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A Review of the Effect of Baffles Geometry on Heat Transfer Enhancement Techniques

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Abstract

The thermal performance of a heat exchanger depends upon various parameters like inlet temperature of a hot fluid, type of hot fluid, type of cold fluid, shape of baffles, material of baffles, baffles angle and property of ribs. Basically fluid flow and heat transfer characteristics are largely depends upon the Reynolds number (Re). Reynolds number is basically the ratio of inertia force to viscous force. Re is only the factor by which we can decide whether the fluid is laminar or turbulent in shell and tube type of heat exchanger. Heat exchanger is an adiabatic device in which heat is transferred from one fluid to another fluid across a plate surface. In this paper we have introduced some special type of triangular baffles with rectangular channels. The purpose of this apparatus is to enhance the performance of the heat exchanger. Heat exchangers, nowadays, are one of the most important heat & mass transfer apparatus in industries like oil refining; heat treatment plants, electric power generation etc. are long service life.
Keywords: Heat Exchanger, Ribs, Baffles, Reynold no., Tubbulent flow

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I. INTRODUCTION

Heat exchangers have always been an important part to the lifecycle and operation of various systems. A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy.

Mainly heat exchangers are of two types:

- Direct contact type of heat exchanger, where both media between which heat is exchanged are in direct contact with each other.
- Indirect type of heat exchanger, when both media are separated by a wall through which heat is transferred so that they never mix.

Heat transfer enhancement methods are broadly classified into three major groups:

1) Active method: In this method some external power input is required for heat transfer in the heat exchanger. Some examples of active method include flow in a impeller of a centrifugal pump.
2) Passive method: In passive heat transfer method no external power input is needed. Some example of this method are rough surfaces, flow in washbasin etc.
3) Compound method: The combination of active and passive methods is the compound method.

These are the various components of the heat exchanger which effect the thermal performance of the apparatus

A. Ribs
Placing ribs sporadically on the heat transfer surface increases the turbulence and since these ribs are small they do not disturb the core flow hence a high heat transfer performing surface could be achieved without incurring the penalties of frication and pressure drop .

B. Baffles
Inserting baffles into the heat transfer devices promote mixing of coolants. These baffles can greatly disturb the bulk flow

C. Extended Surfaces
Use of heat sink such as fins increases the surface area in contact with the coolant. These extensive dissipation area are widely recognized to improve the heat transfer. Variety of examples are louvered fin, plain fin, offset-strip fin, wavy fin, etc.

D. Twisted Tapes and Wire Coils
Spiral tapes are metallic strips twisted in some ratio known as twist ratio, inserted in the flow.

Wire coil inserts are made by tightly wrapping a coil of spring wire on a rod. When the coil helix is pulled up the wires forms a helical roughness. This section includes such surface which has fin scales or coating which may be continuous or discontinuous. It also includes rough surfaces which promotes turbulence in the flow field. It involves high velocity jet to cool directly the surface of inserts. It also includes the direction of heating or cooling fluid perpendicularly or obliquely to the heat transfer surface

E. Additives
These include addition of gas bubbles, solid particles, liquid droplets, , etc. which are introduced in single phase flow. Additive for gas is introduced as a dilute phase (gas solid suspension) or as dense phase (fluidized bed). Liquid additives usually depress the surface tension of liquids for boiling system.

II. VARIOUS TYPES OF BAFFLE GEOMETRY

Huge number of baffle geometries has been proposed for the use in heat exchanger channel and more are still being developed Common Attributes of Baffles are

1) Shape: The majority of the baffles found in literature are square, rectangular, triangular, helical or wedge shaped in the present work rectangular baffles have been studied.
2) Height: Small height baffles are chosen to minimize the pressure drop.
3) Spacing: It is the distance between two successive baffles.
4) Perforations: Perforations are the holes or slots in the baffles which causes less resistance against the stream and improve heat transfer and pressure drop over the channel.
5) Porosity: Porous medium can be defined as a material consisting of a solid matrix with an interconnected void. Due to its structural stiffness and light weight, thermal management can be used for in aerospace applications.

A. Types of Baffles
Implementation of baffles are decided on the basis of cost, size, and their ability to lend support to the tube bundles and direct flow, Often this is connected to available pressure drop and the size and number of passes within the exchanger. Special allowance changes are made for finned tubes. The special types of baffles:

- Diamond Shaped baffles
- Z-Shaped baffles
- V-baffles
- 45° inclined baffles
- Porous baffles

III. GOVERNING EQUATIONS

The steady state of the heat transfer rate is implicit to be equal to the heat loss from the test section which can be expressed as:

$$Qair = Qconv \quad (1)$$

Where, $$Qair = Cp,a\,(To-Ti) \quad (2)$$

$$Qconv = hA(\,Tw - Tb) \quad (3)$$

Where, $$Tb = (To + Ti)/2 \quad (4)$$

$$Tw = \sum Tw/N \quad (5)$$

Where, N – Total number of thermocouples or resistance temperature detectors between inlet and exit of the test section and evaluation is done at the outer wall surface of the inner tube.

The convective heat flux is implicit to be uniformly distributed over the heated wall tube and can be evaluated as:

$$Qconv = hA\,(Tw-Tb) \quad (6)$$

Where,

$$Tb = (To + Ti)/2 \quad (7)$$

The averaged heat transfer coefficient, *h* and the mean Nusselts number, *Nu* are estimated as follows:

$$h = m.\,Cp,a(To-Ti)\,/\,A(\,w-Tb) \quad (8)$$

The averaged heat transfer coefficient, *h* and the mean Nusselts number, *Nu* are estimated as follows:

$$h = m.\,Cp,a(To-Ti)\,/\,A(\,w-Tb) \quad (9)$$

$$Nu = \frac{hD}{k} \quad (10)$$

The Reynolds number is given by,

$$Re = \frac{uD}{v}$$

IV. REVIEW OF WORK CARRIED OUT

Literature survey of work carried out by various authors using heat transfer enhancement techniques.

