DESIGN AND FABRICATION OF MINI CENTRIFUGAL PUMPING SYSTEM

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FACULTY OF ENGINEERING

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING,

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.SC.) DEGREE IN PRODUCTION ENGINEERING

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CERTIFICATION

This is to certify that this project work was carried out by IKHISEMOJE OSEJIE EMMANUEL with matriculation number ENG1704464 in the Department of Production Engineering, Faculty of Engineering, University of Benin, Benin City in partial fulfillment of the requirement for the Award of Bachelor of Engineering (BEng.) in Production Engineering.

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Prof. O.R. EDOPKAI (Head of Department)	Date

DEDICATION

I dedicate this Project to Almighty God, my creator and source of inspiration and knowledge. I would also like to dedicate this project to my family, The Ikhisemoje-Oigbochie family, Ibhadode family, Oamen family, Omo-Erhabor family, Monye family, Omokhua family and Akhimien family for their unending love, support and encouragement which has brought me thus far and for cheering me on from start to finish.

ACKNOWLEDGEMENT

Firstly, I would like to express my deepest gratitude to Almighty God for giving me the strength and the composure to complete my Bachelor's degree program.

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I want to specially appreciate and express my sincerest gratitude to my Supervisor, Prof. P.E AMIOLEMHEN who guided and taught us on our journey and advised us on what best to do on the Project.

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Finally, I would like to express my special thanks to my families and friends who helped me in all aspects by accommodation, feeding and transportation, I could not have done this without them.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

BEP: Best Efficiency Point

NPSH: Net Positive Suction Head

GPM: Gallons per Minute

LPM: Liters per Minute

NOMENCLATURE

Cm2 = Radial velocity at impeller discharge

b2 = Inside impeller width

A8 = Volute throat area

Vr1 = W1= Relative velocity of flow

C1 = Absolute velocity of flow

d = diameter of shaft.

Su = Vane thickness

Cm1 = Suction eye velocity.

Ut = peripheral velocity of impeller blade

g = Gravitation constant

Km2 = capacity constant

D1 = Diameter of impeller.

D3 = Cut water diameter

ABSTRACT

This project addresses the critical need for efficient and accessible water pumping solutions in various applications, particularly in contexts with limited access to conventional power sources. Water pumping systems are integral to industries ranging from agriculture to disaster relief. However, challenges such as power dependency, infrastructure limitations, and environmental concerns persist.

This project introduces a transformative approach by integrating a hand drill as the primary power source within a centrifugal pump system. This innovative solution leverages the portability, affordability, and versatility of this device, making it a practical and cost-effective alternative. The hand drill-powered system eliminates the reliance on electricity or fuel, enhancing accessibility in remote or emergency situations.

In addition to its applicability in car washes, low volume irrigation, and medical microfluidics, this project extends its impact to various fields, including agriculture, disaster relief, and remote research stations. It offers a sustainable, portable, and environmentally responsible water pumping solution that aligns with modern needs. By combining the convenience of hand drills with the efficiency of centrifugal pumps, this project represents a significant advancement in water pumping technology.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Pump systems are integral to a wide range of industries and applications, serving the purpose of transporting fluids from one location to another. Among the various types of pumps, centrifugal pumps have gained significant popularity due to their efficiency, versatility, and ability to handle different types of fluids. These pumps operate based on the principle of centrifugal force, which is the outward force experienced by an object moving in a curved path.

At the heart of a centrifugal pump lies the impeller, a rotating component with curved blades or vanes. When the impeller rotates within the pump, it generates centrifugal force. This force causes the fluid to move outward from the center of rotation, creating a pressure difference that enables the fluid to be pumped through the system. The impeller's design, including the number, shape, and arrangement of blades, is carefully engineered to maximize the efficiency and performance of the centrifugal pump.

Numerous applications, including general service, household, agricultural, and industrial use, prefer centrifugal pumps. These pumps are favored for their simple design, flexibility to various flow rates, silent operation, ability to be driven by an electric motor or a turbine, affordability of maintenance, and compatibility with abrasive solutions. It's interesting to note that centrifugal pumps can also work backwards as water turbines. In this capacity, they transform the mechanical rotational energy that results from the potential energy of water pressure.

Hand drills, commonly used in various applications, offer a convenient and portable source of rotational power. These tools typically operate using battery power, providing flexibility and ease of use. By utilizing the rotational motion of a hand drill, it is possible to generate mechanical power for different purposes.

In the context of water pumping, there is a need for a handheld solution that is efficient, portable, and versatile. Traditional water pumping systems often rely on electricity or large-scale equipment, which can limit their applicability in remote areas, emergency situations, or smaller-scale applications. A handheld water pump offers a compact and lightweight alternative, allowing for easy transport, setup, and operation in various contexts.

Centrifugal force has been a subject of study since the time of Isaac Newton, who described it as the tendency of an object moving in a curved path to move away from the center of rotation. This principle forms the basis for the operation of centrifugal pumps, where the impeller's rotation generates the centrifugal force needed for fluid movement.

In summary, the background of this study encompasses the importance of pump systems, particularly centrifugal pumps, and their reliance on centrifugal force and the impeller's design. It also highlights the versatility and convenience of hand drills, powered by batteries, in generating rotational power. The need for a handheld water pump arises from the demand for a portable solution that can efficiently pump water in various situations and it also describes the role centrifugal force in the development of pump technologies.

1.2 Statement of problem

The idea of pumping water has been in existence since the evolution of man. Pumping plays a very pivotal role in the day-to-day existence of mankind and as a result, different methods have evolved over the years to pump or displace water. Water supply has been a very critical issue, mostly affecting the rural areas. Water is one of nature’s most important gifts to mankind. It is one of the most essential elements to good health and as such, it should be readily available to all and sundry. To address this problem, different methods and techniques have been used over the years ranging from man-powered operated ones down to the more efficient, but costly electrically and internal combustion engine powered pumps. This project seeks to design and fabricate a product can address several of these problems. By that will be The proposed project, involving the use of a rechargeable DC motor portable hand drill as the drive for the centrifugal pump, the project provides a portable and readily available water pumping solution, with minimal demand on electrical consumption and dependence on large-scale equipment. This enables flexibility in pump placement and operation, making it suitable for remote areas or emergency situations.

1.3 Aim of the study

This project aims to design and fabricate a Portable/handheld, Effective Centrifugal Pump Augmentation through Hand Drill Power Integration

1.4 Objectives of the study

i. Successfully integrate a hand drill as the power source within a centrifugal pump system, ensuring seamless compatibility and efficient power transfer.
ii. To Enhance energy efficiency by minimizing power consumption and optimizing power transmission from the hand drill to the centrifugal pump, thereby reducing energy losses and improving overall system efficiency.
iii. To Design the integrated system to be portable, lightweight, and easily transportable, allowing for convenient deployment in diverse environments and applications. Ensuring the reliability and durability of the integrated system
iv. To Develop a cost-effective solution

1.5 Significance of the study

The project holds significant importance as it addresses key challenges and offers practical solutions in water pumping. By integrating a hand drill with a centrifugal pump system, it provides a portable and versatile water pumping solution, improving access to clean water in remote areas and during emergencies. The cost-effectiveness of the system makes it accessible to individuals and communities with limited resources. Additionally, the project promotes environmental sustainability by reducing reliance on fossil fuels and showcasing innovative engineering solutions. Overall, it offers practicality, affordability, and environmental responsibility in water pumping

1.6 Scope of the study

The project's scope encompasses combining a hand drill with a centrifugal pump system that includes a shaft connected to the impeller. The goal is to develop a portable water pumping solution with a strong emphasis on efficient power transfer from the hand drill to the pump. The objective is to ensure optimal performance and enhance mobility, allowing for easy movement of the pumping system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction to water pumps

The development of water pumps has played a significant role in shaping human civilization and facilitating the efficient use of water resources. The origins of water pumping can be traced back thousands of years to ancient civilizations, where ingenious methods were devised to harness the power of water.

One of the earliest recorded instances of water pumping dates back to around 3000 BCE in ancient Mesopotamia. The Sumerians, known for their advanced irrigation systems, developed the shaduf, a simple lever-operated device that allowed them to lift water from rivers and canals for irrigation purposes. This early form of pump laid the foundation for future advancements in water pumping technology.

During the Roman Empire, engineers and architects demonstrated exceptional skill in hydraulic engineering. The construction of aqueducts allowed water to be transported over long distances, supplying cities with a reliable water supply. In some instances, the Romans employed water-powered pumps called "hydraulics" to lift water to higher elevations. These pumps utilized the force of water to power reciprocating mechanisms.

In the early 19th century, the invention of the centrifugal pump by French engineer and physicist Blaise Pascal revolutionized water pumping technology. The centrifugal pump employed a rotating impeller to impart kinetic energy to the fluid, causing it to move outward and create a pressure gradient. This innovative design allowed for the efficient transfer of large volumes of water, making centrifugal pumps ideal for applications such as irrigation, water supply, and industrial processes.

Centrifugal pumps are renowned for their simplicity, reliability, and ability to handle large flow rates. These pumps operate based on the principle of centrifugal force, utilizing an impeller to convert rotational energy into kinetic energy, thereby increasing the pressure of the fluid being pumped. The impeller, a rotating component within the pump, transfers energy to the fluid, causing it to move outward from the center of rotation. This outward motion creates a pressure gradient, resulting in fluid flow through the pump system. Centrifugal pumps are widely employed in various applications, including water supply, wastewater treatment, irrigation, and industrial processes.

The integration of a hand drill with a centrifugal pump system is a novel approach aimed at addressing the challenges and limitations of traditional pumping systems. Traditionally, pump systems have relied on electric motors or fuel-powered engines to drive the centrifugal pump. These systems often require substantial infrastructure and are not easily portable. By integrating a hand drill as the power source, this project aims to create a portable and cost-effective water pumping solution that can be easily deployed in various settings.

The use of a hand drill as a power source presents several advantages. Firstly, it eliminates the need for electricity or fuel, making the pumping system more accessible and cost-effective, particularly in areas with limited access to reliable power sources. The hand drill can be powered by a battery, providing a reliable and portable power supply that can be easily recharged. This opens up new possibilities for water pumping in remote locations or during emergencies when access to electricity may be limited.

What sets this project apart is the unique combination of a hand drill with a centrifugal pump system. While previous projects and research have focused on enhancing the efficiency and performance of centrifugal pumps, the integration of a hand drill as the power source is a new concept that has not been extensively explored. This innovative approach allows for the development of a portable water pumping solution that can be operated using a readily available tool like a hand drill.

The project aims to capitalize on the use of hand drills and their ease of use. By coupling a hand drill directly to the impeller shaft, the rotational motion of the drill can be converted into the rotational energy required by the centrifugal pump. This integration offers advantages such as portability, cost-effectiveness, and the ability to operate in areas with limited access to electricity or fuel.

The developed hand drill-powered centrifugal pump system offers several advantages and improvements over traditional pump systems. Firstly, it eliminates the need for electricity or fuel, making it cost-effective and accessible to a wider range of users. This is particularly beneficial in areas with limited resources or unreliable power supply. The hand drill, powered by a battery, provides a reliable and portable power source that can be easily recharged.

The project's potential applications are vast. The hand drill-powered centrifugal pump system can be utilized in agriculture for irrigation purposes, enabling farmers to efficiently water their crops without the need for extensive infrastructure or access to electricity. It can also be employed for water supply in rural areas or during emergencies, providing immediate access to clean water. Additionally, the system can find applications in car wash, construction sites, mining operations, and industrial processes where mobility and versatility are critical factors.

