COMBINED LOADING OF THE SPECIMENS AND REALIZED EXPERIMENT

Fr. Fojtík, J. Fuxa
Department of Mechanics of Materials
VSB-Technical University of Ostrava, Czech Republic

e-mail: frantisek.fojtik@vsb.cz

The article describes experimental results under combined loading of specimens manufactured from common construction steel 11523. Specimens were gradually loaded by amplitude of the torque and then by combination tension prestress. For evaluation of the results the Fuxa's criterion was applied. The performed experiments and their results embody a good agreement with bellow mentioned conjugated strength criterion. The experiments were performed on reconstructed testing machine Shenck. The reconstruction and experiment will be described in the following article.

Keywords
Combined loading, High-cycle Fatigue, Experiment, Multi-axial fatigue, Mean stress effect

1. Introduction

The rotary parts are characterized by concentration of certain part of the mass to the given volume and from dynamic point of view is this mass described by moment of inertia. This fact led the authors to an idea – to use the dynamic inertial effect of the mass for the testing of the material in high – cycle fatigue in torsion and for combination of torsion and axial tensile/compressive force. This idea became the basis for the design of the reconstruction of the testing machine. The reconstruction and experiment will be described in the following article.

2. Testing machine reconstruction

For materials testing in the field of high-cycle fatigue and strength criterion verification there was designed a new conception of the testing machine (see Fig. 1). The new created design of the test machine results from the nowadays used conception of the test machine SCHENCK type PWXN [Fojtík 2004].

From this "old" conception the frame (3), asynchronous electromotor, the gear-box with the regulation of the eccentricity by the help of worm gear (2) and revolution sensor (1) were used. The outgoing shaft from the four-articulated mechanism is followed by fixation head (4) that includes double row axial bearing. The bearing avoids the transmission of the axial force to the lodgement of the driving the four-articulated mechanism. The specimen (6) [Fojtík 2007] is connected with the test shaft of the fixing head by the help of wale (5). The same way is the specimen connected with the measure head that is joined on the strain gauge sensor (7). By the sensor is possible the measurement of the torque and axial force in the same time. At the periphery of the sensor at the angle 45 deg the strain gains are glued on. The placing and the circuitry are showed in [Fuxa 2007]. The measured values are directly evaluated by the measuring card in the PC [Fusek 2007]. Axial tension/pressure force is evocated by the hydraulic cylinder (9).

The new conception changes loading characteristics of testing specimen out of deformation to the force. The new conception of the testing machine is applied for protection as utility patent under the name: "Equipment for cycle fatigue testing specimens by torsion moment", utility patent number – number notation: 17226 (2007) and further under the name: "Equipment for combination load of testing specimens", utility patent number – number notation: 17286 (2007).

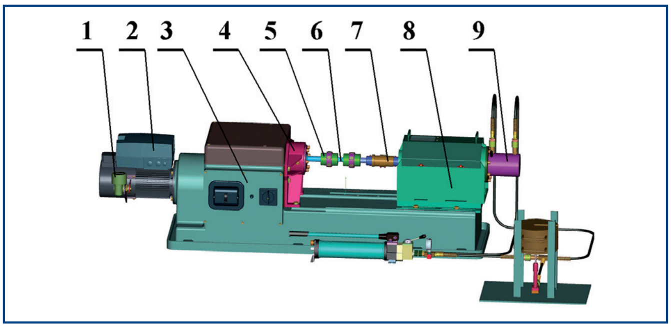

Figure 1. New design of testing machine

3. Experiment – cyclic stress

Testing specimens made of steel 11523 smelt T18556, were loaded by cyclic torque. On Fig. 2 are shown measured points and drawn curves of Basquin's approximation (1) and Fuxa's approximation (2) [Fuxa 2006]. The failure point in the static torsion was measured in the Department of Mechanics of Materials and its laboratory on a redesigned machine INOVA [Frydrysek 2004].