1) Somchai Sripattanapipat and Pongjet Promvonge,Conducted a numerical study of laminar periodic flow, the heat transfer characteristics and pressure loss behaviors in a two-dimensional channel fitted with staggered diamond-shaped baffles and reported that the diamond baffle with half apex angle of 50–10° provided slightly better thermal performance than the flat baffle. Paper ID: J2013279 21 of 23 International Journal of Scientific Engineering and Research (IJSER) www.ijser.in ISSN (Online): 2347-3878 Volume 2 Issue 5, May 2014
2) Chinaruk Thianpong, Parkpoom Sriromreun, and Pongjet Promvonge, Conducted measurements on heat transfer channel with Z-shaped ribs for different rib pitches at Re from 4400 to 20,400. The baffles are placed in a zigzag shape aligned in series on the isothermal- fluxed top wall, The Z-baffles inclined to 45° relative to the main flow direction are characterized at three baffle- to channel.
3) Pongjet Promvonge and Sutapat Kwankaomeng, Carried out experiment to examine periodic laminar flow and heat transfer characteristics in a three-dimensional isothermal wall.To generate two couple of key stream wise vortex flows through the tested section, V-baffles with an attack angle of 45° are mounted in tandem and staggered arrangement on the lower and upper walls of the channel. Heat transfer and pressure drop in the channel are studied and the results of the V-baffle pointing upstream are also compared with those of the V-baffle pointing downstream.
4) P.Promvonge et. el, Investigation of laminar periodic flow and heat transfer in a three-dimensional isothermal- wall square channel fitted with 45° inclined baffles on one channel wall . The 45° baffle mounted only on the lower channel wall of height of b and an axial pitch length (L) equal to channel height (H). The blockage ratios, BR =0.1–0.5, on heat transfer and pressure loss in the square channel are compared with the typical case of the transverse baffle (or 90° baffle).
5) Yue-Tzu Yang and Chih-Zong Hwang, Heat transfer characteristics for rectangular channel with porous baffles are arranged on the bottom and top channel walls in periodically staggered way. The parameter studies include the entrance Reynolds no Re 1x104 to5x104, the baffle height h=10,20 and 30mm ad kind of baffles are solid and porous; whereas the baffle spacing are fixed at 1.0 and working medium is air . The heat transfer effect of the solid type and porous type baffles walls enhanced the heat transfer relative to the smooth channel.
6) Pongjet Promvonge et el, Investigation carried out to examine laminar flow and heat transfer characteristics in a three-dimensional isothermal wall square channel with 450 angled baffles. The fluid flow and heat transfer characteristics are presented for Reynolds numbers based on the hydraulic diameter of the channel ranging from 100 to 1000. To generate a pair of main stream wise vortex flows through the tested section, baffles with an attack angle of 450 are mounted in tandem and inline arrangement on the lower and upper walls of the channel.
7) Kang-Hoon Ko, N.K. Anand, Investigated experimentally the average heat transfer coefficient in a rectangular channel which was heated from all the four sides, spongy baffles were mounted alternately on the top and bottom walls in staggered way. Reynolds number was varied between 20,000 and 50,000. The experiment was conducted with three different pore densities (viz.: 10 PPI, 20 PPI, and 40 PPI) and two different thickness (viz.: 1and 0.25in
8) Ko and Anand, Experimentally studied the heat transfer enhancement in a rectangular channel by using a porous baffle made up of aluminum foam. The experiments showed that the use of porous baffles resulted in heat transfer enhancement as high as 300% compared with heat transfer in straight channel with no baffles and the heat transfer enhancement ratio was found to be higher for taller and thicker porous baffles. Furthermore, Yang and Huang
9) Yang and Huang, Presented a numerical prediction on the turbulent fluid flow and heat transfer characteristics for rectangular channel with porous baffles. They found that, together the solid and porous baffles walls enhanced the heat transfer relative to the smooth channel while the porous baffle channel has a lower friction factor due to less channel blockage.
10) Huang and Vafai, presented a detailed investigation of forced convection in a channel filled with multiple emplaced porous blocks. With comparison of the local Nusselt number distributions between the channel with and without porous blocks, they found that significant heat transfer augmentation can be achieved through the emplacement of porous blocks.
11) Huang et. al, Presented a similar investigation in cooling of multiple heated blocks covered with porous media. The results showed that significant cooling augmentation of the blocks can be achieved through the cover of finite-sized porous substance. Other similar studies of forced convection in a channel filled with porous block.
12) M. N. Lokhande, Dr. V. M. Kruplani, experimentally studied the results of Heat Transfer Enhancement Techniques Using Ribs and Baffles

Experimental investigations have been carried out in the rectangular duct to study the effect of Diamond shaped baffle of tip angle 100 on heat transfer enhancement, friction factor. The heat transfer in rectangular duct with Diamond shaped baffle of tip angle 100 is to be more as compared to without baffle. The increase in heat transfer coefficient of air higher for flat baffle and for Diamond shaped baffle over when no baffles in duct drop.

V. CONCLUSION

Case study has been done in the rectangular channel to study the effect of heat transfer in a rectangular channel with triangular baffles using special type of hot fluid with baffle angle 10º and the baffle material used is copper. The increase in heat transfer occurs because more turbulence is generated within the duct by using triangular shaped baffle as compared without baffle. The overall effectiveness of an heat exchanger is increased as compared to without baffle.

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