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# Criticality of Adiabatic Length for a Single Branch Pulsating Heat Pipe

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**Abstract :** To meet the extensive requirements of thermal management of the circuit card assemblies (CCAs), satellites, PCBs, microprocessors, any other electronic circuitry, pulsating heat pipes (PHPs) have emerged in the recent past as one of the best solutions technically. But industrial application of PHPs is still unexplored up to a large extent due to their poor reliability. There are several systems as well as operational parameters which not only affect the performance of an operating PHP, but also decide whether the PHP can operate sustainably or not. Functioning may completely be halted for some particular combinations of the values of system and operational parameters. Among the system parameters, adiabatic length is one of the important ones. In the present work, a simplest single branch PHP system with an adiabatic section has been considered. It is assumed to have only one vapour bubble and one liquid plug. First, the system has been mathematically modeled using film evaporation/condensation model, followed by the steps of recognition of equilibrium zone, non-dimensionalization and linearization. Then proceeding with a periodical solution of the linearized and reduced differential equations, stability analysis has been performed. Slow and fast variables have been identified, and averaging approach has been used for the slow ones. Ultimately, temporal evolution of the PHP is predicted by numerically solving the averaged equations, to know whether the oscillations are likely to sustain/decay temporally. Stability threshold has also been determined in terms of some non-dimensional numbers formed by different groupings of system and operational parameters. A combined analytical and numerical approach has been used, and it has been found that for each combination of all other parameters, there exists a maximum length of the adiabatic section beyond which the PHP cannot function at all. This length has been called as “Critical Adiabatic Length (L_ac)”. For adiabatic lengths greater than “L_ac”, oscillations are found to be always decaying sooner or later. Dependence of “L_ac” on some other parameters has also been checked and correlated at certain evaporator & condenser section temperatures. “L_ac” has been found to be linearly increasing with increase in evaporator section length (L_e), whereas the condenser section length (L_c) has been found to have almost no effect on it upto a certain limit. But at considerably large condenser section lengths, “L_ac” is expected to decrease with increase in “L_c” due to increased wall friction. Rise in static pressure (p_r) exerted by the working fluid reservoir makes “L_ac” rise exponentially whereas it increases cubically with increase in the inner diameter (d) of PHP. Physics of all such variations has been given a good insight too. Thus, a methodology for quantification of the critical adiabatic length for any possible set of all other parameters of PHP has been established.

**Keywords :** critical adiabatic length, evaporation/condensation, pulsating heat pipe (PHP), thermal management
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