REVIEW PAPER OF HEAT TRANSFER ENHANCEMENT TECHNIQUES OF RIBS

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ABSTRACT: *The presented study is considered as a review related to early researches on heat transfer enhancementby means of ribs mounted in duct. One of the considerable topics used for developing highly-effective, inexpensive and light-weight heat exchangers is the heat transfer enhancement. With regard to the energy saving purposes, different techniques of heat transfer enhancement like rib tabulators, dimples, pin fin and swirl chamber were utilized in various industrial heat exchanger devices. Ribs' attachment to flow passage is the majorly utilized technique of heat transfer enhancement. In addition, the ribs can be constructed easily and thoroughly utilized in various industries. There were various types of ribs for enhancing the heat transfer rate like circular and segmented ribs, rectangular and triangular ribs, and V-ribs (broken and simple v-ribs). The rib's shape is of high importance in the heat transfer enhancement since it is affecting the bubbles' separation behind the ribsas well as the amount related to turbulent kinetic energy productions. With regard to utilizing many rib types, the enhancement of the heat transfer is on the basis of height and number of ribs and many arrangements of ribs. This study is showing a review regarding various non-conventional, conventional rib shape as well as the combined effect related to ribs arrangements on the force convection heat transfer in the duct.*

Key Words: *Rib shape, Reynolds number,heat transfer enhancement.*

1. INTRODUCTION

The more and more requirements to save materials and energy resulting from world resource shortages, also the environmental concerns encourageddeveloping more sufficient heat transfer equipment [1].Generally, heattransfer from surface might be improved via the increase in surface's heat transfer area, increase in the heat transfer coefficients between the surface andthe surroundings of thatsurface, or via the two. In the majority of conditions, extended surfaces are utilized for increasing the heat transfer area [2].The technology of heat transfer enhancement is one of the processes that are used for enhancing heat transfer system through the increase in convection in addition to thecoefficients of the radiation heat transfer. In the past four decades, such technique was thoroughly utilized in heat transfer equipment and heat exchangers in the thermal power plants, vehicle radiators, air conditioning equipment, chemical processing plants and refrigerators[3]. For promoting turbulence and enhancing convective heat transfer, a lot of roughness elements like ribs were utilized on the heat exchanger surfaces. These various types of ribs have been mounted on wall and majorly utilized in the applications of engineering for enhancing heat transfer, for example heat exchangers and mixing chambers, turbine blade cooling, electronic equipment cooling [4].In pipes, when carry cold and hot fluids, such as oils, steam, refrigerants, and other chemicals. Inautomotive systems, it includes fuel lines, exhaust system, and cooling system. Internal forced convection isalso in application of air ducts which is used for heating and air conditioning. In heat exchanger, convectionheat transfer is enhanced in thermal systems by many engineering applications by reducing size, weight, andcost.In various chemical process plants like heat exchanger, most heat transfer frequently utilized mode is forcedconvection. Ribs, wires, or grooves are welded on the surface to get roughness elements to improve heattransfer [5].The maintechniques of heat transfer enhancement which were utilized in commercialapplication were passive techniques characterized with various types of heat transfer enhancementelements [6]. Heat transfer enhancement has 3 techniques as follows;

1. Active method –A few external power sources were needed for enhancing the heat transfer, for instance, fluid's vibrating, fluid's stirring, using magnetic fields for disturbing particles related to flowing fluid,induction pulsating regarding cam as well as reciprocating plunger.

2. Passive approach-There aren't any required external power for augmentations, for instance, roughness surface, grooves, ribs, treating surface,utilizing many inserts.

3. Compound approach-which iscarried out on the basis of combination related to passive and active approaches.

The passive approach was utilized for intensifying the heat transfer since there is no requirement for external power. With regard to such approach,modifications of geometry and surface of duct was utilized [7]. Also, the ribs were majorly utilized for achieving improved convective heat transfer with regard to the internal cooling channels,solar air heaters and heat exchanger. Generally, the ribs which are utilized for singlephase flow cooling since they are promoting flow mixing as well as creating more heat transfer area[8].The presented study is providing overview of convective heat transferand fluid flow in a few of the ribbed ducts. Furthermore, the details related to flow pattern and impact of rib configurations and arrangements on heat transfer were provided.

