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V. Glouschenkov, V. Grechnikov. STRUCTURAL CHANGES ORIGINATING IN THE BLANK MATERIAL AT THE MOMENT OF COLLISION WITH TOOLING AND THEIR INFLUENCE ON THE QUALITY OF THE FINISHED WORKPIECE. Journal de Physique IV Proceedings, 1991, 01 (C3), pp.C3-335-C3-339. 10.1051/jp4:1991348 . jpa-00250492

HAL Id: jpa-00250492

<https://hal.science/jpa-00250492>

Submitted on 1 Jan 1991

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STRUCTURAL CHANGES ORIGINATING IN THE BLANK MATERIAL AT THE MOMENT OF COLLISION WITH TOOLING AND THEIR INFLUENCE ON THE QUALITY OF THE FINISHED WORKPIECE

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Résumé: Cette étude considère les conditions pour générer les changements de structure et leur influence sur le degré de déformation d'un tube avant la collision, sur la vitesse de collision et sur les propriétés physiques et mécaniques du matériau impacté. Les limites supérieures et inférieures pour la vitesse de collision qui permettent de déterminer les changements de structure ont été fixées. On montre l'influence de la vitesse sur la valeur des contraintes résiduelles et les dimensions finales de la pièce.

Abstract - The paper considers the conditions of generating structural changes and their dependence on the degree of tangential structural strain of a blank before the collision, on the collision velocity and on the mechanical and physical properties of the colliding materials. Lower and upper boundaries for the collision velocities determining structural changes are set. The velocities influence upon the value of residual stresses and upon the workpiece final dimensions is shown.

Products of different branches of machine building include hollow members. There exist various technological processes of such members manufacturing and among them impulse and magnetic-pulse techniques are widely adopted /1/.

Under the pressure of an impulse magnetic field a blank shaping is performed, the process resulting in a blank impingement against a die. By the moment of collision the blank has been deformed to the degree $\epsilon_p = \ln D_k/D_0$ and has acquired the velocity V_c (Fig.1).

Fig. 1. The scheme of magnetic-pulse stamping of an adapter:
a) initial position;
b) final position.

The speed of collision in this process influences the final work-piece dimensions (Fig. 2).

Fig. 2. An example of a blank circumferential deformation change resulted from its collision with tooling under $\epsilon_\varphi = 5\%$. The collided material of a die is St45, the material of a blank is AMg6M.

Collision may be either elastic one when despite plastic deformation of the blank it induces only elastic waves of strain and deformation through its thickness or plasto-elastic one when both elastic and plastic waves of strain and deformation propagate along plastically stretched blank (Fig. 3) /2/.

Fig. 3. The scheme of strain and deformation wave propagation under elastic collisions (a) and plasto-elastic collisions (b). Respectively S_{el} and S_{pl} are speeds of elastic and plastic wave propagation.

Under plasto-elastic collision some structural changes are observed at the depth of plastic wave propagation. So, AMg6M alloy structures being obtained as a result of plastic form-changing up to $\epsilon_p=5\%$ illustrate possibilities of plastic and plasto-elastic collisions. When the collision velocity is $V_c=30$ m/sec the structure of the material remains uniform and bears no changes generated by the impingement. The structure of workpiece material experiencing collision velocity of $V_c=50$ m/sec has two typical zones: a zone with a strong plastic deformation of the impinged surface and a zone with a slight deformation. Etched microsection metallographic specimens were subjected to microstructural investigation by means of MM-8M microscope. The depth of plastic wave propagation depends upon the conditions of interaction between direct strain and deformation waves and waves reflected by the free surface.

Structural changes result in changes of residual stress level σ_{res} through the blank thickness [3]. Professor Birger's method was used as a basis for determining residual stresses. Fig.4 shows an example of the relation $\sigma_{res}=f(V_c)$, where ϵ_p equals 1.25 (for outer fibres of the finished workpiece). As the figure shows the relation contains three typical zones. Within the first one the residual stress amplitude does not depend on the collision velocity. Further on σ_{res} is increasing (zone 2). Under the collision velocities more than $V_c=110$ m/sec this relation remains straight but the angle of its slope to the abscissa axis changes (zone 3).

Fig.4. Relation between residual stresses σ_{res} and collision velocity V_c .

The die stability and its possible plastic deformation set a limit on the ultimate collision velocity V_{ult} (Fig.5).

Fig.5. A steel die inner diameter change depending upon the velocity of its collision with an aluminium blank.

The table below gives formulae for V_{el} and V_{ult} computation in accordance with the mechanical properties of the colliding materials, their acoustic stiffness gS and ϵ_φ value at the moment of collision, the data being obtained for short blanks.

Under the collision velocity $V_c < V_{el}$ collision is elastic, under the velocity $V_{el} < V_c < V_{ult}$ collision is plasto-elastic. For an aluminium AMg6M blank and a steel St45 die when $\epsilon_\varphi = 1.25$ these values are as follows: $V_{el} = 44.5$ m/sec, $V_{ult} = 130$ m/sec.

Table

Ultimate collision velocity	$V_{ult} = \left(\frac{G_{a2}}{gS_{el}} \cdot \frac{1-\nu}{1-2\nu} \right)^{die} \cdot \left[1 + \frac{(gS_{el})^{die}}{(gS_{el})^{el}} \right]$
Ultimate elastic collision velocity	$V_{el} = \frac{2}{\sqrt{3}} \cdot K \epsilon_\varphi^n \cdot \frac{(gS_{el})^{die} + (gS_{el})^{el}}{(gS_{el})^{die} (gS_{el})^{el}}$

Thus, for developing technological processes for impulse shaping of hollow workpieces it is necessary to consider the collision velocity, level and distribution of residual stresses and the final dimensions of the workpiece.

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