

# Dynamics of Laminar Flows in Vibrating Channels

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Properties of laminar flows in vibrating channels are of interest from the fundamental point of view, as uncontrolled vibrations may lead to an increase in flow losses and premature laminar-turbulent transition. Artificially generated vibrations may be used as a tool to rearrange the flow into a form more desirable for applications, such as improving mixing or reducing flow losses.

This analysis is focused on vibrations in the form of travelling waves. The field equations are solved using a spectrally accurate Immersed Boundary Condition (IBC) method. It employs Fourier expansions in the streamwise direction and Chebyshev polynomials in the wall-normal direction. The analysis focuses on sinusoidal waves characterized by their wavenumber, phase speed, and amplitude, which provide a reduced-order model for arbitrary wave shapes, and aims to determine the reduction in flow losses associated with their use. Their effectiveness is assessed through the pressure-gradient correction required to sustain a constant flow rate relative to the non-vibrating baseline.

The first part of the analysis involves vibrations of only one wall. It is shown that upstream-propagating waves always increase pressure losses, whereas the response to downstream-propagating waves depends on the flow Reynolds number. At low Reynolds numbers, these waves reduce pressure losses; however, at higher Reynolds numbers, this effect occurs only when the phase speed is sufficiently large, with the required minimum phase speed increasing with Reynolds number. Furthermore, shorter waves are more effective, and the greatest reduction in pressure losses is achieved for fast, short waves. It is shown that vibrations can activate resonance when their properties match the natural flow frequencies, resulting in a significant increase in flow losses even for very small-amplitude waves.

The impact of wall vibrations is further enhanced when waves are imposed on both channel walls. The level of enhancement depends on the relative phase between the waves, with out-of-phase configurations yielding the largest reduction in pressure losses, nearly doubling the effectiveness compared to single-wall actuation. It is shown that the peristaltic mechanism induced by the waves can generate sufficient propulsion to overcome viscous resistance and drive flow in the direction of wave propagation without the need for an externally imposed pressure gradient.