2. TYPICAL RIBS ATTRIBUTES

a) **Spacing**represents the distance between 2 consecutive ribs.
b) **Height**: the rib's small heights required for minimizing pressure drop.
c) **Shape**the majority of ribs identified in literature wereV-shaped, M-shaped, rectangular, triangular, square and W-shaped. In this study, the W-shaped type was utilized.
d) **Width** the ribs' small widths were required for minimizing pressure drop.

3. LITERATURE REVIEWS

For the purpose of getting high heat transfer rate in addition to the pressure drop within limit, various rib shapes were analyzed in the past and recent year in the following way:

PriyankLohiya, Shree Krishna Choudhary [9]examined the heat transfer enhancement in rectangular ducts with the rib turbulators, where the ribs were utilized as one of the tools for the enhancements of heat transfer through the increases in the levels of flow's turbulence mixing, whereas the roughness or rib on the underside of duct's top wall identified for considerably enhancing the heat transfer coefficient. Furthermore, a 2D CFD investigation was carried out for studying the forced convection related to fully-established turbulent flow in rectangular ductswith the ribs on top wall's underside.

Satyanand Abraham, Rajendra P. Vedula [10]provided a comparable study related to pressure drop measurements and heat transfer in the converging channel of square crosssection with W & V rib turbulators, where the ribs on opposite walls regarding internal cooling passage of the gas turbine blades were sometimes utilized for the heat transfer's enhancements, such passages might be straight, diverging or converging. With regard to this work, the experimental data related tothecoefficients of the local heat transfer were provided toconverge the channel with theelements of the rib roughening with crosssection that is kept square from the inlet to the exit. Furthermore, the coefficient of the local heat transfer distributions showing an identicalqualitative behavior which has been identified for straight channels.

Giovanni Tanda [11]carried out experimental study for examining the influence of rib spacing on heat transfer as well as a friction in the rectangular channel with 450-angle rib turbulators on 1/2 walls. In addition, experimental researches which arerelated toheat transfer of the forced convection in rectangular channels, with an (AR = 5) aspect ratio and angled rib turbulators, which are inclined at 450, was provided. Furthermore, the angled ribs have been used with parallel directions on 1 or 2channel surfaces. Convective fluid has been air, and Reynolds number (Re) changing between9,000 and 35,500.

R. Tauscher, F. Mayinger [12]examined numerically and experimentally forced convection heat transfer in a flat channel with cross-section of therectangular shape. Using Reynolds number in range of (500 to 10,000), also they examined many configuration types like duct height and width, attack angle, size, spacing, rib shape. In addition, they judged heat transfer as well as mean heat transfer performance through estimating the average fluid temperature at exist and entrance of testingsection, the study indicated that the major efficient ratio of the rib-pitch to height of P/e= 10, while the application which is related to groove in ribs' spacing showing excellent performance.

A. R. BineshandR. Kamali[13]provided experimentation on a square duct for studying impact of the shape of therib on the local transfers of theheat. Trapezoidal, triangular and squarewith reduction in height of flow direction as well as trapezoidal with increase in the height of flow direction rib shape have been utilized for experimentation. Also, they have indicated that trapezoidal rib with reduction in height offlow directionsis providing high rate of the heat transfer.

Rawat, jaurker et al. [14]examined the thermal efficiency and heat transfer coefficient through supplying 60^0 inclined V-SHAPED ribs. In addition, they examined the effect of friction factor and heat transfer via utilizing V-continuous, inclined, transverse and V-discrete ribs on absorber plate in the solar air heater duct. Examining parameters related to Re of range between 3,000 and 15,000, 7.19-7.75 pitch duct ratio, 10mmpitch\roughness height, 60^0angle of attack, 0.0287 pitch rib ratio (e\d). The wall roughness has beenheated bya heat flux electric heater, whereas the running walls have been insulated.It is indicated that 60° inclined rectangular ribs showing excellent results compared to transverse ribs as well as thermal performance related to heat transfer was 1.82 times better compared to smooth duct.

