AN INFLUENCE OF CYCLIC LOADING ON STRESS COMPONENT REDUCTION IN THE TRANSVERSAL DIRECTION

Tadeusz Szymczak[1a)], Zbigniew Kowalewski[2]
[1]*Centre for Material Testing, Motor Transport Institute, Warsaw, Poland*
[2]*Department for Strength of Materials, Institute of Fundamental Technological Research, Warsaw, Poland*

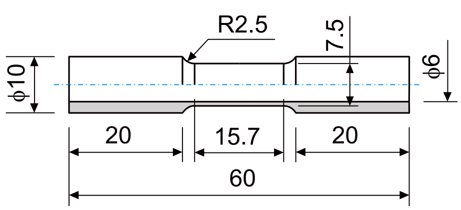
Summary The paper reports results of tests where monotonic deformation was conducted in assistance of cyclic straining in the perpendicular direction. Two variants of strain signals combinations were applied, i.e. monotonic tension with torsion cycles and monotonic torsion with tension-compression cycles. The amplitudes of cyclic strain were lower than ±1%, frequency levels were selected within the range from 0.005 to 1 Hz. Independently of the cyclic strain direction applied the material response was similar. A stress reduction with the cyclic strain amplitude increase was obtained for direction of monotonic loading.

INTRODUCTION

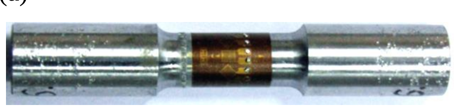
An effect of cycles on material subjected simultaneously to monotonic loading was investigated with special emphasis to find possible application for technological forces reduction. Such approach is widely used by research groups trying to modify the so called KOBO method, [1, 2]. This technique enables to produce tubes, rods and other types of profiles at lower forces, than those necessary during conventional processes execution, [3]. In typical procedures an application of the KOBO technique enforces large deformation in direction of cyclic loading [1, 2]. However, as it has been shown by other researches [4, 5] the same effect can be achieved using cyclic loading of significantly lower strain amplitude. Such aspect of analysis is not sufficiently recognized as yet. Therefore, the main aim of this paper is to study variations of stress-strain curve due to monotonic deformation assisted by cyclic loading under a range of strain amplitudes and different frequencies.

EXPERIMENTAL PROCEDURE

The experimental procedure contained three stages. Firstly, monotonic tension and monotonic torsion tests were carried out. Afterwards, monotonic tension assisted by cyclic torsion (symmetrical cycles) with step increasing strain amplitude was performed. The third stage was planned to have step increasing strain amplitude of tension-compression cycles superimposed on monotonic torsion. All tests were performed at room temperature using thin-walled tubular specimens of: 60 mm – total length; 15.7 mm – gauge length; 0.75 mm – wall thickness, Fig. 1. Axial and shear strain components in the form of monotonic and sinusoidal functions were used to control the loading programme, Fig. 2a. In the case of torsion-reverse-torsion cycles the following magnitudes of shear strain amplitude were taken: ±0.1, ±0.2, ±0.4, ±0.8%, while frequency was equal to 1Hz. The tests to identify a frequency effect were conducted for values lower than 1Hz under constant strain amplitude equal to ±0.4%. An influence of tension-compression cycles on monotonic torsion was investigated for axial strain amplitude equal to: ±0.1, ±0.15, ±0.3 and ±0.75%.

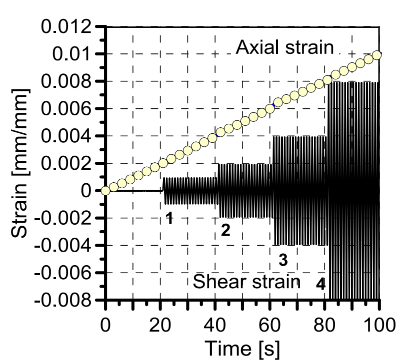


(a)

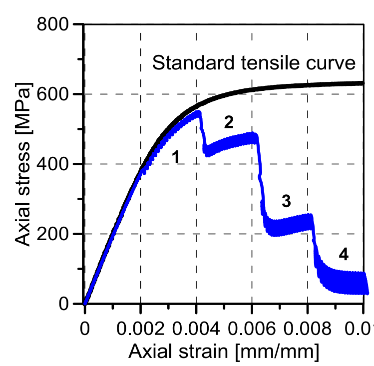


(b)

Fig. 1. Thin-walled tubular specimen: (a) geometry and dimensions, (b) zone for location of strain gauges



(a)



(b)

Fig. 2. Test details: (a) loading programme, (b) comparison of standard tensile characteristic to the responses under combined loading programme illustrated in Fig. 2a

