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LAMINAR FLUID FLOW AND HEAT TRANSFER CHARACTERISTICS OF WAVY MICROCHANNELS WITH WALL PHASE SHIFT

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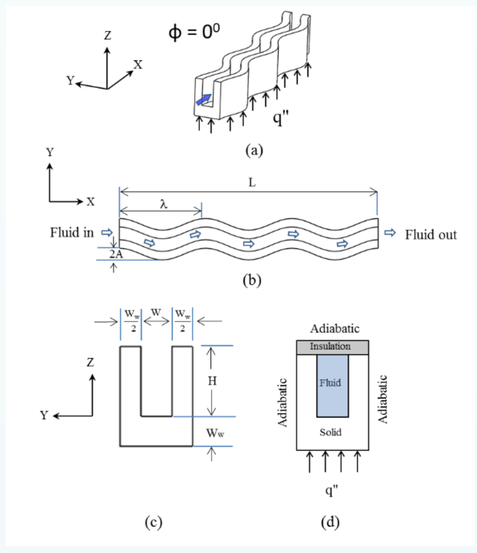
ABSTRACT

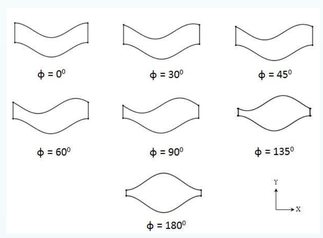
- 3D Conjugate Analysis was done to investigate the influence of wall phase-shift on the flow behaviour and heat transfer characteristics of the wavy micro-channels in the low Re laminar flow regime.
- 7 different configurations with φ = 0°, 30°,45°,60°,90°,135°,180° were studied for Re = 50,100,150,200 flow conditions.
- Single microchannel engraved on a copper block with water as working fluid was used.
- In the low Re regime, channel with φ = 60° was found to have best heat transfer characteristics.
- With increase in Re, φ = 0° channel was found to perform better, which can be explained by the increase in strength of Dean vortices due to higher Re and higher asymmetry.

DETAILS OF NUMERICAL SIMULATION

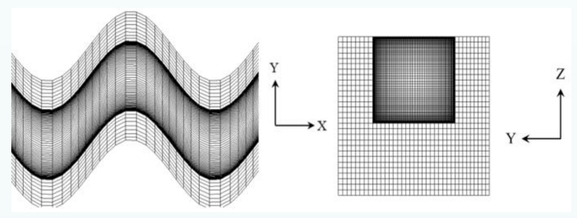
- Continuity, Navier Stokes and Energy Equations were solved using a **3D conjugate analysis** for a **laminar**, **incompressible** flow in **steady** state.
- Single micro-channel engraved on a copper block with water as the working fluid. L= 15000 µm, λ = 1000 µm, A = 150 µm, W x H = 400 x 400 µm^2, W_w = 250 µm.
- Pressure based solver used. '**SIMPLE**' scheme for pressure velocity coupling. '**Standard**' scheme for pressure interpolation. '**Second Order Upwind**' scheme for continuity, momentum and energy equations. Convergence criteria – **Residuals < 1e-6**. Schemes validated with experimental data.



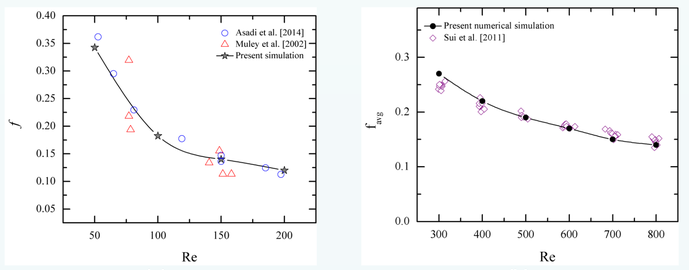
Computational Model Details for φ=0° (a)Isometric View (b)Top View showing important geometric parameters of the channel (c)Cross-sectional view with dimensions, and (d)with Boundary Conditions



Different geometrical configurations considered for analysis

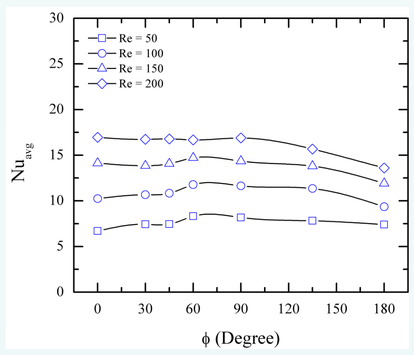


Structured hexahedral meshing on the computational domain. Finer near the boundaries. Approx. 3 lakh nodes.

