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Numerical and Experimental Investigations of Tube-to-Tube Interaction of Air Heat Exchangers of PFBR under Seismic Excitations

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Numerical and experimental investigations of seismic response behavior of the air heat exchanger (AHX) of prototype fast breeder reactor (PFBR) were carried out for operating basis earthquake (OBE), safe shutdown earthquake (SSE) and beyond design basis earthquake conditions. For the numerical study, a finite element model consisting of AHX header and connecting tubes were developed using general purpose finite element code CAST3M and time history analyses were performed for all the three earthquake loading conditions. To perform the analyses, spectrum compatible time histories were generated from the floor response spectrums at the support location of the AHX. Studies predicted the possibility of tube-tube interaction between the middle and outer tubes due to the presence of circumferential fines provided along the tube length. To confirm the analyses findings, shake table experiments were performed using 100 t multi axial shake table. The test set up consists of five AHX tubes along with fines arranged in triangular pitch with tube to tube spacing same as the AHX in the reactor. The tubes were supported simulating the actual supporting conditions in the reactor. To simulate the fluid effects under dynamic conditions, tubes were filled with water and pressurized up to 7 bars. Prior to the seismic studies, free vibration characteristics of the tube bundle were estimated by performing resonance search tests and compared the results with numerical predictions. The responses were captured using accelerometers, strain gauges and no contact type displacement sensors. Tube responses are assessed for OBE, SSE and beyond SSE conditions by performing the tri axial excitations as per IEEE-344 guidelines using spectrum compatible time histories and responses are captured using a 96 channel data acquisition system. Tube to tube interactions at fin locations were observed under SSE and beyond SSE conditions as evidenced from the response spikes in accelerometers and strain gauge readings and from the relative displacements measured using non contact type displacement sensors. However, the structural integrity of tube bundle is demonstrated by repeating the experiments many times for SSE and beyond SSE conditions. From these experiments it is confirmed that, the local impacts at the fin locations are not a concern for the structural integrity of AHX.

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