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Experimental Investigation of Flow and Heat Transfer in a Smooth Channel Affected by Vortex Generator with a Punched Hole

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ABSTRACT: Heat transfer and hydraulic performance for flow in a rectangular channel with LVGs (longitudinal vortex generators) are experimentally investigated using the different shape of LVGs. Firstly, a precise and reliable experimental setup was designed and fabricated to generate a constant heat flux boundary condition. In order to analyze the effect of shaped LVGs, three different of the rectangular, trapezoidal and delta winglet pair vortex generators with and without punched holes on the flow field and heat transfer characteristics at the different attack angle of 15º, 30º, 45º and 60º with a small thickness has been studied. Effects of the number of punched holes were evaluated by using dimensionless numbers, friction coefficient ratio (f/f_0), Nusselt number ratio (Nu/Nu_0) and overall performance ((Nu/Nu_0)/(f/f_0)). According to the experimental results, the rectangular winglet pair without punched holes vortex generator has the highest values of friction factor ratio and increased with bigger attack angle. The friction factor decreased and heat transfer and also overall performance increased with implementing of perforated rectangular, trapezoidal and delta winglet pair in the channel but in the case of implementing trapezoidal vortex generator with two punched holes heat transfer is a little more than the vortex generator with three punched holes.

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1- Introduction

Due to the application of heat exchangers in many fields such as automotive, aerospace industry, electronics cooling and chemical engineering on the one hand and the importance of saving materials, energy and restriction of the required design space on the other hand, have promoted researchers to carry out extensive studies to find novel ways to increase overall performance for exchangers. For heat transfer enhancement, bypassing techniques, using typical fins such as louvers, wavy and slotted fins seems to be remarkable [1]. Jacobi and Shah [2] and Fiebig [3] both indicated that longitudinal vortices cause weaker flow losses but a better heat transfer performance than the transverse vortices, and consequently, the longitudinal vortices embedded in turbulent boundary layers can occur in a wide range of flow and heat transfer control cases. Tiggelbeck et al. [4] considered two rows of delta winglet pairs; the aligned and the staggered rows. Their results showed that the heat transfer increased 60% in the aligned rows, but 52% for staggered rows. Zhou and Ye [5] experimentally investigated a new Longitudinal Vortex Generator (LVG) model called curved trapezoidal winglet and compared it with traditional LVGs by using dimensionless factors. The results showed that the DWP has the best thermal performance in laminar flow, while CTWP has the best thermal performance in turbulent flow. Zhou and Feng [6] extended their work and experimentally investigated the performance of the plane and curved LVGs with and without punched holes. The results showed that the punched holes improve the thermal performance of LVGs. The optimum diameter of the punched holes is relative to the area of the LVG, i.e. for the LVG with smaller face area, small holes are more reliable.

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The main goal of the present paper is to give a clearer comparison of the heat transfer and hydraulic performance for the flow in a rectangular channel with LVGs with and without punched holes, by the experimental tool. Also, the effect of the number of the punched holes on the performance is focused. In the following sections, experimental setup, flow and temperature fields, and the heat transfer enhancement factor will be presented.

2- Experimental Setup

The experiment is conducted in a rectangular channel with air flow as the working fluid, as shown in Fig. 1. According to this setup, the bottom side is a copper plate and heated by electric heating. This plate has 860 mm long, 300 mm wide and 50 mm thick which is insulated from heat transfer. The vortex generator is embedded in the copper plate. In order to measure the pressure difference between the inlet and outlet of the test section, two orifices at the channel wall in the inlet and outlet are perforated. The temperature data logger can measure temperatures with its internal sensors and the data recorded by the logger was transferred to a personal computer.

3- Results and Discussion

Fig. 2 shows a visual comparison of the flow structure in the channel in the presence of LVG with and without punched holes. It is apparent that the strength of the main vortex and horseshoe vortex were reduced by using holes. The reason could be that the jet originated from the holes passes through the vortex and disturbs and weakens the main longitudinal vortex generated at the inclination edge.

For the trapezoidal vortex generator, using LVG in the channel would significantly increase heat transfer rate. Whereas the increase in the number of punched holes, would slightly increase the rate of the heat transfer. It should be noted that

