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Research Paper

Study on the flow resistance performance of fluid cross various shapes of micro-scale pin fin

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HIGHLIGHTS

- The higher pin fin density and height result in a higher pressure drop.
- The vortex resistance of the circular pin fin is the largest; that of the oval one is the smallest.
- The micro-scale correlation formula is fitted according to the experimental results.

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ABSTRACT

The experiments on flow resistance characteristics of various shapes of pin fins have been conducted, including the influences of different sizes, as well shapes of pin fin on pressure drop and friction coefficient. The results show that a higher density and height result in a higher pressure drop. And compared the three circular shape pin fins, the CP1 with height as 0.75 appears better pressure drop performance. When the Reynolds number is less than 600, the friction coefficient decreases quickly with the increase of the Reynolds number. While as the *Re* is more than around 600, the friction coefficient changes slowly. With the flow rate less than 20 ml/min, the shape of the pin fin has little effect on the resistance characteristics, and the influence increases with the increase of the flow rate, in which the friction coefficient of circular pin fin is the largest and the oval one is the smallest. Besides, the micro-scale correlation formula between the friction coefficient and the Reynolds number is fitted based on the experimental data.
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1. Introduction

As the development of modern science and technology, the micro scale fields are improved quickly. Because the small volume brings a sharp increase in heat flux, the normal combination of the general common cooler and fan could not meet the needs of heat dissipation. At this time, the microchannel cooling technology is developed, which holds the virtues of low heat transfer temperature difference, high heat transfer efficiency and the compact structure [1]. And the microchannel heat sink structure is one example of this technology, which is proposed by Tuckerman and Pease [2] as a water cooling fin type radiator, with the width of fin and channel as 50 μm. And according to their works, the friction coefficient of the fluid in the microchannel is slightly higher than that estimated in the classical theory.

Since then, many researchers have worked on the flow characteristics of fluids cross the micro-scale pin fin [3–15]. Many researchers focus on the novel micro-size heat exchanger with pin fin structure [3–8], and results show that utilizing the micro-scale pin fin is beneficial for the flow quality of surface of the equipment with high heat flux. Besides, many other researches [9–15] make the experimental studies for the fluids that cross the micro-scale pin fin, and the results show that the ratio of the height to equivalent diameter of the micro-scale pin fin has a significant effect on the friction coefficient. However, for the complex and unique flow characteristics for micro-scale fields, the research still need to be investigated and studied.

In this paper, the flow characteristics of pin fin with various shapes of pin fin density and sizes have been conducted. The factors that affecting pressure drop and friction coefficient have been analyzed, including how the density or the shape as well as Reynolds number affects the pressure drop or the friction coefficient. Besides, the micro-scale correlation formula relationship between

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Nomenclature

Symbols

A	the cross section area of the pin fin (m^2)
A_{min}	channel minimum cross-sectional area (m^2)
D	equivalent diameter (m)
f	friction coefficient
H	height (m)
L	length (m)
N_t	total number of pin fins
N_x	number of pin fins per row in the flow direction
p	pressure (Pa)
P_s	wetted perimeter (m)
Δp	the pressure drop of inlet and outlet
Q	volume flow rate (m^3/s)
Re	Reynolds number
S_D	oblique space (m)
S_L	longitudinal space (m)
S_T	transverse space (m)
u_{max}	maximum velocity in channel minimum cross area (m/s)
v	kinematic viscosity (m^2/s)
W	channel width (m)
ρ	density of fluids (kg/m^3)
ε	pin fin density

the friction coefficient and the Reynolds number is fitted, based on the experimental data.

2. Experimental system

2.1. Experimental system description

The experiment system focuses on the flow behavior of the micro-scale pin fin heat sink with different sizes and cross-section shapes, including pressure drop and friction coefficient as the main parameters. The inlet fluid temperature and volume flow are controlled in order to facilitate the comparison of different parameters.

As shown in Figs. 1 and 2, the system is composed of an experimental section with a micro-scale pin fin, a pressure controlled feed circuit, as well as sensors and data acquisition systems. The pressure is provided by the 12 MPa high-pressure nitrogen cylinder. The high-pressure nitrogen gas flows through the gas filter and a pressure control device, and then pushes the deionized water in storage tank going into the throttle pipeline. The deionized water realizes the pressure drop in a throttle pipeline placing at the test section inlet then enters experiment section and the high precision measuring cylinder. In the experiment system, the pressure can be adjusted to the required pressure accurately (accuracy as 100 Pa) by the precision pressure reducing valve, which meets the requirements of stable flow and pressure parameters. In the experimental system, the precision pressure reducing valve is utilized to adjust the pressure of nitrogen gas, and then it pushes the working into the test section. In this way, the inlet pressure could be seen as adjusted by the precision pressure reducing valve, and

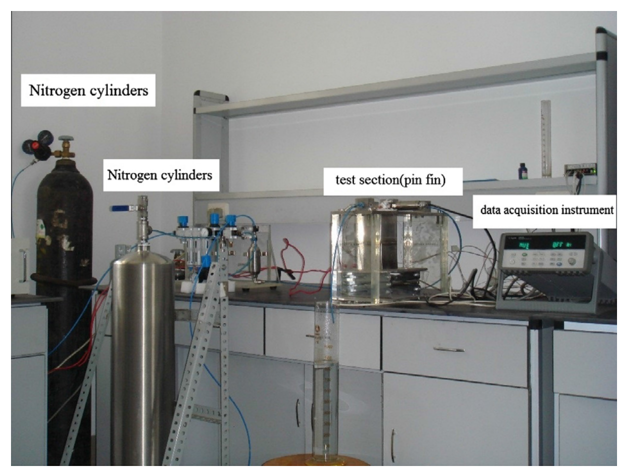

Fig. 2. The actual experimental set up.

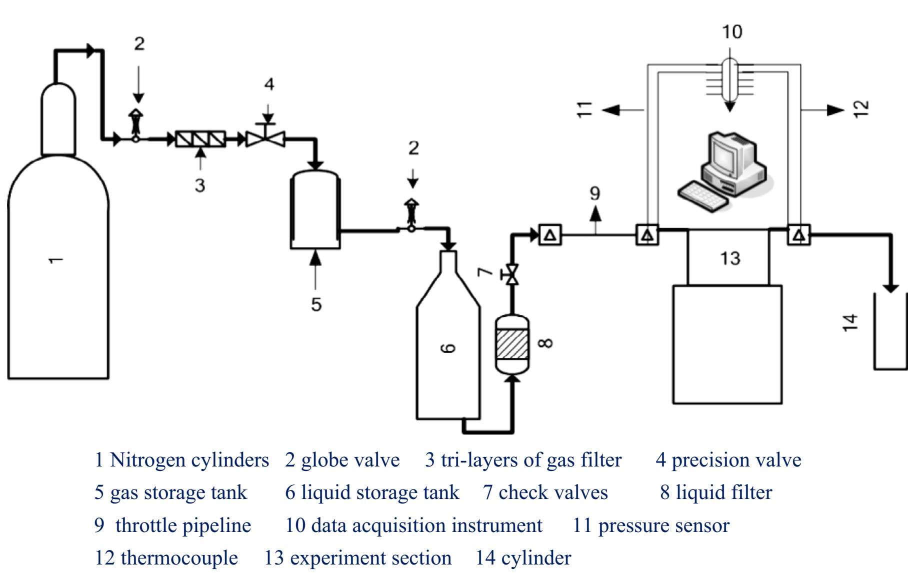

Fig. 1. Experimental system.

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