About the nature of the threshold tension

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Abstract

The problem is to determine the threshold tension of the high-temperature deformation of aluminium alloys in a wide speed range, including intervals of superplasticity. The problem is solved in the framework of a dynamic model, formulated from the perspective of synergy; the catastrophe theory have been used for a mathematical description. Analyzed the discussion over the existence of the threshold tension and its dependence on temperature and the size of feed grain. In this case, the threshold tension is the value considered as a limit of tension when strain rate tends to zero. In a sense, the presence of the threshold tension is linked with the ability to implement the effect of superplasticity.

1 Introduction

Dynamic plasticity caused by the appearance and development of compelling phase transitions of different nature can be interpreted as a special condition in the changing temperature-rate conditions. This approach assumes specific requirements to the developed model representations. Thus, the equation of state should reflect the synergetic processes of self-organization of dissipative structures and require to be suitable for describing the s superplasticity state border.

2 Governing results

It is known that in research of the effects arising at dynamic superplasticity [1], [2], the predominating role is allocated for carrying out and the analysis of results of mechanical experiments.

Within a synergetic approach (in the framework of the synergetic approach) [3] the mathematical apparatus of the catastrophe theory used to describe the skilled data on high-temperature stretching and compression of industrial aluminum alloys [1], [2], [4]. As the power function of the condition reflecting saved-up experimental data, the potential of accident of assembly was accepted. To an equilibrium state thus there corresponds the equation:

$$q = m_0\eta^3 + \beta(\xi)\eta. \tag{1}$$

Here

$$q = \frac{\sigma}{\sigma^*} - 1; \quad \eta = \frac{\dot{\varepsilon}}{\dot{\varepsilon}^*} - 1; \quad \xi = \frac{\theta - \theta_c^l}{\theta_c^u - \theta_c^l} - 1, \tag{2}$$

$m_0 \sim const$; σ, $\dot{\varepsilon}$ - respectively the direction and speed of deformation; σ^*, $\dot{\varepsilon}^*$ - alternative internal parameters of a condition; ξ - the normalized temperature, where θ,K -

temperature; θ^u, θ^l_c - the lower and upper the critical temperatures limiting a range of superplasticity; $\beta = \beta(\xi)$ -the control parameter, and $\beta(\xi) < 0$ for superplasticity.

The equation of a state is written down from a condition of qualitative identity to experimental data on the aluminum alloys received in a wide range of temperatures and speeds of deformations, and satisfies to conditions of transition to a superplasticity condition [1], [2]. Differently, the equation (1) is suitable for the description as well boundary superplasticity of areas of thermoplasticity and high-temperature creep [5]. Let's note also that within a synergetic approach function $\beta = \beta(\xi)$ defines family of operating parameters, and size $\eta = \eta(\dot{\varepsilon}, \theta)$ the role of parameter of an order belongs.

Established [1], [2] that the control parameter should obeys the evolution equation

$$\frac{d\beta}{dt} = \dot{\xi} f(\beta, q), \tag{3}$$

where $\dot{\xi}$ - the rate of increase in the normalized temperature, and $f(\beta, q)$ is named in [1], [2] - function of sensitivity of a material to structural transformations.

The explicit expression has been proposed for the function $f(\beta, q)$; that takes into account the implementation of a process of heating and deformation of structural transformation - the dynamic recrystallization. The above expression is

$$f(\beta, q) = \frac{4}{\alpha} \frac{(\mu - 1)}{(\mu + 1)} \left[\Gamma(\xi) - \frac{1}{2} \right], \tag{4}$$

and α, μ - material constants, and function $\Gamma(\xi)$ represents degree of completeness of phase transition for which it is had

$$\Gamma(\xi) = (1 - \beta)^{-\alpha} \frac{(1 + \mu)}{2} \frac{2\xi - 1}{1 + \mu(2\xi - 1)^2} + \frac{1}{2}. \tag{5}$$

For alternative internal state parameters proposed evolution equations of the form of:

$$\frac{d \ln \sigma^*}{d\xi} = A_0(1 - n)(\beta - \beta_0)^{-n} \frac{d\beta}{d\xi}; \tag{6}$$

$$\frac{d \ln \dot{\varepsilon}^*}{d\xi} = B_0(1 - l)(\beta - \beta_0)^{-l} \frac{d\beta}{d\xi}, \tag{7}$$

where A_0, n, B_0, l - constants for this alloy.

By the extension to the three dimensional case the model (1)...(7) allowed to formulate and solve a class of problems in form of the surround modes superplasticity; it was done with involving equations of the theory of elastic-plastic processes of the lesser curvature.

3 Results

To extend the idea of the possibilities of the model (1)...(7) dwell on value called the threshold tension [5]. It refers to a value of the tension which specify the conditions of temperature ratio where the plastic deformation is impossible.

The problem of the threshold tension in the context of the superplasticity effect occurred in designing the EVP-continuum [6]. Established in framework of this model, the value is essentially found by extrapolation of experimental data when compared with the theoretical and corresponding strain rate close to zero.

