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Technical Note

An experimental investigation on capillary pumped loop with the meshes wick

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Abstract

A copper-water capillary pumped loop (CPL) is developed for heat recovery applications in the field of the refrigeration and air conditioning. The multi-layer copper meshes are used as the capillary structure in the CPL. The startup characteristics and heat transfer performance of the CPL are investigated experimentally. The experimental results show that for a range of power applied to the evaporator, the system presented reliable startups and continuous operation. The heat transfer performance of the evaporator will be improved if the charging rate of the working fluid or the heat flux is increased properly. The optimal charging rate could be obtained in the range of 70–76% for the given experimental conditions. The study has demonstrated the proposed CPL configuration is able to perform the heat recovery applications.

Keywords: Capillary pumped loop; Heat transfer; Heat recovery

1. Introduction

The capillary pumped loop (CPL) uses the same basic principle as widely known heat pipe, i.e., closed evaporation–condensation cycle maintained by capillary pumping. The separation of the liquid and vapor transport lines is a key character of a CPL over a heat pipe. Thus, the major advantage of CPL over a heat pipe is that it can transport energy over a longer distance. CPL technology has been developed as an option for transporting thermal energy within spacecrafts, satellites and electronic components [1,2]. Moreover, numerous investigations have also been performed with the innovating CPL technology in the past. Muraoka et al. [3] investigated a new CPL with a condenser containing a porous wick structure. Bazzo and Nogoseke [4] proposed the capillary pumping system assisting flat solar collectors, which using fine circumferential grooves as capillary structure and acetone as the working fluid. A series of study on the thermal transport characteristics were also conducted on CPL systems. LaClair and Mudawa [5] developed an analytical model of conduction during the initial heating of a cylindrical capillary evaporator, which is applicable to standard CPL evaporators. Chen and Lin [6] investigated the effects of parameters on the CPL used for cooling of electronic components. Bazzo and Riehl [7] studied the operation characteristics of a small-scale capillary pumped loop. Pouzet et al. [8] studied the dynamic response of a capillary pumped loop subjected to various heat load transients.

Recently, there are efforts to extend the application of CPL to commercial and industrial systems. The use of such devices offers many advantages regarding the flexibility in operation and application, as they are very efficient in transporting heat, even under a small temperature difference. Therefore, CPL could also be used as heat recovery devices applied to the field of the refrigeration and air conditioning. For this purpose, this paper presents a novel design of a CPL, which uses multi-layer copper meshes as

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the capillary structure in the evaporator. The startup characteristics of the CPL are investigated experimentally. The effects of the working fluid charging rate on the CPL operation are also investigated. Details of the CPL, test setup and test procedure are described in the following sections.

2. Description of CPL and experimental setup

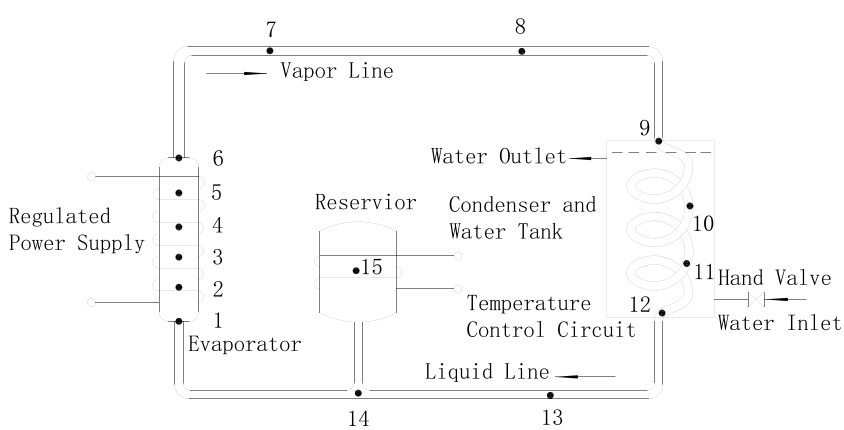
The CPL configuration studied in this paper is schematically presented in Fig. 1. It is composed of an evaporator, condenser, liquid and vapor lines and a two-phase reservoir. The helical coiled condenser is made of a long copper pipe with the length of 0.8 m and the outer diameter of 8 mm. The two transport lines for vapor-phase and liquid-phase are thin-walled copper pipes with the inner diameter of 4 mm and the thermal transport distance is about 1.1 m. The reservoir is connected to the condenser through a copper pipe with the inner diameter of 4 mm, which is responsible for establishing the loop operation pressure and temperature, as well as the working fluid inventory in the CPL. In contrast with the conventional CPL configuration, in the present design the evaporator is equipped with a multi-layer copper mesh wick structure. Metal meshes, as tested here, are widely used as the capillary porous media in heat pipe wicks due to their low cost and relative simplicity of manufacture. Fig. 2 shows the schematic diagram of the evaporator. And some configuration parameters are listed in Table 1.

Distilled water is used as the working fluid in the present study. The working fluid must operate without impurities as an important condition. The presence of non-condensable gases (NCG) in a CPL can cause a general failure of the capillary evaporator. The presence of NCG in present CPL can be minimized because the materials in CPL are compatible with the selected working fluid. Moreover, to further avoid the presence of NCG in the loop, strict cleaning is carried out by using acetone solvent, mixed solution (the proportion of phosphorus acid and nitric acid is 1:1) and distilled water in procedure.

A charging system is also designed in order to ensure that the correct amount of water was charged into the loop. In this system, a vacuum-pump is connected to the CPL and the charging reservoir including a burette and a flask. The whole system is evacuated for a minimum of 8 h prior to charging. Distilled water is refluxed (boiled and condensed) in a flask to remove air. Charging is accomplished by operating the on/off of several vacuum valves from the vacuum-pump to the reservoir and loop system. The amount of fluid that is added to the CPL is controlled at the burette by keeping a meniscus in the graduated portion.

The experimental setup comprises heating system, cooling system and measurement system. Electrical resistance heaters are located on both the reservoir and evaporator as shown in Fig. 1. The wires, as a heater, are wound around the outer wall of the evaporator and the reservoir with a proportional interval for supplying the constant thermal load. The reservoir heater is connected to temperature controllers to maintain the temperature of the reservoir at the desired set point. On/off temperature controllers are used to control the reservoir heater. The condenser of CPL is cooled by the water tank with circulating water. In addition, the entire CPL except the condenser is insulated with thermal insulating material. The experiment data are collected by Agilent data acquisition system, model 34970A.

The temperatures along the CPL are measured with T-type thermocouples. The thermocouple locations are also shown in Fig. 1. All thermocouples were calibrated in conjunction with the data acquisition system. The accuracy of temperature measurement was at range of ±0.5 °C. The heater power of evaporator was calculated by multiplying the voltage and the current measured from the digital mul-



Point 1~ point 15 are points for measuring temperature.

Fig. 1. Schematic diagram of the experimental setup.