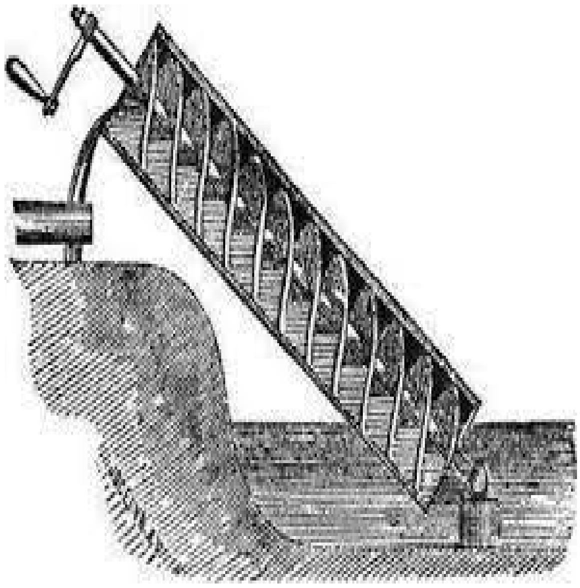


FIGURE 2.2 ARCHIMEDES SCREW

FIGURE 2.1 SHADUF USED FOR IRRIGATION IN EGYPT

FIGURE 2.4 VINTAGE HAND PUMP

FIGURE 2.3 PERSIAN WHEEL IN HAMA, SYRIA

2.2 Water pumps and classes

Water pumps are mechanical devices designed to move water from one location to another. They play a crucial role in various applications, including water supply, irrigation, drainage, and industrial processes. Water pumps can be classified based on their operating principles, design features, and specific applications. Let's explore the classifications and provide a detailed explanation of each:

2.2.1 Classification of pumps

a) Positive Displacement Pumps

b) Centrifugal Pumps

2.2.2 Positive displacement pumps

Positive displacement pumps work by trapping and displacing a fixed volume of water to create pressure. They include:

Reciprocating pumps (such as piston, plunger, and diaphragm pumps) that use a back-and-forth or up-and-down motion.Rotary pumps (such as gear, vane, screw, and peristaltic pumps) that rely on a rotating mechanism.

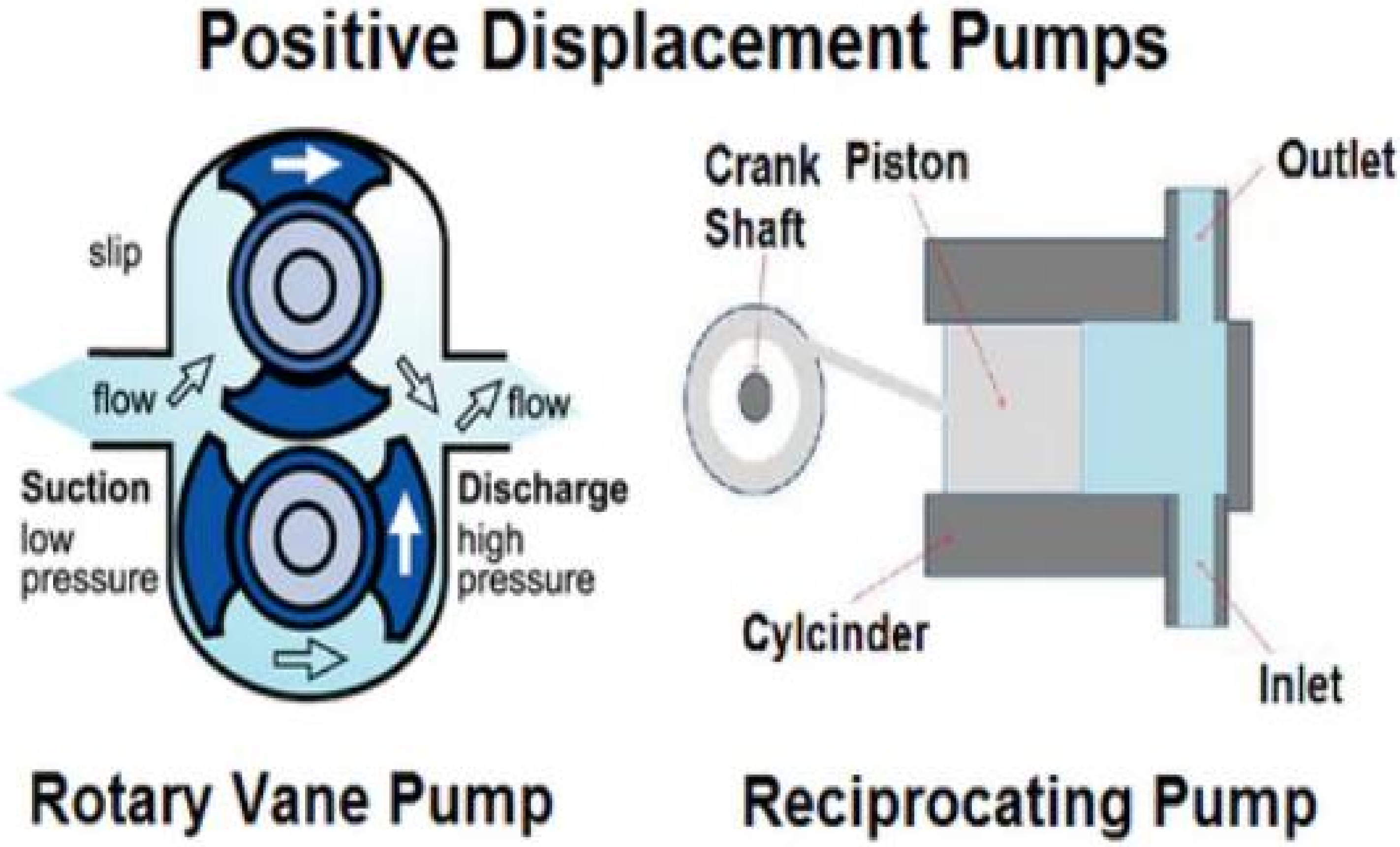


Figure 2.1 Positive Displacement Pumps

2.3 Centrifugal pumps

Centrifugal pumps are a type of dynamic pump widely used for fluid transportation in various industries. They operate based on the principle of centrifugal force, which allows them to generate pressure and move fluids efficiently. Let's explore the history, mechanism, and key aspects of centrifugal pumps.

The development of more sophisticated centrifugal pump designs began in the 17th century. One notable figure in pump history is Denis Papin, a French physicist who invented the first centrifugal pump known as the "vortex pump" in 1689. Papin's pump featured a rotating impeller enclosed within a volute casing, which improved fluid velocity and pressure generation.

Centrifugal pumps may consist of the following types:

(a) Radial Flow Pumps

(b) Axial Flow Pumps

(c) Mixed Flow Pumps

Radial flow pumps generate pressure purely by centrifugal force of the liquid due to rotation of the pump impeller.

Axial flow pumps develop pressure by propelling or lifting the liquid by the pump impeller vanes.

Mixed flow pumps use a combination of radial and axial flow pumps. When high heads are required, radial flow pumps are used. Axial flow and mixed flow pumps are generally used with low head, high capacity systems.

The mechanism of a centrifugal pump involves several key components working together:

Impeller: The impeller is typically made of metal (such as cast iron or stainless steel) or other materials with high strength and corrosion resistance. It is designed with curved blades or vanes that rotate to create the centrifugal force necessary for water movement. The impeller's shape and number of blades can vary, affecting the pump's performance in terms of flow rate and pressure generation.

Casing: The casing is the outer covering or housing of the pump. It surrounds the impeller and provides a passage for water flow. The shape of the casing is crucial in converting the kinetic energy of the water into pressure energy. It can be either a volute casing or a diffuser casing, depending on the specific design of the pump. The casing is often made of cast iron, stainless steel, or other durable materials.

Suction and discharge ports: The suction port, also known as the inlet or intake, is where water enters the pump from the water source. It is connected to a pipe or hose that delivers the water to the impeller. The discharge port, also called the outlet, is where the pressurized water exits the pump after passing through the impeller and casing. The size and location of these ports are important factors in determining the pump's flow capacity and efficiency.

Shaft: The shaft is a rotating component that connects the impeller to the power source, such as an electric motor or an engine. It transmits the rotational motion from the power source to the impeller, causing the impeller to spin. The shaft needs to be sturdy and properly aligned to ensure smooth operation and minimize energy loss.

2.3.1 Pumping process of a centrifugal pump

Centrifugal pumps operate on the principle of centrifugal force, which is the outward force experienced by an object rotating in a circular path. The key steps in the pumping process are as follows:

Water Intake: The pump's suction port is connected to a water source, such as a reservoir, well, or tank. As the impeller rotates, it creates a low-pressure zone at the inlet, causing water to flow into the pump through the suction port.

Impeller Rotation: The impeller is a vital component of the centrifugal pump. It consists of curved blades arranged radially. When the impeller rotates, it accelerates the water radially outward due to centrifugal force. This creates a high-velocity water flow within the impeller.

Conversion of Kinetic Energy to Pressure Energy: As the water moves radially outward, it enters the volute or diffuser, which is part of the pump's casing. The volute is a spiral-shaped chamber that gradually expands in size. This expansion converts the high-velocity water flow into pressure energy by reducing the water's velocity and increasing its pressure.

Water Discharge: The pressurized water exits the pump through the discharge port, where it can be directed to the desired location or application, such as a water distribution system, irrigation network, or industrial process.

