Research Papers

STUDY OF HEAT TRANSFER ENHANCEMENT IN RECTANGULAR CHANNEL WITH DIFFERENT INLET CONDITIONS

Bharat Wandhare[1] and G. D. Gosavi[2]

[1]Student,Mtech Heat Power Engineering ,
Dr. BabasahebAmbedkar College of Engineering Research,Nagpur, India.
[2]Assistant Professor, Mechanical Engineering Department ,
Dr. BabasahebAmbedkar College of Engineering Research , Nagpur, India.

Abstract

Heat transfer enhancement is the process of improving the performance of a heat transfer system. It generally means increasing the heat transfer coefficient. The performance of heat exchanger depends how effectively heat is utilized. The high performance of heat exchangers are very much essential in many practical applications such as aerospace, vehicles, refrigeration and air conditioning, cooling of electric equipment and so on. Reduction of the size of the heat exchanger may be possible due to improvement in the performance of heat exchanger. On the other hand, a high performance heat exchanger of a fixed size can give a increased heat transfer rate and also there is decrease in temperature difference between the process fluids enabling efficient utilization of thermodynamic availability. The performance can be improved by using various augmentation techniques such as finned surfaces, integral roughness and insert devices. A variety of different techniques are employed for the heat transfer

KEYWORDS:

Heat transfer, Dieffernt entry Condition, Duct.

INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment.

Generally, heat transfer augmentation techniques are classified in three broad categories:

(a) Active method: This method involves some external power input for the enhancement of heat transfer; some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, fluid vibration, jet impingement etc.

(b) Passive method: These methods generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, use of inserts, use of rough surfaces, extended surface etc.

(c) Compound method: When any two or more techniques employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually ,is termed as compound enhancement. This technique involves complex design and hence has limited application.

II.HEAT TRANSFER AUGMENTATION METHODS

Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system.

Following Methods are used generally used,
1. Extended surface
2. Use of Additives
3. Inserts

1.Extended Surface:-

Extended or finned surfaces increase the heat transfer area which could be very effective in case of fluids with low heat transfer coefficients. This technique includes finned tube for shell & tube exchangers, plate fins for compact heat exchanger and finned heat sinks for electronic cooling. Finned surfaces enhance heat transfer in natural or forced convection which can be used for cooling of electrical and electronic devices. The use of extended surfaces for cooling electronic devices is not restricted to the natural convection heat transfer regime but also can be used for forced convective heat transfer. Segmented or interrupted longitudinal fins, promote boundary layer separation of the fluids and disturb the whole bulk flow field inside circular tubes. Separation and restarting of the boundary layers increases the heat transfer rate. Plate fin or tube and plate fin type of compact heat exchangers, where the finned surfaces provide a very large surface area density, are used increasingly in many automotive, waste heat recovery, refrigeration and air conditioning , cryogenic, propulsion system and other heat recuperative applications. A variety of extended surfaces typically used include offset strip fins, louvered fins, perforated fins and wavy fins.

2.Use of additives:-

Pressure drop in tube flow is consequence of the frictional losses with solid surface. The frictional loss occurs because of the drag force of fluid. This technique is basically concerned with reducing the drag coefficient using some additives to fluid in single phase flows. Additives when added to fluids are found to have operational benefits by lowering the frictional losses. Polymeric additives induce a viscoelastic characteristic to solution which promotes secondary circulation in bulk flow. These secondary flow have significant effect on heat transfer coefficient some soluble polymeric additives in water have shear thinning effect on solutions, which lead to significant reduction in frictional loss as well as increase in heat transfer coefficient. Some of additives used are polystyrene spheres suspension in oil and injection of gas bubble.

3. Inserts

Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment

heat transfer. Different types of inserts are
1. Twisted tape and wire coils
2. Ribs, Baffles, plates

The present paper Contributes for review of Ribs, baffle in duct and insert in tube.

