Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 2; January-March, 2015 pp. 109-113

http://www.krishisanskriti.org/jmsme.html

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

Piyush Kumar[1], Vipin Sharma[2] and Rajneesh[3]

[1]*Research Scholar Mechanical Engineering Dept. NIT, Kurukshetra*
[2]*Research Scholar Mechanical Engineering NIT, Kurukshetra*
[3]*Dept. Mechanical Engineering Dept.NIT, Kurukshetra*
E-mail: [1]piyush101289@gmail.com, [2]vipin322@yahoo.com, [3]rajneesh@nitkkr.ac.in

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 range of film Reynolds Number(13460-22745) 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 Reynolds Number is increased at constant heat flux(26511 Wm^{-2}), 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 Reynolds Number for the smooth and the other two enhanced tubes.*

1. INTRODUCTION

Falling film type (i.e sheet film) horizontal tube evaporators have been utilized in the refrigeration, chemical, petroleum refining and the desalination industries. This type of heat exchanger has been studied over the year in terms of effect such as liquid flow rate, the liquid distribution, flow pattern, tube spacing and heat flux etc.

Gorgy et al.[1] tested four different combination: R-134a on a smooth tube, R-123 on smooth tube, R-134a on Turbo-Bii HP tube and R-123 on Turbo-Bii HP tube and concluded that the heat transfer coefficient increases with increase in the heat flux for all the cases.Habert et al.[2] concluded the pool boiling performance of the Turbo-EDE2, Gewa-B4, Gewa-C LW and a plain tube using refrigerants R-134a and R-236fa at saturation temperature of 5, 10 and 20^{0}C and the study generated show the similar result with the literature in term of heat transfer coefficient.

Moeykens et al.[3] concluded that the enhanced surface gave higher result than finned tubes but lower performances than enhanced condensing surfaces used foe evaporation . they showed that an increase of heat transfer coefficient with heat flux up to a specific heat flux, after which, with further increase in heat flux, the heat transfer coefficient decreased ant this was probably due to partial dry-out.

Chien and Webb et al.[4,12] tested enhanced tube similar to the Turbo-B using R-11 and R-123. It was concluded that, at the low heat flux, the tube having smaller total open areas gave higher heat transfer coefficient and at the higher heat fluxes, tube having larger total open areas yielded higher heat transfer coefficient. Chien and Webb et al.[5] also performed a visualization study that supported these trends.

Fujita and Tsutsui et al.[5,6] defined the two flow modes as follows: a distinct droplet mode and a disturbed jet mode. They noted that the transition between the droplets and the jet mode occurred at Reynolds Number around 100 independent of feeding method. Hu and Jacobi et al.[7] suggested the following flow modes: the droplet mode, the droplet jet mode, an unsteady jet mode- characterized by a steadiness in the location of the jet departure site-the inline jet mode, the staggered jet mode, the jet-sheet mode, and the sheet mode.

Nomenclature

d	tube diameter, mm
q_w	average wall heat flux, Wm^{-2}
Re	film Reynolds number, ($Re = 4\Gamma / \mu$)
T_1	liquid temperature at the exit of feeder, K
T_w	average wall temperature , K
ΔT	temperature difference between tube surface and liquid ($\Delta T = T_w - T_1$)

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. They also suggested that the both regime is independent of the surface configuration. Wang et al.[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 tube. At constant heat flux , as Reynolds Number increases, heat transfer also increases for all the three tubes.

2. EXPERIMENTAL APPARATUS

Fig. 1 shows a schematic view of the experimental 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