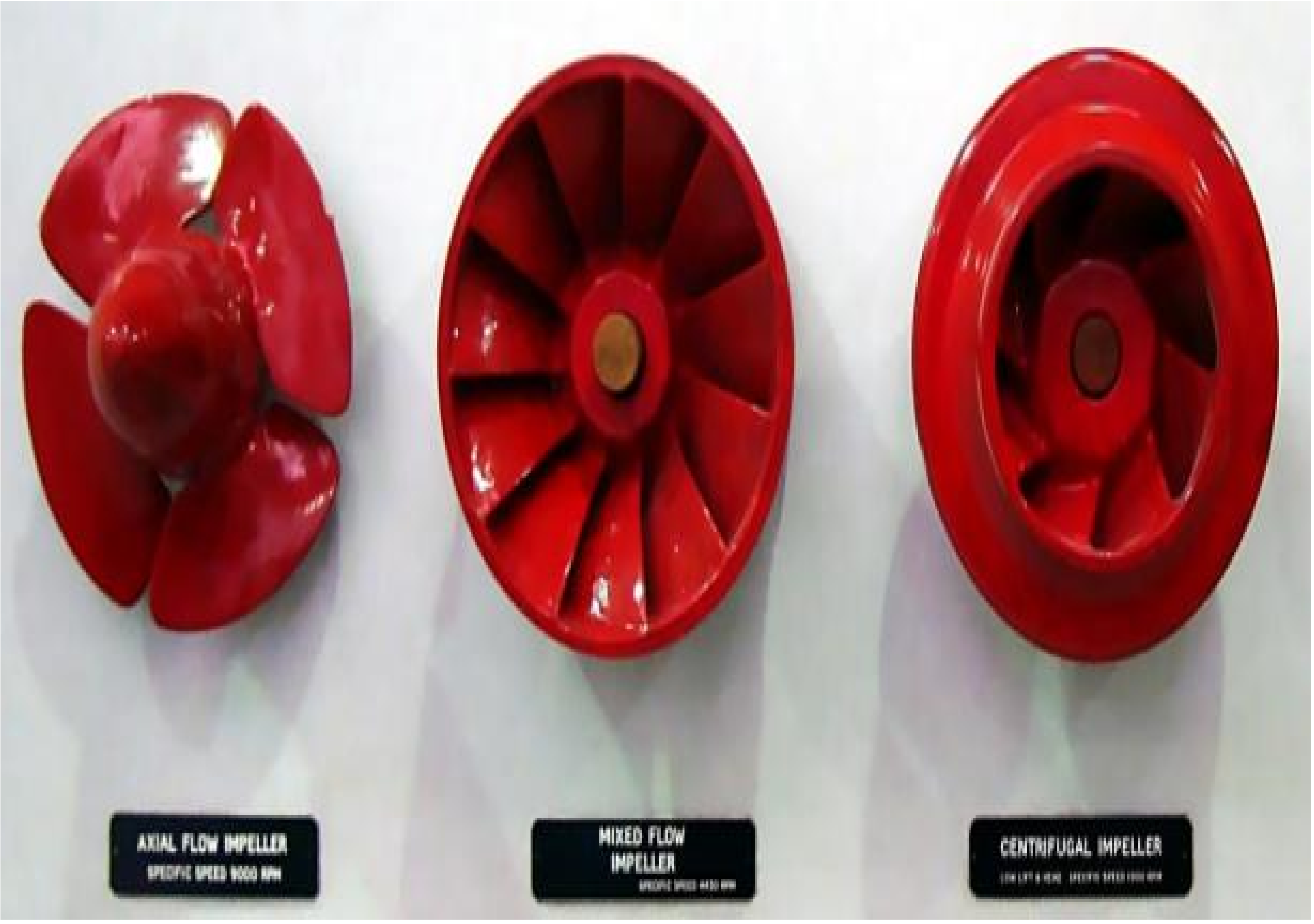
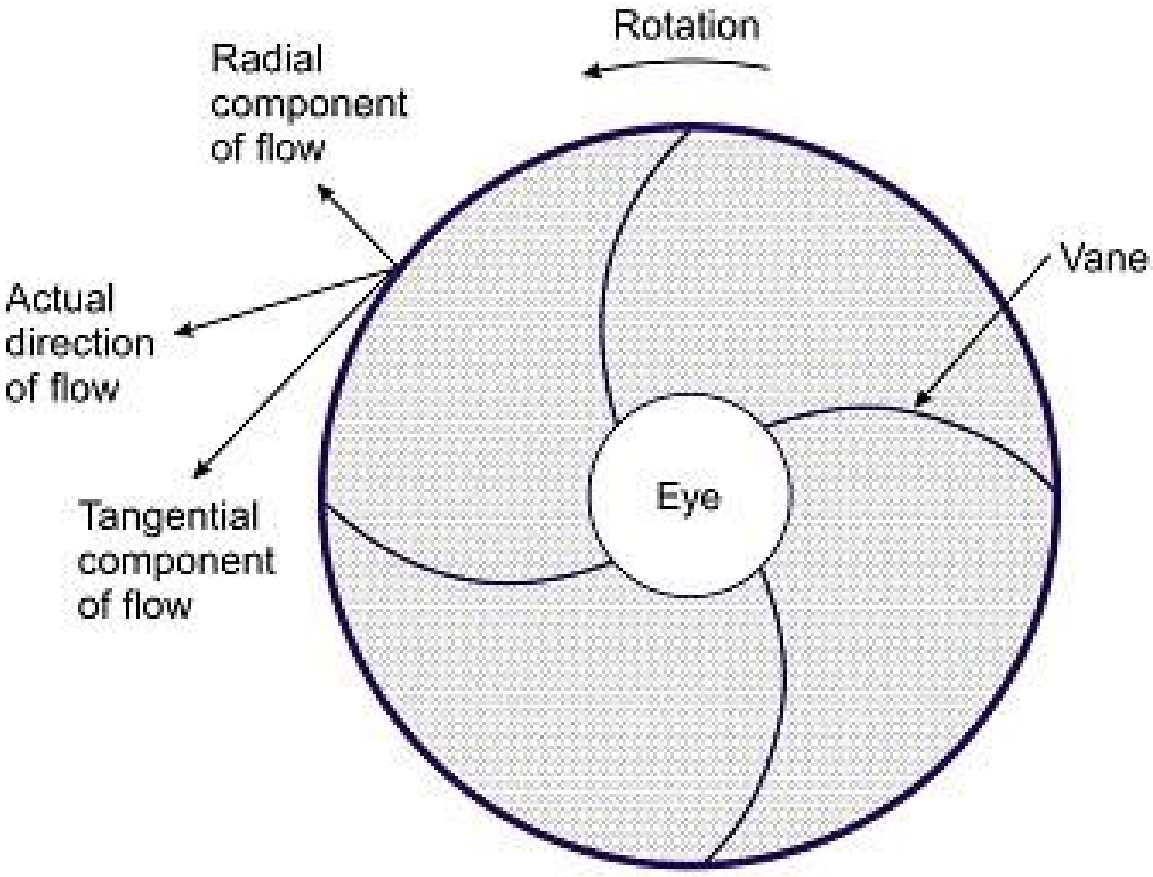
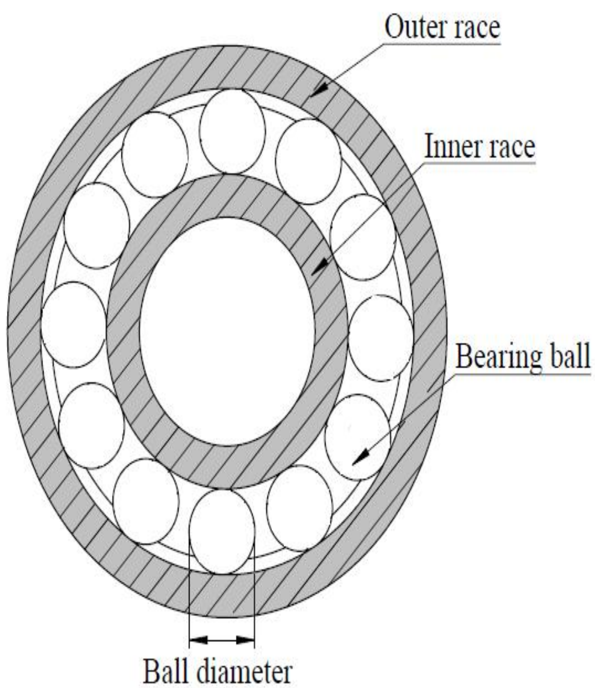


Figure 2.2 Examples of impeller for the three types of Rotodynamic pumps


Rotation
Radial component of flow
Actual direction of flow
Tangential component of flow
Vane
Eye


Outer race
Inner race
Bearing ball
Ball diameter

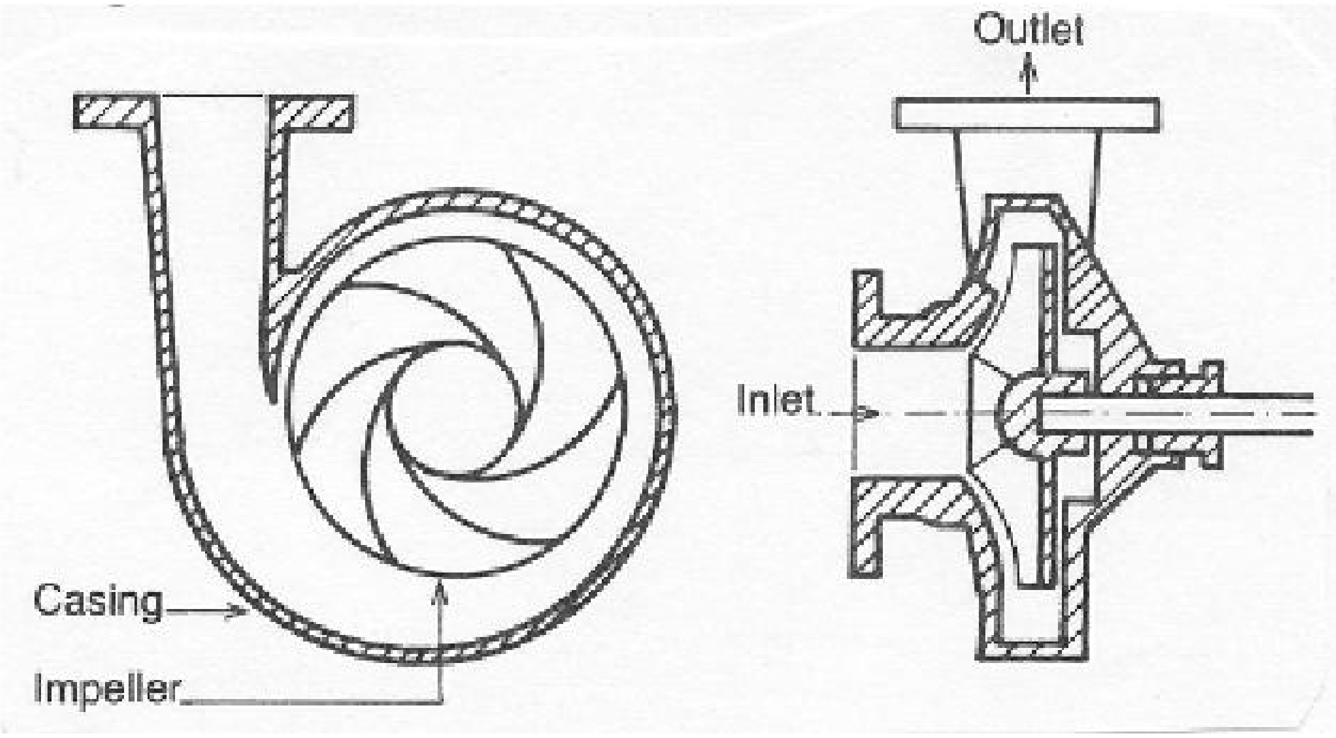


Figure 2.5 Centrifugal pump

2.3.2 Classification of centrifugal pumps

Centrifugal pumps can be further classified based on their design and application:

1. **Single-stage Centrifugal Pumps**: These pumps have a single impeller and are used for low to moderate flow rates and pressure requirements. They are commonly found in residential and small commercial applications.
2. **Multistage Centrifugal Pumps**: These pumps consist of multiple impellers stacked in series. They are used for higher pressures and can handle larger flow rates. Multistage pumps are often utilized in industrial settings, high-rise buildings, and water treatment plants.
3. **Vertical Centrifugal Pumps**: These pumps have a vertical shaft orientation. They are suitable for applications where space is limited, such as sump pumps or deep well pumps. Vertical pumps are commonly used in mining, oil and gas, and wastewater treatment industries.

4. **Horizontal Centrifugal Pumps**: These pumps have a horizontal shaft orientation. They are widely used in industrial and commercial applications, including water supply systems, HVAC (heating, ventilation, and air conditioning), and agricultural irrigation.
5. **End-Suction Centrifugal Pumps**: These pumps have the suction and discharge ports located at the same end of the pump, facilitating easy installation and maintenance. They are commonly used in HVAC systems, water circulation, and irrigation.
6. **Split-Case Centrifugal Pumps**: Split-case pumps have a horizontally split casing, allowing easy access to the internal components for maintenance or repairs. They are used in large-scale water supply systems, municipal water distribution, and industrial processes.
7. **Submersible Centrifugal Pumps**: Submersible pumps are designed to be submerged in the fluid being pumped. They are commonly used in wells, boreholes, and water bodies for applications such as groundwater extraction, drainage, and sewage pumping.
8. **Self-Priming Centrifugal Pumps**: Self-priming pumps can create a vacuum and prime themselves, eliminating the need for external priming. They are often used in applications where the pump may need to handle air or gas entrained in the fluid, such as dewatering, construction, and marine applications.

2.3.4 Performance parameters

The key performance parameters of centrifugal pumps are capacity, head, BHP (Brake horse power), BEP (Best efficiency point) and specific speed. The pump curves provide the operating window within which these parameters can be varied for satisfactory pump operation. The following parameters or terms are discussed in detail in this section.