4. Ribs:

There are several techniques available to enhance the heat transfer coefficient of gases in internal cooling. One of the common internal cooling enhances techniques is the placement of internal flow swirls, tape twisters, or baffles. The swirl insert and tape twister techniques create a flow disturbance, and the pressure drop losses are much higher compared to the gain in heat transfer coefficient. Different rib shapes and baffles create bulk flow disturbance, but unlike tapes or swirls, ribs and baffles are discrete objects. Therefore, the flow disturbance created by ribs and baffles may be localized, but more intense. Usually ribs and baffle plates are attached to the thermally active surface to augment heat transfer by providing additional fin-link surface area for heat transfer and better mixing.
Use of ribs and baffles:

- The main roles of a ribs and baffle in a shell and tube heat exchanger are:-
- To prevent the effect of vibration which is increased with both fluid velocity and the length of exchangers.
- To increase the heat transfer area.
- To promote mixing in static mixture. In a chemical reactor , baffles are often attached to interior walls to promote mixing and thus increase heat transfer and chemical reaction rates.
- To increase the stiffness of the system.

III.TYPES OF RIBS & BAFFLES

Implementation of ribs & baffles is 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 allowances/changes are also made for finned tubes. The different types of ribs & baffles include:

- Z-shaped ribs.
- Segmented ribs.
- Corrugated surface.
- Inclined ribs.
- Porous ribs.
- Segmental Baffles (of which single segment is the most common)
- Longitudinal Flow Baffles (used in a two-pass shell)
- Orifice Baffles.

Heat transfer augmentation techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. Passive techniques, where inserts are used in the flow passage to augment the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition (both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported. The present paper is a review on progress with the passive augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. In the present paper, emphasis is given to works dealing with twisted tapes and wire coils because, according to recent studies, these are known to be economic heat transfer augmentation tools.

Some of the common Rib and Baffle Configurations are shown in following figure.

IV.REVIEW OF LIETRATURE

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

MonsakPimsarn, et al. [1] Investigated the heat transfer characteristics and associated friction head loss in rectangular channel with Z-shaped ribs. These ribs were set on the rectangular duct at 30º,45 º,60 ºof flat rib was set at 90 º relative to air flow directions. These ribs were fitted in Z-shape (Z-rib) aligned in series on whole surface of upper plate. The constant heat flux was provided to top surface only .The comparison of the result of Z-ribs with 30º,45 º,60 º and flat rib with same rib height ,pitch ratio and smooth channel is done. The thermal enhancement factor of all Z-ribs are higher than flat rib.The 45º Z-rib provide highest increase in heat transfer rate and best thermal performance.

SooWhanAhn,et al. [2] Investigated the heat transfer and friction factor characteristics in rectangular duct with one side roughened by five different shapes. In this they examined the effect of rib shape geometries as well as Reynolds number on heat transfer .They used five different shape of ribs e.g. square, triangular, circular, semicircular and arc. These ribs were sequentially installed at bottom wall of duct. To understand the characteristics of heat transfer enhancement the friction factor is also measured. The square rib has highest value of friction

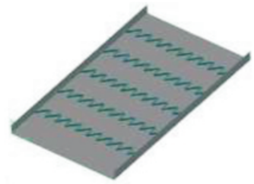

Fig 1: Z-Shaped Ribs

Fig 2: Segmented Ribs.

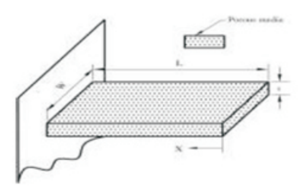

Fig 3: rectangular Porous Ribs

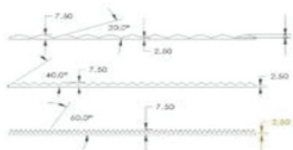

Fig 4: Corrugated Surface

Fig 5: Tape with attached baffle

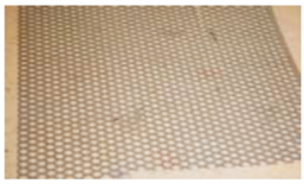

Fig 6: Porous Baffles

Fig 7: Twisted tape in tube

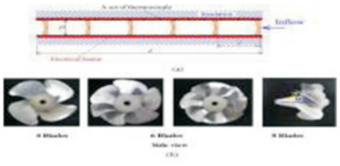

Fig 8: Tube equipped with propeller

FIGURE. 1. DIFFERENT TYPES OF HERT ENHANCING PROCESS

factor ,while triangular type rib has a substantially higher heat transfer performance than any other one. Rajendrakarwa , et al. [3] Carried out the experiment to measure heat transfer rate and friction factor in rectangular duct with fully perforated baffles and half perforated baffles fixed to one of broader wall. The baffled wall of duct is uniformly heated while remaining three walls insulated. The study shows an enhancement of 79-169% in Nusselt number over a smooth duct for fully perforated baffles and 133-274% for half perforated baffles while the friction factor for fully perforated baffles is 2.98-8.02 times that of half perforated baffles. Half perforated baffles are thermodynamically superior than fully perforated at same pitch.

