A ROLE OF CYCLIC LOADING FREQUENCY IN ESTABLISHING OF DIRECTIVE LINES FOR TECHNOLOGICAL PROCESSES DESIGN

T. Szymczak[1] and Z.L. Kowalewski[2]

Centre for Material Testing, Motor Transport Institute, 03-301 Warsaw, Poland

Department for Strength of Materials, Institute of Fundamental Technological Research, 02-106 Warsaw, Poland

Abstract: An influence of torsion cycles frequency on material behaviour in direction of monotonic deformation simultaneously realized is discussed in this paper. All tests were carried out at room temperature using thin-walled tubular specimens. They were made of the steel recommended to operate in power plant industry. Experimental procedure was designed to determine the effects due to step increasing frequency of torsion cycles within a range from 0.25 to 10Hz, and to examine material behaviour at low magnitudes of this parameter (from 0.005 to 0.05Hz). The results enabled recognition the stress reduction level for selected magnitudes of frequency.

1. Introduction

Production of various types of elements delivered in the form of bars, rods and profiles is connected with a high consumption of energy, especially when a large structures have to be prepared. As a consequence, the production costs may increase significantly. It was presented by Lange [1], that hot die forging requires the relative energy demand close to 50 MJ/kg. In the case of cold or warm forging it equals around 41 MJ/kg. Taking into account a need for reduction of these numbers a lot of work has to be done in searches of optimal loading conditions for production. An important step in this matter was made by Korbel and Bochniak [2]. They have proposed the usage of torsion cyclic loading during drawing and extrusion processes. Cyclic torsion of the die enabled a significant reduction of technological forces, even up to 50%. Also other researchers obtained very promising results in this area. Kong and Hodgson [3] achieved 20% decrease of driving force during drawing conducted in assistance of cyclic torsion with increasing level of frequency. Bochniak and Korbel [4] obtained 30% stress drop during forging when cyclic torsion was simultaneously carried out for increasing frequency from 0.4 to 1.6Hz [4]. Kowalewski and Szymczak [5-7] achieved 80% tensile stress reduction depending on cyclic torsion parameters. Despite of many tests carried out a knowledge in this research field is still not sufficient for effective prediction of the optimal magnitudes of frequency or amplitude of cyclic loading. Therefore, the objective of this paper is concentrated on further analysis of an influence of cyclic loading frequency on monotonic deformation in the transversal direction.

2. Results

The thin-walled tubular specimens of 0.75 mm thickness and 15 mm gauge length were fabricated using the 14MoV6-3 steel rods. Experiments were carried out at room temperature on the typical servo-hydraulic testing machine. Axial and shear strain signals were applied to control the loading programme, Fig. 1. Experimental procedure contained two stages. In the first stage tests being combination of monotonic tension and cyclic torsion with step increasing frequency were carried out. Cyclic torsion frequencies varied from 0.25Hz to 10Hz, while the amplitude

[2] Corresponding author
E-mail address: zkowalew@ippt.pan.pl (Z.L. Kowalewski)

was kept constant (±0.4%). In the second stage similar experiments were performed, however, in this case both frequency and amplitude were constant. Tests were executed for frequency equal to 0.005Hz and 0.5Hz for strain amplitude equal to ±0.4%.

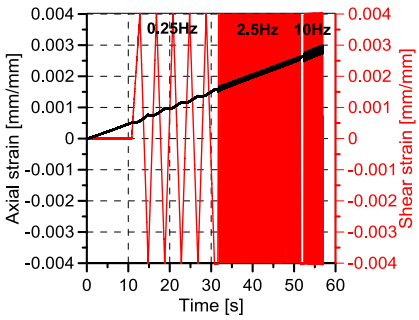

Figure 1. Strain controlled loading signals for the first stage of experimental programme

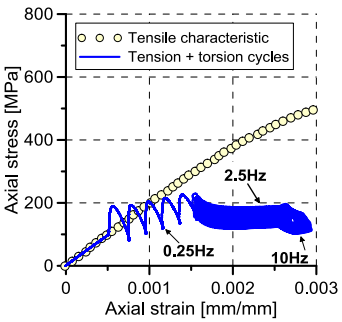

Figure 2. Comparison of standard tensile curve to the tensile characteristics obtained from the loading programme shown in Fig. 1

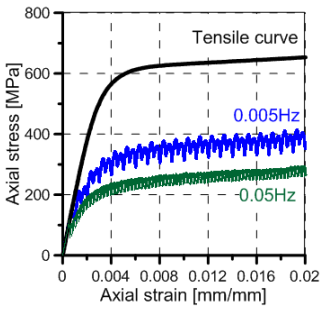

Figure 3. Tensile curve and characteristics obtained in assistance of cyclic torsion for two levels of frequency

An influence of torsion cycles frequency on material response in the tensile direction was clearly shown in Fig. 2. It is manifested by a gradual decrease of the axial stress with the increase of frequency. For the frequency equal to 2.5Hz and 10Hz the stress drop was larger than that observed for 0.25 Hz. As it is shown in Fig. 3, also low frequency magnitudes of torsion cycles can modify the stress-strain curve of the material tested. Comparison of the standard tensile characteristic with tensile curves obtained during loading assisted by torsion cycles identifies important feature, namely, even small magnitudes of cyclic loading frequency my change markedly a stress-strain curve of the material. Taking into account the stress level achieved for the axial strain equal to 2% one can noticed its reduction from 650 MPa achieved for the standard test up to 400 MPa and 300 MPa for tensile tests assisted by torsion cycles at frequency equal to 0.005Hz and 0.05Hz, respectively.

3. Conclusions

Frequency of cyclic loading belongs to such group of important parameters that may affect material characteristic during monotonic loading when combination of stress components takes place. Even small magnitudes of cyclic loading frequency change stress level. Such feature enables beneficial modifications of some technological processes, leading to the significant cost reduction during production of some elements. The results enabled identification of the cyclic loading frequency range to be recommended for technological forces reduction.

References

[1] K. Lange. Modern metal forming technology for metal production, *J. Proc. Tech.*, 1997;71:2-13.

[2] A. Korbel, W. Bochniak. Refinement and control of the metal structure elements by plastic deformation. *Scr. Mater.*, 2001;51:755-759.

[3] L.X. Kong, L. Lin, P.D. Hodgson. Material properties under drawing and extrusion with cyclic torsion. *Mater. Sci. Eng.*, 2001;A308:209-215.

[4] W. Bochniak, A. Korbel. KOBO type forming: forging of metals under complex conditions of process, *J. Mater. Tech.*, 2003;134:120-134.

[5] Z.L. Kowalewski, T. Szymczak. Modification of simple deformation processes of metallic materials by means of cyclic loading, *Mater. Res. Innov.*, 2011;15(1):73-76(4).

[6] T. Szymczak, Z.L. Kowalewski. Variations of mechanical parameters and strain energy dissipated during tension-torsion loading, *Arch. Metall. Mater.*, 2012;57(1):193-197.

[7] Z.L. Kowalewski, T. Szymczak, J. Maciejewski. Material effects during monotonic-cyclic loading. *Int. J. Solid Struct.*, 2014;51(3-4):740-753.