inspire centre for
mechanical integrity

Inspire AG is a technology transfer organisation with strong links to ETH Zürich. The **Inspire Centre for Mechanical Integrity (ICMI)** was established at the beginning of 2012 and aims to develop and provide mechanical integrity solutions for a wide range of applications in a way which is underpinned by fundamental research. ICMI operates in a close collaboration with the High Temperature Integrity Group (HTIG) of EMPA (Dübendorf). It currently offers a PhD position on:

Physical-microstructurally based modelling of primary creep persistency

Project Description

The project aims to gain a fundamental understanding of the physics of high temperature viscoplastic deformation under cyclic stress conditions based on comprehensive high temperature mechanical testing and advanced microstructural analyses (e.g. TEM, SEM-ECCI/EBSD and neutron diffraction). The gained knowledge will then be employed to develop physically-based constitutive model equations for describing the evolution of microstructural features (e.g. densities of different types of dislocations) and mechanical behaviour of the materials under high temperature cyclic loading conditions. The Annex gives a summary of the research proposal.

Through this PhD study, the student will gain skills and knowledge in different microstructural analysis techniques, advanced mechanical analysis, high temperature mechanical testing and physical-microstructurally based modelling of inelastic deformation.

The successful candidate of the PhD position will be awarded a PhD degree from Department of Mechanical and Process Engineering of ETH Zürich.

We are looking for an outstanding candidate with a solid background in material science and mechanical engineering with excellent academic qualifications, good communication skills and a strong self-motivation. In addition, enthusiasm and talent to engage in challenging scientific questions and the underlying mechanisms as well as in theoretical/modelling aspects are required. Experience in one or more of a) microstructural analysis techniques (e.g. TEM, SEM-ECCI/EBSD and neutron/X-ray diffraction), b) physically-based constitutive modelling (e.g. dislocation based modelling), c) high temperature mechanical testing and d) crystal plasticity modelling will be an advantage. Programming experience as well as excellent written and verbal English is required.

Please submit your application including a comprehensive CV, publication list, BSc and MSc transcripts, English language test result (if available) and a "statement of motivation" (less than 2 pages) outlining your research interests and motivation in particular in relation to the current PhD position to Dr. Ehsan Hosseini (hosseini@inspire.ethz.ch).

Annex: Research Proposal Summary

With the emergence of renewable energy sources and the demand for greater efficiency and lower carbon gas emissions, there is an increasing requirement for the more flexible, higher temperature operation of conventional fossil-fired turbo-machinery. Increasingly, power plants are required to come on-line very quickly, and for relatively short periods when there is no wind or sun to provide renewable energy. As a consequence of this form of operation, high cyclic stresses of yield point magnitude are generated at critical locations in high temperature power plant components during start-up, thus possibly impairing their mechanical integrity.

An important consideration in mechanical analysis of such components is the calculation of inelastic strain accumulation under cyclic stress conditions. In particular, a key question is whether to assume that viscoplastic deformation increases continuously in line with the material's primary-secondary creep profile (as if there had been no deformation reversal), or to acknowledge that creep strain accumulation restarts from the beginning of primary after each reversal (as from time (strain) equal to zero). The latter behaviour is known alternatively as primary creep persistency (PCP) or creep re-priming. The consideration of PCP has a strong influence on the calculated inelastic strain per cycle and ultimately on the estimated magnitudes of accumulated damage and predicted component lifetime. Despite the importance of this question, the governing mechanism for the regeneration of primary creep for high temperature steels has not been systematically identified and the very few studies which have considered PCP for the calculation of creep strain accumulation have employed an empirical based trigger for re-priming. What is more, depending on the deformation mechanism and loading conditions, the question may not simply be to apply PCP or not, but to what intermediate extent. A microstructurally based understanding of PCP and other associated phenomena is thus required to reliably predict the accumulation of creep strain under high temperature cyclic stress conditions.

With this research proposal, we aim to gain a fundamental understanding of the physics of high temperature rate-dependent deformation during and after stress reversals. The research work will involve comprehensive and systematic high temperature mechanical testing to generate representative metallographic samples for the evolution of microstructural state of material deformation before, during and after stress reversal. Different state of the art microscopy techniques (e.g. TEM, EBSD-SEM, ECCI and ND) will be employed to characterise the evolution of microstructural features (e.g. dislocation and subgrain structure characteristics). To gain a more general understanding, the investigation will involve the examination of two high temperature steels with very different metallurgical-mechanical characteristics, one solid-solution hardened with an austenitic (FCC) structure and one precipitate strengthened with a martensitic (BCT) structure. The gained knowledge in term of responsible mechanisms and influential parameters will then be employed to develop physically-based constitutive model equations which track the evolution of microstructural features (e.g. densities of different types of dislocations) as internal state variables. The effectiveness of the developed model will ultimately be verified based on the results of a set of independent benchmark tests.

The research will be supervised by Dr. Hosseini (ICMI) and Dr. Holdsworth (ICMI, EMPA) and Prof. Mazza (ICMI, EMPA, ETHZ).