PrashantDatta, et al.[4] investigated the local heat transfer characteristics and the associated frictional head loss in a rectangular channel with inclined solid and perforated baffles. The main objective of the study was to augment both local and global heat transfer behavior of a gaseous fluid (air) by placement of two inclined baffles. Since the flow disturbances and wakes generated by the upstream inclined baffle can potentially affect the performance of the downstream baffle, an average heat transfer performance is considered to cover the entire heated length. The local Nusselt number ratio with two inclined baffles significantly depends on the arrangement (orientation, perforation, and position of the baffles) used. Two inclined baffles augment the local heat transfer coefficient for a longer region of interest. The overall heat transfer coefficient is much higher with two inclined baffles than that with a single baffle placed in the same channel. The average Nusselt number can be as high as 5.0 times the average Nusselt number of a smooth channel.

Localized high heat flux zones can be effectively cooled with properly designed perforated baffles in those regions. The local Nusselt number ratio is not a strong function of flow Reynolds number. However, in a particular arrangement the friction factor ratio increases with increase in the flow Reynolds number. For two inclined baffle cases, the frictional head loss is much higher than that of a single baffle arrangement. Moreover, in two baffle cases the friction factor ratio is larger if the second baffle is attached to the bottom plate instead of the top heated surface.

Kang-HoonKo, et al. [5] carried out experiment to measure module average heat transfer coefficients in uniformly heated rectangular channel with wall mounted porous baffles. Baffles were mounted alternatively on top and bottom of the walls. Heat transfer coefficients and pressure loss for periodically fully developed flow and heat transfer were obtained for different types of porous medium (10,20, and 40 pores per inch) with two ratios baffle height to channel hydraulic diameter and baffle thickness to channel hydraulic diameter ratios. The experimental procedure was validated by comparing the data for the straight channel with no baffles with those in the literature [Publications in Engineering, vol.2, University of California, Berkeley,1930,p.443,Int.Chem.Eng. 16 (1976)359].the use of porous baffles resulted in heat transfer enhancement as high as 300% compared to heat transfer in straight channel with no baffles. Experimental procedure was validated by making heat transfer measurements for flow through a straight channel without any baffles. The variation of average Nusselt number with Reynolds number for fully developed flow in straight channels without any baffle.

PaisarnNaphon [6] investigated the heat transfer characteristics and pressure drop in a channel with V corrugated upper and lower plates under constant heat flux. He has carried out the analysis on channel with two opposite corrugated plate on which all configuration peaks lie in staggered arrangement. Corrugated plates with three different corrugated angles of 20º,40ºand 60º for Reynolds number and heat flux in the ranges 2000-9000 and 0.5 -1.2KW/m2 respectively. He found that the heat transfer rate increases as air flow rate increases. For a given Reynolds number and heat flux ,the average plate temperatures at higher wavy angle are lower than those from lower wavy angles. However ,the increase in heat transfer rate is less than that of the air mass flow rate .Therefore, the outlet air temperature tend to decrease as air mass flow rate increases. The pressure drop is continuous to increase with Reynolds number, the pressure drop obtained from channel with higher wavy angle are higher than those with lower wavy angles. The measured pressure drop obtained from channel with corrugated surfaces are 1.96 times higher than those from plane surface.

Teerapatchompookham et al. [7] In their experimental investigations they studied the effect of combined wedge ribs and winglet type vortex generators (WVGs) on heat transfer and friction loss behavior for turbulent air flow through a constant heat flux channel. To create reverse flow in channel ,two types of wedge (right-triangle) ribs were introduced .The arrangements of both types of ribs placed inside the opposite channel walls are in-line and staggered arrays. To generate longitudinal vortex flow through the tested section, two pairs of the WVGs with the attack angle of 60º were mounted on test channel entrance. The test channel had an aspect ratio,AR=10 and height H=30mm with rib height e/H =0.2 and rib pitch,P/H=1.33.The presence of combined ribs and WVGs shown the significant increase in heat transfer rate and friction loss over the mooth channel. The Nusselt number and friction factor values obtained from the conjunction with the WVGs ,the inline wedge pointing downstream provides the highest increase in both heat transfer rate and friction factor while the staggered wedge pointing upstream yield the best thermal performance.

