RHEOLOGIC MODEL AND DESTRUCTION CRITERION OF METALLIC MATERIALS

Radchenko, V.P.,[x] Kuzmin, S.V.,[x] Yeremin, Yu.A.,[x]

The paper aims to elaborate a phenomenologic model and a destruction criterion over a wide range of stresses, including those above elasticity level. To reach the aim on the level of microheterogeneous surroundings a complex mathematical model was worked out by Samarin et al (1). With the help of this model the behaviour of metals under creep till their destruction was observed numerically and analytically. On this information the destruction criterion was based and a structure of phenomenologic equations was chosen.

On the level of mechanics of heterogeneous surroundings polycrystallic material is modelled by a system of chaotically oriented homogeneous bars (local elements) with simplest deformational properties: linear elasticity, ideal plasticity and nonlinear sticking. The orientation of local elements is given by two spheric angles θ $(0 \leq \theta \leq \frac{\pi}{2})$ and φ $(0 \leq \varphi \leq 2\pi)$. An energetical criterion of destruction of the local element was introduced and the principle of linear summing of microstress work on momentary plastic deformation and deformation of creep was used. Within the third stage of creep the local elements start getting out of operation. At a given moment the destruction of local elements, even in an elastic area goes with increesing of microstresses in elementary bars, exceeding the microlimit of yielding, and creep is accompanied by plastic deformation. That is why the fourth ("avalanche") stage of creep can be picked out off the stage of material rupture.

Figure 1 presents the calculation of uniaxial creep with the help of the structure model the authors suggest. The numerals mark the characteristic points and microstress fields in these points, not depending from angle φ in the case of uniaxial stretching ($\langle\sigma\rangle$ - macrostress, lower than elasticity level).

To elaborate phenomenologic equations of uniaxial creep and destruction criterion describing the fourth

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[x] Kuibyshev Polytechnical Institute, USSR

stage of creep, the whole deformation is presented as a sum of elastic deformation, plastic deformation (ε^p) and creep deformation (ε^c). The method of partial deformation: $\varepsilon^c = U + V + W$, where U is viscoelastic, V is viscoplastic and W is viscid components, was used for ε^c. In the equations for U, V, W a real stress but not a nominal stress was used (Samarin and Radchenko (2)):

$$\langle \sigma_0 \rangle = \langle \sigma \rangle (1 + \omega)$$

$$\omega = \gamma \int_0^{\varepsilon^p} \langle \sigma_0(t) \rangle \, d\varepsilon^p(t) + \alpha \int_0^t \langle \sigma_0(t) \rangle \, d\varepsilon^c(t),$$

where ω is the destructiveness parameter; α and γ are material constants. The period till destruction $t = t^*$ is defined from $\Omega(t^*) = 1$, where

$$\Omega(t) = A_1(t)/A_1^* + A_2(t)/A_2^*, \qquad A_1(t) = \int_0^{\varepsilon^p} \langle \sigma_0(t) \rangle \, d\varepsilon^p(t),$$

$$A_2(t) = \int_0^t \langle \sigma_0(t) \rangle \, d\varepsilon^c(t),$$

A_1^*, A_2^* - material constants.

Figure 2 and Figure 3 present the creep curves predicted by phenomenologic model, rheologic equations and destruction criterion suggested by Samarin and Radchenko (2).

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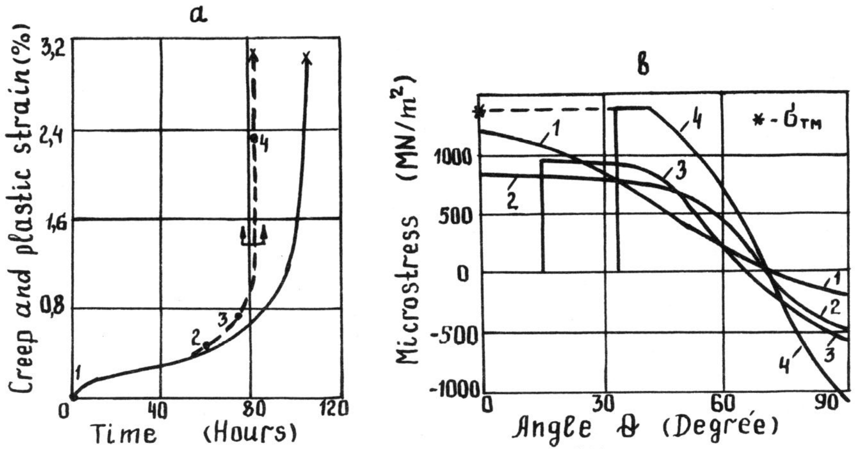

Figure 1 a - uniaxial creep curves of ЭИ 698 alloy at $\langle\sigma\rangle$ =380 MN/m², T=750°C: —— experimental; ---- predicted by structural model; x - destruction; ↑⎵↑ - the beginning of the fourth stage of creep;
b - microstress epures, corresponding to points 1 - 4 on the Fig. 1, a; σ'_{TM} - the microlimit of yielding of local element

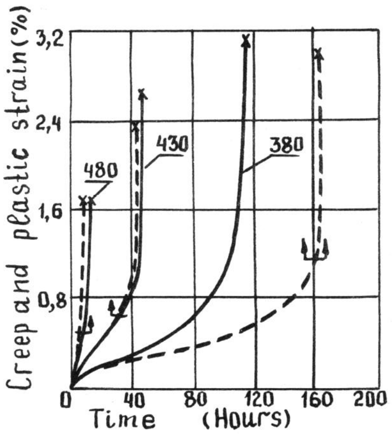

Figure 2 The creep curves of ЭИ698 alloy at T=750°C: —— experimental, ----theoretical; x - destruction. Numerals means stress $\langle\sigma\rangle$ in MN/m²

