REFURBISHMENT OF THE CASING COVER OF A CENTRIFUGAL PUMP

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Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

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DECLARATION

I declare that this report entitled “Refurbishment of The Casing Cover of a Centrifugal Pump” is the result of my own research except as cited in the references.

Signature :

Name : MUHAMMAD IRFAN MUQRI BIN ISMAIL

Date : Jan 2025

APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature	:
Supervisor Name	: **TS. AZRIN BIN AHMAD**
Date	: Jan 2025

DEDICATION

I dedicate to my supervisor, family and friends whose guidance and expertise have shaped my academic growth and inspired me to pursue excellence.

ABSTRACT

The refurbishing of a casing cover for a centrifugal pump is an essential process that is used to make sure that the pump continues to operate effectively for its whole life span. This thesis examines in detail the technique used in repairing a casing cover that has been worn out or damaged in order that it can have precise measurements taken during the process and uses CAD system in which different component parts are mould separately for making them fit together perfectly which is done through cutting operation carried out at predetermined points around their edges to avoid joining lines through post-processing. The project started with a thorough examination and measurement stage utilizing highly accurate tools like callipers and rulers in order to capture key dimensions of the current casing cover. 3D model of casing cover was created using SolidWorks after collecting data, where detailed model was created for stress analysis and simulations that would be carried out in order to confirm the design and point out enhancements if any. This entailed revisiting modifications which were meant to cater weaknesses reducing on the general efficiency of the casing cover. The pattern was followed by creating a pattern blank out of the SolidWorks design during sand casting. Afterwards, to facilitate creation of new casing cover, the hot liquid metal was poured into a sand mould that had been made. It was then removed, cleaned up and any excess material or sand was removed before it was cooled down and solidified. Milling operations are then started with rough milling being done first in order to cut down unnecessary material amounts with finish milling done in the end meeting up final dimension sizes together with how smooth the surface should be according to the sketches. The performance of the centrifugal pump was confirmed after subsequent assembly and functional testing for the renewed cover, confirming if it met or exceeded the initial specifications. Initial data collected makes it possible to argue that this new casing cover does not only restore operability in pumps, but it is also aimed at increasing their efficiency and serviceability. This explicatory text presents every step of the rebuilding method meticulously; hence, helping other users to perform the procedure in quite an organized manner. It also highlights an ideal way for which one can use in achieving long lastingness as well as optimizing productivity with centrifugal pumps within pump maintenance and engineering territories. The thorough strategy provided in this thesis ensures that the new case covering is functional and dependable. This holds useful lessons for subsequent refurbishments.

ABSTRAK

Pembaikan semula penutup selongsong bagi pam sentrifugal adalah satu proses penting yang memastikan pam terus beroperasi dengan berkesan sepanjang hayatnya. Tesis ini meneliti secara terperinci teknik yang digunakan dalam membaiki penutup selongsong yang telah haus atau rosak untuk mendapatkan ukuran yang tepat semasa proses tersebut serta menggunakan sistem CAD di mana bahagian-bahagian komponen yang berbeza dibentuk secara berasingan untuk memastikan mereka bersatu dengan sempurna. Ini dilakukan melalui operasi pemotongan pada titik-titik yang telah ditetapkan di sekitar tepi mereka untuk mengelakkan garis sambungan melalui pasca-pemprosesan. Projek ini bermula dengan tahap pemeriksaan dan pengukuran menyeluruh menggunakan alat-alat yang sangat tepat seperti kaliper dan pembaris untuk menangkap dimensi utama penutup selongsong semasa. Model 3D penutup selongsong telah dibuat menggunakan SolidWorks selepas data dikumpulkan, di mana model terperinci dibuat untuk analisis tekanan dan simulasi yang dijalankan untuk mengesahkan reka bentuk dan mengenalpasti peningkatan jika ada. Ini melibatkan revisi modifikasi yang bertujuan untuk mengatasi kelemahan yang mengurangkan kecekapan keseluruhan penutup selongsong.Corak tersebut diikuti dengan mencipta corak kosong daripada reka bentuk SolidWorks semasa proses tuangan pasir. Selepas itu, untuk memudahkan penciptaan penutup selongsong baru, logam cecair dituangkan ke dalam acuan pasir yang telah dibuat. Ia kemudian dikeluarkan, dibersihkan dan sebarang bahan atau pasir berlebihan dikeluarkan sebelum ia didinginkan dan dipadatkan. Operasi pengilangan kemudian dimulakan dengan pengilangan kasar dilakukan terlebih dahulu untuk mengurangkan jumlah bahan yang tidak perlu dengan pengilangan halus dilakukan pada akhir untuk memenuhi saiz dimensi akhir bersama-sama dengan bagaimana kelicinan permukaan mengikut lakaran. Prestasi pam sentrifugal disahkan selepas pemasangan dan ujian fungsi penutup yang diperbaharui, mengesahkan sama ada ia memenuhi atau melebihi spesifikasi asal. Data awal yang dikumpul membolehkan kita berhujah bahawa penutup selongsong baru ini bukan sahaja memulihkan kebolehlaksanaan pam, tetapi juga bertujuan untuk meningkatkan kecekapan dan kebolehgunaannya.Teks penjelasan ini mempersembahkan setiap langkah kaedah pembinaan semula secara terperinci. Oleh itu, membantu pengguna lain melaksanakan prosedur tersebut secara teratur. Ia juga menyoroti cara ideal yang boleh digunakan untuk mencapai ketahanan yang lama serta mengoptimumkan produktiviti dengan pam sentrifugal dalam bidang penyelenggaraan dan kejuruteraan pam. Strategi menyeluruh yang disediakan dalam tesis ini memastikan bahawa penutup casing baru adalah berfungsi dan boleh dipercayai. Ini memberikan pengajaran yang berguna untuk pembaikan semula yang akan datang.

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LIST OF SYMBOL AND ABBREVIATION

FTK	-	Fakulti Teknologi Kejuruteraan
FTKM	-	Fakulti Teknologi Kejuruteraan Mekanikal
UTeM	-	Universiti Teknikal Malaysia Melaka
CAD	-	Computer-Aided Design
FEA	-	Finite Elements Analysis

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Chapter 1

Introduction

1.1 Background of Study

Centrifugal pumps provide a gateway into understanding the fluid dynamics devices that revolutionized various industries and everyday applications. A centrifugal pump is a mechanical device is designed to run fluids through a system by converting mechanical energy into kinetic energy. Centrifugal pumps use the centrifugal force to drive liquids, as opposed to positive displacement pumps, which use rotating motors.

One of the distinct features of centrifugal pumps is their simplicity and efficiency. They generally include a casing cover, an impeller, and inlet and output openings. When operating, the impeller will rotate and create a centrifugal force that propels the fluid outward from the center of rotation. The process may increase the fluid velocity to generate enough pressure, and the fluid will flow through the pump into the discharge system.

Centrifugal pumps are used in a variety of industries, such as water supply and wastewater management, chemical processing, oil refining, and HVAC systems. Their versatility and ability to handle a wide range of fluids make them indispensable in countless processes and operations.

Understanding the basic principles of centrifugal pump operation is important for engineers and technicians. However, the centrifugal pumps have a common failure that makes the system fail during the operation. The common failure includes the wear and tear failure in the casing of a centrifugal pump that usually occurs due to protracted use, improper operating conditions of the centrifugal pump, and insufficient maintenance.

1.2 Problem Statement

Basically, centrifugal pumps play important rule in fluid management as well as the challenges that may arise during their operations. This project focusing on refurbishing casing cover for centrifugal pump. The casing cover of the centrifugal pump has broken on the mounting for bolts and nuts. Theses broken parts have affect the centrifugal pump process because the bolts and nuts cannot hold the casing properly and cannot be sealed when install the part. A common failure involve can cause the leakage for centrifugal pump.

Centrifugal pump often used mechanical casing cover seals to prevent fluid from escaping along the shaft where it exits the pump casing. This project intended to refurbishing new casing cover for the centrifugal pump that damaged during the lab session because of the improperly installed that can result in leakage. This failure must be solved because the centrifugal pump in the lab are used for student during the lab session.

1.3 Research Objective

The main of this research is to refurbish casing cover for centrifugal pump with reasonable accuracy. Specifically, the objectives are as follows:

a) To design a new casing cover for centrifugal pump.

b) To fabricate new casing cover using sand casting.

c) To evaluate strength, durability, type of material and suitability for student learning outcome.

1.4 Scope of Research

This project may use the CAD drawing using SolidWorks software to design the 3D drawing of the casing for the centrifugal pump and sand casting to rebuild it. These processes need to be done carefully, especially during the sand casting. The technique for the sandcasting process must have perfect molding and melting of cast iron to get the perfect result for the casing, and the holes for bolts and nuts will be done by using table drilling machines. After the casting is removed from the mold, the finishing process such as the grinding process, needed for the desired surface finish, dimensional accuracy, and mechanical properties.

The scope of this research are as follows:

- Designing with 3D drawing by using SOLIDWORKS software for casing cover of centrifugal pump.
- Investigation of stress and torsion on the mounting bolts and nuts for casing cover of centrifugal pump.
- The material selection is considered for fabricating good quality product.
- The fabrication involving sand casting and milling for the accuracy measurement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The casing cover of a centrifugal pump is an important component that affects the performance of the centrifugal pump. Understanding the principles of designing centrifugal pumps is crucial for optimizing their performance. A literature review explores many aspects of casing design, analysis stress, and torsion and fabricating. This chapter will discuss the literature related to the refurbishing casing cover centrifugal pump to replace the broken one in the laboratory. With the 3D design and good fabrication, the process can be planned correctly and in a timely and effective manner.

2.2 CAD Modelling Casing Cover of Centrifugal Pump

Computer-Aided Design (CAD) modelling is a modern revolution for engineers, designers, and architects to create and build products, structures, and system. The advanced system of CAD software modeling has substantially increased the ability to enable more exact digital representations of real-world objects. CAD modelling encompasses a number of techniques for creating and manipulating digital representations of objects. Parametric modelling is a significant methodology that allows designers to express geometry and relationships with parameters and restrictions, making design adjustments and iteration easier. Other ways include direct modelling, which allows you to freely change geometry, and surface modelling, which focuses on creating complex surface patterns. Furthermore, solid modelling approaches enable the creation of three-dimensional (3D) solid objects with established borders and volumes.

CAD modelling has been used in many industries, such as automotive, aerospace, architecture, manufacturing, and healthcare. CAD modelling is used to create car components, optimize aerodynamics, and simulate crash tests in the automotive industry. CAD technology improves automation in industrial production (Fei Li, 2022). In aerospace, software is used for creating aircraft structures, engines, and avionics systems. Architectural uses CAD modelling to develop efficient and precise building designs, floor plans, and interior layouts. CAD modelling also plays an important role in machining process such as CNC, 3D printing, and mold creation that enable the prototype and production of components. Medical devices, implants, and devices that are customized to patients' unique requirements also use CAD modelling to design unique products for healthcare. In this context, CAD model quality is a key concept, as the quality of a manufactured product depends on the quality of its design processes, which then depend on the quality of their data (González-Lluch et al., 2017).

