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A COMPARISON OF HEAT TRANSFER DURING FREE CONVECTION CONDENSATION OF STEAM ON HORIZONTAL COPPER INTEGRAL FIN AND PIN-FIN TUBES

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1. ABSTRACT

Condensation heat transfer is obtained on integral fin and Pin-Fin horizontal Copper tube using steam. Finned Copper tube having fin height and thickness of 1mm each and longitudinal pitch of 1.5mm was used while Pin-Fin tube had Pins of 1mm thickness and height while circumferential thickness was taken as 0.8mm at the root circle and 1.2mm at the top with circumferential and longitudinal pitch as 1mm and 1.5mm respectively. Results reveal that heat transfer rate increases with the introduction of fins on the outside of tubes. The results for heat transfer due to steam condensation is found to be best for Pin-Fin tube while integral fin tube shows higher heat transfer performance than that of plain tube.

2. INTRODUCTION

Film-wise condensation on the outside surface of horizontal tubes has been extensively studied by researchers for many years. The effectiveness of condenser tubes is influenced by the thermal resistance of vapor side, water side and tube wall. In general, vapor side and water side thermal resistance has more impact on heat transfer rate as compared to that of the tube wall. Enhancement in heat transfer on water side is possible by introducing turbulence in the flow using internal fins, twists and ribs [1]. Water side enhancement is usually disregarded due to its economical disadvantages, persuading the researchers to investigate vapor side enhancement. It has been found by various investigators that enhancement in condensation heat transfer can be achieved by employing different types of surface geometries over condenser tubes [2–4]. Cheng et al. [5] conducted a detailed study of condensation heat transfer over six different geometrically enhanced tubes. The heat transfer coefficient for three dimensional finned tubes was found to be greater than that of the two dimensional low finned tubes and strongly dependent on the temperature difference.

It is quite evident from the literature cited that a reasonable amount of experimental and theoretical data is available for enhancement of condensation heat transfer. Several investigators have worked on heat transfer enhancement using different fluids and surface geometries. In contrast, no experimental study has been performed for comparison of heat transfer rate between horizontal finned condenser tubes of different geometry. In the present work, three copper tubes with different surface geometries (plain, integral-fin, Pin-Fin) have been used to compare the heat transfer rate during condensation of high surface tension fluid, i.e. steam.

3. EXPERIMENTAL SETUP

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Apparatus

Fig. 1 shows the apparatus. It is a stainless steel apparatus with an inverted U-tube shape to let steam fall on the testing tube. On one side of U-tube is the electric heated boiler of approximately 3kW power. The other side of U-tube is the testing tube, placed horizontally and coolant would be flowing inside it. Steam would generate from boiler and through inverted U-tube would fall on the copper tube and would condense on it. The remaining steam, which could not condense on copper tube will fall further downward in the auxiliary condenser. This water, due to apparatus being a closed loop structure, will again be the feed to the boiler. Atmospheric pressures were maintained during the experiments and the velocity of vapor upon reaching the test section was 0.48 m/s. A window was kept at the test section with sight glass installed to watch the condensation process or even to record it. The apparatus was thermal insulated fully to avoid any loss of heat. The data was taken after achieving the steady state condition.

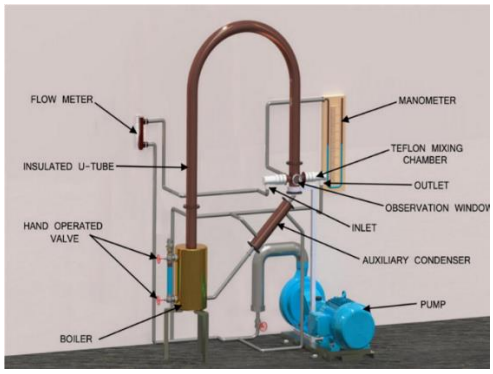

Fig. 1 Experimental Apparatus

4. RESULTS

Tests were performed on plain, integral finned and Pin-Fin tube at atmospheric pressure and saturated temperatures. Validity of these tests were proved by taking the results of condensation on plain horizontal tubes and comparing its results with Nusselt theory. The test showed results in accordance with the Nusselt theory of condensation on horizontal tubes. These results are repeatable as tests revealed identical results when performed at different days at different times.

Enhancement of heat transfer is shown in Fig. 2 through plot between heat fluxes and vapor-side temperature difference. Fig. 2 shows the results of condensing steam on Pin-Fin tube, integral fin tube and plain copper tube. The heat transfer rate of Pin-Fin tube and integral fin tube is higher than that of plain tube. All three tubes have same dimensions except for the increased area due to integral fin and Pin-Fin. This increased surface area allows more path for heat to transfer thus the heat fluxes to increase.

Enhancement ratios

Enhancement ratios have been calculated for Pin-Fin and integral fin tube. This is the ratio of heat flux of integral or Pin-Fin tube to the heat flux of plain tube at same vapor side temperature difference. Thus enhancement ratio can be found as

$$\varepsilon_{\Delta T} = \frac{\mathbf{B}\ \text{integral fin or pin fin tube}}{\mathbf{B}\ \text{plain tube}} \qquad (1)$$

Where $q = B\Delta T^{3/4}$, and constants B can be found through this equation.

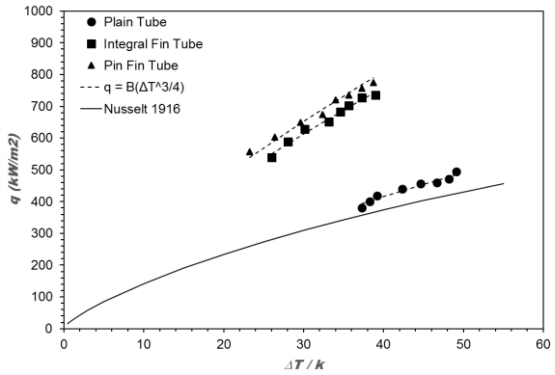

Fig. 2 (Comparison of Heat Fluxes)

Using the above explained method, the enhancement ratio of Pin-Fin tube is found to be 1.55 while that of integral fin tube is 1.49 against the plain tube.

5. CONCLUSIONS

The major findings of these experiments have been descried below:

- The heat transfer rate of plain tube was less than that of enhanced tubes.
- The Heat transfer for Pin-Fin Tube and Integral fin Copper tube has been found 35.77% and 32.96% higher than the plain tube respectively due to greater surface area.
- The heat transfer rate of Pin-Fin tube was found to be approximately 4% higher than that of integral fin tube. The reason can be explained due to the fact that Pin-Fin tube has lower flooding as compared to the integral fin tube.

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