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# An Experimental Investigation of Convective Heat Transfer of Slurry Phase Change Material in a Tube with Butterfly Tube Inserts

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**ABSTRACT:** In this study, the effect of adding of microencapsulated phase change material to pure water base fluid as a working fluid was investigated. To this end, a laboratory apparatus was prepared and used. The main part of this setup is a tube which is called test section. The test section has a circular cross-section under a constant heat flux and is equipped with 6 thermocouples for measuring wall temperature at 6 different points as well as 2 thermocouples to measure the inlet and outlet flow temperature into the tube. The effect of butterfly tube inserts was also studied and the results were compared with each other. The results indicated that adding phase change material to base fluid could improve the heat transfer rate up to 41%. In addition, when the butterfly blades were placed in the test section, it was observed that the heat transfer rate increased to 234% for pure water and up to 180% for the slurry with 10 wt% of microencapsulated phase change material. The blades increased heat transfer by creating turbulence in the flow and eliminating the thermal boundary layer.

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## 1- Introduction

Using nanoparticles and producing a suspension which is called nanofluid could improve heat transfer remarkably [1]. Many experimental [2-4] and numerical [5-7] researches have investigated the effect of adding nanoparticles to a base fluid on the thermo-physical properties. Slurry of MicroEncapsulated Phase Change Materials (MEPCM) is another type of fluid that is used to improve the thermal properties of a working fluid [8-10]. Phase Change Materials (PCMs) are substances that melt and solidify at nearly constant temperature. They are capable to store and release large amount of thermal energy during phase change from solid to liquid or vice versa, respectively.

The previous works on MEPCM slurry have only investigated the effect of MEPCM. This research will evaluate the effect of MEPCM and butterfly tube inserts simultaneously.

## 2- Experimental Setup

Fig. 1 shows the experimental setup. It contains a heat transfer section as the test section, a plate heat exchanger for slurry cooling, two pumps for cooling water and slurry, two rotameters for the flow rate monitoring and controlling, two reservoir tanks for cooling water and slurry, and a U-tube manometer for measuring the pressure drop. A copper tube with 7.9 mm inner diameter, 2 mm thickness and 1285 mm length with a surrounding thick thermal isolating layer for minimizing the heat radiation was used as the test section. Fig. 2 depicts the butterfly tube insert used in copper tube. The butterfly tube insert consist of a holding rod with 1 mm diameter. The pitch length is 12 cm. Six K-type thermocouples with the precision of 0.1 °C were soldered to measure tube wall temperature.

In order to heat the slurry, an electrical wire with the power of 1000 W were twisted uniformly around the tube. The plate heat exchanger was used to maintain the inlet temperature of the slurry at 25 °C for all tests.

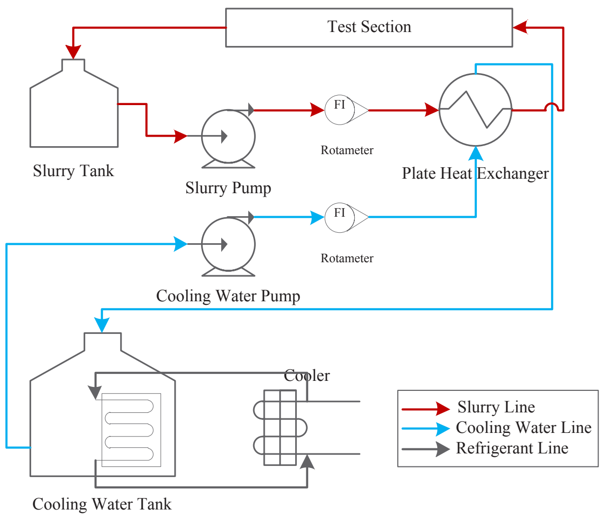


**Fig. 1. Schematic diagram of experimental setup.**

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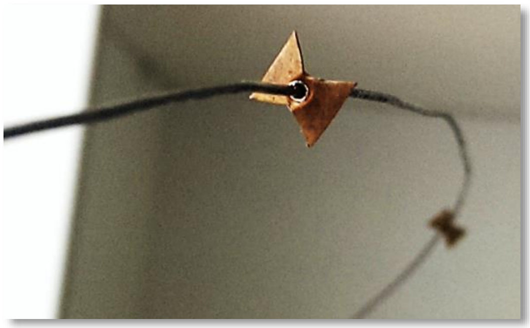

Fig. 2. Butterfly tube insert for using in copper tube.

