FLUID-STRUCTURE INTERACTION ANALYSIS OF LARGE-BREAK LOSS OF COOLANT ACCIDENT

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Extended Abstract

Large-Break Loss of Coolant Accident (LBLOCA) is a design base accident of nuclear power plants, where a rapid depressurization of the reactor occurs. In a hypothetical accident, a guillotine break of a main steam line occurs near the reactor pressure vessel and a pressure transient propagates inside the pressure vessel, where it causes large loads on the reactor internals. Within first hundreds of milliseconds after the break, the pressure loads induce deformations in the structures inside the reactor pressure vessel (RPV) and threats their integrity.

The guillotine break of a cold leg near the RPV of a pressurized water reactor (PWR) is investigated. The deformations of the core barrel, structure between the downcomer and reactor, are calculated by taking into account the effect of fluid-structure interactions, i.e., the effect of the motion of the core barrel on the pressure in the downcomer and in the reactor core. The fluid-structure interactions are resolved by coupling the computational fluid dynamics (CFD) codes Star-CD and Fluent with the Abaqus finite element code, which solves the motion of the structure. The two-way coupling of the CFD and finite element codes is done by using the Mesh-based parallel Code Coupling Interface (MpCCI) middleware. The two-phase phenomena near the break location are resolved with the Apros system code, which provides the boundary condition for the CFD calculation.

The fluid-structure interaction calculations are validated by comparing the numerical results to HDR (Heissdampfreaktor) experiments performed in the early 1980's in Germany [1]. In the HDR experiments, the size of the pressure vessel was comparable to that of a PWR: the length of the core barrel was 7.6 m and its diameter was 2.7 m. The other parameters, such as pressure (110 bar), temperature (240...310 °C), the break diameter (0.2 m) and the break opening time (1 ms), had also values relevant full size reactors.

In the present work, fluid-structure interaction calculations are presented for HDR-experiments. The boundary condition calculated with the two-phase models of Apros at the break location is compared to the experimental results. The three-dimensional single-phase CFD calculation of the propagation of the pressure transient into the downcomer and reactor core are analyzed and compared to HDR results. The motion of the core barrel calculated with Abaqus is resolved and compared to measurements. In particular, the effect of fluid-structure interactions on the pressure loads on the core barrel are described and compared to experiments. The effect of the motion of the structure on the propagation speed of the pressure transient is analyzed and compared to HRD measurements. The results are also compared to calculations, where a rigid core barrel is assumed. The experiences obtained in two-way coupling of CFD and finite element codes are summarized.

1. Wolf, L., Nuclear Engineering and Design **70**, 269–308 (1982).