STUDY TO OPTIMISE INTERIOR FIELD FLOW OF A LOBE PUMP

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STUDY TO OPTIMISE INTERIOR FIELD FLOW OF A LOBE PUMP

This report submitted in accordance with requirement of the
Universiti Teknikal Malaysia Melaka (UTeM)
for the Bachelor Degree of Manufacturing Engineering
(Manufacturing Design)

By

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TAJUK : **Study to Optimise Interior Field Flow of a Lobe Pump**

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory is as follow:

………………………………………

(DR. SHAJAHAN BIN MAIDIN)

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ABSTRAK

Pam Lobe digunakan secara meluas untuk pengangkutan cecair yang mempunyai kepekatan tinggi dan kelikatan yang medium melalui satu saluran paip. Rekabentuk simulasi pam dijalankan dengan menggunakan perisian “Computational Fluid Dynamics (CFD)” dan prestasi rotor profil pam juga boleh dikenalpasti. Pelbagai parameter pam yang berkaitan dengan prestasi pam telah dititik beratkan. Masa dan kedudukan rotor berputar, saiz rotor dan bentuk ruang dalaman pam itu sendiri adalah parameter yang paling penting untuk digunakan sebagai ramalan nilai pencapaian kecekapan pam berkenaan kelak. Dalam projek ini, prestasi rotor profil pam mempunyai lengkungan geometri yang berbeza. Pada masa ini, kesan dan sifat rotor profil pam Lobe tidak difahami sepenuhnya. Maka, cara simulasi berangka dan penentuan eksperimen digunakan bagi mengkaji kesan rotor profil pam vorteks dalaman sedia ada. Bidang aliran dalaman dan sifat rotor profil pam Lobe dengan kelima-lima rekabentuk direka rotor profil pam yang berbeza, seterusnya simulasi dijalankan dalam keadaan stabil dengan menggunakan “Autodesk Simulation CFD 2016”, kegeloraan Standard k-ε model dan algoritma PISO digunakan untuk menyelesaikan persamaan. Dalam laporan ini, analisis berangka telah menetapkan kepada 1400RPM, 2400RPM, 3400RPM dan 4000 RPM sebagai salah satu parameter penting dan satu perubahan kecekapan telah disiasat. Keputusan menunjukkan bahawa melalui analisis kadar aliran untuk rekabentuk optimum pam Lobe, lebih tinggi kadar aliran isipadu profil rotor akan mewujudkan kecekapan tinggi pam Lobe dalam segi prestasinya. Lima rekabentuk rotor profil mempunyai identiti tersendiri diantara prestasi (kadar aliran isipadu) dan ketahanan (jangka hayat) pam Lobe. Melalui kajian ini, ia boleh disimpulkan bahawa rekabentuk yang digunakan oleh industri pada masa kini adalah yang paling optimum kerana memerlukan lebih banyak ketahanan berbanding prestasi. Secara umumnya, industri lebih mengutamakan dari segi aspek keunggulan prestasi (kadar aliran isipadu) berbanding ketahanan (jangka hayat) akan memilih Design A dan jika industri ingin mengutamakan dari segi aspek seimbang antara prestasi dan juga ketahanan akan memilih Design D rotor profil.

