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Influence of chevron fin interruption on thermo-fluidic transport characteristics of nanofluid-cooled electronic heat sink

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HIGHLIGHTS

- Thermo-fluidic transport characteristics of a chevron heat sink are investigated.
- Different fin interruptions are proposed and apprized.
- Water and Al_2O_3/water nanofluid are considered as coolant.
- Using interrupted fins leads to superior heat transfer coefficient and lower pressure drop.

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ABSTRACT

In the current study, the effects of different interruptions of fin on the transport characteristics of a nanofluid-cooled electronic heat sink with chevron shape are analyzed numerically. Seven interruptions of fin are explored and compared with the integral case. Water and water-based nanofluid with Al_2O_3 nanoparticle at volume fractions of 0.5% and 1.0% are tested as the coolant in laminar flow regime (Reynolds number less than 900). All coolants are also tested experimentally in the heat sink equipped with the integral fin, and the achieved data are used to verify the numerical approach. The obtained results disclose that the use of interrupted fins leads to a superior heat transfer process due to a decrease in the fin surface temperature and a rise in the outlet coolant temperature. Simultaneously, it causes considerable decrements in the pressure drop which is because of an increase in the fin porosity of the heat sink. The percentage variation in heat transfer coefficient for the interrupted fins as compared with the integral case is in the range of −9.3% to +43.6% while the percentage variation in the pressure drop is in the range of −43.5% to −92.7%. Among all interrupted models, the one reaching the performance index of 3.09 at the Reynolds number of 300 is the best. Furthermore, the water-based nanofluid shows a better thermal performance and a certain penalty in the pressure drop compared to water. The water-based nanofluid can enhance the performance index of the heat sink by an average of 14.7% and 28.3%, which correspond to 0.5% and 1.0% volume fractions of Al_2O_3 nanoparticle, respectively. Finally, it can be concluded that the compound technique used for the chevron fin (interruption + nanofluid) can be a good choice in practical applications to improve the overall performance of electronic heat sinks.

1. Introduction

The rapid development of the electronic industry has forced thermal engineers to look for ways to effectively remove the heat generated in compact chips so as to ensure their reliability. Liquid-cooled heat sinks with integral and interrupted fins are one of the unique instruments utilized for cooling electronic chips. A liquid-cooled heat sink contains a liquid as coolant that flows through the fins and carries away the heat. Evidently modifying the geometrical parameters of the fin and enhancing the thermal behaviors of the coolant are two effective techniques to improve thermo-fluidic transport characteristics of the heat sink. Several efforts have been made in recent years on the same lines, some of which have been outlined below.

Circular pin fin with CuO and Al_2O_3 nanoparticles were examined by Seyf and Feizbakhshi (2012). It was observed that CuO nanoparticle had a better performance compared to Al_2O_3 nanoparticle in the heat sink equipped with circular pin fin. Also, decreasing the diameter of the nanoparticle had a positive effect

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on the thermal performance of Al_2O_3/water nanofluid, while it had an inverse effect on CuO/water nanofluid. Hung and Yan (2012) tested a double-layered channel and Al_2O_3 nanoparticle. This study displayed the relationship between the thermal resistance and the channel aspect ratio. Kuppusamy et al. (2013) proposed trapezoidal grooved geometry in the presence of different nanoparticles (CuO, ZnO, Al_2O_3, and SiO_2). The effects of design parameters were also examined. It was found that Al_2O_3 nanoparticle with the diameter of 25 nm and the volume fraction of 4% had the best thermal performance. Hasan (2014) tested three shapes of pin fins (square, triangular, and circular) and two types of nanoparticles (Diamond and Al_2O_3). In the other work, two advanced channel geometries (double-layer and double-side) were examined by Sakanova et al. (2014) using Al_2O_3 nanoparticle for further improvement. Reductions of about 50% in thermal resistance were reported for these advanced geometries having counter flow arrangement. Kuppusamy et al. (2014) examined the triangular grooved channel as well as four types of nanoparticles (Al_2O_3, CuO, SiO_2, and ZnO) in different base fluids (water, ethylene glycol, and engine oil). Zhai et al. (2015) studied a complex geometry of channel designed with cavities in the presence of Al_2O_3 nanoparticle. Two pin fin configurations (circular and square) and two types of nanoparticles (ZnO and SiO_2) were the cases studied by Duangthongsuk and Wongwises (2015), Duangthongsuk and Wongwises (2015). It was concluded that the use of square pin fin and ZnO/water should be avoided in favor of circular pin fin and SiO_2/water. The improvement of performance of the heat sink using wavy channel and different nanoparticles (Diamond, SiO_2, and CuO) was investigated by

