Microelectronics Reliability xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/microrel

Comparison of hydrothermal performance between plate fins and plate-pin fins subject to nanofluid-cooled corrugated miniature heat sinks

M. Khoshvaght-Aliabadi [a,*], S.M. Hassani [b], S.H. Mazloumi [b]

[a] Department of Chemical Engineering, Shahrood Branch, Islamic Azad University, Shahrood, Iran
[b] Department of Chemical Engineering, Faculty of Engineering, Ferdowsi University, Mashhad, Iran

ARTICLE INFO

Article history:
Received 15 October 2016
Received in revised form 10 January 2017
Accepted 10 January 2017
Available online xxxx

Keywords:
Corrugated miniature heat sink
Corrugation shape
Nanofluid
Plate fin
Plate-pin fin

ABSTRACT

Thermal and hydraulic performances of two types of fin, namely plate and plate-pin, in water-cooled corrugated miniature heat sinks (MHSs) having triangular, trapezoidal, and sinusoidal shapes are evaluated. In fact, the plate-pin fins are designed and constructed based on the plate fins. Experiments are performed on the fabricated corrugated MHSs in range of Reynolds number between 100 and 900. Temperature contours and velocity vectors are also studied numerically using a CFD approach. The numerical results are validated with recorded experimental data in the present and previous studies. In addition to water, the Al_2O_3/water nanofluid is also testes in the corrugated MHSs, as nanofluid-cooled corrugated MHSs. The obtained results show that the thermal performance of a corrugated MHS with plate-pin fins is better than that of a corrugated MHS with plate fins. Another obvious advantage of plate-pin fins is that designers can reduce the pressure drop (or pumping power) in the corrugated MHSs for the same heat dissipation. The maximum hydrothermal performance factor of 1.84 is detected for 0.3% nanofluid flow in the corrugated MHS with sinusoidal plate-pin fins.

1. Introduction

Water-cooled miniature heat sinks (MHSs) are efficient equipment in thermal management of electronic or mechanical devices. They are often 4–5 times more efficient compared to air-cooled types. Plate, pin, and plate-pin shapes are three common types of fins which are widely used in the MHSs (Fig. 1). The plate fins are easy to fabricate and have simple structure and low cost while the pin fins provide better hydrothermal performance with higher production cost.

In modern electronic or mechanical devices, a powerful thermal management system is required, especially in harsh operating conditions such as high heat fluxes. The technique to improve the thermal performance and solve the hot point is referred to heat transfer enhancement. Generally, the heat transfer enhancement in the MHSs can be carried out either by modifications of surface geometry and fluid property. Some previous studies tried to modify the surface geometry of water-cooled MHSs [1–5]. In addition to water which still has extensive applications, another type of coolant, namely nanofluid, was considered in recent years by researchers [6–10]. However, because of relatively new history of nanofluid-cooled MHSs with modified geometries, the number of researches on this topic is very scarce.

Flow and heat transfer behaviors of CuO/water and Al_2O_3/water nanofluids inside the pin-fin MHSs were studied numerically [11]. It was reported that the performance of MHSs enhanced as the nanofluids were replaced with the base fluid. Also, decreasing the diameter of Al_2O_3 nanoparticles in the base fluid increased Nusselt number values while the trend was reverse for CuO nanoparticles. In the other numerical study [12], the performances of Al_2O_3, CuO, and SiO_2 nanoparticles as additives in water flowing in an interrupted MHS were evaluated. It was detected that the interrupted MHS had higher values of Nusselt number compared with the integral MHS. Also, the highest Nusselt number enhancement was predicted for Al_2O_3, followed by CuO and SiO_2. Temperature and flow fields in a trapezoidal grooved MHS were investigated for different nanofluids [13]. The results clarified that the trapezoidal grooved MHS with higher maximum-width and lower minimum-width displayed the maximum thermal performance. It was also reported that Al_2O_3/water had the highest thermal performance with 4% volume fraction and 25 nm nanoparticle diameter. The performance of a pin-fin MHS with different configurations (square, triangular, and circular) was numerically investigated in the presence of diamond/water and Al_2O_3/water nanofluids [14]. The results shown that using of nanofluids instead of the base fluid enhanced the thermal performance with a certain penalty in the pressure drop for all configurations; the diamond/water nanofluid was better than Al_2O_3/water. A complex structure and Al_2O_3/water nanofluid were tested in a MHS under constant heat flux [15]. The performance evaluation factor displayed that the higher volume fraction of nanofluids had better comprehensive

* Corresponding author.
E-mail addresses: mkhaliabadi@gmail.com, mkhaliabadi@iau-shahrood.ac.ir (M. Khoshvaght-Aliabadi).

http://dx.doi.org/10.1016/j.microrel.2017.01.005
0026-2714/© 2017 Elsevier Ltd. All rights reserved.

