Passively Enhanced Natural Convection Heat Transfer via Swirl Effect

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Introduction

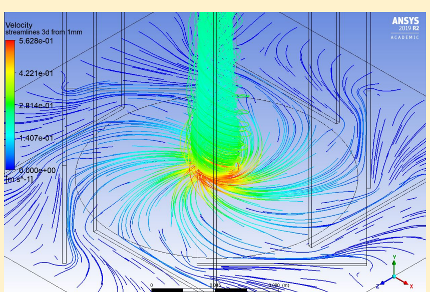
A numerical and experimental study, in the preliminary stages, has been conducted examining the effect of swirling flow on the natural convective heat transfer rate from a flat, horizontal, heated, upward facing, isothermal circular disk surrounded by insulation.

Objectives

- To improve the heat transfer rate for the above geometry without the use of externally powered devices such as a fan.
- To better understand the mechanisms of heat transfer for a swirling flow and to use this understanding to help develop more efficient thermal management systems for electronics and computer chips.

Solution Procedure

Both numerical and experimental methods have been employed in this problem. A Computational Fluid Dynamics (CFD) model has been developed to simulate the swirl effect over a range of Rayleigh numbers. Swirl has been induced with 8 vanes at a set angle, height, and length.



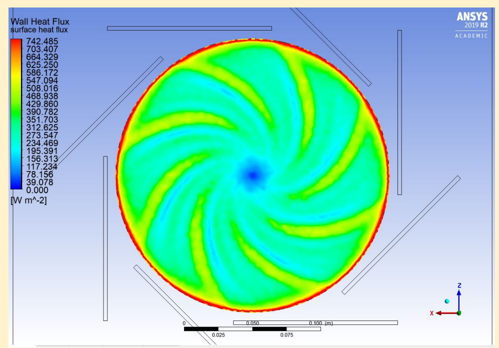
Vane Induced Swirl in the CFD Model

The CFD model was developed using ANSYS FLUENT software and uses the finite volume method. The RNG k-epsilon turbulence model was used in the simulations. A circular disk was manufactured and tested using a Mach-Zender Interferometer (MZI). A mathematical model based on the principle of axisymmetry has been derived to relate observed fringe spacing to surface heat flux over the 3D geometry.

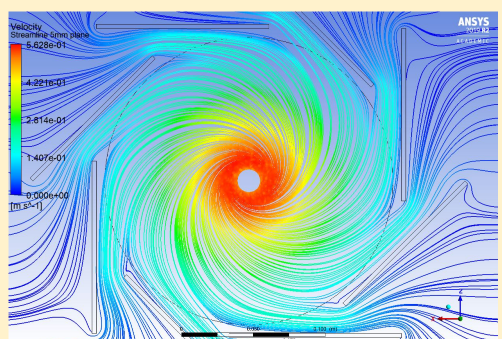
Preliminary Results

Numerical solutions have been obtained for:

$$1.3\times10^6 < Ra_D < 2\times10^8$$



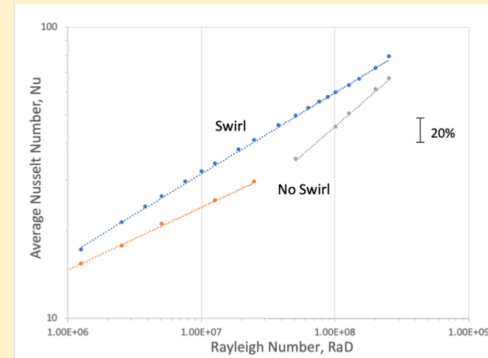
Surface Heat Flux with Swirl



Velocity Streamlines in a Swirling Flow

Comparison to Model with no Swirl

CFD has shown the swirl effect increases heat transfer between 20-30% for the range of Rayleigh numbers tested when compared to a model with no swirl.



Nusselt Number Results for Swirl and no Swirl

Conclusions

- Vertical vanes can effectively induce swirl over the tested geometry.
- The model with vane-induced swirl provides modest heat transfer enhancement over a model with no swirl.

Future Work

- Better understand the secondary flow patterns and how they affect heat transfer.
- Run numerical solutions for a wider range of design parameters: height, length, angle, and number of vanes.
- Develop an experimental model of a disk with vanes.

Acknowledgements

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