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FRM II: EXTENSION OF CORE COMPONENT LIFETIME BY APPLICATION OF FRACTURE MECHANICS

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The FRM II is Germany's most modern research reactor. It became critical for the first time on March 2nd, 2004. Since routine operation started in May 2005, it has just completed its first ten years of operation. The FRM II is a multi-purpose reactor and operates at nominal power of 20 MW. It is light water cooled and heavy water moderated. It is used predominantly for neutron scattering experiments in a wide range of applications from fundamental physics to material and life sciences but also runs a prompt gamma neutron activation analysis facility, a tomography beam line, a positron source and a medical irradiation facility. Important fields of activity include also isotope production and Silicon doping.
Most of the core components of the FRM II are made from Aluminium (EN AW-5754, AlMg3). This material undergoes embrittlement under neutron irradiation, mainly by Silicon formation in the Aluminium by capture of thermal neutrons. Since only few data on highly irradiated Aluminium are available worldwide the FRM II runs its own irradiation programme. This is also a requirement of the licensing procedure. Based on the concept of tensile strength samples of the same Aluminium are irradiated during the operation. After accumulation of certain neutron fluences the samples are removed and the remaining tensile stress as well as fracture mechanics parameters are determined. The concept of using tensile stress is the only one accepted for the FRM II so far. Although it is a well-established procedure, it is in the case of the FRM II core components very conservative and not necessarily in line with the latest knowledge in science and technology. Consequently, it may lead to the requirement of exchange of some components before they reach their true end of lifetime. This, in turn, unnecessarily reduces the availability of the FRM II due to additional maintenance breaks and generates avoidable radiation dose for the personnel. Therefore together with external fracture mechanics experts, the expert organization and the licensing authorities a different concept has been developed: The proof of sufficient stability shall now be performed using fracture mechanics. To this end, detailed calculations on the mechanical stress on the affected components have been carried out. These components are mainly the central channel that houses the fuel element, the moderator tank itself, the beam tubes as far as they are located in high neutron flux areas and other components made form Aluminium that reach into the moderator tank and into areas with high neutron flux. Maximum undetected fracture size and fracture growth have been assumed in application of the relevant codes. Detailed neutron fluence calculations have been carried out and parameters on the material properties after irradiation in the light of fracture mechanics were deduced from the samples irradiated at the FRM II. Finally all these results were put together leading to a detailed picture of required material properties –as necessary for safe operation –and existing material properties –after a certain irradiation was accumulated –which lead to a prediction of the remaining lifetime of the core components made from Aluminium.
Although the final result has not been approved in every detail by the licensing authority already now a premature exchange of some components could be avoided. The complete new concept for the lifetime of core components made from Aluminium, based on analyses of irradiated samples, fracture mechanics and detailed fluence calculations will be available soon.

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