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SECONDARY FLOW IN HELICAL SQUARE DUCTS WITH COCHLEA-LIKE CURVATURE AND TORSION

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The cochlea is a fluid-filled spiral-shaped organ that hosts our hearing sense. The current understanding of cochlear mechanics is incomplete, as some fluid dynamic phenomena remain unclear. The aim of this study is to investigate the influence of cochlear geometry (i.e., curvature and torsion) on secondary flow arising in the cochlea. Bolinder (1996) studied stationary flows in helical rectangular ducts for industrial applications. Extending his analysis, we analyzed secondary flow under oscillating stimulation.

We applied computational fluid dynamics (CFD) and used the unsteady Navier-Stokes equations for incompressible flow to describe fluid phenomena, especially secondary flows, in simplified models resembling the curvature and torsion present in the human cochlea. The CFD simulations are performed with a finite element solver for a harmonically oscillating pressure at the inlet. Phase lags, particle trajectories, and secondary flow patterns and magnitudes are analyzed for different stimulation frequencies (0.125 Hz - 128 Hz).

The simulations show that secondary flow at low Reynolds numbers is dominated by torsion, as suggested by Bolinder (1996) for stationary flow. While the curvature's effect decreased for higher frequencies, secondary velocities arising because of torsion increased and reached up to several percent of the primary velocity magnitude. This finding is interesting because torsion was mostly neglected in previous cochlear models. Furthermore, we found that the phase lag of secondary flows differs from the phase lag of the primary flow and depends strongly on the models' geometry. In addition, our results show that particles experience a net drift (steady streaming) which is heavily influenced by the secondary flow pattern. The particle net motion in curved ducts follows the streamlines of Dean cells and is much higher than in twisted ducts at 1 Hz. At higher frequencies, however, effects of torsion become more important and cause stronger secondary flows. The observed net particle motion may provide new insight into biomedical mass transport and mixing for metabolites and drugs in the inner ear.

REFERENCES

[1] C. J. Bolinder, First- and higher-order effects of curvature and torsion on the flow in a helical rectangular duct. *Journal of Fluid Mechanics*, Vol. **314**, pp. 113–138, 1996.