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# Direct Numerical Simulation of Turbulent Flow and Heat Transport In a Tightly-Spaced Rod Bundle

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Direct Numerical Simulation (**DNS**) is increasingly used for generating reference databases, which are crucial for validating lower-order turbulence models. This allows more pragmatic Computational Fluid Dynamics (**CFD**) approaches, such as **RANS** and **LES**, to be improved through new correlations and refinements, enhancing their reliability in capturing turbulent flow and heat transfer phenomena.

In this study, DNS of fully developed flow and heat transfer is conducted for a bare rod bundle with a low pitch-to-diameter ratio (1.107) using the highly scalable spectral element code Nek5000. The simulation is performed at a Reynolds number ($Re_h$) of 9800, based on bulk velocity and hydraulic diameter, under both **iso-temperature** and **iso-flux** thermal boundary conditions, with **Prandtl numbers** of **0.025, 1.0,** and **2.0.**

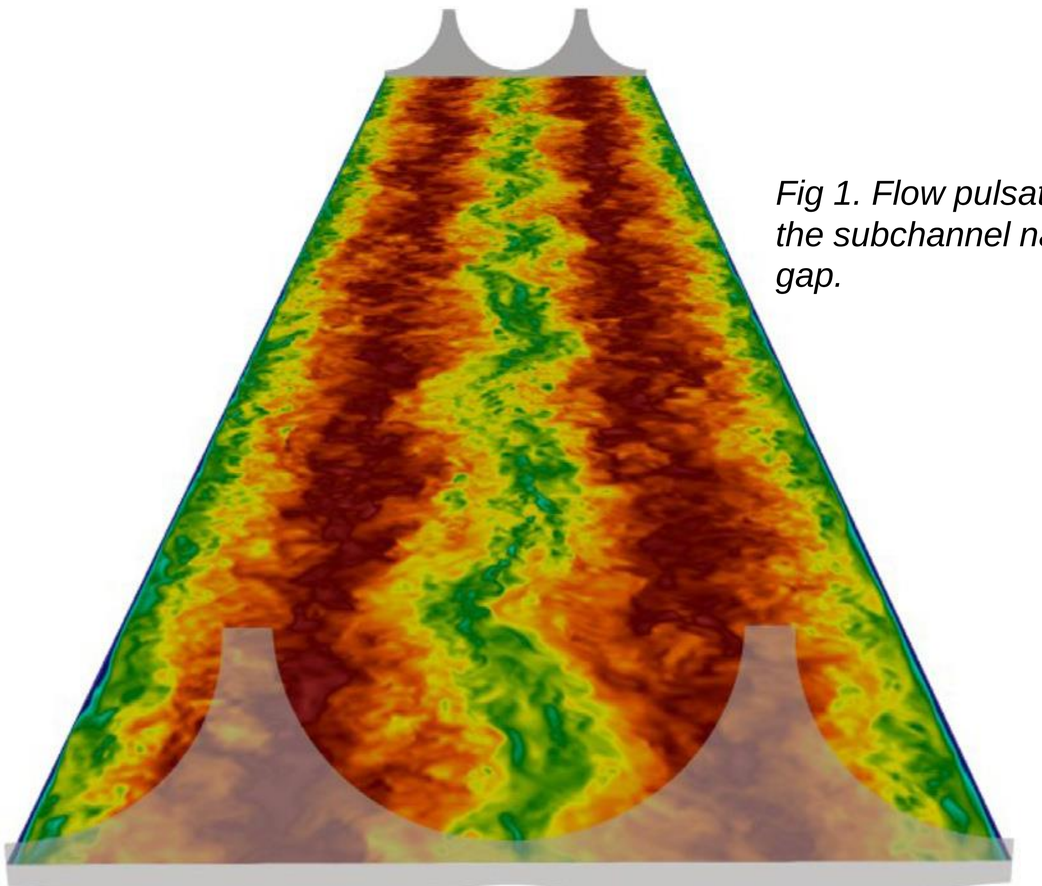

*Fig 1. Flow pulsations in the subchannel narrow gap.*

Flow through a rod bundle with a low pitch-to-diameter ratio is known to be characterised by large-scale motions, commonly indicated by the term **flow pulsations**. Fig. 1 presents the velocity magnitude contours on a horizontal cross-sectional plane in the domain for the present case. Here, the sinusoidal-like shape of the low-velocity contours along the narrow gap illustrates the pulsating motion. The characterization of these oscillations is **important for the design and optimization** of rod bundles in a nuclear fuel assembly. The frequency may be determined by calculating the power spectral density (PSD). The **PSD** of the horizontal velocity at the centre of the narrow gap is illustrated in Fig. 2. It is seen that a dominant frequency of **3.7 Hz** is captured by the peak in the spectrum.

