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Experimental study on the effect of perforations shapes on vertical heated fins performance under forced convection heat transfer

Thamir K. Ibrahim [a], Marwah N. Mohammed [b], Mohammed Kamil Mohammed [c], G. Najafi [d], Nor Azwadi Che Sidik [e,*], Firdaus Basrawi [f], Ahmed N Abdalla [g], S.S. Hoseini [d]

[a] *Mechanical Engineering Departments, College of Applied Engineering, Tikrit University, Iraq*
[b] *Faculty of Chemical & Natural Resources Engineering, Universiti Malaysia Pahang, 26300 Pahang, Malaysia*
[c] *Mechanical Engineering Department, University of Sharjah, United Arab Emirates*
[d] *Tarbiat Modares University, P.O. Box: 14115 111, Tehran, Iran*
[e] *Malaysia – Japan International Institute of Technology (MJIIT), University Teknologi Malaysia Kuala Lumpur, Jalan Sultan Yahya Petra (Jalan Semarak), 54100 Kuala Lumpur, Malaysia*
[f] *Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Pekan, Pahang 26600, Malaysia*
[g] *Faculty of Electronic Information, Huaiyin Institute Technology, Huai'an, Jiangsu, China*

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ABSTRACT

This paper investigates the effect of perforation shape or geometry on the heat transfer of perforated fins. The type of heat exchanger used is heat sink with the perforated fins under the forced convection heat transfer to determine the performance for each perforation shape between circular, rectangular, triangular and also with the non-perforated fins. The experimental result compared between the perforation shape and the heat transfer coefficient to clarify the best perforation shape for the plate heat sink. The fluid and heat transfer properties of plate fins or normally heat sink were studied experimentally and numerically using CFD. The difference between experimental and numerical results was reported to be about 8% and 9% for temperature distributions when the power supplied are 150 W and 100 W respectively. The highest temperature different of the fin are with the circular perforation shape which is 51.29% when compared the temperature at the tip of the fins with the temperature at the heat collector followed by the rectangular perforation shape with 45.57% then followed by the triangular perforation shape by 42.28% then lastly the non-perforated fins by 35.82%. The perforations of the fines show a significant effect on the performance of forced convection heat transfer.

1. Introduction

Heat is usually being perceived as the sensational of warmth. The true physical understanding about the nature of heat happened in the middle of the nineteenth century due to the development of the kinetic theory which treats molecules as a tiny ball that is in motion, thus possess kinetic energy [1–3]. Then the energy associated with the random motion of atoms and molecules are being defined as the heat. The fundamental of the heat transfer theory are being proposed by the Fresh Chemist Antoine Lavoisier (1743–1794) in 1789 based on the *Caloric Theory* [4]. Caloric theory asserted the heat (*caloric*) is the fluid substance that is massless, colorless, odorless and tasteless substance when added to a body the temperature will increase and when removed the temperature will decrease. In 1843, the Englishman James P. Joule carries a careful experiment that convinced the heat is not a substance after all results the caloric theory is put into rest. In later when the caloric theory is combined with the law of conservation energy, the caloric theory still shows the valuable physical aspect about the heat. *Heat* is the form of energy that can be transferred from one system to another as a result of temperature difference [5].

Most of the engineering system will produce heat when operated. This generates heat will become as the major role of system failure when overheating [6,7]. Processes of removing the excessive heats from a system or component are crucial in order prevent the damaging effect and also the overheating problems. Therefore, there are many experiments or invention of the product has been done by the researcher to get the most effective way to dissipate heat from a system or component. There are heat transfer enhancement device call fins [8,9]. According to Jassem [10], nowadays fins normally used in engineering application to enhance the convec-

* Corresponding author.
E-mail address: azwadi@mail.fkm.utm.my (N. Azwadi Che Sidik).

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tive heat transfer with the large total surface area but without using the excessive surface area. Fins also commonly applied in automotive, electrical, and power management system to works as the heat management to dissipate the excessive heat from the processing or moving system or mechanism [11–13] such as engine cooling, a condenser in refrigeration and air conditioning [14–16]. The heat exchanger is an apparatus which used to transfer heat from hot fluid to cold fluid or vice versa. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. Heat exchangers are commonly used in many engineering applications such as space heating, refrigeration, air-conditioning, and power stations [17–20]. Heat exchangers can be classified into different types based on their construction and application [21–23]. Some of them include shell and tube heat exchanger, plate heat exchangers, plate and shell heat exchanger, plate fin heat exchanger. For instance, plate fins heat exchangers are the simplest example of heat exchangers that consist of the vertical or horizontal plate. The procedure of thermal exchangers design is quite complicated, as it analyzes the real needs the rate of heat transfer efficiency and pressure drop than issues such as long-term performance and economy aspects of the equipment. Whenever, technology is used to improve heat transfer, together with an increase in the rate of heat transfer, pressure drop to increases, which pushed higher pumping costs. In order to increase the heat transfer rate and to reduce the material weight of the fins, the fins can be perforated so that the fins are more efficient in size and weight [24]. The spacing between the fins and fins shapes has a significant effect on the heat transfer characteristics [25–27]. However, the best perforation shape for enhanced heat transfer has not been fully understood. According to [17], heat transfer process generally can be enhanced by increasing the heat transfer coefficient or by extending the surface area of the fins. Many researcher had done experiment and analysis about how to increase the rate heat transfer for fins, According to [27] who performed experimental analysis in the design of modern thermal system by study the effect of perforation on the heat transfer believed when the heat coefficient increased, the rate of heat transfer also increase.