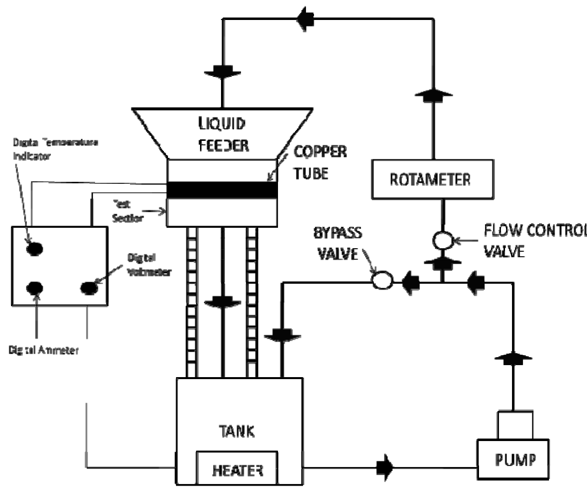
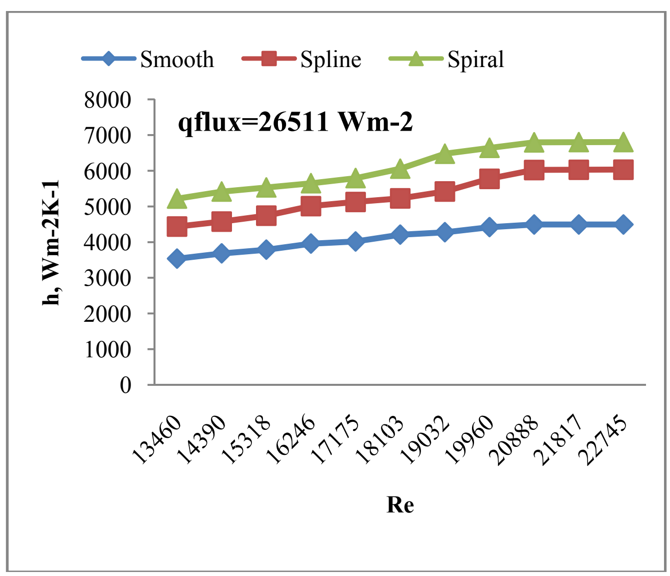


Fig. 1: Line diagram of experimental setup

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.

3. EXPERIMENTAL RESULTS

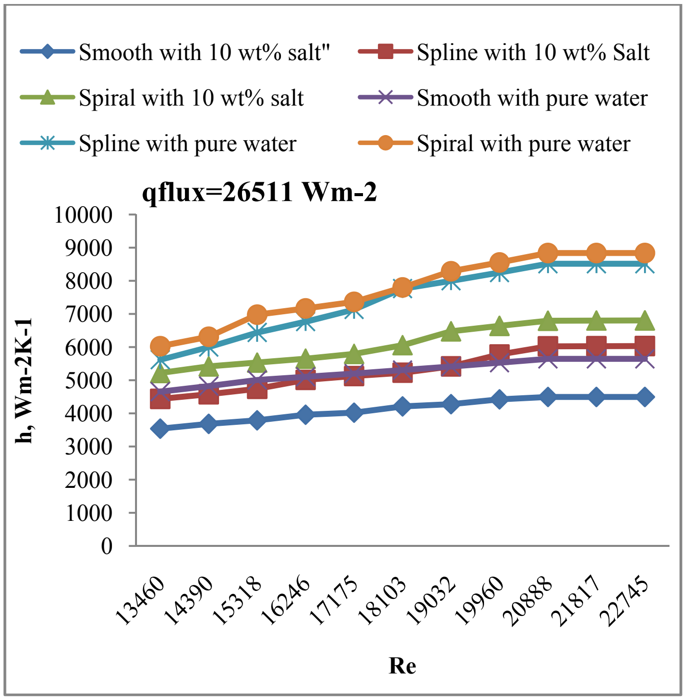
3.1 Effect of Reynolds Number



As the Reynolds Numberincreases, heat transfer coefficient increases in the range of Reynolds Number (13460-19960) and beyond this Reynolds Number the heat transfer coefficient remain constant for the given heat flux. As the Reynolds Number increases there is greater fluctuation of the fluid over the heating tube which enhances the convective heat transfer

3.2 Comparison with pure water and water-salt solution

At the given Reynolds Number, the heat transfer coefficient for the pure water in little more than the



