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

ILMAN HAKIM BIN MUHAMAD JAMALUDIN

B091910216

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (Technology Automotive) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

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

Ilman Hakim Bin Muhamad Jamaludin

Bachelor of Mechanical Engineering Technology (Technology Automotive) with Honours

2022

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

ILMAN HAKIM BIN MUHAMAD JAMALUDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Technology Automotive) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this Choose an item. entitled "Effect of Hot Heat Exchanger Parameter on The Gas Flow in The Thermal Traspiration 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 : Ilman Hakim Bin Muhamad Jamaludin

Date : 11/1/2023

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 and Manufacturing Engineering Technology (BMMA) with Honours.

Signature :

Supervisor Name : Sushella Edayu Binti Mat Kamal

Date : 20/1/2023

DEDICATION

I woild like to express my dedication from the bottom of my heart specially to my parents Muhamad Jamaludin Bin Yasin and Wan Pisah Binti Wan Jaafar for providing me moral as well as financial support throughout the years. Not to forget my siblings, friends, and my Final Year Project members for their unconditional support throughout the process. I would like to thank my supervisor madam Sushella Edayu Binti Mat Kamal for the full endless support and guidance for me to finish my Final Year Project. This project seems impossible without her guidance to keep me on the right track. Last but not least, all these bittersweet moments and memories upon completing my studies and research will always be cherish.

ABSTRACT

The Knudsen pump (KP) is a type of micropump that may produce thermally induced flows in rarefied gas environments. These flows are caused by temperature fields in the environment. It offers the benefits of having no moving components, having a basic structure, being easy to construct and extend, having access to a wide variety of energy sources, and having a low overall energy usage. This project focuses on designing hot chamber with heating element. As the heating element being heated, it will produce hot gas within the chamber. Thus, the gas flow as well as the temperature difference can be analyzed. As the heating element is used to heat up the chamber, a thermocouple which functions as sensor that is used to measure the temperature as it is placed inside the hot chamber. After the temperature rises to desired value, the gas flow is then can be analyzed and observed. The observation is made by witnessing the hot gas flow transferred from the hot chamber to a narrow channel which then transferred to cold chamber. The comparison of temperature difference can be compared by the data observed.

ABSTRAK

Pam Knudsen (KP) ialah sejenis pam mikro yang mungkin menghasilkan aliran teraruh istilah dalam persekitaran gas jarang. Aliran ini disebabkan oleh medan suhu di persekitaran. Ia menawarkan faedah tanpa komponen yang bergerak, mempunyai struktur asas, mudah dibina dan dilanjutkan, mempunyai akses kepada pelbagai jenis sumber tenaga, dan mempunyai penggunaan tenaga keseluruhan yang rendah. Projek ini memberi tumpuan kepada mereka bentuk ruang panas dengan elemen pemanas. Apabila elemen pemanas dipanaskan, ia akan menghasilkan gas panas di dalam ruang. Oleh itu, aliran gas serta perbezaan suhu boleh dianalisis. Memandangkan elemen pemanas digunakan untuk memanaskan ruang, termokopel yang berfungsi sebagai sensor yang digunakan untuk mengukur suhu kerana ia diletakkan di dalam ruang panas. Selepas suhu meningkat kepada nilai yang dikehendaki, aliran gas kemudiannya boleh dianalisis dan diperhatikan. Pemerhatian dibuat dengan menyaksikan aliran gas panas dipindahkan dari ruang panas ke saluran sempit yang kemudiannya dipindahkan ke ruang sejuk. Perbandingan perbezaan suhu boleh dibandingkan dengan data yang diperhatikan.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

My utmost appreciation goes to my main supervisor, Sushella Edayu Binti Mat Kamal from Faculty Mechanical and Manufacturing, UTeM for all her support, advice and inspiration. Her constant patience for guiding and providing priceless insights will forever be remembered. Also, to my academic supervisor, Universiti Teknikal Malaysia Melaka (UTeM) who constantly supported my journey. My special thanks go to Amiera Husna student master at Universiti Teknikal Malaysia Melaka (UteM) for all the help and support I received from him.

