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# Influence of nanofluids on parallel flow square microchannel heat exchanger performance☆

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ABSTRACT

The effects of using various types of nanofluids and Reynolds numbers on heat transfer and fluid flow characteristics in a square shaped microchannel heat exchanger (MCHE) is numerically investigated in this study. The performance of an aluminum MCHE with four different types of nanofluids (aluminum oxide ($Al_2O_3$), silicon dioxide ($SiO_2$), silver (Ag), and titanium dioxide ($TiO_2$)), with three different nanoparticle volume fractions of 2%, 5% and 10% using water as base fluid is comprehensively analyzed. The three-dimensional steady, laminar developing flow and conjugate heat transfer governing equations of a balanced MCHE are solved using the finite volume method. The MCHE performance is evaluated in terms of temperature profile, heat transfer rate, heat transfer coefficient, pressure drop, wall shear stress pumping power, effectiveness, and overall performance index. The results reveal that nanofluids can enhance the thermal properties and performance of the heat exchanger while having a slight increase in pressure drop. It was also found that increasing the Reynolds number causes the pumping power to increase and the effectiveness to decrease.



## 1. Introduction

Heat exchangers play an important part in the field of energy conservation, conversion and recovery. With the advancement in miniaturization technology and pronounced need for higher efficient equipments, mini-scale and micro-scale devices are proving to be beneficial and advantageous. These micro-scale devices, commonly known as MEMS (Micro Electromechanical Systems) are getting more advanced and complex. However, there are two problems: the reduction in channel dimensions were accompanied by higher pressure drop, and the amount of heat transfer was limited by the heat transfer fluid used. There are two important phenomena happening in a heat exchanger: fluid flow in channels and heat transfer between fluids and channel walls. Thus, improvements to heat exchangers can be achieved by improving the processes occurring during those phenomena. Firstly, the rate of heat transfer depends on the surface area to volume ratio, which means that smaller channel dimensions provide better heat transfer coefficient. For the case of uniform wall temperature and thermally fully developed region the Nusselt number is constant and given by $Nu_D = \frac{hD}{k} = 3.657$, from which the convective heat transfer coefficient is $h = 3.657\frac{k}{D}$. From this relation, it can be concluded that as the diameter decreases, the heat transfer coefficient increases. Based on this, Tuckerman and Peace [1] suggested the concept of using microchannel heat sink for Very Large Scale Integrated (VLSI) circuits to obtain high performance cooling about two decades ago. Since then, numerous studies have shown high heat transfer rate obtained by the use of microchannels cooling devices.

Secondly, improving the properties of the heat transfer fluids (nanofluids) can yield higher heat transfer coefficient in a heat exchanger. Nanofluids refer to engineered fluids that contain suspended nanoparticles with average size below 100 nm in traditional heat transfer fluids such as water, oil and ethylene glycol. The idea of using metallic particles to increase the thermal conductivity of fluids was proposed by Maxwell [2], who knew that metals in solid form have much higher thermal conductivity than fluids. This was followed by many trials by dispersing millimeter and micrometer sized particles in liquids. However, these large particles had several problems such as particle sedimentation, passage clogging, and high pressure drop. The recent development of nanotechnology; however, opened up the opportunity to revisit Maxwell's idea by using nanometer sized particles. Since Choi et al. [3] reported that the addition of a small amount (less than 1 vol.%) of nanoparticles to traditional heat transfer liquid approximately doubled the thermal conductivity of the fluid, the frenzy into nanofluids research for heat transfer applications is started. Several other researchers have reported similar trend in the increase of heat transfer in conventional fluids by the addition of nanoparticles. For example, Masuda et al. [4] and Xuan and Li [5] stated that with low nanoparticle concentrations (1–5 vol.%), the thermal conductivity of the suspensions can increase by more than 20%.

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