World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:11, No:12, 2017

Heat Transfer Performance of a Small Cold Plate with Uni-Directional Porous Copper for Cooling Power Electronics

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Abstract : A small cold plate with uni-directional porous copper is proposed for cooling power electronics such as an on-vehicle inverter with the heat generation of approximately 500 W/cm2. The uni-directional porous copper with the pore perpendicularly orienting the heat transfer surface is soldered to a grooved heat transfer surface. This structure enables the cooling liquid to evaporate in the pore of the porous copper and then the vapor to discharge through the grooves. In order to minimize the cold plate, a double flow channel concept is introduced for the design of the cold plate. The cold plate consists of a base plate, a spacer, and a vapor discharging plate, totally 12 mm in thickness. The base plate has multiple nozzles of 1.0 mm in diameter for the liquid supply and 4 slits of 2.0 mm in width for vapor discharging, and is attached onto the top surface of the porous copper plate of 20 mm in diameter and 5.0 mm in thickness. The pore size is 0.36 mm and the porosity is 36 %. The cooling liquid flows into the porous copper as an impinging jet flow from the multiple nozzles, and then the vapor, which is generated in the pore, is discharged through the grooves and the vapor slits outside the cold plate. A heated test section consists of the cold plate, which was explained above, and a heat transfer copper block with 6 cartridge heaters. The cross section of the heat transfer block is reduced in order to increase the heat flux. The top surface of the block is the grooved heat transfer surface of 10 mm in diameter at which the porous copper is soldered. The grooves are fabricated like latticework, and the width and depth are 1.0 mm and 0.5 mm, respectively. By embedding three thermocouples in the cylindrical part of the heat transfer block, the temperature of the heat transfer surface ant the heat flux are extrapolated in a steady state. In this experiment, the flow rate is 0.5 L/min and the flow velocity at each nozzle is 0.27 m/s. The liquid inlet temperature is 60 °C. The experimental results prove that, in a single-phase heat transfer regime, the heat transfer performance of the cold plate with the uni-directional porous copper is 2.1 times higher than that without the porous copper, though the pressure loss with the porous copper also becomes higher than that without the porous copper. As to the two-phase heat transfer regime, the critical heat flux increases by approximately 35% by introducing the uni-directional porous copper, compared with the CHF of the multiple impinging jet flow. In addition, we confirmed that these heat transfer data was much higher than that of the ordinary single impinging jet flow. These heat transfer data prove high potential of the cold plate with the uni-directional porous copper from the view point of not only the heat transfer performance but also energy saving.

Keywords : cooling, cold plate, uni-porous media, heat transfer
Conference Title : ICFMT 2017 : International Conference on Fluid Mechanics and Thermodynamics
Conference Location : Sydney, Australia
Conference Dates : December 04-05, 2017