Last but not least, from the bottom of my heart a gratitude to my beloved parents Muhamad Jamaludin Bin Yasin and Wan Pisah Binti Wan Jaafar, for their encouragements and who have been the pillar of strength in all my endeavors. My eternal love also to all my teammates for their patience and understanding. Finally, thank you to all the individuals who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Mechanical gas pumps are distinguished from nonmechanical pumps, which are distinguished by the presence or absence of moving parts. Mechanical pumps drive fluid flow by utilizing the mechanical energy of its moving parts, and the working mediums of mechanical pumps are primarily liquids. Because of the moving parts, their life spans, sensitivity, and stability are all significantly reduced. On the contrary, fluid flow is driven by nonmechanical kinds of energy such as electric, thermal, chemical and magnetic energy in nonmechanical pump applications. In addition to liquids, they can work with gases and solids in the form of nanometer-sized particles as well as solids in the form of nanometer-sized particles.

Knudsen pumps functioning mechanism is based on thermal creep effect. Many academics have long been interested in KPs because of its advantages of having no moving parts, simple architectures, a wide variety of energy sources, low energy consumption, and the ease with which they can be mass produced and expanded.

1.2 Problem Statement

A Knudsen Pump (KP) is a form of thermal transpiration that may generate thermally induced flows as a result of temperature fields configuration of Knudsen pump which has hot temperature and cold temperature flow. This project will concentrate on designing a hot chamber using heating element which will be connected to alternating current electricity power supply. This will produce hot gas which roughly 100 °C to 150 °C inside the chamber as the heating element heated up the chamber. However, the chamber suffered significant heat loss due to conduction, which occurs when heat is transported to the chamber surface, causing the temperature to drop.

On the contrary, by creating a thermal insulation cover to enclose the chamber, it is possible to limit the amount of heat lost. This is due to the fact that insulating materials are poor conductors, and hence could help to prevent heat loss by conduction. It will also be the emphasis of this project to design the insulating chamber cover, which will be necessary in order to attain and maintain the desired temperature inside the chamber.

1.3 Research Objective

The main objectives of this project design are as follows:

a) To review and identify the parameters that effect the performance of thermal transpiration pump.

b) To evaluate the effect of hot chamber parameters on the temperature.

c) To analyze the effect of temperature difference on the gas flow properties in the thermal transpiration pump.

1.4 Scope of Research

The scope of this research are as follows:

- Designing hot chamber with heating element for Knudsen pump thermally induced flow system
- Designing thermal insulator cover applicable for hot chamber
- Conduct a temperature analysis before and after the insulator cover has been installed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The thermally induced flow of rarefied gas is well understood to be caused by the temperature gradient along the walls of the Knudsen pump, and the gas is propelled to flow from the low-temperature side to the high-temperature side. That is the fundamental mechanism of the Knudsen pump, which was proposed in 1909 by Danish physicist Martin Knudsen. The Knudsen pump can deliver continuous gas flow and has no moving parts, a simple structure, ease of operation, a long-life span, low energy consumption, and a wide range of energy sources. The traditional rectangular Knudsen pump is made up of a succession of wide and narrow micro-channels that are alternately connected. By imposing high-temperature and low-temperature heat resources at the two ends of the large channels, a tangential temperature gradient arises. This causes the gas flow to experience thermal creep.

