Experimental Investigation of Heat Transfer Enhancement in Air Channel with Broken V-Shaped Baffles

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***Abstract*— The paper presents an experimental study on the heat transfer rate, nusselt number and heat transfer coefficient of solar air channel fitted with discretized broken V-pattern baffle on the heated plate. Experiments have been carried out for system parameter such as a relative gap width $g_w/H_b = 1.0$, relative baffle height $H_b/H = 0.50$, relative pitch ratio $P_b/H = 1.5$ and angle of attack $\alpha_a = 60^\circ$. It has been found that heat transfer rate of broken multi type V-baffles air channel is better than the heat transfer rate of smooth surface air channel.**

***IndexTerms*— Solar energy, Turbulence, heat transfer, baffle width, baffle distance, solar air channel**

I. INTRODUCTION

Solar air channel (SAC) is one of the basic equipment through which solar energy is converted into thermal energy. The thermal efficiency of SAC is low because of low value of convective heat transfer coefficient between the flowing air and heated plate due to the formation of thin laminar viscous sub-layer on its heated plate. Air channel is one of the simplest and extensively used types of heat exchanger in which heat energy is being exchanged between heated wall and air streaming through the system. The efficiency of SAC can be improved by modifying the boundary layer developed on the heated surface. One of the well-known methods of modifying the boundary layer is to break the laminar viscous sub-layer formed on the heat transfer surface by creating artificial roughness in the form of blocks, winglet, dimples and baffles. Baffles used as disturbance promoters increase fluid mixing and interrupt the development of the thermal boundary layer, leading to enhanced heat transfer in the air channel. The baffle roughness has been used extensively for the augmentation of forced convective heat transfer coefficient of air channels. The main applications of SAC are space heating, seasoning of timber, curing of industrial products.

II. LITERATURE REVIEW

R.P. Saini.et.al. [1] They have carried out an experimental study to investigate the effect of roughness and operating parameters on heat transfer and friction factor in a roughened duct provided with dimple-shape roughness geometry. The duct having the dimensions of inner cross-sectionals 2400mm$\times$300mm$\times$25mm was made of wooden panels. The test section having a length of 1000mm was provided. The length of entry and exit section was provided as 900mm and 500mm, respectively. An electric heater having a size of 1500mm$\times$290mm was fabricated by combining series and parallel loops of heating wire on a 5-mm-thick asbestos sheet. Enhancement of Nu and frs was reported to be of order 2.49 and 2.98 times respectively over smooth channel.

Nuntadusit C. et. al [2] worked on heat transfer characteristics in a channel fitted with zigzag-cut baffles. They have study, 4 types of baffles were examined; conventional baffle (Rectangular cross section with no cut), baffle with rectangular zigzag-cut, baffle with triangle zigzag-cut at 45 degree and at 90 degree. All of the baffles have the same height at H = 15 mm and flow blocking area. The baffle with rectangular zigzag-cut gives the superior thermal performance about 1.84 times over smooth channel.

Parkpoom Sriromreun. et.al [3] experimental and numerical study on heat transfer enhancement in a channel with Z-shaped baffles. In the experiment, the baffles are placed in a zigzag shape (Z-shaped baffle) aligned in series on the isothermal-fluxed top wall, similar to the absorber plate of a solar air heater channel. The aim at using the Z-baffles is to create co-rotating vortex flows having a significant influence on the flow turbulence intensity leading to higher heat transfer enhancement in the tested channel.They observed that significant improvement in Nu and frs with the presence of Z- shaped baffle as compared to without baffle channel.

Tang LH. et. al [4] focus his work on A New Configuration of Winglet Longitudinal Vortex Generator to Enhance Heat Transfer in a Rectangular Channel. Comparing with the delta winglet configuration, the *Nu* of the rectangular winglet configuration are larger when operates in the same Reynolds number. The cross-sectional flow area of the channel with rectangular winglet configuration is smaller than that of the channel with delta winglet configuration. The result shows that the pressure drop performance of common-flow-up configuration is better than that of common-flow-down configuration. 2.98 and 3.56 times enhancement in Nu and frs respectively were reported over smooth surface channel.