Mohammed rayed facraqui et al. [15]Numerical researchon the impact of rectangular-shaped ribs in various patterns on the thermal efficiency which isrelated to solar air heater duct. In addition, the study is concerned with 2D work carried out for predicting the impact of transverse rectangular crosssectional ribs. Experimentally, they examined single wall arrangement, inline arrangement of ribs and staggered arrangement. Furthermore, the individual parametersrelated to Reynolds number in range of (3,000-18,000), 10mm pitch height (e\d),0.018-0.052 artificial roughness height, $\alpha=60^0$angle of attack, and 6.8-11.5rectangular duct ratio. It has beenstated that inline ribs providing excellent thermal efficiency regarding1.82 compared to staggered counter parts of relative gap widths.

N.K. AnandandKang-HoonKo[16]experimentally examined the meancoefficient of the heat transfer in rectangular channel that has been heated from all 4sides, the porous baffles have been alternately mounted on bottom and top walls in staggered way. Also, Reis in range between (20000-50,000). The experiment is carried out with 3 pore density values (PPI 10, PPI20, and PPI 40) and 2 different thickness (1and 0.25in).

ZHU Dongsheng&TANG Xinyi[1]have examined turbulent flow in addition to the heat transfer enhancements in channels or ducts with groove, rib, or rib-groove tabulator, the study indicated that low Reynolds number (Re) is providing high enhancement index and when put to comparison with smooth duct, all the arrangements of the ribgroove have considerably improved heat transfer about 80.0%, 60.0%, and 46.0%, respectively using tabulators. After that, the factors of thefriction have been about 6.90, 5.50 and 4.80 times over the smooth ducts.

Nabeel A. Ghyadh[3]examined heat transfer and the thermal performance properties in pipe flow with 3 rib tubes' types (elliptic, circular and square) at a constant wall flux condition examined for Rein range of (5,000-15,000) for examining impact of rib shape on the transfer of theheat. In addition, the re-normalization group k-ε model was utilized for simulating turbulence in the ANSYS - FLUENT 6.3, while the results regarding temperature and velocity distributions along the tube in terms of a tube with internal ribs have been put to comparison with that related to smooth tube, the results are showing that using the internal ribs is enhancing the rate of the heat transfer and have maximum performance factors for the turbulent flow.

R. TAUSCHER and F. MAYINGER [17]numerically and experimentally examined the heat transfer of theforced convection in the flat channels with the rectangular cross-section. A lot of configurations (duct: wall temperature, height and width, rib: arrangement, attack angle, size, spacing and shape) were examined. In addition, local heat transfer coefficients were acquired via holographic interferometry, whereas LDV is used for measuring thelocal hydro-dynamic factors (with particular interests to the turbulent kinetic energy and Reynolds shear stress values). Based on the configurations experimentally investigated, the numerical CFDcalculations were carried out. For increasing the precision of numerical calculations with regard to issues with thesimultaneous regimes of the laminar and turbulent flow, the study suggested empirical process.The major efficient rib spacing was at ratio of rib-pitch-to-height of p/e = 10. Generally, turbulence promoters showing an excellent impact in the area of the transition from the laminar tothe turbulent flows.

Kaewkohkiatetal. [18]have examined (experimentally) heat transfer as well as the friction properties in rectangular channel with theturbulators of the ribgroove and indicated the fact that the friction factor and Nusselt number (Nu)have been increased with a decrease in the pitch ratio.

Liouetal. [19]examined (experimentally and numerically) the ribbed surfaces utilizing *k--A* algebraic stress as well as heat flux model and LDV measurements, they indicated that there is excellent agreement between experimentation and modellingfor 2-D case.

Archarya et al. [20]utilized non-linear and linear*k*-_ models to successive 2Drectangular ribs, also identified that the performance regarding the 2 models is comparable, apart from the nonlinear model creating more realistic distributions of the Reynolds stress in comparison to linear form in the area which isimmediately over ribs.

SumanSaurav and V.N.Bartaria[21]examined heat transfer in the rectangular ductsrelated to solar air heater with triangular rib roughness on absorber platesthrough utilizing CFD, the impact of Re on the Nuis examined for studying the friction factor, heat transfer and flowproperties in the solar heaterswith triangular rib roughness on absorber plates. In addition, the calculationsaccording to finite volume technique with a method of SIMPLE were carried out for air flow with regard to Rein range between (4,000 and 20,000) and p/e (4-20) was conducted with k-ε turbulence model chosen via the comparison of the predictions regarding various models ofturbulence with the experimental results that have been availablein different literature, it has been indicated that Nusselt number increases as Re is increased. The maximal value which is related to Nu friction factor was acquired at relative roughness pitch which is equal to4.

