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DEFORMABILITY OF BLANKS IN CONDITIONS OF COMPLEX LOADING

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The tendency of the evaluation of maximum forming of purveyances in the conditions of the difficult loading and unmonotonous deformation are resulted in work. It is rotined that on the basis of development of mathematical theory of plasticity and phenomenological theory is possible prognostication of technological heredity of purveyances without the leadthrough of labour intensive experimental researches.

Key words: deformability of blanks, plasticity, deformation, diagram, invariant.

Introduction

The current stage of development of domestic and foreign engineering is characterized by the creation of new advanced technologies to ensure the quality and favorable technological heredity of finished products. It raises the need to apply together with the known theories and methods to assess new approaches for various application tasks , the study on a new level of metal flow processes under complex loading.

In metal forming widely applied phenomenological theories, which are based on the hypothesis of plasticity depending on the loading history, which is defined in the stress space. Characteristics of stress state can be indicators to investigate the loading path is not in the space of the stress tensor, and in the space of its invariants.

Formulation of the problem

The practical interest is evaluation of the possibility of using the plasticity chart built in flat or linear stress state to assess the deformability of metals deformed under bulk stress state. The solution of this problem is due to the difficulties in carrying out specific experiments in high-pressure. In our research, it is shown that the dependence of the plasticity of the stressed state of the circuit can be characterized by two indicators of stress state, and justified that the volumetric stress state must take into account the impact on the plasticity of the third invariant of the stress tensor [1, 2, 3].

Research results

During traditional solutions of technological problems loading process is given six functions of time $\sigma_{ij}(t)$ or functions Sij(t) and the independent function of time σ(t). In connection with the assignment to the trajectory in the space of the pro-stress may use two dimensionless parameters of stress state:

$$\eta = \frac{I_1(T_\sigma)}{\sqrt{3I_2(D_\sigma)}} = \frac{\sigma_1 + \sigma_2 + \sigma_3}{\sigma_u}\ ; \qquad \chi = \frac{\sqrt[3]{I_3(T_\sigma)}}{\sqrt{3I_2(D_\sigma)}} = \frac{\sqrt[3]{\sigma_1\sigma_2\sigma_3}}{\sigma_u} \tag{1}$$

The main advantage of the approach, in which the trajectory of the load is given in the space of dimensionless parameters η and χ lies in the fact that its appearance is uniquely determined by forming conditions for the process and practically does not depend on the mechanical properties of deformed metal. This gives ample opportunity for computer modeling and the selection of optimal materials products, for which you need to know the parameters of approximation coefficients flow curve and surface boundary plasticity. In addition, this approach significantly reduces the amount of labor-intensive experimental studies.

The magnitude of the boundary deformation e_p significantly affected by the third invariant of the stress tensor $I_3(T_\sigma)$. Plastic material deformable under hydrostatic pressure, one can imagine a boundary surface constructed in coordinates $e_p = e_p(\eta, \chi)$. Surface constructed at the specified coordinates, can be defined as three-dimensional diagram of plasticity. When designing processes shaping blanks in a volumetric stress state and complex loading is necessary to consider the influence of various invariants of the stress tensor on the resource of plasticity, the nonlinearity of damage accumulation and nonmonotonic loading. Evaluation of formability of blanks can be carried out if the known dependences of stress state and the accumulated strain intensity in the most dangerous (in terms of damage) fields blank on the magnitude characteristic of deformation and other process parameters have a decisive influence on the stress-strain state.

As an example, consider we investigated the formation of the internal spline profile compression method billets on a rigid mandrel [3]. It was found that the most dangerous area of contact is the contact area of the wedge slot mandrel and plastic region in which indicators (1) reach the maximum (including sign) values, therefore, it is the most rigid. While studies have investigated the movement of dots dangerous areas in the physical plane through the simulation on composite samples and in the plane of the indicators $\overline{e}_u$; η; χ, components which are calculated at various stages of the blanks formation.

To investigate the influence of the third invariant of the stress tensor was conducted a comparative analysis of the calculations used resources plasticity by the criterion of G.D. Del, V.A. Ogorodnikov, V.G. Nakhaychuk, based on the nonlinear theory of damage accumulation [4]:

$$\psi = \int_0^{e_u} n \frac{e_u^{n-1}}{e_p(\eta)^n} de_u = 1; \qquad n = 1 + 0,2 arctg \frac{d\eta}{de_u}, \tag{2}$$

and also by the criterion of G.D. Del [5], who takes into account the orientation of nature damage and contains the tensor model of damage accumulation:

$$\psi_{ij} = \int_0^{e_u} \left(1 - a + 2a \frac{e_u}{e_p(\eta)}\right) \beta_{ij} \frac{de_u}{e_p(\eta)}; \qquad \psi_{ij}\psi_{ij} = 1. \tag{3}$$

On the picture 1 is a graph of ductility steel 20X and ways of deformation dangerous areas during the introducing of splined stamp (for a detailed description of the results is presented in the work [3]. Picture 2 - discrepancy between the results of calculations $\psi(\chi)$, $\psi(\eta)$, $\psi_{ij}(\chi)$, $\psi_{ij}(\eta)$. Picture 3- presents the plane deformation and boundary surfaces, which show an adequate supply of plasticity.

