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The effect of hole on the rectangular vortex generator on thermal-hydrodynamic performance of the minichannel

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ABSTRACT: There are several ways to increase heat transfer in mini-channels, like adding a vortex generator. In this paper, the effect of the presence of the hole on vortex generators on the heat transfer parameters is examined. In this study, a 50 mm long minichannel with eleven rectangular vortex generators, with holes with area of 5 to 60% of the vortex generator area, was analyzed with water-based fluid under constant flux in the range of Reynolds numbers 200-1000. The results showed the presence of holes on the vortex generators reduced the pressure drop resulting from the obstruction against the fluid flow and 34.7% decrease in pressure drop is observed for minimum and maximum area of holes in Reynolds number 1000. The Nusselt number is increased by existence of a hole in the Reynolds numbers range and then is decreased by increasing the size of the hole due to the reduction of the vortex size behind the obstacle, so that in the maximum Reynolds number by increasing hole size, 34.3% decrease is observed.

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1.INTRODUCTION

There are many parameters that effect on performance enhancement of electronic equipment such as increasing heat dissipation from the equipment. Heat transfer enhancement in heat exchangers can be divided into two main methods, active and inactive solutions. utilizing vortex generators are one of the effective methods in inactive category. Vortex generators cause increment in pressure loss and accordingly increase in pumping power. One of the solutions for decreasing pressure loss is to make hole on the vortex generators. Hole existence in cylindrical ribs in minichannel is investigated by Al-Asadi et al. [1]. The results show that by making hole in the ribs pec is enhanced in uniform heat flux and Reynolds number 300. Kamboj et al. [2] in a numerical investigation with finite volume method has shown that hole existence can lead to heat transfer enhancement due to decrease in thermal resistance. Numerical simulation on heat transfer characteristics of rectangular vortex generators with a hole is studied by Han et al. [3]. They compared pressure drops in vortex generators with and without hole. The results show increment in pec in rectangular vortex generators with hole in compression with the one without hole. Zhou and Feng [4] investigated experimentally rectangular and trapezius and delta, plain and curved vortex generators with punched holes. They observed that vortex generators with punched hole have better thermal performance. Results of 3d investigation by Boukhadia et al. [5] show that punched vortex generators increase heat transfer in comparison with simple vortex generators. Circle rectangular and triangle vortex generators have better heat transfer coefficient, respectively. In a study carried out by Ameur and Menni [6] circle holes are made on vortex generators in a heat exchanger in order to decrease pressure drop. The results show that by using this type of vortex generators pressure losses decrease and Performance evaluation criteria increases in comparison with the one without hole. Ameur et al. [7] compared heat transfer coefficient and pressure drop and performance evaluation criteria in baffles that were perforated in circle and oval shapes. performance evaluation criteria enhanced 55 and 74 percent for circular and oval respectively, to simple channel. Lu and Zhou [8] in a 3D numerical investigation on 6 different vortex generator shapes observed that performance evaluation criteria enhanced in vortex generators with hole in comparison with the one without hole.

2. METHODOLOGY

In this study, Fig. 1, a mini channel with inlet area of $H_{ch} \times W_{ch}$=1 mm2 and length L=50 mm including 11 vortex generators with equal distance and dimensions is investigated. Six different holes are designed with 5 to 60 percent of simple vortex generators that are compared with simple mini channel without vortex generator named Ch-b as base case. Fluid flow is considered as laminar, steady state, incompressible and all mini channel surfaces have no slip condition. Gravity and other volumetric forces are neglected. Water and aluminum specifications are considered constant. Ansys fluent is used