2.2.1 SolidWorks and AutoCAD for Design and Drawing

SolidWorks and AutoCAD are two of the most popular computer-aided design (CAD) software tools in the world. They are widely used in multiple industries for different purposes. Its 3D modelling capabilities, effectively developed by Dassault Systems, have made SolidWorks highly preferable in areas of product design and mechanical engineering. The use of modern methods means the use of personal computers both for the evaluation of already set methods and for the development of new methods, which bring to a new light all the features evaluated by older methods (Dragne, C., Todirite, I., Pandelea, M., Frenţ, C. R., Cotfas, P. A., Chiroiu, V., & Iliescu, M. , 2022). It means that complex assemblies and simulations are more easily adapted through, and so mechanical engineers can model, test and deliberate different conditions of airflow within the same platform. One of the biggest changes over the past 30 years has been the development and widespread usage of solid modelling software (Howard, W. E., & Musto, J. C., 2022).

When it comes to creating casing covers for centrifugal pumps, SolidWorks and AutoCAD are two software programs that excel at others and have unique capacities while focusing on different design and engineering processes. SolidWorks, on the other hand, is preferred for its robust 3D modelling capabilities, which allow users to come up with precise, detailed, and complex geometry. Its parametric design approach allows for frequent design specification changes' frequent changes, making it ideal for the development of intricate pump casings that have to be modified regularly. Thus, the software becomes the most appropriate choice for such situations dealing with intricate pump casings that require changing specifications often with many iterations. The software has also improved through the addition of simulation tools such as stress analysis, fluid dynamics simulation, and thermal analysis, which help to ascertain that the casing cover meets all performance and safety standards before physical prototyping.

Conversely, AutoCAD, which is best known for its 2D drawings, has much flexibility and is mostly preferred at the beginning stages of design making since it can make any kind of starting sketch. AutoCAD, however, is not modelling-intensive as it cannot be compared to SolidWorks in terms of the complexity of features such as filleting and chamfering. While, AutoCAD may not match SolidWorks in modelling complexity like filleting and chamfering, its extensive component library and drafting tools streamline the generation of detailed sketches crucial for industrial applications (Osakue, E. E. ,2015). Its narrow drafting tools and wide collection of components in AutoCAD are what make it effective and can simplify the process of generating particularized sketches and layout plans vital for industrial processes. Besides that, its ability to work with multiple file formats and relate to other Autodesk software is handy for improving the efficiency of a person's work flow, especially when working on a project requiring several departments.

The centrifugal pump casing cover design project would require us to make a choice between using SolidWorks and AutoCAD. Based on this analysis, it has been found that SolidWorks is more preferred when it comes to producing high-fidelity 3D models and conducting extensive simulations. This is because it possesses advanced features as well as user interface, making it easier for an individual to use than AutoCAD does. On the other hand, if one wants more detail in their documentation than a broader integration of the same with other aspects like process flows. By developing a capacity to predict whether a plan is implementable or not, framers will be better able to control the outputs of drafting processes and advance arguments coherently in favour of this perspective which shall need to integrate scalar mis-specifications of detail. By integrating scalar mis-specifications of detail, framers can better assess plan feasibility and articulate coherent arguments in support of their design choices, ultimately improving the overall design process and outcomes (Andrei, Alexandru, Scupi., Mariana, Panaitescu., Fanel-Viorel, Panaitescu, 2023).

2.3 Finite Element Analysis (FEA) of The Casing Cover of Centrifugal Pump

Finite Element Analysis (FEA) of engineering has become a critical tool in the study of the structural integrity and performance of different machine parts. In this vast field, the analysis of casing covers in centrifugal pumps is a major focus point. Casing cover is extremely important to maintain performance and durability when it comes to centrifugal pumps as it protects internal parts against external forces and keeps fluids from leaking. This is a topic that has been studied by many scholars who have used FEA technique to analyse what goes on in terms of stress as well as mechanical action inside casing covers at different operating states.

An extensive search that encompasses many aspects and concerns different features in their full scope when dealing with how well covers for casings work based on what they're made up from, the shape they take versus time, fluids that move within them, as well as forces acting on them during their usage, can be found in many pieces of writing where it is mentioned that such factors somehow affect how caps protect spool pieces. Researchers have shown that the key to how strong casing covers are and how long they last are in the choice of the material. We have pulled apart a lot of different alloys, composites, and polymers to see which ones will work well in different working conditions.

2.3.1 FEA Evaluation

In analysing centrifugal pump casing covers, FEA is primarily used to evaluate structural integrity under various loading conditions. This includes static load analysis to assess the casing cover's ability to withstand static loads, such as internal pressure from the fluid being pumped and external loads from connected piping systems, and dynamic load analysis to evaluate the response to dynamic loads like vibrations and pulsations caused by pump operation and fluid flow. The casing cover's response to temperature changes is examined under thermal stress analysis where thermal expansion is taken into account in order to investigate thermal stress as well as deformation effects. FEA is also applied towards assessing fatigue and fracture behaviour by not only estimating fatigue life but also identifying cycles beyond which casing cover experiences load leading to breakdowns then considering crack development patterns that enable prediction of possible catastrophic failures from critical crack sizes. Furthermore, FEA aids in assessing fatigue and fracture behaviour by estimating fatigue life, identifying critical crack sizes, and predicting possible catastrophic failures based on crack development patterns (Jiang'ao, Zhao., Deming, Zhu., Yuxuan, Ma., Yongling, Fu., Jian, Fu. ,2022).

The choice of material for centrifugal pump casing covers influences the outcomes of FEA in a tremendous way. Popular materials are a variety of stainless steels, cast irons, and high-performance alloys. Input variables for FEA models for each of those materials are Young's modulus, Poisson's ratio and yield strength, among other things. A number of researches works and practical applications have already shown that FEA can be effectively used to optimize designs of casing covers in centrifugal pumps.

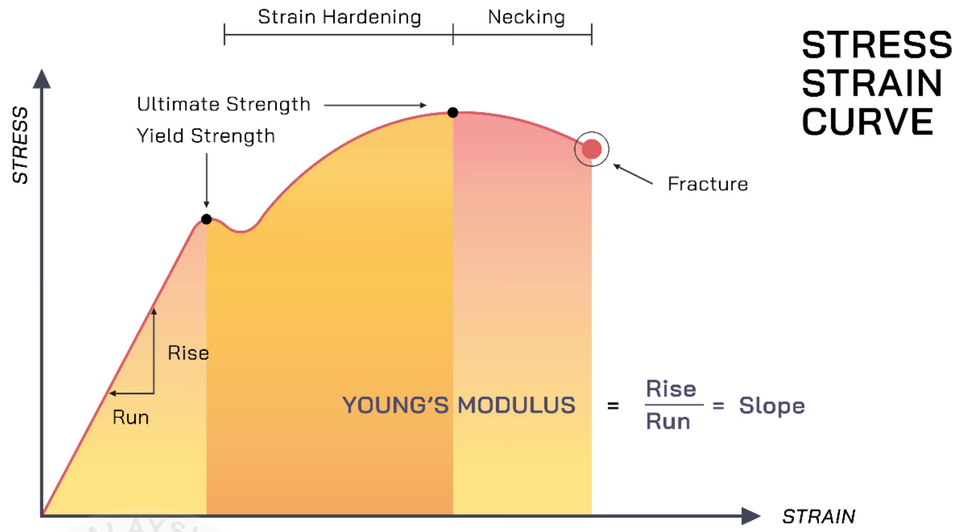


Figure 2.1 Stress strain curve

(Source: *xometry.com*)

The figure 2.1 describing the stress-strain curve shows some major mechanical properties, and it gives us an idea of how stress and strain are related for any substance that is undergoing tensile loading. One can easily notice that at the beginning of the graph, there is a straight line with slope equal to young's modulus, while this seems very strange mathematically speaking because expect it to go through zero, what such behavior that this material has high stiffness. When we get to where this line doesn't pass through zero anymore, there comes another critical point called yield point. This is important because it indicates where plastic deformation occurs. Further on, material starts to deform in a different way, with it growing stronger and becoming less brittle until it reaches ultimate strength-that is the best stress it can endure. After reaching the highest value, the graphical representation starts to decline showing that the substance undergoes thinning which results into breaking after deformation stretches have been achieved. It is this curve that helps us understand how different materials respond when stressed at various levels therefore allowing for the choice of materials based on their mechanical properties by engineers.

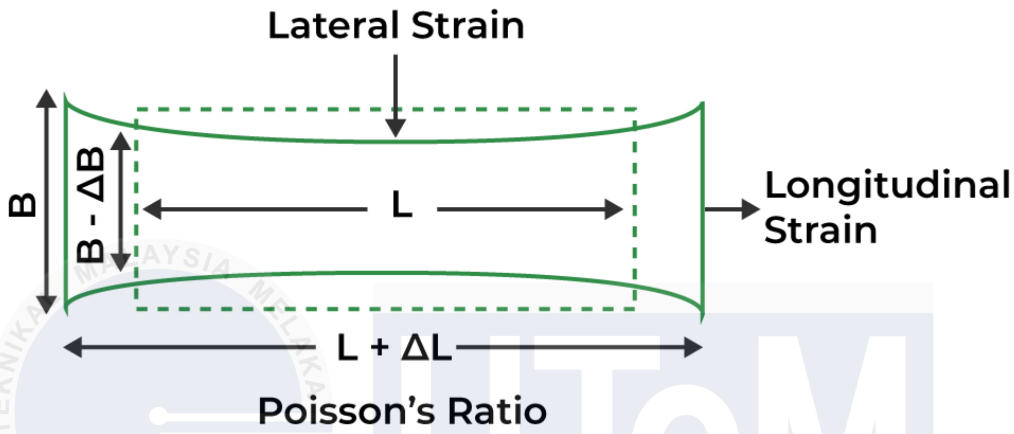


Figure 2.2 Poisson's ratio

(Source: *geeksforgeeks.org)*

The diagram 2.2 displays Poisson's Ratio which is a critical factor in material science on uniaxial stress investigating the connection between lateral and longitudinal stress in a material. When a piece of material is pulled lengthwise (getting longer every ΔL), it shrinks widthwise (getting narrower every ΔB), the behavior that is characterized through Poisson's Ratio (ν). Negative ratio between the lateral strain and longitudinal strain defines it ($\nu=-\Delta B/B/\Delta L/L$). It serves as a vital ratio for elucidating the deformation behavior of materials as well as aids in enabling engineers and researchers in predicting the behavior of materials under different loads enabling them to design structures and parts that are safe and efficient.

Even though FEA has its pluses, there are various challenges and limitations associated with this method, complex modelling requirements or poor-quality material information. Developing precise FEA models such as those in the manufacture of pump casing covers can take time as well as demand substantial experience, whereas the process demands enormous computational power and memory for conducting FEA simulations with high fidelity. Accurate material properties are essential for reliable FEA results, but such data may not always be readily available, especially for new or specialized materials.

