

Investigation of Flow Stability of Baffled Pipe - A Comprehensive Report

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ABSTRACT: The baffles play an important role in heat and mass transfer phenomenon, this improve the performance on implementing this in the flow path. In this paper the applicability of baffles in different engineering application has been briefly discussed. In presence of baffles; secondary flows takes place and the viscous sub layer breaks during fluid flow through channel or pipe, which ultimately improve the mixing and heat transfer characteristics. Several experiential, computational and numerical analyses have been carried out by the various researchers to investigate the applicability of baffles. Furthermore, various co relations have been developed by the researchers in terms of Nusselt number, friction factor for different configuration of baffles, which are briefly illustrated in this comprehensive report.

KEY WORDS: Baffles, CFD, Heat and Mass transfer, Shell and Tube Heat Exchanger, Solar Air Heater

I. INTRODUCTION

In heat exchanger, baffles are the important structural element which acts as an obstruction. A baffle helps in diverting the flow so as to take the advantage of mixing, momentum transfer and formation of secondary flow. It is generally used in various engineering applications. Some engineering applications are solar air heater, mixer, cooling ducts etc. Navier-stokes equation has been used for fluid flow in baffled channel, duct, pipe etc. and governed by the Bernoulli's equation of flow. Moreover, a set of partial differential equations are used in finite difference approach and other iterative approaches (Yadav et al., 2017).

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + \text{div}(\mu \text{gradu}) + S_{Mx} \quad \dots\dots (1)$$

$$\rho \frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + \text{div}(\mu \text{gradv}) + S_{My} \quad \dots\dots (2)$$

$$\rho \frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + \text{div}(\mu \text{gradw}) + S_{Mz} \quad \dots\dots (3)$$

For compressible Newtonian fluid the equation of motion can be given as in term of energy and momentum equation.

$$\text{Continuity: } \frac{\partial \rho}{\partial x} + \text{div}(\rho u) = 0 \quad \dots\dots (4)$$

$$\text{x-momentum: } \frac{\partial(\rho u)}{\partial x} + \text{div}(\rho uu) = -\frac{\partial p}{\partial x} + \text{div}(\mu \text{gradu}) + S_{Mx} \quad \dots\dots (5)$$

$$\text{y-momentum: } \frac{\partial(\rho v)}{\partial y} + \text{div}(\rho vu) = -\frac{\partial p}{\partial y} + \text{div}(\mu \text{gradv}) + S_{My} \quad \dots\dots (6)$$

$$\text{z-momentum: } \frac{\partial(\rho w)}{\partial z} + \text{div}(\rho wu) = -\frac{\partial p}{\partial z} + \text{div}(\mu \text{gradw}) + S_{Mz} \quad \dots\dots (7)$$

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Energy equation:
$$\frac{\partial(\rho i)}{\partial t} + \text{div}(\rho i u) = -p \text{div} u + \text{div}(k \text{grad} T) + \Phi + S_i \quad \dots\dots (8)$$

II. LITERATURE REVIEW

Richman et al. (1973) investigate the modeling of break-up in an inhomogeneous flow in concentric restriction of a pipe using Euler-Lagrange method for simulations of the drop motion of interface deformation model. While, the interface deformation is computed by Rayleigh–Lamb type oscillator forced. The fluid properties, turbulent flow statistics and break-up probability calculations have taken to compare with the experimental data.

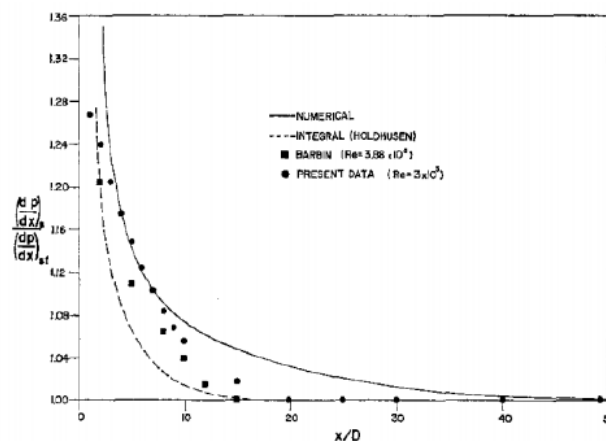


Fig. 1: Pressure gradient ratios in developing flow, $Re = 3 \times 10^5$.

