UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVEMENT ON WATER PUMP BLADE DESIGN BY USING CFD SIMULATION

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours.

by

TEONG JET FANG

B071410210

940302-01-5292

FACULTY OF ENGINEERING TECHNOLOGY

2017

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **IMPROVEMENT ON WATER PUMP BLADE DESIGN BY USING CFD SIMULATION**

SESI PENGAJIAN: **2017/18 Semester 2**

Saya **TEONG JET FANG**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐ TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐ TIDAK TERHAD	

Disahkan oleh:

_____ _____

Cop Rasmi:

Alamat Tetap:

NO. 39, JALAN TUN RAZAK,
85400, CHAAH,
JOHOR.

Tarikh: _____ Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled “Improvement on Water Pump Blade Design by Using CFD Simulation” is the results of my own research except as cited in references.

Signature	:	……
Author’s Name	:	……
Date	:	……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

. . . . . .

(Project Supervisor)

ABSTRAK

Pam air adalah alat yang digunakan untuk memindahkan air dari satu tempat ke satu tempat untuk beberapa tujuan. Pendesak merupakan komponen utama dalam pam air kerana ia mempercepatkan aliran bendalir dan meningkatkan tekanan di dalam air. Reka bentuk pendesak mempunyai kesan kritikal kepada prestasi pam. Tujuan projek ini adalah untuk meningkatkan prestasi pam dengan mengubah suai reka bentuk bilah. Kaedah yang dicadangkan untuk meningkatkan prestasi pam adalah parameterisasi, yang berbeza-beza parameter bilah. Parameter bilah diubahsuai adalah jumlah bilah, sudut bilah masuk dan sudut bilah outlet. Simulasi Dinamik Cecair Pengkomputeran (CFD) adalah alat yang berguna untuk menganalisis dan menggambarkan aliran dalaman pendesak. Ia menjalankan ujian maya yang tidak memerlukan prototaip untuk menganalisis. Oleh sebab simulasi CFD menggunakan masa yang kurang, kebanyakan pengajian menggunakan simulasi ini.

ABSTRACT

Water pump is a device used to transfer water from one point to another for some purpose. Impeller is a main component in water pump as it accelerates the flow of a fluid and increase the pressure inside to discharge water. Design of the impeller has a critical effect to the performance of a pump. The aim of this project is to improve pump performance by modify the blade design. The method proposed to improve pump performance is parameterization, which is varying the blade parameters. The blade parameters to be modified are number of blades, inlet blade angle and outlet blade angle. CFD simulation is a useful tool to analyse and visualise the internal flow of impeller. It conducts virtual test which no prototype is required for analysing. Due to that CFD simulation consumes less time and cost, most of the studies of pump flow and optimization of pump impeller utilize CFD analysis.

DEDICATION

This thesis is dedicated to my beloved parents, supervisor and friends for their help and guidance to complete the final year project successfully.

ACKNOWLEDGEMENT

I would like to convey my gratefulness to my supervisor, Mr Kamarul Bin Amir Mohamed for giving me such the precious chance to have my final year project under his supervision. Without his supervision, encouragement and patience, this project would never have been completed on time. Besides, I appreciate all the guidance, motivation and invaluable discussion throughout the project. Despite he is being extraordinary busy with his jobs and duties; he still managed to guide me along, apart from suggesting me the best solutions to almost every challenge. I would like to thank all my friends for their encouragement and support when I faced any problems and difficulty in completing this project. Last but not least, I would also like to dedicate my special appreciation to my family for the unceasing support and attention in my entire study. Their endless support has extended to me throughout my study life and general life.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CAD	-	Computer-Aided Design
CCD	-	Central Composite Design
CFD	-	Computational Fluid Dynamics
SST k-ω	-	Shear Stress Transport k-omega
H	-	Head Pressure
Q	-	Flow Rate
n	-	Rotational Speed
N_s	-	Specific Speed
P	-	Shaft Power
η_v	-	Volumetric Efficiency
D_1	-	Inlet Diameter
D_2	-	Outlet Diameter
β_1	-	Inlet Blade Angle
β_2	-	Outlet Blade Angle
Z	-	Number of Blades

CHAPTER 1
INTRODUCTION

1.1 Background

Water pump is a device used to increase water pressure in order to transfer water from one point to another for some purpose (Abelin et al. 2006). For example, it can be used to provide energy in hydraulic system, to transfer water for processing and also used to provide cooling and lubrication services for industrial, municipal and residential uses. Due to various conditions and purposes, water pump is classified and being chosen for an application. Typically, the types of water pumps are positive displacement pump and centrifugal pump, which have the same function in transfer water but different theory in operation. However, centrifugal pump is the main subject to be discussed and investigated in this project.