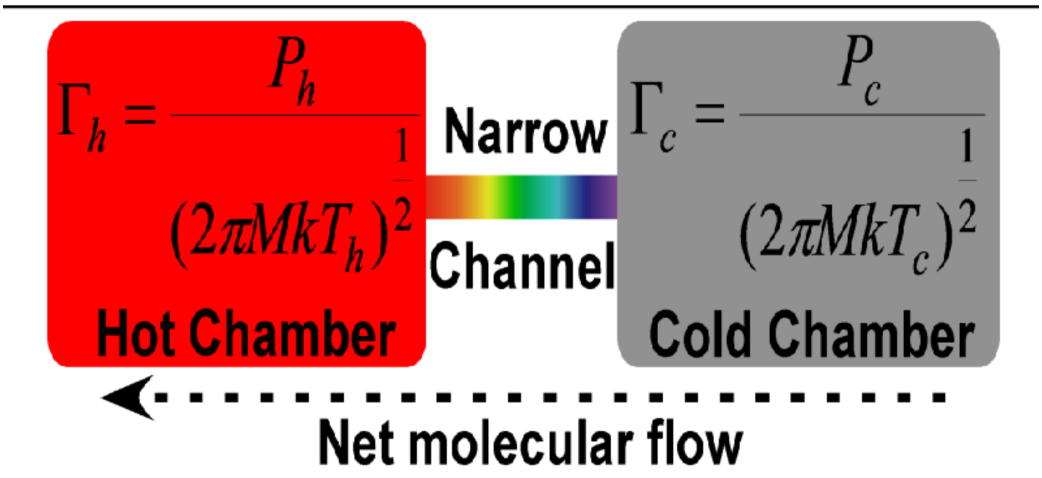

Figure 2.1 Knudsen pump diagram (Retrieved from: https://www.semanticscholar.org/paper/Human-powered-Knudsen-pump-for-pneumatic-delivery.)

2.2 Knudsen Pump

(Zhijun Zhang, et. al, 2019) explained that the traditional rectangular Knudsen pump is made up of a number of large and narrow micro-channels that are connected to one another in alternating fashion. When high-temperature heat resources are introduced at one end of the wide channels and low-temperature heat resources are introduced at the other end, a tangential temperature gradient is produced. Because of this, a thermal creep effect is produced for the flow of the gas. In recent years, with the development of materials technology and micro-machining technology, it has become possible to produce the pump structure by using poly-silicon material. Additionally, the flowing channel of the Knudsen pump can now be constructed by using the inter-molecular gaps in porous materials such as aerogel membranes, mixed cellulose ester (MCE), zeolite, porous ceramics, and Bi2Te3.

Since the rectangular Knudsen pump has been suggested, numerous configurations for the channel have been constructed and investigated in succession. (Zhijun Zhang, et. al,

2019) added that there are a number of studies that use the DSMC approach to analyze the flow of gas mixtures. It has been discovered through the modelling of DSMC that the Knudsen pump demonstrates a good capability in gas separation. Studies on Knudsen pumps have, for the most part, concentrated on developing new aspects of the structure, developing methods to improve performance, and developing applications in the real world.

Most of the gas that is utilised in simulations is a monatomic noble gas. On the other hand, gas mixes have been used more frequently than individual gases, and the proportions of noble gases found in the atmosphere are extremely low. In addition, the width of the micro-channel has already reached the nanoscale level, which ensures that the Knudsen pump is able to function normally even when subjected to air pressure.

By imposing high-temperature and low-temperature heat resources at the two ends of the large channels, a tangential temperature gradient arises. This causes the gas flow to experience thermal creep. With the advancement of materials technology and micro-machining technology in recent years, the pump structure can now be produced by using poly-silicon material and the inter-molecular gaps in porous materials such as aerogel membranes, mixed cellulose ester (MCE), zeolite, porous ceramics, and Bi2Te3. Since the rectangular Knudsen pump was introduced, other channel structures have been built and examined. There are different types of Knudsen pump channel structures as shown in figure 2.2 which are curved-straight channel, double-curves channel, sinusoidal channel, matrix channel, ratchet channel, an tapper channel.

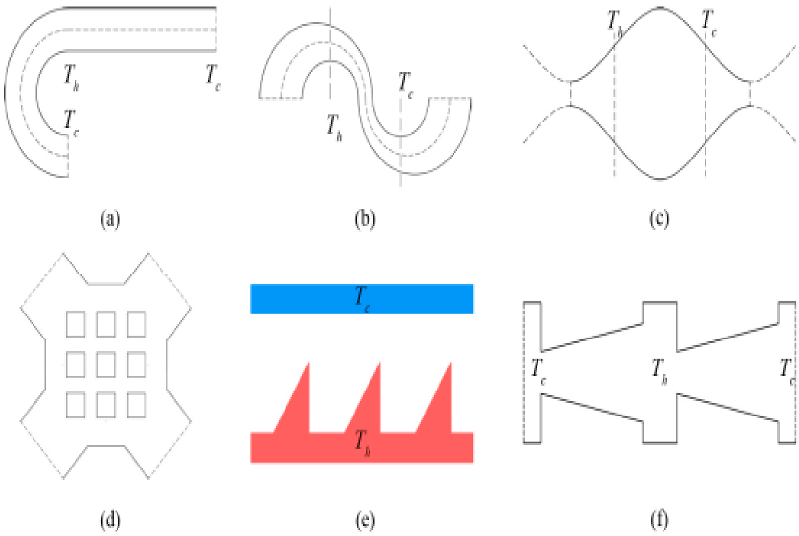

Figure 2.2 Common Knudsen pump channel structures (Zhang, et. al, 2019).