Capacity

Capacity means the flow rate with which liquid is moved or pushed by the pump to the desired point in the process. It is commonly measured in either gallons per minute (gpm) or cubic meters per hour (m3/hr). The capacity usually changes with the changes in operation of the process. For example, a boiler feed pump is an application that needs a constant pressure with varying capacities to meet a changing steam demand. The capacity depends on a number of factors like:

- Process liquid characteristics i.e. density, viscosity
- Size of the pump and its inlet and outlet sections
- Impeller size
- Impeller rotational speed RPM
- Size and shape of cavities between the vanes
- Pump suction and discharge temperature and pressure conditions

As liquids are essentially incompressible, the capacity is directly related with the velocity of flow in the suction pipe. This relationship is as follows:

$$\mathbf{Q = 449*V*A}$$

Where

Q = Capacity in gallons per m (GPM)

V = Velocity of flow in ft/sec

A = Area of pipe in ft^2

Head

The pressure at any point in a liquid can be thought of as being caused by a vertical column of the liquid due to its weight. The height of this column is called the static head and is expressed in terms of feet of liquid. The static head corresponding to any specific pressure is dependent upon the weight of the liquid according to the following formula:

$$\textbf{Head (ft)} = \frac{\textbf{Pressure (psi)} * \textbf{2.31}}{\textbf{Specific gravity}}$$

Water has a specific gravity of 1.0.

Static suction head (hS) : Head resulting from elevation of the liquid relative to the pump center line. If the liquid level is above pump centerline, **hS** is positive. If the liquid level is below pump centerline, **hS** is negative. Negative **hS** condition is commonly denoted as a "suction lift" condition

Static discharge head (hd): It is the vertical distance in feet between the pump centerline and the point of free discharge or the surface of the liquid in the discharge tank.

Friction head (hf): The head required to overcome the resistance to flow in the pipe and fittings. It is dependent upon the size, condition and type of pipe, number and type of pipe fittings, flow rate, and nature of the liquid.

Vapor pressure head (hvp): Vapor pressure is the pressure at which a liquid and its vapor co-exist in equilibrium at a given temperature. The vapor pressure of liquid can be obtained from vapor pressure tables. When the vapor pressure is converted to head, it is referred to as vapor pressure head, **hvp**. The value of **hvp** of a liquid increases with the rising temperature and in effect, opposes the pressure on the liquid surface, the positive force that tends to cause liquid flow into the pump suction i.e. it reduces the suction pressure head.

Pressure head (hp): Pressure Head must be considered when a pumping system either begins or terminates in a tank which is under some pressure other than atmospheric. The pressure in such a tank must first be converted to feet of liquid. Denoted as **hp**, pressure head refers to absolute pressure on the surface of the liquid reservoir supplying the pump suction, converted to feet of head. If the system is open, **hp** equals atmospheric pressure head.

Velocity head (hv): Refers to the energy of a liquid as a result of its motion at some velocity '**v**'. It is the equivalent head in feet through which the water would have to fall to acquire the same velocity, or in other words, the head necessary to accelerate the water. The velocity head is usually insignificant and can be ignored in most high head systems. However, it can be a large factor and must be considered in low head systems.

Total suction head (HS): The suction reservoir pressure head **(hpS)** plus the static suction head (**hS**) plus the velocity head at the pump suction flange (hVS) minus the friction head in the suction line (**hfS**).

HS = hpS + hS + hvS – hfS

The total suction head is the reading of the gauge on the suction flange, converted to feet of liquid.

Total discharge head **(Hd)**: The discharge reservoir pressure head (**hpd**) plus static discharge head (**hd**) plus the velocity head at the pump discharge flange (**hvd**) plus the total friction head in the discharge line (**hfd**).

Hd= hpd + hd + hvd + hfd

The total discharge head is the reading of a gauge at the discharge flange, converted to feet of liquid.

Total Differential Head (HT): It is the total discharge head minus the total suction head

HT = Hd + HS (with a suction lift)

HT = Hd - HS (with a suction head)

NPSH (Net Positive Suction Head**)**

The Net Positive Suction Head (NPSH) is the total head at the suction flange of the pump less the vapor pressure converted to fluid column height of the liquid. It is a function of the pump design.

Power and Efficiency

Brake Horse Power (BHP)

The work performed by a pump is a function of the total head and the weight of the liquid pumped in a given time period.

Pump input or brake horsepower (BHP) is the actual horsepower delivered to the pump shaft.

Pump output or hydraulic or water horsepower (WHP) is the liquid horsepower delivered by the pump.

These two terms are defined by the following formulas.

$$\textbf{BHP} = \frac{Q * H_T * Sp.Gr.}{3960 * Eff}$$

Where

Q = Capacity in gallons per minute (GPM).

H_T = Total Differential Head (ft)

Sp.Gr. = Specific Gravity

Eff = Pump Efficiency, %

$$\textbf{WHP} = \frac{Q * H_T * Sp.Gr.}{3960}$$

Where

Q = Capacity in gallons per minute (GPM).

H_T = Total Differential Head (ft)

Sp.Gr. = Specific Gravity

The constant 3960 is obtained by dividing the number or foot-pounds for one horsepower (33,000) by the weight of one gallon of water (8.33 pounds).

Therefore the pump efficiency is the ratio of these two values.

$$\textbf{Pump Efficiency (Eff)} = \frac{WHP}{BHP}$$

Specific Speed

Specific speed as a measure of the geometric similarity of pumps Specific speed (Ns) is a non-dimensional design index that identifies the geometric similarity of pumps. It is used to classify pump impellers as to their type and proportions. Pumps of the same Ns but of different size are considered to be geometrically similar, one pump being a size- factor of the other.

The following formula is used to determine specific speed:

$$N_S = \frac{N * Q^{0.5}}{H^{0.75}}$$

Where

Q = Capacity at best efficiency point (BEP) at maximum impeller diameter, GPM

H = Head per stage at BEP at maximum impeller diameter, ft

N = pump speed, RPM

Centrifugal pumps are the ultimate in simplicity. In general there are two basic requirements that have to be met at all the times for a trouble free operation and longer service life of centrifugal pumps. The **first** requirement is that no cavitation of the pump occurs throughout the broad operating range and the **second** requirement is that a certain minimum continuous flow is always maintained during operation.

2.3.5 Pump drive/prime mover

Having explained the types, the parts, and the working principle of centrifugal pumps, the prime movers can now briefly be mentioned to complete this section. According to Karrassik (2011), pumps can be driven by electric motors, by steam turbines, by internal combustion engines, by hydraulic turbines, and by gas turbines depending on the application. Since DC electric motors are to be used as the prime mover in this design, the details are presented only for this driver only in this study.

Electric motors can most basically be classified into two: alternating current (AC), and direct current (DC) motors. The mechanism of these electric motors is that, mechanical energy is obtained from electrical energy by means of the magnetic flux linkage of the two magnetic circuits, one of which is in the stator and the other is in the rotor. Due to magnetic flux created between the circuits, a torque is produced resulting in the relative rotation of the motor shaft. The value of the torque is so important such that it determines the output power of the motor when multiplied by the rotational speed.

AC motors operate with 50-60 Hz alternating voltages from public mains. The number of magnetic poles and the sinusoidal frequency of the voltage determine the speed of the motor. DC motors, on the other hand, requires additional storage batteries or a DC generator. AC motors are much more preferred over DC motors due to their ease of availability, excellent reliability, excellent performance characteristics, and ease of replacement.

On the contrary, DC motors are also preferred in some cases. The reason is its variable speed capability by simply changing the voltage. Despite DC motors' not having a long useful life without maintenance, the brushless DC (BLDC) motors began to eliminate this problem with higher reliability, superior performance, and longer life.

However in this project, a DC motor with rechargeable batteries as power source will be used as the prime mover for the pump. This ensures its portability and efficiency for the design purpose.

2.3.6 Hand drill

A hand drill is a handheld, manual tool designed for drilling holes in a variety of materials, including wood, metal, and plastic. It features a handle or grip for comfortable operation and a chuck that securely holds the drill bits in place. Hand drills are compact, portable, and do not rely on external power sources, making them ideal for use in remote areas or situations where access to electricity is limited.

The hand drill plays a crucial role in this project by simply rotating the shaft which is connected to the impeller and automatically works as a centrifugal pump. Hand drills also finds usefulness in various other areas as well. In this, the hand drill serves as the primary power source for driving the pump.

2.3.5 The future of water pumping and distribution

The Centrifugal Pump Augmentation through Hand Drill Power Integration offers a promising future for water pumps and distribution by addressing the existing problems mentioned above. It presents a range of solutions and benefits:

Accessibility and Portability: Hand drills are widely available, portable, and require minimal infrastructure, making them accessible and suitable for deployment in remote or underserved areas.

Cost-Effectiveness: Hand drills are affordable and can be easily procured, reducing the financial burden associated with conventional water pumping systems. This integration significantly lowers the upfront costs of equipment and reduces operational expenses, making it an economically viable solution for communities with limited financial resources.

Versatility and Adaptability: The hand drill-powered integration offers versatility and adaptability for various water pumping applications. It can be used for irrigation, livestock watering, emergency relief operations, and other water-related tasks. Its portability allows for rapid deployment and flexibility in addressing dynamic water supply needs.

Sustainability and Environmental Impact: This integration promotes environmental sustainability by reducing carbon emissions and dependence on fossil fuels. The hand drill-powered approach is eco-friendly, as it harnesses human energy and eliminates the use of electricity or non-renewable energy sources.

Low Maintenance and Ease of Use: Hand drills are mechanically simple and require minimal maintenance. Users can easily maintain and repair the hand drills themselves, reducing the need for specialized technical expertise and costly maintenance services.

2.3.5 Research gap

With this project, we would identify and implement improved technologies and design features that improve the efficiency, durability, compatibility and portability and user friendliness of the pump and make them more reliable and effective for the design purpose.

CHAPTER THREE

DESIGN METHODOLOGY

Throughout the completion of this project, the author had accomplished two majormilestones in conjunction with the project's objectives. They are:

a. Impeller design and modeling.

b. Impeller prototyping and manufacturing.

The sub-methodologies and procedures of each of these major milestones are illustrated in subsequent subsections.

3.1.1. Impeller Design and Modeling

Prior to doing the calculation of designing the impeller, the specifications of the pump were first defined. The definition of pump specifications followed actual parameters on existing standards. The essential information in defining thespecifications of the pump is:

a. Suction Pressure.

b. Discharge Pressure.

c. Design Capacity.

The specification definition of the pump will be further defined by these preceding procedures:

- Selection of Rotating Speed.
- Pump Head and Stages Definition.
- Pump Specific Speed Definition.
- Pump Shutoff Head Definition.
- Development of Pump Characteristics Curve.

Once the pump characteristics curve is developed and essential data is compiled, the impeller design phase commenced. The methodology of impeller design followed the procedures described by Lobanoff V. S. et al., (1992). The theoretical analytical steps adopted in the design of the mini-impeller is as follows; Several parameters to be considered include,

1. Impeller Modelling and Design

   In the modeling phase, the calculated and defined parameters of the impeller were gathered and interpreted. Using appropriate Computer Aided Design (CAD) software, the numerically designed impeller is translated into a virtual three-dimensional model. From this point on this software will be referred to as Autodesk Fusion 360 Mechanical Design Software only

   a. Impeller cross sectional area
   b. Impeller and pipe diameter
2. Shaft diameter
3. Power requirement
4. Energy
5. Total head of pump
6. Speed
7. Torque
8. Pressure
9. Design Temperature
10. Flowrate
11. Kinematic Viscosity
12. Head loss
13. Mass flow rate and
14. Reynolds number

3.1.2. Pump Specifications

Flowrate

In selecting a centrifugal pump, the flowrate Q, is usually of utmost importance, and it is defined as the usable flow (volume of liquid per unit of time) discharged by the pump through its outlet branch, measured in m^3/s or L/s. In this case flow is extracted in minute amount, i.e., 2 L/s since it is designed as mini water pump impeller.