Kang et al. (2012) has analyzed the flow instability in heat exchangers with simple geometry of baffles. To verify the effect of baffles aspect ratio, a parametric analysis has been done with taking in consideration of baffle interval and variable Reynolds number. The main aim for stability analysis is to investigate the secondary instability in three-dimensional flow. Finally the results are compared with computational result and showing good agreement.

Chen et al. (2012) represents a novel heat exchanger with baffles to improve the thermal performance with separation of liquid vapor in comparison to conventional fin –tube heat exchanger. To study the optimal capillary tube length and refrigerant charge amount, experimental data has considered for both of the heat exchanger. The obtained result shows that the energy efficiency ratio and cooling capacity of the novel heat exchanger has been comparatively better.

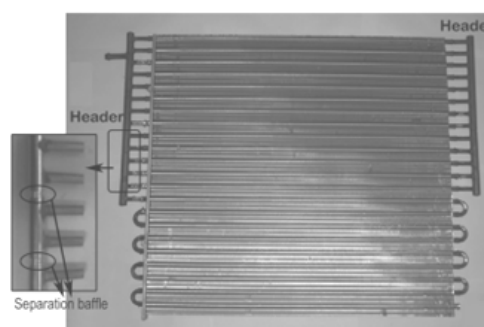


Fig. 2: Picture of the condenser with liquid vapor separation baffles.

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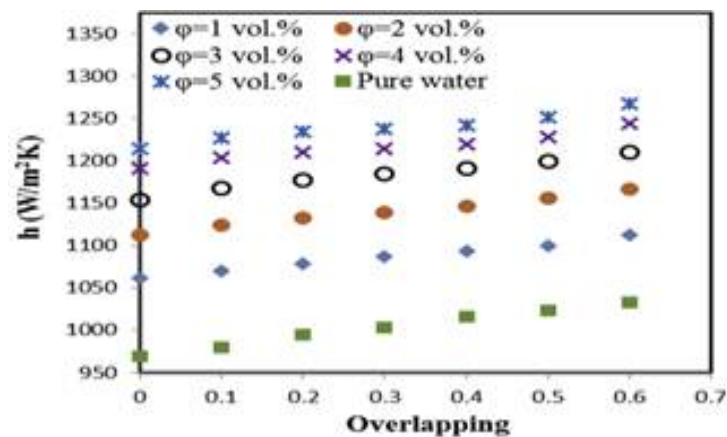


Fig. 3: Convective heat transfer coefficient in terms of baffle overlapping at different concentrations

Mehdi et al. (2015) has investigate two phase mixture (nano-fluids water-alumina) model for evaluation of hydrothermal behavior of nano-particle and helical baffle overlapping, which directly influence the pressure drop and heat transfer for a shell and tube type heat exchanger which contain helical baffles as shown in figure 3. Pressure drop and convective heat transfer coefficient has calculated by the neural network model, the mean relative error is 0.65% for pressure drop and 0.089% for convective heat transfer coefficient.

Bin et al. (2015) investigate the effects of baffle helix angle on shell-side performance of shell and tube heat exchangers with wide range of helix angles and discontinuous helical baffles. A second-law based thermodynamic analysis has been conducted to investigate the effects of baffle helix angle on the irreversible loss of heat exchangers. The results shows that the shell-side pressure drop and heat transfer coefficient of the shell and tube type heat exchanger with larger helix angle are lower than those with smaller helix angle at a given shell-side volume flow rate.

