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Review of Heat Transfer Enhancement in Plate Heat Exchanger with Non-Conventional Shapes of Rib

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***Abstract* — The heat transfer rate is enhanced by rib- groove arrangement applied on rectangular duct. For energy saving purpose, various heat transfer enhancement techniques such as pin fin, dimples, swirl chamber and rib tabulators are used in many industrial heat exchanger devices. Mostly used heat transfer enhancement technique is the attachment of ribs to the flow passage. Ribs are simple in construction and extensively used in many of the industries. The production of turbulent kinetic energy increases the turbulent heat transfer in channel due to the flow disturbances caused by rib arrays. The shape of rib plays the important role in heat transfer enhancement as it affects the formation of separation of bubbles behind the rib and amount of turbulent kinetic energy production. In comparison with the smooth duct rib- groove arrangement significantly enhance the heat transfer rate. As the groove between the ribs in the reattachment and recirculation areas can shift the transition to the lower Reynolds number and improves the heat transfer rate. The present paper shows the review different conventional, non-conventional rib shape and combined effect of rib- groove arrangement on force convection heat transfer in rectangular duct.**

Keywords— Rib shape, heat transfer enhancement, groove

I. INTRODUCTION

The study of improved heat transfer performance is referred to as heat transfer augmentation, enhancement. The common thermo hydraulic goals are to reduce the size of a heat exchanger required for a specified heat duty and to upgrade the capacity of an existing heat exchanger, also to reduce the pumping power. Heat transfer enhancement techniques are commonly used in areas such as process industries heating and cooling in evaporators, thermal power plants, air conditioning equipments, refrigerators and radiators for space vehicles, automobiles. These are classified into three categories

- Passive techniques
- Active techniques
- Compound techniques
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In passive techniques inserts are used in flow passage to augment the heat transfer rate and it is advantageous compared with active techniques because the insert manufacturing process is simple and these techniques are easily employed in existing heat exchanger. For design of compact heat exchanger passive techniques of heat transfer augmentation can plays the important role if proper insert configuration can be selected according to the heat exchanger working condition. Several studies are taken on passive techniques of heat transfer augmentation. Most commonly used passive heat transfer augmentation techniques are ribs twisted tape, wire coils, fins dimples etc. in active heat transfer enhancement techniques external power is required to cause the desired flow modification and improvement in the rate of heat transfer. These methods are not commonly used because of need of external power. Compound techniques are the combination of passive and active heat transfer enhancement techniques.

II. RIB SHAPES

The heat transfer rate is increased by using different shapes of rib. The rib geometry, pitch ratio, rib arrangement, spacing angle of attack, rib size, rib groove arrangement have significant impact on the performance of heat exchanger.

A. Different non- conventional rib shapes are as follows:

1) Fan shaped:
   The fan shaped rib is modified from the isosceles triangular shape rib

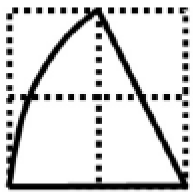

Fig.1 fan shaped rib [1]

2) House shaped:

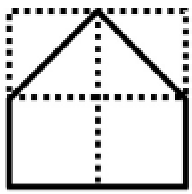

Fig.2 house shaped rib [1]

3) Reverse cut trapezoidal and Cut trapezoidal:
   These are modified from the right angle trapezoidal rib shapes

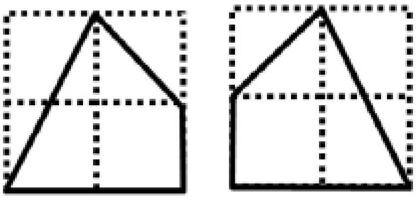

Fig.3 Reverse cut trapezoidal and cut trapezoidal rib shape

4) Boot shaped and Reverse boot shaped:

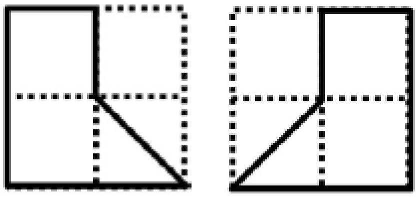

Fig.4 Boot shaped and Reverse boot shaped rib [1]

5) Reverse pentagonal and Pentagonal:

