1. Introduction

A plastic deformation is usually the main physical quantity which determines a fatigue life of structural parts during their cyclic loading. Not only the amplitude or the range of a cyclic deformation is the decisive factor of a cyclic behaviour, but also the cyclic creep or the ratchetting and residual strains are very important parameters, which are measured and analysed during the cyclic loading. Electrical resistance strain gauges are usually used for experimental investigation of small plastic deformation. Nowadays, new optical method as well as optic interferometry or image correlation can be successfully applied.

In the last two decades fibre optic sensors with Fibre Bragg Gratings (FBG sensors) have a progress in application for a strain measurement [1]. The main advantage of these sensors is their non sensitivity to the electromagnetic field, and potential for high fatigue resistance in the large deformation area.

2. Experimental investigation and results

The elasto-plastic behaviour of structural steel specimens were investigated during a harmonic loading with the constant stress amplitude.

Tubular specimens of the outer/inner diameter of 30/26 mm (see Fig. 1) were simultaneously monitored by FBG sensor (length of grating 5 mm, central wavelength about 836 nm), strain gauges (HBM - 1-LY11-6/120) and extensometer (measured length 20 mm).

At first, a calibration of the specimen with installed FBG sensor was made to compensate a temperature strains during a cyclic loading when temperature of the specimen has changed, see Fig. 2. Temperature was measured by the thermocouple sensor.

The hysteresis loops and their cyclic changing were evaluated from loading-strain-time history. The hysteresis loops showed a shift of the total strain in the longitudinal axis of the specimen due to a ratcheting of material, (see Fig. 3).

Ratcheting was gradually stabilized in the high cycle area. The cyclic stabilized hysteresis loops were then reconstructed and the cyclic...
stress-strain curve (CSS curve) described by analytic equation. Consequently, up and down branches of the hysteresis loop were reconstructed.

3. Elasto-plastic FEM analysis and results

The FE model of tubular specimen (see Fig. 1) was prepared and the FEM calculations of stress-strain distribution by cyclic loading were simulated in the ABAQUS Software. The elasto-plastic model according Chaboche [1] were implemented and all ten materials parameters of this model were optimized to have reasonable agreement of the FE model with the experimental CSS curve, see Fig. 4.

Fig. 4: Branch of the hysteresis loop (comparison of the first estimate, final FEM model and experiment)

The simulation of the loading history with application of the Chaboche’s model and identified parameters comparing to experimental investigation is depicted in the Fig. 5. This model was then used for extending FE-calculation for more complicated loading paths in the fatigue process (multiaxial fatigue).

Fig. 5: Branch of the hysteresis loop (comparison of the first estimate, final FEM model and experiment)

4. Conclusions

The experimental investigation has confirmed that FBG sensors can be successfully used for cyclic elasto-plastic measurement of a stress-strain loading history.

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6. References

