ADVANCEMENTS IN CENTRIFUGAL WATER PUMP DESIGN: A COMPOSITE MATERIAL APPROACH

BY

AKPOBI URIOGHENE ASHLEY - ENG1805353

OBOSI IKEM DAVID - ENG1805362

IBADIN MESHACH EIDENEHI - ENG1805388

CHILOTAM EROMOSE JEFFREY - ENG1805360

A REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE

BACHELORS OF ENGINEERING DEGREE (B. ENG.) IN MECHANICAL ENGINEERING OF THE UNIVERSITY OF BENIN

DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY OF BENIN

BENIN CITY

APRIL, 2024

ADVANCEMENTS IN CENTRIFUGAL WATER PUMP DESIGN: A COMPOSITE MATERIAL APPROACH

BY

AKPOBI URIOGHENE ASHLEY - ENG1805353

OBOSI IKEM DAVID - ENG1805362

IBADIN MESHACH EIDENEHI - ENG1805388

CHILOTAM EROMOSE JEFFREY - ENG1805360

A REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE

BACHELORS OF ENGINEERING DEGREE (B. ENG.) IN MECHANICAL ENGINEERING OF THE UNIVERSITY OF BENIN

DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY OF BENIN

BENIN CITY

APRIL, 2024

CERTIFICATION

This is to certify that this research work on the “Advancements in Centrifugal Water Pump Design: A Composite Material Approach” was carried out by

ENG1805353
ENG1805362
ENG1805388
ENG1805360
Of the Department of Mechanical Engineering, University of Benin, Benin City.

Engr. Odudu Thomas Ebu-Nkamaodo *Date*

Supervisor

Prof. Sajere *Date*

Head of Department

DEDICATION

This project is dedicated to God Almighty, my family, and my friends for their emotional and financial support.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to God for his mercies and guidance throughout this project. I also want to thank my Supervisor ENGR. Odudu Thomas Ebu-Nkamaodo for his advice and counsel.

Appreciation is greatly expressed to my parents, Dr. Francis Inegbedion, Dr. Voke and all other staff and members of the Engineering Workshop that helped in one way or the other to ensure the successful completion of this project.

ABSTRACT

In the ever-evolving landscape of fluid mechanics and engineering, the integration of composite materials has propelled centrifugal water pump design to new heights. This abstract delves into the groundbreaking developments and transformative potential inherent in the adoption of composite materials for centrifugal pump systems.

With a laser focus on optimizing performance, durability, and efficiency, this study explores the intricate interplay between composite materials and centrifugal pump design. By harnessing the unique properties of composites—such as their exceptional strength-to-weight ratio and corrosion resistance—engineers are reshaping traditional pump design paradigms to meet the demands of modern applications.

Through an interdisciplinary lens encompassing materials science, fluid dynamics, and mechanical engineering, this abstract highlights the collaborative efforts driving the adoption of composite material solutions in centrifugal pump design. By embracing the latest advancements in material science and innovative design methodologies, researchers and practitioners are poised to revolutionize pump technology, paving the way for sustainable water management solutions across diverse industries.

TABLE OF CONTENTS

FREQUENTLY USED SYMBOLS, LABELS AND TERMS

Q = Capacity (m^3/s)

H = Head (m)

N = Rotational Speed (rpm)

Ns = Shape Number (m/s)

Nusf = Useful power (kW)

ρ = Density (Kg/m^3)

Nmp = Motor power (kW)

η= Efficiency

D_1 = Impeller eye diameter (mm)

D_2 = Impeller outer diameter (mm)

b_1 = Impeller eye width (mm)

b_2 = Impeller outer width (mm)

ϕ= Speed ratio

U2= Impeller rim velocity (m/s)

U_1 =Impeller inner velocity (m/s)

ηh= Hydraulic Efficiency

Vn= True whirl velocity component (m/s)

$V\infty$ = Ideal whirl velocity component (m/s)

Z =Number of blades

KS = 3.65

Kn = Factor ranging from 3-5

Y_2 = Velocity of flow (m/s)

Ψ = Flow ratio

γ = Outlet blade angle (deg)

Y1 = Inlet flow velocity (m/s)

β = Inlet blade angle (deg).

D3 = Casing inside diameter (mm)

b3 = Casing width (mm)

TC = Casing thickness (mm)

D4 = Casing outer diameter (mm)

NPSH = Net Positive Suction Head

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Centrifugal water pumps, integral to fluid transportation, employ centrifugal force to propel fluids through piping systems. There is always a need to move liquids from one point to another, for example, water movement from underground tanks to overhead water tanks, water from dams and rivers to homes, industries, and farm settlements, or water for general purposes (Okokowa (2003)). A pivotal element in diverse sectors, including domestic, commercial, agricultural, municipal, and industrial services, these pumps are ubiquitous in applications such as water supply, irrigation, and industrial processes. Additionally, they provide municipal water, wastewater, and industrial services for food processing, chemical, petrochemical, and mechanical industries today. (Anup kumar dey, 2019).

Centrifugal pumps, commonly used for efficient fluid transportation, face challenges such as cavitation, mechanical faults, and failures within the fluid. Addressing these issues is crucial for optimal pump performance. Vibration monitoring, particularly through permanently fixed condition monitoring sensors, proves valuable, especially in inaccessible environments common in water supply and sewerage industries.

Despite being a century-old technology, the underlying physics of centrifugal pumps remains unchanged. Recent advancements, however, focus on utilizing pumps more effectively, with potential energy savings through field inspection and performance testing. Energy efficiency can be achieved by adjusting pump flow rates and eliminating redundant pressure drops.

The study's emphasis on centrifugal pumps aligns with their essential role in water treatment plants, ensuring efficient water transfer between plant sections. With varied pump designs available, the focus extends to understanding pump efficiencies and optimizing pumping systems. This research contributes to the broader understanding of pumps' applications, their efficiency, and the potential for energy savings.

Furthermore, as a notable global trend, traditional materials are gradually being replaced by polymer composites. In the realm of centrifugal pump design, the integration of polymer-composite materials, such as aluminum alloy and bamboo fiber powder, is gaining prominence. These materials offer unique properties, allowing for optimization in pump impeller manufacturing. The study explores the use of aluminum alloy and bamboo fiber powder in centrifugal pump design, aiming for pump weight reduction and increased productivity within individual design constraints.

1.2 STATEMENT OF THE PROBLEM

Centrifugal pumps play a vital role in sustaining the operations of various industries, from paper mills to water treatment plants. However, these pumps encounter a multitude of challenges that affect their efficiency, reliability, and longevity. These issues stem from both mechanical and operational failures, such as mechanical seal leakage, foreign object malfunctions, low flow operation, fatigue stresses, and inadequate pressure generation. Additionally, specific hydraulic and material challenges, including cavitation, impeller wear, corrosion, overheating, and surge problems, further exacerbate the performance and reliability issues.

Moreover, the prevalent use of mild steel in pump impellers presents material limitations, such as increased weight, susceptibility to corrosion, and reduced fatigue strength. To address these challenges, this research proposes exploring alternative materials like aluminum alloys and integrating bamboo fiber into centrifugal pump design. The objective is to enhance corrosion resistance, reduce weight, and improve fatigue strength, thus mitigating the identified problems. By leveraging innovative design and material science approaches, this project aims to enhance the efficiency, durability, and reliability of centrifugal pumps, contributing to the sustainability and operational continuity of industries relying on these essential components.

1.3 AIM AND OBJECTIVE OF THE STUDY

1.3.1 AIM

The primary aim of this research project is to design and develop an efficient centrifugal water pumping system that surpasses traditional designs through the utilization of locally available materials, specifically aluminum alloy and bamboo fiber powder. The project seeks to create a pump that is stable, fast, reliable, and cost-effective, capable of delivering a flow rate of 1.5 liters per second and more.

1.3.2 OBJECTIVES

1. Conduct detailed design analysis of centrifugal pump components, prioritizing efficiency, durability, and performance.
2. Select appropriate locally sourced materials, focusing on aluminum alloy and bamboo fiber powder, for pump fabrication based on material properties and compatibility.
3. Fabricate and assemble the centrifugal pump system with precision and attention to detail, implementing the designed components.
4. Perform comprehensive testing and evaluation of the fabricated pump, including water flow simulations, mechanical and physical tests, and assessment of overall efficiency and reliability.
5. Contribute to the development of efficient and sustainable centrifugal water pumping systems by promoting the use of locally available materials for improved performance and cost-effectiveness.

1.4 SCOPE OF WORK

The scope of this project work is limited to

1. **Design Creation and Optimization:** Using SolidWorks CAD software, a monoblock centrifugal pump will be designed, featuring a circular casing and enclosed impeller made from an aluminum-bamboo fiber composite. Optimization simulations will be conducted to enhance efficiency.
2. **Material Composition Analysis:** Minitab mixture Design of Experiments (DOE) will determine the optimal blend of aluminum and bamboo fiber for durability, mechanical strength, and efficiency based on pump requirements.
3. **Mechanical and Physical Testing:** Mechanical tests (impact, hardness, tensile strength) and physical tests (corrosion resistance, water absorption) will validate the material's suitability for pump construction.

4. **Prototype Manufacturing:** A prototype will be fabricated based on the optimized design, involving processing the composite material and assembling the pump to meet specifications.

5. **Performance Evaluation:** The assembled pump prototype will undergo testing to assess efficiency, operational reliability, head capacity, and flow rate compared to conventional pumps.

6. **Analysis and Documentation**: The project process, from design to testing, will be documented, including analysis of results, comparison with existing technologies, and exploration of environmental and economic impacts.

1.5 SIGNIFICANCE OF THE STUDY

The study on designing and constructing a more efficient centrifugal pump using an aluminum and bamboo fiber composite holds significant importance across multiple dimensions, addressing both immediate technical challenges and offering broader implications for sustainability, economic efficiency, and technological innovation.

1. **Technological Advancement:** This project introduces a novel composite material to pump manufacturing by integrating bamboo fiber with aluminum, potentially setting a new benchmark for lightweight, durable, and efficient pump designs. Aimed at delivering a centrifugal pump with improved performance metrics such as higher head, better flow rate, and reduced energy consumption, it drives advancements in pump technology

2. **Environmental Sustainability:** Leveraging bamboo, a fast-growing and sustainable resource, alongside aluminum emphasizes the project's commitment to environmental sustainability. This approach reduces reliance on non-renewable materials and decreases the carbon footprint associated with pump manufacturing. Additionally, by improving pump efficiency, the project contributes to reduced energy consumption in industrial and water management applications, aligning with global efforts to combat climate change.

3. **Economic Impact:** Utilizing locally-sourced bamboo and optimizing material use through composite technology can lower the production costs of centrifugal pumps, making the technology more accessible to a wider range of users, including those in developing regions. Furthermore, improved pump efficiency leads to lower operational

costs for industries reliant on these systems, potentially resulting in significant savings in energy expenses over the pumps' lifespan.

4. **Social Implications:** The project's innovative approach may stimulate interest in pump design and manufacturing, contributing to skill development in this niche engineering field. Additionally, the adoption of new manufacturing techniques could lead to job creation in the production and maintenance of these pumps. In regions where water access is limited, more efficient and affordable pumping solutions can significantly impact water availability for agriculture, drinking, and sanitation purposes, thereby improving quality of life.

5. **Academic and Research Contributions:** This project lays the groundwork for further exploration into the use of composite materials in various types of machinery, opening new avenues for research and development. By documenting the design process, material selection, and testing methodologies, the project serves as a valuable educational resource for students and professionals interested in mechanical engineering, sustainable materials, and renewable energy sources.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

This chapter explores the historical evolution of centrifugal pump technology, tracing its development from its inception to modern applications in various industries. It also investigates the fundamental operational principles of centrifugal pumps, laying the groundwork for understanding the role of material properties in pump design and functionality.

Furthermore, the chapter delves into the incorporation of composite materials in centrifugal pump manufacturing, examining their properties, benefits, and challenges. Comparative analyses, performance evaluations, and case studies are scrutinized to highlight the advantages and practical implications of using composite materials in pump design. This review extends to seminal and contemporary studies, encompassing a wide range of research that illuminates the transformative potential of composite materials in enhancing pump performance and longevity.

Structured systematically, the chapter begins with a historical overview of centrifugal pump development, followed by an exploration of their operational fundamentals. It then proceeds to discuss the advent of composite materials in this domain, analyzing their impact on efficiency, maintenance requirements, and overall lifecycle of centrifugal pumps. The chapter concludes by identifying gaps in current research and proposing potential avenues for future investigations, setting the stage for subsequent chapters of the report.

Through this literature review, the chapter aims to articulate a coherent narrative that not only presents the current state of centrifugal pump technology but also elucidates the compelling advantages and untapped potential of composite materials. This examination serves to substantiate the hypothesis that composite materials represent a frontier for innovation in centrifugal pump design, offering pathways to superior performance, sustainability, and cost-efficiency.

2.2 HISTORICAL DEVELOPMENT OF CENTRIFUGAL PUMPS

The history of water-lifting devices spans back to 3000 BC, marking the advent of early innovations such as water wheels and chutes, which harnessed animal energy for operation

(Oleson, 1984). These ancient tools played a crucial role in the survival and development of settlements in regions with scarce water resources. The ancient Greeks, in particular, were instrumental in advancing hydraulic technology, improving upon the water-lifting techniques inherited from other civilizations (Antoniou et al., & Angelakis et al., 2014). Among these innovations was the helicoid or Archimedean pump, a device that remains in use to this day for irrigation and mining purposes. Additionally, the tympana, or drums, served similar purposes until the previous century (Tassios, 1998).

The evolution of the centrifugal pump can be traced back to the Mesopotamians around 3000 BC, who employed simple bucket systems for crop irrigation along the Nile River (Inegbedion et al., 2021). This rudimentary pump, known as the Shaduf, relied on a counterweighted lever system to lift water from the river to the fields, a method that became widespread across the Middle East for over two millennia (Wallace, 2012). The development of waterwheel technologies, such as the noria and the Persian waterwheel, further exemplifies the advancements in water lifting, with the latter being distinguished by its pump-like operation due to an endless series of weighted pots (Eubanks, 1971; Hazen, 2000).

The introduction of the hydraulic wheel in Fez, Morocco, in the 13th century (Cohn, 1933), and its subsequent adoption across North Africa and Asia, highlights the global spread of water-lifting technologies. These innovations paved the way for the development of modern hydropower systems and dynamic water lifting devices, extracting power from water flow (Molenaar, 1956; Bazza, 2007).

The Renaissance period marked significant advancements with the invention of the first machine resembling a centrifugal pump by Francesco di Giorgio Martini in 1475, and the later development of sliding vane water pump technology by Agostino Ramelli in 1588 (Champlin, 2018). The invention of the first true centrifugal pump by Denis Papin in 1687, and its refinement with curved vanes by John Appold in the 19th century, demonstrates the ongoing innovation in pump technology (Inegbedion et al., 2021).

Today, the principles of ancient water-lifting technologies continue to influence modern water resource management and exploitation, through the use of centrifugal devices, pistons, and vacuum pumps (Yannopoulos et al., 2015). The applications of these technologies have expanded into various industries, including oil pipelines and booster stations, underscoring the critical role of pump development in advancing economic civilization and environmental comfort (Anderson, 1957; Ozora & Ojoborb, 2012).

This historical overview illustrates the evolution of water-lifting devices from ancient times to the present, highlighting the enduring legacy of these technologies in shaping modern water management and industrial applications.

2.3. CLASSIFICATION OF PUMPS

Pumps can be categorized based on various factors, including their operating principle, design, construction, and application. Understanding these classifications is crucial for selecting the most suitable pump for specific fluid transfer tasks.

2.3.1. CLASSIFICATION BASED ON OPERATING PRINCIPLE:

Pumps can be classified based on their operating principles, which define how they generate flow and pressure. The main categories include:

1. Positive Displacement Pumps: These pumps trap a fixed volume of fluid and then force it into a discharge pipe. Examples include reciprocating pumps, rotary pumps, and diaphragm pumps (McCabe W.L. et al, 2005).

