# PhD Studentships in Nuclear Structural Integrity

The Solid Mechanics Research Group (SMRG), based in the Department of Mechanical Engineering at University of Bristol (UoB), has PhD positions available in the field of structural integrity for nuclear industry applications. These studentships provide an excellent opportunity to carry out research in close collaboration with industry supporting the low carbon energy sector in the UK.

The SMRG has a long-term research partnership with EDF Energy, who are responsible for operating the UK's Advanced Gas-cooled Reactor (AGR) nuclear power plants. This focuses on the behaviour of nuclear plant operating at high temperatures and has recently been extended for another 5 years, resulting in these new studentships becoming available. A related stream of research with UK Atomic Energy Authority (UKAEA) at Culham Centre for Fusion Energy has broadened SMRG's structural integrity activities to include nuclear fusion.

You will join a highly dynamic and well-resourced research group; you will receive excellent support for technical training and personal development and, should you want them, there are many opportunities for STEM outreach and public engagement. SMRG currently has nine academic staff and approximately twenty researchers (postdoctoral staff and research students). The group has substantial laboratory capabilities at Bristol, including the support of two full-time technicians. SMRG is also a regular user of international and UK central multi-user facilities such as Diamond Light Source and ISIS Neutron and Muon Source.

These PhD studentships offer an excellent platform for future career opportunities; many SMRG alumni have gone on to work in significant roles in academia and industry spanning a range of industrial sectors. SMRG is a key contributor to the UoB-led South West Nuclear Hub, which is gathering momentum in bringing about a step change in nuclear research, innovation and teaching activities across the wider south west region of the UK. This is an exciting time to be involved in nuclear industry-related activities at UoB and the structural integrity theme.

The positions are open to candidates with a 1st or 2:1 first degree (and/or Masters) in Engineering, Materials Science, Physical Sciences or Mathematics. Experimental and theoretical modelling projects are available; there is sufficient flexibility in the research programme so that candidates can shape research projects in line with their own interests in consultation with their supervisors.

The proposed topics include:

## 1. Multi-axial Creep

Large plant components such as thick-walled boiler headers which operate for long timescales at high temperature are susceptible to creep deformation. The creep behaviour of materials under a simple uniaxial stress states is relatively well characterised, but the effects of multi-axial stress stages which exist in thick components is not understood in sufficient detail and it is often these very components which suffer from accelerated damage. Most service components endure complex loading (e.g. thermal transients) thus understanding the creep behaviour of materials under fluctuating multi-axial loading is a critical subject which will be explored in this project.

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This is a joint PhD project between EDF Energy and UKAEA. The project will involve using digital image correlation (DIC) to characterise multi-axial creep deformation and finite element simulation to interpret the experimental data; and carrying out neutron and synchrotron experiments working alongside experienced SMRG postdoctoral researchers. The research will also involve correlating results against modelling activities

## 2. Creep Damage

Micromechanical analysis and characterisation can help identify the mechanisms by which creep damage propagates, and to help inform and refine structural integrity engineering assessments. The focus of this project will be microstructural analysis of structural materials used in nuclear plants, including ferritic and austenitic stainless steels, identifying the key aspects of the microstructure in which damage evolves and how it is influence by stress/strain.

The work will include the use of state-of-the-art characterisation equipment such as scanning electron microscopy, laboratory and synchrotron X-ray tomography and electron back-scatter diffraction.

## 3. Plasticity

Creep damage is one of the main limiting factors in the design life of a thermal plant. The damage accumulates over decades; researching creep in experimental work over reasonable timescales therefore requires its pace to be increased.

Often creep is modified by other deformation processes of time-independent plasticity and this is also thought to influence damage evolution. Decomposition of creep damage from other damage processes in high stress creep tests, which incorporate a level of plasticity, is the focus of this project.

The project will include extensive use of high temperature laboratory facilities at UoB and close interaction with EDF Energy technical experts based at Barnwood, near Gloucester.

## 4. Weldments

Welded joints can be susceptible to creep damage due to the metallurgical and mechanical mismatch between weld fusion zone and parent material. Weldments often have complex microstructures and possible residual stress fields, with research required to help support structural integrity assessments. The focus of this project is to quantify the contribution of the weld-parent mismatch on creep behaviour.

The work will involve the use of high temperature laboratory equipment at UoB and microstructural analysis, along with DIC and finite element analysis.

## 5. Probabilistic Modelling

The majority of damage mechanisms in nuclear plants are highly sensitive to material properties and service conditions. Structural integrity assessments have typically employed deterministic analysis to consider lower bound conservative conditions. However, recent trends towards probabilistic assessments have proven promising in providing a more robust and representative approach to underpinning safe, cost effective design and operations. This project aims to include service loading and material properties in an integrity analysis through a probabilistic approach.

This project is supported by EDF Energy and Atkins. The work will include extensive use of finite element simulations and would be particularly well suited to a candidate with a background in mathematics and statistics.

## 6. Fracture of Thin-walled Components

Failure characteristics of thick-walled austenitic steel structures containing crack-life defects have been well established. It is well known that thin-walled structures exhibit higher toughness and hence are more defect tolerant; however, this is not exploited in assessing the integrity of non-safety critical, high integrity components. Many of these items are still central to reliable operation of plant; nonetheless a substantial reduction in the conservatism associated with assessment of their defect tolerance is sought, to avoid undue inspection, maintenance or replacement.

The aim of this research is to characterise fracture of thin section components and link this to critical defect sizes in components such as tubes and insulation present in Advanced Gas-cooled Reactors (AGRs) operated by EDF Energy.

This is a project supported by the Engineering and Physical Sciences Research Council (EPSRC) by an Industrial CASE award to EDF Energy. The project is expected to exploit advanced and novel experimental techniques such as integrated DIC-FE modelling to unravel the characteristic strain fields ahead of defects.

## Further Information

For further information, please contact Professor David Knowles (Head of SMRG; david.knowles@bristol.ac.uk) or Dr Mahmoud Mostafavi (Reader in Structural Integrity; m.mostafavi@bristol.ac.uk).

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Further postgraduate study information and application details online via:

http://www.bristol.ac.uk/engineering/postgraduate/

http://www.bristol.ac.uk/study/postgraduate/

SMRG: http://www.bristol.ac.uk/engineering/research/solids/

Nuclear industry-related activities at UoB: https://southwestnuclearhub.ac.uk/