There are technological advances in the FEA software and hardware industry, but the real change lies in artificial intelligence and machine learning. These two promises to make simulations better and faster. During the design process, research will likely be concentrated on arising of real-time FEA to enable prompt feedback, combining structural, thermal, and fluid dynamics analyses in one FEA model for more accurate depiction of complex interactions in centrifugal pumps; researching new materials and composites for enhancing their performance in cases of application as centrifugal pumps while at the same time helping to develop and validate these designs through FEA. When it comes to centrifugal pump casings, most people use Finite Element Analysis (FEA) to check if they can hold together well when they are under different kinds of loads. It checks how much weight the casing cover can carry while staying still without breaking into pieces. That means looking at things like the pressure inside the casing that moves fluids or forces coming from outside pipes connected to it.

A celebrated feature of FEA in stress analysis is how it accurately distributes casing stress over the surface and mounting for screws and nuts. The distribution of these stresses can be visualized through an accurate map created using FEA technique which will reveal important parts of the cover which encounter large quantities of stress and can break. The importance of such discoveries cannot be overemphasized as such regions of casing cover always act as potential failing points. Through the identification of these areas, the Finite Element Analysis (FEA) technique allows for specific alterations on targeted basis that can strengthen it hence reduce chances for breakdown in future as well as prolong its service duration.

In material optimization, one of the most remarkable achievements of FEA is that it can simulate the way different materials respond to operational stresses, pressures and temperatures. This capability enables engineers to carefully compare different materials and select one that perfectly meets the centrifugal pump casing cover's specific needs. An example is finite element analysis of alloy behaviour under extreme pressure conditions indicating both strengths and drawbacks to which it might be subjected, therefore, ensuring that as a result the chosen materials are the most appropriate, reliability and the efficiency of the pump being greatly enhanced by this detailed research level.

Finite Element Analysis (FEA) completely changed the design and analyse centrifugal pump casing covers. This was a big leap forward since its increased engineering accuracy, material optimization and performance in pumps. Through FEA, engineers can now conduct stress, thermal, and vibration analyses, enabling them to pinpoint areas of high stress and optimize material properties for enhanced load-bearing capacity of casing covers (Das, Ashish., B., Ch., Nookaraju, 2023). Stress, thermal and vibration analyses are now possible using FEA because of which engineers can discover where the stress is too high and change material properties for the better load -bearing ability of casing covers. The way the pumps are made is changed to improve the strength and quality of their structure in addition to making them more cost-effective and environmentally friendly.

2.4 Fabrication Casing Cover of Centrifugal Pump (Sand Casting and Milling)

The production of case covers for centrifugal pumps is an important process which very much affects the pump's performance and its endurance, and its efficiency too. Considering that their output results into solid and long-lasting parts, older techniques like casting, forging and even machining have always been a success story. The casting process, which more frequent involves materials such as cast iron and stainless steel than others because it is cheaper than other methods but is able to create a variety of forms even though faults like porosity may arise from it. Meanwhile, forging provides better mechanical qualities because it enhances the grain structure of metals to produce better quality casing covers making them more resilient however pricier and less flexible than spent casting when real nature comes due to high temperatures together with deformation which could cause changes in their mechanical behaviour so that they become malleable-contained iron coatings when sustainability is affected under operating temperatures if forced into brittle regions. Machining ensures exact dimensions and good surface finish, so it is typically held as a follow-up process for precision.

During the fabrication process, it is very important to pay attention to the type of materials used as this impacts the casing covers ability to resist corrosion and wear as well as its resistance to mechanical stress. As a material of choice for making machine parts, cast iron is not only strong and wear resistant but also brittle at the same time. When it comes to stainless steel, there are some advanced alloys such as super duplex and duplex which have better strength and resist corrosion hence, they are suited for use in tough environments. In this project the sand casting is the best choice to perform the fabrication process in making casing cover of centrifugal pump.

2.4.1 Sand Casting for Fabrication

Metal components such as casing covers for centrifugal pumps are often produced using casting and casting is a common process. Crucially, the casing covers the pump mechanism and maintain their efficient operation. This process involves pouring hot metal into sand mould to create the shape wanted. Hence, sand casting particularly in relation to centrifugal pumps involves selection of materials used in sand mould preparation or choice till metal solidifies, management of quality throughout this entire procedure, specifications of process as well as recently published research findings are equals important areas for investigation within this approach. The choice of material is a significant matter when it comes to centrifugal pumps that operate in tough environments. Some of the common materials that are employed in these machines include stainless steel and different cast iron grades.

Notably, many people prefer to use grey cast iron because it is outstanding in abrasion resistance, has the ability to flow easily during casting, and can be cast effortlessly. Also, this material has better machine ability as well as ability to dampen vibrations. Grey cast iron is a preferred material due to its exceptional abrasion resistance, ease of flow during casting, and machining capabilities, making it ideal for tough pump environments (M., G., Potapov., B.B., Zaritskiy., Nataliya, Kuts. ,2022). For high-quality sand casting, it is important to keep in check many process parameters to achieve the final product integrity as well as quality in it. One of the most important things is the mould quality, whose optimization is essential to reaching the desired surface finish and dimensional accuracy through ensuring that parameters such as binder type and moisture content of sand grain size are taken care of in advance. To ensure high-quality sand casting, meticulous attention to process parameters is vital, with mould quality optimization being paramount for achieving desired surface finish and dimensional accuracy (Максимов, В., П. ,2022).

The casting's microstructure and mechanical properties get significantly influenced by the temperature at which the molten metal is poured finer sand yields an improved surface finishing albeit susceptible to mould permeability. Finer sand can improve surface finishing but may increase susceptibility to mould permeability (Chakrabarty, Saurish.,2023). A high temperature may result in defects such as sand burning and greater shrinkage, while too low a temperature leads to the casting not being completely filled in the mould. Controlled cooling has an effect on final microstructure as well by which internal stresses are minimized. Defects in metal castings including warps and cracks do not form during this process. High pouring temperatures can lead to defects like sand burning and increased shrinkage, while low temperatures may result in incomplete mold filling (Futas, P., Pribulova, A., Petrik, J., Blasko, P., Junakova, A., & Sabik, V. ,2022).

Numerous inspection and testing techniques are used in quality control in sand casting to guarantee that the final product meets the required standards. The detection of internal and surface defects in components is done using non-destructive testing (NDT) methods such as X-ray radiography, ultrasonic testing, and dye penetrant inspection._Non-destructive testing methods like X-ray radiography, ultrasonic testing, and dye penetrant inspection are crucial for detecting internal and surface defects in components (Pravat, Kumar, Dhal., P., V., Arul, kumar., Ganesh, Muthu., Senthil, Kumar, Kaliappan., L., Natrayan., Gori, Yatika, 2023). The production of casing covers for centrifugal pumps has experienced significant changes in recent past as far as the technology and materials used in sand casting are concerned. What has been transformed is the process of sand mould, the process is now more accurate, allows complex geometries, and is faster than the latter. It is now possible to predict casting parameters and optimize existing methods for the Advanced casting simulation software. This can be done using fluid flow, heat transfer, and solidification processes. This reduces defects while increasing produced useful items. In addition to this, the fabrication of advanced alloy combinations designed for particular pump casing cover uses contributes to increased durability parameters like rigidity, corrosion resistance as well as wear of the item hence extending further such capabilities beyond ordinary sandcasting limits.

2.4.2 Milling for Better Finishing

The production of casing covers for centrifugal pumps also involves a complex range of operations in the plant. The most critical of all these operations is milling. In its ability to produce precise and intricate shapes, milling ranks highly among the production processes of casing covers. Some common types of milling include horizontal, vertical, and CNC machines. There are various types of techniques used in milling, such as conventional milling, climb milling and CNC milling. Each of the techniques mentioned above has its own unique advantages. Creating screw holes in casing covers is crucial during manufacturing centrifugal pump components. Rotary cutters remove material in this flexible machining process that helps in producing the exact features for pump assembly. The materials used to make these covers include cast iron, stainless steel, and a range of various alloys. These machining processes enable the production of the exact features necessary for pump assembly. The materials commonly used for casing covers include cast iron, stainless steel, and a variety of alloys, highlighting the diverse material requirements in centrifugal pump component fabrication (Wang, Xiao'ou. ,2019).

During the manufacturing of centrifugal pump components, it is important to create screw holes on casing covers. In the manufacturing of centrifugal pump components like casing covers, a flexible machining method utilizing rotary cutters is crucial for creating screw holes accurately (Felix, Hernández., Alex, Fragoso. ,2022). A flexible machining method is employed in this process that removes material using rotary cutters to produce the exact features of the pump assembly. These covers are typically made from materials like cast iron, stainless steel, and various alloy compositions. Materials commonly used for these covers include cast iron, stainless steel, and various alloys, each requiring specific machining parameters for optimal results (L., A., Kalashnikova., 2022). Speeds and tool life are examples of process parameters that are very important in machining. Cutting stainless steel will be done at a slower pace to ensure there's no overheating or tool wear. With aluminium you need its speed to be higher while taking care not to have any burs hence leading to poor surface finishes. When cutting stainless steel, a slower pace is necessary to prevent overheating and tool wear, while higher speeds are needed for aluminium to avoid burs, and poor surface finishes (Diógenes, Barbosa, Teles., Mauricio, R., Policena., 2023). The depth of cut is crucial because as it increases, it leads to higher forces on the tool and increases the probability of fracture especially in hard materials. Additionally, the depth of cut is a critical factor, especially in hard materials, as it influences tool forces and the risk of fracture (Oleksiy, Larin., K., Potopalska., Yevgen, Grinchenko., 2022). The way the covering covers the outside affects how the milling machine moves. While stainless steel offers excellent resistance to corrosion, it also presents some difficulties, including increased cutting forces and elevated rates of tool wear. Aluminium alloys are easier to machine, but need particular concerns for keeping their surfaces within quality standards. The use of coolants helps in maintaining temperatures, enabling tools to remain usable for longer periods, thereby improving the surface finish as well as size accuracy.

Milling technology has advanced to the point where it can now create holes in pump casing covers with higher levels of accuracy than before. Component parts require very strict tolerances, due to which there is a need to employ a high level of precision in machining such workpieces as pump case covers. At the same time, high-speed machine (HSM) technology increases productivity rates using higher spindle speeds and feed rates, thereby allowing for higher precision when working on components with required accuracy or even advanced tool materials. HSM allows for increased cutting performance by utilizing higher spindle speeds and feed rates, resulting in improved accuracy when working on components that demand high levels of precision or advanced tool materials (Anna, Kiseleva., N., N., Barbashov,2022).

Consideration is key when it comes to creating holes in centrifugal pump casing covers during the process of milling, which is one of the parameters concerned with material properties in this process. This has in turn led to improved efficiency and accuracy through developments in CNC milling, high-speed machining, and smart manufacturing technologies. In the realm of centrifugal pump casing covers, the strategic placement of holes during milling plays a crucial role in enhancing efficiency and accuracy (Won-Sik, Kim., Jeong-Eui, Yun. ,2020). Improved results are aimed at by modernizing tool materials, geometries, and cooling techniques, in addition to research that keeps pushing these limits.