2. Dynamic (Centrifugal) Pumps: Dynamic pumps operate by imparting kinetic energy to the fluid to increase its velocity, which then converts to pressure. Centrifugal pumps are the most common type in this category, utilizing a rotating impeller to create centrifugal force (Karassik, I.J. et al, 2001)

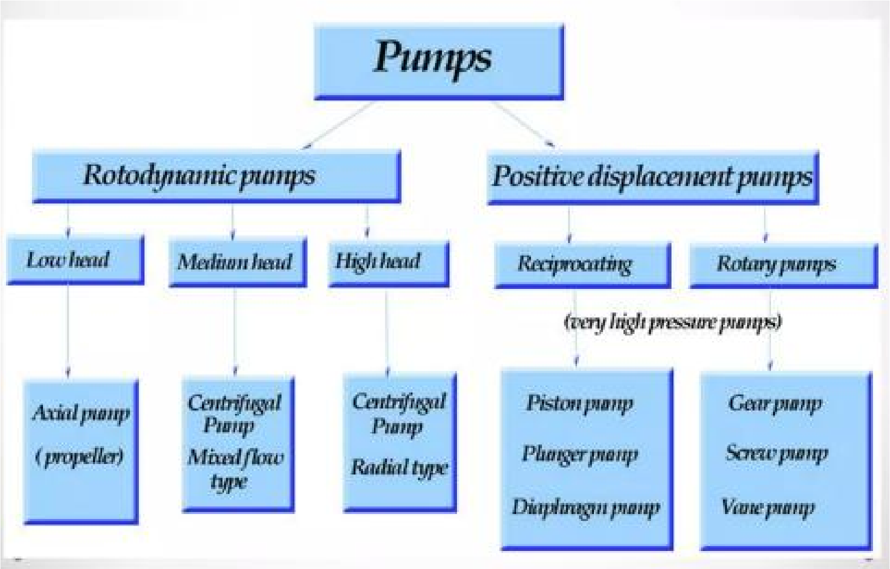


Fig 2.1 - Classification of pumps

2.3.2. CLASSIFICATION BASED ON DESIGN AND CONSTRUCTION:

Pumps can also be classified based on their design and construction features, which impact their performance and suitability for specific applications. This classification includes:

1. Centrifugal Pumps: Further categorized based on the number of impellers (single-stage or multi-stage) and the orientation of the shaft (horizontal or vertical) (Levenspiel, O. et al 1999).

2. Reciprocating Pumps: Such as piston pumps and plunger pumps, known for their pulsating flow and high-pressure capabilities (McCabe W.L. et al, 2005).

3. Rotary Pumps: Including gear pumps, vane pumps, and screw pumps, characterized by continuous fluid delivery and low pulsation (Karassik, I.J. et al, 2001).

2.3.3. CLASSIFICATION BASED ON APPLICATION:

Pumps are often classified according to the applications they serve, addressing specific requirements and challenges. Common classifications based on application include:

1. Water Pumps: Used for various purposes such as irrigation, municipal water supply, and HVAC systems (Gopal, B. et al, 2010).
2. Chemical Pumps: Designed to handle corrosive fluids in chemical processing industries (Ludwig, E.E. et al 1998).
3. Oil and Gas Pumps: Specifically designed for transferring crude oil, refined petroleum products, and natural gas (Perry, R.H. & Green, D.W. (Eds.) et al, 2007).
4. Slurry Pumps: Built to handle abrasive slurries containing solid particles, commonly used in mining and dredging operations (Ramesh, A. et al, 2018).

2.4. CENTRIFUGAL PUMPS

Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. A typical centrifugal pump set up is comprised of one or more impellers attached to a rotary pump shaft. This arrangement provides the energy required to conduct fluid through the pump system and the associated piping. The impellers turning in sync with the pump shaft converts dynamic mechanical energy from the pump motor into the energy of moving fluids. While most of the energy derived from the motor will be converted to kinetic energy in the pumped fluids, a portion will be channeled as potential energy in fluid pressure calculated against gravity.

2.5. CLASSIFICATION OF CENTRIFUGAL PUMPS

The major centrifugal pump variations include the following: Axial, radial, and mixed flow centrifugal pumps represent three prominent configurations, each exhibiting unique flow characteristics and performance attributes (Karassik, I.J et al, 2001).

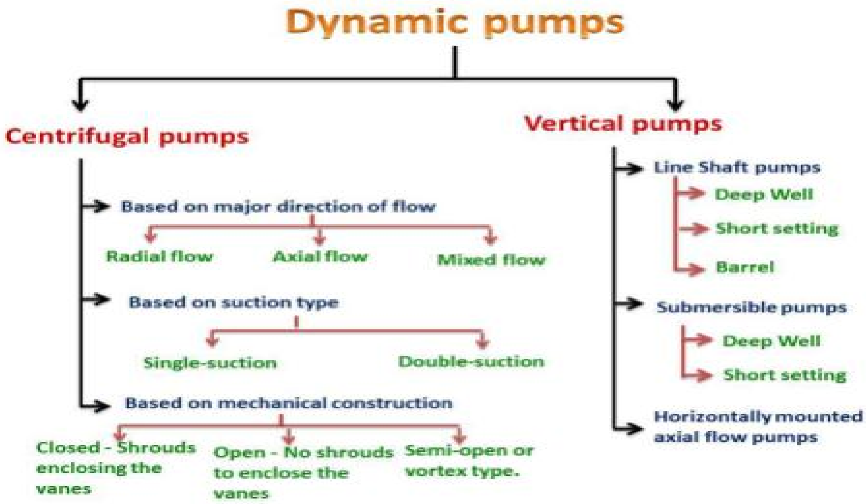


Fig 2.2- Classification of Dynamic pumps

2.5.1 CLASSIFICATION OF CENTRIFUGAL PUMPS BASED ON MAJOR DIRECTION OF FLOW

1. Axial Flow Centrifugal Pumps:

Axial flow pumps are characterized by fluid flow parallel to the pump shaft, resulting in a streamlined flow pattern along the pump axis (Ludwig, E.E. et al, 1998). These pumps feature an impeller design that imparts kinetic energy to the fluid, propelling it in a linear direction. Axial flow pumps are well-suited for applications requiring high flow rates and low heads, such as water circulation in large-scale irrigation systems, flood control, and cooling water circulation in power plants (Perry, R.H. and Green, D.W. (Eds.).et al, 2007). Pressure is developed wholly by the propelling action of the impeller vanes.

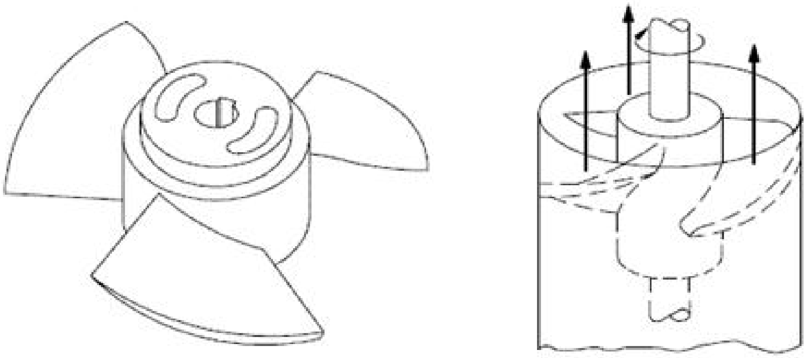


Fig 2.3 - Axial flow impeller.

2. Radial Flow Centrifugal Pumps:

In contrast to axial flow pumps, radial flow pumps direct fluid flow perpendicular to the pump shaft, creating a radial outflow pattern from the impeller (Coulson, J.M., Richardson, J.F & Sinnott, R.K. et al, 2018). This configuration enables radial pumps to generate higher pressure heads at the expense of lower flow rates compared to axial pumps. Radial flow centrifugal pumps find application in processes requiring moderate flow rates and higher discharge pressures, including water supply systems, industrial process fluid transfer, and HVAC applications (Munson, B.R., Young, D.F. et al, 2012). Pressure is developed wholly by centrifugal force.

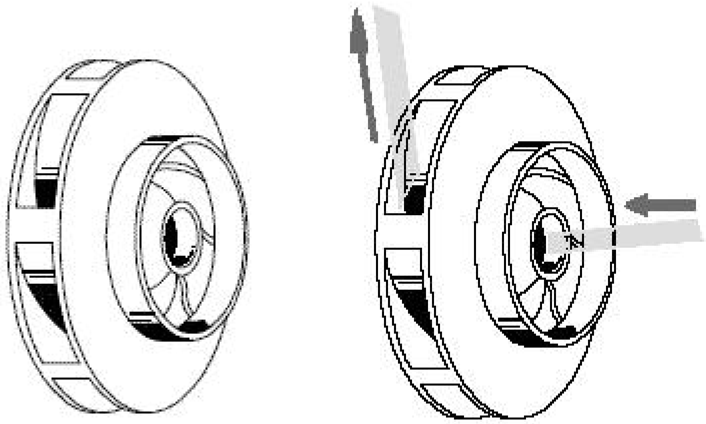


Fig 2.4 - Radial flow impeller.

3. Mixed Flow Centrifugal Pumps:

Mixed flow pumps combine features of both axial and radial flow configurations, producing a flow path that combines axial and radial components (McCabe, W.L., et al (2005). They push liquid out away from the pump shaft at an angle greater than 90°. This hybrid design allows mixed flow pumps to achieve a balance between flow rate and head, making them versatile for a wide range of applications. Mixed flow centrifugal pumps are commonly used in wastewater treatment, stormwater drainage, agricultural irrigation, and aquaculture systems (Ramesh, A. et al., 2018). Pressure is developed partly by centrifugal force and partly by the lifting action of the impeller.

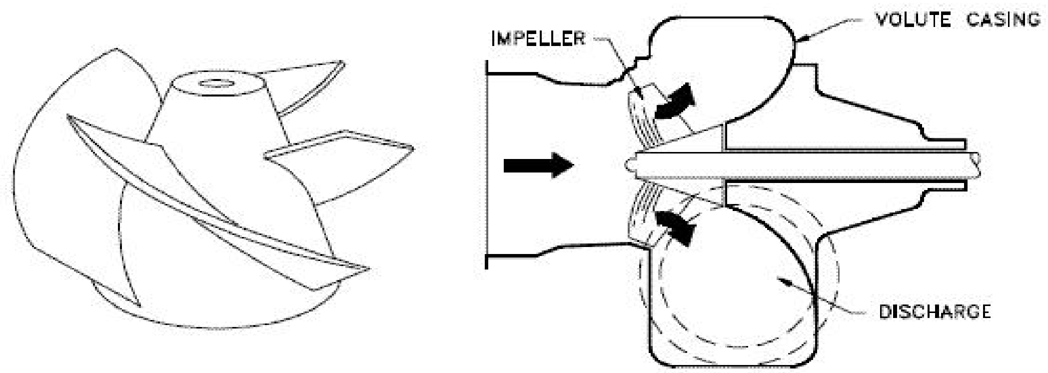


Fig 2.5 - Mixed flow impeller.

The image below provides visual example of how liquid might flow through these different types of pumps:

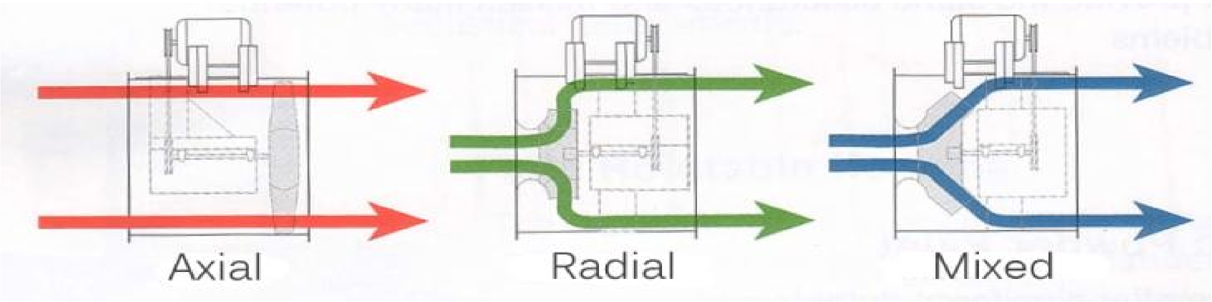


Fig 2.6 - Flow of liquid through centrifugal pumps.

2.5.2 CLASSIFICATION OF CENTRIFUGAL PUMPS BASED ON NUMBER OF IMPELLERS AND PRESSURE CAPABILITIES

1. Single-Stage Centrifugal Pump

Characterized by containing only a single impeller, this type of pump is favored for its straightforward maintenance. Commonly used in water supply systems, irrigation, and general industrial applications. It is typically employed in scenarios requiring high flow rates at lower pressures.

2. Two-Stage Centrifugal Pump

Equipped with two impellers working in unison, the two-stage centrifugal pump is adept at handling medium-head applications, efficiently moving process liquids.

3. Multi-Stage Centrifugal Pump

Multi-stage pumps feature multiple impellers arranged in series on a single shaft.
Each impeller adds pressure to the fluid, allowing these pumps to generate higher discharge pressures.
Ideal for applications requiring high-pressure delivery, such as boiler feedwater, high-pressure cleaning systems, and industrial processes, the multi-stage centrifugal pump, with its assembly of three or more impellers, is engineered for peak efficiency.

2.5.3. CLASSIFICATION BASED ON SHAFT ORIENTATION

1. **Horizontal Centrifugal Pumps**:

These pumps have a horizontal shaft orientation, with the shaft typically mounted on bearings in a horizontal plane. Horizontal pumps are commonly used in industrial settings where space is not limited.
They offer easy access for maintenance and are often used in applications such as water circulation, chemical processing, and HVAC systems.

2. Vertical Centrifugal Pumps:

In vertical pumps, the shaft is positioned vertically, usually extending upward from the pump casing. Vertical pumps are ideal for applications where floor space is limited, such as sump pumping, deep well pumping, and offshore oil production.

2.6. FUNDAMENTALS OF CENTRIFUGAL PUMP OPERATION

Inegbedion et all (2021) describe a centrifugal pump as an apparatus consisting of rotating blades encased within a shell, which transfers energy to a fluid predominantly via centrifugal force. This process propels the fluid in concert with the pump's rotating components, which include both an impeller and a shaft. This mechanism represents one of the centrifugal pump's fundamental components. The other is a static element composed of the pump casing, stuffing box, and bearings. Centrifugal pumps, heralded for their simplicity within process facilities, fulfill a similar role to positive-displacement pumps but operate through a distinct mechanism, as noted by Anup Kumar Dey (2019).

These pumps generate pressure through acceleration and deceleration as the fluid navigates through the system. Essential to the pump's operation is the flow or gallons per minute entering the pump's suction side, a phenomenon referred to as NPSH (Net Positive Suction Head). Echoing the functionality of positive-displacement pumps, centrifugal pumps are incapable of increasing flow rate; they cannot transform three gallons per minute at the inlet into four at the outlet, as elucidated by Bachus and co-authors (2003). The liquid is drawn into the pump via the suction nozzle, reaching the impeller's eye. Here, trapped between the impeller's blades and driven by the impeller's velocity, the fluid experiences a significant velocity surge. According to Bernoulli's principle, an increase in velocity leads to a decrease in pressure, creating a low-pressure zone at the impeller's eye. The liquid, upon exiting the impeller at high velocity, collides with the volute's internal wall, where its velocity sharply decreases, and its pressure correspondingly increases, as per Bernoulli's Law. This transformation from velocity to pressure, or head, is efficiently delivered at the discharge nozzle. Given the generally fixed impeller diameter and motor speed, centrifugal pumps are often considered constant head or pressure machines, as illustrated in Bachus et al.'s (2003) theoretical pump curve depiction.

Functionally, centrifugal pumps are rotodynamic machines that enhance fluid pressure via a rotating impeller. These pumps are integral for moving liquids through piping systems. Fluid is drawn into the pump near the impeller's rotating axis, accelerated radially outwards into a diffuser or volute chamber, and then discharged into the piping system. Centrifugal pumps excel in applications requiring high flow rates across relatively low heads.

To ensure adherence to industry benchmarks, various configurations of radial centrifugal pumps have been developed. Notably, these include pumps conforming to standards set by the American National Standards Institute (ANSI) and the American Petroleum Institute (API). ANSI pumps feature a single impeller and are praised for their high quality, ease of maintenance, and interchangeability with pumps of similar ratings. They are particularly suited for managing low-rate fluid flows. API pumps, conversely, are engineered for heavy-duty applications, incorporating specific industrial dimensions such as hold-down bolt sizes and predetermined pump coupling heights. Predominantly radial by design, they are indispensable in the oil and gas sector.

2.7. COMPONENTS OF CENTRIFUGAL PUMPS

A centrifugal pump comprises several integral components, each playing a crucial role in its operation. These components include:

1. **Impeller:** It is a wheel or rotor which is provided with a series of backward curved blades or vanes, responsible for imparting kinetic energy to the fluid. It is mounded on the shaft which is coupled to an external source of energy which imparts the liquid energy to the impeller there by making it to rotate.