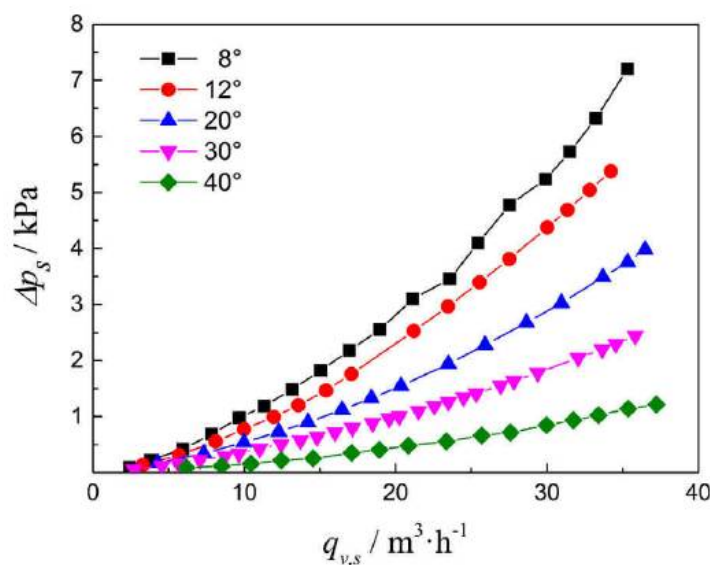


Fig. 4: Pressure drop in shell-side tube bundle zone versus volume flow rate.

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Kwon et al. (2016) conducted a series of experiment and computational analysis to investigate the influence of low velocity and effect of baffles on the composite box enclosing water and baffles as shown in figure 5. The result for fluid structure interaction shows that the structural response varying with the water level and the position of baffles also affects the performance.

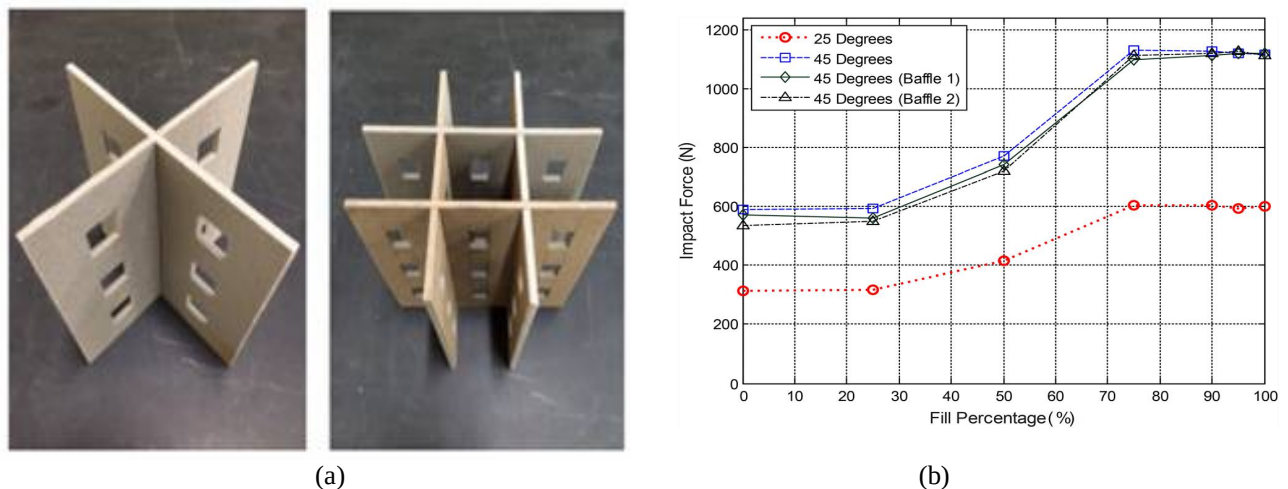


Fig. 5: (a) baffle 1: cross-shape baffle and baffle 2: box-shape baffle (b) Plot of maximum impact force for different water fill levels and baffle type.

Afaq (2017) conducted series of experiments to investigate the convective heat transfer characteristics for a double pass solar air heater with different number of transverse baffles in the lower collector channel and examine the influence of air flow rate and number of baffles in terms of thermal efficiency. The maximum efficiency (i.e. 68%) has been achieved with seven number of baffles. this experiment shows that thermal performance of double pass solar air heater with transverse baffles gives better performance than conventional double pass solar air heater.