In order to qualitatively observe the influence of **Pr**, the instantaneous snapshots of scalars with iso-temperature BC are presented in Fig. 3. It can clearly be seen that the scales of motion of temperature are different for each Pr. For the sake of differentiating between behaviour of temperature at different Pr values, scalars with **Pr = 1** and **2** are referred to as "**high Pr**" in the present research, while **Pr = 0.025** is termed "**low Pr**". At high Pr, the temperature field has much finer structures and the temperature gradients within the flow are much steeper. At such Pr values, where thermal and momentum diffusivities are strongly correlated, the scales of temperature are similar to that of velocity. At low Pr, however, the distribution becomes much smoother as a result of the higher thermal conductivity. A similar trend is also observed for the scalars with iso-flux BC.

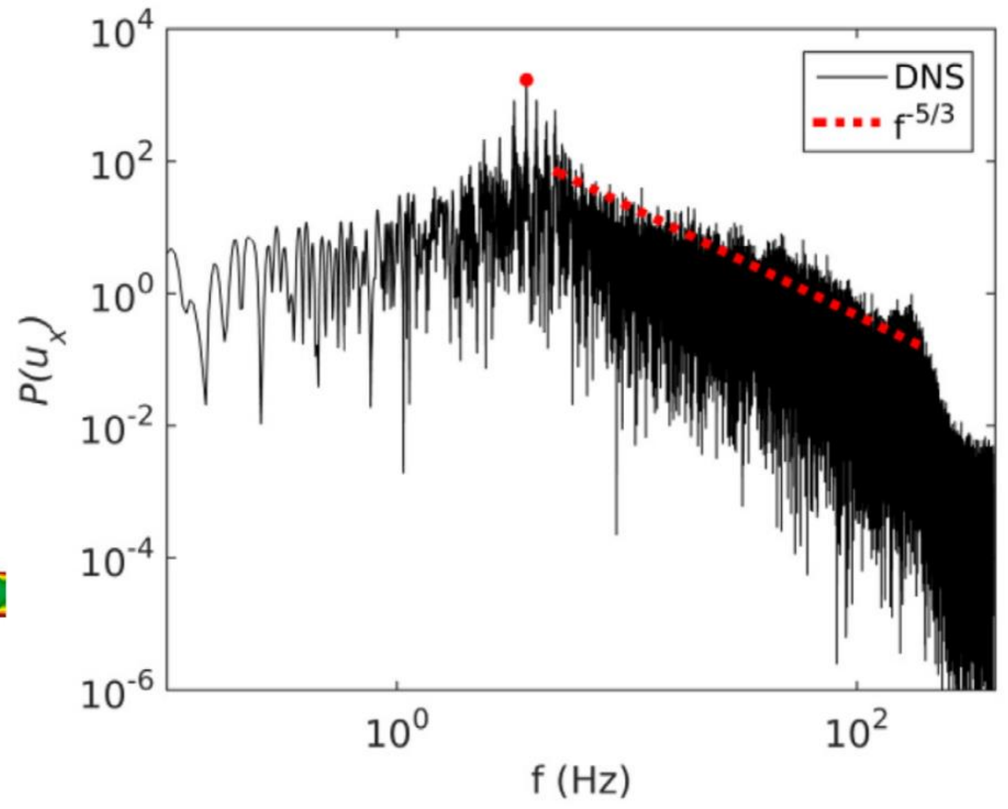


*Fig 2. Flow pulsations in the subchannel narrow gap.*

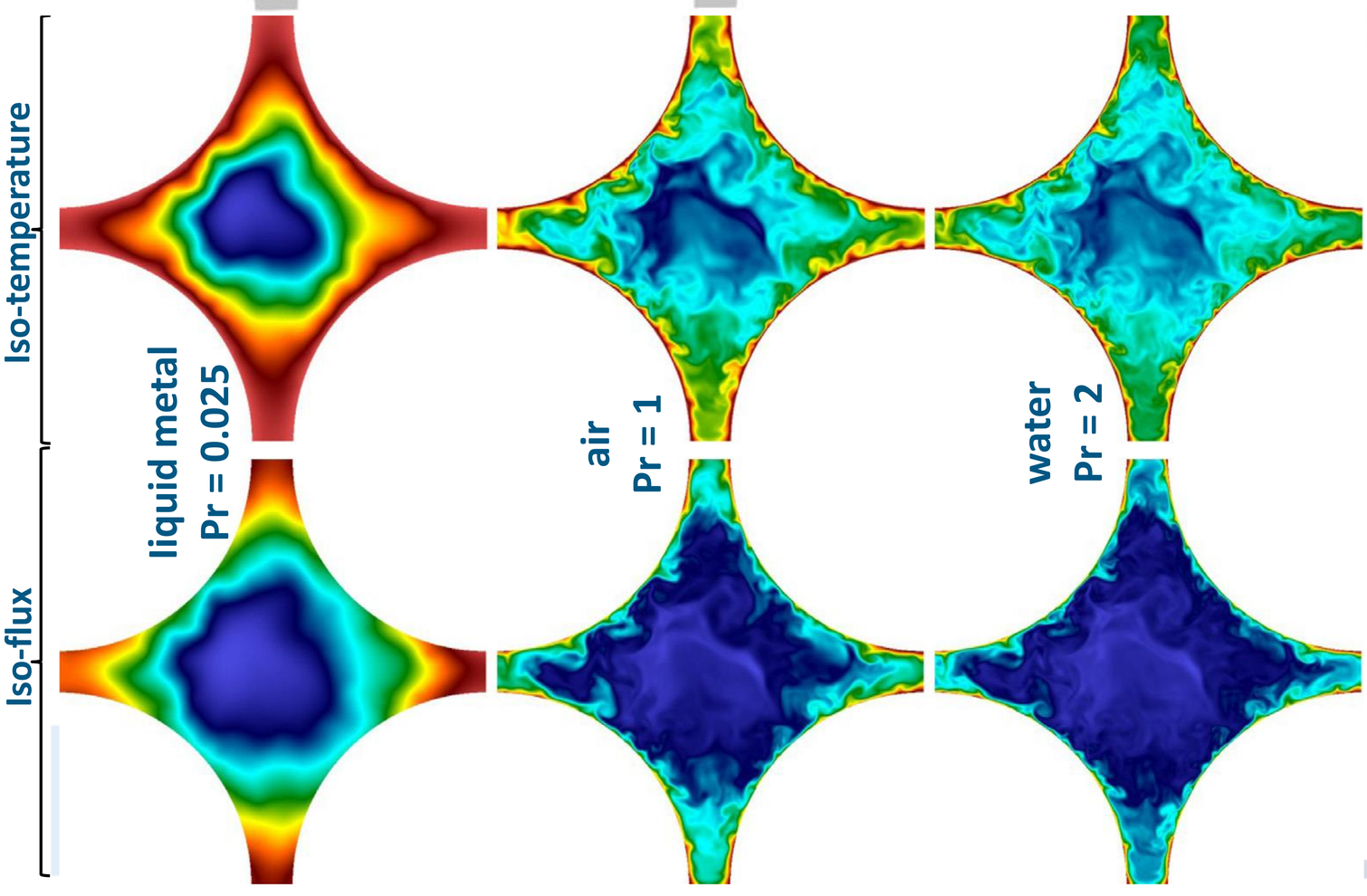


*Fig 3. Instantaneous snapshot of temperature with (top) iso-temperature BC and (bottom) iso-flux BC, each with Pr value.*

**Data will be made available on request.**

A. Mathur, T. Kwiatkowski, S. Potempski, E. Komen, Direct Numerical Simulation of flow and heat transport in a closely-spaced bare rod bundle, International Journal of Heat and Mass Transfer, 211, p. 124-226, 2023, https://doi.org/10.1016/j.ijheatmasstransfer.2023.124226