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Study of water falling film over horizontal drop shaped and inverted drop shaped tubes

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ABSTRACT

In this paper, computational modeling of water falling film over two horizontal drop shaped and inverted drop shaped tubes was carried out under adiabatic condition. Numerical simulations were performed using Computational Fluid Dynamics (CFD), FLUENT for 2D models. The Volume of Fluid (VOF) technique was adopted to investigate the influence of different tube spacing ranging from 10 mm to 20 mm and Reynolds number ranging from 800 to 1960 on the water film distribution and velocity profile. We also analyzed the water-air interference and motion of water film falling technique. The variation of velocity profile of water film over drop shaped & inverted drop shaped tube was analyzed. The computational modeling was carried out at 27 ^{o}C temperature and ambient pressure. The numerical investigation showed that minimum value of water falling film thickness appeared approximately at 150^{0} and 140^{0} for drop shaped tube and inverted drop shaped tube respectively and investigation was performed from 20^{o} to 160^{o} for circumferential angle of tube. It was also seen that water film falling thickness was different for upper and lower part both for the geometries.

Keywords: Adiabatic Condition,CFD Simulation, Drop Shaped Tube,Horizontal Tube,VOF

I INTRODUCTION

Water film falling around horizontal tube is widely used in various industrial processes like heat exchanger, food drying and air conditioning industry. This kind of arrangement is useful when temperature gradient between water liquid and heating medium is less than 8 ^{o}C to 9 ^{0}C. When a liquid is sprayed uniformly to top outside of horizontal tube, it flows from one tube to another and falls off the bottom. The process in which fluid flows from one tube to another under gravitational effect is known as falling liquid film. Asbiket. al. [1] studied laminar flow for non- Newtonian falling liquid for isothermal surface using implicit finite difference method. They also investigated solution mass flow rate, cylinder diameter and inlet temperature for non-Newtonian liquid. Shenet. al. [2] studied the asymmetric distribution of falling film which contradicts the Nusselt theory. They concluded that effect of momentum cannot be ignored. Mitrovicet. al. [3] explained that film thickness is uniformly distributed along apex of upper part of tube, when convective heat transfer is neglected. Cheng et. al. [4] studied water film falling around non- circular shaped tube. They also studied different patterns of flow on tubes. Wu et. al. [5] analyzed film thickness using displacement micrometer. They carried out about validation of Nusselt theory with small consideration. They also analyzed of pure water with respect to sea water. Gao et. al. [6]

studied two intermediate and three principal transition mode and also explained the influence of tube spacing on hydrodynamics characteristics of flow. Many researchers also found that when water falls off from horizontal tube the distribution of velocity in lower and upper parts of tube are not symmetric and velocity profile on bottom part of tube tends to be greater. On increasing Reynolds number falling film thickness also increases. The falling film thickness is also affected by tube pitch.

Now a day, while most of the studies focus on the horizontal circular tubes, more attention is needed for non-circular tube like drop shaped and inverted drop shaped tubes. In this present work the superiority of non-circular drop shaped tubes and their orientation is demonstrated. The falling film distribution around tubes, velocity profile, effect of mass flow rate and liquid water feeder height are also investigated.

Nomenclature

δ	falling film thickness
μ	dynamics viscosity of liquid
L	liquid feeder height
Γ	mass flow rate of liquid per unit side
ρ_L	density of liquid
ρ_G	density of gas
g	gravitation constant
β	circumferential angle

II NUMERICAL APPROACH

In this present work numerical simulations of water falling film over horizontal drop shaped and inverted drop shaped tubes of same exposed heat transfer area are carried out using ANSYS FLUENT 15.0. It is assumed that the flow of film falling water over tubes is viscous, incompressible and influenced by gravity. In the simulation process, the evaporation & condensation at liquid-vapour interface are neglected. The results of numerical analysis are ended when each flow a model has been completely transformed into sheet flow mode under steady state, all results must be conserved before analysis ended. The physical properties of water and air are considered at 27 ^oC temperature and pressure of 1 bar.

