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博　士　論　文　の　要　旨

専攻名　システム創成科学専攻

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博士論文題名

（外国語の場合は，和訳を付記する。）

Experimental Study on Loop Heat Pipe with Flat Evaporator

（平板型蒸発器を有するループヒートパイプの実験的研究）

要旨（２，０００字程度にまとめること。）

Loop heat pipe (LHP), a passive two-phase heat transport device, operates based on the phase changing processes and the natural motivations such as capillary or gravitational force. Different with conventional heat pipe (HP), vapor and liquid in LHP flow in separated pipes and the fine pore wick occurring inside the evaporator only. Hence, LHP accesses some favor characteristics such as flexibility, compact ability, high heat transfer capacity with low thermal resistance and high-reliability characteristics. LHP has been applied successfully and commonly in the thermal management systems functioning on the orbital vehicles or machines like spacecraft, satellites, orbiters which operates in the zero-gravity environment. Nowadays, LHP is considered as one of the potential solutions to the challenges that the cooling system of modern electronics devices is facing such as high heat power and heat flux dissipation, stable and reliable performance as well as electricity consumption or environmental problem. There are numerous experimental and computational studies conducted to evaluate the performance, the phenomenon happening inside the LHP under the effects of different parameters. However, until now LHP has not approved the commercial situation as the normal HP does. One of the reasons can be caused by the complicated structure of evaporator, especially sintered porous wick that increases the LHP manufacturing cost. In this study, a new pattern of evaporator was suggested, and various experiments were conducted to find out the thermal performance of this evaporator as well as the whole LHP operating under different conditions including orientations, working fluids, cooling conditions. From the experimental results, the assumption above

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boiling and heat transfer process happen inside this evaporator was withdrawn. This assumption can be used as one of the factors to improve the design of LHP in future.

The works done in this thesis can be summarized as follows

- Designing and fabricating the first pattern of the evaporator. This pattern was accompanied with the sintered stainless-steel wick, and water was the working fluid inside the LHP. The LHP's performance was investigated under both gravity-assisted and horizontal orientation condition.

  - In the experiment that LHP worked in condition advantage in gravity, the condenser was cooled by water at 27.5°C with mass flow rate at 27 kg/h, the LHP could operate stably in the range of 50 to 520 W (19.2 W/cm^2) and maintain the temperature on the top surface of the heating block not be higher than 105°C. The total thermal resistance of LHP reduced with heat power increment and had the minimum value 0.149 K/W at the heat power of 520 W. For the target of cooling, this LHP could take the heat at the rate of 350 W (12.9 W/cm^2) from the heater while the temperature on the top surface of heating block was kept at 85°C. The start-up characteristics of the LHP under different heat power were analyzed and discussed. Moreover, the experimental results included the changing of evaporation heat transfer coefficient on the heat flux. Through the results, an assumption about boiling phenomenon happening inside the evaporator was introduced. This experiment also examined the cooling performance of the LHP after turning off the heater.
  - Within the horizontal condition, the performance of LHP was investigated when the inlet temperature of cooling water was adjusted at different values including 18.5°C, 28.5°C, 36.5°C. When cooled by water at 28.5°C, the LHP could operate in the range of heat load from 10 W to 94 W and maintain temperature at the top surface of heating block lower than 100°C; however, the LHP demonstrated the weak

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oscillating behavior under heat load at 10 W. Experimental results also show that the total thermal resistance of LHP, when cooled by water at 28.5°C and 36.5°C, are nearly equal together and smaller than the case that cooling water was set at 18.5°C. This result indicates that LHP can function efficiently with natural water without cooled in advance. Besides, the experiment of horizontal condition also found out the overcharged of working fluid is one of reasons caused the LHP to behave different oscillation characteristics.

- However, the first pattern of the evaporator behaved some disadvantage, especially the vapor chamber and compensation chamber could connect with each other, so made the circulation weaker. Therefore, we designed and fabricated the second pattern of the evaporator having some strong points such as prevent the connection between the vapor collector and compensation chamber, easy in changing the wick as well as the base of the evaporator. Within the second pattern, performance of LHP under gravity assisted condition was investigated when operating with different working fluids including water and ethanol. In the experiment, the evaporator's LHP was also equipped with sintered stainless-steel wick. The results show that the performance of water LHP was almost similar to one working with the first pattern of evaporator although the elevation different between evaporator and condenser was smaller. Comparison between water and ethanol LHP, the LHP with water as working fluid had the better performance. In the case of water LHP, when heating power was changed from 33 to 535 W, the temperature at the top surface of the heating block raised from 38°C to 110°C. With the ethanol LHP, this temperature reached the value of 133°C at the heating power of 395 W. If temperature limitation of microprocessors functioning inside the DCs is recognized at 85°C, the cooling capability of LHP will be 220 W and 350 W corresponding to the working fluid was ethanol and water respectively. In addition, the

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discussion about the difference in boiling heating transfer characteristics as well as condenser performances in the cases that water and ethanol were used as working fluid was also presented in this experiment.