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# Analysis of stress and strain of fatigue specimens localised in the cross-sectional area of the gauge section testing on bi-axial fatigue machine loaded in the high-cycle fatigue region

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**Abstract**

Fatigue is a progressive, localized, permanent structural change that occurs in materials subjected to fluctuating stresses and strains that may result in cracks or fracture after a sufficient number of fluctuations. Fatigue fractures are caused by the simultaneous action of cyclic stress, tensile stress and plastic strain. If one of these three acting phenomena is not present, fatigue cracking will not initiate and propagate. Small geometrical changes in the specimens, or specifically, test conditions by invariable angular displacement cannot significantly allow analytical calculation of stresses and strains. Therefore a numerical analysis of stresses generated through bending and torsion fatigue specimens has been performed using available FEM-program ADINA. Computer simulation has been performed on fatigue specimens made of high-strength steel DOMEX 700 MC D.



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## 1. Introduction

Devices for testing fatigue life are divided according to the method of inferring the load into devices with mechanical and hydraulic load inference. Devices with mechanical load inference are able to infer uniaxial stress state usually with a symmetrical loading cycle. This category includes, for example: bending during rotation, and

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tension-compression with electromagnetic resonance drive. Such devices are thus characterised by low electric power consumption for the drive and a symmetric loading cycle.

The second group of experimental devices for fatigue testing consists of devices with multiaxial loading. The most frequent combination is tension-compression with torsion, and bending with torsion. These devices usually have hydraulic transmission, and allow defining asymmetrical loading state with loading amplitude phase shift. The main disadvantage of these devices is their high energy consumption during operation.

In our department we developed a device for testing multiaxial fatigue life, which has low energy consumption, while enabling the definition of asymmetrical combined loading with phase shift.

## 2. Bi-axial fatigue testing machine

The unique device for experimental verification of fatigue life, see Fig. 1, which was developed in our department, uses mechanical drive principle for combined bending and torsion loading. The device structure consists of:

- Electric synchronous motor.
- Eccentric mounted through involute splines on the shaft driven by an electric motor.
- Connecting rod transmitting force effects from the eccentric to the arm.
- Arm firmly connected to the clamping jaw, and carried in bearings.

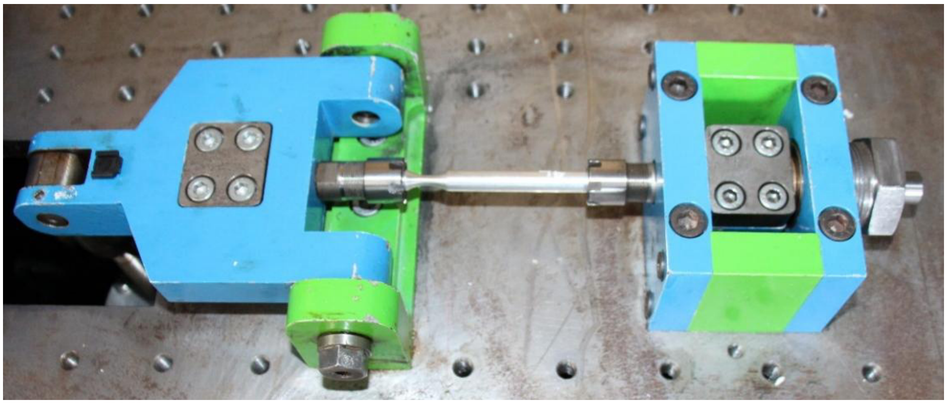

Fig. 1. Bi-axial testing equipment.

Each loading mode (bending and torsion) has its own drive mechanism. Individual parameters of the loading cycle are altered as follows: loading size is altered by means of rotating the eccentric between zero eccentricity and the maximum eccentricity, the step being given by the number of teeth of involute splines; symmetry/asymmetry of the loading cycle is changed by adjusting the connecting rod length. Phase shift of loading amplitudes is controlled by a control unit of the frequency converter of electric drive of the synchronous motors.

The clamping jaw for bending has fixed specimen rotation, the clamping jaw for torsion has a fixed bending. The specimen is of asymmetric shape due to this manner of the clamping jaws mounting. The diameter of a circular specimen at the site of the neck is 6 mm. When loading in the region up to 1.500 MPa, the drive energy consumption is approximately 5 kW at the frequency of loading 50 Hz.

We developed an experimental device that meets the demanding conditions imposed on similar devices manufactured by reputable companies. These conditions include the possibility of using combined loading and the possibility of adjusting asymmetrical loading cycle at simultaneous constant phase shift of the bending load amplitude against torsion at a relatively low energy consumption [1].

A disadvantage of the created experimental device is the requirement for the asymmetrical shape of a specimen, and the impossibility of analytical determination of the loading size. State of stress and strain in the specimen is determined using the finite element method (FEM) in ADINA software [2].