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Vacuum Testbench for use of Heatpipes in Small Satellites

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Extended Abstract

This study presents the development and verification of a testbed build to examine miniaturized commercial off-the-shelf (COTS) heatpipes under ultra-high vacuum environment for use in space.

Heat pipes have seen increasing use in space flight over the last decades. Although mostly used in comparatively large spacecraft, where they are custom-tailored and manufactured for the mission. On the other hand, the number of small satellites is growing steadily during the recent years, for example nanosatellites like CubeSats. The system power provided by these satellites is increasing by higher efficiency and simply by stacking units (e.g. multi-unit CubeSats). This is where heatpipes provide a solution for handling the higher amounts of excess heat produced. They also feature advantages in dissipating heat from high power payloads, which are only operated for short times, e.g. sensors or electric propulsion. Because they are readily available and inexpensive it seems desirable to evaluate commercial off-the-shelf COTS heat pipes for application in space.

Within this study COTS heatpipes are tested for performance under varying angles to earth's gravity and operating limits are reviewed. Moreover the performance degrading effect of heatpipe bends is considered, these are ofttimes necessary for thermal contacting and routing inside the satellite.

The testbed consists of a liquid-cooled cold plate for the condenser-section of the heatpipe and an electrically heated hot plate for the evaporator-section. Heat flow in steady state is measured via the electrical heater power. For thermal clamping the test devices are mounted directly onto these thermal plates or via copper adapters manufactured to dimension, e.g. to accommodate heat pipes with different circular diameter. Hot and cold plate can be placed independently from each other, currently allowing straight heat pipes in lengths from 50 to 350 mm to be tested at any angle to gravity. Cold end temperatures down to -40 °C and hot end temperatures up to 180 °C with a load of 150 W can be achieved for water- and methanol heatpipes. Fast changes in cold plate temperature can be realised with an additional electric heater on the cold plate. Complementary the hot plate is equipped with an additional fluid cooling port. Temperature measurement is currently done on as many as six positions along the adiabatic section of the heat pipe for diagnostic purposes. An extension of the testbench with a far infrared imaging sensor for contactless measurement of the temperature distribution along the heatpipe is planned. In addition work on different concepts for bonding the heatpipe to heat-soure and –sink is ongoing.

Problems with achieving the desired vacuum conditions occurred with the testbench inside the vacuum chamber, equipped with a turbomolecular pump. This could be traced to the microporous surface of the aluminium extrusions, used to hold and angle the test bench inside the vacuum chamber. Pumping time was cut to half by staining the anodised aluminium surfaces with sodium hydroxide solution.

First results have shown that the use of miniaturized COTS heatpipes under vacuum conditions is feasible.