Fuel Rod Behaviour und Accident Condition Analyses with TESPA-ROD

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The ongoing efforts of the fuel rod vendors to improve the performance of the fuel rods for the normal operation resulted in excellent safety records for these fuel rods. Corrosion, fuel element bowing, PCI failures and fretting have lost their importance for the normal operation. This has been obtained with different techniques, among them the modification of the cladding alloying elements. The most important modification is the addition of 1% niobium to the cladding alloy. The advantage of this modification for normal operation is evident but it also might influence the fuel rod behaviour under accident condition. The prediction of this behaviour under accident condition requires predictive models which take into account these modifications.

> The Fuel Rod Code TESPA-ROD

The code TESPA-ROD has been developed to predict the fuel rod behaviour under accident conditions. High burn-up effects as well as effects of the alloying elements in the cladding on the fuel rod behaviour under accident condition are addressed.

Burn-up dependent heat conduction, swelling, densification, relocation and fission gas release are treated in an empirical way. The effects of a hydrogen up-take into the cladding on the high temperature strain are considered. Different claddings Zry-4, M5 (FANP), Zirlo (Westinghouse), DUPLEX (Siemens) and E110 (WWER) are distinguished. TESPA-ROD can be used to analyse the behaviour of a variety of fuel materials from UO2 fuel, MOX fuel to Gadolinium containing fuel. An optional model is available which treats the crystal phase transition from α to β phase state of the cladding in a dynamic way. The stress analysis of the cladding has been extended in order to take into account the elastic and plastic deformation of the cladding. Therefore, the loading of the cladding due to the pellet/cladding interaction can be considered by this deformation model in a consistent way. This deformation model widens the analysis spectrum towards RIA transients.

> The Effect of Hydrogen on Strain and Burst of the Fuel Rod Cladding

The hydrogen up-take in the fuel rod cladding during normal operation modifies the properties of the cladding. Tests in the EDGAR test facility show this effect on the high temperature creep behaviour of the cladding alloy M5. For comparison the strain and burst prediction of TESPA-ROD is shown.

The test procedure starts with heating the fuel rod cladding to a certain high temperature level. When the predefined temperature level is reached the fuel rod is pressurized to a certain pressure level. Under these loadings the fuel rod cladding starts to creep. As a result the cladding thickness decreases and finally bursts. The time period from the beginning of the loading to the burst is measured and plotted in fig. 1.

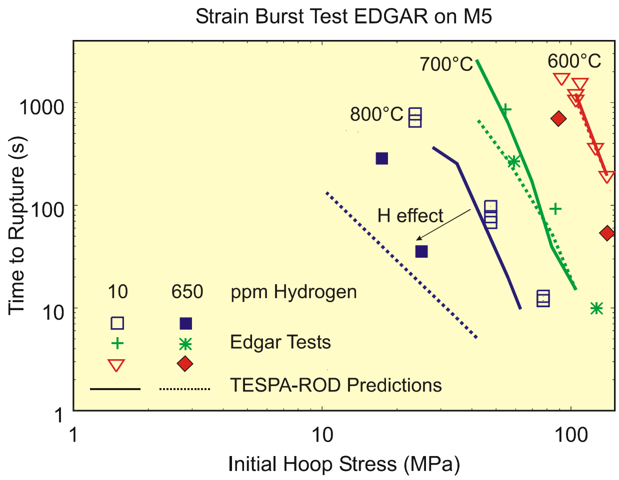

Fig. 1: Hydrogen effect in the M5 cladding (alloy containing 1% niobium) on the strain and burst behaviour and the TESPA-ROD prediction

The comparison demonstrates the ability of TESPA-ROD to predict the effect of hydrogen on the strain and burst behaviour of a M5 cladding.

> Applicability to core analysis under time constrains

The degree of sophistication of the code TESPA-ROD is kept on such a level, that on one side all the relevant effects like hydrogen effect are present and on the other side the calculation time is still low enough to allow a complete core analysis with about 50000 rods to be run within a few hours on a conventional PC.

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