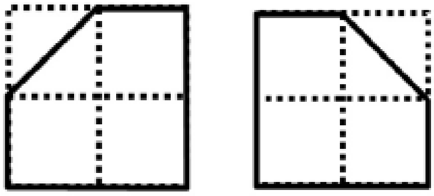

Fig.5 Reverse pentagonal and Pentagonal shaped rib [1]

B. Different conventional rib shapes are as follows:-

1) Rectangular
2) Triangular
3) Circular
4) Trapezoidal

C. For increasing heat transfer rate rib -groove arrangement is more useful:

Groove in spacing of ribs shows higher heat transfer rate than the without groove rib. This is because rib groove arrangement causes the flow separation or reversing flow.
Three rib groove arrangements are as follows:-
1) Rectangular rib with triangular groove

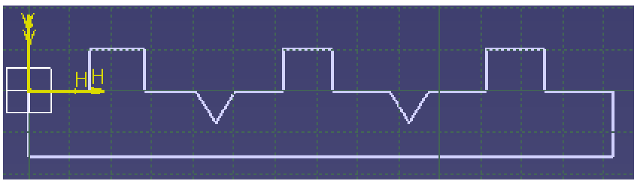

Fig no. 6 Rectangular rib with triangular groove

2) Triangular rib with triangular groove

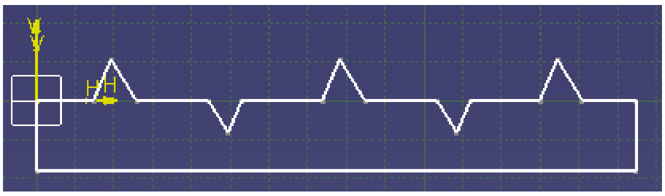

Fig no. 7 Triangular rib with triangular groove

3) Boot shaped rib with triangular groove

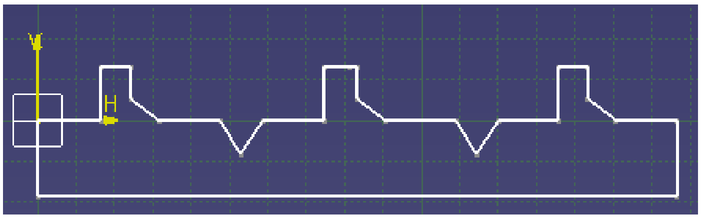

Fig. no. 8 Boot shape rib with triangular groove

III. Reviews Of Research Works Carried Out By Different Authors Using Different Shapes Of Rib And Rib-Groove Arrangement

Mi-Ae Moon, Mean-Jung Park [1] were analyzed the heat transfer and friction loss performance of rib roughened rectangular duct with variety of cross section using three dimentional – reynold-average-navier-stroke equation. They performed experiment on sixteen shapes of ribs which are house shaped, reverse cut trapezoidal, trapezoidal, boot shaped, reverse-boot shaped etc. They investigated the effect of Reynolds number and rib-pitch to width-ratio on the performance of various rib for Reynolds number 5,000-50,000 and rib-width to pitch ratio of 5.0-10.0 respectively. They reported that new boot- shaped rib design showed the best heat transfer performance than the square rib with average friction loss performance.

Monsak Pimsarn, Pongjet Promvonge [2] were performed experiment on z shaped rib in which z shaped rib set on the rectangular duct at 30º, 45º,and 60º relative to the air flow direction. Experiment performed on rectangular duct with aspect ratio, AR=10, height H=30mm with Z rib height e/H= 0.2 and rib pitch (P), P/H= 3. Results shows that 45º Z ribs can increase heat transfer rate than the smooth channel, flat rib, 30º and 60º Z ribs with e/H=0.2 and P/H= 3 at Re= 5000 to 25000. The thermal enhancement factor for Z ribs are 150-160% over flat ribs and 225- 255% over smooth channel.

R. Tauscher, F. Mayinger [3] deals with the experimental and numerical investigation of the forced Convection heat transfer in flat channel with rectangular cross section. Uses Reynolds number ranges from 500- 10000. They studied the various configurations such as rib- shape, size, spacing, angle of attack, arrangement, duct width and height. They judged the mean heat transfer and heat transfer performance by measuring mean fluid temperature at entrance and exit of test section. They reported that most effective rib- pitch to height ratio of P/e= 10 and application of groove in spacing of ribs shows the better performance.

