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To Evaluate Falling Film Heat Transfer Coefficient on Horizontal Enhanced Tubes for Water Salt Mixture by Varying Heat Flux

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Abstract—*An experiment study was carried out for the falling film heat transfer of water and 10% by weight of salt in water salt solutions across horizontal smooth tube and two enhanced tube (i.e spline and spiral tube) in a certain range of heat flux at atmospheric pressure. An experimental study of falling film heat transfer outside horizontal tubes was carried out in order to show how the heat transfer coefficient is affected by different parameters such as flow density, temperature difference between wall and water, and mass concentration of the salt-water. Experiments were conducted using 19mm outer diameter and 100mm long cupper tubes heated by internal electric heaters so that a uniform heat flux was generated on the outside surface of tubes. As the heat flux is increased at Reynolds number heat transfer coefficient increases for the given tube(i.e smooth, spline and spiral tube) but as we compare with the given water-salt solution, the value of heat transfer coefficient decreases for the same heat flux for the smooth and the other two enhanced tubes.*

1. INTRODUCTION

Falling-film-type horizontal-tube evaporators have been utilized in the refrigeration, desalinization industries, chemical , petroleum refining and solar-powered absorption type chillers there are lot of experiments conducted and lot of theoretical and empirical correlations are available for calculating the heat transfer coefficient for smooth tube and helical tube. Chen [1], Lorenze and Yung [2] present analytical correlation for a single horizontal smooth tube. Yih and Liu [3],Chun[4] present numerical simulation for falling film heat transfer for a single smooth tube and bundle of smooth tube

The first study of falling film heat transfer was registered in 1888. before 1970 only a few researcher worked in this area. after 1970 this technology has been studied by many researcher. Between 1970's and 1980's water or ammonia is used as a working fluid. In air conditioning and refrigeration applications, the falling film evaporator possesses number of advantages over flooded tube bundles

1) Improves the cycle efficiency by allowing the increase evaporation temperature
2) Minimizing the evaporator size resulting reduced space and initial cost
3) Reduced the risk associated with leak. this result allow its application for toxic as well as for flammable fluid

Thome [5] in his literature review of horizontal-tube falling film evaporator, focusing on the technical difficulties like liquid distribution and tube alignment which cause flow non-uniformity and dry out

On the other hand there are lot of experiment have been conducted by using special enhanced surfaces like spiral tubes, splined tubes, knurled surfaces and porous matrix surfaces. Nakayama [6] and fujita and Tsutsui [7] carried out a lot of experiments on the various enhanced surfaces. In general the enhanced surfaces made by mechanical process are quite effective in increasing the heat transfer coefficient in low range of film Reynolds number but for very high film Reynolds these surfaces are not much effective on the other hand there are some enhanced tube which increases the heat transfer coefficient and used in the industries but there use is limited due to there high cost

Sometimes these tubes are ineffective in some type of special heat exchanger using impure water i.e. use water and salt mixture such as in desalination devices because the porous pores are easily blocked by the deposition particles with water

Nomenclature

d	tube diameter, mm
q_w	average wall heat flux, Wm^{-2}
Re	film Reynolds number, ($Re = 4\Gamma/\mu$)
T_l	liquid temperature at the exit of feeder, K
T_w	average wall temperature , K

ΔT temperature difference between tube surface and liquid ($\Delta T = T_w - T_l$)
h heat transfer coefficient ($h = q_w/\Delta T$), $Wm^{-2}K^{-1}$
Γ falling film mass flow rate per unit length on one side of tube, $kgm^{-1}s^{-1}$
μ dynamic viscosity, $kgm^{-2}s^{-1}$

Liu and Yi et al.[8] suggested the convective and the boiling regimes for the falling films. In the convective regime, h is constant, while in the boiling regime heat transfer coefficient increases with the heat flux. [9] using boiling –enhanced surfaces, and Zeng et al.[10] using finned and corrugated surfaces, observed the boiling regime only. On the other hand, Kuwahara et al.[11] pointed out a marginal effect of heat flux on a boiling enhanced surface despite the occurrence of the bubble nucleation.

In the present experiment, a spline and spiral groove tube was used as a new type of enhanced heat transfer tube. The working process for the tube was performed simply using lathe machine, and hence was low cost compared with various commercial enhanced tube.

This study evoked firstly the heat transfer of water and water-salt solution falling film on the smooth, spline and spiral grooved tube. The experimental results show that the spiral tube is an excellent heat transfer tube for the convective heat transfer for both the water and water-salt solution in comparison of spline and smooth tubeAt constant Reynolds number , as heat flux increases, heat transfer also increases for all the three tubes.