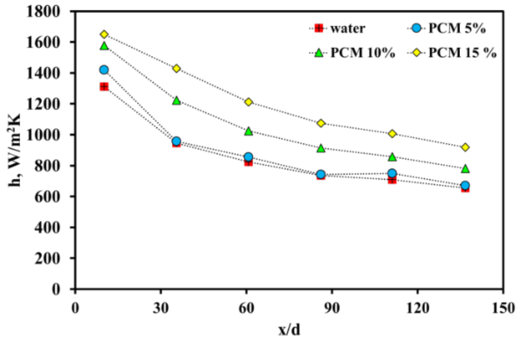


Fig. 4. Heat transfer coefficient with different slurry composition at Re=1500 and without butterfly tube insert.

Table 1. Turbine characteristics

| Property | Value | Unit |
|---|---|---|
| Melting temperature | 25 | °C |
| Solidification temperature | 24 | °C |
| Latent heat | 100 | kJ/kg |
| Density | 300-400 | $kg/m^3$ |
| Particle size | 50-300 | µm |

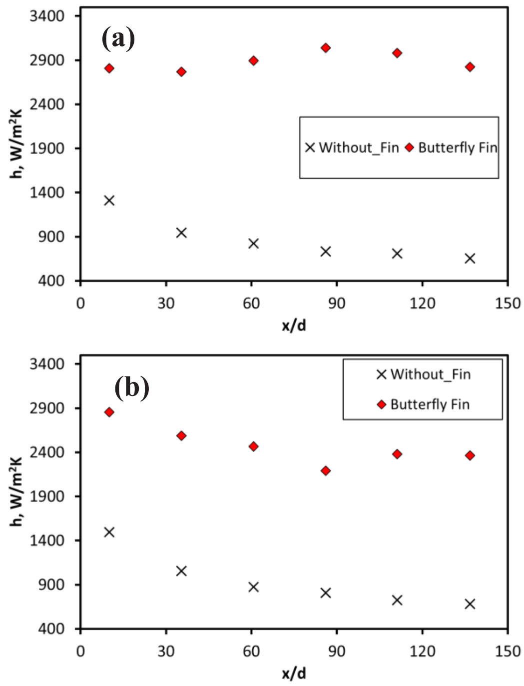


Fig. 5. The effect of using butterfly tube insert at Re=1500 for (a) pure water and (b) 10 wt% slurry

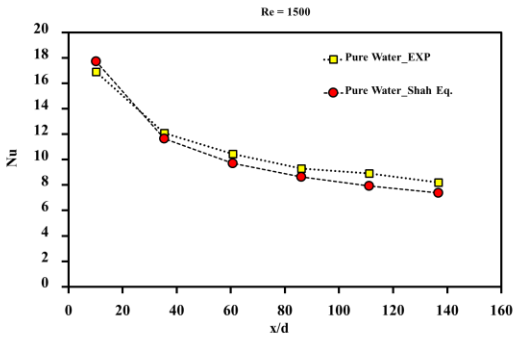


Fig. 3. Validation of the experimental setup

## 3- Slurry Preparation

Micronal® DS 5038X were used as MEPCM. Thermo-physical properties of MEPCM are presented in Table 1. Distilled water was used as working fluid. Four different weigh percent of 0, 5, 10, and 15 of MEPCM at water was prepared by gradually adding MEPCM to water and stirring the slurry.

## 4- Validation of the Experimental Setup

The accuracy and credibility of experimental setup was evaluated by comparing the results with the famous Shah relation [2]. The results are illustrated in Fig. 3. Results show that reasonably good agreement can be observed between the Shah equation and the measurements done in this work.

## 5- Results and Discussion

Fig. 4 shows the effect of adding MEPCM to water at laminar flow without butterfly tube insert. This figure indicated a positive effect of MEPCM on heat transfer coefficient. An average increment of 7.5, 20.7, and 38.9% for 5, 10, and 15 wt% slurry compared to the pure water was observed in heat transfer coefficient.

Fig. 5 compares the heat transfer coefficient for tube with and without butterfly tube insert. According to this figure, using the butterfly tube insert can increase the heat transfer coefficient about 234% and 180% for pure water and slurry, respectively.

## 6- Conclusions

This study is concerned with the convective heat transfer of water based MEPCM slurry in a tube with and without butterfly tube insert. The experimental results reveal that using butterfly tube insert in the tube can increase heat transfer coefficient considerably.

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