Centrifugal pump is a turbo machine which converts mechanical energy to dynamic pressure to transfer water (Muttalli et al. 2014). Normally, it is driven by a motor which rotate the shaft and then transmitting torque to the water pump blade, which is called impeller. Figure 1.1 has shown the centrifugal pump in sectional view and the component in centrifugal pump.

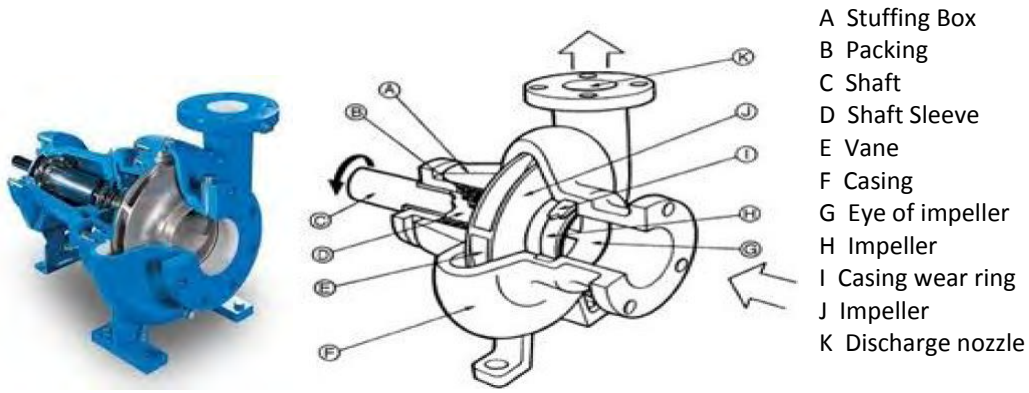

Figure1.1: Centrifugal pump and sectional view. (Russell, 2016)

Impeller is a main component in water pump as it accelerates the flow of a fluid and increase the pressure inside to discharge water. The design of the impeller has a critical effect to the performance of a pump. The type of impellers like closed impeller, open impeller and semi-open impeller are considered for different type and properties of the fluid in the pump. The type of flow in the impeller part is considered as the specific speed for each pump is different. Therefore, the impellers for different flows have a different design, for example radial flow impeller, axial flow impeller and mixed flow impeller.

In addition to this, geometry and parameter of the impeller will alter the pressure or head formed. Inappropriate design and parameter of impeller will cause the defect to occur and then affect the pump performance. The critical perspectives of parameters are the impeller diameter, number of blades, outlet blade angle, and inlet blade angle. These parameters are variable, which can be changed to improve the pump performance.

This project is to improve water pump performance by improving the design of the blade (impeller). To identify the performance of the pump and impeller, analysis on both the original impeller and optimised impellers is done, after that the results are compared to find out which has the highest performance. The performance of the impeller and pump can be determined by observing the pressure contour on the impeller and then based on the theory to find out which area is the cavitation zone. Otherwise, from the result of the analysis, the output data like head, discharge rate and efficiency can be

obtained, and then comparison is done to determine the optimise performance of impeller and pump.

Computational Fluid Dynamics (CFD) analysis is useful software which can visualise the internal flow of the pump impeller. After modelling the impeller design in CAD, the cavity is then created from the model. This cavity is used as the domain of fluid flow for numerical analysis. After that, it will be imported into software which supports CFD analysis. Then, CFD process is performed to run the analysis by following the process: pre-processing, solver, and then post-processing.

List of design parameter and geometry will be created as the testing models. The same numerical method and same boundary condition will be applied on each of the testing models. The best impeller design parameters will be selected and compromise the parameters to create an optimized impeller. The improvement of optimized impeller is determined based on the rise of head generated.

