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Survay of the Variation of the Parameters of Velocity and Deformation Sensitivity in the Process of High-Temperature Plastic Deformation and Superplstic Determination

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ABSTRACT: The aim of the study is to observe experimentally the parallel variation of the parameters of the velocity (m) and the deformation sensitivity (n) of the flow tension σ in the high-temperature deformation process of the grain refined alloy. The deformation process is controlled by varying the deformation temperature and average grain size, so the material shows or not suprplasticity [1]. On the proposed stability criterion a relation between parameters of velocity sensitivity (m) and deformation sensitivity (n) for the hidh-temperature deformation conditions of grain refined material is obtained.
KEY WORDS: superplasticity, zinc alloys, stability flow criterion

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I. INTRODUCTION:

Metallic materials with conventional microstructure behave similary to deformationally reinforced materials at room temperature. They are evenly deformed up to a certain maximum load at the uniaxial deformation, whereby the dimensionless stiffening deformation is approximately 1. The relative elongation is usually not greater than 60%. Their behavior slightly depends on the deformation velocity.

There is an obvious tension sensitivity to the deformation velocity in high-temperature plastic deformation, therefore the rate of deformation localization in the neck decreases and the relative elongation is greater after the uniaxial deformation.

It has been shown that, the deformation at high temperatures of the grain refined materials proceeds through the mechanism of grain boundary sliding. This deformation mechanism is not typical for conventional microstructured materials. It provides an extremely high deformation resource of grain refined metallic materials. [2,3,4]

Such materials exhibit superplasticity at high temperatures and the relative elongation abruptly exceeds 100% when the uniaxial deformation test is provide. Due to the high velocity sensitivity to the deformation velocity, the velosity gradient increases the deformation resistance. The cross section of the specimen reduces its area too evenly and does not form a local thinning of the neck, which would lead to rupture.

In such materials the mechanical process during an established state of uniaxial deformation can be described by the step law:

$\sigma = K\varepsilon^m$ when m > 0,3. (1)

Therefore, a certain conclusion for the parameter of velosity sencitivity m is that it characterizes the materials resistance to the formation of a neck, and their propensity for superplasticity. Typically m <0.2, while superplasticity occurs in metals and alloys when m≥ 0.3. [2, 3]

As m is a material constant, there is a linear dependence of the flow tension σ and the deformation velocity έ in logarithmic scale in the case of convetional (non – superplastic) material. However, in the case of superplastic materials dependence between the flow tension and the deformation velosity is a sigmoidal. (Figure 1)

In general, the parameter of velocity sencability m dependents on the velocity of the deformation and has a maximal value when drawing its dependence on the deformation velocity (Fig. 1b.). Areas I and III correspond to m ≤ 0.3, respectively at low and high deformation rates, while area II - m ≥ 0.3 corresponds to the superplastic state where great elongation is obtained. The maximum value of m, Mmax is unique for a material with a defined grain size and deformation temperature.

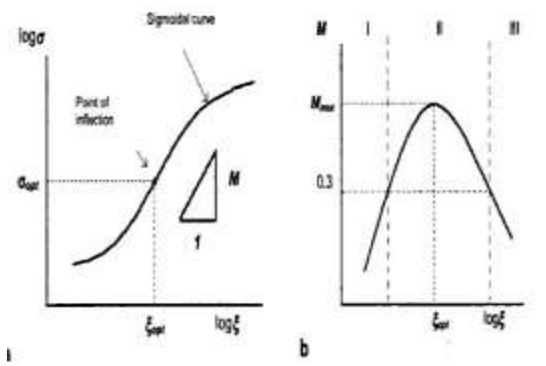

Fig. 1 a. Sigmoidal dependence log σ-log έ and b. schematic variation of M = ∂ (log σ) / ∂ (log έ) depending on the deformation velocity.

There is a criterion of Hart, which determines the effect of the velocity and deformation sensitivity for defining the deformation flow, as follows:

$\acute{\varepsilon} = n/(1-m)$ (2).

where $n = d \ln \sigma / d \ln \varepsilon$ (3) is a parameter of deformation sesitivity.

This criterion reveals the leading role of the parameter m in the increason of the resistance of the flow in velocity sensitiv materials. [3]

If the tension dependence on the deformation velocity is negligible, $m \rightarrow 0$, then the material is deformationally reinforced, and the reinforsing is determined only by the velocity of deformation. For elastic materials, the localization of the neck will begin at such a deformation where m has larger values and n = const.

When m = 1, the material has viscous or Newtonian behavior in a non-superplastic state At n = 1 the material is linearly reinforsed and at n = m = 0 - perfectly plastic.

At small values of m (0.2 to 0.4) and n = 0 the irregularity of the cross-section increases sharply in the process of further deformation. As m increases, the sensitivity of the irregularity to the section weakens. [5]

Material and Methods: In order to monitor the parallel influence of velocity and deformation sensitivity parameters alloy Zn-0.5% Cd -0.5% Mn is used. The alloy exhibits superplastic properties under certain temperature-velocity conditions. The average grain size of the specimens is 2 µm, 6 µm, 20 µm and 35 µm. The deformation process is controlled to proceed with or without superplasticity of the material by varying the test conditions [1].