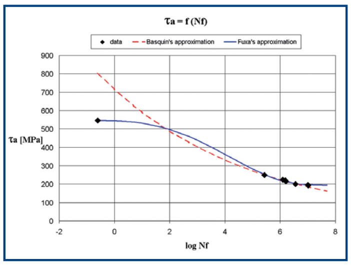

Figure 2. W – curve and its approximation

Basquin's approximation:

(1) $$\tau_a = \tau_f' \cdot (2N_f)^b,$$

Fuxa's approximation [2, 3]:

(2) $$\tau_{aF2} = (\tau_f + \tau_C)/2 + (\tau_f - \tau_C)/ 2 \cdot \cos\left\{ \pi \cdot [\log(4 \cdot N_f)/\log(4 \cdot N_C)]^{a_1} \right\},$$

for N_f in interval $[1/4; N_C]$ a τ_{aF} in interval $[\tau_f; \tau_C]$.

τ_f is a value of real shear strength, τ_C is the stress at the fatigue limit, N_C is number of cycles at the fatigue limit, a_1 is constant, τ_{aF} is the limit stress amplitude under alternating torsion and N_f is the limit number of cycles until crack initiation.

4. Experiment – cyclic torque and tension

Testing specimens made of steel 11523 smelt T18556, were loaded by the cyclic torque and axial tension force. Tests were made the way that every single set of the testing specimens was loaded by different constant value of an axial tension stress (s_t). For the tensional stress there was for each series chosen an initial amplitude of shear stress, by which the specimen was loaded up to the crack occurrence. The amplitude was gradually declined up to the value, which the specimen endured for 10^7 cycles. Overall there were accomplished four series of experiments. The experimental results (see Fig. 3.) are also approximated by lower described Fuxa's approximation (3, 4, 5, 6) which takes the influence of mean stress into account [Fuxa 2006].

$$\tau_{aF2} = (\tau_f^* + \tau_C^*)/2 + (\tau_f^* - \tau_C^*)/ 2 \cdot \cos\left\{ \pi \cdot [\log(4 \cdot N_f)/\log(4 \cdot N_C)]^{a_1} \right\}, \quad (3)$$

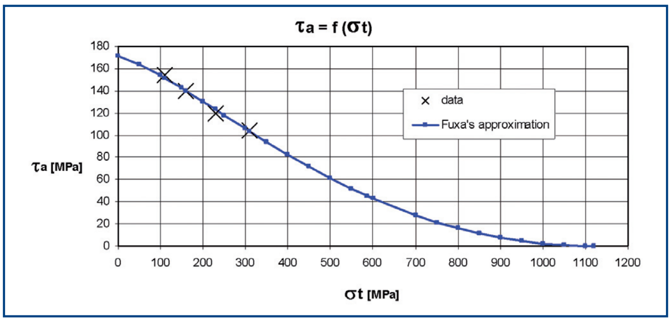

Figure 3. *Influence of mean value tension stress for crack initialization*

$$\tau_f^* = 1/\sqrt{3}\cdot\begin{pmatrix}(\sqrt{3}\cdot\tau_f)^2 - 2\cdot\sqrt{3}\cdot\tau_f\cdot B_O\cdot\sigma_t/3 \\ +\sigma_t^2\cdot B_O^2/9-\sigma_t^2\end{pmatrix}^{1/2} \qquad (4)$$

(4) is static strength condition while $N_f = 1/4$, where constant B_0 [2, 4] is equal:

$$B_O = 3\cdot\left(\sqrt{3}\cdot\tau_f/\sigma_f - 1\right), \qquad (5)$$

$$\tau_C^* = \tau_C/2\cdot\left\{1+\cos\left[\pi\cdot(\sigma_t/\sigma_f)^B\right]\right\}, \qquad (6)$$

is strength condition for ($N_f = N_C$).

In the relations (3, 4, 5, 6) the σ_f is the real tension strength value, τ_f is a value of real shear strength, τ_C is the stress at the fatigue limit, N_C is number of cycles at the fatigue limit, a_1 and B are constants, τ_{aF2} is the limit amplitude of shear stress, σ_t is the constant tension stress and N_f marks the limit number of cycles until crack initiation.