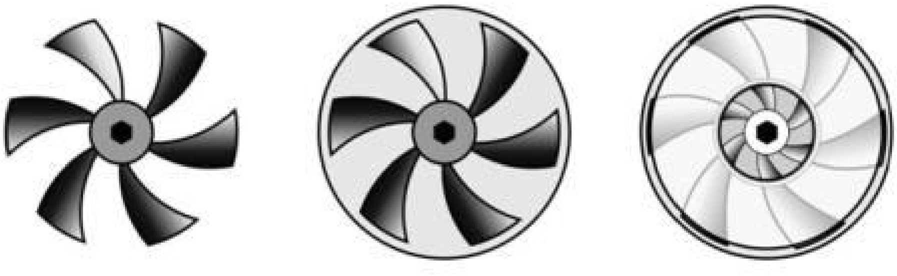


Fig 2.7 - Open, Semi Enclosed and Enclosed Impeller

Impellers are divided into 3 types,

1. Open Impeller
2. Semi enclosed Impeller
3. Enclosed Impeller

2. **Casing:** An airtight chamber surrounding the impeller, ensuring efficient fluid movement. It is a pipe which is connected at the upper end to the inlet of the pump to the centre of impeller which is commonly known as eye. Commonly three types of casing are used in centrifugal pump,

1. Volute Casing
2. Vortex Casing
3. Casing with Guide Blades

3. Suction Pipe with Foot Valve and Strainer: It is connected with the inlet of the impeller and the other end is dipped into the liquid to be pumped, facilitating suction of water. At the water end, it consists of foot value and strainer. The foot valve is a one way valve that opens in the upward direction. The strainer is used to filter the unwanted particle present in the water to prevent the centrifugal pump from blockage.

4. Delivery Pipe: Similar to the suction pipe, one end connects to the impeller's eye, while the other extends to an overhead tank for discharge. It is a pipe which is connected at its lower end to the out let of the pump and it delivers the liquid to the required height. Near the outlet of the pump on the delivery pipe, a valve is provided which controls the flow from the pump into delivery pipe.

5. **Foot Valve:** Permits fluid flow only in an upward direction, aiding in maintaining prime conditions.

6. **Strainer**: Prevents the entry of foreign particles or materials into the pump, safeguarding its internal components.

7. **Shaft**: The rod linking the motor to the impeller, transmitting rotational motion.

Additional components, as identified by Prosoli (2009), encompass:

8**. Motor:** The powerhouse driving the pump, converting electrical energy into mechanical energy.

9. **Seals (Mechanical, Labyrinth, Gasket, or Packing)**: Essential for preventing fluid leakage into the atmosphere. Certain magnetically driven centrifugal pumps may not require these seals.

10. **Bearing:** Facilitates the rotation of the shaft, allowing it to move freely in place.

11. **Outboard Bearing:** Located at the motor end of the shaft, providing support on one side.

12. **Inboard Bearing:** Positioned on the impeller side of the pump, offering support on the opposite end.

13. **Oiler:** Supplies lubricating oil to prevent bearing jamming. Alternatively, grease may be utilized, injected through a grease gun via a nipple, ensuring adequate lubrication.

These components collectively contribute to the seamless functioning of the centrifugal pump, showcasing the intricacies involved in its design and operation.

2.8. PERFORMANCE SPECIFICATIONS

Centrifugal pump selection is defined by a few key specifications, including flow rate, head, power, and efficiency.

1. **Flow rate** describes the rate at which the pump can move fluid through the system, typically expressed in gallons per minute (gpm). The rated capacity of a pump must be matched to the flow rate required by the application or system.

2. **Pressure** is a measure of the force per unit area of resistance the pump can handle or overcome, expressed in bar or psi (pounds per square inch). As in all centrifugal pumps, the pressure in axial flow pumps varies based on the pumped fluid's specific gravity. For this reason, head is more commonly used to define pump energy in this way.

3. **Head** is the height above the suction inlet that a pump can lift a fluid. It is a shortcut measurement of system resistance (pressure) which is independent of the fluid's specific gravity, expressed as a column height of water given in feet (ft) or meters (m).

4. **Net positive suction head (NPSH*)*** is the difference between the pump's inlet stagnation pressure head and the vapor pressure head. The required NPSH is an important parameter in preventing pump cavitation.

5. **Output power, also called water horsepower,** is the power actually delivered to the fluid by the pump, measured in horsepower (hp).

6. **Input power, also called brake horsepower,** is the power that must be supplied to the pump, measured in horsepower (hp).

7. **Efficiency** is the ratio between the input power and output power. It accounts for energy losses in the pump (friction and slip) to describes how much of the input power does useful work.

2.9. WORKING PRINCIPLE OF A CENTRIFUGAL PUMP

The underlying principle of a centrifugal pump's operation is rooted in the physics of centrifugal force. When fluid is spun around an axis by an external force, it is propelled outward, away from the axis, creating a centrifugal head that enables the fluid to ascend to a higher elevation.

1. Initially, with the delivery valve shut, the pump system (comprising the suction pipe, casing, and delivery pipe up to the valve) is primed, ensuring it is filled with water and devoid of air pockets.

2. With the delivery valve still closed, the impeller is set in motion by the motor, generating a powerful suction at the impeller's eye.

3. Once sufficient speed is reached, the delivery valve is opened. Fluid then flows into the impeller vane from the eye and is discharged into the casing.

4. The impeller's action not only accelerates the fluid but also increases its pressure.

5. Consequently, the fluid ascends through the delivery pipe to the desired height.

6. Upon halting the pump, closing the delivery valve is crucial to avert the backflow from the storage reservoir.

The essence of centrifugal force, analogous to swinging a water-filled bucket around, illustrates how increased speed enhances the force exerted outwardly, securing the water inside the bucket regardless of the motion's direction. This same principle applies to the centrifugal pump's functionality:

1. Creating a hole at the bucket's bottom would see water jetting out, demonstrating the direct relationship between the jet's reach and the centrifugal force applied.

2. This force, responsible for retaining water in the bucket, mirrors the centrifugal pump's operational mechanism.

3. Within the pump, a stationary volute houses a rotating impeller.

4. Fluid is drawn into the pump through a suction inlet, reaching the impeller's eye.

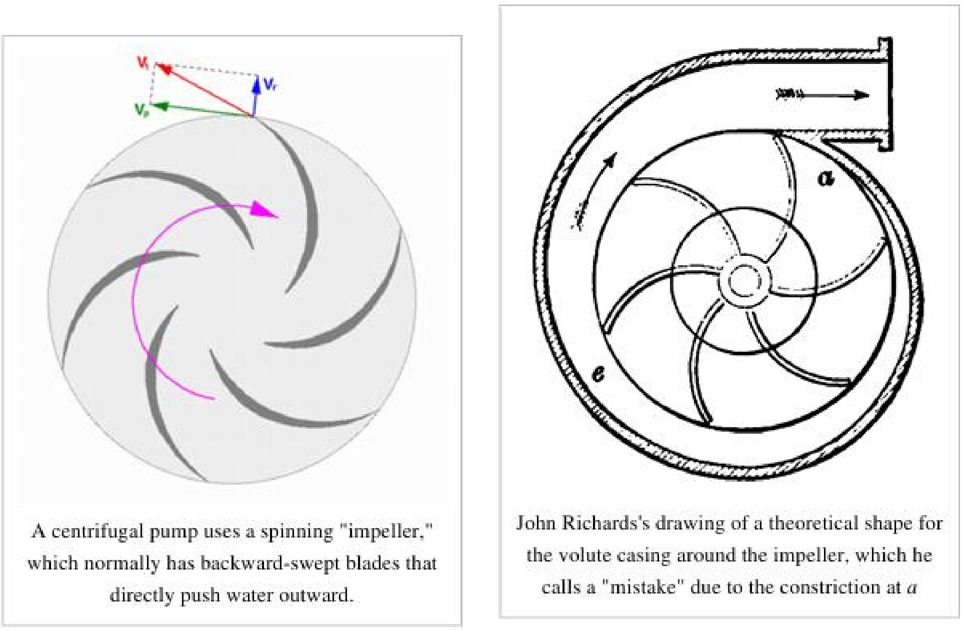
5. The impeller's rotation propels the fluid outward and through the discharge nozzle.

6. Entering under atmospheric pressure, the fluid moves into the impeller's eye.

7. The centrifugal force exerted flings the fluid from the impeller's eye through the vanes to the outer edges, then against the volute's walls, and out through the pump's discharge.

8. A drop in pressure at the inlet and impeller eye continuously draws fluid into the pump.

9. The volute's design, wider at the discharge point, facilitates this process by expanding and slowing the fluid, converting kinetic energy into pressure, which then propels the fluid through the outlet pipelines.



A centrifugal pump uses a spinning "impeller," which normally has backward-swept blades that directly push water outward.

John Richards's drawing of a theoretical shape for the volute casing around the impeller, which he calls a "mistake" due to the constriction at *a*

Fig 2.8 - Shapes of volute casing

2.10. CHALLENGES IN CENTRIFUGAL PUMP OPERATION

Several issues can impair the performance of centrifugal pumps:

1. Cavitation occurs when the net positive suction head (NPSH) is insufficient.

2. Impeller wear can be exacerbated by suspended solids or cavitation.

3. Corrosion within the pump results from the fluid's properties.

4. Overheating may occur due to low flow, while leakage along the shaft is also a concern.

5. A lack of priming can prevent operation, as these pumps require filling with the fluid.

6. Efficiency drops when handling viscous liquids.

7. For high-pressure applications, alternative pump types might be more appropriate.

8. Large solids or debris can obstruct the pump, hindering performance.

2.11. MATERIAL SELECTION FOR CENTRIFUGAL PUMPS

The construction materials for centrifugal pumps are chosen based on the operational conditions and the characteristics of the fluid being pumped. Several factors influence this selection, ensuring the pump's durability and efficiency:

1. Corrosion resistance is paramount, especially in environments where the fluid or external conditions can degrade materials.

2. Electrochemical compatibility must be considered to prevent material degradation through galvanic corrosion.

3. The presence of abrasive solids in the fluid necessitates materials that can withstand wear.

4. The operational temperature of the pump affects material integrity and performance.

5. The developed head and operating pressure dictate the need for materials that can withstand these forces without deformation.

6. Each material's suitability for specific pump features ensures that the pump can operate as intended.

7. The load factor and the expected life span of the pump components guide material choice to ensure long-term reliability.

Pump casings often utilize cast iron for standard applications. However, in scenarios involving mildly corrosive fluids or where weight reduction is beneficial, aluminum is an excellent choice due to its lighter weight and good corrosion resistance compared to traditional materials. Bronze casings are preferred for mildly corrosive liquids, and when the situation demands higher resistances to pressure or temperature, materials like cast steel or forged steel are selected. For highly corrosive or abrasive fluids, stainless steel provides superior durability. In very specialized applications, where the chemical compatibility or purity of the fluid is critical, casings made of porcelain, glass, or advanced synthetics are used.

Impellers, crucial for the pump's operation, are typically made from bronze for regular liquids. However, aluminum is also a viable option for impellers, especially when dealing with lightweight requirements or specific corrosive conditions where its properties are advantageous. For environments involving strong electrolytes or high-speed operations, ferrous materials or stainless steel (Grade 304) are preferred due to their robustness against corrosion and abrasion. Impellers dealing with high-temperature liquids or aggressive chemicals may require alloys enriched with chromium and nickel, or even ceramics and specialized plastics for chemical industry applications.

Shafts are generally manufactured from steel, offering a balance of strength and cost-effectiveness. Yet, in applications where the fluid's nature could cause corrosion, alternatives like high-strength alloy steels, stainless steel, phosphor bronze, or monel metal are considered. Aluminum can also play a role in components where its lightweight and non-magnetic properties are advantageous, although its use in shafts is less common due to strength considerations. The choice of material for shafts and other pump components underscores the need to match the pump design closely with the application's demands, balancing factors such as mechanical properties, chemical compatibility, and operational efficiency.

2.12. ADVANCEMENTS IN CENTRIFUGAL PUMP DESIGN

The landscape of industrial fluid handling is undergoing a transformative phase, driven by cutting-edge advancements in pumping technologies. These innovations are pivotal in enhancing operational efficiency, reducing energy consumption, and improving reliability across various industries. This section delves into the recent trends in advanced pumping technologies, their implications for industrial applications, and how they are shaping the future of fluid management systems

1. **Energy-Efficient Pump Designs:** A cornerstone of modern pumping technology is the emphasis on energy efficiency. Manufacturers are increasingly utilizing computational fluid dynamics (CFD) simulations and innovative engineering techniques to optimize pump designs. These efforts focus on minimizing hydraulic losses and enhancing impeller designs, leading to pumps that are not only more efficient but also environmentally friendly. The integration of Variable Frequency Drives (VFDs) and intelligent control systems allows for dynamic adjustment of pump operations, catering to the actual demand and significantly reducing energy consumption (Saurabh M, November 2023).

2. **Smart Pumping Systems:** The adoption of Internet of Things (IoT) and intelligent technologies marks a significant shift towards smart industrial fluid handling. By equipping pumps with IoT-enabled sensors, industries can monitor performance metrics in real-time, including temperature, pressure, and energy use. This wealth of data, analyzed through predictive algorithms, enables predictive maintenance, thereby reducing downtime and

extending the lifespan of pumping systems. The ability to remotely monitor and adjust pump operations ensures optimized performance, enhancing both efficiency and reliability in fluid handling processes.

3. **Seal-less and Magnetic Drive Pumps:** Seal-less and magnetic drive pumps represent a leap forward in addressing leakage and maintenance issues prevalent in traditional pumping systems. By eliminating the need for mechanical seals, these pumps significantly reduce the risk of hazardous leaks, offering a safer and more environmentally friendly solution. This design not only lowers maintenance requirements but also proves to be cost-effective over the pump's lifecycle. Such pumps are particularly valuable in handling volatile, toxic, or corrosive fluids, finding widespread applications in the chemical, pharmaceutical, and other industries concerned with fluid integrity (Advancing Industrial Fluid Handling, December 2023).

4. **Diaphragm and Peristaltic Pumps:** The advancements in diaphragm and peristaltic pumps have been instrumental for industries that demand precise and contamination-free fluid handling. Improved materials and designs in diaphragm pumps have enhanced their accuracy and reliability, making them indispensable for precision dosing applications. Similarly, peristaltic pumps have evolved with better tubing materials and pump head designs, offering gentle, contamination-free pumping action ideal for the pharmaceutical, food processing, and biotechnology sectors.

5. **3D Printing and Advanced Materials:** The advent of 3D printing technology in pump manufacturing has revolutionized the production of pump components. This technology allows for the creation of complex parts with optimized geometries, facilitating rapid prototyping and customization. Alongside, advancements in material science have yielded more durable, corrosion-resistant, and high-performance materials for pump construction. These developments not only extend the service life of pumps but also expand their applicability across a wider range of fluids, significantly improving operational efficiency and reliability.

2.13. INTRODUCTION TO COMPOSITE MATERIALS IN ENGINEERING

Composite materials represent a revolutionary class of materials that combine two or more distinct constituents to create a new material with properties superior to those of the individual components. This synthesis aims to enhance mechanical, chemical, and physical attributes, thereby offering tailored solutions to specific engineering challenges. Composite materials are engineered to exhibit a synergy of improved strength, reduced weight, increased thermal resistance, and enhanced durability, making them indispensable in various sectors, including aerospace, automotive, construction, and sports equipment.

2.13.1. DEFINITION AND CHARACTERISTICS

A composite material is defined as a material composed of two or more distinct phases, typically a matrix and a reinforcement, which remain separate and distinct within the finished structure. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcement materials impart their special mechanical and physical properties to enhance the matrix properties. The combination of high-strength fibers with a matrix results in composites that are strong, lightweight, and resistant to fatigue and impact, surpassing the limitations of traditional materials. (Team Xometry, 2023).

2.13.2. PROPERTIES OF COMPOSITE MATERIALS

Composite materials are designed to offer a unique set of properties, which include high strength-to-weight ratios, superior impact resistance, and exceptional chemical and environmental stability. These materials can be engineered for specific applications by altering the chemical composition and physical structure, providing tailored solutions that meet unique performance requirements. For example, the integration of high-strength fibers into a polymer matrix can significantly enhance the material's tensile strength, while the matrix contributes to the composite's overall compressive strength (Team Xometry, 2023).

2.13.3. TYPES OF COMPOSITE MATERIALS

The diversity of composite materials is vast, encompassing;

1. Nanocomposites,
2. Metal Matrix Composites (MMCS),
3. Polymer Matrix Composites (PMCS),
4. Glass Fiber Reinforced Polymers (GFRPS),
5. Natural Fiber Composites (NFCS), and more.

Each type offers distinct advantages tailored to specific applications. For instance, PMCs are widely used in industries where high strength-to-weight ratios are crucial, such as in aerospace and automotive sectors. Similarly, GFRPs are favored for their balance of strength and cost-effectiveness, making them suitable for construction and marine applications (Team Xometry, 2023)..