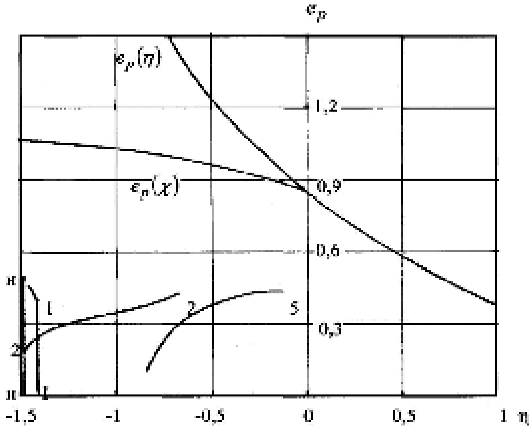

Fig. 1 – Chart plasticity of steel 20X and ways of deformation dangerous areas during the introducing of splined stamp

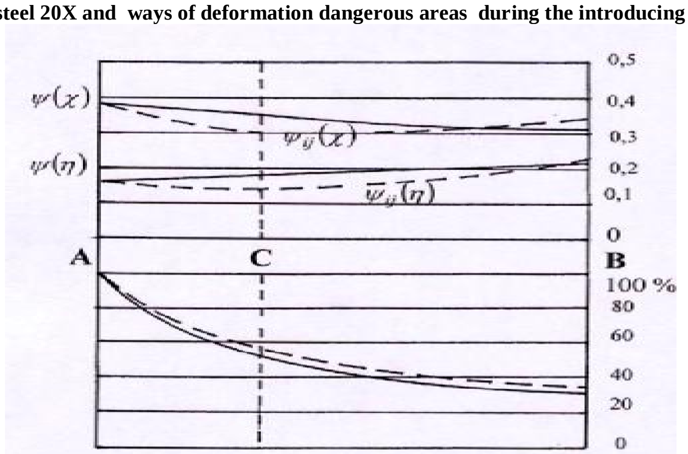

Fig. 2 – The discrepancy between the results of calculations y(c), y(h), y**ij**(c), y**ij**(h

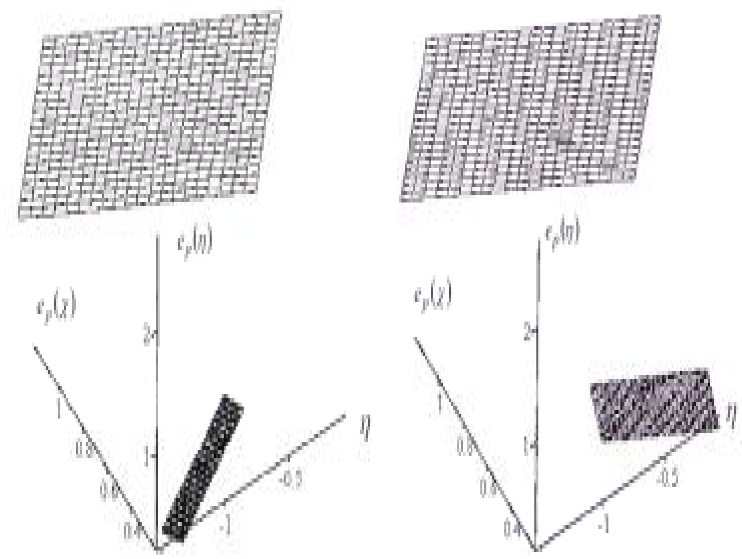

Fig. 3 – Planes deformation of regions close to the destruction $\overline{e}_u = f(h, c)$ **and the boundary surface**

$$e_p = f(h, c)$$

Conclusions

1. From these data it follows that the used resource of plasticity, calculated taking into account the influence of $I_3(T_\sigma)$, appeared at different values of η higher values ψ, calculated excluding the impact $I_3(T_\sigma)$. Thus, the magnitude of divergence depends on the performance η and χ. With decreasing η (increasing of hydrostatic pressure) increases the influence $I_3(T_\sigma)$ on the value of the boundary deformation.

2. At certain levels of hydrostatic pressure ,when its meaning by the module approaching the yield strength of the material in shear, influence $I_3(T_s)$ decreases. A further increase in pressure ,is likely, to lead to an increase of its influence.

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Нахайчук О.В., Пухтицкая Н.А. **Деформируемость заготовок в условиях сложного нагружения.**

Формообразования заготовок сложного профиля сопровождается потерей устойчивости, разрушением металла в процессе его обработки, ростом зерна после термообработки и др. Для устранения указанных явлений необходимо всестороннее изучение процессов холодной объемной штамповки с использованием законов и методов механики сплошной среды, математической и прикладной теории пластичности, а также феноменологической теории деформируемости.

Применение теории деформируемости для решения технологических задач позволяет дать ответ не только на вопрос определения предельных параметров формообразования. Оценка пластичности важна для выяснения возможности выполнения дальнейших операций, поскольку свойства материала зависят от величины накопленной деформации.

В работе представлен поход к оценке граничного формообразования заготовок в условиях сложного нагружения и немонотонного деформирования. Показано, что на основании математической теории пластичности и феноменологической теории деформируемости возможно прогнозирование технологической наследственности заготовок без проведения трудоёмких экспериментальных исследований.

Ключевые слова: деформируемость заготовок, пластичность, деформация, диаграмма, инвариант.