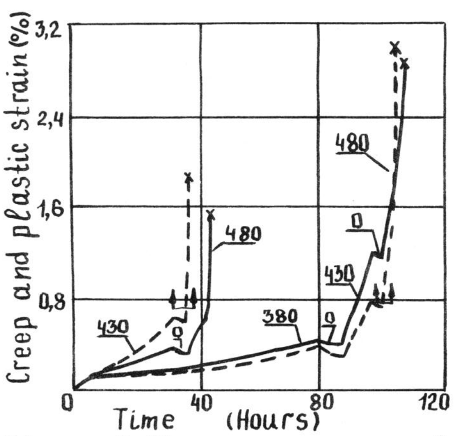

Figure 3 The creep curves of ЭИ698 alloy at 750°C subjected to complex loading programs: ——experimental; -----theoretical; x - destruction. Numerals mean stress $\langle\sigma\rangle$ in MN/m².

A STUDY OF RHEOLOGY IN INDENTATION FRACTURE

V.S. Vasauskas*, R.J. Bansevičius* and S.V. Baskutis*

The problem of elastic - plastic indentation constitutes the base for some technical solutions and physical analyses, e.g. in determining strength (hardness) of metal surfaces, predicting their friction and wear, in the theory of bearings a.o. (1). Still, our understanding of some processes involved in indentation is not sufficient. In a theoretical approach of materials testing, indentation appears as one of its aspects, when different indenters (sphere, cone, pyramid) are applied with constant force and only the ultimate contact parameters are determined. But a highly prospective field of development is still open. Indentations can produce highly concentrated stress fields which can initiate and propagate cracks. Crack initiation and propagation is in turn controlled by the stress field and material properties. We mean techniques (2) based on direct measurements and recordings of indentation parameters with an increasing indentation load, in order to evaluate the level of contact defromation under load and after unloading. In this approach the measured mechanical stress and strain are transformed into electric signals by special transformers.

The technique of indentation can be applied for a compilation of stress - strain curves (the Meyer number - level of plastic deformation - indentation angle) for local material volumes (Fig. 1/a,b, function curves of contact stress - strain, 1-with friction, 2-without friction), so that their rheology can be predicted for the range from elastic deformation to failure. The level of indentation deformation is described by the relative thickness loss of the surface layer (2). Our study suggested that similar phases can be separated in static and dynamic loading, and three types of the failure our can be separated in the behaviour of materials (Fig. 2). These are: elastic-brittle, elastic-plastic and non-fractured materials. But the most popular fracture tests seldom evaluate elastic-plastic behaviour of indentation, which preceeds fracture. In (1/2) it is shown that there are essentially two types of strain field produced by cone indenters. We have suggested earlier (2) a method of evaluating simultaneously both

* Department of Machine Building, Kaunas Politechnical Institute, Lithuania, USSR

rheology and fracture of indentation. Rheology (contact relaxation in time) is determined by generating an acoustic wave in the material and modulating it over the indentation area. Plasticity and microfracture is judged from the shape changes in the indented surface and described by the ratio of the impact and reflected acoustic waves (Fig. 3). The development of microcracks is evaluated by the number of acoustic signals recorded in the course of indentation. An acoustic wave generator made of a piezoceramic transducer with separate induction lines can be used as a recorder.

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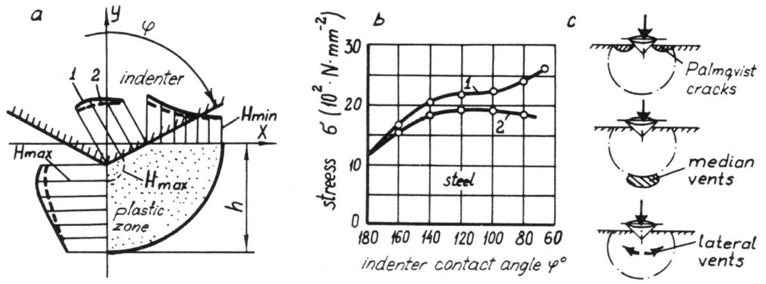

Figure 1 Schematic model of indentation fracture

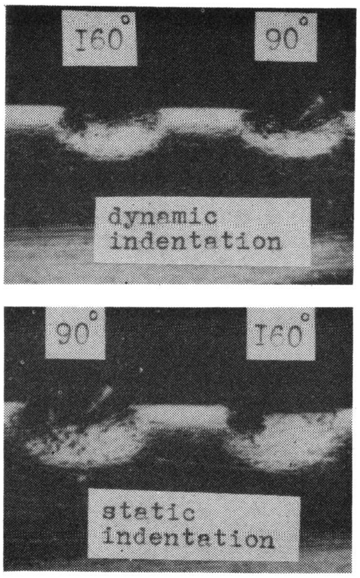

Figure 2 Plastic cores of indentation with varied cones

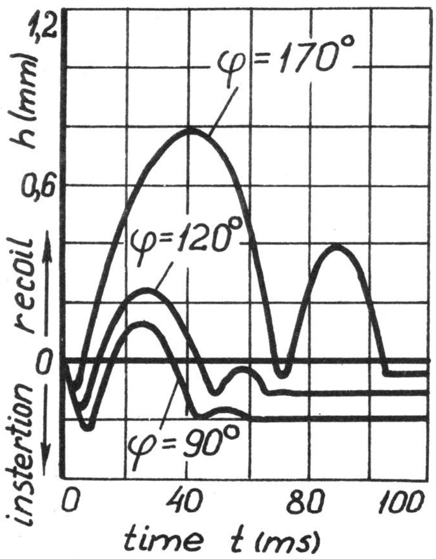

Figure 3 Oscillograms of different phases of dynamic indentation