A MEASUREMENT PRACTICE FOR THERMAL CHARACTERISTICS OF POROUS MEDIUMS

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Abstract : The utilization of micro-channels have an increasing attention in a variety of industrial applications regarding their heat transfer and flow characteristics. Thermal characteristics of porous mediums which are modeled as bulk micro-channel patterns are the attention given in this paper. An experimental investigation is on site . Heat storage and transfer characteristics of copper foams are described as a function of shape, porosity, thickness, micro-structure and time. The basics of the measurements and the range of investigation are presented. The local temperature variations in porous medium are analysed in reference to thermal camera photography and scanning electron microscopy.

Key-Words: Copper Foam , Temperature , Porous Medium, Porosity, Thermal Conductivity, SEM

1 Introduction

Growing energy demands, space limitations for device packaging, energy and materials savings have focused the demand for miniaturized, lightweight heat exchangers that can provide effective heat transfer. Nowadays, the micro / mini channel heat exchangers have been widely applied in power generation, transportation, HVAC, electronics and manufacturing. Moreover, different methods of enhancing the heat transfer performance of micro / mini channel heat exchanger have been studied and applied, several studies also attempted to improve the performance of microchannel heat sink by insertion of porous media [1] . They found a maximum 76.6% improvement in the thermal resistance when the porous insert with a high porosity was adopted. Tzeng et al. [2] experimentally studied mixed convection heat transfer in a rectangular porous channel with sintered copper beads. The effects of the average particle size of the sintered porous shot-copper and porosity with varying Reynolds number and heat flux were investigated. Their findings indicate that at a fixed porosity, higher flow rate increased the efficiency of heat exchange between the solid and fluid phases for the heat sink. Guerroudj and Kahalerras [3] numerically studied mixed convective heat transfer in a parallel plate channel with various porous blocks shapes. Blocks were heated from below and attached to the lower plate while the upper plate was thermally insulated. Varied shapes were studied, from rectangular to triangular. The effects of mixed convection parameter ($Gr=Re^2$), Darcy number, porous block height, thermal conductivity ratio, and Reynolds number were investigated. Their findings indicate that the global Nusselt number increased with increases in mixed convection parameter, Reynolds number, and the thermal conductivity ratio. Rectangular is the optimal shape at high values of these parameters. Kamath et al. [4] experimentally studied mixed convection in a vertical channel containing aluminum foams of varying pore density and porosity in the range 90–95%. In their study, the effects of Richardson and Reynolds numbers and porosity on heat transfer were investigated and their findings indicated that a porous medium in small inlet velocities did not enhance heat transfer, Porous matrix conduction marginally enhanced heat transfer. The average surface temperature of the aluminum plate dropped and heat transfer coefficient increased with increasing power input. At high power input the increased buoyancy forces resulted in an increased heat transfer. Literature reviews show that very limited data and study are available on thermal characteristics . Performance of copper foams for heat transfer enhancement purposes should be studied. As a result, analysis of micro / mini channels as porous structures are studied for future scopes of enhancing thermal performance of channels. This is covered by Msc study topic of the second author under the supervision of the first author . The study is continuing currently[5].

2 Experimental Method

Porous Medium : Porous media with high thermal conductivity have emerged as an effective method of heat transfer enhancement due to their large surface area to volume ratio and to intense mixing of the flow. Porosity can be calculated depended of volume of both sample and solid [6] Kaviany :

$$\varepsilon = 1 - (V_{solid} / V_{sample}) \quad (1)$$

Use of porous metal foams in heat transfer applications is novel. Consequently, numerous investigations have been carried out on this subject in the recent past.

For the experimental studies, different shapes, sizes and thicknesses copper foams are used as a sample listed in Table 1.

