Fluid dynamics of oscillatory flow through stenosed pipes

The onset of turbulence in an ordinary pipe has remained a question of curiosity among scientists, as they seek the value of dimensionless quantity namely the Reynolds number (Re) at which a flow leaves laminar regime to step into a chaotic or turbulent one – a stage that is termed transitional. An oscillatory flow is characterized by reversal of flow in parts of the cycle. Such a flow has a zero mean as it oscillates back and forth in a conduit. When a flow oscillates or exhibits a bi-directional nature, the underlying factors that trigger turbulence are expected to differ from those of a uni-directional pulsating flow, as the mean flow in such a case is zero and the flow reverses its direction in part of the cycle[1].

Such flows have particular significance in physiology as many flows exhibit reversal in part of the cardiac cycle, and in particular the cerebrospinal fluid (CSF) which oscillates in the central nervous system. Furthermore the characteristics of turbulent flow along the cycle is important to be assessed to understand, and associate with pathological conditions. Previous studies have addressed aspects of turbulence in such stenotic flows using numerical simulations[2]. This assignment will perform experimental studies of flow dynamics in such stenosed pipes and provide novel insights into the physics of oscillatory flows.

The master thesis will specifically involve:

- Experimental studies of oscillatory flow in a pipe with 75% sinusoidal area reduction in the center.
- Investigation of detailed physics of flow up to a cycle averaged Reynolds number of ~ 2100.
- Adding synthetic fluctuations at the inlet in the form of distortion in sinusoidal profile as a mechanism for triggering turbulence.
- Investigation of the critical Reynolds number at which the oscillatory flow leaves the laminar regime to step into a chaotic one.
- Investigation of the perturbation mechanisms i.e. if an inflow distortion is necessary to trigger turbulence and what the intensity of this distortion should be.

What we offer:

- Interdisciplinary and international working environment
- Exposure to and experience with state of the art experimental facilities
- Expert interdisciplinary supervision

What we expect:

- Interest in contributing to emerging area of biofluid dynamics
- Basic knowledge of fluid dynamics and turbulent flows
- Proactivity, teamwork, and willingness to learn

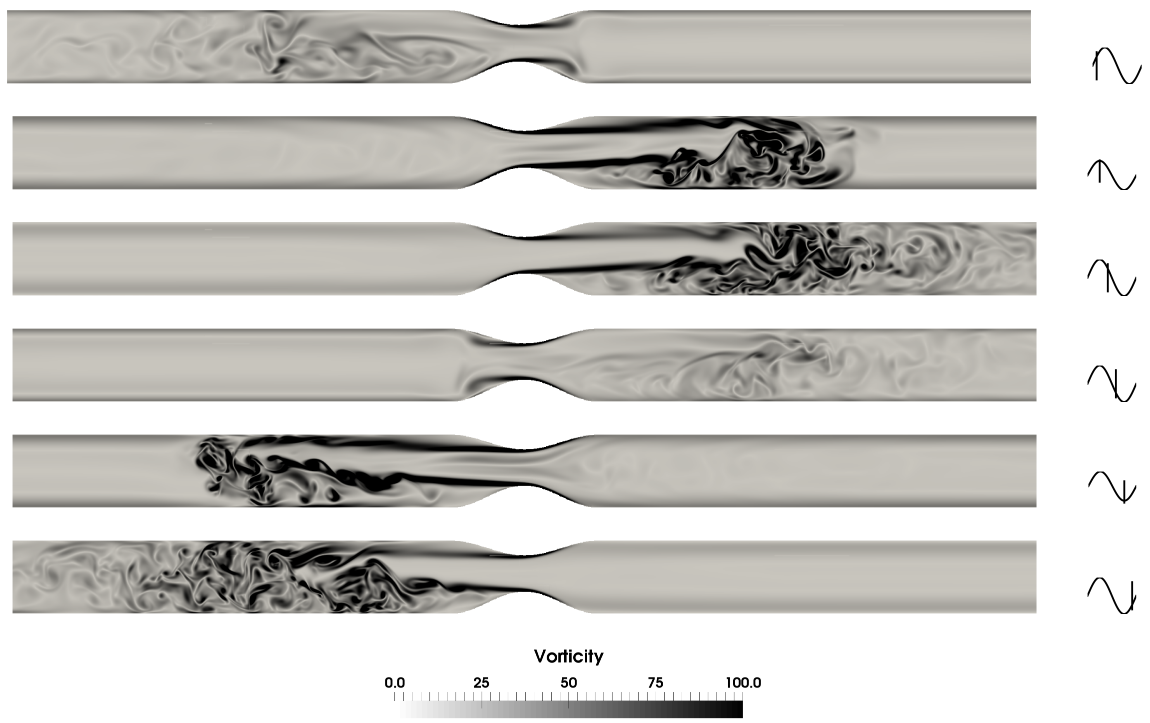

Figure 1 Instantaneous vorticity magnitude at 6 observation points in a sinusoidally oscillating flow in a stenosed pipe. This is a numerical simulation conducted on 28 800 CPU cores of the SuperMUC-NG supercomputer in Germany. The Reynolds number based on the averaged centerline velocity is $Re = 2100$.

For further information, or to apply, please send an email to:

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References

[1] Hino, M., Sawamoto, M., & Takasu, S. (1976). Experiments on transition to turbulence in an oscillatory pipe flow. *Journal of Fluid Mechanics*, 75(02), 193–207.

[2] Kartik Jain (2020). Transition to turbulence in an oscillatory flow through stenosis. *Biomechanics and Modeling in Mechanobiology*, 19, 113–131. PMID:31359287.