EFFECT OF COLD CHAMBER PARAMETER ON THE GAS FLOW IN THERMAL TRANSPIRATION PUMP

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**A thesis submitted
in fulfilment of the requirements for the degree of
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2023

DECLARATION

I declare that this Choose an item. entitled "Effect of Cool Heat Exchanger Parameter on The Gas Flow in The Thermal Transpiration Pump" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Nurul A'tiqah Binti Che Mohd Nasir

Date : 20/1/2023

APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology with Honours.

Signature	:	
Supervisor Name	:	Sushella Edayu Binti Mat Kamal
Date	:	20/1/2023

DEDICATION

I would like to thank my parents, Che Mohd Nasir bin Mohd Yusof and Razmah binti Hassan, for their unfaltering trust and physical, emotional, and spiritual support over the years. I would also like to thank my siblings, friends, and members of my Final Year Project for their endless support over the semesters. I would also like to thank my supervisor, Madam Sushella Edayu binti Mat Kamal, for guiding me and encouraging me to complete my Final Year Project. Without her supervision, it seems impossible to complete this task. Lastly, I'd want to thank those whose prayers and assistance, whether direct or indirect, are constant. Thank you for all prayers!

ABSTRACT

This study of the effects of cold chamber parameter on gas flow in thermal transpiration pumps focuses on the installation of a cooling system to the cold chamber design. This is since a greater temperature in the hot chamber and a lower temperature in the cold chamber might result in a temperature gradient, a pressure difference, and gas flow in the Knudsen pump. As the goal of the cooling system is to help the cold chamber in maintaining a cold temperature without severe temperature increases from hot gas temperatures, the cooling system helps the cold chamber to maintain a cold temperature. TEC1-12706 Utilizing the cold side of the Peltier and a water-cooling system at the hot side of the Peltier, a Peltier is utilised in the cooling system to obtain cold temperatures. Zero changes in the hot chamber, the addition of rockwool, and the addition of both rockwool and wiremesh are investigated. The finding is made by analysing the temperature difference between two regions in which the characteristics of different types of hot chambers are analysed with and without a cooling system. The pressure of the example with the highest temperature gradient is observed to determine the existence of pressure flow. Consequently, the thermal transpiration pump can be improved by the implementation of several suggestions to archive a more efficient gas flow.

ABSTRAK

Kajian kesan parameter ruang sejuk terhadap aliran gas dalam pam transpirasi terma ini memberi tumpuan kepada pemasangan sistem penyejukan kepada reka bentuk ruang sejuk. Ini kerana suhu yang lebih tinggi dalam ruang panas dan suhu yang lebih rendah dalam ruang sejuk mungkin mengakibatkan kecerunan suhu, perbezaan tekanan dan aliran gas dalam pam Knudsen. Oleh kerana matlamat sistem penyejukan adalah untuk membantu ruang sejuk dalam mengekalkan suhu sejuk tanpa peningkatan suhu yang teruk daripada suhu gas panas, sistem penyejukan membantu ruang sejuk mengekalkan suhu sejuk. TEC1-12706 Menggunakan bahagian sejuk Peltier dan sistem penyejukan air di bahagian panas Peltier, Peltier digunakan dalam sistem penyejukan untuk mendapatkan suhu sejuk. Sifar perubahan dalam ruang panas, penambahan rockwool, dan penambahan kedua-dua rockwool dan wiremesh disiasat. Penemuan dibuat dengan menganalisis perbezaan suhu antara dua kawasan di mana ciri-ciri pelbagai jenis ruang panas dianalisis dengan dan tanpa sistem penyejukan. Tekanan contoh dengan kecerunan suhu tertinggi diperhatikan untuk menentukan kewujudan aliran tekanan. Akibatnya, pam transpirasi terma boleh diperbaiki dengan pelaksanaan beberapa cadangan untuk mengarkibkan aliran gas yang lebih cekap.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Background

Microelectromechanical system (MEMS) (Sharp Microfluidics Chapter in CRC MEMS Handbook, n.d.) refers to systems with a characteristic length of less than 1 mm but greater than 1 μm, which include electrical and mechanical components and are manufactured utilizing integrated circuit patch-processing technology. From the research, there are several actuation principles and morphologies for micropumps. The distinction between mechanical and nonmechanical pumps is based on whether or not they have moving elements. Mechanical micropumps utilize the mechanical energy of its moving parts to drive fluid flow, and their primary working media are liquids. Due to its movable components, their durability, sensitivity, and stability are poor. In contrast, fluid movement is induced in nonmechanical micro-pumps by nonmechanical types of energy such as electrical energy, thermal energy, chemical energy, and magnetic energy. Their working media are not confined to liquids, but also contain nanometer-sized particles of gases and solids (Wang et al., 2020). Due to their distinct mechanics, micro-pumps and conventional pumps are distinct from one another. Additionally, pumps can be categorized by their uses. In MEMS, nonmechanical micropump performance and research and development possibilities are often superior to mechanical micropump performance.