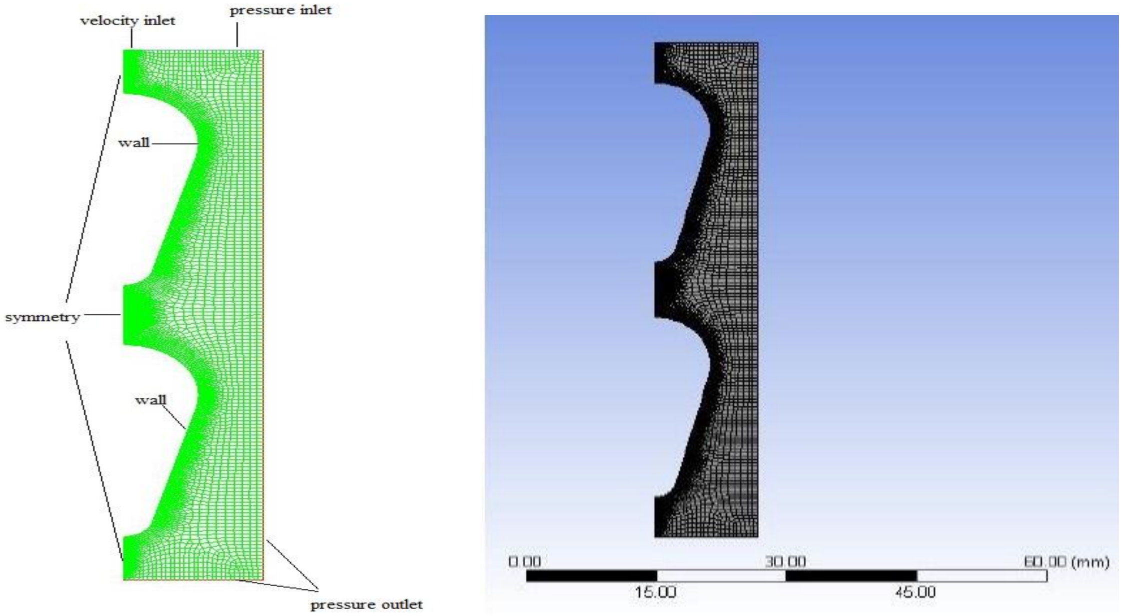


Fig.1 Half domain of drop shaped tubewith meshing

The half symmetric domain for both drop shaped and inverted drop shaped tube is considered for analysis to save computing time as shown in Fig. 1. The solution domain is discretized to quadrilateral elements. The total number of mesh elements and time step are 8226, 9668, 10682 and 0.0001s respectively. The wall and symmetrical edges are meshed using edge sizing technique with 0.1 mm mesh refinement size. The extreme left size of domain solution is set as velocity inlet for water flow and remaining set as pressure inlet; the bottom side is set as pressure outlet with specified pressure as shown in Fig. 1. The tube wall is considered to be no slip, smooth without heat flux. The volume fraction of liquid water at entrance is set as 1 with wall contact angle set as 0 for complete wetting of wall of domain. In this simulation inlet slot width and liquid velocity considered 3mm and 0.1 to 1 m/s respectively. The explicit finite volume method is employed for analysis of water film falling over cylinder and drop shaped tube. The continuity and momentum equations are integrated for numerical solution and discretized by second-order upwind scheme with PISO, pressure-velocity coupling. The volume fraction set as Geo-Reconstruction under default relaxation fraction.

III EQUATION

A number of methods have been used to measure the thickness of liquid films, including contact methods, adding radioactive additives, light absorption, capacitance methods, electrical conductivity, shadow methods, fluorescence methods, and other optical methods. The thickness of falling film can be given by the following relation;

$$\delta = \left(\frac{3\mu_L \Gamma}{\rho_L(\rho_L - \rho_G) g.\sin\beta}\right)^{1/3} \quad (1)$$