Nowadays, there are so many studies regarding enhancement of new design that requires compact size and lightweight properties have been done in order to achieve maximum heat removal with minimum material exposure including a selection of material, perforated and interrupted plate [28,29]. Some studies introduce the shape modification by making cavities, holes, slots, grooves or channels along the fins body to get the higher heat transfer are and also the heat transfer coefficient. Perforated is one of the relevant studies in achieving the higher heat transfer coefficient. By applying the perforated to the fins bodies, it will enlarge the heat transfer surface [24]. According to [27], by applying this method, the heat transfer rate and the heat transfer coefficient is increased with the perforation diameter increased. The perforation shapes also become a major aspect in achieving the maximum heat transfer coefficient and also the temperature distribution along the plate. There are many studies which experimentally and analytically the different shape of perforation. According to [27], they concluded that the gain obtain in heat dissipation rate is the main aspect of perforation dimension and lateral spacing for the perforated fin. According to [30] who investigated the conduction finite analysis which comparing the elliptic perforation with the regular plate fin found that the elliptical perforation provides better heat transfer flow distribution and also reduce the expenditure of the fin material. According to [31] who performed the same experiment found that the same result which the pressure drop along the perforated rectangular fins are higher than the simple plate fin. Al-Doori [31] investigated the effect of the number of circler perforations on the temperature distribution, the heat transfer rate and the coefficient of heat transfer as shown in Fig. 1.

The different shape of perforation will give the different effect of heat transfer coefficient, pressure drop, and also the temperature distribution. According to [17], heat transfer rate will different for the different material. This experiment carried out the triangular shape of perforation in examining the temperature distribution of the perforated fin with the result the temperature at the fin tip is lower than the same location of the simple fin. According to [32] who conducted experiment for the circular shape of perforation also found the same result as the triangular and elliptic perforation which is proof that by applying perforation on the fins, the heat transfer coefficient will increase, the pressure drop are decrease and the temperature distribution are increased along the fins. The number of perforations also becomes the main aspect in the enhancement of the perforation to the plate fin. According to [28], by increasing the number of perforation, the temperature at the fins base and the fin tip become larger which means the efficiency of heat transfer between the surface and the fluid flow by convection are higher. As we can see in Table 1 the percentage of weight reduction caused by the number of perforation.

In this paper, we investigate the effect of perforation shape and type on the heat transfer characteristics of compact cross flow type heat exchangers. The heat transfer enhancement for various perforated shapes, the average Nusselt and Prandtl number, and the temperature distribution will be analyzed and compared based on experimental and CFD analysis.

2. Related work

2.1. Plate fins

Plate fins are designed to consist of thin plated that are joined together with a small amount of space between plates. The surface are of the fin is large with the each rectangular plate allow fluid to flow between the plates. The flows fluid will extract heat from the plate as its flow along the rectangular plate. The plate fins are designed with the different and unique geometries so that it can compensate for the high thermal resistance particular when the fluid is in a gas state such coolant gas or air [33,34]. The plate fins normally categorized as a rectangular fin, triangular fin, wavy fin, and also perforated fin. In the Plate Fin design, the plate or fins chamber are used to transfer heat between the fluid and the fins are design in a compact size to punctuate its relatively high heat transfer surface area to volume ratio [35–37].

This high-efficiency fin type gives a very large surface area ratio that helps increase the distribution process of heat. The fins can be rippled or waffled for greater efficiency or the fin thickness also can be varied from thin to thick and along with the variety of fin

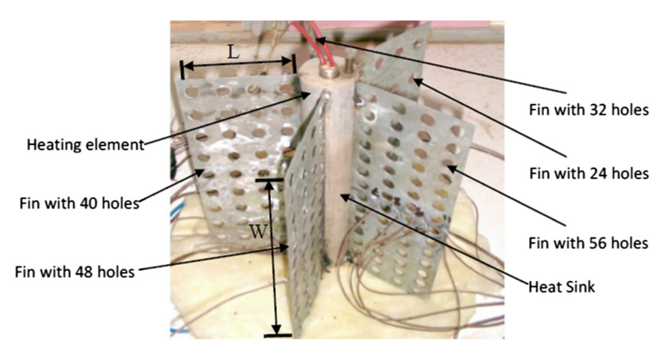

Fig. 1. Heat sink with different number of perforation [31].