Shape	Dimension (mm)	Porosity (%)	PPI	Density (g/cm3)
Cylindrical	25*2	95	40	0.45
Cylindrical	25*3	95	40	0.45
Cylindrical	25*5	95	40	0.45
Plate	150*30* 3	95	40	0.45
Plate	150*30*4	95	40	0.45
Plate	150*30* 5	95	40	0.45

Table 1

Copper Foam Properties

Copper foams are produced with specified dimensions and properties by manufacturing company, Beijing Shunyuan Wangda Trade Co., in China. To perform and analyse the temperature variations in porous medium, a heater unit is used as a heat source and copper foams arranged on it with different shapes and thicknesses. Temperature range of the heater unit changes from 50 to 100 degrees to analyse the thermal characteristics of the copper foams. Thermal views of the copper foams are taken periodically by Testo 875-2i thermal camera photography and temperature variations along the selected region or directions are taken as a case measurement. The thermal camera provides thermal imaging with a high level of thermal sensitivity, outstanding image quality and allowing hot and cold spots to be quickly visible. Hence, the smallest temperature differences can be seen . To describe the effects of the micro-structure of the copper foams on heat transfer performance, scanning electron microscopy (SEM) device is used.

The key parameters for this research : heater unit temperature range, thermal specifications and geometry of the copper foam samples, porosity, pore size and time period.

2.1 Temperature measurements on copper foam

To investigate the thermal characteristics of the copper foam materials along the all surface points, use of the temperature measuring device with high sensitivity plays important role for certain experimental results. Settings of the device with respect to material properties before taking the thermal views of the copper foams are also key points. Especially setting of temperature ranges, emissivity value of the material, quality of the thermal views and position of the measuring device are critical points for taking correct results.

As a case study, plate type copper foam (150 mm * 30 mm * 3 mm) with 95 % porosity, and 40 PPI shown in Fig.1, is arranged on heater surface at 64˚ and temperature variations on the upper and bottom surface of the copper foam are measured by thermal camera instantly. Thermal camera focused precisely on copper foam material at same distance and position. Image clarity set by manually. After taking thermal images of the material, all image views are transferred to computer for thermal analysis. Thermal images analysed with testo software program shown in Fig.2. Temperature profiles are shown in Fig.3 and Fig.4 for copper foam sample.

