Karlsruher Institut für Technologie

Institut für Neutronenphysik und Reaktortechnik (INR)
Leiter: Prof. Dr.-Ing. Robert Stieglitz
Institut für Angewandte Thermofluidik (IATF) Professur:
Prof. Dr.-Ing. Robert Stieglitz

Doctoral Thesis Proposal

Topic: Development and Application of Physical Models of Accident Tolerant Fuels during a hypothetical Severe Accident in Small Modular Reactors

Start: January 2023 **Salary: 75 % of Normal position (PhD Position)**

Duration: 3 years **Institute of Neutron Physics and Reactor Technology (INR), RPD Group**

Doctoral Thesis Description

The Accident Tolerant Fuels (ATF) have been under study since years worldwide as innovative cladding, fuel, and neutron absorber materials with the potential to mitigate the consequences of hypothetical severe accident (SA) scenarios in terms of reduction of, i.e. hydrogen production by steam/clad oxidation, clad time failure, reactor pressure vessel failure. Hence, new core loadings with ATF-fuel are envisaged for both LWR Gen-III including Small Modular Reactors (SMRs) and for innovative Gen-IV reactors.

State-of-the-art integral codes like ASTEC, MELCOR, AC^2 do not include appropriate models to describe the oxidation, chemo-physical behaviour, etc. of ATF-fuels – currently under development and testing - during beyond design basis accidents. In view of the increased interest on ATFs, research, both experimental and analytical work is worldwide increasing to understand and predict the hydrogen generation by the oxidation of FeCrAl-Cladding under steam atmosphere. KIT is providing experimental data generated in single tests and at the QUENCH-facility to the international community in the framework of the OECD/NEA QUENCH-ATF (lead by KIT) and the IAEA CRP "Testing and Simulation for Advanced Technology and Accident Tolerant Fuels (ATF-TS)". Efforts to widen the use of such codes to innovative systems employing ATFs, like SMRs, are needed. Hence, the behaviour of innovative cladding (Cr-coated, FeCrAl, SiC) and fuel (doped and high-density concepts) is important. In particular, physical models must be developed to predict the behaviour of ATFs in each phase of the SA scenario, from intact to full- degraded core conditions, i.e. material interaction with steam and molten fuel, clad melting, eutectic formation, molten corium behaviour and relocation, fission product transport and release.

The Doctoral proposal is focus on the development of such physical models for selected ATF cladding materials and the implementation the European reference Accident Source Term Evaluation Code (ASTEC). For this purpose, the PhD student will take profit of the strong cooperation of INR and IAM-AWP running the QUENCH-tests and the separate effect test devoted to ATF. The unique data of KIT is very valuable for the validation of physical models developed for ATF and implemented in integral severe accident codes.

It is also link to the new EU "Safety Analysis of SMR with PAssive Mitigation strategies – Severe Accident" project (SASPAM-SA) (2022-2026), where INR is leading a work package, and to the German InnoPool SMR project. The models implemented in ASTEC can be applied to analyse the behaviour of a SMR-core loaded with ATF-fuel and study the impact on the accident progression i.e. in-/ex-vessel and radiological consequences.

The Doctoral proposal, therefore, aims providing a first-of-its-kind ASTEC code version for performing reliable evaluations of the safety assessment and radiological consequences of SA scenarios in Gen-III and Gen-IV reactors loaded with innovative fuels (ATF). Furthermore, the Doctoral proposal poses solid basis of understanding for further ASTEC development developments aimed at widening the use of the code to other safety applications related to fusion and interim storage for spent fuel.

Prerequisites:

- Master in Mechanical Engineering, Nuclear Engineering, Physics, Energy Engineering or related fields of Engineering Physics
- Enjoy performing simulations related to fluid dynamics, heat transfer, chemical reactions
- Programming skills in any language e.g. FORTRAN, C, C++, Phyton, etc.
- Enjoy working within international teams and is fluent in English

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