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DEVELOPMENT OF THE TECHNIQUE FOR THE PLASTOMETRIC EXPERIMENT OF THE RHEOLOGICALLY COMPLEX METALS

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A new plastometer was developed for investigation of rheologically complex metals. A procedure was proposed for plastometric tests under conditions of the supergreat deformations and complex kinds of loading.

Key words: *rheologically complex metals, deformation, plastometric test, sample*

Razvitak tehnike za plastometrijsko istraživanje reološki složenih metala. Razvijen je novi plastometar za istraživanja reološki složenih metala. Predložen je postupak za provođenje plastometrijskih pokusa pod uvjetima supervelikih deformacija i složenih načina opterećivanja.

Ključne riječi: *reološki složeni metali, deformacija, plastometrijski pokus, uzorak*

INTRODUCTION

The curves which characterize the rheological properties of metals and alloys serve as starting data while creating the new technologies in the field of the metal forming. They are obtained by the methods of plastometry [1]. The cam plastometers (rheometers) are most in use for these purposes. More often the metals are tested under conditions of the plastic compression of cylindrical samples [2].

The cam plastometer differs from the standard press in the main element of its mechanical part which is the working cam. The constansy of the rate of deformation is maintained by means of the cam profile.

In plastometric experiment a dependence of reliability of results on the degree of deformation uniformity is clearly run down while testing samples [3]. The accuracy of experimental data depends on many factors, the main of them being constancy of the deformation rate, reliability of the work of equipment for measuring forces and displacements. As it has been already shown formerly in the paper [4], not only the forces of the contact friction affect the change of the form of a sample at the plastic compression of the latter, but the degree of the rheological complexity of materials is to be tested too.

The problem of the statement and implementation of a reliable experiment becomes more urgent at the high degrees of deformation. It is connected with appearance of conditions for realization of mechanisms of the formerly unknown phenomena: anomalies of deformation of samples made from the rheologically complex metals, dynamic anisotropy of softening of the latter ones [5]. The rheological curves $\sigma = f(\bar{\varepsilon}, \dot{\varepsilon}, \tau)$ available in the literature were obtained under conditions $\bar{\varepsilon} < 0.6 \ldots 0.8$. In the real processes $\bar{\varepsilon} >> 1$.

Therefore the problem how to obtain the reliable rheological curves of metals at $\bar{\varepsilon} > 1$ is of a high priority. It will favour the development of the principally new technologies. In the field of metal forming.

A NEW TERM

The most of metals are plastically deformed under conditions of the supergreat deformations. What do the authors of the paper mean when they while speak about "a supergreat deformation"? It is a matter of the rheologically complex metals [6]. This degree of deformation will be supergreat when it exceeds its characteristic value - ε_x (Figure 1.). Metals or alloys can have very different values of ε_x (see Figure 1.).

A NEW PLASTOMETER FOR INVESTIGATION OF RHEOLOGICALLY COMPLEX METALS

The first cam-type plastometers were created in England in 1950 [10]. During the past half a century their designs were substantially improved. However, as the over-

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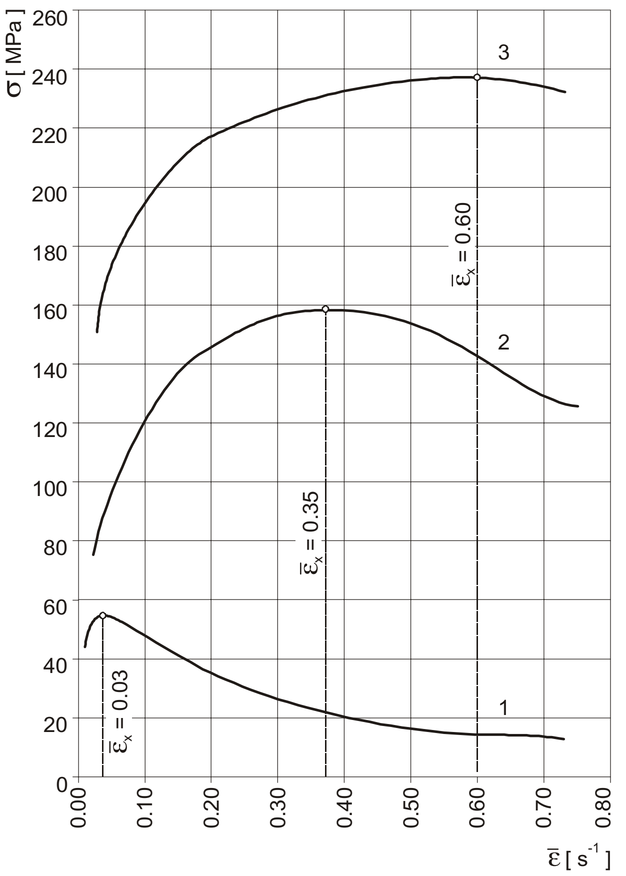