R.M.Majumdar,V.M.Kriplani [8] investigated the effect of the perforated baffle on performance of rectangular channel. The different types of perforated baffle with different diameter (4mm,6mm,8mm) are used. The experimental study investigated the local heat transfer characteristic and friction head loss in channel with inclined solid and perforated baffle .The Reynolds number for this experimental study was varied between 7600 to 54000.The experimental results shows that the heat transfer rate increases with baffle as compared to without baffle and with increase in Reynolds number. The baffle with more number of hole and larger diameter causes more turbulence and maximum heat transfer occur. As the degree of inclination of baffle increases heat transfer rate increases as well as the increase in friction factor occurred.

Smith Eiamsa-ard, et al. [9] Investigated the effect of helical tapes in tube over the heat transfer. Helical tape inserted in tube with a view to generate swirl that helps to increase the

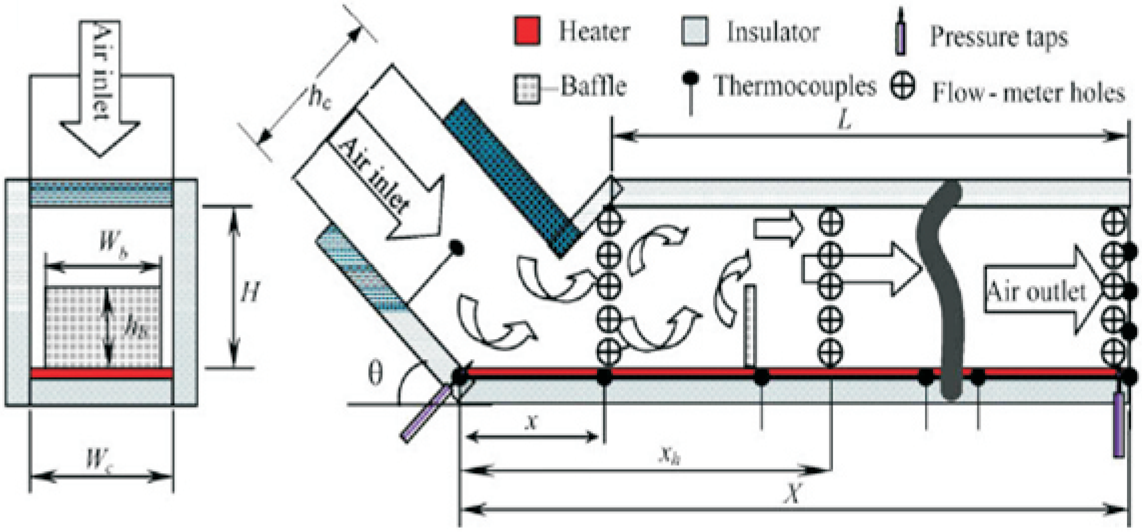

FIGURE 2. EXPERIMENTAL SETUP

Table 1
Dimensions of the independent parameters (mm)

h_b	H	θ	X	W_c	W_b	h_c	L
15		0°				36	515
30	60	45°	600	50	48	60	540
45		90°				85	564

heat transfer rate. Reynolds number considered between 2300-8000. The swirl devices consist of

1.Full length helical tape with and without centered rod.
2.Regularly spaced helical tape without rod.

Hot air flowing through the tube and cold water in annulus space. Experimental data was compared with that of plain tube and found that full length helical tape with rod provides higher heat transfer rate over without rod but increased pressure drop. The maximum mean Nusselt number increased by about 160% for full length tape with rod,150% for full length helical tape without rod and 145% for regularly spaced helical tape.

Smith Eiamsa-ard, et al.[10] Investigated heat transfer ,friction loss and enhancement efficiency behavior in heat exchanger tube with propeller type swirl generator at several pitch ratio. Reynold number ranged from 4000 to 21000 for uniform heat flux conditions. The experiments were also undertaken for different blade numbers (i.e 4,6 and 8) and different blade angle (i.e 30º,45º,60º) and for pitch ratio 5,7 and 10 and effects of above parameters on heat transfer, friction loss. They found heat transfer considerably enhanced by insertion of propeller type swirl generator. The heat transfer enhancement efficiency were found to be increased with increasing blade number and blade angle but decreases with increase in rib pitch ratio.

