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ScienceDirect
Trans. Nonferrous Met. Soc. China 21(2011) 1587−1594
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Forming method of wick structure for heat column

TAO Su-lian[1, 2], TANG Yong[1], PAN Min-qiang[1], WAN Zhen-ping[1], LU Long-sheng[1]

1. Key Laboratory of Surface Functional Structure Manufacturing of Guangdong Higher Education Institutes, South China University of Technology, Guangzhou 510640, China;
2. Department of Mechanical Engineering, Guangdong Technical College of Water Resources and Electric Engineering, Guangzhou 510635, China

Received 1 November 2010; accepted 30 March 2011

Abstract: The intensified boiling and condensation wick structures of heat column were designed and manufactured by ploughing-extrusion (P-E) machining method. The forming process and mechanism were analyzed. The results show that the P-E depth plays a decisive role in forming of wick structure. The larger the P-E depth is, the better the surface characteristics are. Only when the groove spacing is in a certain range, superior surface structure can be formed in the wick. The better enhancement boiling structure forms at P-E depth of 0.3 mm, ringed groove spacing of 0.4 mm, and interior angle of radial groove of 3°; the better enhancement condensation structure forms at P-E depth of 0.3 mm, ringed groove spacing of 0.4 mm, and axial grooves spacing of π/3 mm.

Key words: heat column; wick; ploughing-extrusion; heat transfer; micro-groove

1 Introduction

The heat dissipation problem of high heat flux density is one of the key factors influencing the performances of electronic components [1−2]. Recently, the heat generated per unit area of electronic component increases fanatically, and the available space for installing thermal control devices decreases dramatically. Nowadays, micro heat pipe is regarded as one of the effective components to solve the high heat flux problem of electronic devices. It is usually bended in order to meet the space requirement, which leads to the reduction of heat transfer performances [3]; moreover, the heat transfer capability of micro heat pipe is also limited by the area of the evaporator and condenser. Therefore, multiple heat pipes are generally used for heat dissipation. Cylindrical heat pipe recently begins to appear to meet the cooling and space requirements for high-performance electronic components. Cylindrical heat pipe is also called as heat column. Unlike to common micro heat pipe, heat column is short and thick. It has rapid heat transfer rate, great heat capacity and good adaptability. Its heat capacity greatly exceeds that of normal heat pipe.

Wick structure plays an important role in the heat transfer performance of heat column [4], so how to design wick structure to obtain optimal heat transfer performance is crucial for studying heat column. The available research on heat pipe focused mainly on theoretical model, heat transfer mechanism, performance test and so on [5−6]. However, until now, there are few reports about the study on the manufacture of heat pipe. KANG et al [7] fabricated radial micro grooved heat pipe of 5 cm×5 cm by micromachining and eutectic bonding technology. GILLOT et al [8] developed a plate silicon micro heat pipe with rectangular grooves by etching technology. LEE et al [9] reported the design and manufacturing of an integrated heat pipe system. A layer of nitride film covered on V-shape groove was fabricated by wafer bonding and reverse etching technology. CHEN and HSIEH [10] manufactured heat pipe with microgrooves of 200−500 μm by chemical etching and precision machining method. LI and XIAO [11] proposed high-speed spinning method and machined an axial micro-grooved copper heat pipe. Nowadays the wick on the inner wall of heat pipe was manufactured mainly by micro etching and micro-processing methods,

Foundation item: Project (U0834002) supported by the Joint Funds of NSFC-Guangdong of China; Project (2009ZM0121) supported by the Fundamental Research Funds for the Central Universities, China
Corresponding author: TANG Yong; Tel/Fax: +86-20-87114634; E-mail: ytang@scut.edu.cn
DOI: 10.1016/S1003-6326(11)60901-1

but all the methods are either costly or complex.

In the present work, a new style wick structure was put forward to solve the problem of present high machining cost and low heat dissipation power for wick, multi-dimensional and multi-scale heat function surface structure was applied to the wick of heat column to enhance capillary force, enhancing its heat transfer performance. The wick structure of heat column was fabricated by P-E method. Corresponding formation characteristic, machining condition and formation mechanism were discussed, and the influence of P-E parameters on the wick surface was investigated.