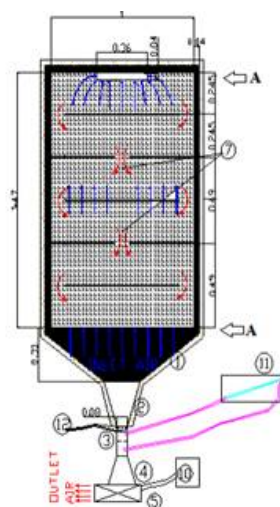


Fig. 6: Schematic assembly of the double-pass solar air heater with five baffles

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Li et al. (2017) experimentally investigated the affect of particle size and its distribution on two pass circulating baffled fluidized bed evaporator by using image processing technique along with the acquisition system. The particle distribution has been uniform in up-flow bed while the uneven sized particle stales at the down flow bed. The uniformity of the big-particle size can be enhanced by using higher flow rate.

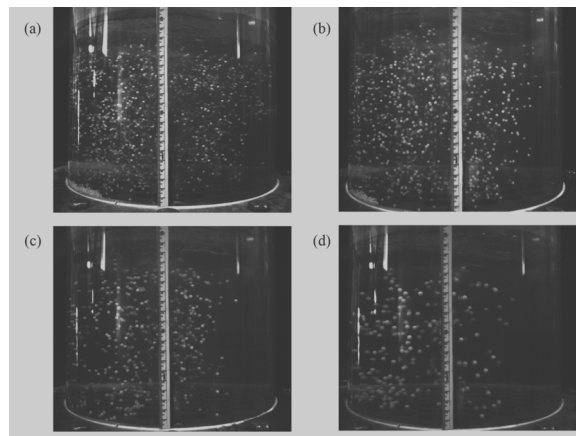


Fig. 7: Particle distribution in the evaporation chamber

Yu et al. (2017) proposed a novel arrangement of baffles in rotating drum for industrial application based on discrete element method to investigate the mixing characteristics of rotating drums with alternately arranged baffles as shown in figure 8. It shows that the alternately arranged baffles gives better axial mixing performance than drums with (or without) traditional baffles, and through a suitable choice of baffle number and dimension maximum mixing

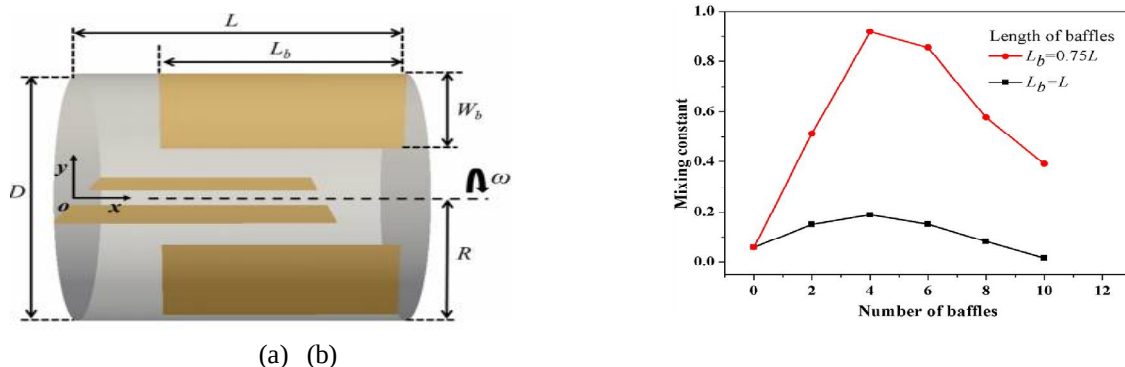


Fig. 8: Schematic diagram of the alternately arranged baffles and effects of baffle number on the mixing constant of drums with different baffle

III. CONCLUSIONS

On the basis of comprehensive report following conclusions has been drawn which shows the advantage and merits of using baffles in various engineering application.

- As number of baffles increases temperature difference, thermal efficiency increases for constant air flow rate in solar air heater.
- As Reynolds number increases, the presence of baffles in the fluid flow path increases the turbulence intensity.
- By decreasing Helix angle of baffles the heat transfer characteristics can be improved.
- Overlapping of baffles also results in improving thermal performance of baffles equipped ducts.

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- The heat transfer coefficient decreases as baffle spacing increasing for a constant mass flow rate.
- The pressure gradient decreases, as the space between baffles increases.
- At a certain baffle spacing the thermal performance decreases, therefore optimum spacing should be evaluated.
- Baffles height and inclination also helps in improving thermo hydrodynamics characteristics

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