2.13.4. AGRO-WASTE COMPOSITE MATERIALS

A notable addition to the array of composite materials is agro-waste composites, wherein natural fibers derived from agricultural by-products, such as bamboo fiber, are integrated into a matrix to create a sustainable and eco-friendly material. This type of composite leverages the strength and lightweight properties of bamboo fibers, contributing to reduced environmental impact compared to traditional reinforcement materials.

2.13.5. ADVANTAGES OVER TRADITIONAL MATERIALS

The adoption of composite materials over traditional monolithic materials, such as metals and alloys, is driven by the unmatched advantages composites offer. These materials can meet the stringent requirements of modern engineering applications, such as the dimensional stability needed in satellite components exposed to extreme temperature variations in space. Composites like graphite/epoxy have become the material of choice for applications requiring low thermal expansion coefficients, which cannot be achieved by traditional materials alone.

Moreover, the use of composites in the airline industry illustrates the significant benefits of weight reduction without compromising strength or stiffness. The fuel savings and consequent cost reductions associated with lighter aircraft demonstrate the economic and environmental advantages of composites. Their superior properties, including improved fatigue and impact resistance, thermal conductivity, and corrosion resistance, further underscore the versatility and efficiency of composite materials in meeting the demands of contemporary engineering challenges (Kaw, 2006).

2.14. APPLICATION OF COMPOSITE MATERIALS IN CENTRIFUGAL PUMPS

In the realm of industrial applications, the durability and resistance of pumps to corrosive substances are paramount. A critical aspect of improving the chemical resistance of pumps, particularly in sectors such as the pulp and paper industry and metal finishing industry, is the integration of composite materials and specialized linings within pump components. The volute, a key component of centrifugal pumps, can be significantly reinforced against chemical damage through the implementation of protective linings. Materials such as rubber and graphite, as well as monolithic ceramics, are commonly employed for their exceptional resistance to a wide range of corrosive liquids, including the highly aggressive hydrofluoric acid (Fathy, 2023).

2.14.1. COMPOSITE MATERIALS IN PUMP BODIES

Beyond linings, composite materials are increasingly being utilized in the manufacture of pump bodies themselves. The inherent characteristics of composite materials, such as their high strength-to-weight ratio and excellent corrosion resistance, make them ideally suited for this purpose. These materials can withstand the rigorous demands of continuous exposure to corrosive substances while maintaining the pump's performance and reliability. The integration of composites into pump design not only extends the equipment's service life but also enhances its efficiency and safety in handling hazardous liquids.

The application of composite materials and specialized linings represents a forward-thinking approach to addressing the challenges posed by corrosive environments in industrial pumping systems. By leveraging these technologies, manufacturers are able to produce pumps that offer superior chemical resistance, durability, and operational reliability, meeting the stringent requirements of modern industrial processes.

2.15. BENEFITS AND CHALLENGES OF USING COMPOSITE MATERIALS

The adoption of composite materials in the manufacturing of pump components marks a significant advancement in the pursuit of efficiency, durability, and performance in industrial applications. Derived from the insights provided by "5 Ways Structural Composites Improve Pump Efficiency" (Simsite, 2023), this section delves into the multifaceted benefits of utilizing composite materials in pumps, alongside an examination of the challenges encountered.

2.15.1 BENEFITS OF COMPOSITE MATERIALS IN PUMPS

1. **Enhanced Durability and Corrosion Resistance:** Composite materials are inherently inert and offer exceptional resistance to corrosion, a property that significantly extends the lifespan of pumps. Unlike traditional metallic components, such as bronze, which are susceptible to corrosion and cavitation, composite materials maintain their integrity even in aggressive environments. This durability not only reduces the need for frequent replacements but also ensures consistent pump performance over time.

2. **Energy Efficiency:** The optimization of pump structures through the use of structural composites leads to notable reductions in energy consumption. The advanced mechanical properties of composite materials allow for the design of more efficient pump systems that require less power to operate, translating into lower energy costs for users.

3. **Reduced Vibration and Improved Balance:** Completely machined structural-composite impellers exhibit significantly less vibration compared to their metallic counterparts. This is largely due to the superior mechanical and hydraulic balance afforded by composite materials. Reduced vibration and lower radial and axial movements contribute to smoother pump operations and minimize wear and tear on components, enhancing overall reliability.

4. **Lightweight Design:** The lightweight nature of composite impellers reduces shaft deflection, which is crucial for maintaining the alignment of pump components and ensuring efficient operation. This reduction in weight also facilitates easier handling and installation of pump units, further contributing to operational efficiency.

5. **Minimized Leakage and Prevention of Pump Wash-Out:** Composite impellers and casing rings offer a tighter fit and superior wear resistance, which significantly reduces leakage rates. Furthermore, the resistance of composite materials to erosion and corrosion prevents pump "wash-out," a common issue in pumps handling abrasive or corrosive fluids, thereby maintaining the pump's performance integrity over time.

2.15.2. CHALLENGES OF USING COMPOSITE MATERIALS IN PUMPS

While the benefits are considerable, the integration of composite materials into pump design also presents certain challenges:

1. **Cost Considerations:** The initial cost of composite materials and the technology required to manufacture composite components can be higher than that of traditional materials. This may affect the upfront investment in composite-based pump systems.

2. **Material Selection and Design Complexity:** The selection of appropriate composite materials and the design of pump components to leverage the advantages of these materials require specialized knowledge and expertise. Incorrect material selection or design flaws can negate the benefits and potentially lead to pump failure.

3. **Repair and Maintenance Specialization**: Repairing and maintaining pumps made with composite materials may require specialized tools and techniques. The availability of skilled

technicians familiar with composite materials is crucial for ensuring the longevity and performance of these pumps.

The integration of composite materials into pump design represents a promising advancement in the field of industrial machinery, offering significant benefits in terms of efficiency, durability, and performance. Despite the challenges associated with cost, material selection, and maintenance, the advantages provided by composite materials, as outlined by Simsite (2023), underscore their potential to revolutionize pump technology and contribute to more sustainable and cost-effective industrial processes.

CHAPTER THREE

MATERIALS AND METHODS

3.1. MATERIAL SELECTION AND ANALYSIS

Mild steel, being the most used traditional material in pump impellers, is questioned to not be as efficient due to its weight, low corrosion resistance, etc.

Bamboo fiber was integrated into the research due to its lightweight and durability. As well as the project's commitment to environmental sustainability. We know composite materials tend to create a material with superior properties. So by integrating bamboo fiber with aluminum, the primary aim is to design a centrifugal pump more efficient than the traditional models through the use of locally available materials therefore reducing the problems of weight and corrosion resistance.

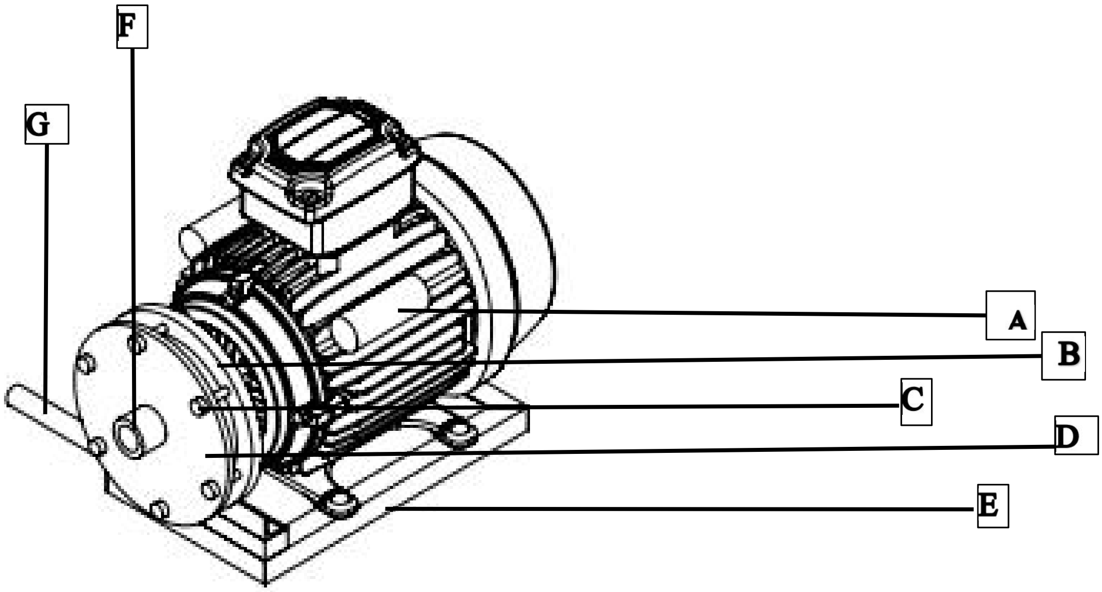


Figure 3.1: 3D Model of an assembled centrifugal pumping system with labeled paths (circular casing)

PARTS

A - Motor Capacitor

B - Impeller casing

C - Nut and bolt (Fastening mechanism)
D - Impeller casing cover
E - Base
F - Suction outlet
G - Discharge outlet

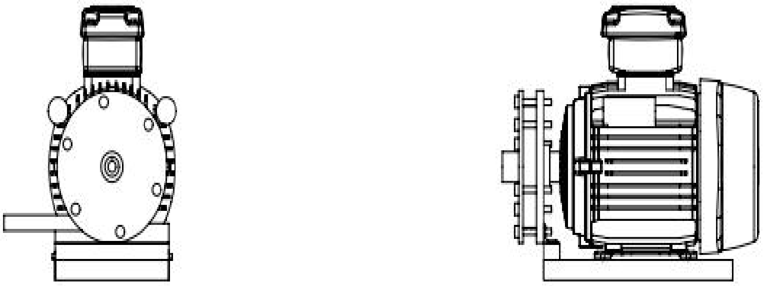


Figure 3.2: front and side view of the assembled centrifugal pumping system

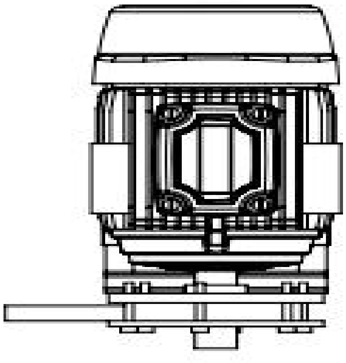


Figure 3.3: Plan of the assembled centrifugal pumping system

3.2. CONCEPTUAL DESIGN

3.2.1. CONCEPT ONE - CENTRIFUGAL PUMP WITH A FLAT CYLINDRICAL CASING

3.2.1.1. FOCUS: Enhancing pump efficiency and fluid flow dynamics through innovative casing design.

3.2.1.2. ADVANTAGES:

1. **Optimized Fluid Flow**: The flat cylindrical casing configuration is engineered to promote smooth and efficient fluid flow within the pump. By minimizing turbulence and pressure losses, this design enhances overall pump performance and efficiency.
2. **Space-Efficient Design:** The flat cylindrical casing allows for a more compact pump assembly compared to traditional designs. This space-saving feature is beneficial for installations where space is limited, enabling easier integration into existing systems.
3. **Ease of Maintenance**: The simplified design of the flat cylindrical casing facilitates easier access for maintenance and repairs. Technicians can quickly inspect and service the pump components, reducing downtime and operational disruptions.
4. **Reduced Energy Consumption:** The streamlined flow path within the flat cylindrical casing minimizes energy losses, resulting in lower energy consumption during pump operation. This reduction in energy usage translates to cost savings and environmental benefits.
5. **Versatile Application:** The flat cylindrical casing design is adaptable to various pumping applications across industries such as agriculture, water management, and industrial processes. Its versatility makes it suitable for a wide range of fluid transfer tasks.

3.2.1.3. DISADVANTAGES:

1. **Limited Head Capacity:** Depending on the specific design and operational parameters, flat cylindrical casing pumps may have limitations in achieving high head capacities compared to other pump configurations. This could restrict their suitability for certain applications requiring significant vertical lift.
2. **Complex Manufacturing**: The design and manufacturing of flat cylindrical casings may require specialized techniques and equipment, potentially adding complexity and cost to the production process. This complexity could also extend to maintenance and repair procedures.
3. **Potential Flow Instabilities**: In certain operating conditions, flat cylindrical casing pumps may experience flow instabilities or performance fluctuations. Proper design optimization and testing are essential to mitigate these issues and ensure consistent pump performance.

4. **Specific Application Requirements**: While versatile, flat cylindrical casing pumps may not be the optimal choice for all pumping scenarios. Certain applications may require specialized pump designs tailored to unique operational requirements, potentially limiting the applicability of this concept in some contexts.

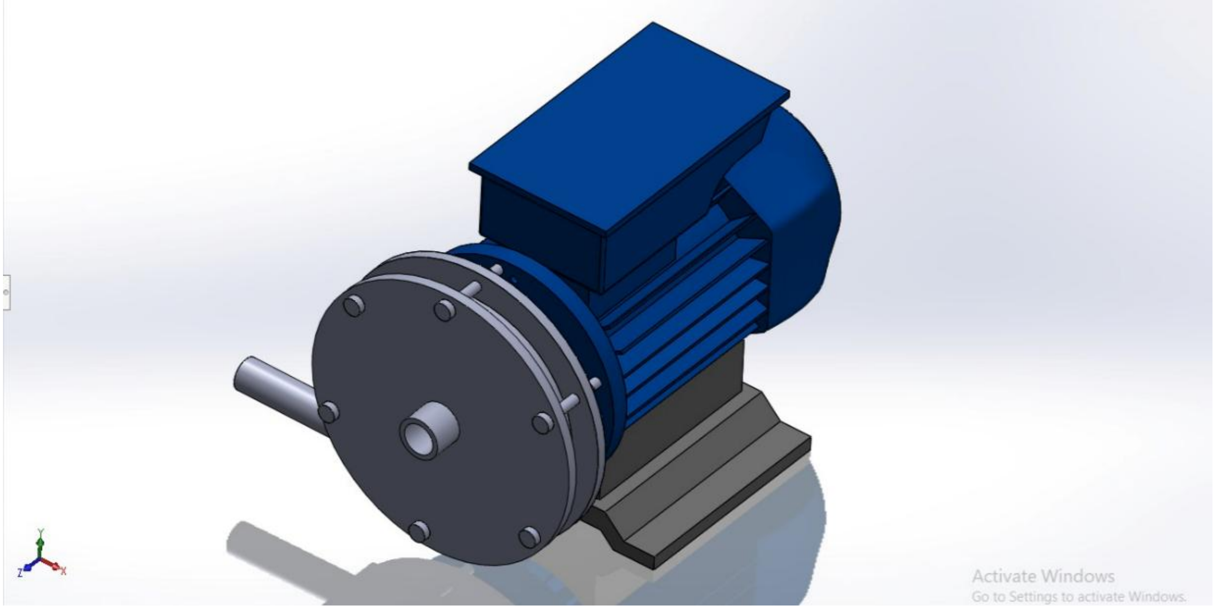


Fig 3.4 - solid works design of concept one

3.2.2. CONCEPT TWO - CENTRIFUGAL PUMP WITH AN INVOLUTE CASING

3.2.2.1. FOCUS: Leveraging a typical centrifugal pump casing design known for its efficiency and performance characteristics.

3.2.2.2. ADVANTAGES:

1. **Proven Performance**: The involute casing design is well-established in centrifugal pump engineering, known for its ability to efficiently convert kinetic energy into pressure. This design has been extensively tested and optimized for various pumping applications.

2. **High Head Capacity:** Involutes casing pumps are capable of achieving high head capacities, making them suitable for applications requiring significant vertical lift, such as water distribution networks and industrial processes.

3. **Robust Construction:** The involute casing design offers structural robustness, with reinforced geometry to withstand high pressures and mechanical stresses. This durability enhances pump reliability and longevity in demanding operating environments.

4. **Broad Industry Adoption:** Involutes casing pumps are widely used across industries due to their reliable performance and versatility. Their established reputation and compatibility with existing infrastructure make them a preferred choice for many pumping applications.

5. **Efficient Fluid Handling:** The streamlined flow path within the involute casing minimizes energy losses and turbulence, resulting in efficient fluid handling and reduced operational costs over the pump's lifespan.

3.2.2.3. DISADVANTAGES:

1. **Complex Casing Geometry:** The intricate geometry of involute casings may present challenges in manufacturing and maintenance. Specialized machining techniques and equipment may be required, increasing production costs and complexity.t.

2. **Space Requirements**: Involutes casing pumps typically have larger footprints compared to some alternative designs, potentially limiting their suitability for installations where space is constrained.