Figure 1. **Curves for different degree of rheologically complexity: (1) zirconium alloy with 2.5 % niobium at 775 °C and $\bar{\varepsilon}$ = 3·10^{-3} s^{-1} [7]; (2) high-speed steel R6M5F2 (0.88 % C; 0.39 % Si; 0,23 % Mn; 0.03 % O; 0.01 % S; 3.3 % Cr; 6.39 % W; 4.75 % Mo; 2.23 % V) at 1100 °C and $\bar{\varepsilon}$ = 3.5 s^{-1} [8]; (3) steel 20 (0.19 % C; 0.04 % Si; 0.86 % Mn; 0.022 % P; 0,029 % S) at 900 °C and $\bar{\varepsilon}$ = 20 s^{-1} [9]**

Slika 1. **Krivulje različitog stupnja reološke složenosti: (1) Slitine cirkonija s 2,5 % niobija na temperaturi od 775 °C i $\bar{\varepsilon}$ = 3·10^{-3} s^{-1} [7]; (2) brzorezni čelik R6M5F2 (0,88 % C; 0,39 % Si; 0,23 % Mn; 0,03 % O; 0,01 % S; 3,3 % Cr; 6,39 % W; 4,75 % Mo; 2,23 % V) na temperaturi od 1100 °C i $\bar{\varepsilon}$ = 3.5·10^{-3} s^{-1} [8]; (3) čelik 20 (0,19 % C; 0,04 % Si; 0,86 % Mn; 0,022 % P; 0,029 % S) na temperaturi od 900 °C i $\bar{\varepsilon}$ = 20 s^{-1} [9]**

view of publications, shows in spite of diversity of the kinds of plastometers, they all have a number of constructive short comings.

Some are deficient for stiffness [11], others have the imperfect mechanical system of engaging the cam into the work. [12]; the third ones have a complex system "a cam - a flywheel" with great impact loads between members while engaging the system into the work [13]. Besides that, they all are designed for testing metals at the moderate degrees of deformation (till $\bar{\varepsilon}$ = 0.6 … 0.8). In the real processes of the metal forming is $\bar{\varepsilon}$ >> 1 … 2.

Plastometry by tension in general has no sense under these conditions. The rheologically complex metals are failing at the small degrees of deformation [14].

The authors have developed and manufactured in National Metallurgical Academy of Ukraine a scale model of plastometer of a new design allowing to study the properties of the rheologically complex metals (Figure 2.).

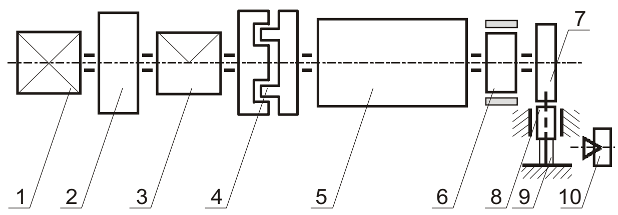

Figure 2. **Structural scheme of the new plastometer: 1 - engine; 2 - flywheel; 3 - reduction gear; 4 - coupling; 5 - mechanism of compensation of time of engaging the coupling; 6 - brake; 7 - cam; 8 - die; 9 - sample; 10 - videocamera**

Slika 2. **Strukturna shema novog plastometra: 1-motor, 2-zamašnjak, 3-redukcijski zupčanik, 4-kvačilo, 5-mehanizam kompenzacija vremena zahvata kvačila u zupčanike, 6-kočnica, 7-brijeg, 8-matrica, 9-uzorak, 10-videokamera**

