The development of next-generation nuclear reactors requires a comprehensive understanding of strongly coupled physical phenomena across multiple scales. Modern reactor concepts demand not only high performance but also enhanced safety, efficiency, and compliance with evolving regulatory and non-proliferation requirements.

In this context, the Professorship for Applied Nuclear Technologies is looking for a

PhD student in physics or engineering (m/f/d)

Achieving these goals necessitates advanced fuel designs, innovative core configurations, and improved materials, all of which must operate reliably under extreme conditions, including high temperatures, irradiation, and complex thermo-mechanical loading. As a result, reactor design has become an inherently multiphysics and multiscale challenge, involving the tight interaction of neutronics, thermal-hydraulics, and structural mechanics.

A key difficulty in this context is the accurate prediction of irradiation-induced material behavior, such as swelling, creep, and oxide layer growth, and its impact on thermal-hydraulic performance and overall system response. While high-fidelity models exist for individual physical domains, there remains a significant gap in the development of consistent, coupled simulation frameworks that integrate these effects from the material scale up to full reactor system behavior, particularly under transient and accidental conditions.

At the Technical University of Munich, research focuses on the development of integrated multiphysics modelling approaches to support advanced reactor design and safety analysis. This includes the coupling of detailed numerical simulations with reduced-order models to enable predictive, efficient, and scalable analysis tools.

Research Objectives:

The objective of this PhD is to develop a fully coupled, multiscale and multiphysics simulation framework for irradiated fuel elements, enabling the analysis of both nominal operation and accidental scenarios.
A central goal is to bridge the gap between detailed physics models and system-level safety analysis through consistent coupling strategies.

Scope of Work:

The research builds on existing modelling capabilities and extends them into an integrated framework consisting of three main components:

1. Development of a 1D System Code
   A key original contribution of this PhD is the development of a dedicated 1D system code, including:
   a. Governing equations for mass, momentum, and energy conservation
   b. Implementation of transient and accident scenarios
   c. Reduced-order modelling of fuel element behavior
   d. Coupling interfaces to CFD and structural models
   e. Verification and validation of the developed code

2. Development and extension of finite element models (ANSYS Mechanical):
   a. Irradiation-induced swelling
   b. Creep and stress evolution
   c. Oxide layer growth and its thermo-mechanical impact
   d. Temperature- and irradiation-dependent material properties
   e. Validation against benchmark and experimental data

3. CFD Simulation of Fuel Element Behavior
   Extension of existing CFD models to include evolving geometry and material effects:

   a. Conjugate heat transfer between fuel, cladding, oxide, and coolant
   b. Influence of swelling and oxide growth on flow channels
   c. Pressure drop and temperature distribution
   d. Analysis of:
      i. Nominal operating conditions
      ii. Accidental scenarios (e.g., loss of flow, power transients)

Coupling and Multiscale Integration

A major research focus will be on:

a. Coupling strategies between:
    i. Structural mechanics ↔ CFD
    ii. CFD ↔ system code
b. Data transfer and reduced-order modelling approaches
c. Stability, robustness, and computational efficiency
d. Consistency across spatial and temporal scales

Expected Scientific Contributions

a. Development of a novel, integrated multiphysics simulation framework
b. Original contribution through the implementation of a new system code
c. Improved understanding of irradiation effects on fuel performance
d. Quantification of safety-relevant phenomena under accidental conditions
e. Publications in peer-reviewed journals and conference contributions

Candidate Profile

a. Master's degree in computer science, mechanical engineering, physics or nuclear engineering
b. Solid software development skills (Python, C++, or similar)
c. Strong background in computational mechanics and/or CFD
d. Experience with simulation tools (e.g., ANSYS, OpenFOAM) is advantageous
e. Interest in complex, interdisciplinary and multiscale problems
f. Very good English communication skills

Please submit your CV, academic transcripts, and a brief statement of research interests.
For questions regarding the project, please contact thesis.ant@ed.tum.de