Therefore, flowrate assumed throughout the design process of the mini water pump impeller is 2 L/s

3.2. Impeller Design

3.2.1. Data Acquisition

For this project, the design constants (pressure, volume, temperature) of the pump followed actual water injection module Table 3.1 summarizes the design constants for water pumps for domestic purposes:

Table 3.1: design specifications

Constants	SI Unit
Suction Pressure	5 bar
Discharge Pressure	3 bar
Design Temperature Max/Min	60^0 deg C
Design Flow Rate	50 Liters per Min

In the case of this project, the water injected in Field A is deoxygenated seawater. The specific gravity of seawater for this application is.

SG = 1.022

3.2.2. Selection of Rotating Speed

This selection will enable the usage of a DC electric motor and eliminates the need to include speed converter components (belt drive, chain drive, gears, etc.) inside the drive arrangements. The rotating speed is selected to be 3000 rpm (50 Hz), which is part of the information gotten from the Gespasa DC pump catalogue. Although this selection is arbitrary, the selection of speeds ranging from 2000 to 4000 rpm is essential in order to match the most efficient pump with respect to its specific speed, N_s, which will be described later.

3.2.3. Pump Head and Stages

The pump head for this application is defined as:
H = 2.31 (Change in Pressure / Specific gravity of fresh water)

Therefore H = P2 – P1 / SG

Where,

P2 = Suction Pressure = 5 bar

P1 = Discharge Pressure = 3 bar

SG = specific Gravity of Fresh Water = 1

Therefore, H = 4.62m.

Which is approximately, 4.6m

The pump head computed signifies the height to which the fluid (water) can be lifted, I.E, any height beyond 4.6m might hinder the overall efficiency of the pump.

In order to have specific speed N_s inside a desired range, the head must be in the range of 200to 800 ft, which will incorporate multistage pump concept for this design. The author has chosen the implementation of seven stages (seven impellers) horizontal pump, to meet the desired pressure design. The seven stages will be designed to carry same number of head, which will leave each stage with:

From this point onwards, calculations will be focused on developing the impeller for the first stage of the pump. The word "pump" will refer to the first stage and first stage impeller of the pump, where applicable.

3.2.4. Pump Specific Speed

The specific speed for this pump stage (or impeller) will be:

$$Ns = n\sqrt{Q}/H^{\frac{3}{4}}$$

Where H = Head of pump

Q = capacity in GPM = 13.2gpm

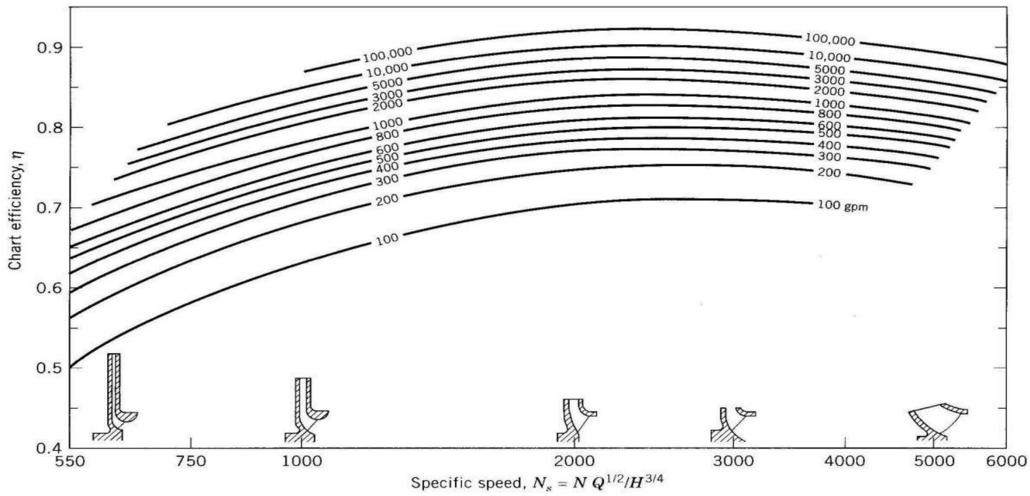
N = Impeller Speed in rpm = 3000rpm

Ns = Specific Speed

Ns =3470

From Chart of Efficiency of Pumps versus Specific Speed by Tuzson J., (2000) [12], the correlative pump efficiency with respect to N_s = 3470and *Q = 13.2 GPM* is: $\eta = 35\ \%$.

The 35% efficiency obtained from the figure 3.4 below shows that it's a pump to be used on a small application due to its DC power source as compared to an AC powered pump which possible have a



higher pumping efficiency, i.e., pumping fluid at a higher speed, head and torque.

Figure 3.1: Pump Efficiency chart with respect to Specific speed

3.2.5. Pump Shut-Off Head

This pump will be designed to have continuously rising characteristics, in which the head (pressure ratio) rises continuously as the capacity of the pump is decreased. The selection of shut-off head and characteristics is important for the design to commence. It is typical for many pumps to have shut-off head value from BEP as 20 %, thus this pump will follow that value.

For this project, as the optimum (BEP) value of head at Q = 50LPM is H = 4.6m, for 20% shut-off from BEP, it is assumed theoretically that its head at Q = 0 GPM is:

$H_{0\ GPM} = 1.2 \times 4.6m$

$H_{0\ GPM} = 5.52m$

3.2.6. Calculation of Impeller Diameter

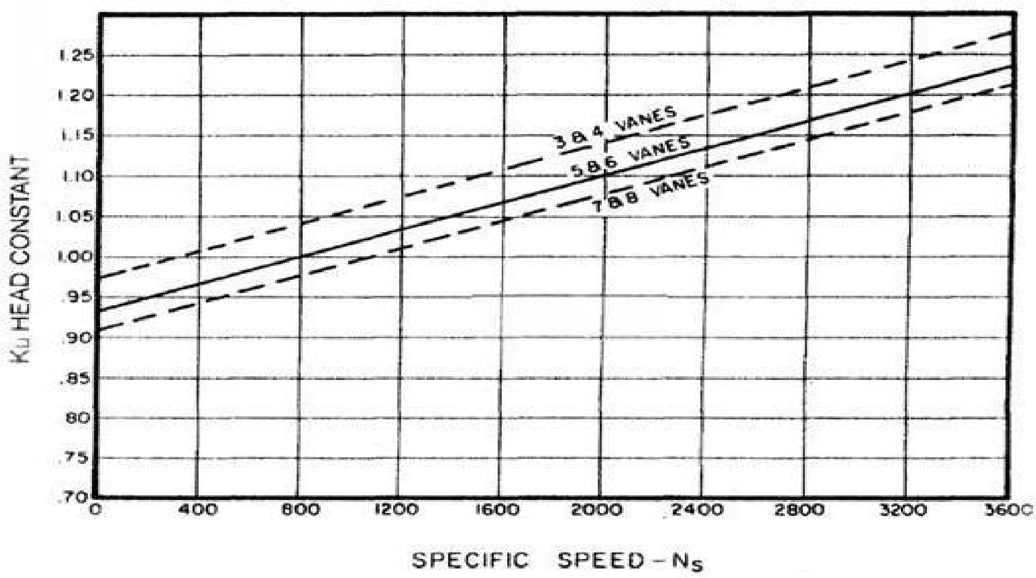


Figure 3.2: Head Constant Graph

Here we assume the minimum number of vanes as five (5) for this application since is designed as a mini pump, and then correlate the calculated specific speed of 3470 to obtain Ku from the Head Constant Graph.

From Head Constant Graph, the corresponding value of Head constant K_u, for this impeller

$K_u = 1.23$

The impeller diameter, D_2, is therefore:

D2 = 1840 (Ku) (√H) /n

Where Ku = Head Constant

H = Pump Head

n = Specific Speed

D2 = 13.90cm = 139mm

Impeller eye diameter, D1

$D_1/D_2 = 0.45$

$D_1 = 0.5*D2 = 0.45*139 = 62.55mm$

The impeller eye width and impeller outer width can be obtained thus;

$b_1 =1.5D_1*D1/4$

$b_1 =1.5 * 0.06255/4$

$b_1 =0.02346$ m = 23.46mm

$b_2 = b_1*D_1/D_2$

And recall that

$D_1/D_2 = 0.45$

Therefore, $b_2 = 0.45 * 0.02346m = 0.010557m = 10.56mm$

Cut water diameter

A minimum gap must be kept in between the impeller and the volute lip to prevent it from noise, pulsation, and vibration and which is called as cut water diameter (D3).

$D_3=D_2 *(\delta + 1)$

And, $\delta= 0.07$

$D_3= 139 *(0.07 + 1) = 148.73mm$

Volute width,

$b_3 = 1.25\ b_1$

$b_3 = 1.25 * 23.46mm = 29.325mm$

3.2.7. Calculation of Impeller Width

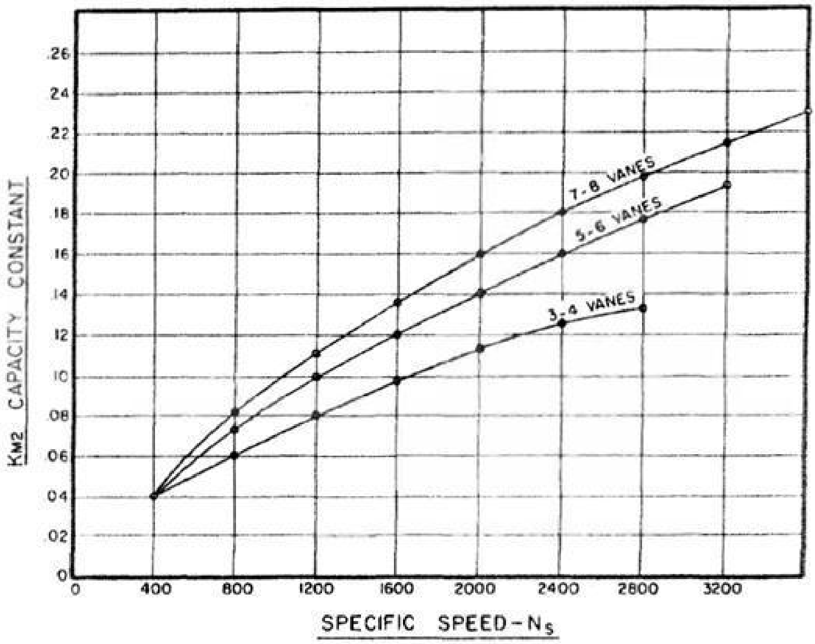


Figure 3.3: Capacity Constant Graph

Since the specific speed from the initial computed analysis was 3470, From K_{M2} Capacity Constant Graph (Figure 3.2), the corresponding value of K_{M2} is: 0.20.

Therefore, $C_{M2} = (K_{M2})\sqrt{2gH}$

Where:

K_{M2} = Capacity Constant

C_{M2} = Radial Velocity at Impeller Discharge

G = gravitational acceleration constant,

H = Pump Head

$C_{M2} = 0.20*\sqrt{2} * 9.81 * 4.62$

C_{M2} =1.90 m/sec

3.2.7. Shaft Sizing

To determine shaft diameter for this application, it expedient to first select the suitable material for freshwater pumping purposes. Based on material selection chart provided by gespasa DC Pumps, the suitable and economical material would be alloy 2205 duplex stainless steel. This material combines high strength and high corrosion resistance to produce high corrosion fatigue strength, and therefore can be subjected to aggressively corrosive environment such as handling freshwater. Alloy steels exhibits mechanical properties superior to that of ordinary carbon steel with respect to hardenability, toughness, orreduction of environmental degradation under specific service conditions. As suggested by Karassik et al., typical torsional stress for alloy steel is:

τ = 55 MPa which is equivalent to (8,000 psi);

The pump is going to be built with only one shaft, that is. Thus, the procedure of sizing the shaft would have to consider the power developed by just one stag. As specified before, the one stage, will be carrying the same amount of head, with the total head adds up to 4.6m. efficiency of 35%, the power required by the pump at BEP would be:

P = Q.H.SG/3960.n

Where Q = Volumetric flowrate

H = Pump Head

SG = Specific gravity of fresh water = 1

n = pump efficiency

Therefore, P = 0.17kw

The power requirement obtained above signifies the small amount of power needed to run the DC motor and the impeller.