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ABSTRACT

Lobe pumps are widely used for transportation of high concentration and viscosity liquid of the medium through a pipeline if the requirements are simple head and discharge. Pump design is simplified by the development of Computational Fluid Dynamics (CFD) and complexity profile lobe pumps can also be predicted. Various parameters affect the performance of the pump. Time and position of the rotating rotor, rotor size and shape of the room is the most important parameter that should be considered to achieve high efficiency. In this project, the performance profile of the pump rotor lobe has different geometric curves which can be carefully evaluated. The investigation focuses mostly on the performance characteristics of the pump. At this time, the effect lobe pump rotor profile and lobe pump characteristics are not fully understood. Thus, the methods of numerical simulation and experimental verification are used to study the effects of existing internal vortex pump lobe. The internal flow field and characteristics of lobe pump with five design different rotor profile design simulation and forecasting in stable condition by using Autodesk Simulation CFD 2016 Standard k-ε turbulence model and PISO algorithm was used to solve the equations. In this report, numerical analysis was carried out at 1400RPM, 2400RPM, 3400RPM, and 4000 RPM and a change in head and efficiency were investigated. The results show that through the analysis of the flow rates for the optimum design of the lobe pump, the higher the volume flow rate of the rotor profiles will generate higher efficiency of the lobe pump in terms of its performance. The five designs rotor profile designs have their own compromises between their performance (volume flow rate) and its durability (life-span) of the lobe pump. Through this study, it can be concluded that the existing design is the most optimum because the application purposes require more durability over performance. In general, those applications that require more performance (volume flow rate) over durability (life-span) will choose Design A and if the application purposes require balanced between the performance and also the durability will choose Design D of the rotor profiles.

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DEDICATION

I would like to dedicate this work to my:

Beloved parents

Dearest siblings

Honorable supervisor and lecturers

Supportive friends and mates

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CHAPTER 1

INTRODUCTION

This chapter will introduce the project. It contains the background, the problem statement, objectives, the scopes of the project and the finally the outline of the report is briefly discussed.

1.1 Background of Study

Lobe pumps are used in a variety of industries including, pulp and paper, chemical, food, beverage, pharmaceutical, and biotechnology (Liu & Lu, 2014). They are popular in these diverse industries because they offer superb sanitary qualities, high efficiency, reliability, corrosion resistance, and good *clean-in-place* and *sterilize-in-place* (CIP/SIP) characteristics. This pump offers a variety of lobe options including double folium, tri-folium and multi-folium (Smith, 2007). Rotary lobe pumps are non-contacting and have large pumping chambers, allowing them to handle solids such as cherries or olives without damage. They are also used to handle slurries, pastes, and a wide variety of other liquids (Tuzson, 2000). If wetted, they offer self-priming performance. A gentle pumping action minimizes product degradation. They also offer reversible flows and can operate dry for long periods of time. Flow is relatively independent of changes in process pressure, so the output is constant and continuous.

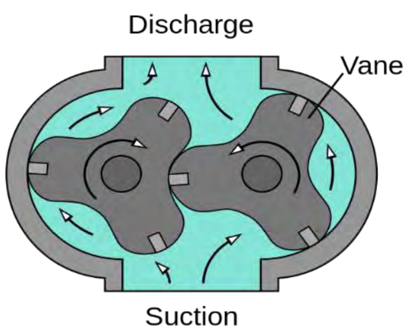

Figure 1.1: Tri-Folium of the Lobe Pump

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The rotary lobe pump belongs to the positive displacement pump family. It is a dual shaft pump design with external timing gears, allowing two intermeshing rotors to operate synchronously (Tuzson, 2000). The pump operation is similar to the function of a positive displacement blower. By minimizing the clearances between the rotors and the pump casing allow pumping action by forming a seal with the liquid between the suction and discharge side. Most positive displacement pumps need to be operated with elastomers (Liu & Lu, 2014). Since the rotary lobe pump has no preferred rotation direction, it can be operated in a reversible mode.

The basic configuration and working action of a lobe pump assembled with a pair of two lobe rotor (Lich, 2010). Positive fluid displacement is achieved by the continuous rotation of the conjugate rotors. Because the driving rotor of the pump can only drive the driven rotor half cycle, an external driving gear pair is needed in order to provide a continuous output motion (Smith, 2007). To improve the performance of the positive displacement blower, it is imperative to understand the detailed internal flow characteristics or enable a visualization of flow status.

By comparing the experimental measurements and the numerical results on the variation of flow rate with the outlet pressure, the maximum relative error of the flow rate is less than 2.15%, even at the maximum outlet pressure condition, which means that the calculation model and numerical computational method used are effective (Lich, 2010).