ArkanAltaieet al. [22]examined the heat transfer in addition tothermal performance properties numerically in a steel tube with length of 50cm, 60mm outer diameter and 30mm innerdiameter with constant outer surface temperature which is equal to 1,000, 1,200 and 1,400 K. In addition, the ribs assembly (5mm x 5mm cross-section) have been fitted in tube as well asdivided by an8cmpitch, while the results regarding temperature and velocity distributions along tube center line with regard to a tube with internal ribs have been put to comparison with that related to plain tube, such results are showing that using internal ribs is enhancing the heat transfer rate and indicating for having maximum performance factors for the turbulent flow. Furthermore, the CFD predictions with regard to a tube with ribshave been put to comparison against the tube with no ribs.

Iacovides etal. [23]studied and examined the results which are related to combined numerically and experimentallyof flow as well as heat transfer in straight ducts, with the square crosssection ribs along 2 opposite walls, in the staggered arrangements and ata 45°angle to the direction of main flow.

Ponnusamy SELVARAJ et al. [24]examined via utilizing the computational fluid dynamics the heat transfer, friction factor, pressure drop, thermal hydraulic performances and Nusselt numberrelated to plain tube and tube which is equipped by3 types of internal grooves (trapezoidal, square and circular).Water is utilized as working fluid. In addition, the tests have been achieved for Reynolds number in range of (5000-13500) with regard to plain tube and various geometriesin the grooved tubes, while the maximal increase regardingthe drop of thepressure is acquired from numerical modeling square38%, circular74%, trapezoidal 78%grooved tubes put to comparison with plain tube. On the basis of computational fluid dynamics analyses, average Nusselt number subjected to increase by up to 26%, 42%, and37%, for the square, trapezoidal, andcircular grooved tubes, whereas put to comparison with plain tube. Furthermore, thermal hydraulic efficiencyis acquired from the computational fluid dynamics analyses of up to 27% for the square grooved tubes,38.0% for the circular grooved tubes, and 40% for the trapezoidal grooved tubeswhen compared to plain tubes.

Han etal. [25]examined the impact of rib geometry involving the attack angle and ratio of pitch-to-height on thermal behaviors in a duct and proposed that 45° ribs provided high thermal performance compared to 90°ribs.

S. Skullong[26]experimentally examined the thermal characteristics and fluid friction in solar air heater duct artificially roughened by the inclined ribs. Also, new absorber plate with the inclinedrib vortex generators was suggested for improving the thermal performance with regard to energy saving. In addition, the experimental works were conducted in duct with constant heatflux on absorber throughthe variation of the air-flow in duct for lettingthe Re be in range between (5,300 and 23,000). Impacts of 2angles of therib inclination (α = 45°& 60°)as well as 3 relative rib height values (b/H=BR = 00.10, 00.20 and 00.30) on the behaviors of the heat transfer and flow friction have been examined. Furthermore, the experimental results have indicated that using inclined rib vortex generators providing significant increasing in the transfer of the heat over smooth surface duct approximately (3.70 to 4.70) times, whereas friction factor (f) increase approximately (24.40 to 70.70) times. It was identified that Nuis increased with an increase in relative and height and inclination angle. Maximal thermal efficiencyfor utilizing rib vortex generators was approximately 1.40 at BR = 0.20 andα = 45°.

Ghorbani-Tari et al. [27] Studied experimentally the heat transfer behavior between the 1st two neighboring ribs in straight rectangular channel. Those ribs have been transverse and continuous in the flow direction which is attached to one channel cross section side and evenly heated. The parameters of the experiment have been the ratio of rib pitch to 10, 20 & 30height values where the range of the Reynolds number has been between 57,000 and 127,000. Results have shown that distance between the point of the reattachment and the upstream edge of the rib is more at the area of the entrance compared to the one that occurs at the fully developed area in flow field, in the case where ribs have been transversely positioned in the flow of the channel.

