28th Danubia-Adria-Symposium on Advances in Experimental Mechanics, Siofok, Hungary, 28 September 01 October 2011

MATERIAL EFFECTS DURING MONOTONIC-CYCLIC LOADING

Tadeusz Szymczak [1), Zbigniew L. Kowalewski [2)]

[1)] Motor Transport Institute [2)] Institute of Fundamental Technological Research

80 Jagiellonska Str., 03-301 Warsaw, Poland 5B Pawińskiego Str., 02-106 Warsaw, Poland

Corresponding author: tadeusz.szymczak@its.waw.pl

1. Introduction

A lot of elements of the machines operate under different types of loading. Rarely the stress states are simple, but contrary they are usually becoming complex in different cases. Therefore, many material laboratories focus their efforts on the investigations under multiaxial stress states in spite of the well know fact that such kinds of tests are not easy to perform. Since the number of multiaxial experiments is still modest, the current knowledge about materials behaviour under such conditions is insufficient for reasonable modelling. Such situation takes place for example during an effective fracture predictions of engine turbine blades [1], [2], failure assessments of ball bearing [3] or damage analysis of vehicle drive shaft [4]. On the other hand, complex loadings play an essential role in modifications of technological processes [5], [6]. Taking into account an increase of the industrial devices lifetime and possible redesigning of certain technological processes, the experimental program presented in this paper was designed in such a way that torsional cycles were superimposed on monotonic tension.

2. Experimental Results

Two different materials, i.e. the P91 steel and M1E copper, were investigated under biaxial stress state. Stress-strain characteristic of the tested materials are presented in Fig. 1. There are significant differences between them, what is obvious since they represent different kinds of material. However, an interesting thing is that both characteristics can be modified applying simultaneous torsion-reverse-torsion cycles during monotonic deformation, Fig. 1. The results exhibit a significant reduction of the selected mechanical parameters, and as a consequence, the courses of hardening curves for steel and copper are located lower than those without cyclic loading. As it was shown, a decrease of mechanical parameters depends on the amplitude of cyclic loading. An increase of the cyclic strain amplitude led to further decrease of the mechanical parameters. For example, in the case of M1E copper tested for the highest cyclic strain amplitude applied a reduction of proportional limit and yield point was equal to 220 MPa and 160 MPa, respectively. In many industrial applications the lowering of selected stress parameters may extend the lifetimes of some engineering components.

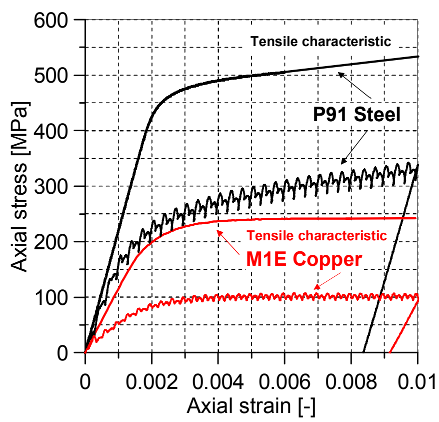

Fig. 1: Comparison of tensile characteristic and stress-strain curve obtained at presence of torsion cycles for P91 steel, and M1E copper

This is especially important taking into account those elements for which the manufacturing costs are extremely high. Differences of mechanical behaviour between both tested materials are well reflected in Fig. 2, where their hysteresis loops are compared for the same cyclic strain amplitude equal to ±0.3%. In the case of P91 steel a stress drop at the first cycle was obtained, and next the cyclic stability was achieved rapidly, whereas for copper a gradual cyclic softening was observed. The subsequent hysteresis loops allow to assess a variation of the plastic strain energy dissipation. For the P91 steel and M1E copper it increases but in the case of copper it achieves smaller magnitudes. The effect is more visible for higher magnitudes of the cyclic strain amplitude. Further differences between both materials can be identified on the basis of diagram showing effective stress-effective strain characteristics, Fig. 3.

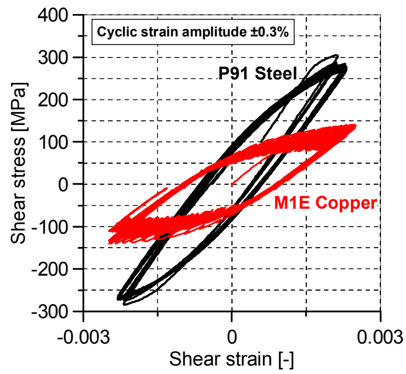

Fig. 2: Hysteresis loops of torsion cycles for amplitude equal to: ±0.3%

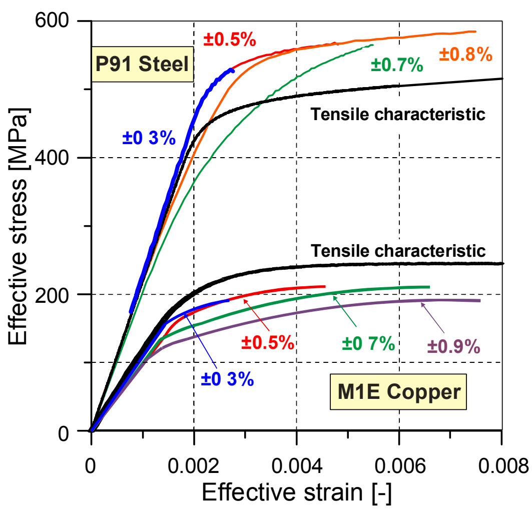

Fig. 3: Comparison of effective stress-strain characteristics under combination of monotonic tension and cyclic torsion for steel and copper (numbers denote magnitudes of cyclic strain amplitude applied)

An increase of the cyclic strain amplitude led to gradual drop of the stress-strain curves in comparison to the tensile curve obtained without torsion cycles in the case of copper. An opposite behaviour was achieved for the steel, Fig. 3.

3. Conclusions

Experimental results enabled to formulate the following conclusions:

- torsion-reverse-torsion superimposed on monotonic deformation causes reduction of proportional limit and yield point, but the effect do not have a permanent character, after termination of cyclic loading it vanishes,
- effective stress-strain curves identify an increase or decrease of the mechanical parameters with the increase of the cyclic strain amplitude depending on a type of material.

4. Acknowledgements

The support from the Ministry of Science and Higher Education (Poland) under grant No N N501 121 036 is greatly appreciated.

5. References

[1] Salam I, Taugir A., Khan A.Q., Creep-fatigue failure of an aero engine turbine blades, Eng. Fail. Anal., 9, (2002), 335-347.

[2] Hou J., Wicks B. J., Antoniou R. A., Investigations of fatigue failures of turbine blades in a gas turbine engine by mechanical analysis, Eng. Fail. Anal, 9, (2002), 201-211.

[3] Salam I, Tauquir A., Haq U., Khan A. Q., An air cash due to fatigue failure of a ball bearing, Eng. Fail. Anal., Vol. 5, 4, (1998), 261-269.

[4] Vogwell J., Analysis of a vehicle wheel shaft failure, Eng. Fail. Anal.,Vol. 5, 4, (1998), 271-277.

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

[6] W. Bochniak, A. Korbel, R. Szyndler, Innovative solutions for metal forming, Proc. Inter. Conf. MEFORM 2001 – Herstellung von Rohren und Profilen,

Institut für Metallformung Tagungsband, 239, Freiberg/Riesa, (2001).