Test of the technically pure copper on a new plastomer were carried out at the temperature 20 … 25 °C. Method for providing the uniform deformation of the plastometric

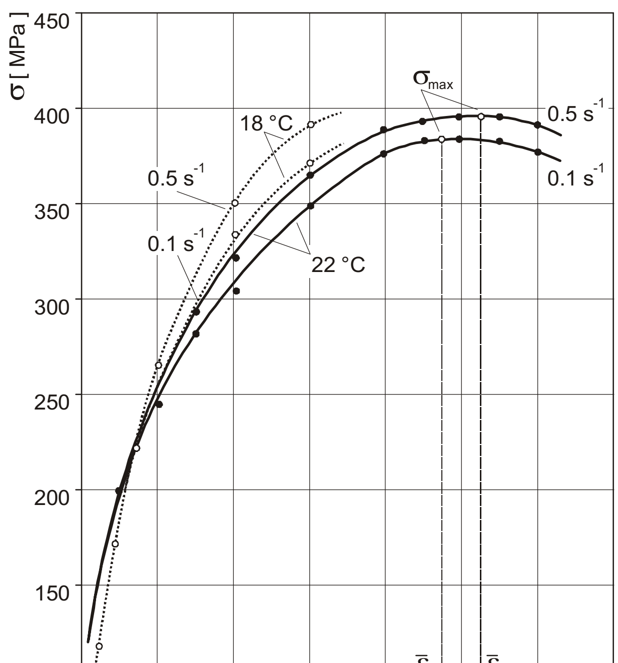

Figure 3. **Results of investigation of rheolog of technically pure copper (99.2 ... 99.5% Cu): unbroken curves σ-ε - obtained by authors on a new plastometer; dotted curves - data of the work by Suzuki H. [9]**

Slika 3. **Rezultati istraživanja reologije tehnološki čistog bakra (99,2 ... 99,5% Cu): pune linije krivulje σ-ε - koje su autori dobili na novom plastomeru; točkaste krivulje - podaci iz rada H. Suzukia [9]** samples has been described earlier in the paper [3]. It has been established that in conditions of indoor temperature the technically pure copper at deformations $\varepsilon > 0.8$ was a rhelogically complex metal too. Maxima on the curves σ-ε appear at $\varepsilon \approx 1$ (Figure 3.).

Other advantages of the new plastometer are the simplicity of design, small-size and the small energy intensity as well as a low manufacturing cost.

DEVELOPMENT OF THE PLASTOMETRIC EXPERIMENT'S TECHNIQUE

Besides the main equipment and a special methodology of experiment, an important complex of auxiliary equipment and devices has to be included in the notion "plastometry".

While investigating the rheologically complex metals, a special attention had to be given to auxiliary facilities. In this case a scheme of a passive complex loading is realized: the resistance to deformation σ_s decreases with increase of deformation σ_i at the expense of metal softening. The scheme of the active complex loading at the plastometric tests can be realized e.g. by additional torsion of a sample.

As it was stated formerly by the way of investigations, the character of the metal flow can be very complex [3]. During sample upsetting it is necessary to carry out the continuous visual control of the process and ensure the uniformity of deformation. On this purpose a new universal container for plastometric tests of metals was developed, predominantly of the rheologically complex ones. It allows to carry out the plastic upsetting of cylindric samples with simultaneous twisting of the latter.

To ensure the uniformity of sample's deformation the upper and lower punch of universal container are made with conic (0.02 rad) polished (till $R_a < 0.2$ µm) surface. In container, design provides a rigorous alignment of a sample. Method and device being proposed allow to extend substantially scope for plastometric tests of rheologically complex metals under different kinds of loading.

CONCLUSIONS

1. A new plastometer has been developed.
2. A new procedure of plastometric metal testing under conditions of supergreat deformations was proposed for investigation of rheologically complex metals.
3. The new auxiliary facilities were developed allowing to extend the scope for plastometric testing rheologically complex metals under conditions of the complex kinds of loading.
4. For the first time it has been established by means of plastometric test that the technically pure copper was a rheologically complex metal. The dynamic deformational unhardening appears at the grades of deformation $\varepsilon \geq 1$.

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