In a wide range of application situations, bidirectional gas flow is required. Certain analytical devices, such gas chromatographs (Agah et al., 2006; Kim et al., 2011; Terry et al., 1979;

Zhou et al., 2016) and mass spectrometers (Hauschild et al., 2007; Syms & Wright, 2016), need gas flow in opposite directions for sampling and analysis phases. It has been demonstrated that Knudsen pumps enable bidirectional pumping without moving elements (Pharas & McNamara, 2010; Qin & Gianchandani, 2014, 2016). I Knudsen pump implement the principle of thermal transpiration, in which the net flux of gas molecules is induced against the temperature gradient from the low temperature region to the high temperature region (Qin, Y. (n.d.). This flow is only apparent when viscous flow is repressed, i.e., when collisions between gas molecules do not significantly outweigh collisions between gas molecules and flow channel walls. Due to limited availability of small narrow channels, the Knudsen pump has only recently been proved to perform successfully at atmospheric pressure. (Gupta & Gianchandani, n.d.-a) Numerous experts have long paid close attention to Knudsen pump due to their lack of moving parts, Knudsen pump minimize the friction and stiction difficulties that plague other types of micropumps, allowing them to operate silently and without incurring wear. Due to the static nature of Knudsen pump, its architecture is relatively simple and may be simply scaled and integrated into various microsystems.

Essentially, this chapter establishes the context for this report. This thesis will discuss how to begin conducting research for a thesis or project on developing cooling systems for thermal heat exchanger in Knudsen Pump. This chapter includes a background study, problem statement, objective, project scope, project importance, thesis outlines, and anticipated results.

1.2 Problem Statement

The Knudsen pump relies on a physical phenomenon known as thermal transpiration in order to function. Two adjacent volumes of gas with different temperature in the free molecular flow regime display the following relationship due to thermal transpiration (Mcnamara & Gianchandani, n.d.). According to (Gupta & Gianchandani, 2008), the idea of thermal transpiration upon which the Knudsen pump is built, explains the difference in equilibrium pressures between two chambers maintained at different temperatures and connected by a channel that allows gas flow in the free molecular or transitional flow regimes, but not in the viscous regime. For the chamber to maintain the temperature difference between hot temperature (T_H) and cold temperature (T_C), the chamber must be insulated (T_C). The Knudsen pump uses a heat exchanger to keep the cooling system cold.

1.3 Research Objective

Based on the project survey or background information and the problem description given above, this project's research is organized and presented to achieve the following three primary objectives or end results:

identifying current cold heat exchanger technologies

1. To review and identify the parameters that effect the performance of thermal transpiration pump.
2. To evaluate the effect of adding a cooling system on the temperature of cold chamber, hot chamber, and water.
3. To analyse the influence of temperature differences on gas flow properties in the thermal transpiration pump.

1.4 Scope of Research

The project's research scope is determined by the following objectives as;

- Designing a cool chamber for Knudsen pump thermally induced flow.
- Designing a cooling system to maintain a constant temperature in the cool chamber.
- Conduct a temperature analysis depending on the ratio of fluids.

CHAPTER 2

LITERATURE REVIEW

2.1 Knudsen Pump Operation

Knudsen pump employing thermomolecular flow through narrow channel. Atmospheric pressure and free molecular gas flow allow molecules to travel from the hot end to the cold end of a tube having a temperature gradient along its length. Knudsen pumps, which are based on the phenomenon of heat transpiration, may be effective in resolving some of the difficulties encountered by existing micropumps. Figure 2.1 shows the thermal transpiration principle in a clear manner. The rate of gas flow from one chamber to another is directly proportional to the chamber's pressure and inversely proportional to its temperature's square root.