This project will embark on a study to optimize the interior field flow of a lobe pump by conducting literature review on types of rotary pump to determine the differences of functions and its applications, developing 3D CAD model of a lobe pump and the utilization of the Autodesk CFD Simulation to find the optimum parameter of rotting time and positon, size and shape of rotors to analyses the flow rates at the optimum design of the lobe pump. These objectives are achieved with the methods of numerical simulation and experimental verification to study the effects of existing internal vortex pump lobe.

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1.2 Problems Statement

From the previous years, there is a lot of techniques to produce the optimum existing vortex of the lobe pump. Industry standards (ASME, API, ISO, Hydraulic Institute) prescribe test procedures for the experimental determination of NPHRS (Smith, 2007). These generally base the definition of NPHRS on that pressure head at the pump inlet at which the pump head drops off by 3%. Computational fluid dynamics (CFD) is the application in lobe pump operations are one of the best ways to investigate energy transfer, specific driven speed, design of machine components and systems and cost reduction (Liu & Lu, 2014). It is very complicated to determine the optimization of interior field flow of a lobe pump condition in real machine process due to a lot of experiments needed to be conducted. By using Autodesk CFD software, it provides fast results, reduces the time step, and it is 90% accurate with the actual process. It can also determine the flow rate of the lobe pump. Basically, to optimize this vortex that consists of pressure and velocity, the previous researchers just derive the formula to get the best result in term of gearing ratio, chamber of shape and size (Liu & Lu, 2014). Therefore, this project wants to study the optimization of the interior field flow of a lobe pump by using mathematical modelling technique to find the optimum parameter of rotating time and positon, size and shape of rotors and combine all together the previous result from researchers via journals to optimize rotor profile to determine the best efficiency of pump performance in terms of volume flow rate and Reynold number.

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1.3 Scope of Study

This project focus on the optimization of existing vortex of 3 elements which is rotating time of gearing ratio position, size and shape of the rotor will use to investigate the effect on final pressure and velocity by using Autodesk CFD Simulation software. The design of the size and shape of the rotor used with the different dimension (Sang & Meng, 2013). In this software the method to produce the part is using an air flow technique which is rotary of vacuum pump. This technique begins with difference shape of rotor folium, which is double folium and tri-folium will be studied. The Autodesk CFD Simulation software was used as 2D air flow simulation tools in order to simulate the behavior of characteristics of part produce with different rotting time and the position (Smith, 2007). After the simulation process completed, the pressure and velocity will be investigated by the software. Finally, the best results of the selection of vortex parameters will be suggested.

1.4 Objectives of Study

1. To conduct literature review on types of rotary pump to determine the differences of functions and applications.
2. To develop 3D CAD model of a lobe pump.
3. To use the Autodesk CFD Simulation to find the optimum parameter of rotating time and positon, size and shape of rotors.
4. To analyse the flow rates of the optimum design of the lobe pump.

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1.5 Outline of Report

To complete this project, this following will give a systematic of the report are divided into five chapters, namely:

Chapter 1: Introduction

This chapter is an introduction to the problem that will be in discuss problems such as background of study, problem statement, scope of study, research objectives and systematic writing.

Chapter 2: Literature Review

This chapter is part of the basic theories used in solving and discuss the existing problems. Outlines a summary of the theory that is the basis and general view in theory as a supporter in problem solving based on the existing product of the lobe pump.

Chapter 3: Methodology

This chapter is an outline description of the method research used by the researcher as well as the framework in solve the problem.

Chapter 4: Results and Discussion

This chapter presents the data obtained from the company and journal which is further processed in accordance with the existing material, ie data regarding corrective vortex parameter and data on machine will then be processed by the methods already mentioned above.

Chapter 5: Conclusion

This chapter contains the conclusions are derived from problem solving as well as from the results of the data collection and suggestions for improvement for the product.

