PAUL SCHERRER INSTITUT

Technology Transfer **R&D Services**

Investigation of highly radioactive nuclear fuels, components and other materials

Testing of radioactive samples

Introduction

Engineering components exposed to a radioactive environment or an irradiation field may become contaminated or activated, and radiation exposure may induce deterioration of their original mechanical properties. Lifetime prognosis of such engineering parts is essential and of increasing importance for the operational safety of nuclear plants and research facilities.

Due to their inherent radioactivity, these materials can not be tested with standard laboratory equipment. For the operator's safety, these experiments need to be performed using both appropriate handling procedures and radiation shielding.

Applications

Such components and materials are of particular concern in specific industrial sectors such as in nuclear medicine, nuclear power plants, research institutes or advanced large-scale accelerator units. These facilities have a vital interest in reliable operation and safety considerations.

The scope of PSI's materials analysis and validation encompasses, for instance, diverse metallic parts, metal components, fuel rods, cladding materials, tubes, valves, electrical insulation components, polymers, and adhesives joints.

Selected examples of the PSI facilities

Manipulators allow the remote handling of active samples and tools inside a shielded box (Fig. 1). The testing machine permits loads up to 30 kN and temperatures up to 750 °C, in various gaseous atmospheres, to be applied. Testing can be optically recorded by means of a long-distance microscope.

Typical subjects of studies are:

- Investigation of irradiation-induced embrittlement of adhesives and loss of adhesivity (see Fig. 2).
- Diffusion processes in hydrogen-charged nuclear fuel rod cladding.
- Thermo-mechanical loading of fuel rod cladding and its impact on the mechanical properties.

Figure 1: **Integration of a universal testing machine in a completely shielded α-radiation-proof box.**

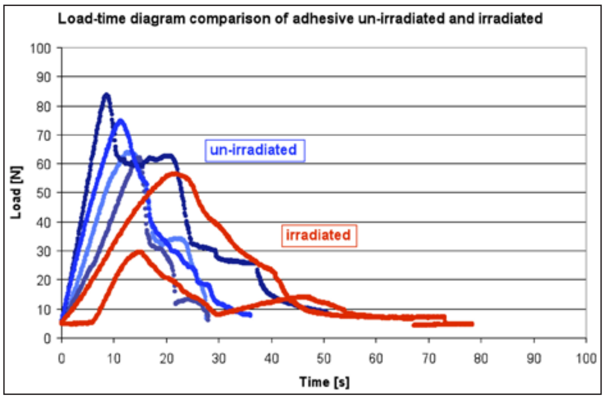

Figure 2: **Comparison of unirradiated and irradiated adhesive bonds.**

Often, mechanical testing is backed up by stress/strain calculations for the tested part, to obtain a full picture of the materials behaviour. Finite Element Method (FEM) simulation helps to synchronize the acquired experimental data through testing (Fig. 3).

Hydrogen loading of materials

A furnace and gas chamber allow hydrogen loading at high temperatures. The ingress may be intentional, for materials as used in energy production, or detrimental for nuclear fuel cladding in power stations, for instance.

Micro-scale sample preparation and TEM

With the help of the Focused Ion Beam (FIB) equipment, very tiny sample slices can be produced. This is particularly of interest in the case of highly precise sample positioning.

The oxide can be seen on the left-hand side of Fig. 4, with a lighter contrast and few micro-cracks. The cut samples can be further processed to be used for investigations with synchrotron radiation or in a Transmission Electron Microscope (TEM), revealing features even at a sub-nanometre level.

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X-ray Absorption Spectroscopy and X-ray Diffraction

PSI operates a synchrotron radiation facility, the Swiss light Source, SLS. The Hotlab (AHL) together with the Laboratory for Nuclear Materials (LNM) provide the know-how for analyzing radioactive sample material at the SLS. X-ray Absorption Spectroscopy, XAS (e.g. EXAFS, XANES), and X-ray diffraction, XRD, allow sophisticated structural analysis to be performed.

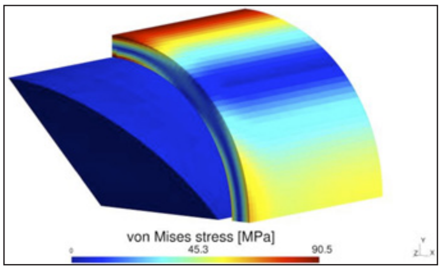

Figure 3: **Example of the stress distribution obtained through FEM.**

Figure 4: **Intersection of a sample at the interface of a zirconium alloy and its oxide (width 20 µm).**

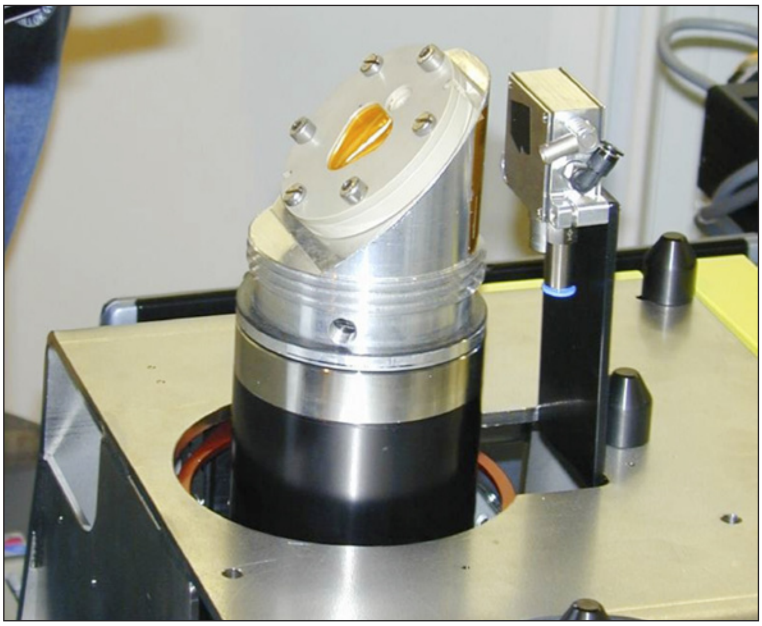

Figure 5: **Specimen holder for radioactive samples to be investigated at the Swiss Light Source, SLS.**

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