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EVALUATION OF CASTING FATIGUE LIFE BASED ON NUMERICAL MODEL AND FATIGUE TESTS

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1. Introduction

Estimation of the fatigue life of a construction requires, on the one hand, the experimental determination of material characteristics, while, on the other hand, it requires our knowledge of the components of the state of stress and strain in the examined element. Fatigue tests are usually carried out under uniaxial loads, which makes their use in the analysis of the structure stability, in most cases subjected to multiaxial loads, quite difficult. The criteria of multiaxial fatigue enable reducing the spatial state of stress to a uniaxial tension, which is used in the determination of fatigue life based on standard tests. The reduction is usually done through the use of a relationship linking the components of the state of stress and strain; often, however, the applied criterion is also based on the measured strain energy. Among the numerous multiaxial fatigue criteria, attention deserve those that have been formulated basing on the concept of the, so-called, critical plane, assuming that the fatigue crack is triggered by the effect of stress or strain operating in this plane. Critical plane defines the place of crack initiation; thus, initially, it has been applied to the high-cycle fatigue test (HCF) only, but - as confirmed by numerous studies - it operates equally well also in the low-cycle fatigue tests (LCF) [1].

2. Experimental

The successive steps accompanying the performance of a numerical model, the calculation of stress and strain and the determination of fatigue life involved:

1. Conducting the static tensile test.
2. Conducting fatigue tests by the LCF and MLCF method.
3. Interpretation of the obtained results and their incorporation into the numerical model of a sample subjected to cyclic loading to test the validity of the "virtual properties".
4. Building a numerical model of the lock with description of material allowing for the effect of load on the fatigue behaviour (mixed kinematic and isotropic hardening).
5. Determination of components of the spatial stress-strain state in the lock.
6. Selection of multiaxial fatigue criterion based on the interpretation of the results of calculations made by FEM.
7. Prediction of the fatigue life of the lock based on the numerically determined value of deformation and fatigue life curve plotted for the cast 25HGNMA steel.

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In further part of the article, some of the above mentioned items, more important in terms of the applied methodology, will be developed.

3. Results and discussion.

Conveyors are important elements of equipment during the coal transport in longwall excavations and drift mining, where they form an integral part of the cutting and loading machines and of the wall casing [5]. Typically, parts of conveyors are forgings made of the low-alloy structural steel - 25HGNM (Figs. 3a, 3b).

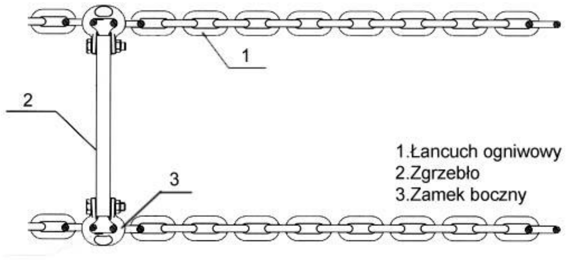

Fig. 3a. Fixing of scraper in a conveyor.

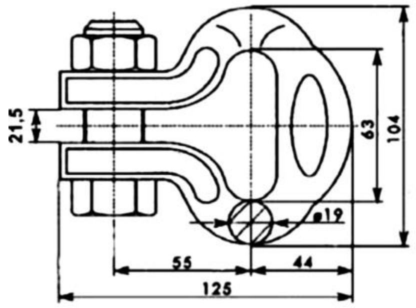

Fig. 3b. Sample solution of lock design

The numerical model of the lock was designed in the Abaqus programme [1, 5-11]. Due to the symmetrical geometry of the lock-chain system and the assumed symmetry of load, for calculations, a half-object was used. The chain link had a mechanical type of contact with the surface of the lock. The force exerted by the chain link varied in a large range of values, in extreme cases causing reduced stress in the lock, close to the boundary tensile strength R_m of cast steel. From the area of the model where the calculated stress values were the highest, and where usually cracks in the conveyor locks are observed to occur, a few elements were selected, and in those elements changes in the components of the state of stress and strain were recorded and depicted in the form of graphs showing the "virtual fatigue" of the examined material (Fig . 4).

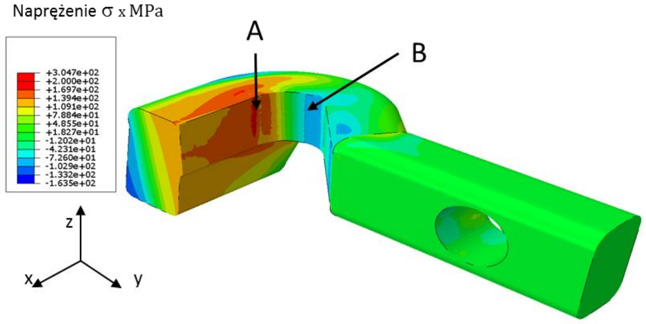

Fig. 4. Image of stresses σ_x in the lock model induced by impact force of the chain; A - the area of occurrence of the largest tensile stresses σ_x possibly causing cracks, B - the area of contact with the chain link, where compressive stresses coloured in blue are visible

4. Conclusions

The methodology proposed in this article, combining experiments with numerical calculations, allows us to estimate the fatigue life using maximum allowable strain determined for the aximum number of cycles corresponding to a fatigue limit and deformation as a function of the predetermined number of cycles operating in a high and low range of values. The values determined experimentally are compared with the values of the deformation calculated numerically for the most loaded areas of the examined structural element. In the case under discussion, in the tensor of the state of strain, only one component was dominant, and therefore the determination of equilibrium strain was relatively easy - simply the value of this component was adopted. Considering the fact that the crack initiation usually occurs on the surface of the element, the above case of the determination of equivalent strain will occur quite frequently, but when the shape of the structure is more complex, appropriate deformation criteria will be necessary. If numerical calculations are carried out to determine the value of the equivalent strain for vastly different loading ranges of the structural element, the LCF experimental studies should be conducted for several ranges of the deformation, to properly define the material properties in a calculation model.

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