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CHAPTER 2
LITERATURE REVIEW

This chapter discusses about various literature reviews that serve as a guide in this project. The reviews are from books, journals, articles and conference paper. The major topic reviewed such as vacuum definition, vacuum pump, type of vacuum pump, how lobe pumps work, comparing 4 types of PD pumps, advantages and disadvantages, applications of the lobe pump and Taguchi method approach in finding optimum parameters that will be discussed in this chapter.

2.1 Vacuum Definition

Pressure is generally the result of molecules, within a gas or liquid, impacting on their surroundings usually the walls of the containing vessel (Tuzson, 2000). Its magnitude depends on the force of the impacts over a defined area hence, for example, the Newton per square meter, given the special name Pascal and the traditional (but obsolete) unit pound force per square inch. The relationship between pressure (p), force (F) and area (A) is given by:

P : Pressure (N/m^2)
F : Force (N)
A : Area (m^2)

$$P = \frac{F}{A}$$

This equation applies whether the pressure is very small, such as in outer space, or very large, as in hydraulic systems for example (Tuzson, 2000). Thus the word pressure is correct when referring to the entire range of force per unit area' measurements, although at extremely low pressures the concept of molecules exerting a force becomes more abstract.

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Definition of vacuum is not precise but it is commonly taken to mean pressures below and often considerably below, atmospheric pressure (John, 2007). It does not have separate units and we do not say that vacuum equals force per unit area. Thus, strictly do not need to talk about both pressure and or vacuum because vacuum is pressure. But the differences are often misunderstood and thus leaving out the word vacuum can falsely imply that the pressure in question is above that of atmospheric pressure.

2.2 Vacuum Pump

Vacuum pumps are used to remove gas molecules in the gas phase from a gas filled volume and to maintain a required degree of gas rarefaction in that volume (John, 2007). A vacuum pump converts the mechanical input energy of a rotating shaft into pneumatic energy by evacuating the air contained within a system. The internal pressure level thus becomes lower than that of the outside atmosphere. The amount of energy produced depends on the volume evacuated and the pressure difference produced. Mechanical vacuum pumps use the same pumping mechanism as air compressors, except that the unit is installed so that air is drawn from a closed volume and exhausted to the atmosphere (John, 2007). A major difference between a vacuum pump and other types of pumps is that the pressure driving the air into the pump is below atmospheric and becomes vanishingly small at higher vacuum levels. Other differences between air compressors and vacuum pumps are:

1. The maximum pressure difference produced by pump action can never be higher than 29.92 in. Hg (14.7 psi), since this represents a perfect vacuum.

2. The mass of air drawn into the pump on each suction stroke, and hence the absolute pressure change, decreases as the vacuum level increases.

3. At high vacuum levels, there is significantly less air passing through the pump. Therefore, virtually all the heat generated by pump operation will have to be absorbed and dissipated by the pump structure itself.

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Chiu and Yu (2015) developed a design method for improving the flow characteristics of a multistage roots pumps, about the research field on the flow characteristics of multistage Roots pumps with serial and parallel connections are investigated. They concluded that the better progression phase angles in the serial and parallel connection designs are 30 and 45, respectively.

Based on the ideas with Sang and Meng (2013), they stated about transient simulation in interior flow field of lobe pump, they focused on the development and control of the double folium and tri-folium lobe pump profiles. They result shows more vortexes in double folium lobe pump.

However, investigated about Prediction of protein shear stress at different pump efficiencies (Tong & Yang, 2000). They also mentioned on simulated in order to predict variations in shear stress and pump efficiency with varying gap size which is 1mm, 2mm, 3mm and 4mm between the lobe and pump housing. The data shows with an increase in the gap width, the pump efficiency drops dramatically.

2.3 Type of Vacuum Pump

A pump is defined as a device that moves a liquid by increasing the energy level of a liquid. There are many ways to accomplish this objective (Zhang & Fong, 2015). For the conclusion of this chapter, will be able to identify all of different types of pumps on site and to state the function of each specific types. Positive displacement (PD) pumps are divided into two broad classifications, reciprocating and rotary. In this project, currently focuses on rotary pumping principles. Refer Figure 2.1 and observe all of the different types of pumps which will discussed in this chapter.

