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The effect of amplitude in minor cyclic torsion on the behaviour of CuAl8 aluminium bronze

Z. Gronostajski, N. Misiołek

Institute of Engineering and Automation, Wroclaw University of Technology
ul. Łukasiewicza 3/5, 50-371 Wroclaw, Poland

In the paper the effect of different amplitude obtained in minor cycling torsion at higher temperature on the flow stress and structure of CuAl8 aluminium bronze has been investigated. It has been found that the flow stress in hot minor cyclic torsion is substantially dependent on values of amplitude. The decrease of flow stress under minor cyclic torsion stress is obtained for all applied strain amplitude, but application of the higher amplitudes have less effect on the decrease of flow stress.

1. INTRODUCTION

The temperature, strain rate and strain have important effect on the structure and mechanical properties of hot deformed metals and alloys [1-2]. The change of mechanical properties and structure can be also obtained by change of strain path, but especially in the case of massive metal forming processes that phenomena is less known. Only in the case of sheet metals the effect of strain path is widely investigated and forming limit diagrams (FLD) are created to proper design the sheet metal forming processes. But even in that case application of the FLD in design sheet metal forming processes is not so easy, because they are affected also by strain paths. So instead forming limit diagrams forming limit stress diagrams were elaborated [3, 4], which is independent on strain paths. In the case of massive processes the investigation of effect of strain path on the structure and mechanical properties of materials is more difficult and complex. So more easy, in the case of massive processes, is to investigate the effect of strain path on behaviour of metals and alloys in simple test like torsion test. The effect of monotonic versus cycling torsion for copper, interstitial free steel in the ferrite and austenite ranges [5-7] and in strain reversal under torsion for an HSLA steel [8] were under investigation. The strain paths similar to those found in cycling torsion are also observed in other industrial processes like: rolling, forging, rotary swaging and other processes.

It has been found that in the case of above mentioned materials the flow stress in hot cycling of torsion reaches lower values than that under monotonic torsion for strain amplitude ε_{ac} lower than 0.2. The main aim of the paper is to analyse the effect of different symmetrical minor cycling amplitude versus monotonic cycling in torsion test of CuAl8 aluminium bronze containing 7.2% Al on effective stress and strain. All the experiments were performed in the wide range of temperature with constant strain rate.

2. EXPERIMENTAL PROCEDURE

Monotonic and symmetrical minor cycling torsion was conducted in a plastometer for complex strain paths. The plastometer was design and produced in Engineering Metal Forming Processes Department of WUT [9]. The plastometer can be used for monotonic torsion, for cycling torsion with different values and course of amplitude and during these kinds of deformation the specimens can be simultaneously monotonic or cycling straining by tensile or compression. The view of plastometer is shown on Fig.1.

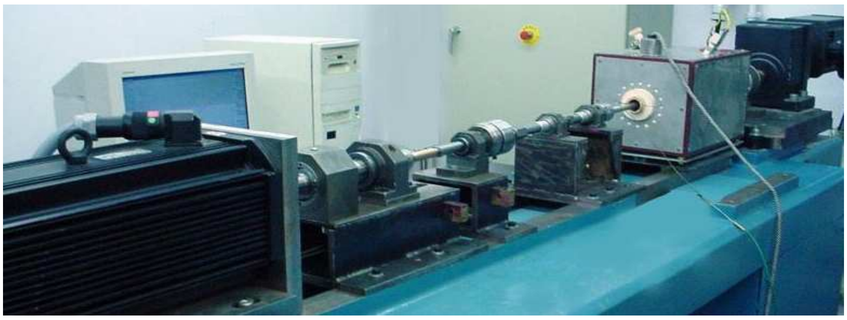

Fig.1. The view of plastometer for complex strain paths

For heating system the two kinds of furnace were used. In the first one as heating element the tantalum is used and different kinds of protective atmosphere can be applied. In the second one as heating element the special profile of steel tube to obtain the uniform distribution of temperature in specimens was applied. By very strong injecting stream of water into the tube the high temperature structure of deformed materials can be frozen. The rate of cooling is about 250 ^{0}C/s. For investigations the specimens shown on Fig.2 were used. The specimens were deformed in the temperature range of 25-650 ^{0}C with strain rate $\dot{\varepsilon}$=0.1 s^{-1}. The minor cycling straining was performed for different amplitudes ε_{ac}=0.1, 0.2, and 0.4 rotation, the temperature was measured by a thermocouple in contact with surface of the gage length of the specimens.

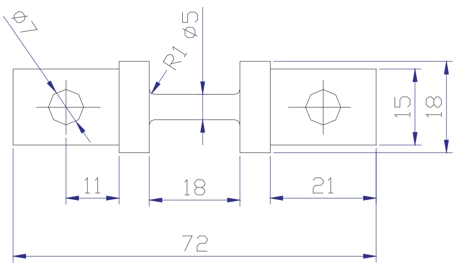

Fig. 2. Scheme of specimens used for monotonic and cycling deformation

Precise determination of relation between flow stress and effective strain is dependent on the method of stress and strain calculation as well as an accuracy of deformation conditions control. Up to now the simple precise method of flow stress determination in the torsion test is not elaborated. Comparing the flow stress course as a function of deformation calculated by using conventional method with one obtained by numerical calculated modelling the visible differences are observed. The reason is that in the conventional method the heterogeneity of deformation mainly in perpendicular cross section of specimens is taking into account in small amount only. The new method for more precise deformation is not enough popular [10]. The differences obtained by using different conventional method are not so large, so for calculation of flow stress the simplest classical method was applied [11]. Especially that the more important aim of the work is the comparison of flow stress obtained at different strain path of deformation then precise calculation of them.