The speciments are cylindrical with a working diameter of 5mm. The tests were performed on a uniaxial tensile test machine to maintain a constant deformation velocity έ. [6]

Results and discussion: Observed dependencies are known for many materials and alloys [2, 3]. The observed relation of m and n in conditions of high-temperature deformation is more impressive.

The values of the parameters m and n are determined by mathematical processing of experimental results.

d, µm		Temperature [°C]			
		170	220	275	320
2	m	0.25	0.39	0.37	0.32
	n	0.02	0.02	0.01	0.02
6	m	0.18	0.32	0.36	0.29
	n	0.02	0.02	0.03	0.03
20	m	0.16	0.16	0.19	0.32
	n	0.37	0.30	0.06	0.03
35	m	0.11	0.12	0.17	0.27
	n	0.22	0.21	0.15	0.05

Tab. 1. Values of velocity sensability (m) and deformation sensability (n) parameters for variation of deformation temperatures and average grain size for alloy Zn-0,5% Cd -0,5% Mn.

In Table 1. the values of m and n when deformation temperatures are in and out the optimal temperature-velocity range for the occurrence of superplastic properties of the alloy are reveald. The optimal temperature-velocity conditions for the occurrence of superplastisity of this alloy are at T=275°C and $\varepsilon = 1.10^{-3}s^{-1}$. The average grain size in the range of 2 ÷ 35 µm is also varied.

It can be seen that, the value of the parameter m decreases and the value of the parameter n increases as the grain size increases. It can also be seen that by increasing test temperature the value of n decreases. The variation of the parameter of velocity sensitivity m is characteristic for grain refined material. [2, 3] It has maximum value coinciding with the optimum temperature of the boundary sliding process.

Various expressions for the relation between m and n in the superplastic deformation of metals and alloys are suggested. [3, 7] However, these dependencies are not consistent with the experimental data except in rare cases of conventional deformation conditions.

d,	Temperature [°C]			
	170	220	275	320
2	0.035	0.037	0.019	0.043
6	0.078	0.040	0.058	0.073
20	1.590	1.100	0.320	0.086
35	1.400	1.225	0.620	0.130

Tab. 2. Values of the constant B calculated at the variation of the deformation temperature and the average grain size of the alloy Zn - 0.5% Cd -0.5% Mn.

Relation between m and n for high-temperature deformation conditions of grain refined materials is obtained as a result of the observation of the effects of the proposed criterion of stability of the superplastic flow [8]:

$n/m = B/\ln\varepsilon \,\big|\, \acute{\varepsilon},T,d$ (4)

where έ is the degree of deformation, B = const

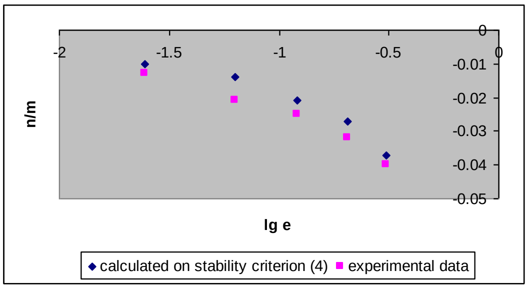

Fig. 2. Dependence of parameters of velocity sensitivity (m) and deformation sensitivity (n) of alloy Zn-0.5% Cd -0.5% Mn at T = 275 ° C; $\varepsilon = 10^{-3}s^{-1}$; d = 2μm according to experimental data and calculated on the proposed stability criterion.

Fig. 2. shows the dependence n / m of ln έ in experimental data and the same dependence calculated by the proposed formula for T = 275 °C; $\varepsilon = 10^{-3}s^{-1}$; d = 2μm. The value of constant B ranges from 0.019 for d = 2μm to 0.62 for d = 35μm (Table 2. shows the values for the other temperatures and grain sizes). Fig. 2. shows the good match between the calculated values (4) and the experimentally obtained values of n/m. From Table. 2. it can also be seen, that the value of the constant B of criterion (4) can determine the tendency of the material to exhibit grain boundary sliding. As a conclusion - the value of B indicates the occurance of superplactistity in the material. When values of B are up to 1, the superplastisity of the material is predominate. For values B>1, the material goes beyond the optimal superplastic state.

II. CONCLUSIONS:

1. Experimental variation of m and n from the conditions of hihg-temperature and superplastic deformation in alloy Zn-0.5% Cd -0.5% Mn was found.
2. The validity of dependence (4) when varying deformation conditions for alloy Zn-0.5% Cd -0.5% Mn was confirmed experimentally.
3. It has been found that the constant B of dependence (4) can serve as a criterion for grain boundary sliding mechanism occurance in materials.

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