

Opponency review of PhD dissertation

Title: Short Crack Growth in Materials for High Temperature Applications

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a) Up-to-dateness of dissertation topics

The driving force of technical progress is the development of new and more efficient materials with improved parameters. This is valid also in power generation industry for design of the critical components of biomass-fired power plants with low emissions of greenhouse gases. Advanced high strength heat resistant austenitic alloy Sanicro 25 is suitable material for construction of supercritical boilers with higher temperature and pressure. In addition to creep and high temperature corrosion, low cycle fatigue belongs to decisive degradation processes in the critical component. During service conditions, both high and room temperature cyclic straining can result in the component failure. The focus of the submitted dissertation on fatigue crack initiation and short crack growth is very proper for these domains determine the fatigue life. Thus, it can be concluded that the topic of the dissertation is up-to-date.

b) Dissertation objectives and their accomplishment

The objectives of the dissertation are stated in section II. They include analysis of fatigue crack initiation, study of short crack growth mechanisms and evaluation of characteristic parameters which determine short crack growth kinetics. The dissertation has met the stated objectives completely.

c) Procedure applied to problem solving and the results of dissertation

Before cyclic deformation, the microstructure of material Sanicro 25 in its initial state was analysed using techniques of electron microscopy. Specimens with polished shallow notch were cyclically strained and the notch surface was monitored and recorded for later evaluation. Attention was paid to the observation of surface relief with the aim to reveal major fatigue crack initiation sites and fractions of the individual sites were evaluated. The complicated shape of persistent slip markings, particularly extrusions and intrusions and their profiles were documented in detail using FIB technique. Dislocation structure of persistent

slip bands and matrix both in the bulk and close to the surface is obtained. Mechanisms of short crack growth were investigated and individual stages of crack growth were distinguished. Fatigue crack paths (transgranular and intergranular) at ambient and high temperatures were shown. In order to characterise the kinetic of short crack growth, the plots of the crack length versus number of cycles of individual cracks were obtained. Oxides developed at grain boundaries at high temperature were analysed.

d) Importance for practice and development of the scientific discipline

The submitted dissertation contributes to understanding of low cycle fatigue degradation mechanisms of prospective high temperature material. Particularly, fatigue crack initiation sites and short crack growth rates with possibility of residual fatigue life prediction are of great importance for practice.

Nice micrographs of dislocation structures in the matrix and in persistent slip bands corresponding to complicated tiny profiles of extrusions and intrusions down to the width of 10 nm add to the general knowledge of material science.

e) Formal arrangement of dissertation and its linguistic level

The dissertation 147 pages in length is divided into 8 sections with figures, diagrams and tables included in text and with 205 references. After Introduction and Aims of the work, section III shows Current state of the knowledge with basic characteristics of low cycle fatigue followed by description of models of surface relief evolution and extrusions and intrusions formations, fatigue initiation and mechanisms and kinetics of short crack growth using literature data. Experimental details are described in section IV. Section V presents acquired experimental results that are discussed in section VI. Section VII includes main conclusions of the dissertation. The work is accompanied with number of high quality images. Text of the work is clear and lucid with minimum typing errors. E.g. the word “vortex” is used instead of “vertex” in several places. References are placed frequently after the full stop of a sentence. E.g. “...to the loading axis. [2]” instead of “...to the loading axis [2].”

f) Subjects to discussion, questions and critical comments

- Page 53. End of the second paragraph. Can you explain: “The specimen was kept in tension (at zero strain) to ensure open cracks...”?
- Page 53. Middle of the third paragraph. “...thermocouple monitoring the temperature in the middle of the gage length.” Can you specify the experimental arrangement?
- Page 63. Middle of the second paragraph. Can you explain: “It is apparent that the intrusion is composed of several small extrusions growing within the intrusion.”

- Page 75, Fig. 9.2.3 and Page 64, Fig. 9.1.3. Extrusions are comparatively thin (~ 200nm) but their profile is very ragged. What is your opinion on the formation of such ragged surface (random slip or mechanism based on point defect production and migration and mass redistribution or ...)?
- Page 79, the first paragraph. Marking of slip systems should be amended.
- Did you observe crack initiation at GB without assistance of PSMs?
- Did you observe persistent slip markings at 700 °C?
- Page 73, Fig. 9.2.1. "... marked by triangle" should be replaced by "... marked by rectangle".
- Page 68, Fig. 9.1.8. Lettering is too small to read.

g) Brief statement of the thesis of dissertation

The structure of thesis corresponds to requirements. Thesis briefly describes the content, objectives, main results and conclusions of the dissertation.

h) Conclusion

The submitted dissertation meets the requirements set on PhD dissertations. The stated objectives were met completely. The PhD student performed complex experiments and observations, obtained original research results, made their analysis and critical evaluation and showed the ability for creative scientific work. Therefore, after the successful defence I recommend the award of PhD academic degree to Ing. Veronice Mazánové.

21 November, 2019.



Doc. RNDr. Karel Obrtlík, CSc.