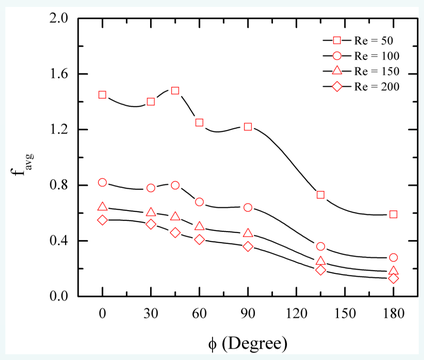


Validation of numerical schemes.
(a) *f*-normalized pressured drop vs Re (b) f-fanning friction factor vs Re

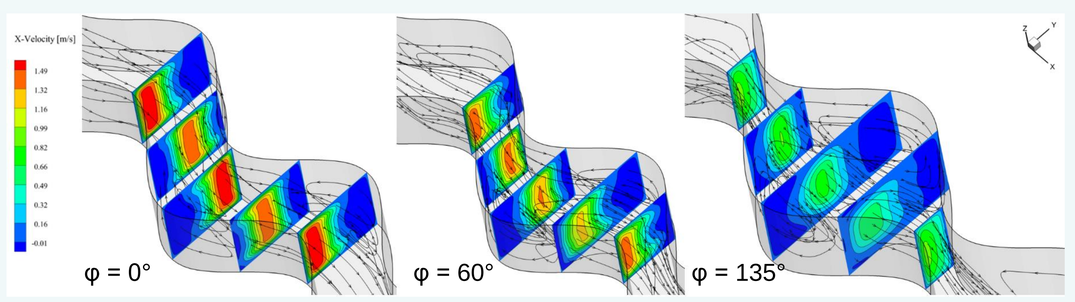
RESULTS



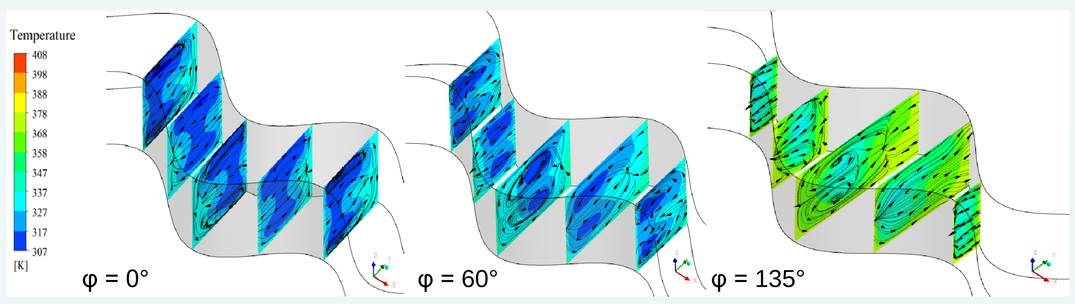
Variation of Average Nusselt Number with phase-shift at different Re



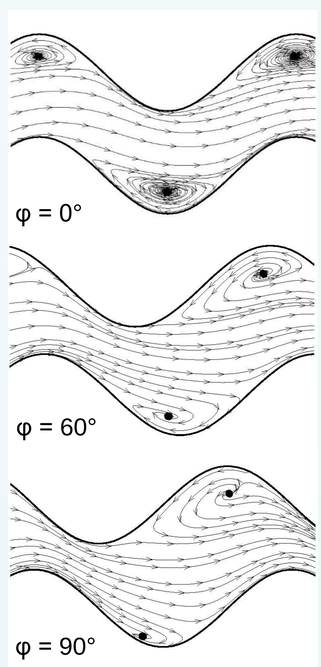
Variation of Fanning Friction Factor with phase-shift at different Re



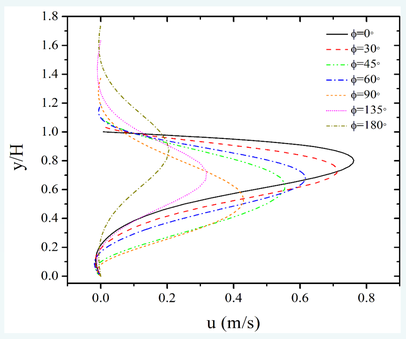
Velocity profiles at different axial locations and Streamlines along the channels at Re=200



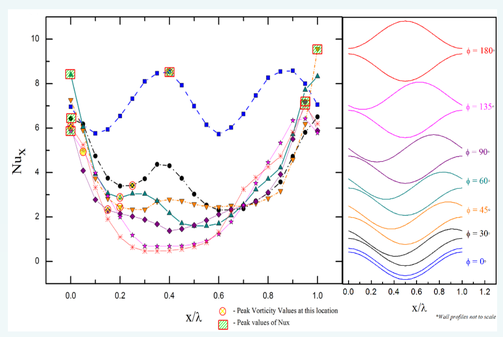
Cross-sectional streamlines and Temperature contours at different axial locations of the channels at Re=200



Streamline distribution for the different configurations at Re=100



Variation of velocity profile for different channel configurations, at an axial distance of 7500 mm from the inlet



Local Nusselt Number variation in a single wavy unit for different configurations at Re=100, with vorticity peaks marked.

CONCLUSION

- In the low Re regime, **φ = 60°** channel was found to have highest average Nusselt Number. As the Re was increased, **φ = 0°** showed better heat transfer characteristics.
- Flow characteristics vary significantly with phase-shift. More asymmetric channel causes a more asymmetric flow.
- Presence of **Dean and expansion vortices** have been observed in all the channels, which cause higher mixing of flows.

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