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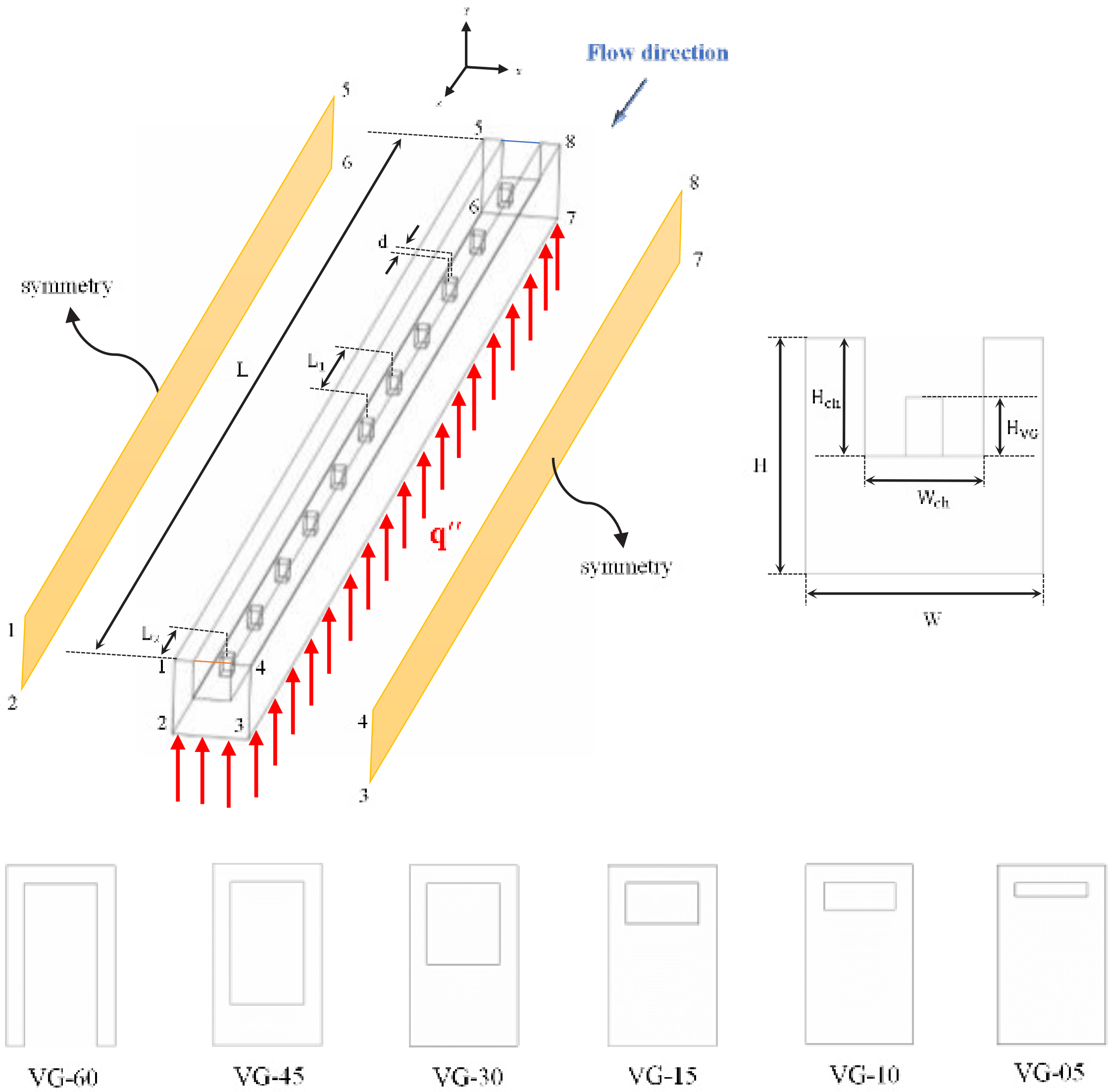

Fig. 1. 3D view schematic of minichannel

to solve governing equations. The channel is designed to cool CPU with 127 W/m^2 heat dissipation. Inlet water temperature is 300K and 5 different velocities in Reynolds 200 to 1000 are considered. Sidewalls have symmetry conditions and adiabatic condition is set for top wall.

3. DISCUSSION AND RESULTS

Fig. 2 shows pressure variations versus Reynolds number for simple mini channel and with vortex generators with different hole percentages. As it can be seen pressure drop increases in mini channel contains vortex generators in comparison with simple mini channel. Also, by increasing Reynolds number pressure drop differences between simple and mini channel with vortex generators increases. For example, pressure drop difference between simple mini channel and the one with vortex generators in Reynolds number 200 is 37% and in Reynolds number 1000 is equal to 60%. By increasing Reynolds number, pressure drop increases because vortices created behind vortex generators are smaller in lower Reynolds number so pressure drop is smaller. In higher Reynolds number larger vortices are created so pressure drop increases. In addition, it is observable in the Figure that by increasing holes size percentage pressure drop decreases. Because by increasing hole area, fluid encounter with ribs that have lower areas, so smaller vortices are created and pressure drop decrease. In maximum Reynolds number, Pressure drop increases 60.3% by adding vortex generators to simple mini channel and decrease 34.7 in VG-60 in comparison with VG-0.

