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TOPIC 2

MECHANICS

2.2.1 In-vessel components and fluid-structure interactions

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Significant nuclear fuel assembly and in-vessel components design innovations are regularly incorporated to meet the highest expectations in terms of safety, performance and flexibility. Despite the continuous upgrades of fuel designs and materials, the fuel failure rate has not markedly decreased during the last decade, partly because of higher burn-up, longer cycle lengths, mixed cores... also, time constant to improve a component design is long and validation of corrective action is often seen years later and in-reactor feedback is an a posteriori indicator.

The data collected worldwide show that fuel assembly damages, that did not always result in breach of the fuel cladding, cause significant problems for plant operators. Similar in-reactor problems affect the most part of designs simultaneously. These damages have different root causes but fluid-structure interaction is almost always the source of these difficulties. The grid-to-rod fretting is the dominant fuel rod leaker mechanism worldwide. Fuel assembly bow can seriously affect plant operations too, with its consequences on incomplete control rod insertion and spacer grid damage during loading or off-loading. This concern is of similar importance today as fuel failures. Control rod guide wear is also a hot topic.

How to be sure the fuel and components are reliable, robust and high performance? Research, development and qualification programs are a major concern for industrials. Fuel design innovation is mainly based on intensive out of pile hydromechanics research and development programs and qualification testing. The aim of these programs is to reproduce the hydromechanical phenomena, understanding the root causes, and finally improve and qualify the new designs. Tests on full scale or reduced scale fuel assemblies mock-ups are performed in different experimental facilities.

One way to anticipate is also simulation. To address the different fuel failures, we need accurate predictions of fuel rod vibration and wear under turbulent fluid excitation, of fuel assembly buckling, of induced hydrodynamic forces... Then we have to develop appropriate models and benchmark them with tests results. It’s a complex composite combining thermal-hydraulic, mechanics, neutronics,… Computational Fluid Dynamics simulations of the reactor cores and of the facilities are performed. Modelling fluid-structure interactions is a major challenge.

The improvement of these methodologies is an ongoing process, made possible thanks to extensive research and development programs dedicated to the study of the fuel assembly hydrodynamics and material behaviour.

We will present different approaches to problems of in-vessel components.

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