There was a discussion of the reality of the threshold tension in one way or another associated with superplasticity [7]...[15]. By the definition of the threshold tension is stated that the deformable material went beyond the speed range of superplasticity and, therefore, does not appear superplastic properties. So, apparently, the presence of the threshold tension can be considered as characteristic for sensitive materials at high temperatures to change the rate of deformation. It can be argued that the model of a mechanical type that ignores the reality of the existence of the threshold tension can't be considered acceptable to describe the patterns of high temperature deformation of materials in a wide range of strain rates.

The formalization of alloys introduction of the threshold tension in the defining relations is different matter. As the rule, the value does not revealed directly from the defining relations, but it is suitable for boundary condition for the establishment of permanent material [6].

Therefore proposed, for example in [7 – 15], a number of experimental and analytical approaches to the definition. In this matter the physical nature of the threshold tension is associated with the test temperature and grain size, fluctuating according to [5] within 1.0. . . 12.0 microns.

In [1], [2] it was suggested that the evolutionary nature of the threshold tension depends, of course, only on the temperature. This assumption is justified by the fact that in the dynamic model (1) – (7) for the threshold tension can be obtained directly from the equation of state (1), (2) if we put. We have

$$\sigma^0 = \sigma^*(1 - m_0 - \beta), \tag{8}$$

where, as above - control parameter defined by equation (3) with the use (4), (5), and for the internal state variable recorded the evolution equation.

4 Analytic results

It is interesting to compare the results obtained with the use of (8) and the known data found in other approaches. The above collected and presented in tabular form in [5]. The calculation of the value implemented for the aluminum alloy AMg5 for structure without prior preparation. The material for the calculations are taken in [1], [2] and in the table.

The mark of alloy	State	Aspect of a strain	Values of constants				
			m_0	α	μ	A_0	n
AMr5	strain	stretching	0.3333	0.54	1.08	-0.8434	-0,093
		compress	0.3333	0.54	1.08	-0.8434	-0,093

From the data in Figure 1 are constructed graphic dependence of the threshold tension σ^0 on the temperature ξ. The values $\xi > 0$ meet the the thermal range of superplasticity. Clearly, in the middle of the range the values σ^0 take the minimum, those data do not contradict known for various compositions based on aluminum, up 0.15. . . 4.8 MPa.

5 Conclusion

In conclusion, we note that the values σ^0 obtained by (8), are not related to the size of the original grain, because the experiments were conducted for commercial aluminum alloys.

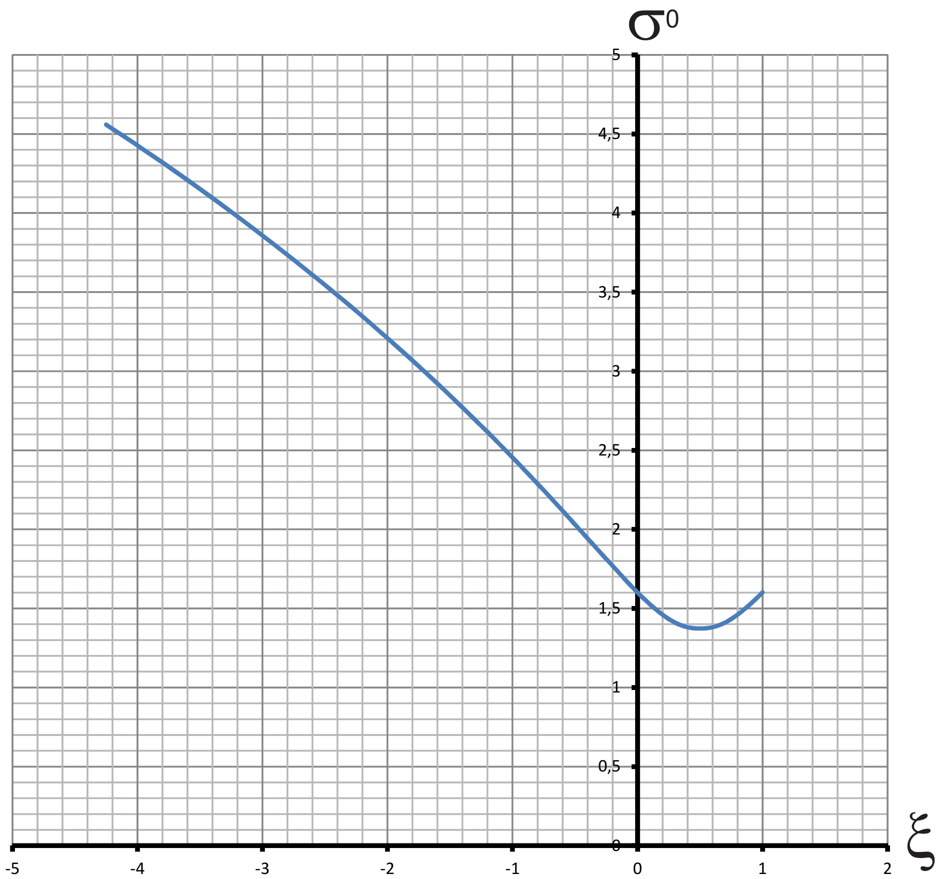

Figure 1: Dependence of the threshold tension σ^0 on the temperature ξ

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