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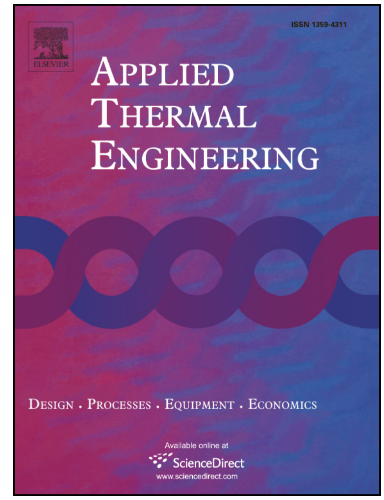

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Heats pipes for temperature homogenization: a literature review

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Abstract

Heat pipes offer high effective heat transfer in a purely passive way. Other specific properties of heat pipes, like temperature homogenization, can be also reached. In this paper, a literature review is carried out in order to investigate the existing heat pipe systems mainly aiming the reduction of temperature gradients. The review gathering more than sixty references is sorted into various application fields, like thermal management of electronics, of storage vessels or of satellites, for which the management of the temperature uniformity differs by the isothermal surface area, temperature ranges or the targeted precision of the temperature flattening. A summary of heat pipe characteristics for this function of temperature homogenization is then performed to identify their specificities, compared to other applications of heat pipes.

1. Introduction

The applications of heat pipes have increased over time, due to new thermal constraints for which standard cooling systems are more and more limiting. Based on an evaporation/condensation cycle, heat pipes exhibit a high effective thermal conductivity and offer the advantage of operating in a purely passive way. A heat pipe consists of a sealed container, a wick structure and an amount of a working fluid at liquid/vapor equilibrium. Heat is applied externally to the evaporator section and is released by an external heat sink at the condenser section. From the evaporator, the generated vapor is driven to the condenser thanks to the difference of pressure between the hot and cold sections. The liquid resulting from the condensation flows back to the evaporator by the capillary pumping created by the presence of the wick structure.

Specific properties of heat pipes with various sizes or shapes allow them to be used in various applications, as introduced in several literature reviews about heat pipe research and development [1-7]. For instance, Lips et al. [7] classified the type of heat pipes depending on whether the return of the liquid to the evaporator is gravity or capillary assisted. Other heat pipes, as rotating and pulsating heat pipes are also described. The diversity of the different kinds of heat pipe reflects the diversity of the applications in which they are used. The main function of heat pipes is to transfer high heat fluxes with a low temperature difference between the hot and the cold sources. However, other functions can also be used by choosing a specific type of heat pipe. Thus, heat pipes can be used for heat flux spreading, for thermal control, as thermal diodes or for temperature homogenization. Obviously, several of these functions can be combined in the same system. A short description of each function is introduced hereafter.

In most cases, heat pipes improve heat transfer between the heat source and the heat sink, especially when they are distant. Conventional heat pipes are able to transfer a power of around one kilowatt over a distance of about one meter. Loop heat pipes (LHP) can dissipate around 10 kW over several meters [8]. The most typical examples come from electronics cooling, from smallest components like chips [9] to largest power electronics like railway applications [10], via battery cooling [11].

Furthermore, when high heat flux densities are dissipated, heat pipes can assist in spreading the heat flux from the small surface of the evaporator section to a larger cooling surface. This function is widely used for electronics cooling. The typical heat pipes are here flat heat pipes, like vapor chambers [12-14], or solid plates with embedded conventional heat pipes or pulsating heat pipes [15-16]. A vapor chamber is a capillary-driven planar heat pipe with a small aspect ratio. If the condenser is above the evaporator, the wick is not necessary. The pulsating heat pipe (PHP) consists of a long capillary tube bent in many turns, looped or unlooped. Due to capillary action, the fluid is distributed