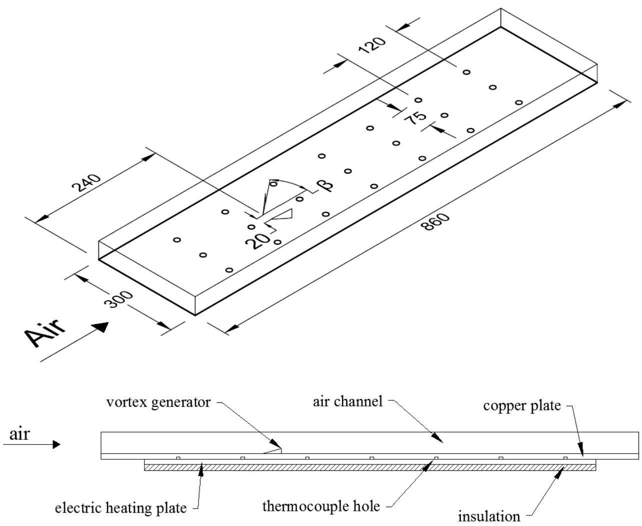
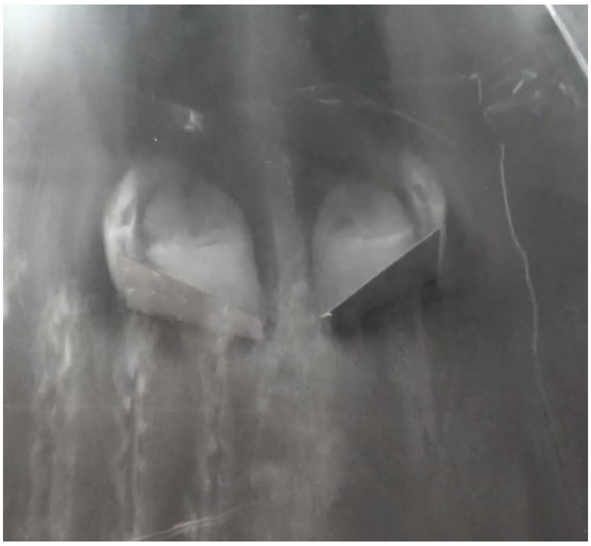
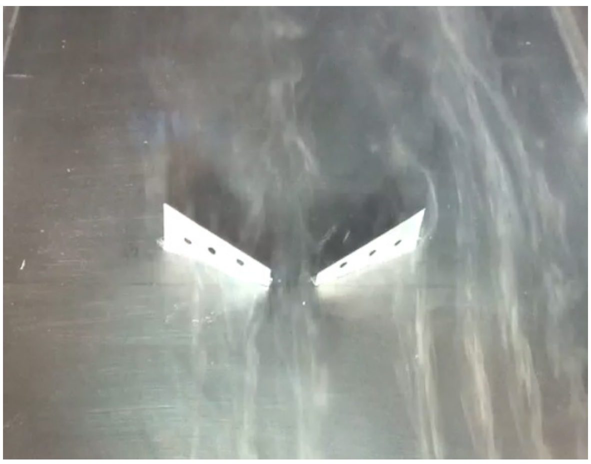


Figure 1. Schematic sketch of the test section, copper plate, and their dimensions.



(a)



(b)

Figure 2. Visualization of the flow in the presence of LVG (a) without punched holes (b) with punched holes

when three holes are located in the LVG, the rate of the heat transfer is less than two holes, due to the reduction of the LVG effect on the main flow. In addition, it can be seen that the overall performance increases by using punching holes on LVG increasing the number of punched holes, and decreases with Reynolds number increment. However, punching two holes on the LVG decreases the friction factor ratio by 12-27% and increases the Nusselt number and overall performance by 2-7% and 15-33%, respectively.

For the rectangular LVG, the increment in the number of punched holes leads to the excess of the friction factor, as the same for the trapezoidal LVGs. The punched holes on the LVG reduces the surface area of LVG that leads to the reduction of the flow resistance and friction factor. According to the results, friction factor ratio of rectangular LVG with three holes reduces about 14-28% with respect to rectangular LVG without holes. Also, it can be seen that the heat transfer rate in the channel with rectangular LVG with holes, is higher than the case with plane LVG. The results also show, by increasing the number of punched holes on the rectangular LVG, the heat transfer and friction factor decrease, and therefore the overall performance improves; the punched three holes on rectangular LVG increases the overall performance about 14-35%.

Also, for the triangular LVG, similar to trapezoidal and rectangular LVGs, by increasing the number of punched holes, friction factor increases. According to the curves, punched holes in delta LVG decrease the friction factor ratio by 12-25% and increase the Nusselt number and overall performance by 3-9% and 16-20%, respectively.

4- Conclusions

In the current research, the effect of punched holes on the performance of the LVG has been studied experimentally. The Nusselt number ratio, friction factor ratio, and thermal performance have been presented. In accordance with the gained results, the following statements can be concluded:

- The rectangular LVG pair has the highest friction factor than others. Also, rectangular LVG pair has a little higher thermal than others, but not as high as it can change the f/f_0. The delta winglet LVG has the best overall performance, and the trapezoidal LVG pair has a higher overall performance than the rectangular LVG pair.
- Punching holes on the LVG strongly affects the flow and heat transfer in the channel. It is apparent that the strength of the main vortex and horseshoe vortex were reduced by using holes. The reason could be that the jet originated from the holes passes through the vortex and disturbs and weakens the main longitudinal vortex generated at the inclination edge.
- For all three LVGs, the punched holes decrease the friction factor ratio and Nusselt number ratio. While overall performance is increased due to the reduction of friction factor.

References

[1] Molki, M., Damronglerd, P., 2006. Electrohydrodynamic Enhancement of Heat Transfer for Developing Air Flow in Square Ducts. *Heat Transfer Engineering*, 27, pp. 35–45.

[2] Jacobi, AM., Shah, RK., 1995. Heat transfer surface enhancement through the use of longitudinal vortices:

a review of recent progress. *Experimental Thermal and Fluid Science*, 11, pp. 295–309.

[3] Fiebig, M., 1995. Embedded vortices in internal flow: heat transfer and pressure loss enhancement. *International Journal of Heat and Fluid Flow*, 16, pp. 376–388.

[4] Tiggelbeck, S., Mitra, NK. and Fiebig, M., 1993. Experimental Investigations of Heat Transfer Enhancement and Flow Losses in a Channel with Double Rows of Longitudinal Vortex Generators. *Int. J. Heat Mass Transfer*, 36, pp. 2327-2337.

[5] Zhou, GB., Ye, QL., 2012. Experimental investigations of thermal and flow characteristics of curved trapezoidal-winglet type vortex generators. *Applied Thermal Engineering*, 37, pp. 241-248.

[6] Zhou, GB., Feng, ZZ., 2014. Experimental investigations of heat transfer enhancement by plane and curved winglet type vortex generators with punched holes. *International Journal of Thermal Sciences*, 78, pp. 26-35.

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