2.5 Summary of Literature Review on Refurbishing Casing Cover of Centrifugal Pump

Rehabilitating the casing cover of a centrifugal pump is a complex process that unites hi-tech and traditional manufacturing methods to ensure that it maintains a high operational standard. The review of the literature elucidates the application of SolidWorks design, Finite-Element Analysis (FEA), sand casting, as well as the process of drilling holes for screws and nuts. The pump casing's precise 3D models and technical drawings can be created by harnessing SolidWorks, a highly advanced CAD software. Before production begins, meticulous attention is paid to every single dimension and tolerance values by this particular program such that even the minutest modification could be accurately made. It is important to note that the perfection promoted by SolidWorks for these applications helps not only provide a good basis for any subsequent phases in processing but also reduce errors as well as optimize general design.

In order to determine how well the code looks into the redesigned housing box, Finite Elemental Analysis (FEA) is used. Analysing various aspects of the universe, such as pressure, temperature, and mechanical loads, FEA helps to pinpoint some likely places where the fault can occur and areas of high stress as well. It will hence be crucial for purposes of making sure that the repackaged-housing endures the demands due to operation since this analysis leads to better designs that last longer and perform well. FEA's predictive capabilities contribute significantly to reducing the risk of structural failures and extending the lifespan of the pump components.

Sand casting happens with the process of pouring a lot of liquid metal into a pattern that has been made by hollowing out an object with sand that is full with mould material Mold materials and casting techniques have made it possible to have much closer tolerances on dimensions as well as very smooth surfaces on cast parts in recent times. Due to its various applications and cheap nature, sand casting is still a method of choice for achieving complex pump casing geometries.

The first stage in refurbishing the pumping system is hole milling for screws and nuts. This activity is needed for proper drilling and tapping which secure all parts making the pump casing. Such a machine must be designed to maintain the high standards set on how tightly connected two objects become when they come into contact with each other during its operation. When screws and nuts fit properly into one another, the pump keeps its integrity and works as effectively as possible.

To sum up, the process for renovating the casing cover for a centrifugal pump involves the use of sophisticated modern CAD technology, in-depth analytical capabilities from FEA methods, while combining this with traditional sand casting that has been known for its toughness and observing a high level of detail in milling operations. Through the integration of these technologies, performance and reliability of the pump is improved by the refurbishment process which also shows the effective synergy between traditional manufacturing techniques as well as advanced engineering tools.

Table 2.1 Summary of Research

No.	Literature Title	Strength	Weakness	Notable Features	Reference
1.	Application of CAD Technology in Extracting Line Feature of Industrial Part Image	a. CAD technology permits exact and accurate designs that result in decreased mistakes and outputs of high quality. b. For faster iterations and modifications,CAD automation greatly speeds up the design process.	a. Involving huge initial investment in software, hardware, and training in CAD technology. b. In mastering CAD software there is demand for respect for proficiency and time to be spent.	a. It can enable you to make detailed 3D models and perform simulations so that you can then evaluate design performance and functionality. b. The technology is responsible creating designs that are highly adjustable because they parameter-based hence improving flexibility of the design process.	Fei Li, 2022
2.	A survey on 3D CAD model quality assurance and testing tools	a. One can identify potential problems on CAD models early on by having stress analyses and simulations done on them. b. With CAD models highly precise and accurate designs are made, thus making the final product closely actualized as it adheres to initial specifications to a great extent.	a. The input data quality largely determines the precision and dependability of the CAD model. b. To use CAD systems effectively, one has to be equipped with specialized software.	a. Advanced 3D modelling capabilities provided by CAD systems help the casing cover design be viewed comprehensively. b. Among the CAD system's distinguishable features are its capability to run different kinds of simulations including stress, thermal and fluid simulations.	González-Lluch et al., 2017
3.	New Trends in Robots Engineering with Professional Software SolidWorks.	a. Paying attention to the creation approaches implies that one is devoted towards ever bettering themselves through enhanced creativity.	a. In case of any technical problems or if individuals are not good at computer usage, much reliance on	a. The use of personal computers highlights the integration of modern technology in the evaluation process.	Dragne, C., Todirite, I., Pandelea, M., Frenţ, C. R., Cotfas, P. A.,

		b. With regard to invention there should be nothing hidden from revival that had been under study in previous models and this could possibly lead to broader investigations.	personal computers might bring in difficulties. b. Coming up with them as well as putting in place fresh plans could appear complicated and consume much time and funds.		Chiroiu, V., & Iliescu, M., 2022.
4.	Solid Modeling Using SOLIDWORKS®	a. Making it possible for developers check for stress, load and other factors prior building a physical prototype.	a. Not easy once started requires training practice before understanding it completely	a. Enables creating and handling complex assemblies thus ensuring that everything becomes fitting and functioning	Howard, W. E., & Musto, J. C., 2022
5.	Teaching solid modeling with autocad.	a. The process of producing precise sketches is actually made pretty easy by AutoCAD's well stocked library of parts as well as strong drafting tools.	a. When it comes to complex designs like filleting and chamfering features, nothing can beat SolidWorks though its work cannot be as complicated as SolidWorks.	a. It presents a complete set of drawing utilities for developing accurate and elaborate 2D drawings in industry.	Osakue, E. E ,2015
6.	Numerical simulation of centrifugal pump. Journal of marine technology and environment	a. The entire design process and its consequences are bettered by this path with the main plus of this approach indicated in a comprehensive context	a. It presumes its audience understands what scalar mis-specification and its integration is, but not everybody knows this concept.	a. To justify the design selected, coherent argumentation is highly valued with emphasis laid on clear communication as essential in design cases.	Andrei, Alexandru, Scupi., Mariana, Panaitescu., Fanel-Viorel, Panaitescu. (2023)

7.	Modeling and Experimental Analysis of the Single-shaft Coaxial Motor-pump Assembly in Electrohydrostatic Actuators.	a. Information provided by FEA supports the evaluation of factors causing fatigue and fracture, hence enabling better mitigation of such occurrences. b. Easier to plan maintainability and manage risk through predicting crack sizes or hearing extent of life spans that can be achieved using components.	a. Interpreting results from FEA demands specific skills since it may involve complex procedures	a. Recognizing critical flaw dimensions permits directed examinations and timely actions to be made on them.	Jiang'ao, Zhao., Deming, Zhu., Yuxuan, Ma., Yongling, Fu., Jian, Fu. ,2022.
8.	Computational fluid dynamics (CFD) analysis of centrifugal pumps.	a. FEA enables stress, thermal, and vibration characteristics analysis with a high degree of precision and accuracy that are unavailable elsewhere. b. Possible to identify highly stressed areas which need specific actions taken.	a. Numerous difficulties are involved in the accurate performance and interpretation of FEA results. b. Project timelines may be postponed due to the necessity of conducting these detailed analyses for them to provide useful indications.	a. Capability to conduct stress, thermal, and vibration analyses within a single framework. b. Enables the optimization of material properties for specific applications	Das, Ashish., B., Ch., Nookaraju. ,2023
9.	Development and Introduction of a New Composition of Wear-Resistant Cast Iron with Improved Performance	a. Grey cast iron resists wear really well, so is used in parts that rub against each other or scrape along the ground often while still staying strong.	a. This material is harder than other types of iron, so when its force exceeds its allowable limits through use or unexpected circumstances, maybe it will turn into brookites.	a. In machinery components the vibrations can be absorbed and sound may be dampened by grey cast iron. b. This is generally less costly to produce and machine, and hence	M., G., Potapov., B.B., Zaritskiy., Nataliya, Kuts. ,2022.

	Properties for Castings of Pump Parts.	b. This material is not difficult to cut and so you can do this in a way that gives the best results for your job or project.	b. Sometimes casting of grey iron leads to the presence of voids or bubbles within the ring which can affect its toughness and strength.	it is a solution that is cost effective in many industrial applications.	
10.	Sand Casting of Metallic Parts and Structures.	a. Achieving the desired quality of the final product is all about having a good surface finish and dimensional accuracy.	a. Optimizing mould quality and process parameters can go a long way in achieving this.	a. When it comes to sand casting, one has to look at it in a holistic manner in order to consider various other important factors that impact on it.	Максимов, В., П.. ,2022
11.	Effect of Casting Variables on Mechanical Properties of Direct Chill Cast Aluminium Alloy Billets.	a. Using finer sand in sand casting enhances the surface finish of a casted component.	a. The use of finer sand in a mould reduces its permeability thereby affecting casting.	a. Important to manage changes in sand grain size with utmost care for the best results in terms of both surface finish, and casting characteristics.	Chakrabarty,, Saurish. ,2023.
12.	Metallurgical Quality of Cast Iron Made from Steel Scrap and Possibilities of Its Improvement.	a. The consequences of high and low pouring temperatures are clearly outlined in it.	a. The temperature ranges or specific conditions that cause these defects.	a. It is important to control pouring temperatures so as to avoid defects.	Futas, P., Pribulova, A., Petrik, J., Blasko, P., Junakova, A., & Sabik, V. ,2022.
13.	Investigation on Role and Impact of 3D Printing Technology in Sand Casting.	a. The system generates detailed images of the internal structures, allowing the detection of small imperfections, thus detecting even tiny defects.	a. Special tools with radiation effects are used for operation. b. Complex installation process.	a. It gives cross-sectional views making it useful for accurate analysis of the faults in diverse materials. b. Can detect faults at various depths and therefore this method is applicable for many industries.	Pravat, Kumar, Dhal., P., V., Arul, kumar., Ganesh, Muthu., Senthil, Kumar, Kaliappan., L., Natrayan., Gori, Yatika. ,2023.

		b. The system has sensitivity of defects on both surface and through-thickness together with penetrating thick objects.			
14.	Pump cover drilling device for vacuum pump machining.	a. Machining processes make sure that the features needed for pump assembly are produced accurately, thus making component manufacturing as accurate and consistent as possible.	a. Machining processes may prove intricate and expensive especially with complex designs and hard-to-machine materials which could cause an increase in the cost of production.	a. Machining processes help in achieving a very high level of accuracy and precision which enables casing covers to meet the high-quality standards and tight tolerances required for pump assembly.	Wang, Xiao'ou. (2019
15.	Fabrication of a Stainless-Steel Pump Impeller by Integrated 3D Sand Printing and Casting: Mechanical Characterization and Performance Study in a Chemical Plant.	a. Rotary cutters can be used in order to achieve precision in machining, hence achieving screw holes that are highly accurate.	a. The increased complexity of setup and setting up might make it expensive as well as lead to increased costs of production, as well as having more expensive costs for training.	a. Emphasizes the precision possible through versatile machining when it comes to accurate screw hole creation.	Felix, Hernández., Alex, Fragoso. ,2022.
16.	Application of Design for Manufacturing Technique to Lubricating Oil Pump Body for Reduction of Its Machining Time.	a. Cast iron is less expensive compared with other materials. b. Stainless steel is suitable for environments with high humidity because it does not	a. However, it can be brittle especially white cast iron. b. Stainless steel can be more expensive than other materials.	a. Combines strength and ductility, suitable for specific applications. b. Non-magnetic, excellent corrosion resistance.	L., A., Kalashnikova. (2022).