For the purpose of optimum power requirements, the base point of the selection will be on the specifications obtained from the gespasa VDC pump catalogue, i.e., 12V battery at 18A.

Considering the voltage and current requirement of the gespasa VDC pump, amount to a power of about 0.216KW, which is found to be greater the theoretical power requirement of 0.17KW.

Therefore, a 12V, 18A battery is selected to drive the DC motor and as well, the impeller (5 vanes).

The pump will not be allowed to operate to the right of the BEP. That is, the BEP is the maximum power that is going to be supplied into the pump. However, to cater for unexpected power leap by the driver, failure of equipment's instrumentation and control system, or any undesirable operating conditions by the injection fluid, a factor of safety of 1.5 is incorporated into this value for the shaft sizing. The maximum power for the pump would now be:

Therefore, Pmax = 0.17 x 1.5

Pmax = 0.255KW

The procedures of sizing the shaft are as follows:

Recall that P = Tw

$$J = {\pi \cdot D^4}/_{32}$$

Where

T = Torque

W = angular velocity = 314rad/s

T = P/W

T = 170/314

T = 0.54Nm

Solving for D:

D = $(16P/\tau w\pi)^{\frac{1}{3}}$

D= 17.2cm = 172mm

Driver for any mechanical devices would be operated at variable speeds and powers according to operation requirements. These speeds / powers may be less than the designed values for driver. The power reduction as specified by Waukesha Engines ranges from 0.67 to 0.83 of the maximum power. Thus, any leap of power would be a factor of 1.2 to 1.5.

3.2.8. Key Sizing

According to ANSI-B17.1, the general practice is to use key size of height (W) of one-fourth of the shaft diameter. We know D = 172mm

Therefore, W = 172/4

W = 43m

For the design of impeller key, the author selected alloy 316 austenitic stainless steel for the material. The reasons why this material is used are:

i. Like the shaft material, stainless steel 316 provides extraordinary range of corrosion resistance.
ii. The impeller key is going to be replaced more frequently during maintenance and services rather than the impellers and shaft itself, thus stainless steel 316 is the better choice than alloy 2205 based on:
    a. Most used corrosion resistant alloy (widely available).
    b. Falls in moderately price range.

3.3. Materials

3.3.1. Key Properties

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M.

Similar but not necessarily identical properties are specified for other productssuch as pipe and bar

in their respective specifications.

3.3.2. Composition

Typical compositional ranges for grade 304 stainless steels are given in table 1.

Table 3.2 Composition ranges for 304 grade stainless steel

Grade		C	Mn	Si	P	S	Cr	Mo	Ni	N
304	min.	-	-	-	-	-	18.0	-	8.0	-
	max.	0.08	2.0	0.75	0.045	0.030	20.0		10.5	0.10
304L	min.	-	-	-	-	-	18.0	-	8.0	-
	max.	0.030	2.0	0.75	0.045	0.030	20.0		12.0	0.10
304H	min.	0.04	-	-	-	-	18.0	-	8.0	-
	max.	0.10	2.0	0.75	0.045	0.030	20.0		10.5	

3.3.2. Mechanical Properties

Typical mechanical properties for grade 304 stainless steels are given in table 2.

Table 3.3. Mechanical properties of 304 grade stainless steel

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness	
				Rockwell B (HR B) max	Brinell (HB) max
304	515	205	40	92	201
304L	485	170	40	92	201
304H	515	205	40	92	201
304H also has a requirement for a grain size of ASTM No 7 or coarser.					

3.3.3. Physical Properties

Typical physical properties for annealed grade 304 stainless steels are given in table 3.

Table 3.4. Physical properties of 304 grade stainless steel in the annealed condition

Grade	Density (kg/m^3)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (mm/m/°C)			Thermal Conductivity (W/m.K)		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nW.m)
			0-100°C	0-315°C	0-538°C	at 100°C	at 500°C		
304/L/H	8000	193	17.2	17.8	18.4	16.2	21.5	500	720

3.3.4. Grade Specification Comparison

Approximate grade comparisons for 304 stainless steels are given in table 4.

Table 3.5. Grade specifications for 304 grade stainless steel

Grade	UNS No	Old British		Euronorm		Swedish	Japanese
		BS	En	No	Name	SS	JIS
304	S30400	304S31	58E	1.4301	X5CrNi18-10	2332	SUS 304
304L	S30403	304S11	-	1.4306	X2CrNi19-11	2352	SUS 304L
304H	S30409	304S51	-	1.4948	X6CrNi18-11	-	-
These comparisons are approximate only. The list is intended as a comparison of functionally similar materials. **not** as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.							

3.3.5. Possible Alternative Grades

Possible alternative grades to grade 304 stainless steels are given in table 5.

Table 3.6. Possible alternative grades to 304 grade stainless steel

Grade	Why it might be chosen instead of 304
301L	A higher work hardening rate grade is required for certain roll formed or stretch formed components.
302HQ	Lower work hardening rate is needed for cold forging of screws, bolts and rivets.
303	Higher machinability needed, and the lower corrosion resistance, formability and weldability are. acceptable.
316	Higher resistance to pitting and crevice corrosion is required, in chloride environments

321	Better resistance to temperatures of around 600-900°C is needed…321 has higher hot strength.
3CR12	A lower cost is required, and the reduced corrosion resistance and resulting discolouration are. acceptable.
430	A lower cost is required, and the reduced corrosion resistance and fabrication characteristics are. acceptable.

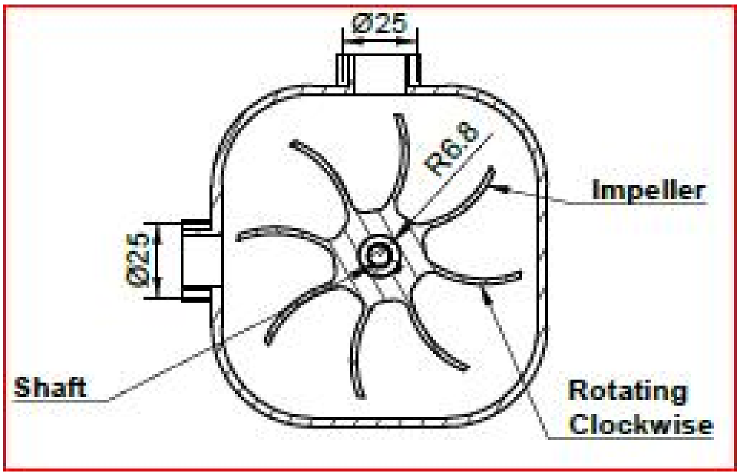
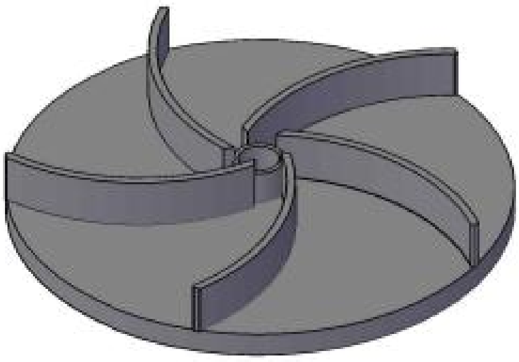
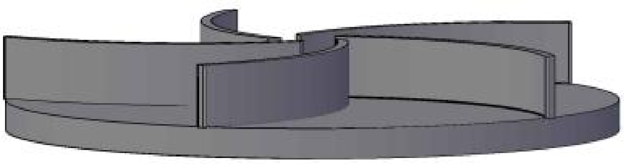


