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Review of Heat Transfer Enhancement Techniques Using Ribs and Baffles

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Abstract: ***Heat transfer in a two dimensional horizontal channel with isothermal walls and with staggered diamond-shaped baffles is investigated numerically. The fluid flow and heat transfer characteristics are presented for Reynolds numbers based on the hydraulic diameter of the channel ranging from 700 to 1500. Effects of different baffle tip angles on heat transfer and pressure loss in the channel are studied and the results of the diamond baffle are also compared with those of the flat baffle. It is observed that apart from the rise of Reynolds number. The computational results that thermal performance is at the baffle angle of 5°-10^0 for baffle height and spacing of 1/3 times of the channel height.***

Keywords: Heat transfer enhancement, Flat baffles and Diamond baffle

1. Introduction

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

a) Active method: In this method some external power input for the enhancement of heat transfer is required few examples of active method include induced pulsation by cams and reciprocating plunger, use of magnetic field to disturb the seeded light particle in a flowing stream, etc.
b) Passive method: In passive heat transfer method no external power input is needed. Few example of this method are rough surfaces, inserts, etc.
c) Compound method: The combination of above two mentioned methods is the compound method.

1.1 Passive Heat Transfer Techniques

In conventional cooling method that are based on forced convection one way to enhance heat transfer is by increasing the effective surface area and residence time of the heat transfer fluid. Passive heat transfer method uses surface or the geometrical modification to the flow channel by incorporating inserts or additional devices. Due to this geometrical modification most of the turbulence enhancement and boundary layer break down are localized near the heat transfer surface and consequently heat transfer coefficient in the existing system is increased. The following methods are generally used.

1.2 Ribs

Placing ribs periodically 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 .

1.3 Baffles

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

1.4 Extended Surfaces

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

1.5 Twisted Tapes and Wire Coils

Twisted 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 spring is pulled up the wires forms a helical roughness.

1.6 Surface Modification

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

1.7 Impingement Cooling

It involves high velocity jet to cool directly the surface of inserts. It also involves the direction of heating or cooling fluid perpendicularly or obliquely to the heat transfer surface

1.8 Additives

These include addition of solid particles, liquid droplets, gas bubbles, 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.

2. Baffle Geometry

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

2.1 Common Attributes of Baffles are

a) **Shape**: Most of the baffles found in literature are square, rectangular, triangular, helical or wedge shaped in the present work rectangular baffles have been studied.
b) **Height**: Small height baffles are preferred to minimize the pressure drop.
c) **Spacing:** It is the distance between two consecutive baffles.
d) **Perforations:** Perforations are the slots or holes in the baffles which causes less resistance against the stream and improve heat transfer and pressure drop over the channel.
e) **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, it can be used for thermal management in aerospace applications.

2.2 Baffle Orientation

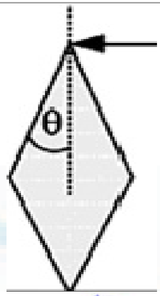
Baffle orientation plays a crucial role to enhance the heat transfer within the channel without incurring the penalties of friction and pressure drop that are severe enough to negate the benefits of heat transfer augmentation. Following are the possible arrangement of baffles in a flow channel. Perforation Baffle Height Rectangular baffle

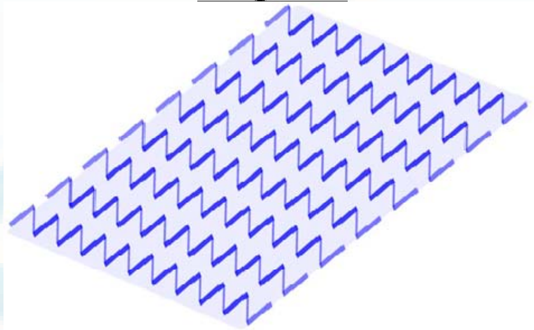
2.3 Types of Baffles

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

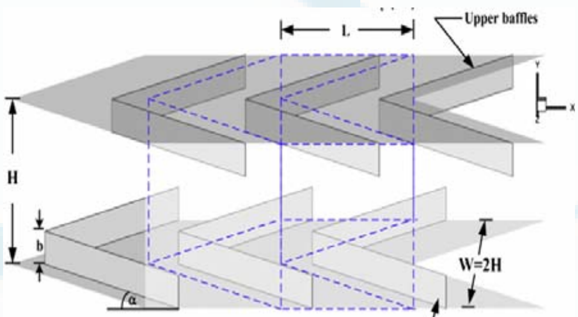
- Diamond Shaped baffles
- Z-Shaped baffles
- V-baffles
- 45° inclined baffles
- Porous baffles

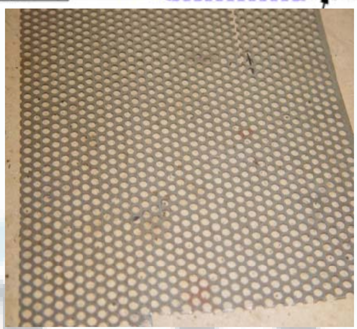
Some of the common baffle configuration a shown in following figure.





Diamond Baffles Z-Shapped Baffle





V-Baffles Porous Baffles

3. Literature Survey

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 5^0–10° provided slightly better thermal performance than the flat baffle.

[2]Parkpoom Sriromreun, Chinaruk Thianpong 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 pair of main 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 R_e $1x10^4$ to$5x10^4$, 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 45^0 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 45^0 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, porous baffles were mounted alternately on the top and bottom walls in staggered manner. 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, both 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.

[11Huang 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]Hadim, Studied the laminar forced convection in a fully or partially filled porous channel containing discrete heat sources on the bottom wall. The Brinkman–Forchheimer extended Darcy model were used for the computations. He found that when the width of the heat source and the space between the porous layers were of same magnitudes as the channel height, the heat transfer enhancement in the partially filled channel was almost the same as that in the fully filled porous channel while the pressure drop was much lower.

[13] Hadim and Bethancourt, Studied the similar problem in a partially filled porous channel. They found that when the heat source width was decreased, there was a moderate increase in heat transfer enhancement and a significant decrease in pressure drop.

4. Conclusion

Experimental investigations have been carried out in the rectangular duct to study the effect of Diamond shaped baffle of tip angle 10^0 on heat transfer enhancement, friction factor. The heat transfer in rectangular duct with Diamond shaped baffle of tip angle 10^0 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. The increase in heat transfer occurs because more turbulence is generated within the duct by using Diamond shaped baffle as compared without baffle and with flat baffle.

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