		corrode or rust due to water contact. c. There are some aluminium alloys that are easy to work with.	c. They are less powerful than steels.	c. Commonly used in machining due to its good strength and machinability	
17.	A Short Literature Review on Turning and Milling of Cobalt Alloys.	a. When you're machining it, stainless steel still doesn't rust or corrode. b. There are some aluminium alloys that are extremely machinable.	a. Stainless steel when you're machining it, gets harder and tougher, which has an influence on tool life. b. Burs will form and finish will be poor if you work at high speeds.	a. Non-magnetic, excellent corrosion resistance. b. Commonly used in machining due to its good strength and machinability.	Diógenes, Barbosa, Teles., Mauricio, R., Policena. ,2023.
18.	Assessment of the residual life-time of the elements of the centrifugal pump of the energy installation on the basis of statistical assessment of fatigue with predicted wear due to corrosion.	a. Deepen the cut to remove materials faster during machining.	a. If you take deeper cuts, you will probably experience high cutting forces which will also reduce the life of your cutter tools and make your machine less stable.	a. Our ability to cut deeper into something also depends on how the tools have been developed	Oleksiy, Larin., K., Potopalska., Yevgen, Grinchenko. ,2022
19.	Making amendments to CNC machines in order to improve manufacturing accuracy.	a. HSM is used for components with tight tolerances, so that it becomes a choice between space saving or precision.	a. When working in this environment; machines need to be able to stand up under immense pressure and shaking.	a. In order to maximize the amount of material that can be removed HSMs are designed with circular tool paths procedures.	Anna, Kiseleva., N., N., Barbashov. ,2022.

20.	CFD Analysis on the Balancing Hole Design for Magnetic Drive Centrifugal Pumps.	a. Smooth operation is guaranteed when the holes are in the right places to reduce the likelihood of cavitation. b. There is always an opportunity to place holes strategically based on different pump designs, and working environments.	a. Inefficient fluid transfer or entrapment may occur where the holes are wrongly placed leading to leakages among other problems. b. Despite being baffling at times, there is a need for precision drilling and alignment.	a. It is important that they are placed in such a way that flow rate is controlled while power losses are minimized. b. They also serve as an entry points for water so that it does not cavitate here either.	Won-Sik, Kim., Jeong-Eui, Yun. ,2020

Table 2.1 show the summary of research for this project. From this table, engineering concepts, technologies, and materials that have found their way through the design and manufacturing process are discussed in the document, with special emphasis on the merits, demerits, and applications of use. CAD technology would take to mind precise designs, acceleration of iterations, and simulation, although it involves a very high investment and expertise. The quality of CAD model, however, reflects the accuracy of the product as influenced mostly to the reliability of input-data. Recent methods of evaluation use personal-computers to enhance creativity and refinement of designs while bringing several technical challenges and resource costs along with it. Solid modeling software allows stress and load analysis to be done before prototyping, but it requires a lot of training for implementation.

Comparing AutoCAD and SolidWorks reveals the advantages of the drafting and component libraries of the former while the latter is noted for complex modeling tasks. Scalar mis-specifications stipulate clarity in the communication process, furthering effective design practices. Finite Element Analysis (FEA) is a state-of-the-art tool for practical stress, thermal, and vibration analysis by which components can be optimized and failure predicted, although such forms of analysis require specialist knowledge and time-consuming.

Cost-effective materials such as grey cast iron display high wear resistance but view crushing, brittleness, and casting defects as challenges. Sand casting techniques point to process control, surface finish, dimensional accuracy, and temperature control as being critical. Non-destructive testing techniques are considered excellent at exposing internal and surface defects with the provision that advanced tools and expertise are required. Machining techniques like High-Speed Machining (HSM) bring in more precision and efficiency particularly on complicated designs, while some materials such as stainless steel and cast iron are suitable for different industries concerning cost, strength, and machinability.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The casing cover of a centrifugal pump plays a vital role in ensuring the operational efficiency and structural integrity of the pump by housing the impeller and other internal parts providing a sealed environment to prevent loss and maintain pressure. In particular, the creation of accurate holes for screws which are essential for fitting and fastening this cover necessitates precise machining processes when manufacturing this cover in order to enable necessary dimensions and tolerances be achieved.

Incorporated in the methodology is the designing and choosing of materials which offer resistance of strength, corrosion, heat-stability according to dimensions as well as structures derived from the operational parameters. This will further be succeeded by prototyping followed by testing where the prototype is developed using quick model making skills before being exposed to both mechanical forces as well as water pressure so as to ascertain whether it conforms to the desired standards or not. The manufacturing process first requires casting the main body of the housing cover using methods like sand. It is then machined accurately to meet necessary tolerances and possessed with surface finishing to improve strength.

3.2 Research Design

The research for designing casing covers of centrifugal pumps is a sequential procedure that guarantees their adherence to strict mechanical, dimensional and functional benchmarks plus cost effectiveness in the manufacturing process. The report has its targets which also include enhancement of the design, material choice and ensuring unyielding quality control processes establishment. To start with, the researchers will comprehensively review current literature sources in order to isolate best practices as well as identify ongoing challenges posed by technology in its recent developments. In the course of design development; detailed models are created employing computer-aided design (CAD) software using SolidWorks after which finite element analysis (FEA) are used for evaluating how well-designed system works at different operational conditions.

3.3 Proposed Methodology

A centrifugal pumps cover containing internal parts, preventing liquid leakage, and their strength under operation pressure should be in a housing plate. If we are to create dependable enclosure cap for centrifugal pumps, there are certain processes that need to be completed. The design phase starts when the operational requirements have been understood. The analysis through SolidWorks software for preliminary stress analysis followed by iterations for conceptual design. Detailed design involves the creation of accurate 3D models, running finite element analysis (FEA) for stress and thermal load simulations then optimizing it for weight, manufacturability and cost. Critical selection of material involves carrying out research and testing for properties such as tensile strength, fatigue resistance, corrosion resistance, and thermal stability, ultimately leading to the best possible materials to use.

The production process begins with the selection of the correct casting method. This can be done through sand casting. Once this is accomplished, a casting plan is developed, which incorporates activities to be carried out promptly. For example, mould design should also be done at this juncture since it determines other processes like pouring hot metals into cavities within it. Creating holes for screws and nuts by milling is a precise machining process which is vital for attaining true angular and fitting in mechanical assemblies. Initially, there are detailed technical drawings which state the diameters, locations and tolerance level of the holes, as well as affirming the kinds of screws and nuts that are used diameter, number of threads and their depth below the surface of the material.

From the figure 3.1, the starting a project requires recognition of its essential constituent parts. It includes an awareness of the constituent parts necessary as well their specific specifications. The project will then proceed to the next step once have fully understood what is needed. In the subsequent step, dimensions of every part are taken. For proper fitness and working ability, it is important that you measure accurately. Now when have this information, the making cad models was started. Then move on to carry out finite element analysis (FEA) after cad modeling. This requires simulating how different structures behave mathematically when subjected to various forces or pressures.

Next is pattern making. Patterns are templates for casting processes, making sure that they are always accurate and uniform. Guided by the patterns made, the molds for sand casting are produced. Finishing aspects come immediately after casting. Finishing a product involves additional machining processes among others such as polishing or applying protective coatings. The final part gets improved in terms of aesthetics and functionality through these processes.

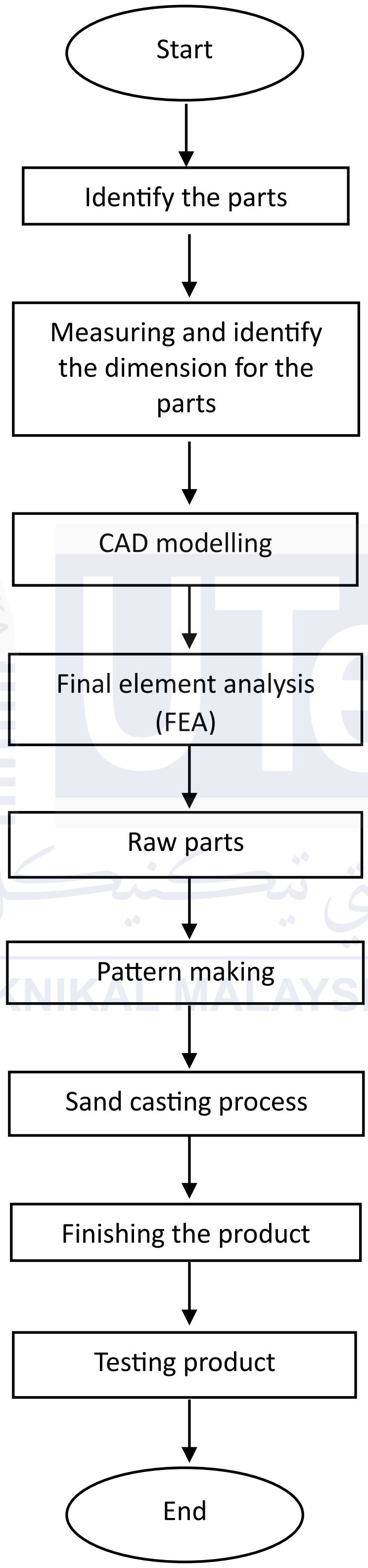


Figure 3.1 Flowchart of project

3.3.1 Project Planning

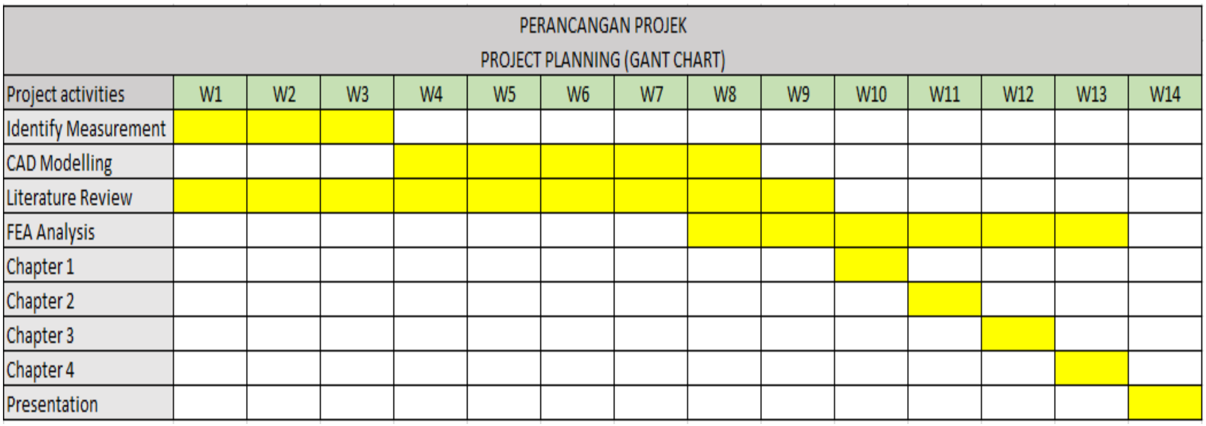


Figure 3.2 Project Planning PSM 1 (Gant Chart)

Figure 3.2 shows the Gant Chart for project planning for PSM 1. The first phase of the project is "Identify Measurement". Its main objective during this period is to gain an understanding of the measurements that are required for the project, which makes it essential as it contributes towards effective planning and eventual execution. The most time-consuming process of the project is “CAD Modelling” which runs from Week 3 to Week 8. In the course of this time period, detailed computer-aided design (CAD) models are created by the team. These models provide the basis for more study and development. During the CAD modelling process, the team also does a literature review which is an examination of past researches relevant materials around the project and good practices. The FEA phase is scheduled within week 8 to week 13 that’s where the conduct finite element analysis (FEA) simulations which are used to assess how structures behave under different conditions so as to detect possible areas of weakness that need strengthening among others such as writing up the final project report in weeks 10 to week 13. The presentation which is made is thought to be a summary of the whole project with an emphasis on key findings, challenges and recommendations.

