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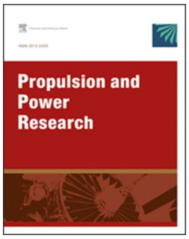

ORIGINAL ARTICLE

Heat transfer and airflow characteristics enhancement of compact plate-pin fins heat sinks – a review

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Abstract Plate-pin heat sinks are widely used for the electronic cooling system, internal combustion IC engine, cooling of gas turbine blades and other different applications to enhance the thermal performance of heat sinks due to simplicity, low cost, and a reliable manufacturing process. However, compact heat sinks give higher pressure drop compared with other types of heat sinks. The purpose of this article is to summarise the main advantages and disadvantages of the compact heat sink with some recommendation studies for future works heat sink thermal airflow experiment and simulations. Furthermore, the research attempts to highlight the importance of balance the relationship between the hydraulic performance and the thermal performance of compact heat sinks.

1. Introduction

Since education, business, transportation, social media and the financial services have depended on information and communication technology (ICT). ICT has become the most important source of information and data in our society [1]. Thus, data centres, which are essentially digital factories, have become a vital part of ICT processing, management, storage and exchange of data [2]. A data centre consists of four main parts: power equipment such as

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Nomenclature

A_c	cross-sectional area of the flow passage of the heat sink (unit: m^2)
D	pin diameter of the pin fin heat sink (unit: mm)
D	perforation diameter of the pin fin (unit: mm)
D_h	hydraulic diameter (unit: m)
H	pin fin height (unit: mm)
θ	Thermal resistance (unit: K/W)
h_p	Projected heat transfer coefficient
h	heat transfer coefficient (unit: $W/(m^2 \cdot K)$)
k	turbulence kinetic energy
n	number of perforations
N	number of pins
Ra	Rayleigh number
Re	Reynolds number
T	thermodynamic temperature (unit: K)
V	electric potential (unit: V)
w	electromagnetic energy density (unit: J/m^3)
Nu	Nusselt number
P	fan power (unit: W)
Δp	pressure drop (unit: Pa)
Pr	Prandtl number
Pr_t	turbulent Prandtl number
Q	power applied on the base (unit: W)
S_z	pin pitch in streamwise direction (unit: mm)

Greek letters

α	fluid thermal diffusivity (unit: m^2/s)
μ	fluid viscosity (unit: $Pa \cdot s$)
μ_t	turbulent eddy viscosity (unit: $Pa \cdot s$)
ρ	fluid density (unit: kg/m^3)
ν	kinematic viscosity (unit: m^2/s)
ν_t	turbulent kinematic viscosity (unit: m^2/s)
σ_ε	k-ε turbulence model constant
σ	turbulence model constant for the k-equation
ω	k-ω turbulence model constant

power distribution units and batteries, cooling equipment (chillers and computer room air-conditioning (CRAC) units), IT equipment (servers, storage and network), and miscellaneous equipment (lighting and fire protection systems) [3]. Electronic component systems that arrange processing, storing and transmission of data is the main part of the data centre, according to Shah et al. [4] and Greenberg et al. [5], all of which and create a large amount of heat, which must be removed from the ICT components at a designed sufficient rate to avoid serious overheating problems and system failures [6]. More than nearly 30% of the heat removal costs of a typical data centre is used in IT equipment and cooling equipment. Thus, an important part of a server is the heat sink that is set over the central processing unit (CPU) [3].

The reliable performance of high power density electronics is important for the design of efficient cooling strategies. The thermal effects cause some of the failure mechanisms in electronic component devices, as metal migration, void formation, and inter-metallic growth. Actually, one of the common factors that control the reliability of electronic products is the maximum temperature of these devices. For each 10 °C increase above the operating temperature (80–85 °C) of high power electronics, the rate of these failures almost doubles [6,7]. Thus, the crucial significance, as is reflected in the market, is electronics thermal management. Another important factor is the costs increase of thermal management products that are from nearly $7.5 billion in 2010 to $8 billion in 2011, and it is reached to $10.9 billion in 2016, the annual rate of increase is 6.4%. Fans and heat sinks (HSs) as thermal management hardware take part for 84% of the total market. However, software, interface materials, and substrates as other main cooling product account between 4% and 6% of the market [8].

2. Heat sinks fabrication

Finned heat sinks have two main types: plate fins heat sink and pin fins heat sink that have been manufactured and produced by several big and small companies. For example, Airedale Company in the UK [9] and The Raypak company in the USA [10]. A set of base tube materials which have high thermal conductivity as copper, aluminium, brass, copper/nickel, aluminium/brass, could be used to manufacture finned heat sinks (FHSs) depending on the cost and the manufacturing simplicity of these materials. In recent years, the technology of finned heat sink design has reached the common techniques for electronics cooling.

One of the most recent vital methods in enhanced heat sink performance is pin fin technology. Because the pinned heat sink appropriates for many applications involving processes using gases or liquids. The main reason for that the characteristic of heat transfer in electronics cooling for pin fins HS technology is excellent [11–14]. Furthermore, to overcome the problems related to heat transfer enhancement as high pressure drop loss; low average heat transfer efficiency; and large thermal resistance, pin fins heat sink as extended surfaces could be utilised in electronic devices. Fins morphology has an important function in manufacturing and heat transfer characteristics. Cylindrical, rectangular and conical or semi conical are the widespread uniform geometry of pin fins. Therefore, it seems that it is a suitable time to employ this technology in traditional heat sinks in industrial applications as well.

In general, pin fin layouts are made up of a network of solid pins mounted directly on the heat sink surface. Either a staggered or an in-line arrangement is usually configured for arrays of pins with the working fluid flowing parallel or perpendicular to the pin axes.

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