1.2 Problem Statement

A pump blade design with good performance will operate well in the pump and raise the pump performance as well. Shyam Karanth (2014) mentioned that optimizing the cost and increasing the overall efficiency of the pump are methods to optimize the pump performance.

Since the impeller design is a factor to influence the efficiency and performance of a pump, pump performance will be lower as the impeller with inappropriate design and parameter is installed.

Besides, the efficiency of water pump is lower by defect, such as cavitation. Cavitation may be caused by the design and trim of impeller, which result to a lower pressure at the suction part to cause the water vaporised and formed bubbles. The bubbles will cause erosion on the impeller, decreasing its performance, shortening the pump and impeller operating life. Therefore, it would be costly for maintenance.

1.3 Objective

This project is aimed to improve the performance of water pump. As the impeller is the major component in water pump, to speed up the fluid velocity and add kinetic energy to the fluid. Hence, improvement on impeller leads to improve pump performance as well. The followings are the objectives for this project:

1. Initial study of base impeller geometry using CFD.
2. CAD model development of new impeller design.
3. CFD Simulation study of design improvement.

1.4 Scope

This project scope is divided into three parts, they are model out the original water pump blade design based on the pump specification, do analysis by using CFD simulation, conduct the testing model to do analysis and compare with the original model.

Mathematical method is used to calculate the parameters of original pump based on the pump specification. From the parameters obtained, the original model is modelled using SolidWorks. The design and parameters of original water pump blade will be used as the benchmark.

Testing models will be developed by varying the parameters. The design after improvement will be modelled in SolidWorks. CFD simulation is run to analyse both the original and testing models, and the result is compared.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Water pump is a device widely used to provide the motive force in hydraulic systems, to transfer fluids for processing, and to provide cooling and lubrication services. Most manufacturing plants, commercial buildings, and municipalities rely on pumping systems in various purposes for their daily operation. For example, pumps are used to provide water for heat transfer in heating, ventilation, and air-conditioning (HVAC) systems, water and wastewater transfer and treatment and for land drainage (Abelin et al. 2006). Therefore, the operating condition and design parameters that yield optimal output and maximum efficiency with lowest power consumption is important to be find out (Ramasamy & Ganesan 2016).

2.1 Type of Pump

There is various sort of pump, which is classified by the manner they add energy to a working fluid. The positive displacement pumps include piston, screw, rotary lobe, and sliding vane types, which squeeze the fluid directly. The centrifugal pumps include axial, mixed-flow, and radial types, which accelerate the fluid and convert this kinetic energy to pressure centrifugal pumps. Appropriate type of pump used for an application is determined by many factors.

2.1.1 Positive Displacement Pump

Positive displacement pumps decrease displacement volume (collapsing volume action) with a piston stroke or shaft rotation to pressurize and discharge fluid. Basically, this pump squeezes an amount of fluid equal to the displacement volume of the system. As the displacement volume is fixed, the generated flow rates are directly proportional to the speed. Typically, positive displacement pumps are used in low-flow, high-head applications and with high-viscosity fluids.

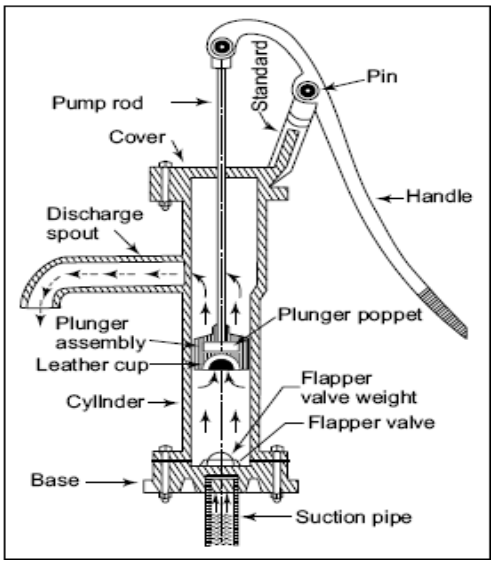

Figure 2.1: Example of positive displacement pump: Sectional view of head assembly of a shallow-well lifts pump. (Khepar et al. 2008)