2.2.1 Thermal Transpiration pump

(Reynold's, et al, 1879) independently began their investigation into the process of heat transpiration which was the year they published their findings. Thermal transpiration is the movement of gas molecules from the cold side to the hot side of a channel that is being subjected to a temperature gradient. The flow of gas molecules is confined to either the free molecular or transitional gas flow regimes within the channel. In order for transpiration to be of any significance, the hydraulic diameter, denoted by d, must be less than the mean free path, denoted by k, of the gas molecules; in other words, the Knudsen number, denoted by Kn(k/d), must be bigger than unity. In the example shown in Figure 1, which consists of two large chambers connected to one another by nanochannels and situated within a thermal transpiration element, the ratio of the equilibrium pressures is found by taking the square root of the difference in absolute temperature between the two chambers. (This is simply an estimate, but it is accurate for the case of free molecular flow under perfect conditions.) Knudsen was the first person to demonstrate that it would be possible to construct a system for the stationary pumping of gas that was based on this phenomenon (Knudsen, 1909). However, because materials with suitably narrow channels were not readily available until the 21st century, the majority of the Knudsen pumps that were documented up until that time worked at pressures lower than the atmospheric pressure.

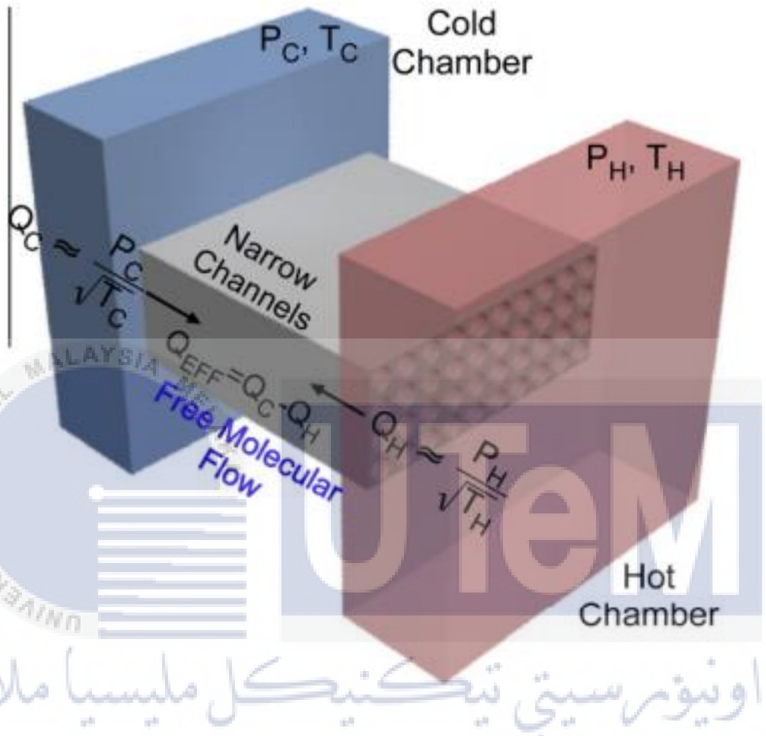

Figure 2.3 Diagram of thermal transpiration pump path channel

2.3 Vacuum Pump without a Moving Part and its Performance

According to (Sone, Yoshio, 2003), The presence of a temperature field can have a significant impact on the mobility of a rarefied gas. The thermal transpiration, which is an example of a flow that is induced by a pipe that has a temperature gradient along it, is a well-known example, and its application to a vacuum pump that does not have a moving part has been considered for a considerable amount of time. A pressure differential is produced when two reservoirs that are connected by a conduit that has a temperature gradient (or reservoirs of different temperatures) are brought together. due to the process of thermal transpiration,