3. **Higher Initial Investment:**: The advanced design and construction of involute casing pumps may entail higher initial investment costs compared to simpler pump configurations. However, this investment is often justified by long-term performance benefits and operational savings.

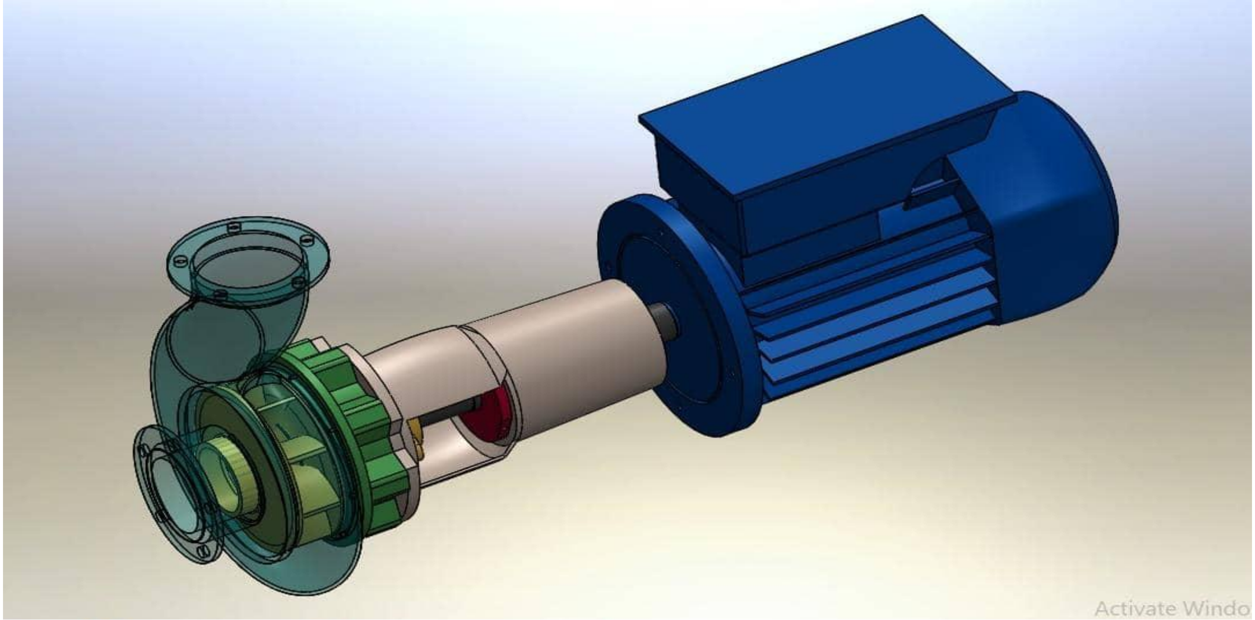


Fig 3.5 - solid works design of concept two

3.2.3. SELECTION OF CONCEPT

Choosing between Concept 1 and Concept 2 involves evaluating the specific requirements and priorities of the pumping application:

1. If space efficiency, ease of maintenance, and versatility are paramount: Concept 1, with its flat cylindrical casing, may offer a more suitable solution. This design excels in applications where compactness, accessibility, and adaptability are key considerations.

2. If high head capacity, proven performance, and robust construction are critical: Concept 2, featuring an involute casing, may be the preferred choice. This design is well-suited for applications requiring reliable operation under high-pressure conditions and where established performance characteristics are essential.

Ultimately, the selection should be based on a comprehensive analysis of the specific operational requirements, budget constraints, and long-term objectives of the pumping system. Both concepts offer unique advantages and may be better suited to different scenarios, highlighting the importance of careful consideration and evaluation during the decision-making process.

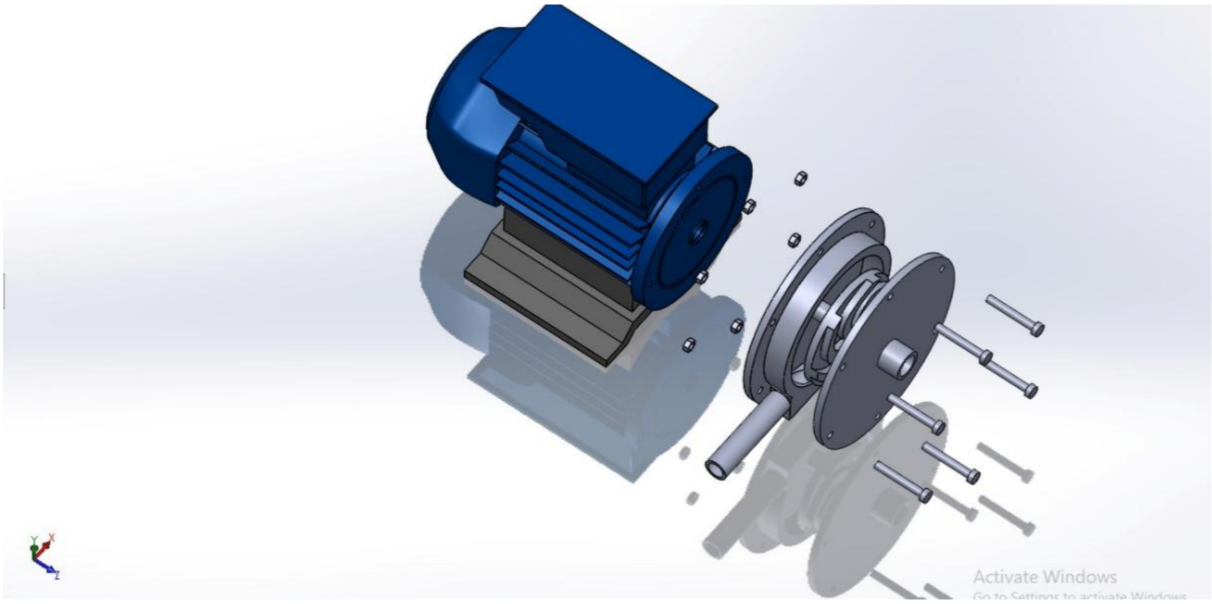


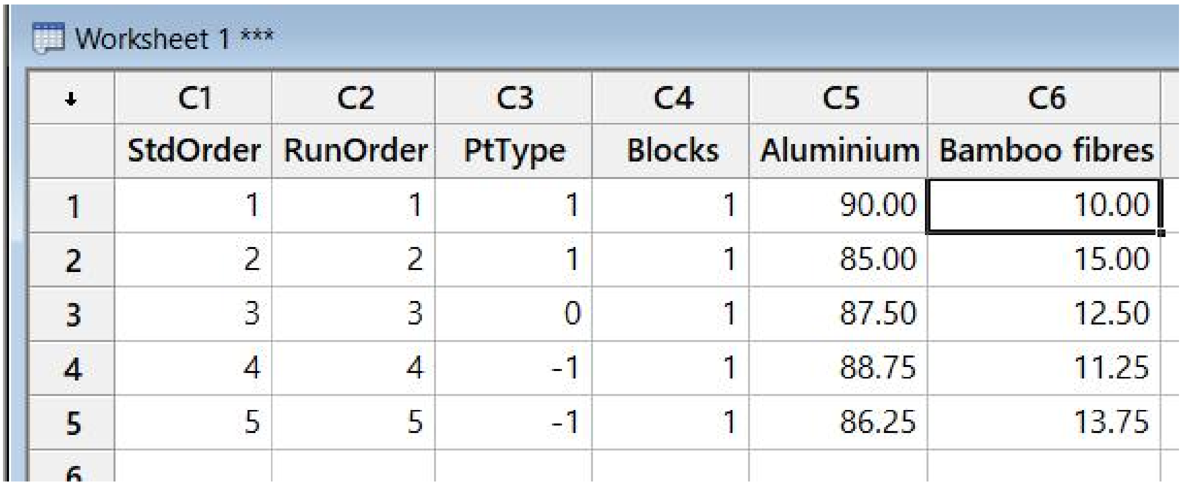
Fig 3.6 - exploded view of concept one

3.3. DESIGN AND SIMULATION

With the aid softwares such as CAD software (SolidWorks) and Minitab mixture DOE, adequate designs and data was achieved. With CAD software (SolidWorks) with a focus on a monoblock pump configuration the design featured a simple circular casing and an enclosed impeller, utilizing an aluminum bamboo fiber composite material for all parts except the motor.

Minitab is a powerful statistical software package used for data analysis, quality improvement, and Six Sigma projects. DOE is a systematic approach used to determine the relationship between factors affecting a process and the output of that process. Using Minitab mixture DOE, the optimal composition of aluminum and bamboo fiber for the pump components was achieved, and five different data was given.

Using a total weight of 2kg for the whole composite material, Minitab was able to give the data of below



Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6
	StdOrder	RunOrder	PtType	Blocks	Aluminium	Bamboo fibres
1	1	1	1	1	90.00	10.00
2	2	2	1	1	85.00	15.00
3	3	3	0	1	87.50	12.50
4	4	4	-1	1	88.75	11.25
5	5	5	-1	1	86.25	13.75
6						

Fig 3.7 - Minitab results

RATIO OF ALUMINIUM TO BAMBOO

ALUMINIUM (KG)	BAMBOO (KG)
1.8	0.2
1.775	0.225
1.75	0.25
1.725	0.275
1.7	0.3

Table 3.1 - Table of values of Aluminium - Bamboo ratio

3.4. SAMPLE FABRICATION

The Bamboo was grinded into powder form. It was then measured using a digital weight scale at the Centre for Research, Innovation, and Development, University of Benin, Edo State to get the ratio of the bamboo fiber that would be melted with the aluminium scraps so as to satisfy the data obtained from Minitab software.

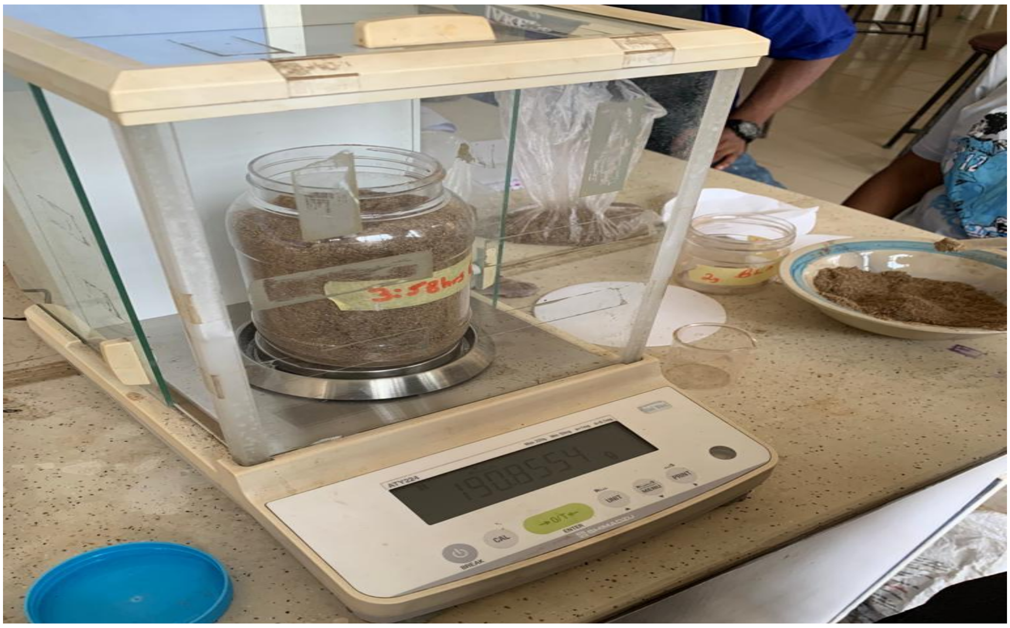


Fig 3.8 - Image of bamboo being weighed at the center for research at the university of benin

Fig 3.9 - Image of bamboo being measured

The five data, including a sixth consisting of pure aluminium was molded into samples in a sand mold with the use of a blast furnace to melt the various compositions of aluminium and bamboo fibre. After melting, each of the compositions were poured into the cavity of the sand mold and left to cool.

The Six samples were then smoothened so as to accurately carry out the various tests.

Fig 3.10 - Molten composite being poured into the cavity

Fig 3.11 - Samples Being Melted in a Blast Furnace

Fig 3.12 - Image of Samples

Fig 3.11 - Image of samples after filing

3.5. MECHANICAL AND PHYSICAL TESTS

The composite materials derived from the Minitab design of experiments were subjected to rigorous physical testing, including impact and tensile testing, at the Centre for Research, Innovation, and Development, University of Benin, Edo State. These tests aimed to evaluate the mechanical properties of each sample comprehensively.

By subjecting the six compositions of composite materials to impact and tensile testing, we aimed to assess their durability, strength, and resilience under different stress conditions. The results obtained from these tests were then fed into the Minitab mixture design of experiments to optimize and determine the most effective composition of the composite material.

The optimized composition from minitab obtained through these physical tests was subsequently utilized in the construction of the centrifugal pump. This meticulous process ensured that the materials used in the pump's construction possessed the requisite mechanical properties to withstand the operational demands and environmental conditions they would encounter.

Through the integration of physical testing into our research methodology, we not only identified the optimal composition of the composite material but also ensured the reliability, durability, and performance of the centrifugal pump constructed using these materials..

3.5.1. IMPACT TEST

Impact tests assess a material's ability to absorb energy during sudden loading or impact. They are crucial for assessing material toughness and resistance to fracture under dynamic loading conditions. The most common method for impact testing is the Charpy or Izod test, where a standardized specimen is subjected to a sudden impact by a pendulum. The energy absorbed by the specimen during fracture is measured, providing a measure of its toughness. (William D. Callister and David G. Rethwisch et at 1997)

‘

IMPACT TESTING MACHINE

Results of Impact Testing for Composite Material Samples

S/N	COMPOSITION	ENERGY
1	Pure	0.2J
2	0.2kg	0.15J
3	0.225kg	0.25J
4	0.5kg	0.08J
5	0.75kg	0.05J
6	0.3kg	0.8J

Based on the impact testing result gotten, The test seems to favor the composite sample with 0.3 kg reinforcement. This sample absorbed the highest amount of energy (0.8 J) among all the samples tested. Higher energy absorption indicates better toughness and resilience, suggesting that the composite with 0.3 kg reinforcement offers superior performance in resisting sudden loading conditions compared to the other samples tested.

3.5.2. TENSILE TEST

Tensile tests measure a material's mechanical behavior under tensile loading, providing valuable data on its strength, elasticity, ductility, and other properties. In a tensile test, a standardized specimen is subjected to gradually increasing tensile force until it fractures. The load and elongation or strain are continuously measured, allowing the construction of stress-strain curves and determination of material properties. (Kyriakos Komvopoulos et al 2018). A universal material testing beam was used to undergo this test.

TENSILE TEST MACHINE

3.6. OPTIMIZING COMPOSITE MATERIAL SELECTION WITH MINITAB: CONSIDERATIONS AND RESULTS

The inclusion of parameters such as cost, weight, and feasibility into the Minitab Design of Experiments (DOE) analysis served to enrich the optimization process, aiming to identify the most advantageous composite material composition for the centrifugal pump. By integrating these factors into the analysis, we sought to ensure that the selected mixture ratio aligns not only with the desired mechanical properties but also with practical considerations essential for real-world implementation.

Throughout the DOE analysis, each parameter was assigned appropriate weightage, reflecting its relative importance in the overall decision-making process. Cost considerations, for instance, played a pivotal role in determining the economic viability of each mixture ratio, ensuring that the final selection remains financially feasible for large-scale production.

Moreover, the weight parameter was instrumental in evaluating the physical characteristics of the composite material, especially its density and structural integrity. By accounting for weight, we aimed to select a mixture ratio that strikes an optimal balance between mechanical performance and lightweight design, crucial for applications where weight reduction is advantageous.

Feasibility assessments were also integrated into the analysis to evaluate the practicality of manufacturing each composite material composition. Factors such as material availability, processing complexity, and scalability were considered to ensure that the selected ratio could be feasibly implemented in industrial production settings.

Ultimately, the Minitab DOE analysis culminated in the identification of the 0.3kg mixture ratio as the optimal result. This selection represents the composite material composition that best satisfies the mechanical requirements of the centrifugal pump while concurrently meeting cost, weight, and feasibility criteria. By leveraging the power of statistical analysis and incorporating multi-dimensional parameters, we have arrived at a robust and optimized solution poised to deliver superior performance and reliability in real-world applications.

3.7. DESIGN CONSIDERATION

The use of research data and experiments in the field of hydraulics has led to constant development of the centrifugal pump over the years. The design of the components of the pump are based on established codes and standards in design and fabrication.

This project considers designs and analysis for a single stage centrifugal pump with the desired capacity (Q) of 12.5litres/sec at a head (H) of 13m and shaft speed of 1400rpm.