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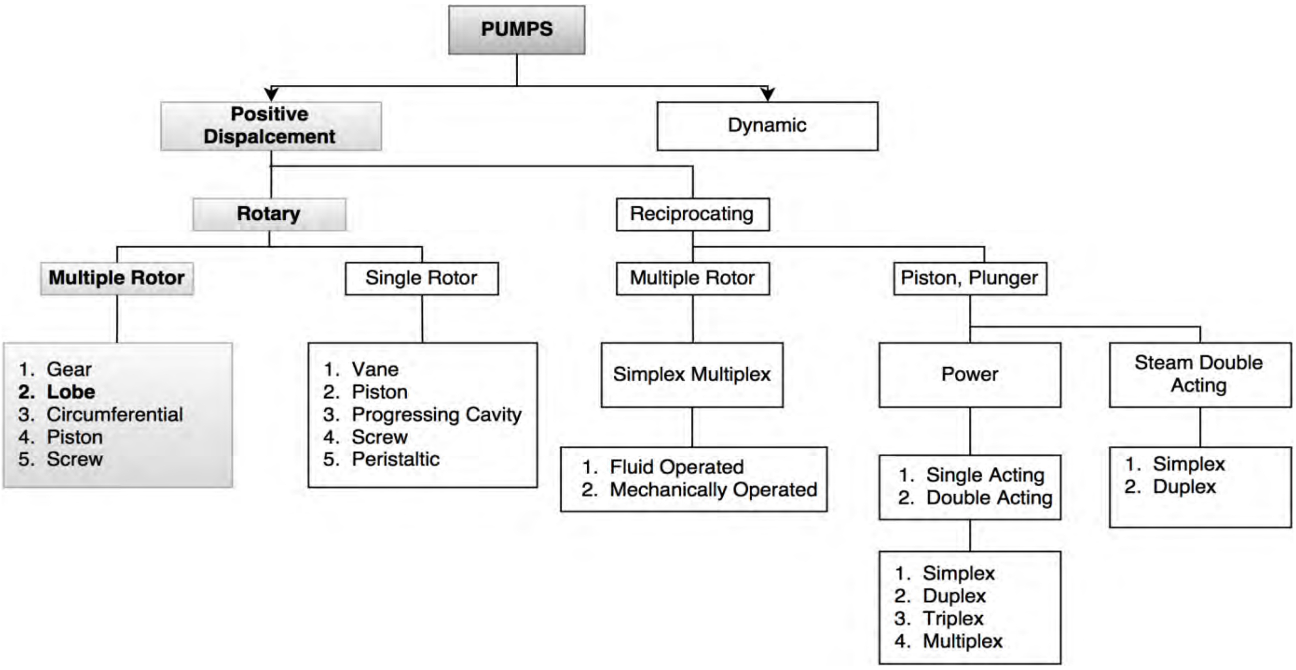

Figure 2.1: Rotary Pump Family Tree

(From Johann, F. G. 2007. Centrifugal Pumps, 2nd Ed. Springer: Verlag Berlin Heidelberg.)

By definition, PD pumps displace a known quantity of liquid with each revolution of the pumping elements examples gears, rotors, screws, vanes (Zhang & Fong, 2015). PD pumps displace liquid by creating a space between the pumping elements and trapping liquid in the space. The rotation of the pumping elements then reduces the size of the space and moves the liquid out of the pump (John, 2007). PD pumps can handle fluids of all viscosities up to 1,320,000 cSt / 6,000,000 SSU, capacities up to 1,150 m^3 / Hr / 5,000 GPM, and pressures up to 700 BAR / 10,000 PSI. Rotary pumps are self-priming and deliver a constant, smooth flow, regardless of pressure variations (John, 2007).

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