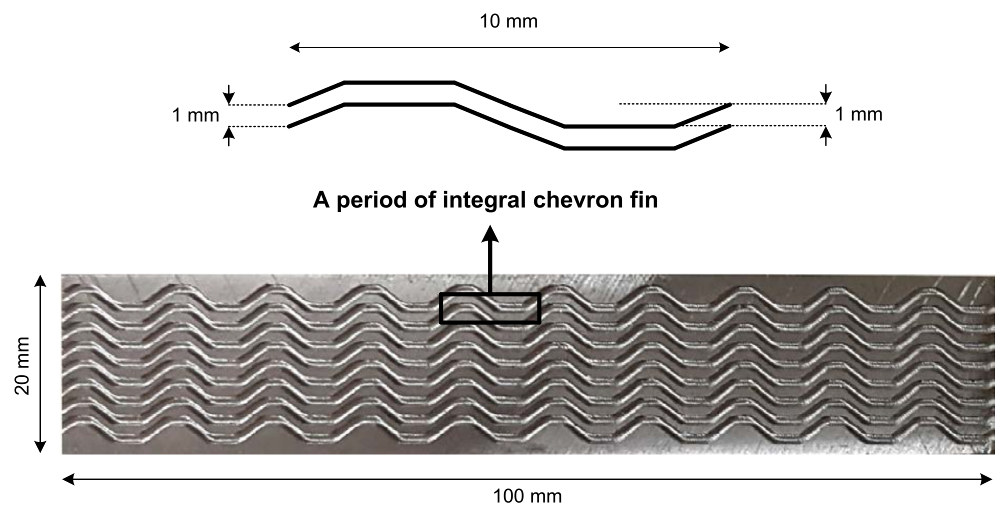

Fig. 1. Liquid-cooled heat sink with integral configuration of chevron fin.

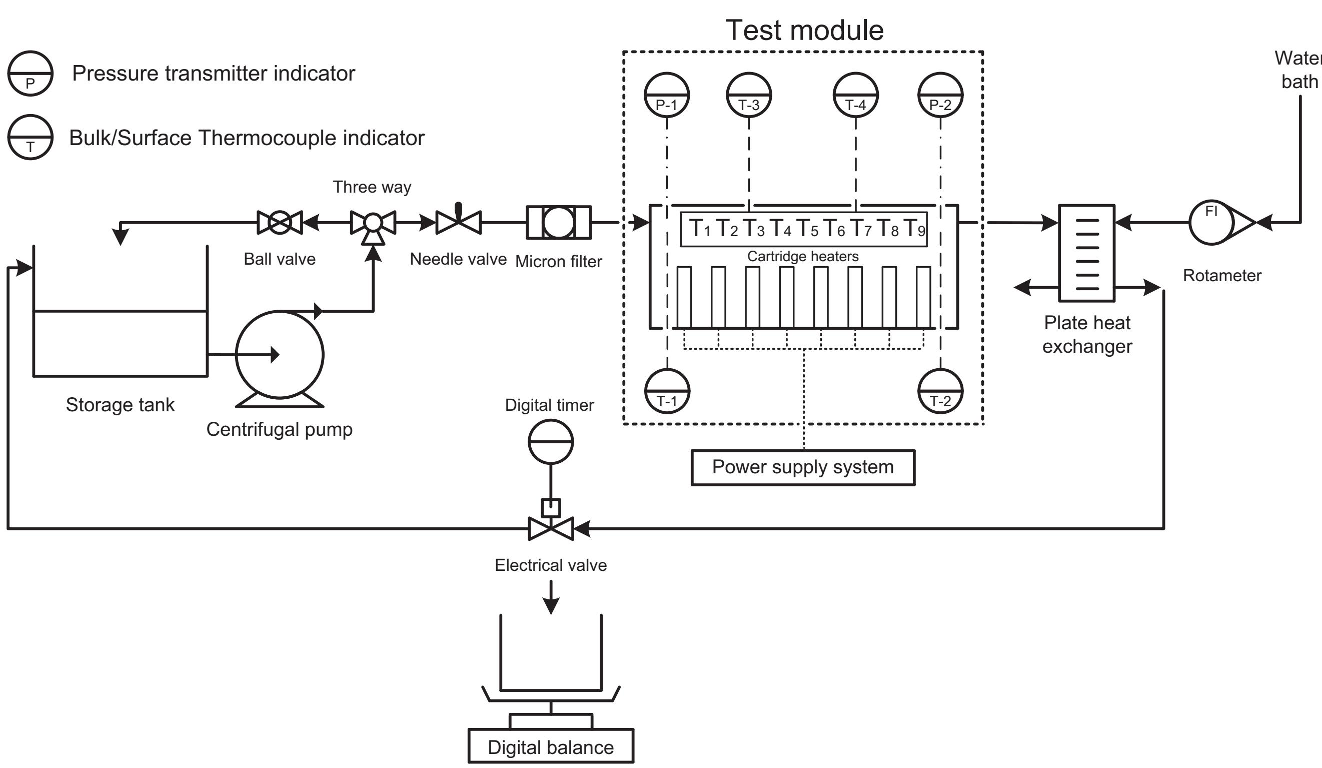

Fig. 2. Schematic illustration of experimental test setup (Khoshvaght-Aliabadi et al., 2016).