Smith Eiamsa- ard, Pongjet Promvonge [4] were performed experiment to examine the combined effect of rib groove tabulators on the turbulent forced convection heat transfer in rectangular duct. They uses three rib groove arrangement rectangular rib and triangular groove, triangular rib with rectangular groove and triangular rib with triangular groove with aspect ratio AR= 20, duct height H=9mm, e= 3mm at three pitch ratio PR= 6.6, 10, 13.3. Result showed that rectangular rib with triangular groove arrangement provide maximum heat transfer rate and friction factor than other. While triangular rib with triangular groove gives higher thermal enhancement index for all pitch ratios. The rib groove tabulators at PR= 6.6 provide higher heat transfer up to 80%. Thermal enhancement index is higher with use of tabulator at lower Reynold number.

Ponjet Promvonge, Chinaruk Thianpong [5] were studied the forced convection heat transfer and friction loss behaviors for air flow constant heat flux channel with different shaped ribs. They used triangular wedge and rectangular shapes rib for experiment with aspect ratio AR= 15, h= 20mm, e= 6mm and rib pitch P= 40mm. They used two rib arrangements in line and staggered arrays. They reported that in line rib arrangement provide higher heat transfer rate and friction factor than staggered one.

C. Thianpong, T. Chompookham, S. Skullong, P. Promvonge [6] were studied the heat transfer rate and friction factor behavior of different height of triangular ribs. Geometry used for the experiment is isosceles triangle with AR= 10, H= 30mm, three uniform rib heights, e= 4, 6 and 8mm and one non uniform rib height, e= 4.6mm (e/H= 0.13, 0.26) and P= 40mm. They reported that i) uniform rib height shows better performance ii) heat transfer enhancement is higher at ratio e/H= o.26 iii) Nusselt number is constant with rise of Reynolds number.

K. H. Dhanwade, H. S Dhanwade [7] were performed experiment to study the heat transfer enhancement with circular perforation equipped on horizontal flat surface in horizontal rectangular duct. Experiment performed with clearance ratio (C/H)= 0.45, inter fin spacing ratio(S/ H)= 0.22, duct width= 150mm, H= 100mm. They reported that heat transfer rate increases with perforated fin that with solid fins. It also reduces the fin weight so low weight saves the material of fin and also decreases the expenditure on fin material.

Seyhan Uygur Onbasiogly, Hueyin onbasioglu [8] were performed experiment on rib with different heights (H= 10, 20, 30, 40mm) and five different angles in inclination (ϴ = 0º, 10º, 20º, 30º, 45º). They performed three dimensional numerical simulation for this. They compare the local heat transfer coefficient and Nusselt number with those of flat plate without rib. They conclude that heat transfer enhancement strongly depend on the geometrical parameters and angle of inclination.

Ting Ma, Qiu- Wang, Min Zeng, Yi- Tungchen, Yang Liu [9] examines the effect of inlet temperature and rib height on the fluid flow inside the high temperature and rib height on the fluid flow inside the high temperature heat exchanger. They reported that i) with increase of rib height flow disturbances and heat transfer performance increases.
ii) More heat can be transferred by increasing inlet temperature as compared to increasing rib height.
iii) It becomes advantageous for to use high rib for low temperature region and low rib for high temperature region.

Dong H. Lee, Jin M. Jung, Jong H. Ha, Young I. Cho [10] were study the effect of perforated circular finned tube (PCFT) on circular finned tube heat exchanger. Two cases were investigated which are 2- hole, 4- hole PCFT respectively. They reported that 2- hole PCFT gives better performance than 4- hole PCFT.

R. Kamali, A. R. Binesh [11] were performed experiment on square duct to study the effect of rib shape on local heat transfer. Square, triangular, trapezoidal with decreasing height in flow direction and trapezoidal with increasing height in flow direction rib shape were used for experiment. They concluded that trapezoidal rib with deceasing height in flow direction provide higher heat transfer rate.

Giovanni Tanda [12] was investigated the effect of traverse continuous, traverse broken and traverse V- shaped periodically on heated surface. Result showed that rib with traverse and broken shaped gives higher performance.

IV. Conclusion

Many researchers are taking interest to enhance the heat transfer rate with passive methods such as extended surfaces, dimple and rough surfaces. The literature review reveals that there is wide applicability of rib in heat exchanger. Heat transfer rate is increased by using groove in spacing of rib as it increases the turbulence degree. And also increases the friction factor. Selection of pitch ratio and rib geometry is most important as it affects the variation in heat transfer with Reynold number and friction factor

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