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# ANALYSIS OF TENSILE FORCE VARIATION DUE TO APPLICATION OF CYCLIC TORSION FOR A RANGE OF FREQUENCY LEVELS

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## 1. Introduction

Experimental results of many research groups report a great influence of loading type on material behaviour. It is often expressed by material hardening due to deformation along non-proportional loadings in comparison to the typical response observed under proportional paths. This phenomenon depends on parameters of strain signals, i.e. shape, amplitude and frequency. An influence of loading type on material softening or hardening was also examined in experiments focused on investigations of KOBO method. It uses torsion-reverse-torsion cycles simultaneously with axial forces. Application of cyclic torsion enables a reduction of major forces in drawing, extrusion, forging or rolling. Previous investigations shown that a magnitude of axial force reduction in technological processes is connected with amplitude and frequency of torsion cycles. An effect of torsion cycle amplitude on tensile curves has been widely investigated by a number of researchers [1, 5, 6]. They have experimentally proved that technological force reduction decreased with increasing of torsion cycle amplitude. An influence of frequency of cyclic torsion on force variations in technological processes has not been efficiently determined up to now. Kong and Hodgson tested an extrusion of pure lead assisted by cyclic torsion at frequency within a range from 6.7 to 20 Hz [1]. They obtained lowering of the extrusion force when frequency decreasing. Similar tests on copper, however for drawing process, confirmed such observation. An opposite effect was discovered by Pawlicki and Grosman who performed compression tests in assistance of torsion cycles under a range of selected levels of frequency [2]. Their results expressed 50% force reduction with an increase of frequency from 0 to 1.8 Hz. Niewielski at al. also observed 20% reduction of compression force due to torsion cycles application to deform copper, however only for single level of frequency equal to 1.6 Hz [3]. In the case of the 7075 aluminium alloy tested by Korbel et al. almost the same level of the compression force reduction was achieved for torsion cycles at frequency equal to 8 Hz [4]. Since the contradictory results related to the effect of frequency of cyclic torsion on tensile characteristics have been obtained, further investigations are necessary. Therefore, the paper is addressed to study this issue more accurately in laboratory tests.

## 2. Details of experimental procedure

Experimental procedure contained two stages:

a) tensile tests assisted by torsion cycles for frequency levels equal of 0.005, 0.05 and 0.5 Hz;
b) tensile tests assisted by torsion cycles under step increasing frequency from 0.25 to 1 Hz.

To determine material behaviour thin-walled tubular specimens and servo-hydraulic testing machine were used. All tests were conducted at room temperature. Axial and shear strain signals were used to enforce monotonic tension and shear cyclic deformation, Fig. 1. The axial strain monotonically increased while the shear strain was activated by torsion at constant amplitude equal to $\pm 0.4\%$ and frequency within a range from 0.005 to 0.5 Hz.

The 10H2M steel was selected to tests. It is commonly applied by engineers designing of some constructions used in power plant industry.

### 3. Analysis of tension assisted by cyclic torsion of various levels of frequency

The results of tests carried out on the 10H2M steel are presented in Fig. 2a, where the tensile characteristic (0) is compared to tensile curves obtained in assistance of cyclic torsion at a range of different frequency levels. They express gradual reduction of the axial stress with an increase of shear strain frequency. For the highest frequency applied it was reduced by 410 MPa. Another effect discovered during torsion cycles superimposed on tension is presented in Fig. 2b. It is manifested by more rapid decrease of the axial stress for higher magnitudes of frequency of torsion cycles applied.

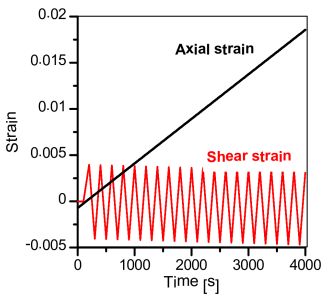


Fig. 1. Loading programme.

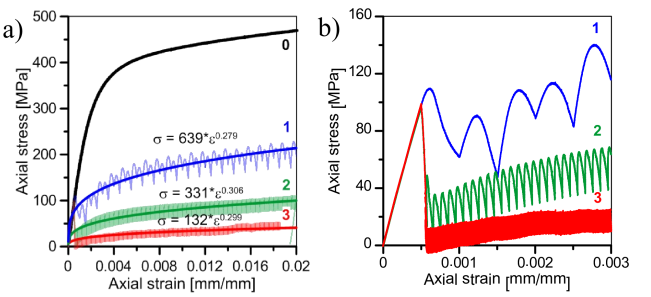


Fig. 2. Variations of stress-strain curves determined during typical tensile test (0) and in assistance of torsion cycles at frequency: (1) – 0.005 Hz, (2) – 0.05 Hz, (3) – 0.5 Hz.

For the higher frequency cycles applied in blocks of step-increasing frequency from 0.25 to 1 Hz for small amplitude of ±0.1% the 20% axial stress reduction was noticed. This effect was not so strong as that observed for higher value of strain amplitude and significantly lower frequency, Fig. 2a.

Calculations of total strain energy were performed to extend the knowledge of steel behaviour under simultaneously activated tension and cyclic torsion. In comparison to the total strain energy calculated on the basis of tensile curve (8.36 MJ/m$^3$) its level was significantly lower (92%) in the case of monotonic tension assisted by cyclic torsion realized under frequency equal to 0.5 Hz.

### 4. Summary

Torsion cycles frequency may reduce significantly the axial stress during monotonic tension. A level of axial stress reduction is dependent not only on the frequency, but also on the cyclic strain amplitude. An influence of both these parameters on the tensile stress drop is complex, hence in order to obtain optimal reduction of it for particular material a range of reasonable selected tests should be executed.

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