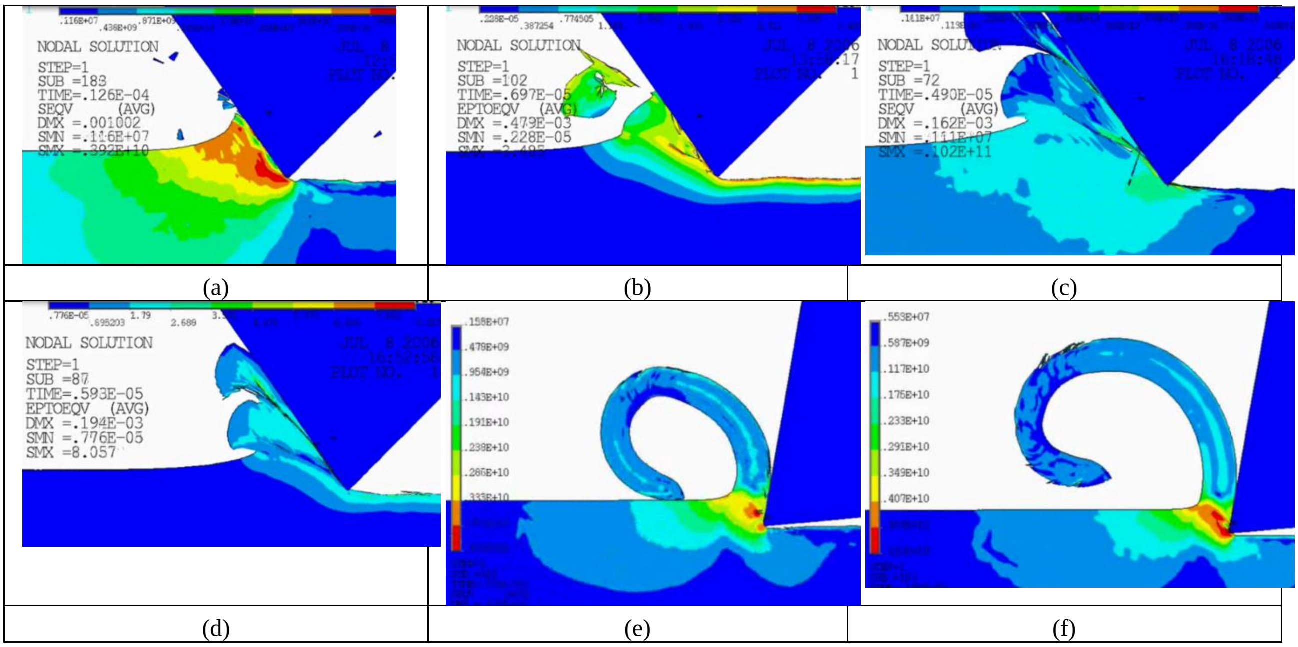

FIGURE 1. Maps of reduced stress and reduced strain in the chip creation phase for different materials (a)-(d) and velocities (e) and (f).

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