On Fig. 4 are shown experimental results obtained by localization of stress amplitudes within limits $N = 10^7$ cycles, for four different values of an axial tension stress. Results of the experiments (along with fatigue limit curve Fig. 3) are smooth by earlier described Fuxa's approximation for the appropriate number of cycles. Particular approximations are based on measured number of cycles which is mentioned in Fig. 4. On Fig. 5 are shown three phases of the crack development at the described cyclical loading.

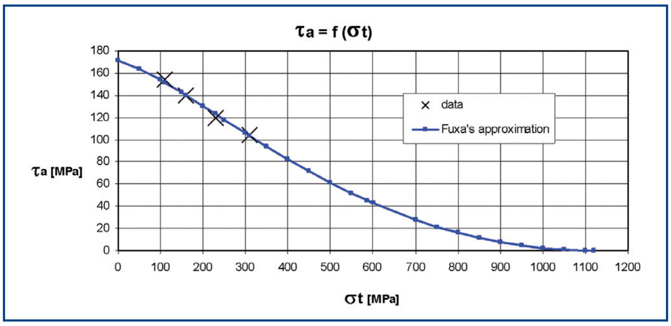

Figure 4. *Fuxa's approximation for the combined loading*

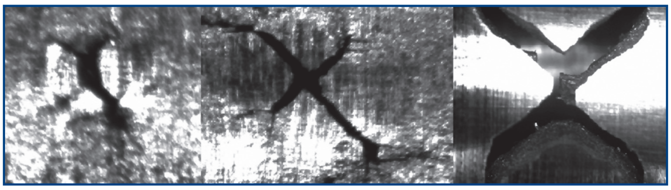

Figure 5. *Three phases of the crack development at the combined loading*

5. Conclusions

The article introduced reconstructed torsion fatigue testing machine, appropriate for constant assessment of fatigue strength criteria. There is also possible to load the testing specimens by combination of time-variable torque and constant tension / press axial force.

In the article there were described results of experiments, executed in the conditions of cycled torsion and torsion in combination with axial tension force. In the first case the results are used for W-curve description with Basquin's and Fuxa's approximation, in the second case are the results of experiments used for expression of strength criteria (6). From Fig. 2, 3 and 4 is visible good match of proposed approximations obtained by experimental data.

Acknowledgements

The paper was created under support of GACR, project no: 101/08/P141.

References

[Fojtik 2004] Fojtik, F. The adjustment of the test machine SCHENCK for the conditions of multiaxis fatigue. In: 2nd International PhD Conference on Mechanical Engineering – PhD 2004, Srni: 2004, pp. 23-24, ISBN 80-7043-330-2

[Fojtik 2007] Fojtik, F. The Experimental Machine for the Multiaxis Fatigue Testing of Material. Dissertation Thesis, FS VSB-TU Ostrava 2007 (In Czech)

[Frydrysek 2004] Frydrysek, K., Halama, R., Fuxa, J., Fusek, M. Torsion Test of Steel Specimens in the Course of Cyclic Loading In: 20th Conference with International Participation "Computational Mechanics 2004, University of West Bohemia, 2004, pp.97-102. ISBN 80-7043-314-0 (In Czech)

[Fusek 2007] Fusek, M., Fuxa, J. Universal Testing Machine. In: Experimental Stress Analysis 2007, Vyhledy, 2007, ISBN 978-80-7043-552-6 (In Czech)

[Fuxa 2007] Fuxa, J., Kubala, R., Fojtik, F. Torque machine fit for high cycle fatigue of material testing. In: Experimental Stress Analysis 2007, Vyhledy, 2007, ISBN 978-80-7043-552-6 (In Czech)

[Fuxa 2006] Fuxa, J., Fojtik, F., Kubala, R., Idea of the Conjugated Strength. In: Experimental Stress Analysis 2006, Cerveny Klastor, 2006, ISSN 1335-2393 (In Czech)

Contacts

Dipl. Ing. Frantisek Fojtik, Ph.D.
VSB-Technical University of Ostrava,
Department of Mechanics of Materials,
17.listopadu 15, Ostrava, 708 33, Czech Republic
tel.: +420 59 732 3292, e-mail: frantisek.fojtik@vsb.cz