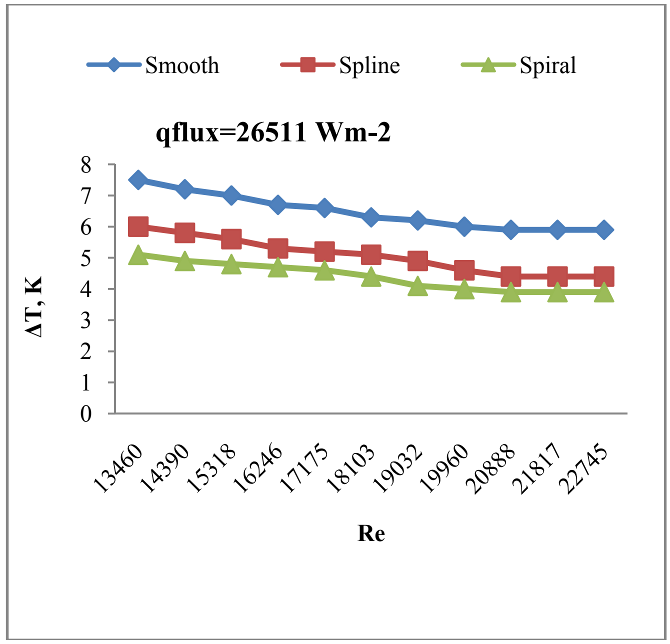
water-salt solution. Because the salt-water solutions viscosity is a little more than that of pure water, so it affects the results of the heat transfer, the heat transfer coefficients of pure water is higher than that of salt-water solution.

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 and Reynolds Number.

3.4 Effect of temperature difference on Reynolds Number

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



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. As the Reynolds Number, heat transfer coefficient increases first and then remain constant for the given heat flux.
3. With the increase in salt percentage, heat transfer coefficient decreases for the given Reynolds Number and heat flux.
4. As Reynolds Number increases, temperature difference between the tube and water-salt solution decreases.

REFERENCE

[1] Gorgy, E.I., 2008. Pool boiling of R-134a and R-123 0n smooth and enhanced tubes. Master`s thesis. Kanass University, Department of Mechanical and Nuclear Engineering.

[2] Habert, M., 2009. Falling Film Evaporation on a Tube Bundle with Plain and enhanced tubes. Ph.D. Thesis. EcolePolytechniqueFederale de Lausanne, Laboratory of Heat and Mass Transfer, Lausanne, Switzerland.

[3] Moeykens, S.A., Huebsch, W.W., Pate, M.B., 1995. Heat transfer of R-134a in single tube spray evaporation including lubrificant effect and enhanced surface results. ASHRAE Trans. 101, 111-123.

[4] Chien, L.H., Webb, R.L., 1998a. A parametric study of nucleate boiling on structured surfaces, part 1: effect of tunnel dimensions. J. Heat Transfer 120, 1042-1048.

[5] Y. Fujita, M. Tsutsui, Experimental and analytical study of evaporation heat transfer in falling films on horizontal tubes, Proceedings of the 10th international heat transfer conference, Brighton, vol. 6 1994, p. 175-80.
[6] Y. Fujita, M. Tsutsui, Evaporation heat transfer of falling films on horizontal tube. Part 2.Experimental study, Heat Transfer – Jpn Res 24 (1995) 17-31.
[7] X. Hu, A.M. Jacobi, The intertube falling film. Part 1. Flow characteristics, mode transitions, and hysteresis, J Heat Transfer 118 (1996) 616-625.
[8] Z.H. Liu, J. Yi, Enhanced evaporation heat transfer of water and R-11 falling film with the roll-worked enhanced tube bundlie, Exp Thermal Fluid Science 25 (2001) 447-455.
[9] G. Wang, Y. Tan, S. Wang, N. Cui, A study of spray falling film boiling on horizontal mechanically made porous surface tubes, Proccedings of the international symposium of heat and mass transfer enhancement and energy conservation(ISHTEEC), Guangzhou, 1988, p. 425-32.
[10] X. Zeng, M. C. Chyu, Z. H. Ayub, Ammonia spray evaporation heat transfer performance of single long-fin and corrugated tubes, ASHRAE Trans 104 (1A) (1998) 185-196.
[11] H. Kuwahara, A. Yasukawa, W. Nakayama, T. Yanagida, Evaporative heat transfer from horizontal enhanced tubes in thin film flow, Heat Transfer-Jpn Res 19 (1990) 83-97.