Pongjet Promvonge.et.al. [5] Heat transfer and pressure drop in a channel with multiple 60° V-baffles. They have been carried out for the channel of aspect ratio, AR=10 and height, H=30mm with three different baffle blockage ratios, (e/H=0.10, 0.20 and 0.30) and three baffle pitch spacing ratios, (PR=P/H=1, 2 and 3) while the transverse pitch of the V-baffle is set to 2H and kept constant. The 60° V-baffle turbulators yield considerable heat transfer enhancements with a similar trend in comparison with the smooth channel and the Nusselt number increases with the rise of Reynolds number. This is because the V-baffle turbulators interrupt the development of the boundary layer of the fluid flow and increase the turbulence degree off low. Due to the V-baffle 13.76–20.34% enhancement in the thermal efficiency was reported over smooth surface channel.

Raj Kumar. et. al [6] They have worked on experimental investigation of effect of flow attack angle on thermo hydraulic performance of air flow in a rectangular channel with discrete V-pattern baffle on the heated plate. The baffle wall was constantly heated and the other three walls of the channel were kept insulated. Making a discrete in V-pattern baffle results in considerable improvement in heat transfer coefficient of air flow channel, the enhancement is a strong function of discrete distance and size. The Nusselt number augmentation tends to rise with the rise in Reynolds number. The use of the discrete V-pattern baffle with angle of attack of 60° causes a very high Nusselt number and friction factor as compared with other values of angle of attack. The upper most thermo hydraulic performance occurs at angle of attack of 60°.

A.M.Shariah. et. al [7] The effect of thermal conductivity of the absorber plate of a solar collector on the performance of a thermosyphon solar water heater is studied by the use of the transient simulation system (TRNSYS) computer program. The results have shows that the annual solar fraction of the system and the collector`s characteristic factors (namely, fin efficiency factor, collector efficiency factor, and heat removal factor) have a very strong dependence on the thermal conductivity for its low values, and weak dependence is observed beyond a thermal conductivity value of 50 W/m$^{\circ}$C for the solar fraction and beyond a value of 100 W/m$^{\circ}$C for the characteristic factors. It is also observed that the annual solar fraction is improved by about 4%-7% and the characteristic factors are improved by about 12%-19% when a steel absorber plate is replaced by an aluminium one, whereas, the solar fraction and the characteristic factors are increased only about 1% and 3%, respectively, when a copper plate is used instead of an aluminium one.

III. EXPERIMENTAL SET UP

To study the outcome of discretized broken V-pattern baffle turbulent promoter on the Nu_{rs} and f_{rs} of air stream an experimental set up will intended and made-up. The air channel is 2000 mm extended with a stream cross section of 300 mm × 60 mm is made-up from aluminium plate of 20 mm thickness. The channel is comprises of inlet section 500 mm long, a test section of 1200 mm length and an exit section of 300 mm length. The complete channel is insulated with 50 mm thick glass wool insulation having thermal conductivity of 0.04 W/mk to minimize heat loss to the environment. The data will also been collected for conventional solar air heater channel under similar system and operating conditions for the validation purpose and so as to compare the same with discretized broken V-pattern baffle solar air channel. The experimental test rig is shown in Fig. 1.

Fig.1. Experimental Setup

The air blower is used to propel the atmospheric air in the air heater channel which passes through the discretized broken V-pattern baffle provided on the plate and then exits at the other end. The air flow in the channel will controlled by means of control valves provided at inlet of the suction blower. A calibrated Orifice meter connected to U-tube manometer will used to measure the mass stream rate of air through rectangular air channel. Discretized broken V-pattern baffle will be attached on the base of heated wall by means of epoxy resin. The temperature of the absorber surface, inlet air and exit air will be measured by digital thermometers. Such thermometer will usually recommend for temperature measurement in the range of 0-110$^{\circ}c$. Total numbers of 8 thermometer will be mounted on the upper surface of the absorber plate from which one will used for measurement of ambient air temperature, one will used for heated air temperature and rest of six will used for absorber plate temperature measurement. The air flows through the rectangular channel will measured by a flange type orifice meter which will be fitted in the pipe of 25 mm diameter connected with a plenum and carrying air to the blower. The ratio of orifice diameter to pipe diameter (β) is 0.80.

The design of multi discretized broken V-pattern baffle provided on the plate in the solar air channel are as below.