Sibendra Kumar Gharai and ApurbaLayek[28] Studied the heat transfer which has been measured in the rectangular channel with the detach transverse square ribs with the use of the liquid crystal thermography. Ribs have beengiven on one broad rectangular duct wall of a value of the aspect ratio which is equal to 4. The surface of theroughened has been evenly heated. The parameters of theroughness that have been chosen for the presentresearchhave been: clearance ratio (C/e) of 0.37-0.57 values, relative pitch ofroughness (P/e) of 7-11values,and Re of 8,100-22,300values. The coefficient of the heat transfer was compared to the attached transverse square ribs at equivalent operating condition and the result has revealed that the roughness of thedetach rib has beenmore sufficient in comparison with attach ribs. It has beennoticed that theparameter of the thermal performance has beenincreased with increasing Reynolds' number.

Rafea A.H. Albaldawiet al. [29]have researchedthe characteristics of the heat transfer and pressure drop in the square duct which is inserted with angle-ribbed straight diagonal tape. The straight tape used in the current study inserted in diagonal side of 44 mm hydraulic diameter square test section duct has uniform heat-fluxed walls. Different angled ribs have been placed repeatedly at similar locations on the two opposite sides of the inserted tape. The investigation covers a range of Reynolds numbers from (3400 to 20,800) according to hydraulic diameter and air is employed as working fluid. For studying the heat transfer dependency on ribs inclination angle, six different inclination angles (α) of 10˚,20˚ ,30˚ ,45˚ , 60˚, 90˚ are examined at constant value for both rib blockage ratio (BR) and pitch spacing ratio (PR) of 0.2 and 1 respectively. The angle-ribbed diagonal tape produce a pair of thelongitudinal vortex flow through the heated duct and it is apparent that these vortices helps the induction of the impingement flows on duct walls, which leadto the massive increases in therate of the heat transfer over duct. Experimentalresults have shown that inserting the ribbed diagonal tape results in significantly increasing the Nu and over the smooth duct without any tape. Ribs at provides higher heat transfer and friction losses as compared to other angles about (77.78, 98.42) % respectively more than smooth duct while ribs at provides higher thermal enhancement factor (TEF) by about 1.297 at lower Re.

Sandeep S Koreet al.[30]Investigated the performance by using ribs in the majority of devices for the internal cooling. Ribs result in the disturbance ofboundary layer and increasing turbulent kinetic energy that results in enhancement of therate of heat transfer. The majority of researchers are concentrated on the rectangular andsquare ribshapes. The rib'scross section hasa significant impact on flow fieldproduction. The ribshape has animpact on theseparation of the boundary layer, attachment and hot spots which have been produced. In the present work, fluid flow andheat transfer properties from the rib roughened rectangular duct with various ribshapes have beenresearched. The experimental setup includes a rectangular channel of an aspect ratio equal to 4. The ratio of the pitch to width has been varied respectively as 5.0, 7.50 and 10.0. Rehas beenrangingbetween 6,000 and 30,000. Ribs which have beenutilized for researcheshave been of house,square and boot shapes. From the researches, it has beenfound that the boot shaped ribs have higher thermal performance compared tothe rest of the geometry types.

Kuan-Tzu Huang and Yao-Hsien Liu [8] Investigation experimentally a square channel that has broken andcontinuous V-shape ribs. For the generation of a mist flow, the microdroplets have been introduced in gas stream. The attack rib angle has been 45^{o}, and theratio values of the rib spacing-to-height have been 10&20. Reynolds number of theair was in the rangebetween 7,900 and 24,000, and aratio of water-to-air volume flow has been < 0.10%. The net heat inputs were in the rangebetween 1.1W/cm^{2}and 3.1W/cm^2 and between 3.4W/cm^2–9.4W/cm^{2}respectivelyfor the cases of the air and mist flow. Due to the fact that deposited liquid portions have created irregular distributionsof thetemperature on heated surface, steady-state infra-red thermography has been utilized for the visualization of the distribution of the heat transfer. 2-7 times greater heat transfer has been attained for broken ribs in the case of the utilization of mist flow compared to it in the case of theuse of the air flow. Such increase has beenmostly a result of broken structure, facilitating the transport of theliquid as well as improved liquid coverage. Moreover, broken ribs have resulted in smaller factor offriction compared to the continual ribs. Broken structures have been advantageous for the higher thermal performances in mist flows.

