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Experimental and theoretical study of a vapour chamber based heat spreader for avionics applications

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ABSTRACT

An experimental and theoretical/numerical study is presented on the behaviour of a vertically placed vapour chamber based heat spreader (190 mm × 140 mm × 15 mm) intended for avionics applications. The experiments were performed with the heat spreader inserted in a mock-up avionics box. The volumetric flow of cooling air was in the range of 5–25 m^3/h, that represents current aeronautics on-board conditions and projected values for the mid-term future. Natural convection conditions were also studied because they represent a failure mode of the aircraft air supply system that has to be accounted for in actual design. Boiling inside the vapour chamber was enhanced by implementing a mini-evaporator area (35 mm × 35 mm) made up of an array of mini-fin-pins having the dimensions of 1 mm × 1 mm × 1 mm. The study considered different heat spreader geometries, including a metallic heat sink made up of rectangular fins that was assumed to be the reference configuration. It was found that, from the heat transfer standpoint, vapour chamber heat spreaders were always more efficient, although heavier, than their metallic heat sinks counterparts. In particular, for a component surface temperature in the range of 80 °C–100 °C, the maximum dissipated power varied between 95 and 145 W. Another conclusion of the study was that the benefit of using a heat spreader instead of a metallic heat sink was larger in the case of natural convection conditions. The experimental results were also used to calibrate a theoretical and numerical model of the heat spreader behaviour. To illustrate an application of the model, an optimization process was carried out to find the minimum weight heat spreader compatible with a series of design requirements.

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1. Introduction

Vapour chamber based heat spreaders are thermal control systems characterised by their robustness and somewhat simple design. These two aspects allow for their use in a wide spectrum of industrial applications in which reliable performance under a variety of operating conditions is more important than peak efficiency. One of the product areas that are suitable for the use of this type of heat spreaders is avionics. The reason is that one of the current design limitations of electronics equipment aboard airplanes, helicopters, et cetera, is the thermal dissipation of the components rather than the electronics aspects themselves. Typically, avionics systems inside aircraft are placed in the so-called “avionics bay” storage area that, because of the fact that free space is a very valuable commodity in aeronautics, tends to be as small as possible. The standard avionics bay contains a series of racks in which avionics boxes are tightly packaged. Boards, motherboards, et cetera, containing all kind of electronic components are assembled inside these boxes. Normally, the cooling of the electronics components is carried out via forced convection generated by air flow supplied by the aircraft that passes through grids of holes that are manufactured in the avionics boxes. This cooling method is robust and reliable, has been used for many years, and it is still the approach preferred by the aircraft manufacturers for avionics thermal control. However, its limitations are twofold: the air mass flow rate supplied by the aircraft cannot be increased indefinitely, and the method cannot deal efficiently with hot spots caused by high power components. Therefore, it is in this context where heat spreaders can play a role because of their capability to effectively transfer heat from localized high temperature areas to regions where the heat can be dissipated using standard means. Furthermore, heat spreaders are attractive for avionics applications because they are self-contained passive systems, and this is important when looking towards the minimization of operational and maintenance costs.

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