To ensure efficiency, reliability and suitability for its applications during the design, there are some key design considerations which includes; Fluid Properties (such as viscosity, density, corrosiveness, temperature, and whether the fluid is a liquid or a gas.), Flow Rate and Pressure Requirements, Pump Type Selection, Pump Efficiency, Material Selection, Sealing Mechanisms, Cavitation (adequate Net Positive Suction Head and system layout considerations help minimize cavitation risks), Suction and Discharge Configurations, Operating Conditions, Installation and Maintenance, Safety and Environmental Considerations, Cost Considerations. (Johann. F. G et at 2009)

By considering these factors during the design process, we can successfully develop pumps that meet performance requirements, ensure reliability, and minimize environmental impact while optimizing costs.

3.7.1. DESIGN CONSIDERATION FOR MAJOR COMPONENTS OF A CENTRIFUGAL PUMP

1. Impeller design

Common types of impeller include closed, semi-open, and open impellers, each suited for different applications. Closed impellers are commonly used in high-efficiency applications and handling clean fluids. Open impellers are suitable for handling fluids with high solids content or viscosity since they are less prone to clogging. They are commonly used in applications such as wastewater treatment, slurry pumping, and handling abrasive fluids. A semi-open impeller combines characteristics of both closed and open impellers. It has a single shroud or cover plate on one side, while the other side is open. Semi-open impellers strike a balance between efficiency and solids-handling capability and are often used in applications with moderate solids content (Johann. F. G et al 2009) The pump being considered is an end-suction pump, therefore a semi-open impeller is employed. The impeller is made up of six vanes and is placed between the impeller casing which connects to the motor. The impeller was cast in a sand mold and machined. The material used is a composite of aluminium and bamboo fibre. The impeller is connected to the motor and rotates when the motor is turned on. It is housed in the casing.

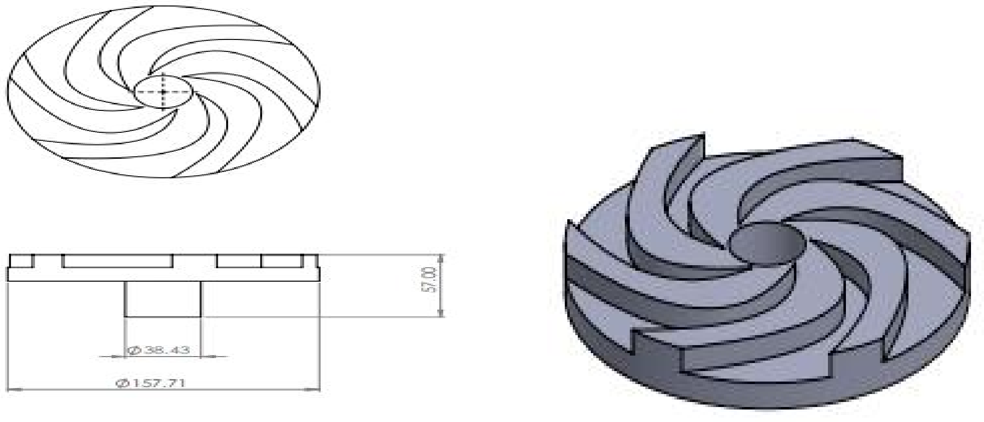


Figure 3.11: 3D model of the impeller

2. Shaft design

The shaft speed of a pump can vary widely depending on factors such as the pump type, its size, design, and the specific application it's being used for. (Richard G. Budynas and Keith J. Nisbett et al 1956). The shaft speed of this pump is 1450 rpm and this differs from the critical speed by about 20%

3. Mechanical Seal

A mechanical seal is a device used to prevent fluid leakage between two rotating or reciprocating shafts. It typically consists of two main components: a rotating seal face and a stationary seal face, which come into contact to create a seal (Richard Salant et al 1985). The internal assembly mechanical seal (hole ring) was adopted for the project. The seal is made of synthetic rubber and spring. Since rubber is flexible, it is more effective.

3.8. DETAILED DESIGN

Some certain information must be available before a suitable pump can be designed, these include:

- Fluid being pumped: Clean water. With a temperature between 15°C to 40°C.
- Rate of discharge (capacity) Q = 0.0125m3/s
- Head or pressure, H = 13m.
- Rotational speed, N = 1050rpm.

$$N_S = K_S.N.(\sqrt{Q}/H^{3/4}) \qquad (3.1)$$

$$K_S = 3.65 \qquad \text{(Inegbedion et al., 2021)} \qquad (3.2)$$

The shape number $N_S = 3.65 \times 1450 \times (\sqrt{0.0125} / 13^{3/4}) = 86.43 m/s$

N_{usf} = ρ QgH/1000 (3.3)

Where ρ = 1000kg/m^3 and g= 9.81m/s^2

The useful power N_{usf} = (1000 x 0.0125 x 9.81 x 13) / 1000 = 1.59KW

N_{mp} which is the motor power = 2.2KW

η = N_{usf} / N_{mp} (3.4)

η = 1.59 / 2.2 = 0.722

η = 72.2%

3.8.1 IMPELLER DESIGN

ϕ = U_2 / √2gH (3.5)

Speed constant of 0.97 is used

The Impeller rim velocity U_2 = ϕ√2gH = 0.97√(2 x 9.81 x 13) = 15.49 m/s

Also, the Impeller rim velocity

U_2 = πD_2N / 60 (3.6)

Making D_2 subject formula

D_2 = 60U_2 /πN (3.7)

D_2 = (60 x 15.49) / (π x 1450) = 0.204m = 204.0mm

Furthermore,

$D_1/D_2 = 0.3$ (3.8)

$D_1 = 0.3D_2 = 0.3 \times 204.0 = 61.2mm = .0612m$

With the impeller eye diameter, the impeller eye velocity can be obtained using

$U_1 = \pi D_1 N / 60$ (3.9)

$U_1 = (\pi \times 0.0612 \times 1450) / 60 = 4.65m/s$

The Impeller eye width and Impeller outer width b_1 and b_2 can be obtained as such:

$b_1 = 1.5D_1 / 4$ (3.10)
$b_1 = (1.5 \times 0.0612) / 4 = 0.02295m = 22.95mm$

$b_2 = b_1 D_1 / D_2$ (3.11)

Recall, from equation (3.8)

$D_1 / D_2 = 0.3$

$b_2 = 0.3b_1 = 0.3 \times .02295 = 0.006885m = 6.885mm$

3.8.2. IMPELLER BLADE ANGLES

Impeller blade angles play a crucial role in determining the performance characteristics of a pump, including efficiency, head (pressure), and flow rate. The design of impeller blades involves several key angles, each contributing to the overall efficiency and effectiveness of the pump. (D.E. Bently and J.S. Hatch et al 2006).

3.8.3. HYDRAULIC EFFICIENCY ƞH,

This refers to the effectiveness or performance of a hydraulic system or component in converting input energy into useful work or output, and it is gotten from the relationship:

$(1-\eta h) / (1-\eta) = Kh,$ (3.12)

Kh usually ranges from about 0.5 to 0.8 depending on the specific speeds.

$Kh=0.5$

Thus $(1-\eta h) / (1-\eta) = 0.5,$

$(1-\eta h) = 0.5(1-\eta)$

$\eta = 0.722$

$(1-\eta h) = 0.5(1 - 0.722) = 0.139$

$(1-\eta h) = 0.139$

$\eta h = 1 - 0.139 = 0.861 = 86.1\%$

3.8.4. TRUE WHIRL COMPONENT, VN

This refers to the component of the fluid velocity that is tangential to the path of rotation or swirling motion of the fluid. For the head H to be attained, the liquid must leave the impeller with a tangential velocity component V, which can be obtained from the relationship below.

$H = \eta h (VnU_2) / g$ *(R.K. Turton et al 1993) (3.13)*

Making Vn subject formula

$Vn= Hg / \eta hU_2 = (13 \times 9.81)/(86.1 \times 15.49) = 0.0956 m/s$

3.8.5. IDEAL WHIRL COMPONENT, V∞

This refers to the component of velocity in a fluid flow that is purely tangential to the direction of rotation or swirling motion, without any radial component. (Frank M. White et al 1979). In other words, it represents the velocity of fluid particles moving strictly in a circular or tangential path around the center of rotation.

Due to the fact the liquid has an imperfect response to the tangential impulsion of the blades, the outlet impeller blade angle must be suited to an ideal tangential component V∞ that is greater than the true value. The relation between the two (ideal and true value) is highly complex, which means, only a rough approximation can be obtained using the relationship below;

$$V\infty = Vn\,[1 + (Kn/Z)] \qquad (3.14)$$

Where Z is the no. of blades, and Kn, is a factor taken as about 3 for low specific speeds, and 5 for high specific speeds.

$V\infty = 0.0956[1 + (3/6)] = 0.1434 m/s$

3.8.6. VELOCITY OF FLOW, Y_2

This is obtained from the expression;

$Y_2 = \Psi \sqrt{2gH}$

Where Ψ is the flow ratio of 0.28. (3.15)

$Y_2 = 0.28\sqrt{(2 \times 9.81 \times 13)} = 4.472 m/s$

3.8.7. OUTLET BLADE ANGLE Γ

This is the angle between the outlet flow direction and the trailing edge of the impeller blade. The outlet blade angle influences the discharge characteristics of the pump, including the pressure and velocity of the fluid as it exits the impeller. Proper outlet blade angles help optimize pump performance and prevent recirculation or backflow. (Frank M. White et al 1979).

This is gotten from the expression.

$$Cot\,\gamma = (U_2 - V\infty)/Y_2 \qquad (3.16)$$

$Cot\,\gamma = (15.49 - 0.1434) / 4.472 = 3.4317$

$\gamma = tan^{-1}\, 1 / Cot\,\gamma = tan^{-1} (1 / 3.4317) = 16.246°$

3.8.8. INLET FLOW VELOCITY

$$Y_1 = (Y_2 \times (D_2 b_2)) / (D_1\, b_1) \qquad (3.17)$$

Therefore, $Y_1 = 4.472 \text{ x } (0.204 \text{ x } 0.006885)/(0.0612 \text{ x } 0.02295) = 3.9220 \text{ x } 1= 4.472 m/s$

Inlet blade angle, β.

$\tan \beta = Y_1 / U_1$ (3.18)

$\beta = \tan^{-1} (Y_1 / U_1) = \tan^{-1} (4.472 / 4.65) = 43.882$

Check for the exact number of blades, Z.

$Z= 6.5 [M+1 / M - 1] \text{ x } \sin [\beta + \gamma]$ (3.19)

Where $M = D_1 / D_2 = 1 / 0.3 = 3.33$

$Z= 6.5 [(3.33 +1) / (3.33 - 1)] \text{ x } \sin [43.882 +16.246] = 6.05$

$Z = 6$ *blades*

3.8.9. CASING DESIGN

For casing inside diameter, D_3.

$D_3 = D_2 (\delta +1)$ (3.20)
where, $\delta = 0.07$
$D_3 = 204 \text{ x } (0.07+1) = 218.28mm = 0.21828m$

For casing width, b_3

$b_3 = 1.25 b_1$ (3.21)

$b_3= 1.25 \text{ x } 22.95 = 28.6875mm = .0286875m$

For casing thickness, Tc

$Tc= [(XYDP) / 200 dt] + Z$ *(Inegbedion et al., 2021)* (3.22) *where* $D = 35.5$, $P = 50\text{m of water}$, $X = 4.5$, $Y = 1.6$, $Z = 2\text{mm}$, $dt = 2.5$

From tables of values;

$10\text{m of water} = 1\text{kg/mm}^2$
$50\text{m of water} = 5\text{kg/mm}^2$

$Tc = [(4.5 \times 1.6 \times 5 \times 35.5) / (200 \times 2.5)] + 2 = 4.556\ \text{mm} \equiv 5\text{mm}$

For Casing outer diameter

$$D_4 = 2Tc + D_3 \qquad (3.23)$$

$D_4 = 2 \times 5 + 95.765 = 105.765\ \text{mm}$

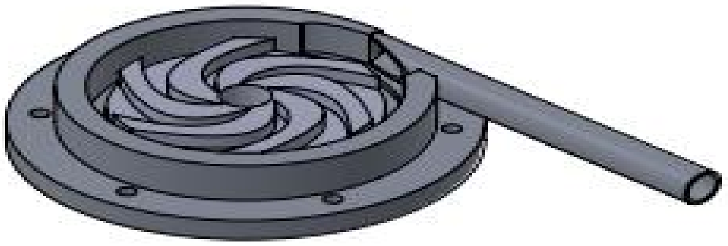


Figure 3.4: 3D model of the impeller in its casing which has the discharge outlet

Figure 3.5: front and side view of the impeller in its casing

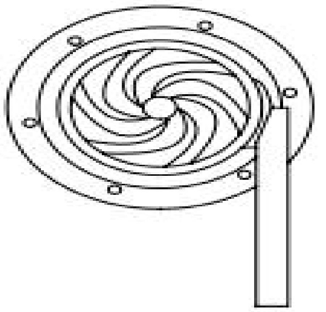


Figure 3.6: the plan of the impeller in its casing

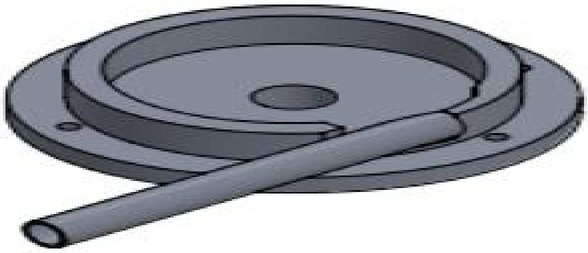


Figure 3.7: 3D model of the impeller casing which has the discharge outlet

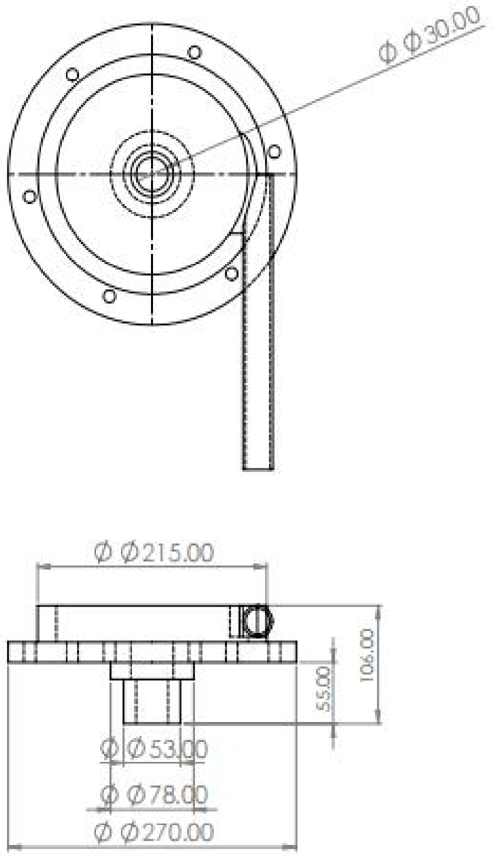


Figure 3.8: Side and plan view of the impeller casing which has the discharge outlet

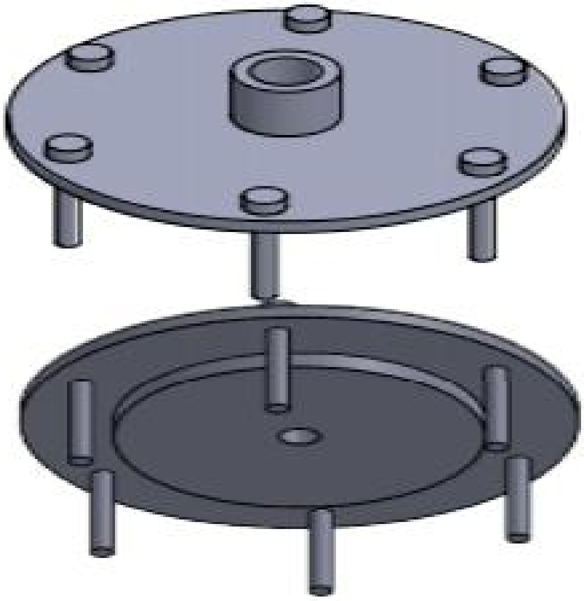


Figure 3.9: 3D model of the impeller casing cover with Bolts

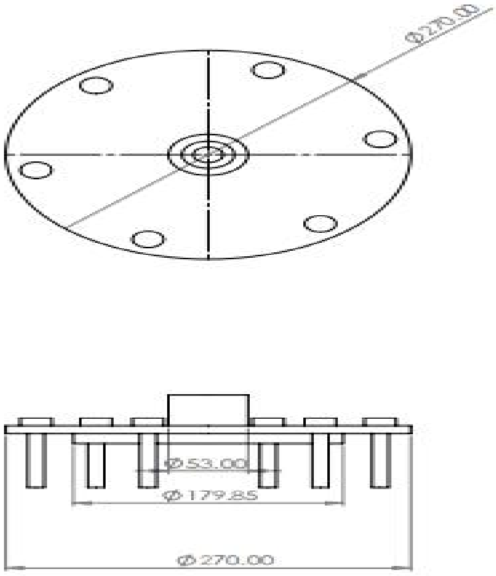


Figure 3.10: Plan and side view of the impeller casing cover

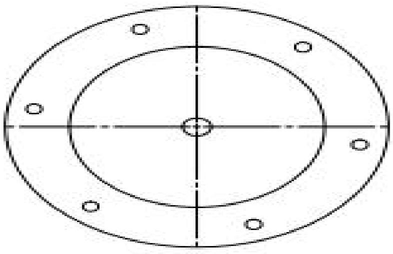


Figure 3.10.1: a plan of the impeller casing cover

3.9. DETAILED DIAGRAMS

3.10. BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

3.10.1. MATERIALS BILLS

The table below shows the average cost of all 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.

