Analogy Based Modeling for Natural Convection

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Natural convection is an important phenomenon for many engineering systems including nuclear reactors. Present day nuclear reactors rely on the phenomenon for decay heat removal. While advanced CANDU-X would incorporate natural circulation for enhanced passive heat removals system to ensure safety, while other GEN IV designs also use natural convection as their main mode of heat removal. For this reason, transient analysis of natural convection has been an area of significant interest.

As a part of our larger project to enhance transport phenomenon at the micro-scale using radiation, we studied the phenomenon of natural convection. Using experimental techniques and numerical simulation (FLUENT code) transient response of a natural convection system was investigated. An Integrator Circuit analogy was proposed for natural convection system. Experimental investigation with three different fluids indicated that the characteristic time constant of the system is related to the Prandtl number of fluid. Moreover, effect of gravity and fluid viscosity were also investigated.

Simulations results suggest that natural convection system acts as a “Low Pass” filter. Transmission characteristics of natural convection system were found to be a function of both fluid properties and the flow characteristics. Transmission factor was found to be a strong function of temperature oscillation frequency. Our numerical simulations also suggested that in additional to the thermal energy stored in the system, for natural convection energy is also stored in the form of kinetic energy of the fluid set in motion due to buoyancy. This energy is found to be related to system’s Rayleigh number.