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Turbulence Assessment in the Main Steam Line of a Nuclear Power Plant With a BWR-5 Reactor

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Abstract : Boundary layer detachment is generated at the intersection of the main steam line (MSL) with a relief safety valve branch, causing vorticity and turbulence. Noise is generated and transmitted along the steam piping system, loading its different elements and compromising its structural integrity. A numerical analysis was carried out with the ANSYS program, using the Fluent module to perform computational fluid dynamics (CFD) simulation. The fluid behavior was simulated at a 90° intersection of a main steam pipe of a BWR-5 nuclear power plant with a safety relief valve branch. Normal operation conditions were considered (pressure = 7 MPa, temperature = 280°C, and steam velocity = 47m/s), and its turbulence was calculated. The nominal diameters of the steam line and its branch are 20 inches and 8 inches, respectively. A 3D mesh of the fluid dominium was generated using mosaic meshing technology and the watertight tool in the ANSYS fluent module. Different cell sizes were developed. Hexahedral-polyhedral elements were combined to ensure orthogonality. Some properties are transported along the flow direction. These elements are appropriate since they can be aligned with the flow direction. This allows for the solution of the conservation equations on which the Navier-Stokes equations that model turbulence are based. Initially, an analysis was performed with the RANS (Reynolds-averaged simulation of the Navier-Stokes equations) approach. Initially, steady-state simulations were performed with the K-ξ model. The turbulence kinetic energy and the dissipation rate were obtained to calculate □□= (□ □/□/□). The last parameter is the Integral length Scale. It represents the eddy average size due to RANS calculation. The average eddy size was estimated, and a suitable mesh was generated to capture the eddies in a subsequent simulation under the LES (large eddy simulation) approach. Subsequently, turbulence, velocity fluctuations, pressure, and turbulence kinetic energy were estimated to couple the results to the main steam line and its branch. Once the behavior of the fluid in the steam pipe is known, the deformations and stresses are calculated. The structural integrity was determined. This information is important to determine the safety levels when a BWR nuclear power plant is repowered.

Keywords : boundary layer, LES, integral length scale, turbulance kinetic energy
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