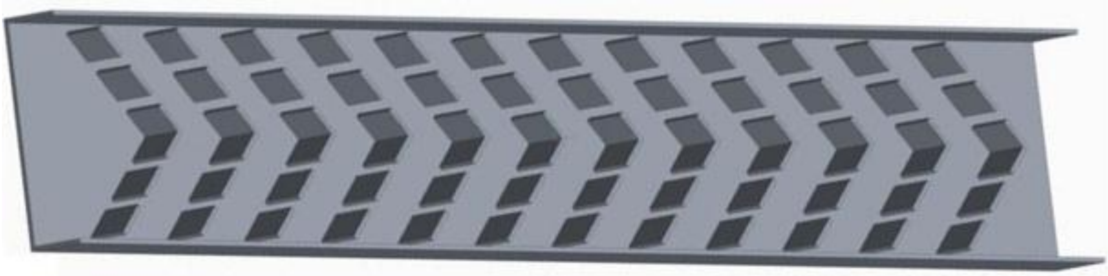

Fig.2. Multi Discretized Broken V-Pattern Baffle

IV. DATA REDUCTION

The mean temperature of the plate (T_p) is the average of all temperatures of the heated plate:

$$T_p = \frac{\sum T_{pi}}{N} \tag{1}$$

The mean bulk air temperature (T_f) is a simple arithmetic mean of the measured data at the inlet and exit temperature of air streaming through the test section:

$$T_f = \frac{T_i + T_\circ}{2} \tag{2}$$

Where $T_\circ = (T_{A2} + T_{A3} + T_{A4} + T_{A5} + T_{A6})/5$, $T_i = T_{A1}$

The mass stream rate (m_a) of air has been calculated from the pressure drop measurement through the orifice meter by using the following formula:

$$m_a = C_{d0} A_0 \left[\frac{2\rho_a (\Delta p_0)}{1-\beta^4} \right]^{0.5} \tag{3}$$

The velocity of air (V) is calculated from the m_a

$$V = \frac{m_a}{\rho_a \times W \times H} \tag{4}$$

Equivalent hydraulic diameter (D_{hd}) is determined by

$$D_{hd} = \frac{4 \times (W \times H)}{2 \times (W + H)} \tag{5}$$

The Reynolds number (R_e) of air stream in the channel is intended from

$$R_e = \frac{V.D_{hd}}{\nu} \tag{6}$$

The heat transfer rate (Q_u) from absorber to the air is given by:

$$Q_u = m_a c_p (T_0 - T_i) \tag{7}$$

The Heat Transfer Coefficient (h_t) for the heated test section has been calculated as:

$$h_t = \frac{Q_u}{A_p(T_p - T_f)} \tag{8}$$

The h_t can be used to determine the Nusselt number (Nu_{rs}), which is defined as:

$$Nu_{rs} = \frac{h_t D_{hd}}{K_a} \tag{9}$$

V. RESULTS AND DISCUSSION

A study was conducted to understand the effect on Nu_{rs}, heat transfer rate, heat transfer coefficients and discretized broken V-pattern baffle used to provide roughness for an air channel. In order to compare the improvement of the Nu_{rs} achieved as an outcome of providing a broken in the V-pattern baffle arrangement.

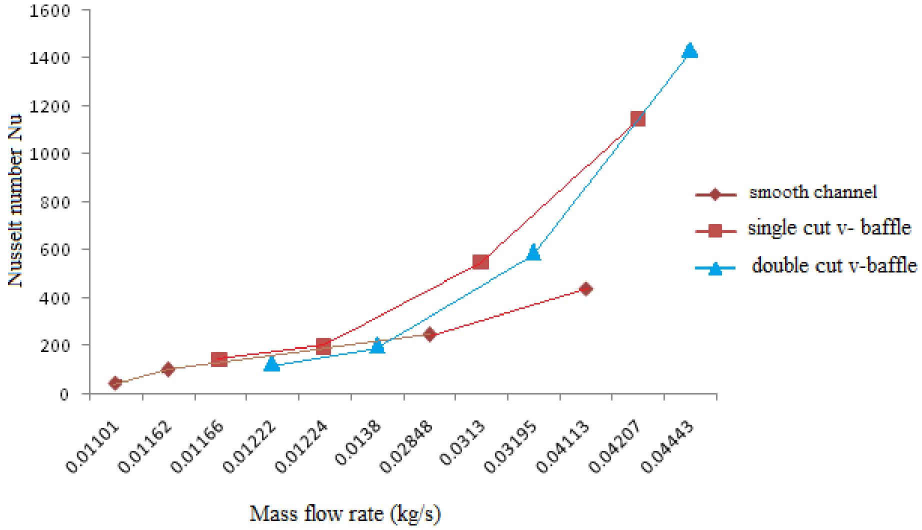

Fig.3. Mass flow rate m_a Vs Nusselt number Nu

As shown in fig.3 the values of Nu_{rs} which increased when the mass flow rate m_a increased. From the comparison double cut V-baffle give the higher value of nusselt number than compare to single cut V-baffle and smooth channel.

