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Title of the thesis: Identification of flow patterns in pulsating heat pipes under microgravity conditions

Abstract

This dissertation addresses an issue directly related to the use of passive heat transfer systems in space technologies. As shown in the scientific literature and in documents made available by major space exploration institutions (including Japan, the United States, and European space agencies), heat transfer systems relying on multiphase flows are currently the most promising direction in systems for thermal management during missions. This is mainly due to the relatively high thermal performance of passive devices, the low mass, and the absence of peripheral devices such as circulating pumps.

In the Introduction, the thesis describes the most important heat transfer methods currently used in space technology. It also presents the principle of operation of a pulsating heat pipe, which is considered one of the most promising devices. A particularly complicated issue in this case is the simulation of two-phase flow under microgravity conditions, where the forces associated with the interaction of the gravitational field are dominated by the forces of surface tension and inertia. A contribution of the dissertation to the development of the scientific discipline is the inclusion of dynamic flows, i.e., flows in which the flow acceleration is nonzero.

The second chapter contains a review of the literature on flow patterns occurring in capillary and larger-than-capillary diameter tubes under conditions of both earth gravity and microgravity. The criteria used so far to define flow structures, even after taking into account a very large number of parameters (diameter, velocity, pressure drop, viscosity, surface tension, etc.), fail to accurately define the criteria for which a transition between flow structures should be expected. At the end of the chapter, the most important dimensionless numbers used in the fluid mechanics of multiphase flows are described, and the flow imaging methods considered in the design of the experimental set-up are presented.

The third chapter defines the objectives and thesis of the dissertation. This section describes the scope of work needed to be carried out to obtain original results that contribute significant and new knowledge to the development of the discipline.

The development process of the research setup is shown in Chapter 4. The first part deals with the conceptual design and construction process divided into mechanical, flow, and measurement parts.The second part of the chapter provides an overview of the most important physical parameters (e.g., velocity, amplitude, and frequency of oscillatory flows) occurring in pulsating heat pipes, which makes it possible to study the flows under conditions similar to those in real applications.

Throughout the study, flow registration was carried out using high-speed cameras; therefore, chapter five describes the implemented image analysis procedure and the method of automatic identification of flow structures.

The first part of Chapter 6 presents the results of research carried out at the ZARM Microgravity Research centre (Bremen, Germany). During the analyses, a new hypothesis was proposed, which is presented and confirmed in this chapter. The last section presents the recorded images of the detected vapour bubble break-up and coalescence phenomena and correlates the moments of registration on the

flow maps. These results are a prelude to the development of a criterion for predicting flow structures in microgravity and, ultimately, modelling flow in pulsating heat pipes for space technologies.

In the last chapter, a summary of the results is provided together with a discussion of the results. The summary confirms the thesis statement and confirms that the supporting objectives have been met. The most important work to be done in the future, to further develop the discipline and to understand the phenomena of vapour bubble break-up and coalescence under microgravity conditions, is also identified.

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