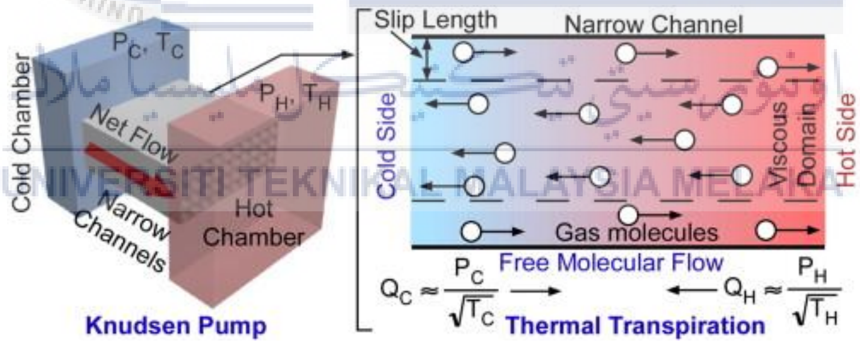

Figure 2.1: Illustrates the Principle of Thermal Transpiration in A Straightforward Manner.

Therefore, if the initial pressures in the two chambers are the same, gas molecules will effectively migrate from the cold chamber to the hot chamber. At equilibrium, the pressure in the hot chamber (P_H) relates to the pressure in the cold chamber (P_H) as follows:

$$\frac{P_H}{P_C} = \sqrt{\frac{T_H}{T_C}} \tag{1}$$

2.2 Heat Exchangers

For the cooling system to stay cool and maintain the temperature, heat exchanger is being chosen with the purpose of removing heat from the heated air inside the Knudsen pump. There are three types of heat exchangers (shell and tube, double pipe, and plate) and 3 of types of flow configuration such as parallel flow, counter flow, cross flow, and hybrid flow) that can be used.

2.2.1 Shell and Tube Heat Exchanger

A shell and tube heat exchanger are a form of heat exchanging equipment comprised of a large cylindrical casing or shell containing bundles of precisely spaced tubes (Kumar Dey, 2019). The most popular form of heat exchangers are shell and tube heat exchangers; the working concept of shell and tube exchangers is shown in Figure 2.2. Hence, Due to the design of these devices, one fluid flows through the smaller tube while the other fluid travels around and between it within the sealed shell. This type of heat exchanger is also available with single- or two-phase heat transfer, finned tubes, parallel flow, counter flow, or single, double, or multiple pass configurations, and crossflow arrangements. Shell-and-tube heat exchangers are the most prevalent type of heat exchangers. According to their qualities, tube type, and other criteria, they are classed.

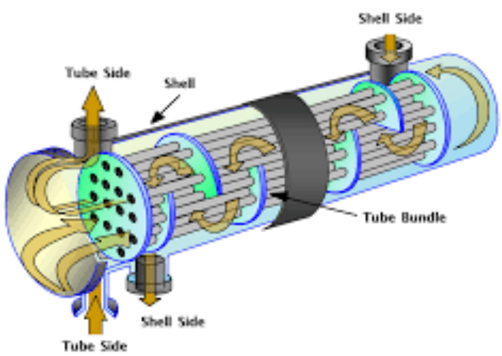

Figure 2.2: Shell and Tube Exchanger Working Principle (Kumar Dey, 2019)

2.2.2 Double Pipe Heat Exchanger

According to Sampson (2017) stated that double pipe heat exchanger is one heat exchanger pipe inside another larger pipe for either counter flow or parallel flow pattern. Among the design requirements for double-pipe heat exchangers is that the fluids remain separated and flow in their allocated channels throughout the heat transfer process. However, double pipe heat exchangers can be built with either a parallel flow or a counter flow design, and they can be utilised modularly in parallel, series, or series-parallel system configurations. Figure 3 displays, for illustration, the heat transfer that occurs within an isolated, parallel-flowing, double-pipe heat exchanger.

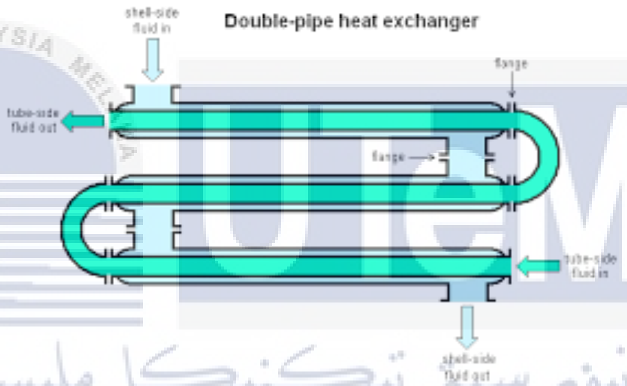

Figure 2.3: Double Pipe Heat Exchanger Parallel Flow (Farhan et al., 2022)