A. Shukla et. Al. [31]have conducted an experimental work, which has been aiming at a comparison of V and ʌ-shaped ribs geometry for the square ductsfor founding out the geometry of therib,which provides maximal transfer of theheat with a high thermo hydraulic efficiency value. The conclusions below may be reached from this study: The maximalimprovement of the values of the friction factor andNu, in comparison with the smooth duct have been of a 8.80 and 3.80 order respectively.

M. Udaya Kumar and Md. Yousuf Ali [32] experimentally researched the friction and thethermal properties of the square ducts with the inserts. The duct is of a square section and uniform heat flux walls and air utilized as working fluid has been presented based onReynold's number between 8,000 and 40,000. In this study, inserts of elliptical ribswereproposedfor ascertaining the improved impact of the heat transfer and equivalent research has not beenperformed earlier. Inserting elliptical ribs has beencarried out with a variety of the intervals of the fin to the duct heightsbased on the orientation of the main flow. Those ductinserts have beenthought to be generating longitudinal vertex flow over duct. In experimental studies, the impact of 16 fins to the height of theduct ratios for every one of the fin pitches on the flow friction andthermal properties of inserted duct wereresearched. Experimentalresults have signified that the elliptical insert is providing the maximum transfer ofheat compared to thethe plain square ducts with no inserts. Thermal efficiency of newly developed finned elliptical ribs has beendiscovered higher than the efficiency of rectangular ribs.

GOKTEPELI Ilkeretal. [33] Performed numerically turbulent flow andheat transfer properties between ribbed plates. Ribs that have rectangular cross-section were putsymmetrically on the bottom and the top duct plates. It hasconsidered that afluid at 300K entered the system whereas walls kept at 400K. Dimensionless spacing andheight were ranging respectively as $0.50 \leq S' \leq 1$ and $0.10 \leq h' \leq 0.30$, and results were compared to the smooth plateresults. Although there have been27 cases that have been obtained due to the parametric combinations, the amount of the variety of the cases wasdecreased from 27 to 9 separate variation cases through the application of Taguchi approach. In addition to that, the impact of all parameters that have been taken under consideration on flow and heat transfer propertieswere specifiedonthe basis of the level of the impact. The optimal pressure loss and Nusselt number parameters were individuallyascertained. In addition to that, the nearly precise pressure loss and Nusselt number values were attained as well by the test of theconfirmation that has a 6%error percentage. The most predominant factor wasspecified as the height of the rib as a result of its impact upon the heat transfer in addition to the flow properties. In a similar, based on numerical results, the increase of the height of therib, Reynolds number, andrib spacing resulted in separately increasing theNusselt number. Never-the-less, the symmetrical flow structure was disturbed due to ascending the height of therib as can beevident for h' = 00.30 from charts. Meanwhile, the pressure loss wasincreasedbecause ofincreasing geometrical parameters as well as the Re. h' = 00.20 with S' = 00.50 at Re = 15,000,h' = 00.10 with S' = 00.50 at Re = 10,000, and h' = 00.10 with S' = 00.75 at Re= 15,000 may be proposed for improving the heat transfer due to the fact that the system'spressure loss has been accepted.

Gurpreet Singh and Dr. G. S. Sidhu[34] Investigation experimentally of the impacts of the geometrical circular transverse ribs'parameters on the rectangular duct'sheat transfer with the heated plate that has the roughness of therib on the underside were stated. The parameters'range for theresearchwasspecifiedbased on thesystem'spractical considerations as well as thesolar air heaters' operating conditions. The experimental research has encompassed a Re that ranged between 2,564 and 6,206; relative pitch ofroughness (P/e) which is equal to 8, attack angle (α) equal to 90^{o} and relative height of roughness (e/D_h) has been equal to 0.047. The roughened duct'sthermal efficiency has beennoticed between 5.0% and 9.0% more incomparison with smooth duct. Thermalefficiency has been increased with the increase in Reynolds number'svalue.