PERANCANGAN PROJEK															
PROJECT PLANNING (GANT CHART)															
Project activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Sand Casting															
Milling Process															
Product Finishing															
Product Repair															
Product Fitting															
Chapter 4															
Technical Report															
Poster															
Preperation Presentation															
Presentation															

Figure 3. 3 Project Planning PSM 2 (Gant Chart)

Efficient project management is the key to success, and the Gant Chart from Figure 3.3 presented provides a straightforward timeline of 15 weeks for intervals of task completion for PSM 2. Thus, one begins with sand casting week 1 until week 3 and proceeds into the milling schedule week 4 until week 7. Product finishing week 8 followed by product repair week 9 to week 10 of the product fitting week 11 until week 12 ensures quality. Documentation work, such as drafting Chapter 4, occurs in week 13 to week 14. The final week, week 15 is critical, with the completion of the technical report, poster preparation, presentation preparation, and the final presentation.

3.3.2 Measurement of The Components

Ensuring accurate supply for appropriate fitting, function, performance of a centripetal pump casing cover components is essential along with the provision of proper dimensions as well as defining details necessary for product quality. So, it starts by taking note of important dimensions or tolerances indicated on the blueprint and design definition. Depending on the required accuracy and dimensions to be measured, the most appropriate measurement tools to use include digital vernier calliper and ruler among others. It is crucial that every tool used when taking measurements is calibrated and working perfectly. In addition, the air within which these measurements are taken should have its temperature and humidity well controlled while anti-vibration tables or mounts should be in place so as to avoid any measurement errors possible.

The measurement process involves several steps. External dimensions are measured using vernier callipers, with multiple points checked along each dimension for uniformity and deviations. Internal dimensions are measured with internal callipers for complex geometries. The accuracy of a vernier calliper is dependent on the right choice and using standard gauge blocks to calibrate it, so, calibration is inevitable. Before measuring anything with a calliper, check it first to see if there is any physical damage that could affect its workability. To measure outside dimensions, clean the casing cover of centrifugal pump surface and then open up and over-rate size of measurement line between two edges using its mouth. Afterwards, the component is gingerly held in between the callipers to ensure they are perpendicular to the surface so as to avoid parallax errors. Whereafter, the main and vernier scales are read together to obtain the ultimate value, which is then measured and assessed against stipulated tolerances.

Figure 3.4 Measurement for casing cover of centrifugal pump

From the figure above, it comprises a wrench, a vernier calliper, a screwdriver, and a measuring tape. The casing cover itself lies on drawing paper or other protective surface while holding it up presumably to take measurements using the tape. Other items on the table such as bolts nuts and pulley suggest that assembly or disassembly work is still in progress. Safety and exactness are emphasized during measurement as shown by red gloves and instruments used for measurements here.

The centrifugal pump casing is represented through a hand-drawn schematic on a piece of drawing paper. It is possibly accompanied with dimensions and some annotations related to the casing cover and its assembly instructions. The drawing seems to be utilized as a point of reference during fabrication, assembly or inspection processes. A casual sketch pad view may have been created using the drawing paper surface so that one would obtain direct measurements from the actual casing cover which can be seen in the previous figure. This methodology aids in visualizing the part's size as well as characteristics thus making it easy for accurate duplication or further examination.

3.3.3 SolidWorks Design and Drawing Process

SolidWorks, designing and drawing casing covers for centrifugal pumps, requires a structured approach to guarantee function, manufacturability, and compliance with industry norms. Design principles are defined, specifications assembled, and functional requirements understood at the start of this process. Initial conceptual designs shall be drawn and evaluated so as to identify a practicable one. When using SolidWorks, one will begin by creating a fresh portion file and sketching out straightforward geometries on its top plane only constructing them and other things we need more space on additional upon it being extruded up beyond our 2D world. Then these flanges may be added using another sketch while bolt holes can appear through an extrude or cut operation respectively before adding some ports too separately drawn out individually before finally getting rounded corners between faces for instance or some sharp edges like knives handles at their joints etcetera within each side piece where required according to certain standards.

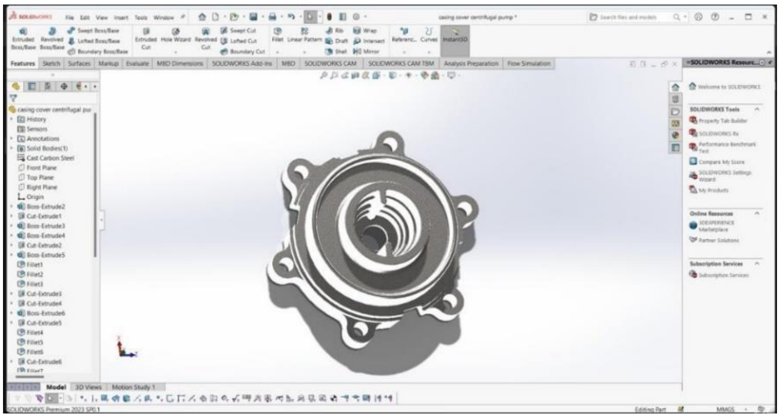


Figure 3. 5 3D drawing process for casing cover centrifugal pump

Finite Element Analysis (FEA) are done in order to confirm the design against operational loads and include steps like model property assignment, meshing, boundary condition application etc. Peer design reviews often help in improving the design while making changes according to feedback received from analysis results. We can then develop detailed 2D drawings from this 3D model with various perspectives, measures and tolerance levels for its production. The design undergoes virtual stress tests using Finite Element Analysis (FEA) to ensure it can resist real-world operational loads. Realization of material properties, mesh generation and boundary set up create a thorough simulation giving necessary guidelines and invaluable insights.

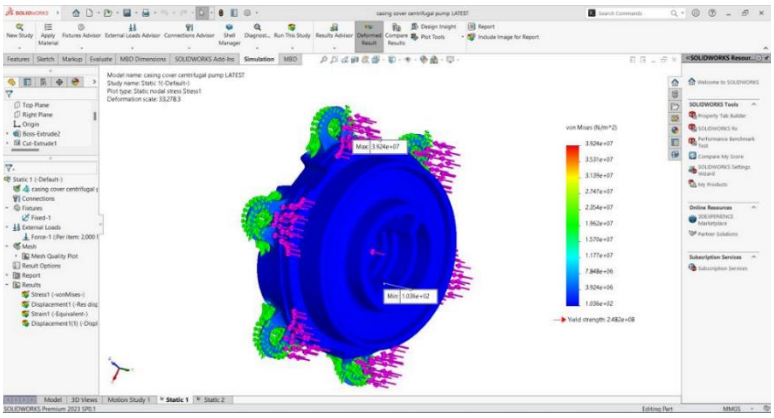


Figure 3.6 FEA Analysis process on casing cover of centrifugal pump

The use of SolidWorks is a powerful tool beginning from the sketch and extrusion features to simulation and drawing annotations so that we can go through it. In addition to that parametric design and configurations provide flexibility thus allowing simple alterations within different designs created. Due to the design library, frequently used aspects are readily available whenever there is need for the other projects.

3.3.4 Fabrication process on refurbishing casing cover of centrifugal pump (Sand Casting and Milling)

When creating a casing cover for centrifugal pump, the process of sand casting is characterized by various careful stages in order to produce items of high quality and precision. Starting with definition of design requirements like size of the material, physical properties in addition to operating parameters. Then, the procedure of preparing the mould starts by installing the flask, which is made up of two parts, the top part called cope and the lower half named drag. In the drag, sand is pressed together with binder around the pattern to produce a mould out of it. These actions are followed by creating a parting line surrounding the pattern, while keeping cope aligned with drag and spraying holes for both pour down metal (sprue) and releasing gases (risers) shown as Figure 3.7. The pattern is then carefully removed, leaving a cavity that is inspected and repaired if necessary.

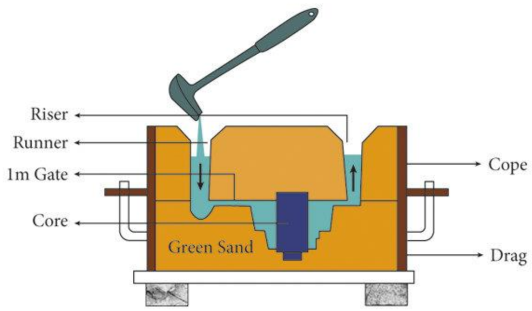


Figure 3.7 Schematic of sand-casting process

(Source: *researchgate.net*)

Figure 3. 8 Process of making core with resin

In sand casting, manufacturers must use cores, which are important parts that will form some voids and undercuts that can't be created with the use of mould alone. The durability and accuracy of the core is one of the important factors determining the quality of the final casting. Resin-bonded sand is especially well suited to core-making due to its very good mechanical properties, excellent thermal stability, and capacity to achieve fine detail.

Figure 3. 9 Burning resin

Figure 3. 10 Finish core

The process of making cores of sand castings using resin, the steps involve mixing sand with resin at the ratio of 0.5% to 3% of the weight of sand and catalyst. This brings uniform coating and activation. The mixture was then compacted into the core box, which acts as a mould for the core. Vents are made for the escape of gases during curing, a release agent is then applied for the easy removal of core after it hardens. Different resin types have varying curing methods, application of heat as shown at Figure 3.9, gaseous catalyst passing, or straight letting hardening through a no bake process. Then, the core is very carefully removed and trimmed before optionally coating it to optimal surface quality and metal penetration prevention. The core is thus finally stored under dry conditions until time for casting as shown at Figure 3.10.