2 Wok principle and design of wick structure of heat column

2.1 Wok principle of heat column

Heat column is a cylindrical copper sealed vacuum chamber, and there exists capillary structure on its inner wall. Its work principle is shown in Fig. 1. The bottom of heat column is the evaporation face contacting the heat source, and the surrounding is the condensation face playing a condensation role. When the heat column works, input heat passes the evaporative section, vaporizing the coolant liquid. Then the vapor transfers to condenser section. In the condenser section, the vapor releases latent heat and gets liquefied. The condensated liquid returns from the condenser to the evaporator through capillary structure, thus heat column completes a work cycle, so repeatedly, thereby the heat diffuses quickly from a concentrated area to the condenser.

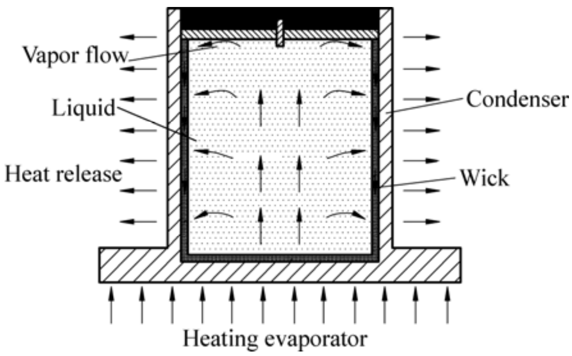

Fig. 1 Principle of heat column

2.2 Design of wick structure

The wick structure on the inner wall of heat column plays a crucial role in its heat transfer performance. The evaporator not only enhances boiling performance but also ensures condensated liquid return from the condenser to the evaporator. Rough surface can improve the boiling performance [12], thus increasing roughness of wick surface can enhance the capillary force of wick. Rough micro grooves were machined on the inner wall of copper tube by P-E, and it can enhance the capillary force when being used in micro-grooved heat pipe [13−14]. The wick structure of heat column was fabricated by P-E method. The evaporator structure is shown in Fig. 2(a). The intersecting micro-grooves are machined by P-E. The groove surface is rough, and a large number of micro-holes come into being on the evaporator surface. Two-phase flow of steam and liquid can flow in staggered vertically and horizontally microgrooves to promote turbulence and boiling. The micro-groove structure is composed of micro-grooves, flanges and intermittent micro-fins. There are flanges between two micro-grooves, which have intermittent micro-fins promoting nucleate boiling. The main function of condenser is to ensure the vapor condensate and condensation liquid return from condenser to evaporator. Figure 2(b) shows the structure of condenser. Micro channel finned cooling structure surface utilizes cross groove fin structure, which is composed of micro-grooves, flanges and intermittent micro-fins. Two-phase flow of steam and liquid can flow in vertical and horizontal micro-channel, and the fins around microgrooves are propitious to nucleate boiling and convection.

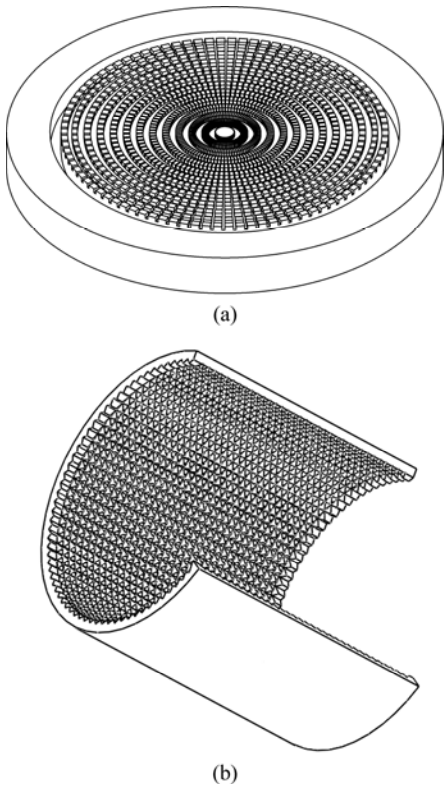

Fig. 2 Wick structure on evaporator (a) and condenser (b) of heat column

3 Experimental

The experiment was carried out on the lathe