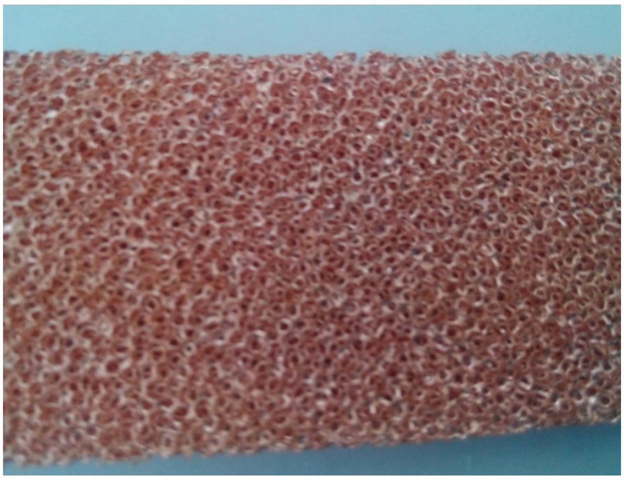

Fig.1

Copper Foam Sample

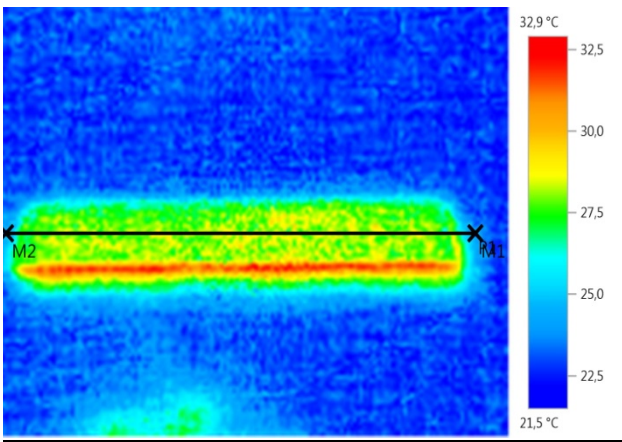

Fig.2

Thermal view and temperature distribution of the copper foam

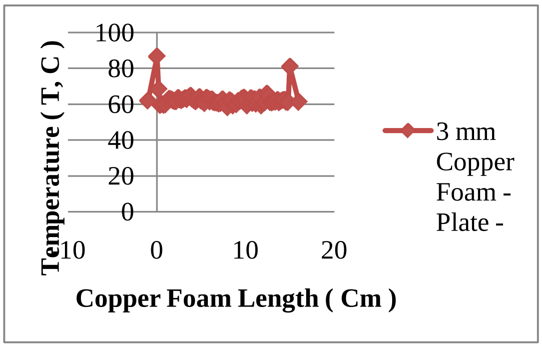

Fig.3

Copper foam upper surface, centerline temperature profile

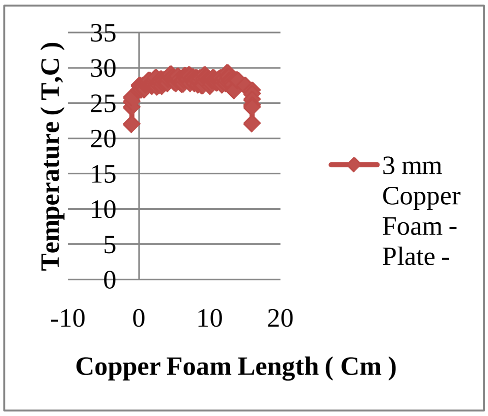

Fig.4

Copper foam bottom surface, centerline temperature profile

2.2 SEM analysis of copper foam

To analyse the micro-structure of the copper foam from a heat transfer point of view, a scanning electron microscope (SEM) is used. Micro-structure of the copper foam specimens observed at a wide range. Fig.5 and Fig.6 show the micro-structure of the copper foam material.

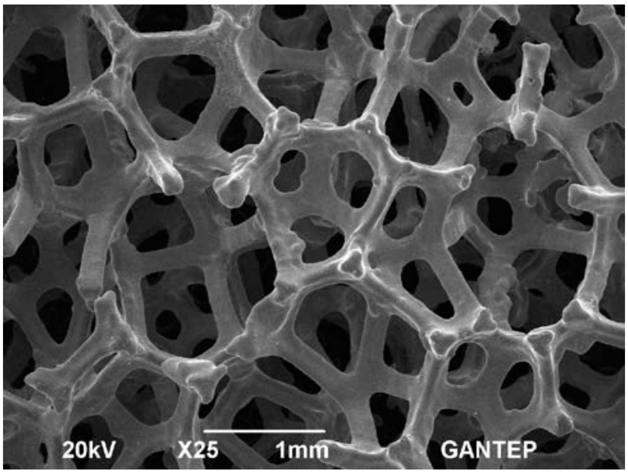

Fig.5

SEM image of copper foam

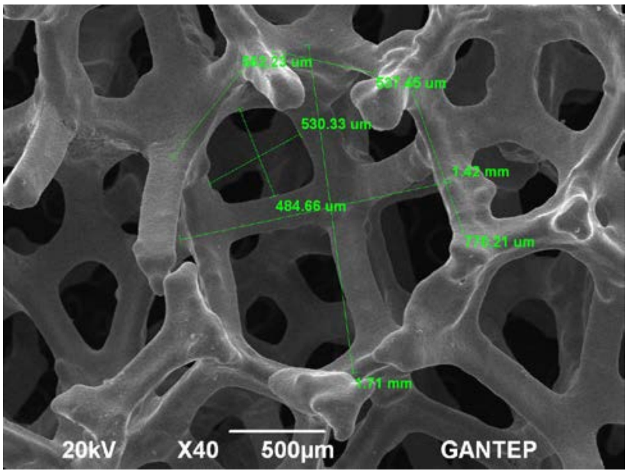

Fig.6

SEM image of copper foam, unit cell

Scope investigation topics of the research can be given :

1) Effects of the micro-structure on heat transfer enhancement
2) Observe and define the influence of pore shape, size, and direction on heat transfer
3) Calculation the thermal conductivity of the material

3 Conclusion

The high thermal conductivity and heat storage capacity make porous copper foams interesting for use as a technique of cooling of many engineering systems. In this context, an experimental research and study under consideration [5] aims to reach the following targets,

1) Analyse and define the thermal characteristics of the copper foam for further heat transfer investigations.
2) Enhance the thermal performance of mini / micro channels for engineering applications.
3) Use of porous copper foam to solve cooling problems
4) Effects of the shape, size, porosity and thickness of the copper foam on heat transfer performance

Therefore local temperature magnitudes over the sample surfaces at different levels of thickness are used in reference to micro pattern . The effect of porosity in various directions of heat transfer and heat storage capacity is going to be determined.

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