FIGURE 3.4 Front view of the Impeller





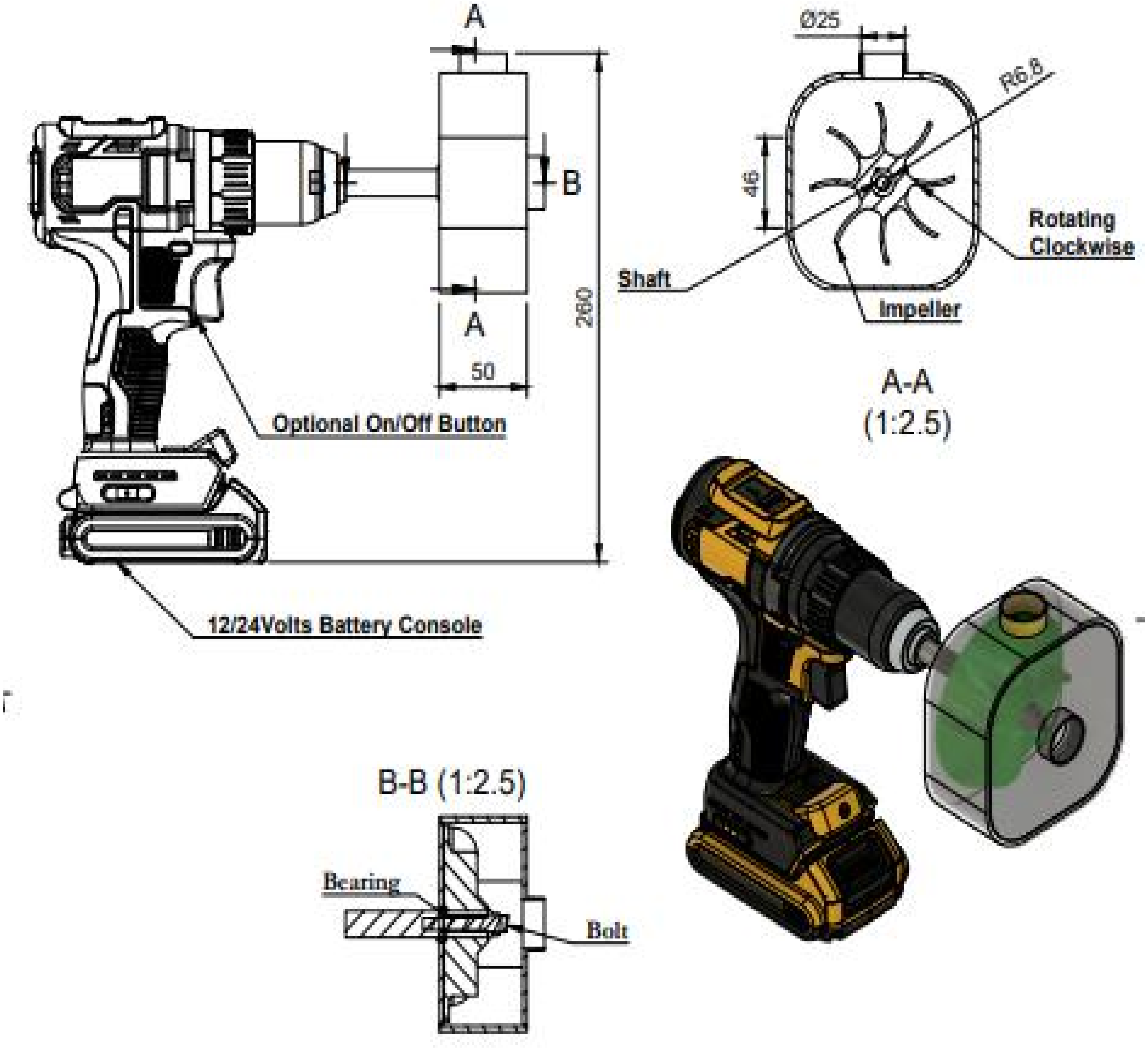


Fig 3.5– orthographic drawing of pump

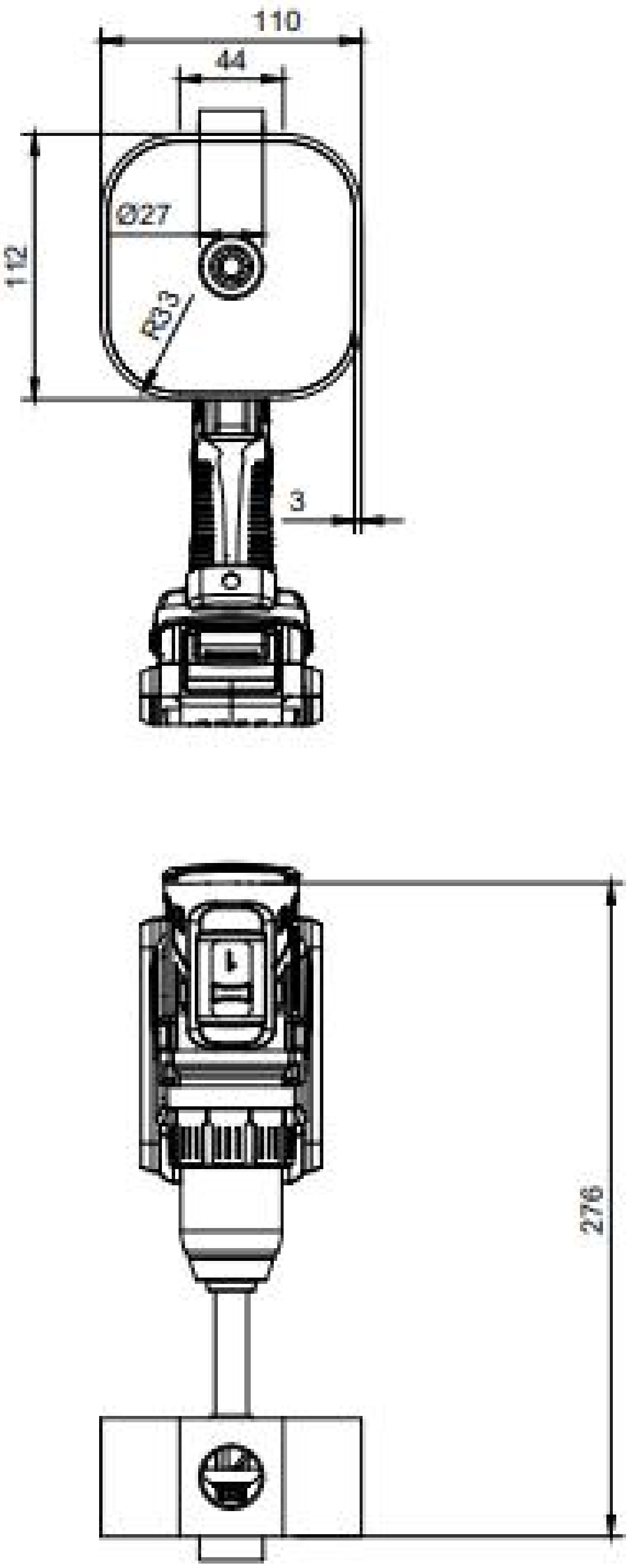


FIGURE 3.6 Front view of the Pump

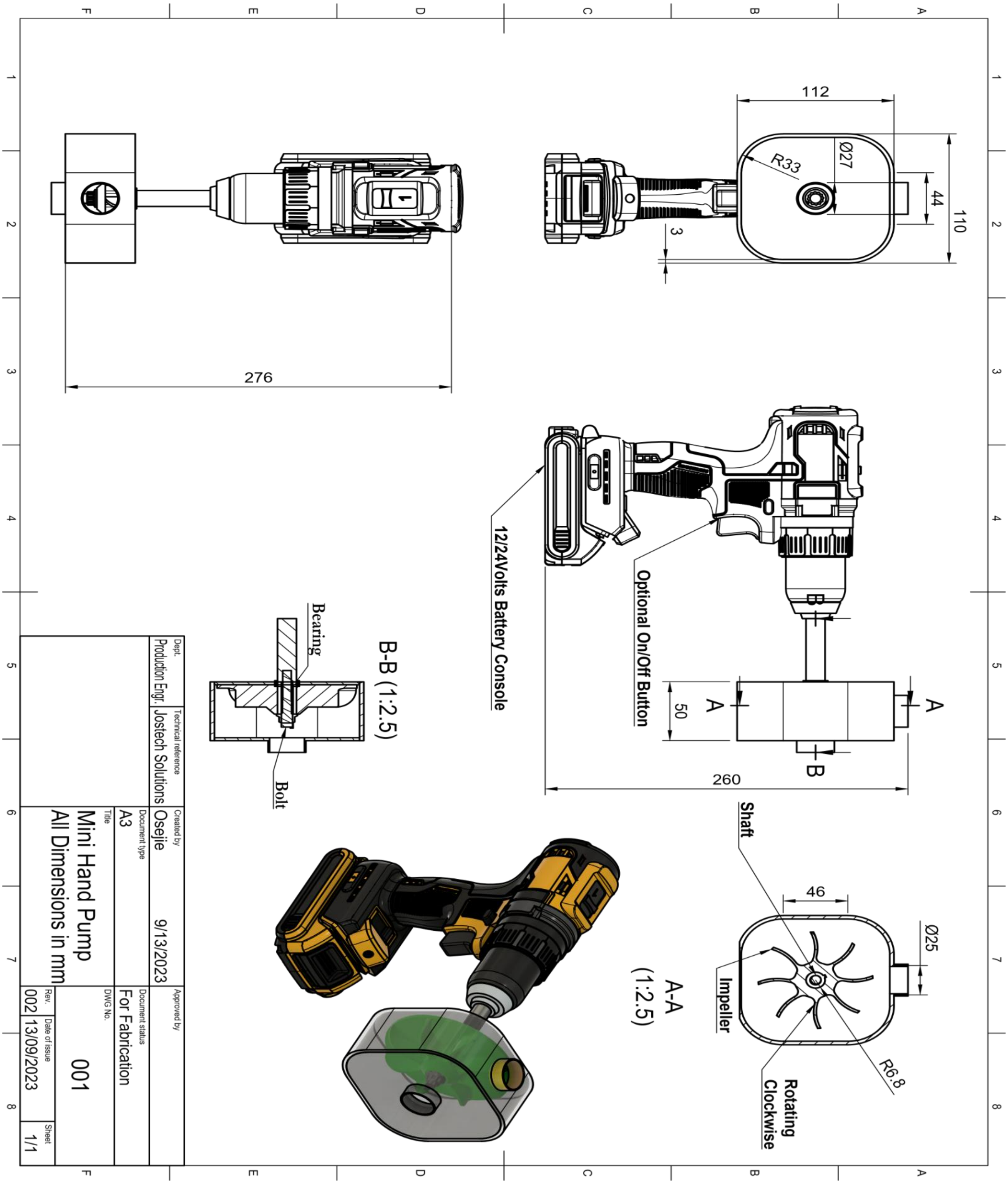


FIGURE 3.7 Orthographic view of the pump

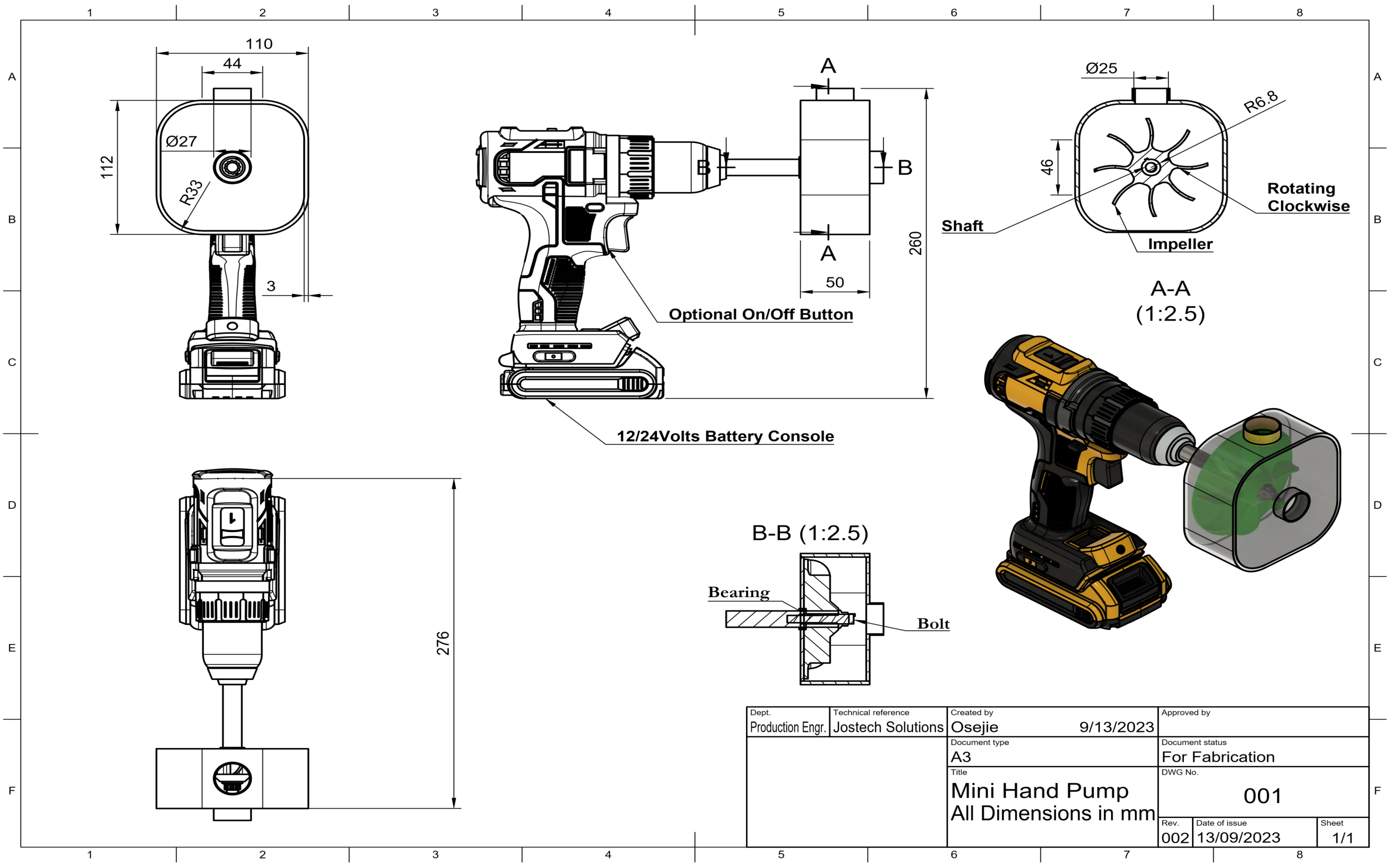


FIGURE 3.8 Orthographic view of the pump

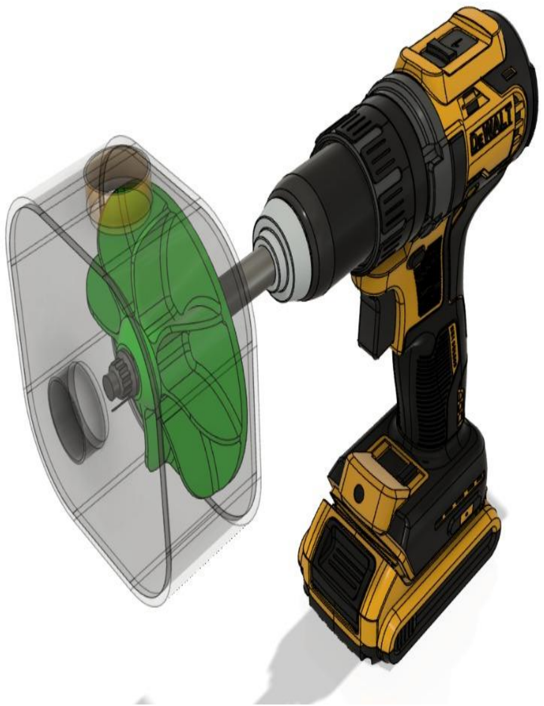


FIGURE 3.9 3D view of the pump

CHAPTER FOUR

RESULT AND ANALYSIS

Fabrication of Impeller and Associated Casing

Fabrication may be defined as a manufacturing process in which an item is made from semi-finished materials instead of being assembled from ready-made components or parts. The parts of the pump such as impeller, casing, outlet, inlet is fabricated using the conventional subtractive manufacturing equipment, which is hand drilling machine, center lathe, angle grinder, welding machines, etc. The combination of all subtractive manufacturing approaches produced the three-dimensional Solid parts all assembled. In this machine, the material is joined or solidified under the shielded metal arc welding process, especially for the impeller and its sheet metal casing. Parts which are designed in Autodesk fusion 360 is converted into a pdf drawing format, and this input is given to the fabricator under close supervision.

