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Investigation of the gap vortex street in densely packed tube arrays in axial flow using CFD and experiments

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Axial flow in tube bundles with small pitch-to-diameter ratio, a geometry encountered in nuclear reactor cores and heat exchangers, often displays periodic fluctuations. A significant velocity discrepancy between the inter-cylinder gap and sub-channel center originates from the difference in through-flow area, feeding an instability. As it is associated with velocity-shear, it is similar to the Kelvin–Helmholtz type [1] and the term 'gap instability' is adopted. A vortex street arises, and structural vibration of the cylinders might develop due to the fluctuating pressure. Numerical simulations of this phenomenon were performed and comparison to experimental results was made.

The computational domain was constructed to match the most important geometrical features of the experimental setup. The bundle consists of 7 steel tubes in triangular array, placed in a hexagonal conduit. A flexible segment made of silicone is embedded in the central tube, with both extremes clamped to the steel part of the cylinder. In the experiment, data of the fluctuating velocity was gathered using laser Doppler anemometry measurements. The dominant frequencies and wavelengths associated with the coherent structures present in the domain were found with this data.

As first step, a completely rigid structure was considered. Unsteady Reynolds-averaged Navier–Stokes (URANS) simulations were used to test if this particular geometry also triggers the gap vortex street, which was the case. After a settling time of 9 seconds the phenomenon clearly appears as oscillations of the velocity components, of which the important frequencies were determined. Subsequently, fluid-structure interaction (FSI) simulations, taking into account the flexible part, allowed to assess the effect of the fluctuating flow field on the structure.

REFERENCES

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