2. EXPERIMENTAL APPARATUS

Fig. 1 shows a schematic view of the exprimental apparatus used in this study. It consists of a liquid circulation system, pump, a liquid feeder, smooth and two enhanced tube (i.e spline and spiral) tubes in a test vessel, Rota-meter, temperature and heat flux controlling devices. The working fluid is pumped up from the reservoir to the feeder through the Rota-meter and regulating valve which maintain the film Reynolds Number. Here the fluid will be heated to a certain temperature by the heater placed in the reservoir, and then it passes through a regulating valve,

Rota-meter and then flows into the liquid feeder, from which the fluid is supplied at the desired flow rate in the form of sheets flow pattern to the constant heat flux heated tube. The distance between the feeder and the horizontal heated tube is 25mm. Fig. 2 shows an evaporation tube instrument with a heater inside and four thermocouples which have an outer diameter of 0.1 mm. The smooth tubes used in this experiment were made of Cupper with an outer diameter of 19 mm, inner diameter of 12 mm and length of 120mm (effective length 100mm). The spline tubes used in this experiment were made of Cupperwith an outer diameter of 19 mm, inner diameter of 12 mm and length of 120mm (effective length 100mm) and the 2mm width and 2mm depth slot are cut throughout its outer periphery with the cross-section angle between the slot is 30^0. The spiral tubes used in this experiment were made of Cupper with an outer diameter of 19 mm, inner diameter of 12 mm and length of 120mm (effective length 100mm) with helix angle 60^0 and pitch 0.6mm. Heat flux is provided by the heater 10 mm in diameter embedded inside of the tube. Two thermocouples are placed on the outer surface of the tube. Average measured temperatures at these locations were taken to be the tube wall temperatures. One thermocouple are placed inside the water reservoir tank. And they were used to define the heat transfer coefficients.

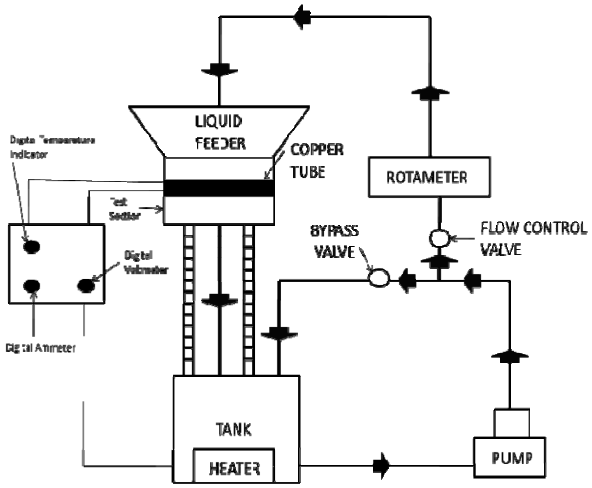
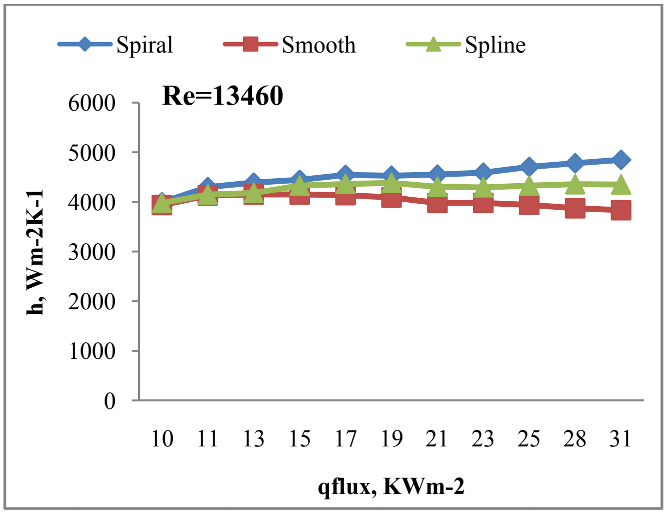


