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ENERGY STORAGE RATE COMPONENTS

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Decomposition of energy storage rate into terms related to different deformation mechanisms has been presented. The energy storage rate is the ratio of the stored energy increment to the appropriate increment of plastic work. Experimental results show that the energy storage rate is dependent on plastic strain. This dependence is influenced by different microscopic deformation mechanisms. Then, the energy storage rate can be presented as a sum of particular components. Two of them are identified.

1. Introduction

When metals deform plastically energy conversion occurs; a part of the mechanical work w_p done during the single cycle of plastic straining is converted into a heat q_d. The rest of it remains in the strained material and it is known as the stored energy e_s, $e_s = w_p - q_d$.

The measure of energy conversion at each instant of the deformation process is the rate of energy storage de_s/dw_p. It has been shown experimentally, that at the initial stage of plastic deformation of annealed polycrystalline materials, the dependence of the de_s/dw_p on the work w_p expended on plastic deformation has a maximum [1, 2]. Such result can be explained by different influence of particular micro-scale deformation mechanisms on the energy storage rate at different deformation stages. Thus, de_s/dw_p is macroscopic quantity that depends on number of internal parameters H_1 ,H_2, ..., H_n. Each of them is related to individual deformation mechanism. In order to distinguish the influence of the given internal parameter, the theoretical analysis of energy storage rate, on the basis of phenomenological thermodynamics of plastic deformation has been performed. The results of the analysis have been used to decompose the total energy storage rate, obtained for the initial stage of uniaxial tension of austenitic steel, into two components. On the basis of the Szczepiński's work [3] and our previous results [4] such decomposition has been done.

2. Decomposition of the energy storage rate

The energy storage rate has been obtained by differentiation of the stored energy e_s as a function of the plastic work w_p. The experimental method of the stored energy determination, as in the previous works by Oliferuk *et al.* [2, 4], was employed.

The stored energy can be divided into at least two parts: the energy of stress field connected with uniform deformation (statistically stored dislocations) and non-uniform one. The second part, connected with non uniform deformation at grain level, is a sum of a lattice stretch energy, energy of geometrically necessary dislocations and the energy of long-range internal stresses due to heterogeneous distributions of dislocations. As in our previous work [4] this part of the stored energy, indicated as e_{s1} has been estimated from experimentally obtained load-displacement curve.

The e_{s1} as a function of plastic work has been determined and the $Z_1 = de_{s1}/dw_p$ was calculated. The remaining term $Z_2 = de_{s2}/dw_p$ can be determined as a difference between experimentally measured total energy storage rate de_s/dw_p and the component de_{s1}/dw_p calculated on the basis of the stress-strain curve.

The experiments were performed on the 304L austenitic stainless steel with mean grain size 7 μm. Specimens were strained using the MTS testing machine at the constant strain rate $\dot{\varepsilon} = 4.3 \cdot 10^{-3}$ s^{-1}. During tensile test the temperature distribution on the surface of the specimen was measured by IR camera. Simultaneously, the stress and strain were determined. On the basis of the thermo-mechanical characteristics, the stored energy as a function of plastic work was calculated (Fig. 1). In the same figure the part e_{s1}, obtained from the stress-strain curve, is shown. Differentiating the total stored energy e_s and the stored energy e_{s1} as a function of plastic work, the total energy storage rate $Z = de_s/dw_p$ and the $Z_1 = de_{s1}/dw_p$ are determined. A result of such operation is shown in Fig. 2. According to theoretical analysis the rate Z_2 of energy accumulated in statistically stored dislocations was calculated as the difference between Z and Z_1.

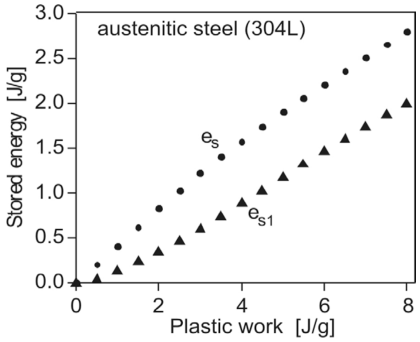

Fig. 1. The total stored energy e_s and the energy e_{s1}connected with non-uniform deformation as a function of plastic work at the initial stage of tensile deformation.

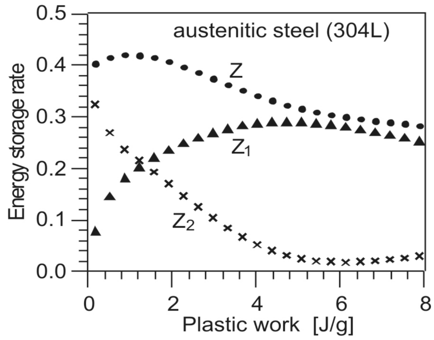

Fig. 2. The total energy storage rate Z as a sum of two components Z_1 and Z_2.

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