2.2.3 Plate Heat Exchanger

A plate exchanger consists of a series of parallel plates that are placed one above the other to allow the formation of a series of channels for fluids to flow between them (PLATE HEAT EXCHANGER WORKING PRINCIPLE, n.d.). Where multiple thin, corrugated plates are packed together to form plate heat exchangers. When the plate pairings are stacked on top of one another and connected, a second passageway for the other fluid is created between the pairings. This allows both fluids to flow through the channels that are formed by the plate pairings. There are also variations on the basic plate design, such as plate fin and pillow plate heat exchangers. These heat exchangers are both examples. Plate fin exchangers use fins or spacers between the plates to enable the passage of more than two fluid streams and a variety of varied flow configurations. The plates in pillow plate heat exchangers are subjected to pressure to improve the rate at which heat is transferred across the plates' surfaces.

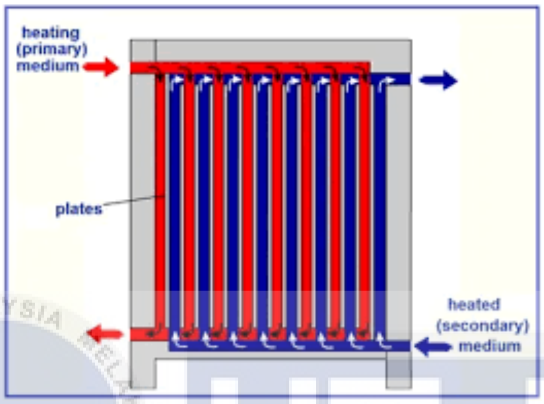

Figure 2.4: Plate Heat Exchanger Working Principle (Enrico Golin, n.d.)..

2.3 Flow Configuration of Heat Exchanger

Yazıcıoğlu (2018) describes flow configuration, also known as flow arrangement, describes the geometric relationship between the streams of fluid and how it relates to the flow routes of the fluid. Within the context of this discussion, the flow configuration of a heat exchanger, which is often referred to as the flow arrangement, refers to the perceived direction of movement of the fluids that are contained within the heat exchanger. Both counter-flow and parallel flow are quite frequent configurations for the flow channels that are contained within a heat exchanger. However, there are several other types of flows, including hybrid flows, parallel flows, counter flows, and cross flows.

2.3.1 Parallel Flow Heat Exchangers

Both fluids in the heat exchanger move in the same direction, parallel to one another, and exit on the opposite side. A parallel flow heat exchanger is another name for this type of heat exchanger. Parallel flow heat exchangers are another name for parallel flow heat exchangers. The efficiency of a heat exchanger with this design is often lower than that of a heat exchanger with a counter flow arrangement; however, it offers the best chance for thermal homogeneity across the heat exchanger's walls.

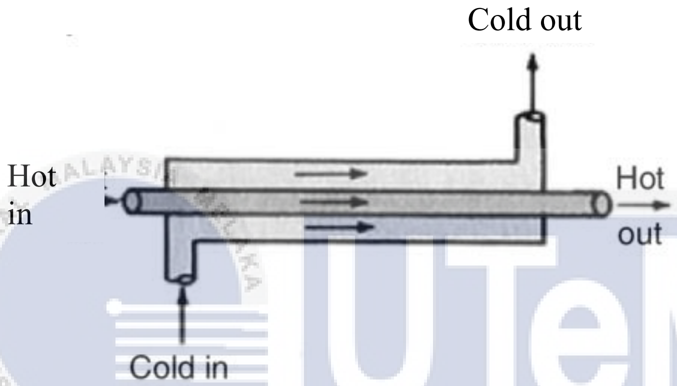

Figure 2.5: Parallel Flow Configuration (Zohuri, 2017)

2.3.2 Counter Flow Heat Exchangers

The fundamental idea of counter flow heat exchangers is identical to that of parallel flow heat exchangers; however, the fluids in the heat exchanger flow in the opposite direction, antiparallel to one another. Counter flow heat exchangers are also known as counter current flow heat exchangers. This is because it facilitates the largest amount of heat transference between fluids and, thus, the greatest change in temperature, the most common flow design is the counter flow arrangement. Because it is the most prevalent flow design, it often displays the best efficiency.