ANALYSIS OF FUEL/CLAD MECHANICAL INTERACTION IN NON-STEADY REACTOR OPERATION VIA FUEL ROD MODELLING CODE IAMBUS

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SUMMARY

Excessive stresses and strains in a fuel rod cladding may be caused by fuel/clad mechanical interaction, i.e. contact pressure between fuel and cladding and axial forces due to fuel/clad friction. The magnitude of these stresses, depending on fuel rod characteristics, operating conditions, power-history, and burn-up, is determined by the relative mechanical strength of fuel and cladding. Although, there are no serious consequences expected in steady reactor operation, the situation in non-steady operation becomes increasingly acute.

The growing interest in this field is reflected by an increasing number of irradiation experiments, especially performed with LWR fuel rods, concerning the investigation of fuel rod behaviour under non-steady operating conditions.

Two typical cases of reactor power changes have to be distinguished:

— power cycling, i.e. periodical change of reactor power between low and high power levels during short periods,

— power ramping, i.e. periodical escalation to power levels not recently attained (for instance: reactor start-up, power increase after extended periods of low power operation).

The fuel rod linear powers of the experiments being in question range from 150 to 610 W/cm and the rates of power change vary from 1 to 500 W/cm min, respectively. The maximum burn-up's achieved are 32 000 MWd/t_M for LWR fuel rods and 105 000 MWd/t_M for LMFBR pins, respectively.

On-line and post-irradiation measurements of fuel rod length changes during operation of LWR rods (experiments performed by KWU in the reactors Obrigheim, Halden and Petten) as well as post-irradiation examination results of differential fuel column length changes in connection with diametral cladding deformations of LMFBR pins (irradiation experiment RAPSODIE I within DEBENELUX-R+D-program) can be reproduced by calculations using the fuel rod modelling code IAMBUS. In addition to models proved successfully up to now, a new model describing the dependence of the compressibility of cracked fuel on fuel/clad contact pressure was accomplished.

As compared to some selected, but representative experimental data, results of IAMBUS calculations are in an overall good agreement. The code predictions support the results of post-irradiation examinations that there is no indication of excessive loadings of the cladding caused by power cycling. The evolution of fuel/clad contact pressure as a function of operating time and power history is on the average approximately represented by the behaviour obtained under steady state operating conditions.

On the other hand, power ramping leads to significant stresses in the fuel rod cladding. This may be understood as a consequence of fuel crack healing and rearrangement on a lower power level, thus offering considerable resistance against shape variations in case of rapid power escalation. Maximum stresses and strains may be exceeded under certain conditions. Thus, on the basis of predictions by the fuel rod modelling code IAMBUS, reactor operating conditions, particularly for start-up phases, are defined in order to avoid the risk of fuel rod failure.