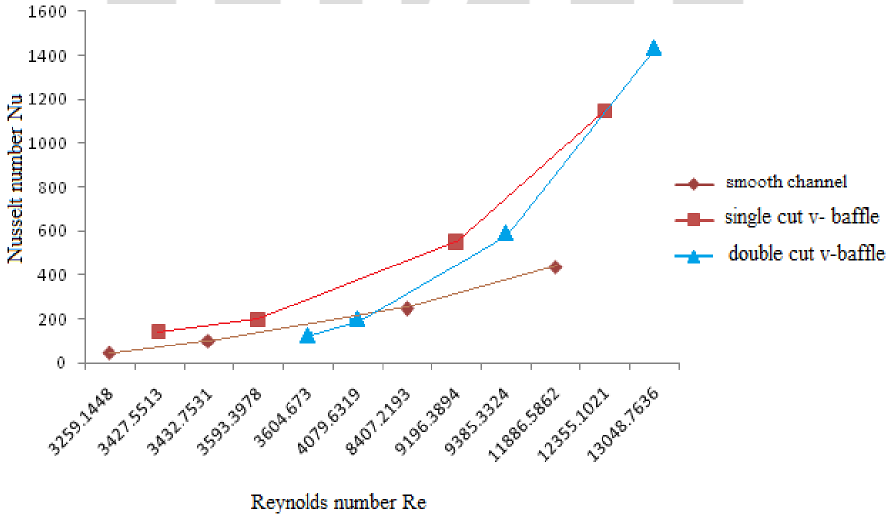

Fig.4. Reynolds number Re Vs Nusselt number Nu

From the fig.4 the values of Nu_{rs} rises when Reynolds number rises. Double cut V-baffle give the higher value of Reynolds number so which give higher value of nusselt number than compare to single cut V-baffle and smooth channel.

Fig. 5 shows the variation of heat transfer rate Qu with Reynolds number Re. The heat transfer rate rises with rises in Reynolds number. Heat transfer rate in double cut V-baffle is higher than the single cut V-baffle and smooth channel.

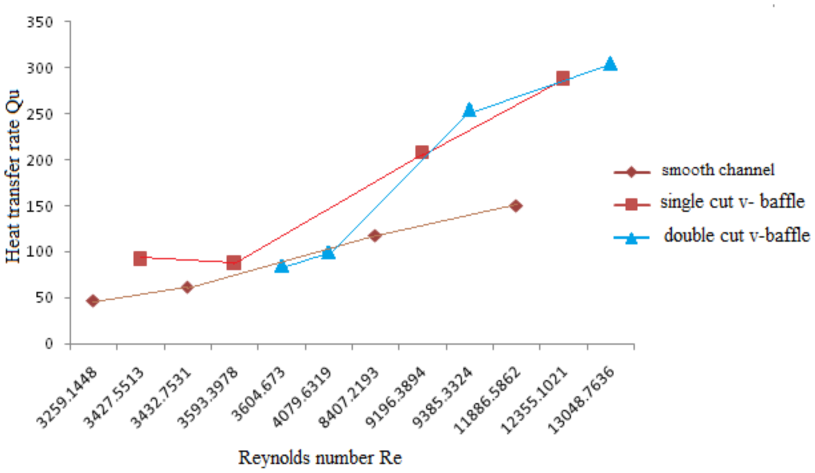

Fig.5. Reynolds number Re Vs Heat transfer rate Qu

VI. CONCLUSION

On the basis of experimental analysis of heat transfer rate of air channel provided with heated plate having discretized broken V-shaped baffles outcomes in substantial improvement in Nu_{rs} of air channel the improvement is a strong function of broken width and broken distance. As compared to the without baffle channel and single cut V-baffle the presence of double cut V-baffle channel give the higher value of heat transfer rate, heat transfer coefficient and nusselt number. V-shaping of the baffle helps in the formation of two leading ends and a single trailing end as well as two secondary flow cells which promote turbulent mixing and hence increased heat transfer. Creating discrete in the V-pattern baffle allows release of the secondary flow and mix with main flow through discrete. This results in its acceleration, which energizes the retarded boundary layer flow along the surface resulting in the increase of the heat transfer through the discrete width are behind the baffles.

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