IV RESULTS AND DISCUSSION

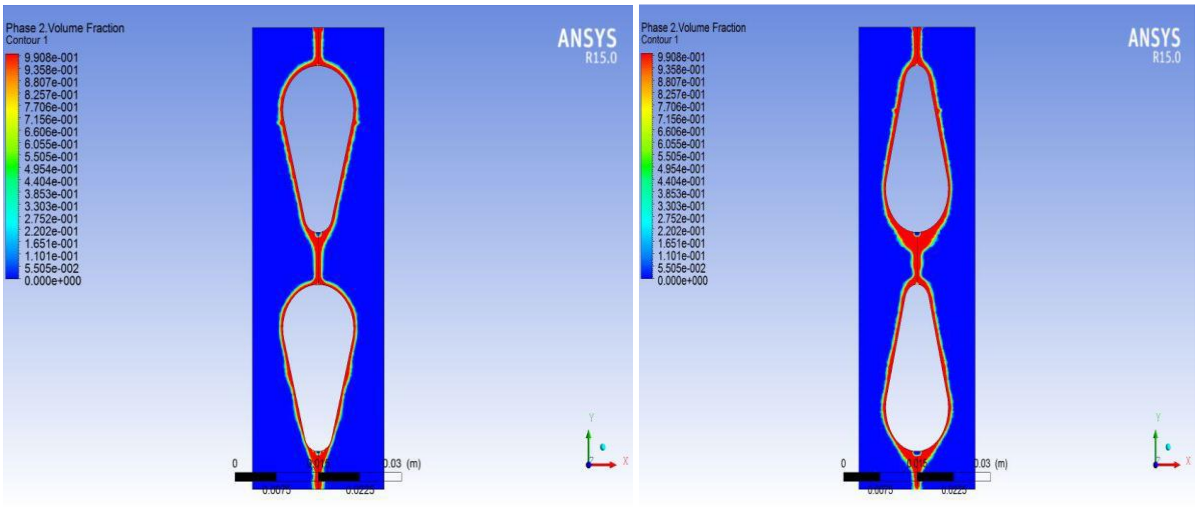


Fig. 2 Water falling film distribution over drop shaped and inverted drop shaped tubes at 0.34801

Fig. 2 shows the water falling film distribution around circumference of drop shaped and inverted drop shaped tubes by (1). Our simulation results suggest that both the intertube spacing effect and momentum effect, when β > 90^0, must be taken into consideration in developing a film thickness correction for a liquid film distribution around horizontal tubes. It depends on Reynolds number as it increases the separation point size becomes large. It also depends upon the curvature of geometry, for inverted drop shaped tube it is smaller and for drop shaped tube it is large.

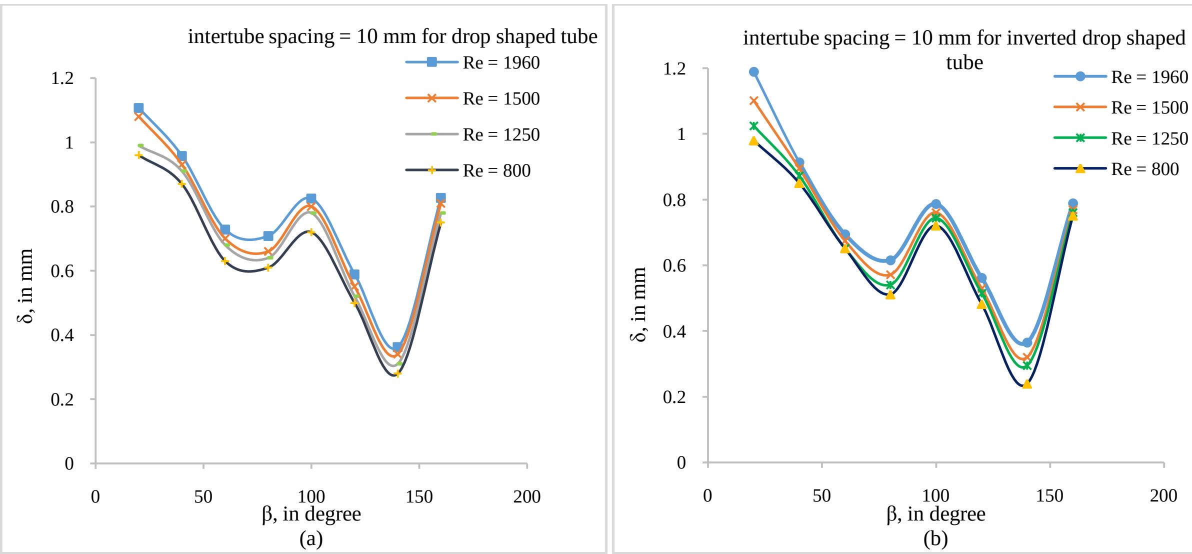
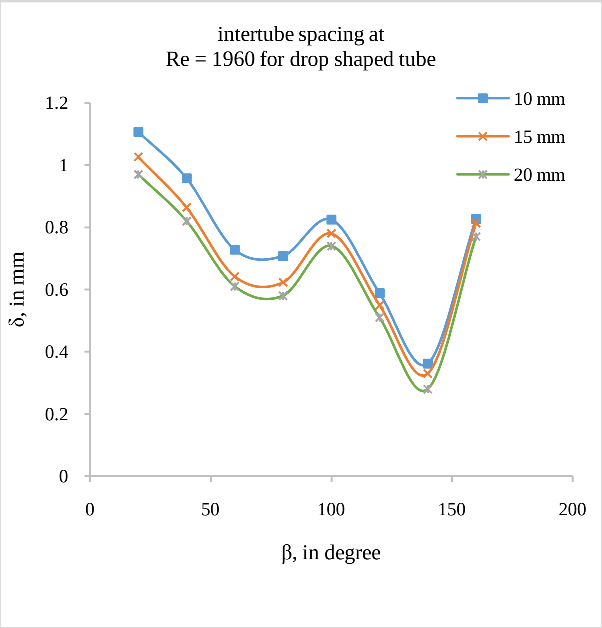