Figure 3. 11 Adding filler to the casing cover centrifugal pump

Figure 3. 12 File process on filler

The process starts with pattern making where they create a pattern of the part to be cast. Patterns are made from metal and modelled to compensate for shrinking during metal cooling. For complex parts, oftentimes split patterns are used to enable accurate shaping of complex forms. This includes allowance for other features, such as gates and risers. Figure 3.11 shows the filler was been adding to the casing cover of centrifugal pump to closed the hole and make a smooth surface when making a mould for sand casting. Then the filler had been file to remove any dirt and make the smooth surface as shown at Figure 3.12.

Figure 3. 13 Filter the sand

Figure 3. 14 Casing cover in moulding box

Figure 3. 15 Mixture sand packed around the pattern

Next comes moulding preparation the mixture of sand must be filter before packed into the moulding box as shown at Figure 3.13. Figure 3.15 shows a mixture of sand, clay, and water is tightly packed around the pattern within a moulding box or flask to produce a mould cavity.

Figure 3. 16 Gates and riser added

In the case of two-part moulds, the drag (bottom section) is prepared first, then the cope (top section). Channels or gates, are formed in the sand to convey molten metal into the cavity, and risers are added in order to supply extra material during solidification as shown on Figure 3.16.

Figure 3. 17 Mould of pattern

Figure 3.17 shows the mould of pattern for the casing cover that had been remove from the moulding box. Cores are formed from resin sand and are prepared separately and placed in the mold cavity for core placement when the casting has to be hollows or has complex internal geometries. A core print will hold them in place and keep them accurate during casting.

Figure 3. 18 Mould assembly

Figure 3. 19 Cutting process aluminium bar

The drag is put together with the cope section while core placement happens accurately as shown on Figure 3.18. The clamping of the three halves securely restricts the molten metal from leaking through the joints while pouring. The mould now stands ready for casting. Figure 3.19 shows the process of cutting aluminium bar on band saw. Metal melting follows where the chosen material is heated in a furnace until it reaches a molten state. The kind of furnace to be used such as induction, cupola, or electric arc relies on the material cast. Impurities that do exist will skim off the molten metal and pour it into the mould carefully. Controlled speed is required during pouring as shown at Figure 3.20 to avoid turbulence that leads to such defects as air entrapment.

Figure 3. 20 Pouring molten metal

Figure 3. 21 Full filling molten metal in the mould

Once the mould is filled as shown at Figure 3.21, the metal cools and solidifies. Cooling time is material, part size, and complexity dependent. Good designs of the mould and risers will minimize shrinkage defects due to contraction of the metal during solidification.

Figure 3. 22 Removing sand from the part

Figure 3. 23 Cooling process for the metal mould

Figure 3.22 shows the removal of the metal mould happens after solidification, known as shake-out. The broken sand mould is now ready for casting withdrawal. In most cases, they will apply the sand again into a future mould, hence making the process sustainable. Then the cooling process for metal mould by put the part into the water as shown on Figure 3.24. Afterward, the retrieved casting undergoes cleaning and finishing to remove excess sands, scales, and surface imperfections. Common methods are shot blasting or grinding, trimming excess material from gates and risers, and may further be machined or polished for more accurate dimensions and surface finish.

Figure 3. 24 Milling process

When needed, the casting is subjected to heat treatment methods, specifically either annealing or tempering, until it attains the needed mechanical characteristics. Afterwards, the casting is attached to a milling machine as shown at Figure 3.25 in order to be accurately machined following an initial inspection for possible faults. At this juncture, accurate holes for screws and nuts are bored and then any other necessary machining is done according to the requirements given at the end of the day. When you have taken the final steps in this regard and they create the whole product, the final steps can be applying surface treatments for appearance and corrosion resistance, assembling the cover if part of a larger unit and compiling comprehensive documentation. Production of a high-quality, durable casing cover that meets all design and operational requirements is ensured using this detailed methodology.

3.5 Summary Methodology

There are several critical steps involved in refurbishing the enclosure cover of a centrifugal pump. Initially an initial thorough inspection is carried out in order to evaluate the wear and tear and this is followed by taking the exact dimensions using tools such as callipers or ruler for instance. Composition of the material is examined by use of spectrometry whereby every result found are recorded down in detail. During the SolidWorks phase of design, the body of measurement is used to form a complex model, which can be modified to further enhance the design. For instance, simulation tests are carried out to check the validity of design, and very detailed drawings made. Finally, final stage involves ensuring that all conditions are met.

Creating a pattern, preparing a sand mould, pouring molten metal, and cleaning the casting are all steps in the sand-casting process. It is then milled beginning with rough milling to get rid of surplus material followed by finish milling to meet final specifications. Dimensional accurateness is checked via precision measurements. Assembly of the reconditioned casing cover onto the pump is carried out before subsequent tests on its operationality. They comprehensively document every stage in the process from taking measurements to making design modifications and finally to testing results. Measures have been taken to ensure that the reliability of the reconditioned casing cover is high while also guaranteeing its long life.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This exercise tackles at ways and means of dealing with normal wear and tear happening in course of time due to operational strains and environmental elements. Initial phases of this revamp consisting of putting measurements in place, designing and making are shown on these pages as brief information. The refurbishment aims to restore the casing cover to its original specifications or better by using advanced measurements techniques and SolidWorks design tools. This introduction lays out the process used and gives an outline of the preliminary discoveries thus paving the way for comprehensive examination and more improvements. By meticulously planning and executing, this initial data provides a solid step towards a successful refurbishment aiming at promoting the performance and reliability of the centrifugal pump.

Figure 4.1 shows two isometric views of the centrifugal pump casing are presented from different angles in the image. Isometric views are 3D pictures that help in understanding the general shape and structure of components. They give an idea of what the casing looks like from outside, including major features such as mounting points and the part’s general outline. Meanwhile, Figure 4.2 shows the Orthographic drawing for casing cover of centrifugal pump. The upper view reveals an aerial perspective of the pump housing disclosing important parameters like outer diameter (Ø83.00 mm, Ø144.00mm) and bolt holes (Ø85.00mm). Section A-A, this section view exposes some features of the internal structure of the pump housing which are not visible from outside, for example thickness of walls or internal geometry. This is a closer look into one specific area on the casing of the pump, particularly at a curve with radius (R13.80) along with some minor elements that need to be manufactured with greater accuracy. B side view is a representation of the pump casing's side profile which gives an idea about its height and some other features from the side. Detail B is similar to detail A, this zoomed-in view concentrates on another specific region of the casing highlighting curves and several features significant for assembly or operation. All dimensions are given in millimetres (mm) and they are important for the manufacturing process to correctly produce the piece.

