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INFLUENCE OF THE SPREAD IN VALUES OF ALUMINIUM ALLOY DYNAMIC PROPERTIES UPON THE FINAL RESULTS OF MAGNETIC-PULSE STRAIN

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Résumé: Dans cette étude on fournit un modèle mathématique pour un procédé d'expansion de tubes par impulsion magnétique au moyen d'une approximation par la loi puissance de la courbe d'écrouissage dynamique $\sigma_i = k \epsilon_i^n$. La méthode par éléments finis permet d'analyser les déformations dues aux contraintes du matériau tubulaire dans le procédé d'expansion par impulsion magnétique et d'estimer l'influence de la dispersion des facteurs k et n sur les résultats de la déformation finale. Les limites de la dispersion des facteurs k et n ont été définies tous deux en fonction des résultats de tests dynamiques cités par d'autres chercheurs sur les alliages d'aluminium et les résultats obtenus par les auteurs.

Abstract - The paper provides for mathematical model of magnetic-pulse process for tubular blanks expansion by means of power approximation of the dynamic hardening curve $\sigma_i = k \epsilon_i^n$. Finite element method allows to analyse stressed strain of the blank material in the process of magnetic-pulse expansion and to estimate the influence of the spread in " k " and " n " factors on final strain results. Boundaries of the spread in " k " and " n " factors were defined both by the results of dynamic tests on aluminium alloys cited by other investigators and by the results obtained by the authors.

Employment of magnetic-pulse treatment of metals is one of the promising tendencies in the development of present-day machine building. The adopted technique of working out and investigating processes of magnetic-pulse treatment is based upon the variational principles of mechanics, the plastic flow theory and the adaptation of the finite element method /1/. The computational algorithm is implemented through a package of applied programmes for the ES type computers.

However our experience of the package service showed that some processes indicate a considerable divergence of calculated and

experimental results. Thus, performing a task of an adapter type blank shaping the discrepancy between calculated displacement values and data obtained from high-speed filming may reach 30%. One of this divergence possible causes may appear to be errors in specifying the strain metal mechanical properties. Analysis of scientific literature and processing of our own experimental results showed that the spread in values of mechanical properties is rather significant (Table I). Thus, for AMg6M aluminium alloy the spread in "k" factor reaches 40%, the spread in "n" factor is 30%.

Table I

Dynamic values of mechanical properties and hardening constants for some aluminium alloys

Alloy grades	Mechanical properties			Hardening constants	
	σ_s , MPa	$\sigma_{0.2}$, MPa	δ , %	k, MPa	n
ADI	II7	384-450	27.0-36.0	I77-I98	0.268-0.224
DI6M	2I0-230	I00-I45	I6.8-22.8	332-357	0.I67-0.I57
AMg3M	270	I68	27.0-36.0	$^{40}I.2-$ $^{44}I.3$	0.I77-0.II8
AMg6M	390-520	252-286	23.0-32.4	624-892	0.234-0.I76

Influence of the spread in "k" and "n" factors upon the final results was estimated when performing a test task of free tubular blank expansion having the length of 30 mm, the outer diameter of 60 mm and the thickness of I.0 mm and being made of AMg3M aluminium alloy. To run a check a blank expansion was conducted under the capacitor bank charge $W = I.83$ kJ by means of a magnetic-pulse installation with the following parameters:
 capacitor bank capacitance $C = 77.9 \cdot 10^{-6}$ F;
 inductance $L = 0.254 \cdot 10^{-6}$ H;
 resistance $R = 0.0I32 \Omega$.

Load inductance was equal to $5.6 \cdot 10^{-7}$ H.

The task was performed with the help of the numerical method for two-dimensional problems. The amount of finite elements through the blank thickness counted as 4 (Fig.I).

The calculation results with $k=k_{\text{mean}}$ and $n=n_{\text{mean}}$ were recognized as basic ones.

Fig.I. The calculated scheme of a free tubular blank expansion

Figure 2 shows an example of two plots of a blank outer surface displacement in time.

Fig.2. Displacement of the blank outer surface:
1) $k=k_{\text{mean}}$, $n=n_{\text{mean}}$; 2) $k=k_{\text{max}}$, $n=n_{\text{min}}$

Analysis of the plots allows to come to the following conclusion: during the initial stage of a tubular blank expansion process the divergence of $S=S(t)$ curves is insignificant, with the increase of strain degree the divergence value is growing. In this connection it is extremely significant to consider displacement values with various combinations of "k" and "n" factors at typical time intervals τ (Table 2).

Table 2
Displacement of the blank outer surface at typical time intervals

Hardening constants		Displacement, mm		Deviation of displacement values from basic magnitudes, %	
k	n	$\tau = 30 \mu\text{sec}$	$\tau = 60 \mu\text{sec}$	$\tau = 30 \mu\text{sec}$	$\tau = 60 \mu\text{sec}$
k_{mean}	n_{mean}	2.28	3.61	0	0
k_{mean}	n_{max}	2.36	4.08	3.74	13.02
k_{mean}	n_{min}	2.17	3.06	-4.62	-15.24
k_{max}	n_{mean}	2.24	3.36	-1.76	-6.93
k_{max}	n_{min}	2.17	2.91	-4.84	-19.40
k_{min}	n_{max}	2.39	4.31	4.84	19.40
k_{min}	n_{mean}	2.31	3.87	1.54	7.20

The data given in Table 2 allow to estimate the calculation error due to the spread in hardening dynamic constant values of the blank material. With high degrees of strain (operations of blank shaping) the calculation error may reach 20%, with low degrees of strain (operations of calibration) it does not exceed 5%.

Reference

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