Doc. Ing. Pavel Hutař, Ph.D.
Institute of Physics of Materials CAS, v. v. i.
Žižkova 22, 616 00 Brno

Review of Ing. Maxim Lutovinov Doctoral Thesis:

Approximate methods for calculating notch tip strains and stresses under multiaxial cyclic loading

This doctoral thesis was prepared during the research conducted by the author under the supervision of prof. Ing. Milan Růžička, CSc. and Ing. Jan Papuga, Ph.D. Presented work is focused on the approximate methods for calculating elastic-plastic stresses and strains on the surface of notched samples under multiaxial loading conditions. Author developed a methodology to combine notch correction with plasticity model. To validate the model predictions, original experiments were conducted using 2124 aluminium alloy.

State of the art – The aim of the presented work was to extend methodologies available in the literature, as well as scarce experimental results in this area. Thus, it can be stated that the work is up-to-date and brings new results useful for rapid evaluation of the elastoplastic state of stress/strain based on the basic results of the elastic solution.
State of the art is described well in the chapter 2. The basic ideas of approximate methods and the models of plasticity on which these estimations are based are clearly presented here. This chapter is written legibly and shows the author's good orientation in the issues addressed.

Aims of the work – The main aim of the work is the development of a novel pseudo-curve-based approximate method for the calculation of the notch tip elastic-plastic stresses and strains under multiaxial cyclic loading conditions. Based on this aim, the following sub-tasks are defined:

- Develop a methodology to combine notch correction and plasticity model.
- Propose a new and original approximate method for calculating elastic-plastic stresses and strains under multiaxial cyclic loading conditions.
- Obtain new and original experimental data of notch tip strains to validate the developed method.

It can be concluded that all the sub-tasks as well as the main aim of the work were fulfilled. New pseudo-curve based approximate method (based on advanced plasticity model Abdel-Karim-Ohno) for calculating notch tip elastic-plastic stresses and strains under multiaxial cyclic loading conditions was developed. Experimental data obtained on 2124 aluminium alloy were used for the model validation and confirm that the presented model is competitive to others.

Methodology – The author very appropriately used the advanced plasticity model (Abdel-Karim-Ohno) to describe the elasto-plastic behaviour of the material. He created a program in the MATLAB environment, which allows to convert the elastic solution (obtained using the finite element method) to the elastoplastic solution, allowing the description of multiaxial cyclic loading. The conversion is based on the cyclic deformation curve of the material. For the verification, the author used his own multiaxial fatigue experiments, which were performed on the material 2124-T851. This shows the author's versatility, because he was able to implement the mathematical models needed in the MATLAB environment and at the same time conducted a demanding experimental program.

Contribution of doctoral thesis – Original approximate method for calculating the elastic plastic stresses and strains at the notch tip under multiaxial loading was proposed. The presented method provides competitive results compared to other methods, which is demonstrated by the publication of the results in relevant journals. This method allows fast estimation of stress and strain response of multiaxial cyclic loading based on elastic finite element solution. As also mentioned by the author, this method can be implemented in any regular finite element solver to help with the estimation of cyclic stress and strain development in critical areas of solved models.

Author's knowledge of the field – As stated in the previous text, the author has demonstrated good knowledge in the field and a broad scope of research in addressing the set goals. He mastered the mathematical procedures necessary to implement the plasticity criterion into the procedure for estimating notch tip elastic-plastic stresses and strains. Thus, he was able to successfully conduct experiments on aluminium alloy and use the DIC technique for experimental determination of stress and strain fields in the notch. He also showed a good orientation in literature in the State of the art chapter.

Formal arrangement of the dissertation – Presented work is divided into 8 main parts. The first chapter is the introduction where author briefly defines the problem and motivation. The following chapter is focused on the state of the art. In this chapter, basic ideas of approximate methods and available experimental data are presented. The overview of plasticity models follows. Based on the current state of the art the aims of the thesis are defined in Chap.3. Chap. 4. presents Abdel-Karim-Ohno model of plasticity and the iteration algorithm. I would appreciate if this chapter contained a comparison of different plasticity models and the explanation why Abdel-Karim-Ohno model was chosen. The experiments and FEM simulations are explained in Chap.5. New methodology and results verification are presented in Chap. 6. Then, outcomes and conclusions follow.
The quality of the text itself is good, language is on good level. The organization of the work reflects the proposed aims. In my opinion, a deeper discussion of each step and broader discussion of results would be beneficial for the work. Nevertheless, the work has a significant scientific quality, and its content is logically organised.

It can be concluded that author addressed the important aspects of the problem well and presented a comprehensive solution of the defined goals. That is why **I recommend presented work for a defence**.

I have the following questions for the work:

How many experimental specimens are used for one particular loading path? What is the reproducibility of the presented experimental data?

The Fig.6.2. shows the effect of the ratcheting parameter on the prediction of the experimental data. It is shown that a simple model without ratcheting has the best agreement with the experimental data. Did you find some good agreement with other materials for higher μ_i ?

What is the main advantage of your model in the comparison with models from the literature?

Brno 20.05.2022

Pavel Hutař