Fig. 3 Effect on water falling film thickness at different Reynolds numbersfor (a) drop shaped tube (b) inverted drop shaped tube



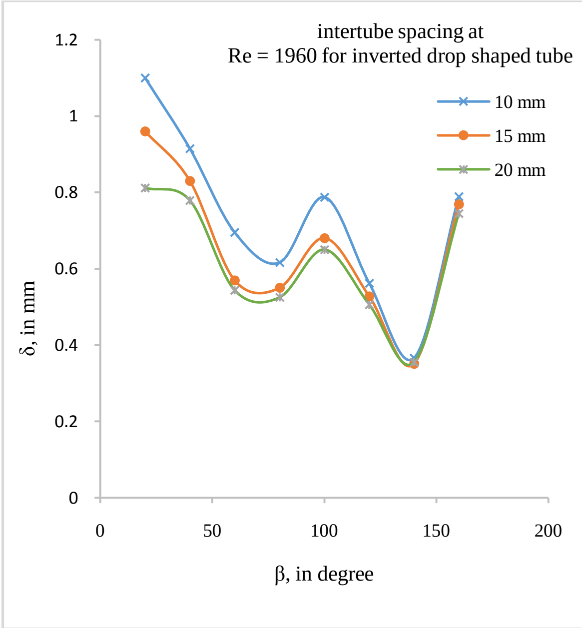


Fig. 4 Variation of water film thickness at different intertube spacing (a) drop shaped tube (b) inverted drop shaped tube

Fig. 3 shows the effect of Reynolds number on the water falling film thickness over drop shaped and inverted drop shaped tubes at 10 mm intertube spacing while Fig. 4 shows for intertube spacing at 1960 Reynolds number.When intertube spacing increases the free falling time of water from one tube to another tube increases and due to gravitational force it gets accelerated. Hence we get thinner water film thickness at large intertube spacing and thicker at small intertube spacing. Water falling film thickness is also influenced by mass flow rate or Reynolds number.

V CONCLUSION

It is found for the simulations that were carried out for drop shaped and inverted drop shaped tube. The water film thickness of drop shaped tube is always greater than circular tube. The velocity profiles on lower and upper parts of symmetric tube are not exactly similar. It attains steady state as it covers full surface. It gets two separation points on lower and upper part of tubes in both cases. The water gets accumulated on lower part of the tube due to inertia. Water film thickness depends on Reynolds number and tube spacing as Reynolds number water film thickness increases while on increasing tube spacing water film thickness decreases.

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