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ABSTRACT of PhD THESIS

"Numeric enhanced method for fatigue life prognosis witch takes account for residual stress gradient."

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The object of this doctoral dissertation was to determine the effect of residual stresses on fatigue life. To achieve this goal, a number of numerical analyses and fatigue tests was performed.

From number of sources that may lead to the formation of residual stresses in structure, heat treatment was selected, precisely induction quenching. For steel subjected to this process, residual stresses are formed due to the occurrence of martensitic transformation. To carry out the process properly, the process parameters should be selected carefully to achieve transformation only near the surface layer. In such components, residual stress forms gradient below quenched faces. A characteristic feature of induction quenched components is the presence of stress gradient. The stress are compressive near the surface and tensile in the core of the sample. Sign change in the distribution of residual stresses corresponds to the end location of the martensitic transformation.

The residual stress are difficult to measure precisely with laboratory methods. The task is difficult in the region of notches and none of the methods available allow to measure the stress distribution in total volume of the sample. For this reason, a numerical method was applied for physical modeling of the quenching process. As such the finite element method FEA have been used.

Quenching simulation have been developed for the analysis of 2D planar models. The results obtained from the analysis and the laboratory measurements were compared with good agreement. Then, a series of three-dimensional simulation using previously tested method was done. In 3D models, residual stresses were comparable to 2D models in regions corresponding to the assumption of plane strain. A dimensionless parameter, that describes the compressive residual stress with respect to quenched layer and specimen thickness was presented.

In the next stage, the two-dimensional and three-dimensional models have been loaded. The load caused high bending stress in the specimen cross section. Due to series of load reversals a redistribution of stresses was observed. Consequently, the surface compressive residual stresses have reduced, and the stress distribution within the cross section changed.

For the 42CrMo4 steel the fatigue properties have been obtained by performing fatigue tests in designed vibration fatigue tests. The novel principle of test system operation is in force control technology. The beam specimen, mounted on a vibration rig, is being cyclically accelerated in its resonance frequency. This causes a significant displacement amplification of the beam free end. The displacement amplitude of during the test is maintained at a constant level. This also ensures constant stress amplitude. The test is automatically terminated at the time of the fatigue damage. Symptom of the damage formation is change in the bending stiffness, and what is its consequence, the change in the resonance frequency. Overall, nine fatigue test have been carried out to adjust fatigue model.

Obtained test results were compared with those reported in scientific journals. A critical discussion have been performed on the methods used to surface finish and sample shape.

Consequently, the reasons were stated for the resulting difference in the obtained results from the other authors.

Stress state from quenching simulation and bending was used to determine parameters of the fatigue cycle. Prediction of fatigue limit distribution in hardened components was done on the basis of stress amplitude and the mean stress. The prediction procedure utilized Goodman transformation and new empirical formula. The results were compared with the fatigue limit shift observed by other researchers, and the similarity was indicated.

In this paper author, set itself the goal use of a combination of innovative methods of numerical analysis and practical knowledge. The study proved staked thesis and develpoed numerical method for predicting structural durability with residual stresses which are resulting from the manufacturing of/and heat treatment.