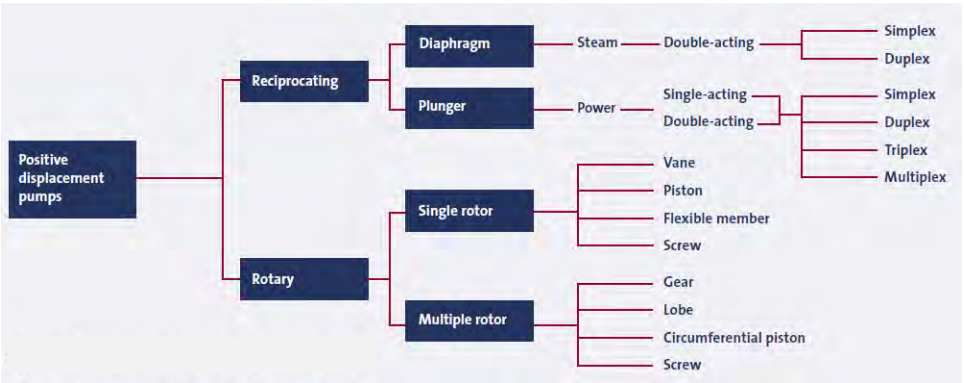

Figure 2.2: Classification of positive displacement pumps. (Grundos 2004)

2.1.2 Centrifugal Pump

Centrifugal pump is a type of a turbo machine which converts mechanical energy to dynamic pressure to enable the lifting of liquid from lower level to higher level due to centrifugal action (Muttalli et al. 2014).

Centrifugal force of a spinning impeller adds kinetic energy to a fluid. The high-velocity fluid leaves the impeller tip to a diffuser, which is a chamber that connects to the discharge piping. The moving fluid will slow down at the pump diffuser section and a higher pressure is converted from the kinetic energy of the fluid.

Centrifugal pumps are used typically in high-flow, low-head applications in which fluid viscosity is not excessively high. It suffers less wear and require less part replacements. It requires only a minor amount of downtime for packing or mechanical seals as well although it must be replaced periodically.

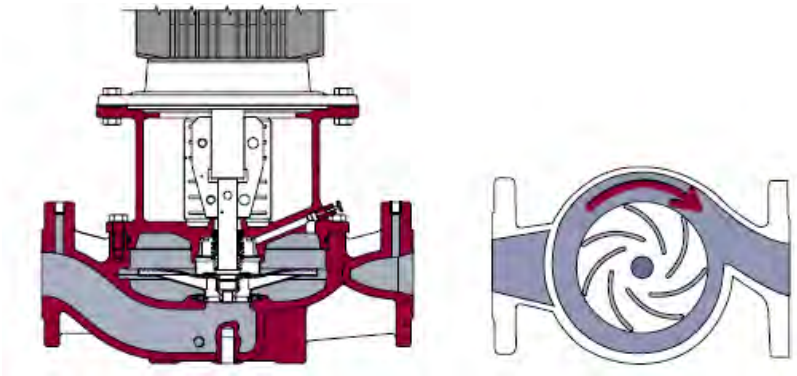

Figure 2.3: Liquid flow through the pump. (Grundos 2004)

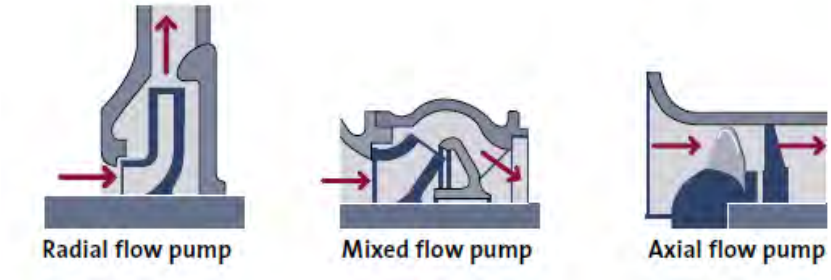

Figure 2.4: Different kinds of Centrifugal Pump. (Grundos 2004)