Fig. 1: Line diagram of experimental setup

3. EXPERIMENTAL RESULTS

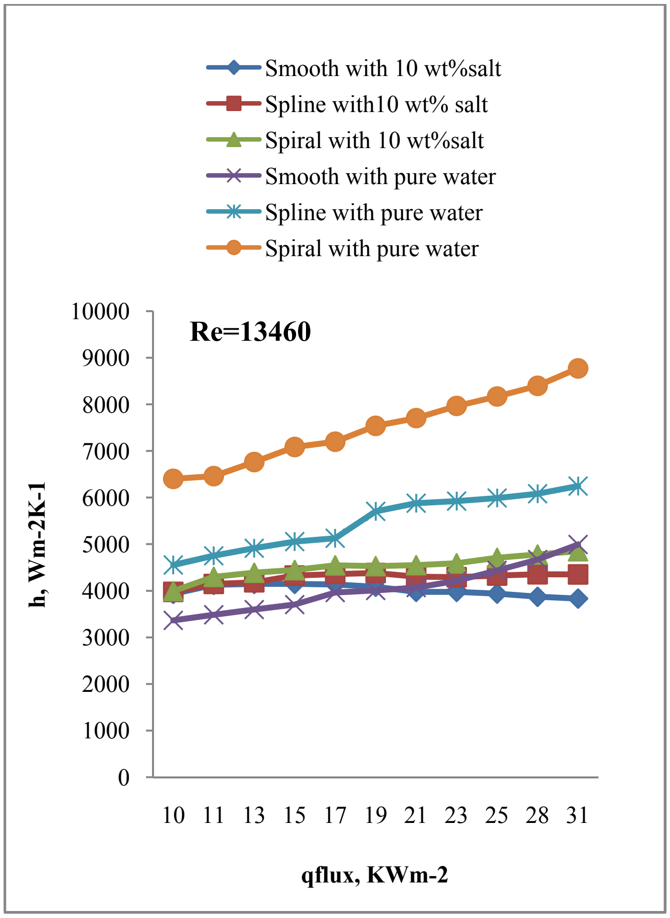
3.1 Effect of Heat Flux



As the heat fluxincreases, heat transfer coefficient increases for given Reynolds Number (13460)but increase in heat transfer coefficient does not show significant changes under low heat flux range i.e.below 30 KWm^{-2}.

3.2 Comparison with pure water and water-salt solution

At the given heat flux, the heat transfer coefficient for the pure water in little more than the water-salt solution. Because the salt-water solutions viscosity is a little more than that of pure water, so it affects the results of the heat transfer, the heat transfer coefficients of pure water is higher than that of salt-water solution.

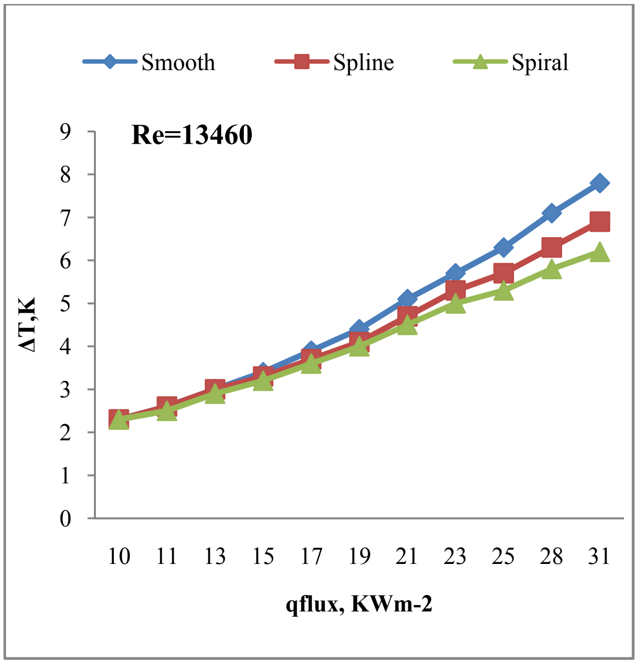


3.3 Heat transfer coefficient of the different tube:

From the above graph we can see that the heat transfer coefficient for the spiral tube is more than the spline tube and more than the smooth tube. In comparison of spline and the smooth tube, spiral tube has more heat transfer coefficient for the given heat flux.

3.4 Effect of temperature difference on Reynolds Number

From the above graph we can observe that as heat flux increases, the temperature difference between the heated tube and circulating water-salt solution increases.



4. CONCLUSIONS

Experiments were carried out on heat transfer coefficients of falling film horizontal heated tube. We can make the following conclusions:

1. Heat transfer coefficient for the spiral tube is more than the spline tube and then the smooth tube.
2. With the increase in salt percentage, heat transfer coefficient decreases for the given heat flux.
3. With the increasing of the heat flux, the heat transfer coefficient increases.
4. As heat flux increases, temperature difference between the tube and water-salt solution increases.

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