Moon & Mean-Jung Park [35]Performed analysisof friction loss andheat transfer performances of the rib roughened rectangular ducts with various cross sectionswith the use of the3-D – Reynold–average–navier–stroke eq. They have stated that the new rib design of the boot- shape hasshown the optimumefficiencyof heat transfer whencompared with the square rib with an average performance of the friction loss.

B Ashwini and J. A. Hole [36] a research wasconducted to measure coefficient of the heat transfer, friction factor for the arrangement of the rib groove of the air for the turbulent flows in the rectangular ducts. The experimental set-up consisted of a Blower, flow control valve for the purpose of maintaining the measured flowquantity, the orifice meter has beenutilized for the flow measurement, the pressure drop has been measuredoverthe section of thetest and the orifice meter with two U-tube manometers. Uniformcondition of the heat flux has beenproduced by the plate type.A 800W nicrome wire heater has beenutilized in testing section and asbestos insulation which is 3mm thick over the heater of theplate type. The temperature of the tube'sexternal surface has beenevaluated at 6 separate test section points by the K-type thermo-couple. Rehas beenranging between 8,000 and 18,000 with the constant heat flux. The Nuwhich has been obtained from the smooth has been compared to the correlation of Dittus- Boelter. The factor of thefriction has been compared against theBlasius Correlation. The experimental set-up has been authorized using theBlasius correlation andDittus-Boelter equation. On the other hand, Re, and Nu in the rectangular duct with the rib insert which isboot-shapedhas been improved 1.85-1.92 times the smooth duct, whilelower factor offriction has beenproduced for the rib which istriangle-shaped.

A M Rathod and U S Bongarde[37] Performedthe thermal characteristics of turbulent flows over ribbed surfaces have been greatly important for the applications ofengineering because of the enhancement of the heat transfer. In experimental study for avoiding the highdrop of the pressure and pumping power of fluid, the flow of the low velocity has beenusually applied. The ribs may be utilizedfor the induction of the turbulence and thereby,improve the transfer of theheat. The measurements of the temperature andvelocity which have been conducted in the wind tunnel have beenevaluated by a copper-constant thermo-couple and a hot wire anemometer ofconstant- temperature, respectively. The ribbed wall has resulted in flowdestabilization. The re-attachments andseparations over the ribbed wall result in increasing the fluid mix, produce unsteadiness of theflow, interrupt thermal boundary layer development and improve the transfer of theheat. Flowrates wereranging between Reynolds numbers 500 and 10000, which cover a range between thelaminar and the low turbulent flow. Results have shown that the Ribbed Wall has resulted in the effectiveimprovement of the efficiency of the Heat Transfer.

J.M. Jalil and H.M. Kadom[38] Studied numerically and experimentally the rib improvement of the transfer of theheat in the duct has beenwhere the hot air is passing through the duct (0.04x0.16x 1.15m3) with different arrangement of therib. The armaments have beenlower 12-rib arrangement; 24 rib staggered arrangement andupper 12 rib arrangement. Staggeredarrangement providesmore sufficient results compared to others. In addition to that, the attack angle has beenresearched for the lower arrangements, 3distinct values have been tested (45°, 60° and 90°). A 60°angle providedthe bestefficiency. In a numerical manner, the 3-dimensional continuity, Navier-Stokes and energy eqs. have been solved with the approach of the finite volume of the flow of air over (0.04x0.16x0.6m3). Code validation has been carried out through the comparison of numerical resultsagainst results which have been experimentally obtained only for the staggered arrangements. The agreement appears adequate. The numerical researches have been were extended for studying the cold air passing case through the hot ribbed ducts.

Chandra Prakash and R.P. Saini[39] Investigation experimentally the properties of the heat and fluid flow of the artificially roughened solar air heater duct was performed. The operating parameters androughness have covered an Rerange between 2,000 and 20,000, the relative length of the rib (r/g) between 0.40 and1, the relative pitch ofroughness (P/e) between 15 and 30, and relative rib pitch (Pr/P) between00.20 and 00.89. Other factors, in other words, theangle of attack (α), the relative height of the roughness (e/D), and the relative gap of theroughness have been kept unchanged. The results have shown that the noticeable enhancement in the Thermo-hydraulicefficiencyand the Nusselt number was obtained with increasing the factor of thefriction with the use of the roughened surface.

