ME – PhD Thesis Defense

Experimental and numerical studies of multi-loop multi-plane pulsating heat pipes

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ABSTRACT

A Pulsating Heat Pipe (PHPs) is a wickless meandering capillary tube bent back and forth parallel to itself. PHPs are classified into single and multi-turn, closed-loop and open-loop. A single loop PHP can be thought of as a building block for multi-turn, single-plane or multiple-plane PHPs. The term "capillary" means that the diameter of the tube is small enough for surface tension effect to become prominent. The capillary tubes are initially evacuated and then partially filled with the working fluid. A PHP contains evaporator, adiabatic and condenser zones. In the present work, the possibility of employing a multi-turn PHP as a pin-finned heat sink attached to a base plate is considered. Hence all the zones, other than the evaporator ones, function as condenser zones. PHPs can be designed to carry more heat load than conventional heat pipes. Differential pressure created in a PHP due to differential heating between the evaporator and condenser acts as the driving force for producing momentum changes and oscillations in the two-phase fluid. This two-phase oscillatory flow causes efficient heat transmission from evaporator to condenser with very low temperature difference.

Experimental investigations are carried on PHPs with multi-turn and multi-plane configurations. The condenser (or fin portion) of the PHPs is cooled by forced air flow. Parametric runs are conducted by varying the number of turns, fill ratio, orientations, and heat loads. Three working fluids, namely, water, methanol and FC-72 are tested. PHPs with 9, 12 and 18 turns are tested for fill ratios of 30%, 50% and 70% and five orientations. Heat loads are increased in steps of 50 W from 50 W to 400 W for testing the PHPs. Based on the experimental data obtained, a heat transfer correlation is constructed with a deviation of less than ± 20% for the Kutateladze number in terms of the relevant dimensionless numbers. The correlation is based on 844 data points across various fluids, fill ratios, number of turns, inclinations, and heat loads. Startup characteristics of the multi-turn PHPs are investigated for both single-plane and multi-plane configurations.
For different PHP physical geometries, the flow regimes change with respect to heat loads. The optimum angle for best heat transfer is found to lie between 60° and 70°. Gravity independent operation observed in all the multi-plane models and generally, the bottom heating mode produce the highest heat transfer.

During the startup, for lower heat loads, a temperature overshoot is observed before the establishment of pulsations. At higher heat loads, pulsations are set up without appreciable temperature overshoot, following a smooth startup. The results have shown that the enhancement in fin thermal conductivity compared to solid copper.

The thermo-hydraulics of a PHP are very complex as they involve moving liquid slugs and vapour plugs of varying size, phase change mechanisms of evaporation and condensation and wall heat conduction effects. Hence most of the work reported in the literature has been experimental. In the recent times some efforts were made to formulate mathematical models for PHPs and to numerically solve the same. In the present work also an attempt is made to formulate a reasonably sophisticated mathematical model of a PHP. The numerical formulation consists of discretized governing equations and the required auxiliary equations. A computer program is written to carry out the numerical procedures and some numerical results with the working fluids methanol and water are obtained.

ABOUT THE SPEAKER

Narendra Babu N is a PhD student in the Department of Mechanical Engineering, IISc Bangalore. He is working with Dr. GSVL Narasimham in the Refrigeration and Air-conditioning (RAC) Laboratory. He completed his B. E. (Mech. Eng.) degree from MS Ramaiah Institute of Technology, Bangalore, and M.Tech. (Mech. Eng.) from NIT Calicut. His research interests are broadly in thermal systems like heat transport devices, and refrigeration and air conditioning systems. His dissertation work focuses on experimental and numerical studies of multi-loop multi-plane pulsating heat pipes.