Heat Transfer Enhancement in Different entry Conditions IrfanKurtbas, evaluated the effect of different inlet conditions of air in a rectangular channel on convection heat transfer: Turbulence flow, an experimental investigation was carried out to determine average heat transfer coefficients in uniformly heated rectangular channel with 45 o and 90o turned flow, and with wall mounted a baffle. The channel was heated through bottom side with the baffle. In present work, a detailed study was conducted for three different height of entry channel named as the ratio of the height of entry channel to the height of test section by varying Reynolds number. Another variable parameter was the ratio of the baffle height to the channel height. Only one baffle was attached on the bottom (heating) surface. The experimental procedure was validated by comparing the data for the straight channel with no baffle. Reynolds number was varied from 2800 to 30,000, so the flow was considered as only turbulent regime. All experiments were conduced with air accordingly; Prandtl number (Pr) was approximately fixed at 0.71. The results showed that average Nusselt number for h = 45_ and h = 90_ were 9% and 30% higher, respectively, than that of the straight channel without baffle. Likewise, the pressure drop increased up to 4.4 to 5.3 times compare to the straight channel.

V.EXPERIMETAL SETUP

Fig. 2 depicts the experimental apparatus used by IrfanKurtbas that shows the schematics of test assembly (a) and the geometrical details of the channel with baffle (b). The main flow of air was supplied using a centrifugal fan (1), and the flow rate was adjusted and controlled by an AC inverter (Ekamad A-2000 with accuracy of 1%) (2). The air was passed through a digital flow-meter (3), then a mixing chamber (4) and then a straightening section (5). The flowing air enters the test section the angular entry or perpendicular entry or straight entry (7). The top and two side walls of the channel were made of non-tempered glass while the bottom wall and the baffle were made of aluminum plate. The bottom surface of the test section received a constant heat flux, q, while the upper and side surfaces were adiabatic. A digital flow mater (Testoterm 4400; measurement range: 0.6–40 m/s; one digit after decimal point) was setup between the fan and mixing chamber. Dimensions of the test section are given in Table 1. A silicone rubber heater is fixed to the outer surface of the bottom of the test section to provide the uniform heat flux. The heat flux was set by adjusting the electrical voltage with the help of AC variable electric power supply (De-Lorenzo, with accuracy of ±1–1.5% for voltage (V) and current (I)), and the constant heat flux was allowed to continue till the steady state is attained (8). The temperature of the heated surface is measured by 11 calibrated and electrically insulated 0.5 mm diameter T-type thermocouples fixed at selected locations in the test section (9). 1 and 3 thermocouples are used to measure inlet and outlet flow temperature too, respectively. The exit temperature of the air is obtained by averaging the three thermocouple measurements. The signals from thermocouples and pressure transducer (6) are collected by a data-logger device (Almemo 5990-0, with a resolution of ±0.05 _C) (11), and recorded by a personal computer (12). Pressure losses throughout the test section were measured using a calibrated differential pressure transducer (Almemo FDA602M1 with accuracy of ±0.5% of final value) connected with pressure taps as shown in Fig. 1b. The experiments of the velocity were also performed. The local average velocity of the air was measured setting Thermoelectric Flow Sensor (Almemo FVA645TH3 with accuracy of ±3% of final value) at the center plane (Wc/2) of the channel (10). After the temperature and pressure drop experiments had been performed simultaneously, the velocity experiments were carried out. Fifteen apertures in total were operated at three different distances from the entrance of the test section. The anemometer was inserted through one aperture. In this way, the local average velocities in the test section were measured at several locations.

Reynolds number is varied from 2800 to 30,000 (7 different value of mass flow rates are tested). The experiments are conducted with only one baffle arrangement (_X ¼ 0:2) and three different baffle height aspect ratio (_Hb ¼ 0:25; 0:5 and 0:75). In order to investigate the effect of the ratio of the entry height to the height of test section on the heat transfer, three different entry height-base ratios were considered (_Hc ¼ 0:6; 1 and 1:4).

Furthermore, the channels with two different flow entry angles were manufactured for each _Hc value. In other words, one being the straight channel, in total seven different flow channels has been manufactured. Heat transfer measurements were performed under steady state conditions. When the variations of local wall temperatures during an interval of 10 min. were less than 0.3 _C, the system was assumed to be in a steady state. The temperatures and pressure drop were recorded simultaneously after the start of test run to achieve steady state. To confirm the experimental data such as temperature, pressure drop and velocity, the experimental results were recorded four times at a time interval of 3 min under steady state conditions. The averages of these four data were used for calculating of depended parameters.