Table 4.1: Materials Cost

Item number (S/N)	Description of components	Material Used	Quantity	Methods of Manufacture	Estimated cost (N)
1.	Impeller casing	Aluminum & Bamboo Fibre	1	Casting	35000
2.	Shaft-Impeller key	Steel	1	Purchased	3500

3.	Bolts and Nuts	Steel	5	Purchased	3600
4.	Electric motor (Single-Phase)	Nil	1	Purchased	80000
5.	Discharge outlet	Stainless steel rod	1m	Purchased	4000
6.	Electric Wire	Copper	8yards	Purchased	9600
7.	Bamboo		¼ cane	Purchased	3500
8.	Yam		1	purchased	2000
9.	Mechanical seal (hole ring)	Rubber	1	Purchased	2500
10.	Base	Mild steel	2 yards	Purchased	3500
	Total				147,200

3.10.2. LABOR COST

The table below shows a summary of the cost of labor incurred

Table 4.2: Cost of Labor And Services

Description of Services	Estimated Cost (₦)
CAD Solidworks design	28,000
Transportation	25,000
Fabrication; Test samples (15 composite samples + 3 pure Aluminium samples)	68,000
Fabrication; Main Pump components (Impeller casing,shaft,and suction pipe)	93,000
Labour for Casting	30,000
Cutting and Grinding bamboo fibre	15,000
Machining	62,000
Weighing various bamboo fibre compositions	1500

Total cost	322,000

3.10.3. MANUFACTURING COST

The total cost of manufacturing the centrifugal pump is obtained by adding the cost of materials and the cost of labor/ services as listed in Tables 4.1 and 4.2 respectively:

Total cost of pump = 145,200 + 322,000 = N469,200

CHAPTER FOUR

DISCUSSION AND RESULT ANALYSIS

4.1. TESTING

In this section, we delve into the outcomes of the testing phase, which played a pivotal role in assessing the performance and characteristics of the composite material samples. Through a series of rigorous tests, including tensile testing and physical evaluations, we aimed to glean insights into the mechanical properties and suitability of the materials for centrifugal pump construction.

4.1.1. PHYSICAL TESTING

1. Results of Tensile Testing for Composite Material Samples

a) **Pure sample of Aluminium**

1st EXPERIMENT

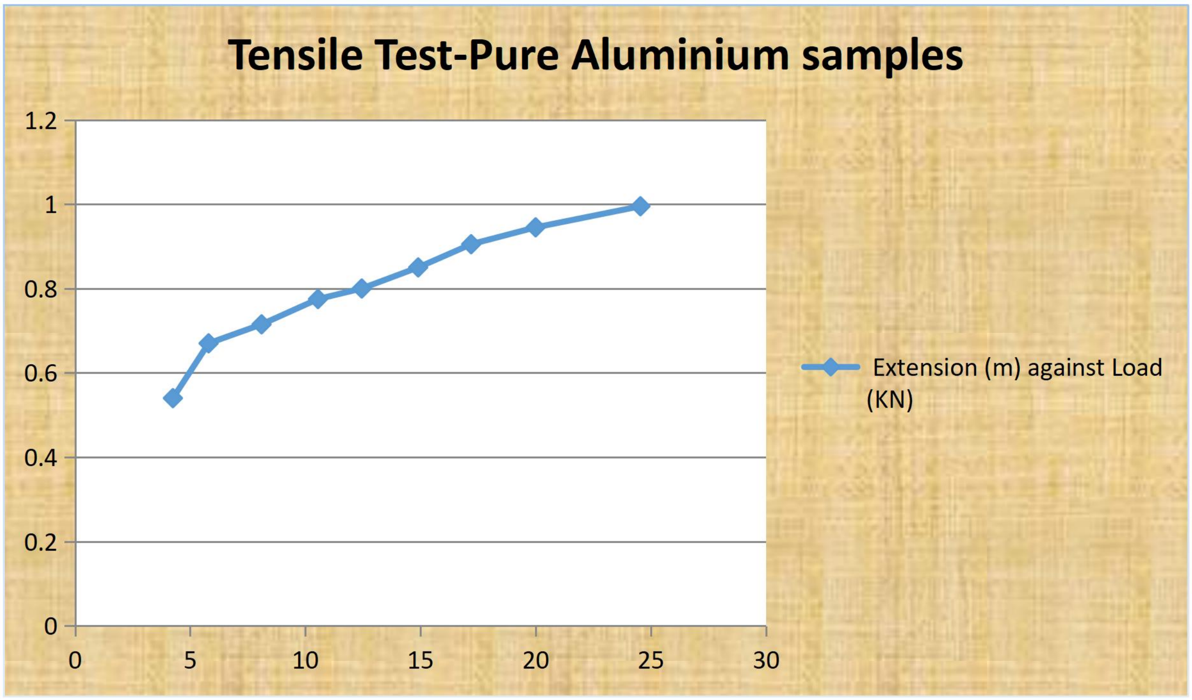
LOAD (KN)	EXTENSION(m)
0.2	0.37
1.3	0.58
4.3	0.63
7.5	0.72
9.5	0.76
12.7	0.81
15.4	0.86
17.6	0.91
26.3	1.02

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
8.3	0.71
10.3	0.76
11.9	0.80
13.6	0.83
15.4	0.84
17.1	0.89
19.0	0.90
20.9	0.93
25.2	1.12

AVERAGE

LOAD (KN)	EXTENSION(m)
4.25	0.54
5.80	0.67
8.10	0.715
10.55	0.775
12.45	0.80
14.90	0.85
17.20	0.905
20.00	0.945
24.55	0.995



b) **0.2kg of composite material**

1st EXPERIMENT

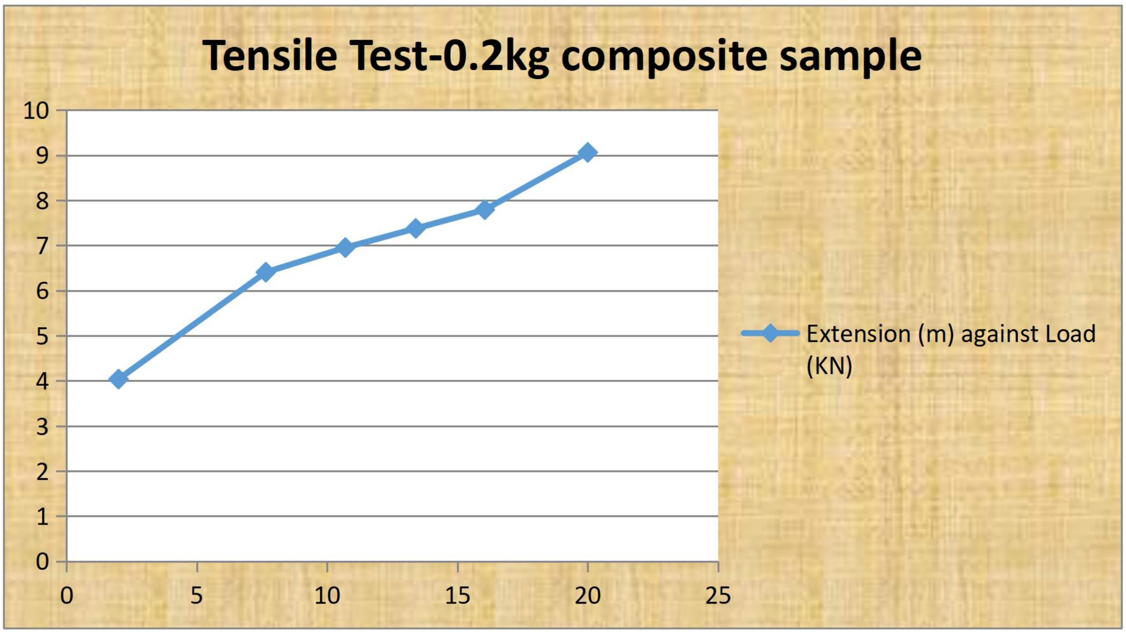
LOAD (KN)	EXTENSION(m)
3.0	5.21
9.0	7.49
10.7	7.91
11.8	8.22
13.3	8.57
17.4	10.67

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
1.0	2.86
6.3	5.32
10.7	5.99
15.0	6.53
18.8	7.01
22.6	7.45

AVERAGE

LOAD (KN)	EXTENSION(m)
2.00	4.035
7.65	6.405
10.70	6.95
13.40	7.375
16.05	7.79
20.00	9.06



c) **0.225kg of composite material**

1st EXPERIMENT

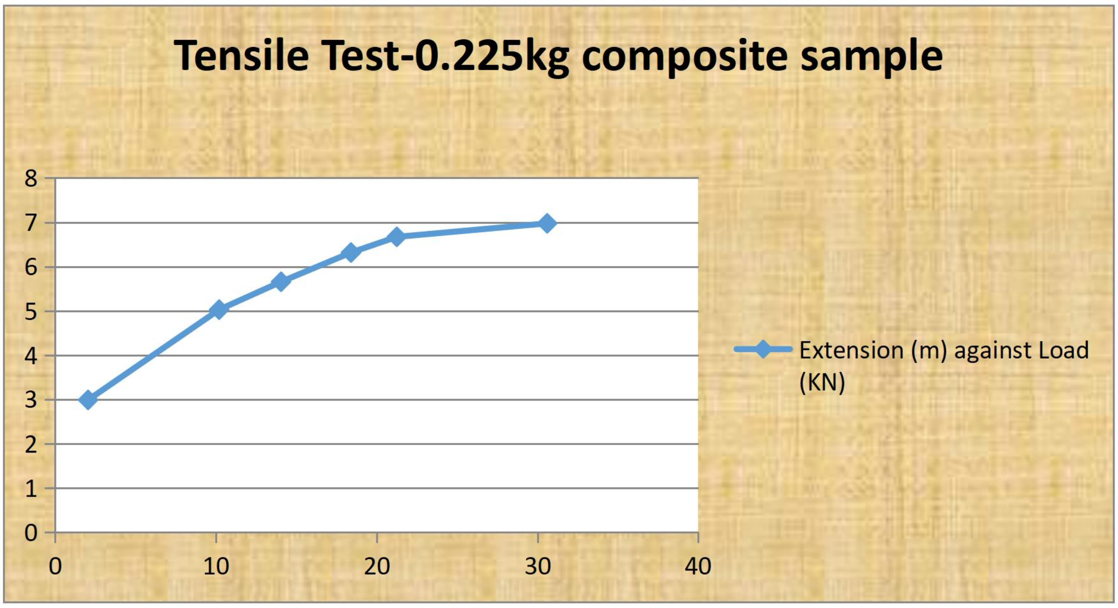
LOAD (KN)	EXTENSION(m)
1.7	3.07
9.9	4.93
14.1	5.40
18.1	5.8
21.6	6.18
39.2	6.6

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
2.4	2.90
10.5	5.12
14.0	5.91
18.7	6.83
20.9	7.16
22.0	7.35

AVERAGE

LOAD (KN)	EXTENSION(m)
2.05	2.985
10.2	5.025
14.05	5.655
18.40	6.315
21.25	6.67
30.6	6.975



d) **0.25kg composite material**

1st EXPERIMENT

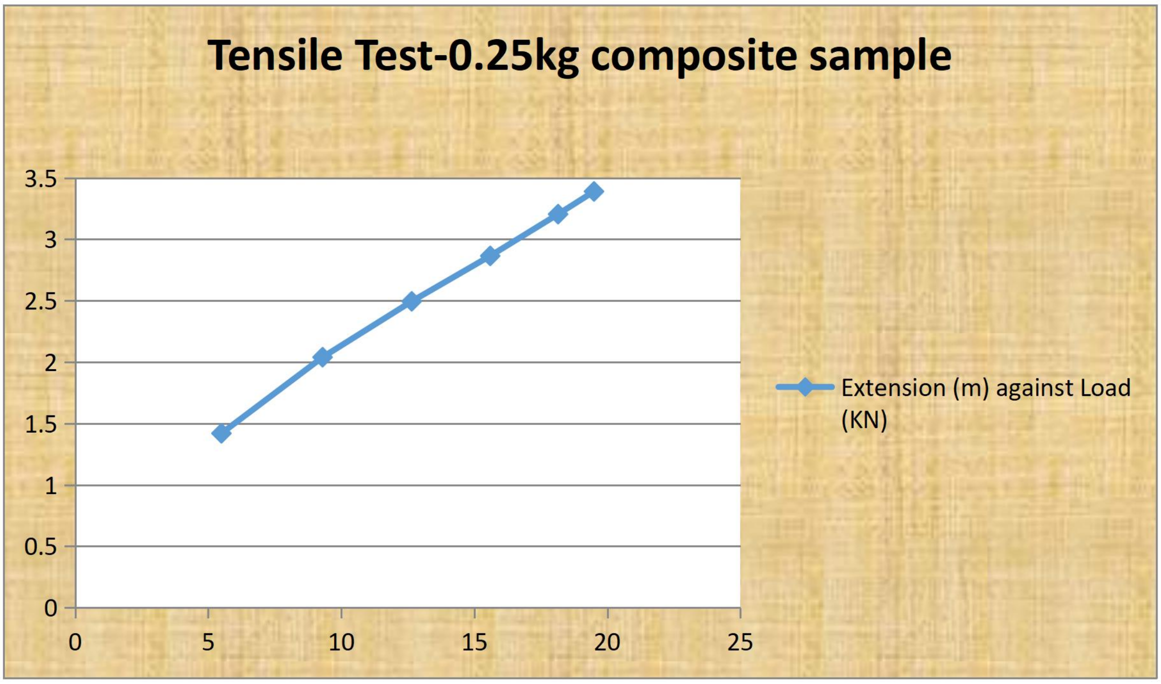
LOAD (KN)	EXTENSION(m)
6.5	1.32
9.7	1.76
12.1	2.16
16.4	2.49
19.2	2.81
20.7	2.99

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
4.5	1.52
8.9	2.32
12.2	2.83
14.8	3.24
17.1	3.60
18.3	3.79

AVERAGE

LOAD (KN)	EXTENSION(m)
5.50	1.42
9.30	2.04
12.65	2.495
15.60	2.865
18.15	3.205
19.50	3.390



e) **0.275kg of composite material**

1st EXPERIMENT

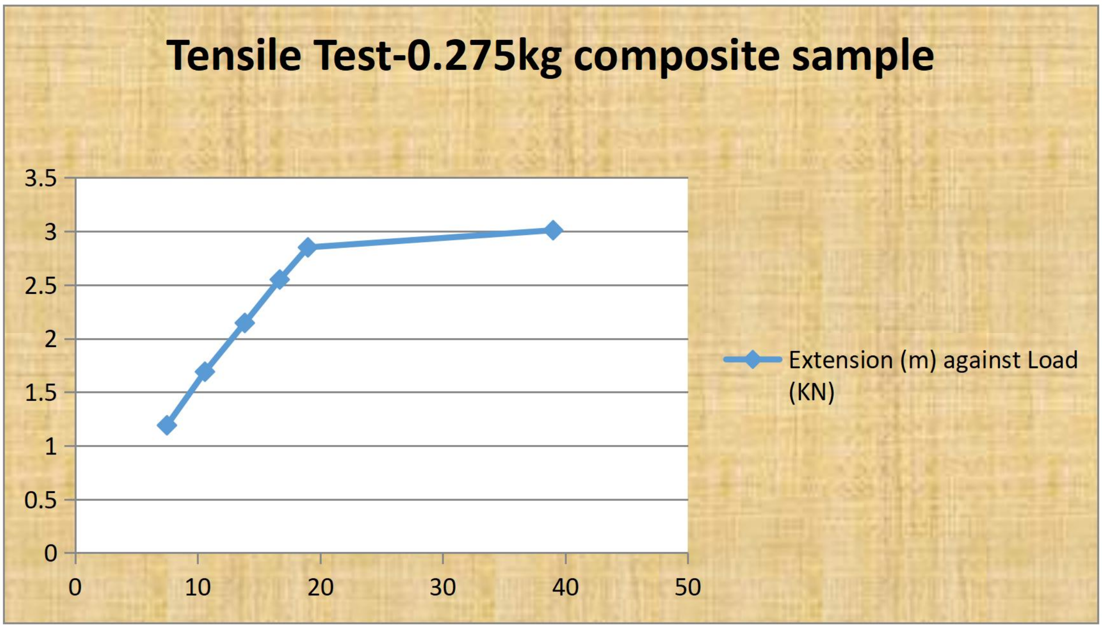
LOAD (KN)	EXTENSION(m)
7.1	0.92
10.1	1.46
13.2	1.89
15.7	2.25
18.6	2.61
39.8	2.90

