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INFLUENCE OF DENSITY CHANGE ON FRACTURE IN THE PROBLEM OF MATERIAL CUTTING

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Abstract. Possibility of using technological process of materials cutting to determine fracture characteristics connected to density change in a neighborhood of a crack's peak is considered.

1. Introduction

Material fracture processes in terms of fracture mechanics are currently associate with the macrocracks propagation tasks. The problem of crack initiation and quantitative description of the processes studied in much lesser degree.

The fracture processes of materials related to their plastic deformation. One of the deformation processes, in which, under certain conditions both process are present is material cutting. The type of the chip (e.g., jointed or drained) depends on the strain rate. The transition from the drained to the jointed chip determined by a certain critical velocity V_c, which effectively divides the cutting process without fracture and the process of the chip fracture. The fracture process is preceded by a process of changing the material structure and, in particular, pore formation, which generally affect the average density ρ of the material chip are not accounted for pore formation. This process may affect the variation of the coefficients of length and thickness of the chip: $K_L = \frac{L_0}{L}$, $K_a = \frac{a_0}{a}$, where L is a chip length, L_0 is a cutting length, a is a chip thickness, a_0 is a thickness of the cutting layer.

Using these parameters to determine the critical value of the average density of the material chip ρ_c, leading to the formation of macrocracks.

2. Determination of kinematic parameters

Let us consider the cutting problem in the framework of [1], taking into account the existence of statically continuation of the stress field to the rigid regions, that is not to exceed the yield stress.

Plastic deformation is carried out along an isolated slip line AB (Fig. 1) under plane strain conditions. Material density ρ left of the AB line when passing through it is subject to change.

Let us consider the problem of determining the kinematic parameters when the particle passing through an isolated slip line AB, is a line of discontinuity of the displacement velocity.

We consider the generalized cutting problem with the irreversible compressibility on the assumption that there exists an isolated slip line, under the Coulomb - Mohr plasticity condition [5]:

$\frac{1}{4}\left(\sigma_{11}-\sigma_{22}\right)^2+\sigma_{12}^2=\left(k+\frac{sin\gamma}{2}\left(\sigma_{11}+\sigma_{22}\right)\right)^2$, where k is adhesion coefficient, $\gamma=\frac{\pi}{2}-2\varphi$ is the angle of internal friction.

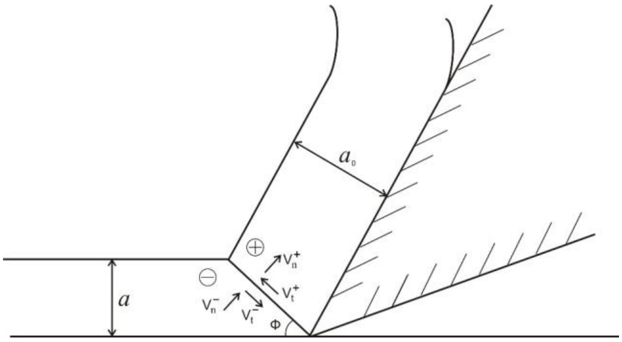

Fig. 1. Isolated slip line at the problem of cutting.

The cutting problem under the Coulomb - Mohr plasticity condition considered in [2-4].

We describe the motion of the medium in the Euler variables. Let us accept the hypothesis of medium continuity, so the functions x_i^0 are continuous. Derivatives of these functions on the surface of velocitys discontinuity displacement must satisfy the geometric and kinematic Hadamard - Thomas compatibility conditions [6]:

$$\left[x_{i,j}^0\right]=\lambda_i n_j, \quad \left\lfloor\frac{\partial x_i^0}{\partial t}\right\rfloor=\lambda_i G, \tag{1}$$

where $\left\lfloor x_{i,j}^0\right\rfloor=x_{i,j}^{0+}-x_{i,j}^{0-}$; n_j are components of the unit vector normal to the surface of discontinuity; λ_i are some functions defined on the surface of discontinuity; indices «+», «–» refers to the part of the surface of discontinuity.

Below the line of the discontinuity of displacement velocities material we shall assume undeformed:

$$x_{i,j}^{0-}=\delta_{ij}. \tag{2}$$

Because along each trajectory of a particle Lagrangian coordinates are constant, we have

$\frac{dx_j^0}{dt}=\frac{\partial x_j^0}{\partial t}+v_k\frac{\partial x_j^0}{\partial x_k}=0,$ which implies $\left\lfloor\frac{\partial x_j^0}{\partial t}\right\rfloor=-\left\lfloor v_k\frac{\partial x_j^0}{\partial x_k}\right\rfloor.$

Taking into account the first relation in (1) and the relation (2) we obtain

$$\left\lfloor\frac{\partial x_j^0}{\partial t}\right\rfloor=-\left[v_j\right]-\lambda_j v_n^+ \tag{3}$$

(v_n^+ is the normal velocity of particles above the line of discontinuity). Vector of the velocity jump can be represent in the form: $\left\lfloor v_j\right\rfloor=\left[v_t\right]t_j+\left[v_n\right]n_j$, where $\left\lfloor v_t\right\rfloor$ is tangential velocity jump; $\left\lfloor v_n\right\rfloor$ is normal velocity jump; t_j and t_n are components of the unit vector tangent and normal (respectively) to the surface of discontinuity.

From the comparison of the right sides of (1), (3) we obtain [3]

$$\lfloor x_{i,j}^{0} \rfloor = -\left(W_1 t_i + W_2 n_i\right) n_j, \quad x_{i,j}^{0+} = \delta_{ij} - \left(W_1 t_i + W_2 n_i\right) n_j, \tag{4}$$

$$W_1 = \left[v_t\right] / \left(G + v_n^+\right), \quad W_2 = \left[v_n\right] / \left(G + v_n^+\right),$$

where W_1 ,W_2 are bulk density of dissipated energy of shear and cubic strains normalized to the yield stress (respectively). These relationships allow us to get the increment of the distortion tensor components on the line of discontinuity.

Let us assume the principal values of the tensor Almansi of finite deformations for the deformation characteristics of the particle:

$$E_{1,2} = \frac{1}{2}\left(E_{11} + E_{22}\right) \pm \frac{1}{2}\sqrt{\left(E_{11} - E_{22}\right)^2 + 4E_{12}^2}, \qquad E_{ij}^{+} = \frac{1}{2}\left(\delta_{ij} - x_{k,i}^{0} x_{k,j}^{0}\right). \tag{5}$$

Density changing of the medium as a result of deformation is determined by the relation

$$\frac{\rho}{\rho_0} = \sqrt{\left(1-2E_1\right)\left(1-2E_2\right)}, \tag{6}$$

where ρ_0 is initial density.

Relations (4)–(6) are determine the relationship between density changes and specific dissipation of the internal forces.

3. Determination of density changes of the material

The coefficients K_L and K_a may be determined experimentally. In this case, density change of the material described by the relation: $\rho_c / \rho_0 = K_L \bullet K_a \bullet K_W$, where $K_W = 1$ is a coefficient of the chip width changing under the condition of plane strain.

4. Conclusion

1. Average density change of the chip is uniquely related to the specific dissipation of the internal forces.
2. The introduction of the new criteria parameter $\rho = \rho_c$ is equivalent to the relation $W = W_c$, where ρ_c and W_c are critical values that determine the moment of macrocracks initiation.

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