CONCLUSION

In this paper, we studied heat transfer enhancement in a rectangular channel with/without baffle. We studied the work of several researchers about various heat transfer enhancement techniques. We also studied about the effect of heat transfer enhancement by varying the inlet conditions in the rectangular duct such as angular entry and different size of entry channel.

REFERENCES

1.The effect of different inlet conditions of air in a rectangular channel on convection heat transfer: Turbulence flow by Irfan Kurtbas, Experimental Thermal and Fluid Science 33 (2008) 140–152.

2.Experimental study of Flow and heat transfer in rib-roughened rectangular channels, Carl-Olof Olsson, Bengt Sunden b ; Experimental Thermal and Fluid Science 16 (1998) 349 to365.

3.Heat Transfer and Flow Structure in a Rectangular Channel With Wing-Type Vortex Generator , Isak KOTCIOGLU, Tr. J. of Engineering and Environmental Science, 22 (1998) , 185 – 195.

4.THE EFFECTS OF DUCT SHAPE ON THE NUSSELT NUMBER M. Emin Erdoğan and C. Erdem Imrak; Mathematical and Computational Applications, Vol. 10, No. 1, pp. 79-88, 2005

5.Monsak Pimsarn, et al. "Augmented Heat Transfer in Rectangular Duct with Angled Z-Shaped Ribs" PEA-AIT International Conference on Energy and Sustainable development: Issues and Strategies (ESD 2010) The Empress Hotel, Chiang Mai, Thailand. 2-4 June 2010

6.Soo Whan Ahn , Kang Pil Son "An Investigation on Friction Factors and Heat Transfer Coefficients in a Rectangular Duct with Surface Roughness" KSME International Journal, VoL 16 No.4, pp. 549-556, 2002

7.Rajendra Karwa , B.K. Maheshwari "Heat transfer and friction in an asymmetrically heated rectangular duct with half and fully perforated baffles at different pitches" International Communications in Heat and Mass Transfer 36 (2009) 264−26

8.Prashanta Dutta, Akram Hossain "Internal cooling augmentation in rectangular channel using two inclined baffles" International Journal of Heat and Fluid Flow 26 (2005) 223−232

9.Kang-Hoon Ko, N.K.Anand "Use of porous baffles to enhance heat transfer in a rectangular channel" International Journal of Heat and Mass Transfer 46(2003)4191-4199.

10.Paisarn Naphon "Heat transfer characteristics and pressure drop in channel with V corrugated upper and lower plates" Thermo-Fluid and Heat Transfer Enhancement Laboratory ,Department of Mechanical Engineering, Faculty Of Engineering, Srinakharinwirot University,63 Rangsit-Nakhornnayok Road, Ongkharak, Nakhorn-Nayok 26120,Thailand Received 17 May 2006;accepted 26 November 2006

11.Teerapat Chompookham, et al. "Heat transfer augmentation in a wedge-ribbed channel using winglet vortex generators" International Communications in Heat and Mass Transfer 37 (2010) 163−169

12.R.M.Majumdar,V.M.Kriplani "Internal cooling augmentation using inclined perforated baffle in rectangular channel" International journal of mechanics and thermodynamics Vol.2,No.2(2011)113-12

13.Smith Eiamsa-ard, Pongjet Promvonge "Enhancement of heat transfer in a tube with regularly-spaced helical tape swirl generators" Department of Mechanical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

14.Smith Eiamsa-ard, Pongjet Promvonge "Turbulent convection in round tube equipped with propeller type swirl generators" International Communications In Heat and

15.Sukhmeet Singh, et al "Heat transfer and friction factor of discrete V-down rib roughened solar air heater ducts" journal of renewable and sustainable energy 3, 013108 -2011. R.Karwa , et al "Heat transfer coefficient and friction factor correlations for the transitional flow regime in rib roughened rectangular ducts" International Journal of Heat and Mass Transfer 31 "0888# 0486_0504

Bharat Wandhare
Student,Mtech Heat Power Engineering , Dr. BabasahebAmbedkar College of Engineering Research, Nagpur, India.