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
7.9	1.46
11.1	1.92
14.5	2.40
17.5	2.85
19.4	3.09
38.2	3.12

AVERAGE

LOAD (KN)	EXTENSION(m)
7.50	1.19
10.60	1.69
13.85	2.145
16.70	2.55
19.00	2.85
39.00	3.01



f) **0.3kg of composite material**

1st EXPERIMENT

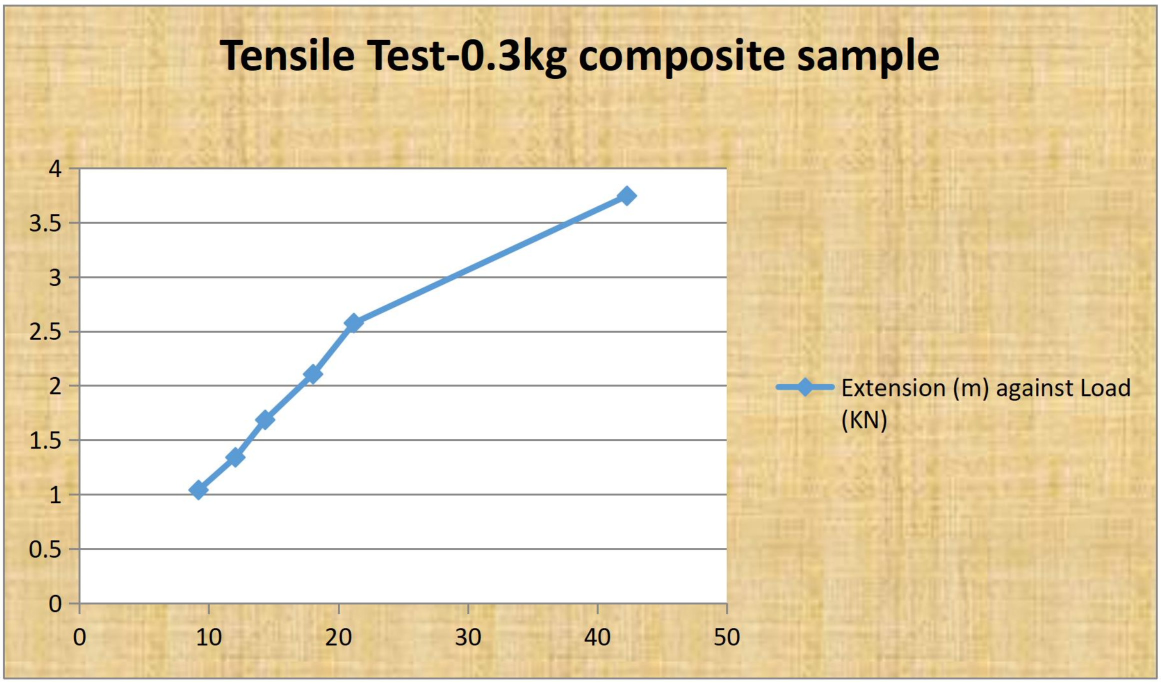
LOAD (KN)	EXTENSION(m)
9.1	1.25
12.8	1.77
15.4	2.30
18.2	2.80
21.1	3.33
54.7	5.65

2nd EXPERIMENT

LOAD (KN)	EXTENSION (m)
9.3	0.83
11.3	0.91
13.3	1.07
17.9	1.41
21.3	1.82
29.9	1.84

AVERAGE

LOAD (KN)	EXTENSION(m)
9.20	1.040
12.05	1.340
14.35	1.685
18.05	2.105
21.20	2.575
42.30	3.745



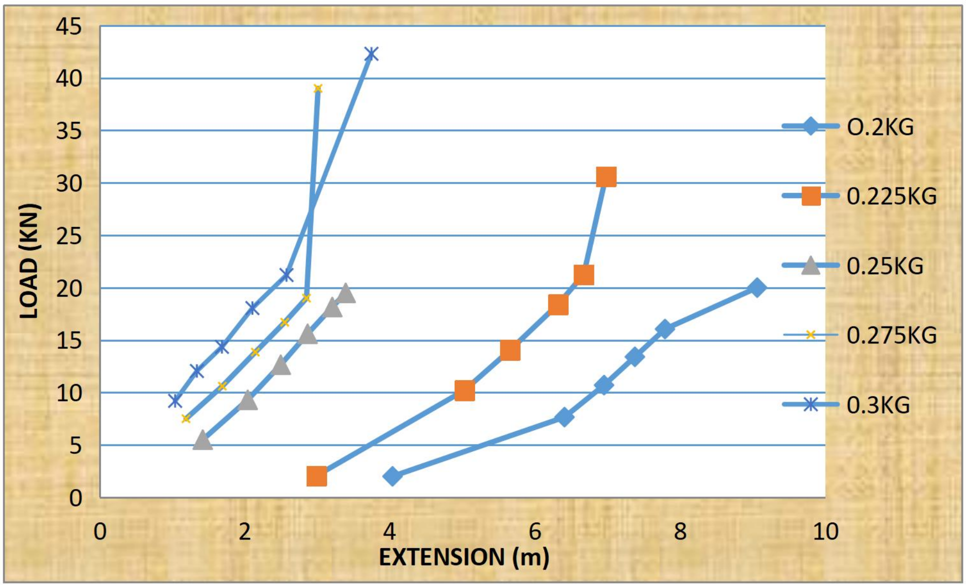
Analyzing the graphs

- Pure Aluminium: Shows a linear increase in load with extension.
- 0.2 kg Bamboo Fiber Added: Displays an initial linear increase followed by a slight curve.
- 0.225 kg Added, 0.25 kg Added, 0.275 kg Added: Show similar behavior with increasing load.
- 0.3 kg Added: Shows a significant increase in load with a slight curve towards the end.

After carefully analyzing the load-extension graphs of the composite materials, it's evident that the sample with 0.3 kg added demonstrates remarkable strength characteristics. Its load-bearing capacity before failure surpasses that of the other samples, indicating superior structural integrity and resilience under stress.

Hence, the decision to opt for the composite with 0.3 kg added is not arbitrary; rather, it is a deliberate choice based on thorough evaluation and understanding of material properties. This selection aligns with the pursuit of enhanced performance and durability, essential factors in achieving the desired outcomes for the application at hand.

Nevertheless, it's crucial to underscore that this decision isn't made in isolation. Consideration of various factors, including cost, weight, and feasibility, has been integral in ensuring that the chosen composite material aligns seamlessly with the overarching objectives and requirements of the project.



4.1.2. PERFORMANCE TESTING

The performance of the centrifugal pump and its 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 is taken to empty each measured container was recorded against the head of water pumped.

The water rose to a height of 23.5m and the discharge recorded was 28800 liters/hr or 8 liters/sec.

The pump was designed to deliver 12.5 liters/sec at a height of 13m therefore the achieved performance of 64% efficiency is satisfactory and acceptable for a centrifugal pump that falls within this capacity of specific speed.

4.2. PUMP OPERATING PROCEDURES

Cherkassky (1969) and Igor et al. (1960), both agree that all centrifugal pumps must be filled with the liquid to be pumped before starting. For satisfactory operations, the following industry standard practices for pump construction have been adopted, before starting the pumping unit. Therefore, the following preparatory steps should be taken;

1. Make sure the shaft is rotating freely.
2. Ensure the pump casing and suction line are primed.
3. Make sure that the stuffing boxes do not leak excessively.
4. Check the grease in the bearings.
5. While running, the temperature of the bearings and motor casing/housing must not be above 60°C under normal conditions.

The operating procedure of this pump is very simple and does not require any special skill to operate. Therefore to operate this pump simply connect the suction and delivery hoses or piping as may be required, to the pump inlet and outlet connections, respectively, and secure them firmly. Prime pump by filling pump casing and suction hose with liquid to be pumped. If a foot or suction valve is installed, make sure it is in the open position, then connect the pump to the source of the power supply (single-phase power supply) and switch it on. At the end of pumping, operations switch off power from the supply and unplug the power source.

4.3. MAINTENANCE

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

1. Breakdown maintenance; is maintenance activities carried out on equipment to bring it back to maintaining its designed/original operating form.
2. Preventive maintenance; is maintenance activities intended to prevent equipment failure, an important form of preventive maintenance activity is regular inspection, vibration, temperature monitoring e.t.c undertaken to identify seemingly failing parts before breakdown eventually occurs. Remedial actions usually taken could be the replacement of parts, greasing, cleaning, etc. (Agbabune, 2002).

The maintenance of a centrifugal, pump is hereby listed as follows;

a. The bearings - The bearings should be inspected every month, and greased if found dry or noisy. Bearings are to be replaced after about 8000 running hours, or whenever the shaft wobbles or stiffens.

b. Gland packing - This should be adjusted to allow a few drops per minute, and replaced whenever the seal, leaks profusely either while running or stopped.

c. Casing gasket - To be replaced when found broken or partially cut. However, gaskets are recommended for replacement during inspections or major repair work on the pump.

d. Pump and motor mounting bolts monthly checks on tightness or otherwise recommended.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

In conclusion, this project has provided valuable insights into the operational principles and performance characteristics of centrifugal pumps. While initial calculations projected an efficiency of 72.2% under specific operating conditions, empirical testing revealed a slightly lower actual efficiency of 64% in practice. Despite this variance, the centrifugal pump demonstrated its capability to raise water to a height of 23.5 meters, surpassing the targeted height of 13 meters.

The centrifugal pump, as a fluid kinetic machine, operates by increasing power within a rotating impeller. Its performance, characterized by delivery heads dependent on flow rate, is critical in various applications. The successful manufacturing of this pump using locally sourced materials, fabricated within the Department of Production Engineering workshop, signifies the potential for domestic production and economic growth.

5.2. RECOMMENDATIONS

1. Enhanced Manufacturing Processes: Implementing advanced manufacturing techniques, such as precision machining and quality control measures, can improve the consistency and reliability of the pump production process. This could result in higher performance and durability of the pumps.

2. Material Selection Optimization: Conducting research to identify and incorporate materials with superior mechanical properties can enhance the pump's efficiency and longevity. Exploring alternative materials or composites could offer cost-effective solutions without compromising performance.

3. Integration of Computer-Aided Design (CAD) Programs: Leveraging CAD software for pump design and simulation can facilitate iterative improvements and optimization of the pump's geometry and performance characteristics. This approach can lead to more efficient designs and reduce the need for costly physical prototyping.

4. Market Expansion and Job Creation: Expanding the production and marketing of locally manufactured centrifugal pumps can stimulate economic growth by creating job opportunities and reducing dependence on imported pumps. Collaboration with government agencies and private enterprises can help promote the adoption of locally manufactured pumps in various sectors.

By implementing these recommendations, the centrifugal pump design can be refined and optimized for broader application, contributing to economic development and self-sustainability in Nigeria's engineering sector.

CHAPTER SIX

REFERENCES.

Okokowa Jeremiah Esiyede, (2003): Thesis on the Design and Construction of a 2-Stage Centrifugal Pump.

Anup Kumar Dey (2019) Pumps & Pumping Systems (With PDF)

Top 5 failures in pumps and how to detect them (https://samotics.com/blog/top-5-failures-in-pumps-and-how-to-detect-them/) Simon Jagers - Samotics 2020

Oleson, J.P. Greek, and Roman Mechanical Water-Lifting Devices: The History of a Technology; University of Toronto Press: Toronto, Canada, 1984.

Angelakis, A.N.; Mamassis, N.; Defteraios, P. Urban Water Supply, Wastewater, and Stormwater Considerations in Ancient Hellas: Lessons Learned. Environ. Natl. Resour. Res. 2014, 4, 95–102.

Valipour, Aldo Tamburrino, and Andreas N. Angelakis (2015). Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide.

Francis Inegbedion, Chidiebele Nnadike Okonkwo and Joseph Okechukwu (2021). Design and Manufacture of a Centrifugal Water Pump with a Circular Casing

Eubanks, B.M. The Story of the Pump and Its Relatives; Bernard M. Eubanks: Salem, OR, USA, 1971; p. 185

Hazen, T.R. Pond Lily Mill Restorations. The Noria Water Wheels 2000.

Bazza, M. Overview of the History of Water Resources and Irrigation Management in the Near East Region. Water Sci. Technol Water Supply 2007, 7, 201–209.

Cohn, G.S. L’origine des Norias de Fés. Hespéris 1933, 16, 156–157.

Molenaar, A. Water Lifting Devices for Irrigation; FAO Paper No.60; FAO: Rome, Italy, 1956; p. 75.

Drew Champlin 2018: An introduction to pump types and their histories.

Stavros I. Yannopoulos, Gerasimos Lyberatos, Nicolaos Theodossiou, Wang Li, Mohammad Ann, C. History of Water Pumps, eHow Contributor. 2009. Available online: http://www.ehow.com/facts_5031932_history-water-pumps.html (accessed on 14 August 2013).

Ozora P.A., Ojoborb S.N., (2012). Design, Construction, And Measured Performance Of A Single-Stage Centrifugal Pump Demonstration Unit Nigerian Journal Of Technology Vol. 31, No. 3

Saurabh M. (November 2023). "Unlocking the Power of Centrifugal Pumps: Exploring the Top Trends." Published by Saurabh M.

"Advancing Industrial Fluid Handling: Innovations in Advanced Pumping Technologies" (11 December 2023).

Team Xometry. (2023, May 16). What is Composite Material? Definition, Properties, Types, and Applications. Xomety X.

Kaw, A. K. (2006). Mechanics of Composite Materials (2nd ed.). CRC Press.

Manohar, D. M. (n.d.). Module 1 - Introduction to composites. Polymer Engineering PEB3213 - Polymer Composites Engineering 9.

Fathy, A. (2023). Exploring the Mechanics and Applications of Centrifugal Pumps.

Simsite. (2023). 5 Ways Structural Composites Improve Pump Efficiency.

Stefanie Wallace (2012): A glimpse into the history of pumps.

Larry Bachus, Angle Custodio (2003). Know and understand centrifugal pumps. Elsevier Ltd. ISBN 1856174093.

Igor J. Karasssik and Ray Carter, (1960): Centrifugal Pumps Selection, Operation, and Maintenance. McGraw- Hill Book Company.

V. Cherkassy, (1990): Pumps, Fans and Compressors, Mir Publishers MOSCOW

Tassios, T. Hellenic Ancient Technology; Kathimerini: Thens, Greece, 1998.

Agbabune Joe B 2002; Design and construction of a submersible pump, M. Eng. Thesis. Ambrose Ali University Graduate School, Ekpoma, Nigeria.

Karassik, I.J., Messina, J.P., Cooper, P., and Heald, C.C. (2001). Pump Handbook (4th ed.). McGraw-Hill Professional.

Ludwig, E.E. (1998). Applied Process Design for Chemical and Petrochemical Plants (3rd ed.). Gulf Professional Publishing.

Perry, R.H., Green, D.W. (Eds.). (2007). Perry's Chemical Engineers' Handbook (8th ed.). McGraw-Hill Professional.

Coulson, J.M., Richardson, J.F., Sinnott, R.K. (2018). Chemical Engineering Volume 1: Fluid Flow, Heat Transfer and Mass Transfer (7th ed.). Elsevier.

Munson, B.R., Young, D.F., Okiishi, T.H., Huebsch, W.W. (2012). Fundamentals of Fluid Mechanics (7th ed.). Wiley.

McCabe, W.L., Smith, J.C., Harriott, P. (2005). Unit Operations of Chemical Engineering (7th ed.). McGraw-Hill Education.

Ramesh, A. (2018). Principles of Mineral Processing. CRC Press.

CHAPTER SEVEN

APPENDIXES.