[a)] Corresponding author. Email: tadeusz.szymczak@its.waw.pl

RESULTS AND THEIR ANALYSIS

The 14 MoV 6-3 steel commonly applied in automotive industry was selected for testing. It is used to produce car elements, engine parts and suspensions. Tensile parameters of the steel were as following: Young's modulus - 1.9×10^5 MPa; yield point - 523 MPa; ultimate tensile stress - 653 MPa. The representative results from tests are presented in Figs. 2÷4. As it is shown in Fig. 2, the steel in tension direction exhibited significant stress reduction due to presence of torsion cycles. This effect became to be stronger with the increase of shear strain amplitude. The tensile stress drop attained 90% for the highest strain amplitude considered. Similar effect has been observed during monotonic torsion assisted by tension-compression cycles, Fig. 3. Again, with the increase of the cyclic strain amplitude, the shear stress magnitudes diminished dramatically. Shear stress drop attained the level of ~30, ~150 and ~200 MPa for cyclic strain amplitude equal to ±0.15, ±0.3, ±0.75%, respectively.

In the final step of the experimental programme an influence of cyclic torsion frequency on the monotonic tension was investigated. Three levels of frequency were taken into account: 0.005, 0.05 and 0.5 Hz. In each test the cyclic strain amplitude was the same: ±0.4%. The results are summarized in Fig. 4. As it can be seen, the axial stress lowered around 250 MPa for the lowest frequency considered. For the higher values of this parameter, i.e. 0.05 Hz and 0.5 Hz, such drop was equal to 370 MPa and 470 MPa, respectively.

The experimental observations were modelled using the three surface model proposed by Mróz and Maciejewski [6].

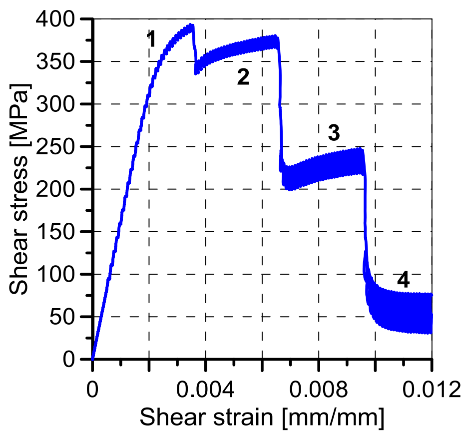


Fig. 3. Variations of shear stress due to presence of step increasing amplitude of tension-compression cycles: 1 - 0.1%; 2 - 0.15%; 3 - 0.3%; 4 - 0.75 %, frequency 1Hz

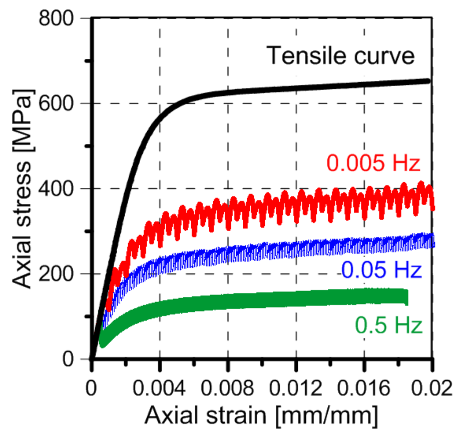


Fig. 4. Effect of cyclic torsion frequency on tensile curves

SUMMARY

Stress occurred during monotonic deformation can be significantly reduced by application of cyclic strain in the transversal direction. This effect was visible for small values of cyclic strain amplitude and frequency, below ±1 % and 0.5 Hz, respectively. In comparison to the initial state even 90 % stress reduction during monotonic loading can be achieved when assisted by cycles.

References

[1] Kong L.X., Lin L., Hodgson P.D.: Material properties under drawing and extrusion with cyclic torsion, *Materials Science and Engineering*, **A308**:209-215, 2001.

[2] Bochniak W., Korbel A., Szyndler R., Hanarz R., Stalony-Dobrzański F., Błaż L., Snarski P.: New forging method of bevel gears from structural steel, *J. Mat. Proc. Tech.*, **173**:75-83, 2006.

[3] Korbel A., Szyndler R.: The new solutions in the domain of metal forming - contribution of the Polish engineering idea, *Metal Forming*, **XXI(3)**, 203-216, 2010.

[4] Szymczak T., Kowalewski Z.L.: Variations of mechanical parameters and strain energy dissipated during tension-torsion loading, *Archives of Metallurgy and Materials*, **57(1)**:193-197, 2012.

[5] Kowalewski Z.L., Szymczak T., Maciejewski J.: Material effects during monotonic-cyclic loading, *International Journal of Solids and Structures*, **51(3-4)**: 740-753, 2014.

[6] Maciejewski J., Mróz Z.: Modelling of plastic deformation of metals at complex loading paths (in Polish), *the I Congress of Polish Mechanics*, Warsaw, 28-31 August 2007, Poland.