S.A. Abdel-Moneim et al. [40]investigated the improvement in heat transfer in addition to the impact of flow friction in the rectangular channel with the use of the periodic zigzag (i.e. multiple V-shaped) ribs which have been affixed, in tandem, on channel'sbottom surface that has been heated with an even heat flux. A horizontal rectangular channel with the aspect ratio, (height/width), of 1:4 was examined. The ribs were arranged in an in-line arrangement such that repeated V-shaped secondary flow cells were established. The present experiments were conducted for an Re that ranges between 15000 and 75000, theratio of the rib height-to-pitch (e/p) from00.0375 to 00.150, and for 3 rib angle values (α) which are equal to 30°, 45° and 60°deg, respectively. An efficiency index of about 0.60has beennoticed for the rib angles that are equal to 45° and 60 deg. At the lowest ratio of rib height to pitch. New relations have been obtained for the impact of rib height-to-pitch ratio, rib angle, and Re on both Nu enhancement ratio and flow friction factor ratio.

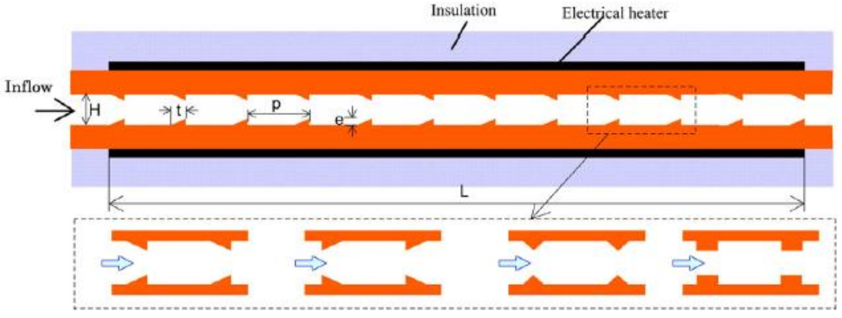

Fig (1)In-line rib arrangement with wedge pointing upwards, wedge pointing downwards, triangular and rectangular.

ChiragMaradiya et al. [41] Studied effected Ribs on the efficiency of the heat transfer and properties of cooling air flow in a variety of the aspect ratio values (AR) U-shape channels under a variety of the working cases have been researched in a numerical manner. Ribsangle andchannel orientations have been respectively 45°& 90°, and aspect ratio values have been 1:2, 1:1, 2:1. Inlet Re varies between $1x10^4$ and $4x10^4$ and the rotational speed values include 0, 550rpm, 1100rpm. The coefficient of local heat transfer, the endwall ratio of the surface heat transfer coefficient and the factor of theaugmentationhave been3main criterions for the measurement of the heat transfer of thechannel. The ribs result in significantly increasing the area of the heat transfer and improving the coefficient of the heat transfer of the ribbed surfaces, particularly in 1-st pass, whereas the surface of the end wall plays a bigger role in channeling the transfer of theheat due to the bigger area and rather alower coefficient of heat transfer. Widechannel (AR = 2:1) has the better factor ofaugmentation compared to narrow channel (AR = 1:2) and the weight of the ribs heat transfer is increased with increasing of inlet Re. Rotating decreases the heat transfer weight of theribs in the channelslightly and trailing surface in the 1-st pass is the basic influence object of rotation.

4. CONCLUSIONS

The literatures about various heat transfer enhancement technique using rib turbulators and effect of rib tabulators on the properties of the heat transfer were reviewed. Several researchers started their attempts towardsthe improvement of rate of the heattransfer with the passive approacheslike the dimple, extended surfaces,and rough surfaces. Heattransfer rate has been increased through the use ofthe rib asit increases the turbulence degree.From this review, authors wereconducted many experiments on ribs by varyingsize, angle, rib height, and roughness ofgeometries.Increasing heat transfer takes placebecause more turbulence has been producedin duct through the use of the ribs compared to it with noribs.The thermal performance of channel or duct with rib turbulators are obviously affected by Reynolds numbers, rib height, rib spacing ratio. rib angle and different arrangement of ribs.

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