Validation of Baseline Model

The discharge obtained for the centrifugal pump modeled and fabricated as mentioned above is compared with the discharge performance available in other existing literature. This performance is shown in figure 4.1. below which graphically detailed the comparison to the trend attained with the mini pump used in this work is almost like that of the trend in other literature. The pump used in this work falls in the category of the mini pump, Obliviously, the discharge values obtained are comparatively smaller. However, the trend of the graph remains the same as that of the macro pump used by John et al. Therefore, the results obtained in this work canbe considered as validated.

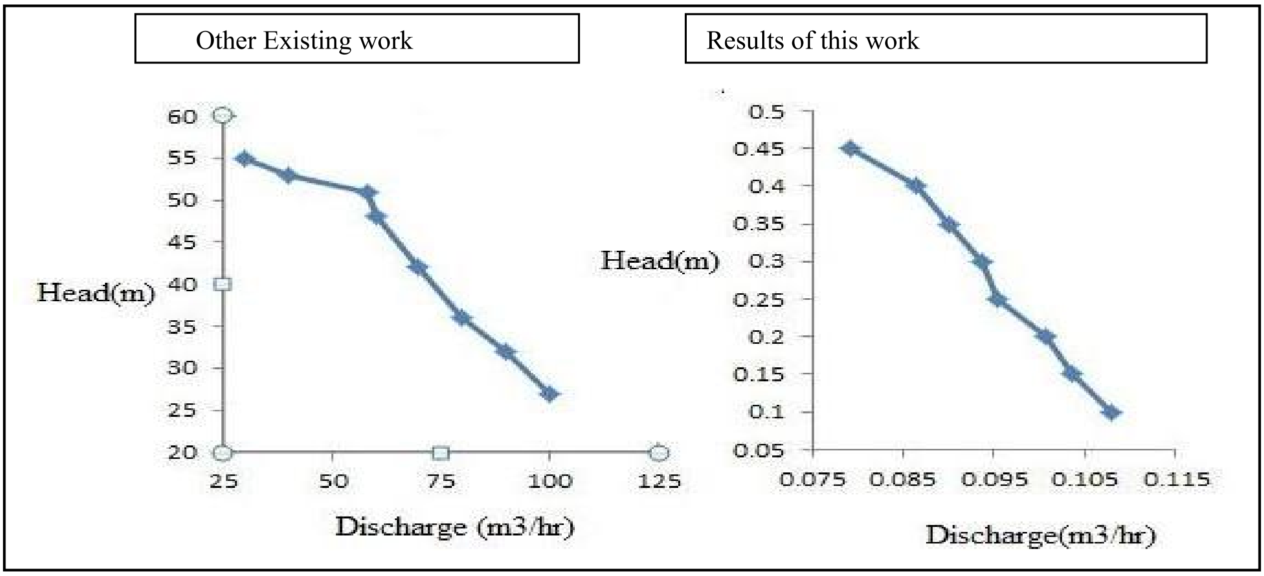


Figure 4.1: Obtained Results Vs Results from Existing work.

Performance Analysis of The Pump

The experimentation done on the centrifugal pump is discussed in this section. The parameters such as discharge, Head, Voltage, and RPM of the impeller are studied under varying conditions and the experimental results obtained are plotted. When the Head is varied from 10 cm to 50 cm, the values of discharge (ml/min) is observed to be decreasing from 20 l/min to 70 l/min. Figure 4.2 shows this trend obtained with the fabricated pump. When the input voltage supplied to the motor used for driving the pump is changed from 12VDC to 24 VDC, the head is observed to increase as shown below.

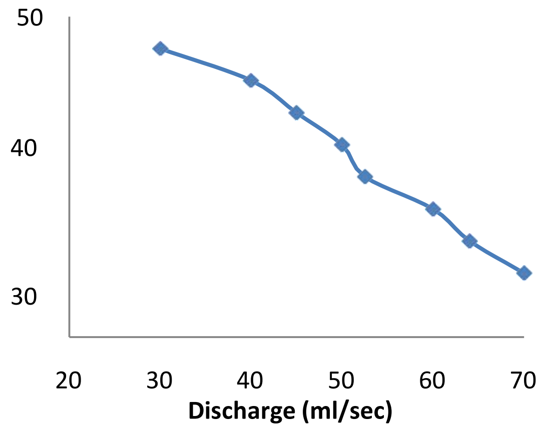


Figure 4.2: Graph of Head against Flowrate (Discharge)

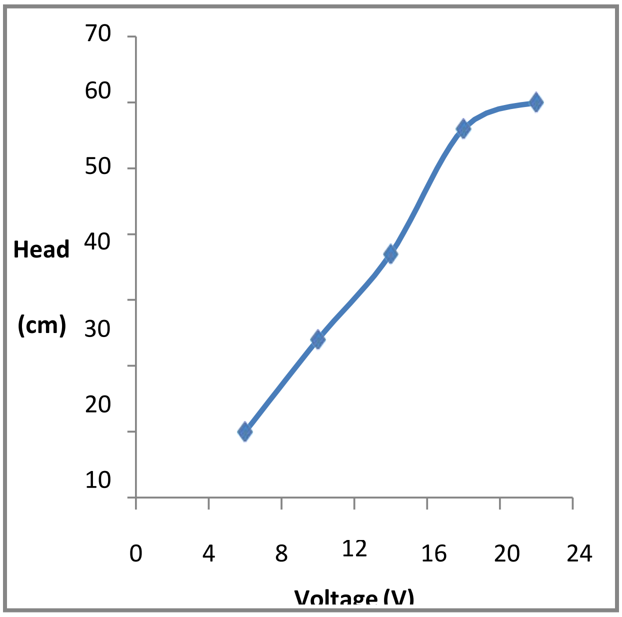


Figure 4.3: Graph of Head against Direct Current

Numerical Results for Impeller design

The procedures to numerically design the impeller followed the steps designed earlier in the methodology. In order to design the impeller, raw data(design constants such as flow rate, pressure, etc.), were plugged in into a series of equations and established constant graphs. The results of the procedures are summarized in the table below:

Table 4.1 numerical results for impeller design

Procedure	Parameters	Results
1	**Vane number (z)**	5
2	**Discharge Angle (β)**	20 degreee
3	**Impeller diameter**	60/0 degC
4	**Impeller width**	50 Liters per Min
5	**Eye diameter**	23.46mm

Material Bills

The table below shows the average cost of all the materials used for the construction or fabrication of the centrifugal pumping system incorporating an electric motor. The method of manufacture for each component used was also shown below

Table4.2: materials cost

Item Number	Description of material	Source material used	quantity	Methods of manufacture	Estimated cost(N)
1.	shaft	Mild steel	1	purchased	2000
2.	Impeller casing	Stainless steel	1	Weld and fabrication	2000
3.	impeller	Mild steel		Weld and fabricate	5000
4.	gasket	rubber			1000
5.	Bolts and nuts	Mild steel			
6.	Electric motor (rechargeable hand drill)	Nil	1	purchased	45,000
7.	Suction hose	Rubber		purchased	1000
8.	Discharge outlet	Iron and rubber		purchased	500
9.	Electric wire	copper			1000
10.					
	total				57500

Labour cost

Table 4.3: Cost of labour and services

S/N	Description of service	Estimated cost (N)
1	Transportation	2000
2	Fabrication / welding	20000
3	Total cost	22000

Manufacturing cost

The aggregate cost spent in manufacturing the portable centrifugal pump is obtained by aggregating the cost of materials and the labour cost as listed in table 4.2 and 4.3 respectively

Total cost of pump = 79000

Testing

The performance of the pump and its operating parameters such as head , capacity and efficiency was measured and investigated during the operation of the pump. This investigation was carried out at the university of Benin workshop using measured filtered water in containers.

The time taken for the pump to empty each container was recorded against the head of water pumped.

The results are tabulated

Head achieved

Quantity discharged

Performance efficiency

Pump Operating procedures

Cherkassky (1969) and Igor et al (1960), both agree that all centrifugal pumps must be filled with the liquid before starting. For satisfactory operations the following industry practices for pump construction and operation have been adopted, before starting the pumping unit.

Therefore, the following

Maintenance

According to Agbabune (2002), maintenance is defined as any activity carried out on an equipment to keep it in a condition necessary for its best performance. Maintenance activities therefore can be classified into two broad categories:

1. Break down maintenance: defined as maintenance activities carried out on equipment in order to return it to its original designed operating condition.
2. Preventive Maintenance: defined as maintenance activities intended to prevent equipment failure, for example regular vibration and temperature monitoring. The process is carried out to identify seemingly failing parts before breakdown eventually occurs. Remedial actions usually taken could be replacement of parts, greasing, cleaning, etc. (Agbabune 2002).

   The maintenance of the centrifugal pump is hereby listed thus:

   1. The Bearings: the bearings should be inspected frequently and greased if found or noisy. Bearings are to be replaced after about 8000 running hours, or whenever shaft is found to start wobbling or if it stiffens.
   2. Casing gasket : the gaskets are to prevent leakage and ensure an air tight vacuum within the pump during operation. It should be replaced if broken or found to be worn out when it cannot hold vacuum anymore. However, gaskets are recommended for replacement during inspections or major repair work on the pump.
   3. Pump and motor bolts should be frequently checked also to ensiure tightness.

CHAPTER FIVE

CONCLUSION AND RECOMENDATION

In concluding this project, it is expected that the simple principle of operation of a centrifugal pump applied in the design of a mini centrifugal pump incorporating a portable hand drill as the prime mover to rotate an impeller can raise water through an appreciable height of 5m. the calculations showed a 30% efficiency with a flow rate of 50l/min and can be applied for low volume service purposes.

The mini-pumps are a good choice for low volupe discharge needed in applications like microfluidics, medicine, and other low volume service purpose among others. The analysis conducted for this project's analysis led to the following conclusions.

1. It is discovered that when pumping head increases, the centrifugal pump's discharge decreases.

2. It is discovered that as pumping head increases, so does the voltage needed to drive the centrifugal pump.

3. It was discovered that the mini-pump employed in this investigation performed similarly to a typical macro pump in terms of discharge.

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