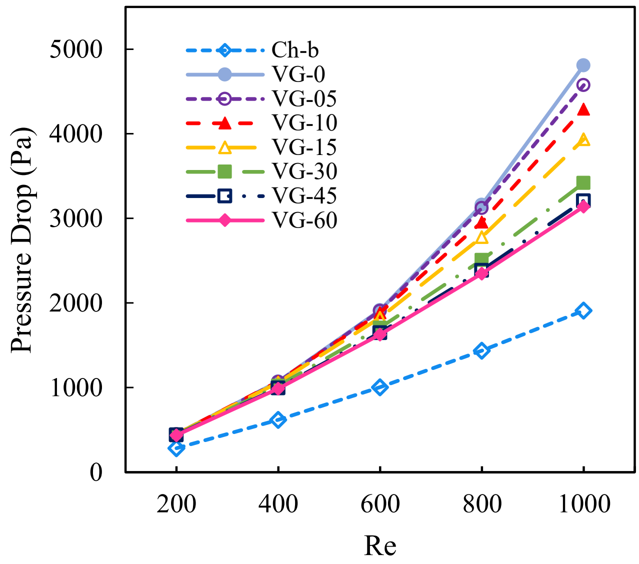

Fig. 2. Pressure drop for all cases in different Reynolds number

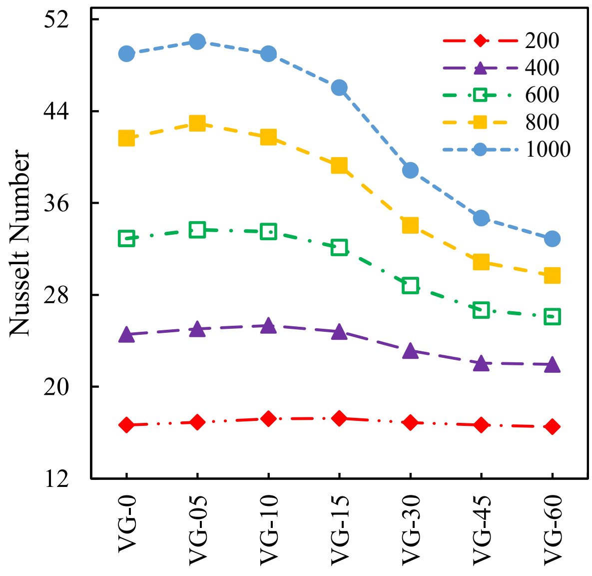

Fig. 3. Nusselt Number for all cases with vortex generator in different Reynolds numbers

Nusselt number variations for all cases with vortex generators in different *Re* number is shown in Fig. 3. As it can be seen by increasing *Re* number due to larger vortices formation behind vortex generators that leads to increase turbulence in the flow, heat transfer coefficient and accordingly Nusselt number increases. Nusselt number increases 49.7% to 66.2% for maximum and minimum hole area between 200 and 1000 *Re* number. Also, it is observable from the Figure that by making hole on the vortex generators Nusselt number increases then decrease. Because by making hole on vortex generator, flow penetration with high speed to the back zone of vortex generator causes dead zone to be smaller and increment in heat transfer rate. On the other hand, increasing hole area leads to decrease vortices size and so heat transfer. As the hole area continues to increase, second factor overcomes first factor therefore Nusselt number decreases. It is notable, Nusselt number decreases 34.3%, by increasing hole size from VG-05 to VG-60 that have maximum and minimum Nusselt number, in *Re* number 1000.

4. CONCLUSIONS

3D numerical simulation on laminar flow in minichannel with vortex generators that have holes on them in different Re umber is conducted. The results show by increasing hole size, pressure drop decreases. Also, by making holes on vortex generators Nusselt number increases and by increasing hole size Nusselt number increases but as hole size continues to enlarge Nusselt number decreases. So that Nusselt number in VG-60 that has the lowest pressure drop and highest Nusselt number, increases 34.3% in comparison with VG-05.

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