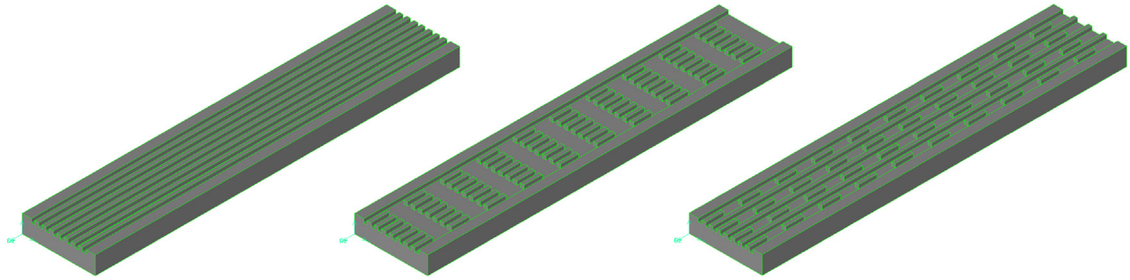

Fig. 1. A schematic of MHSs with plate, pin, and plate-pin fins.

thermal performance. The simultaneous application of wavy channel and nanofluid as a compound technique was examined in the other numerical study [16]. It was reported that nanofluid had higher effect on the performance of MHS with straight channel. Experiments were carried out [17,18] to investigate the performance of a MHS with inline arrangement of circular pin-fins in presence of ZnO/water and SiO_2/water nanofluids. The acquired data explained that the thermal performance of nanofluid-cooled MHS was better than that of water-cooled MHS. Comparison between ZnO/water and SiO_2/water nanofluids, higher heat transfer performance for ZnO/water nanofluid was observed by about 3–9%. The effects of ribs turbulator with different design parameters on the hydrothermal performance of a nanofluid-cooled MHS were numerically investigated [19]. The results showed that both the heat transfer coefficient and the pressure drop of nanofluid in the ribbed MHS were higher than those of the simple MHS, and this enhancement intensified with increasing the width of ribs. An experimental study on a nanofluid-cooled MHS with inline and staggered arrangements of square pin-fins was also performed [20]. The minimum base temperature of 29.4 °C was reported for the TiO_2(Rutile)/water nanofluid flow in the MHS with staggered arrangement of pin-fins. A new innovative design of MHS with rectangular and triangular double-layered channels working with Al_2O_3/water and SiO_2/water nanofluids was tested [21]. The results showed that the MHS with triangular double-layered channels provided a 27.4% reduction in the wall temperature comparing with the MHS with rectangular double-layered channels. Experimental tests were conducted for Al_2O_3/water nanofluid through a MHS with corrugated channels [22]. The base temperature and convective thermal resistance were found to drop by decreasing the wave-length and by increasing the wave-amplitude. In the other experimental study [23] the angle effect of pin-fins on the performance of MHS was examined. It was concluded that the MHS with 22.5 degree channel angle had the lowest convective thermal resistance. Recently, the performance of a nanofluid-cooled MHS with offset-strip fins is investigated by Khoshvaght-Aliabadi et al. [24]. Noticeable values for the heat transfer rate to pumping power ratio were obtained for the MHSs with thinner and longer strips and higher transversal and longitudinal pitches. Also, it was reported that the cooling performance of a nanofluid-cooled MHS is greater than a water-cooled MHS. Likewise, several active heat

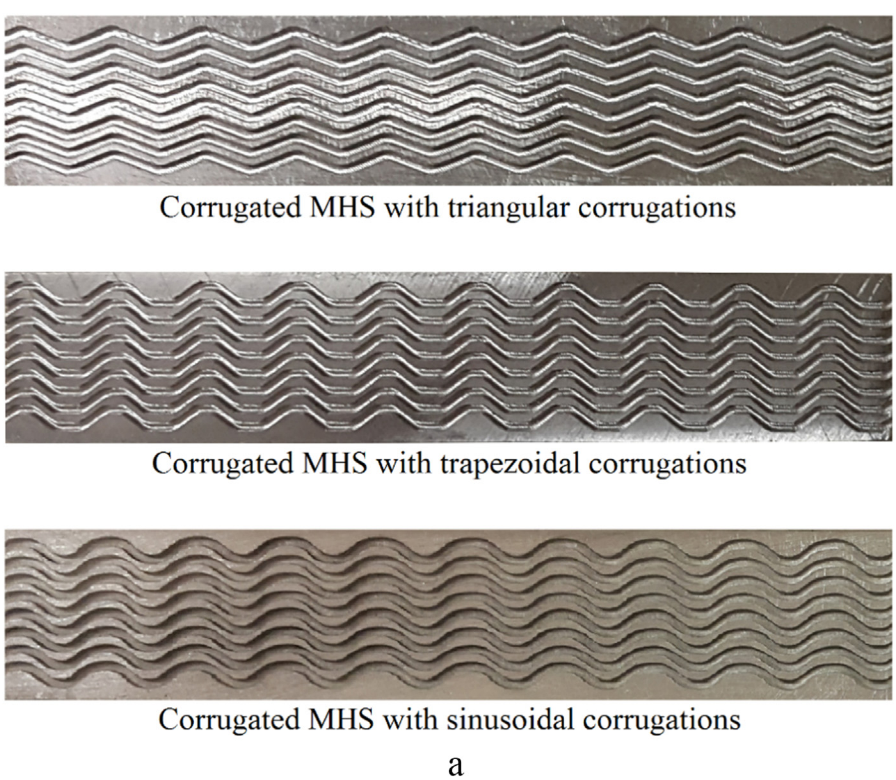

Fig. 2. (a) Basic configuration of corrugated MHSs with triangular, trapezoidal, and sinusoidal plate fins [4] (b) schematic of plate and plate-pin fins (red dashed lines show considered potion in numerical simulation). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)