The shear stress was calculated from the following relation

$$\tau = \frac{3M_s}{2\pi r_{rz}^3}, \tag{1}$$

and shear strain

$$\gamma = \frac{r_{rz}\omega}{l_{rz}}, \tag{2}$$

The measured torque M and angel of twist ω were converted to effective stress and strain using Hubert-Misses criteria.

Flow stress is given by

$$\sigma_p = \frac{3\sqrt{3}M_s}{2\pi r_{rz}^3}, \tag{3}$$

effective strain by

$$\varepsilon = \frac{1}{\sqrt{3}}\frac{r_{rz}\omega}{l_{rz}}, \tag{4}$$

and strain rate by following relation

$$\dot{\varepsilon} = \frac{1}{\sqrt{3}}\frac{r_{rz}\dot{\omega}}{l_{rz}}, \tag{5}$$

Where: M_s – torque, r_{rz} – real sample radius of specimen changed during deformation, γ – shear strain, l_{rz} – gauge length of specimen, ω – angel of twist, $\dot{\omega}$ - rotational speed, $\dot{\varepsilon}$ - strain rate deformation in s^{-1}

3. RESULTS AND DISCUSSION

The relation between flow stress and effective strain for monotonic torsion and symmetrical cyclic torsion at temperature of 200 ^{0}C is shown in Fig. 3. On the case of cycling deformation the decrease of flow stress dependents on applied amplitude ε_a.

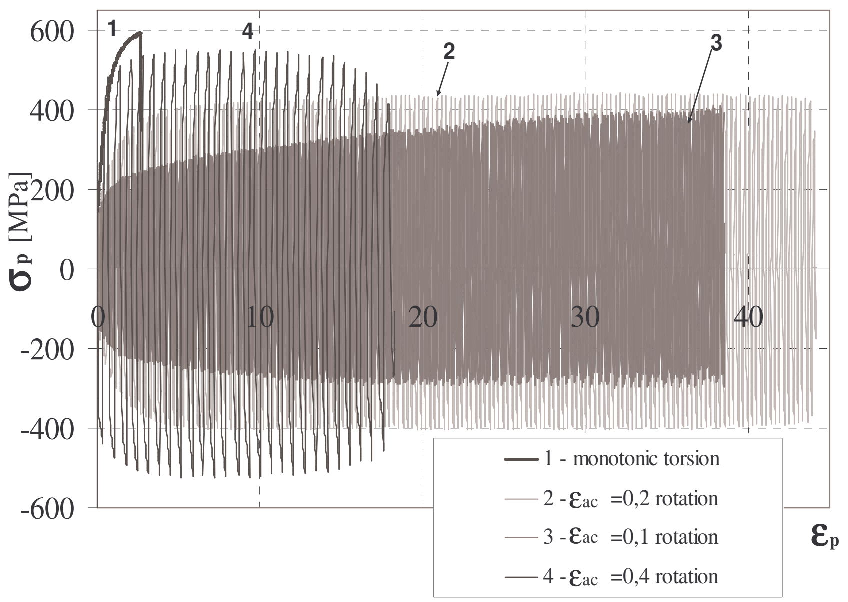

Fig. 3. Relation between flow stress and effective strain for monotonic and minor cyclic torsion at 200 ^{0}C and $\dot{\varepsilon}$ =0,1s^{-1} with amplitude of ε_{ac}=0,1, 0,2, 0,4 of rotation) for CuAl8 aluminium bronze

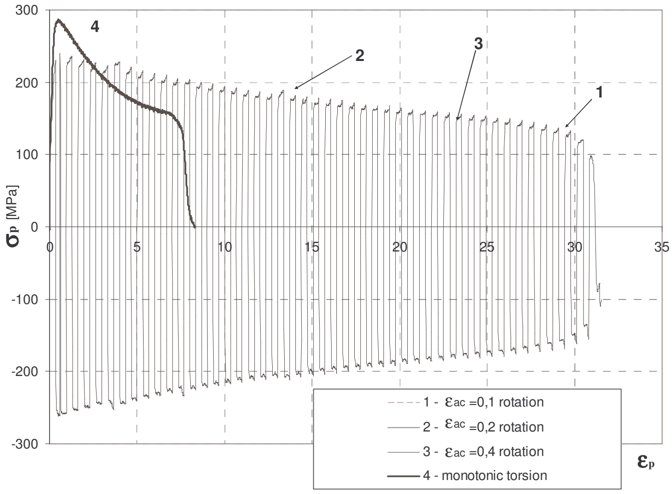

Fig. 4. Relation between flow stress and effective strain for monotonic and minor cyclic torsion at 500 ^{0}C and $\dot{\varepsilon}$ =0,1s^{-1} with amplitude of ε_{ac}=0,1, 0,2, 0,4 of rotation) for CuAl8 aluminium bronze

The hot minor cyclic torsion of CuAl8 aluminium bronze with all applied amplitude at 500^{0}C with $\dot{\varepsilon} = 0{,}1\mathrm{s}^{-1}$ is presented on figure 4. In this case also cyclic torsion leads to decrease of flow stress in comparison with monotonic torsion but not so much as in lower temperature.

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