4.2 Result and Analysis Refurbishing Casing Cover of Centrifugal Pump

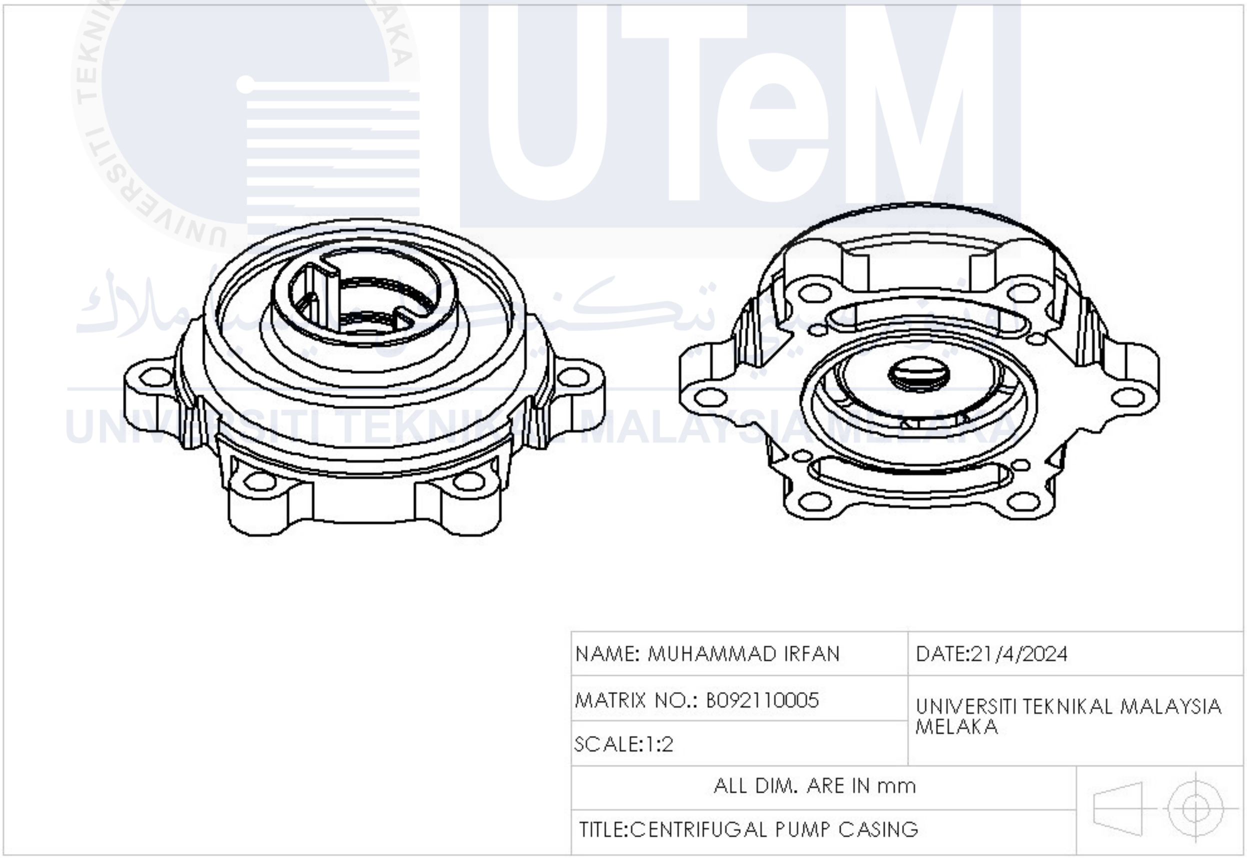


Figure 4. 1 3D drawing for casing cover of centrifugal pump

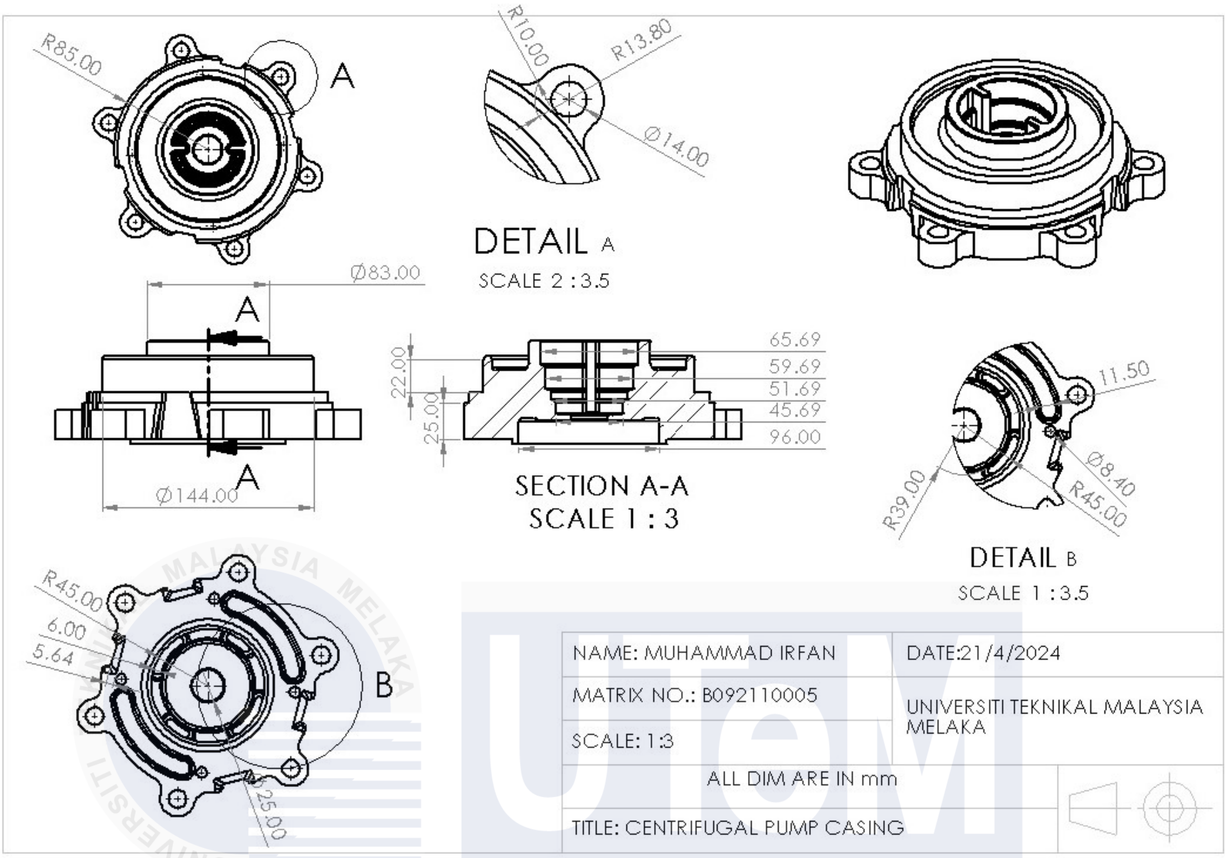
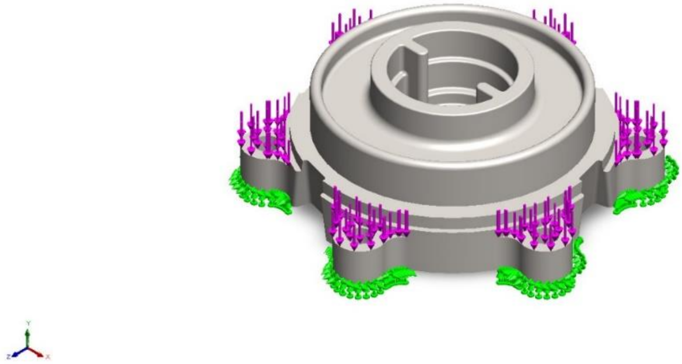


Figure 4. 2 Orthographic drawing for casing cover of centrifugal pump



Model name: casing cover centrifugal pump LATEST
Current Configuration: Default

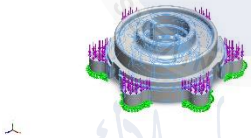
Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Fillet15 	**Solid Body**	**Mass:6.20464 kg Volume:0.000795467 m^3 Density:7,800 kg/m^3 Weight:60.8055 N**	**C:\Users\ASUS\Desktop\IRFAN MUQRI\casing cover centrifugal pump LATEST.SLDPRT May 28 21:59:18 2024**

Figure 4. 3 Model Information

Figure 4.3 shows the model information. Model is regarded as a solid within CAD environment and saved as "Fillet15". The volumetric properties show the casing cover has a mass of 6.20464 kg, volume of 0.000795467 m³ and density of 7800 kg/m³ which is a common thing for metals like steel or cast iron. The casing has a weight of 60.8055N. The model also contains visual elements that probably depict forces or constraints suggesting that this design is likely to undergo some form of structural analysis like finite element analysis (FEA).

Table 4.1 Material properties

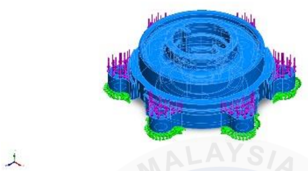
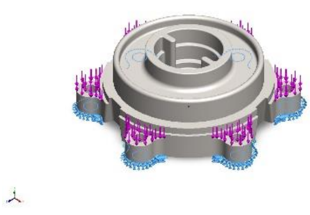
Model Reference	Properties	Components
	Name: Cast Carbon Steel Model type: Linear Elastic Isotropic Default failure criterion: Unknown Yield strength: 2.48168e+08 N/m^2 Tensile strength: 4.82549e+08 N/m^2 Elastic modulus: 2e+11 N/m^2 Poisson's ratio: 0.32 Mass density: 7,800 kg/m^3 Shear modulus: 7.6e+10 N/m^2 Thermal expansion coefficient: 1.2e-05 /Kelvin	Solid Body 1(Fillet15)(casing cover centrifugal pump LATEST)
Curve Data/A		

Table 4.1 shows the material properties for casing cover of a centrifugal pump. The material used is recognized as cast carbon steel, with linear elastic isotropic behaviour that is indicative of its uniform deformation under stress in all directions and return to the original shape after removal of stress within elastic limit. Its yield strength or stress at which it begins plastic deformation is 2.48168e+08 N/m². The tensile strength, which is the maximum stress that it can withstand before turning to be a failure point, comes out approximately at 4.82549e+08 N/m². This material has mass density equal to 7,800 kg/m³ while shear modulus equal to 7.6e+10 N/m² indicates its rigidity against shear stresses amongst other things. Moreover, its thermal expansion coefficient equals 1.2e-05 per Kelvin which simply means what can be understood by every degree rise in temperature with respect to size increase; based on these properties one would be able to predict how pump casing behaves under mechanical loads as well as thermal conditions expected for such environment where such items will have to operate.

Table 4.2 Fixture of casing cover

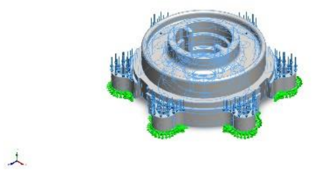
Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 24 edge(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.00150776	12,000	1.90735e-06	12,000
Reaction Moment (N.m)	0	0	0	0

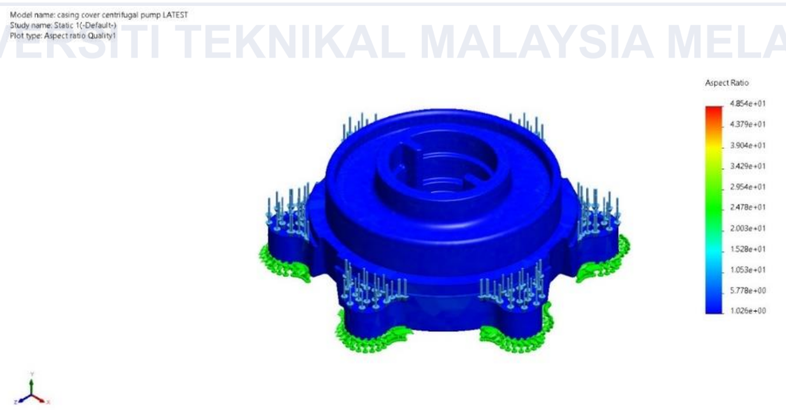
This is the fixed geometry used to constrain the casing cover as detailed in Table 4.2, wherein 24 edges of the component are fixed. The reactions from those restraints are also found in the table. From the results, it can be seen that the reaction force in the Y-direction has the maximum value of 12,000 N. The forces in X and Z directions are so comparatively negligible that they are recorded as 0.00150776 N and 1.90735×10^{-6} N, respectively. In addition, there is no significant reaction moment either, as indicated by the fact that all moments are 0 Nm. This restraint configuration would be an accurate representation of the operating conditions under which the casing cover will be fixed in certain regions.

Table 4.3 Load image of casing cover

Load name	**Load Image**	**Load Details**
Force-1		Entities: 6 face(s), 1 Solid Body (s) Type: Apply normal force Value: 2,000 N

Meanwhile, an operation load has been considered for the purpose of modeling the stresses on the casing cover. The method of applying the load, which is called "Force-1," is given in Table 4.3. A standardized force of 2,000N is distributed in six different surfaces and one solid body of the casing cover. This type of load configuration conveys realistic in-use loading situations that the component will face in its installation in a centrifugal pump.

Name	Type	Min	Max
Quality1	Aspect Ratio	1.026e+00 Element: 92760	4.854e+01 Element: 133080

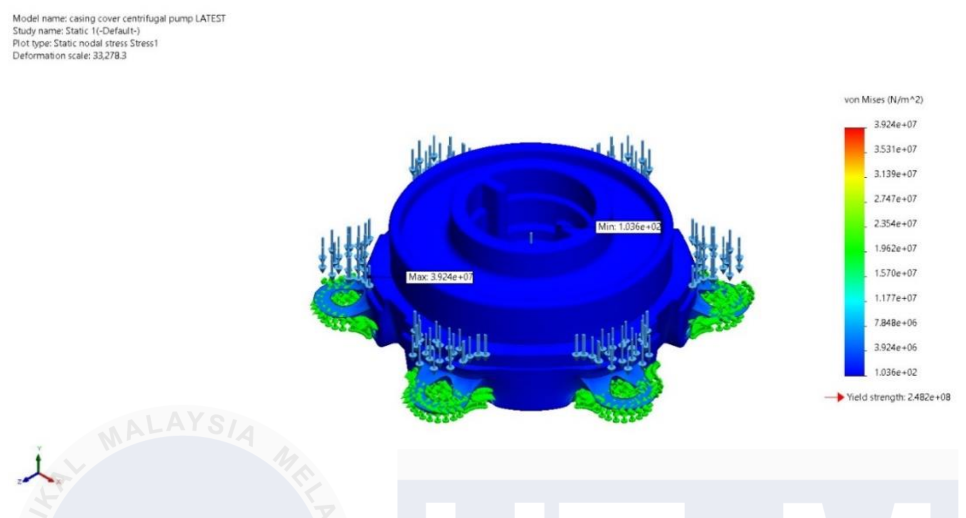


casing cover centrifugal pump LATEST-Static 1-Quality-Quality1

Figure 4. 4 Mesh quality plots

The mesh quality of the model is shown in Figure 4.4, for the distribution of aspect ratios across the finite elements. Good quality in meshing is imperative for to get reliable results from FEA, as bad quality elements can lead to errors for results on stress and strain.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.036e+02N/m^2 Node: 362862	3.924e+07N/m^2 Node: 189



casing cover centrifugal pump LATEST-Static 1-Stress-Stress1

Figure 4. 5 Stress 1

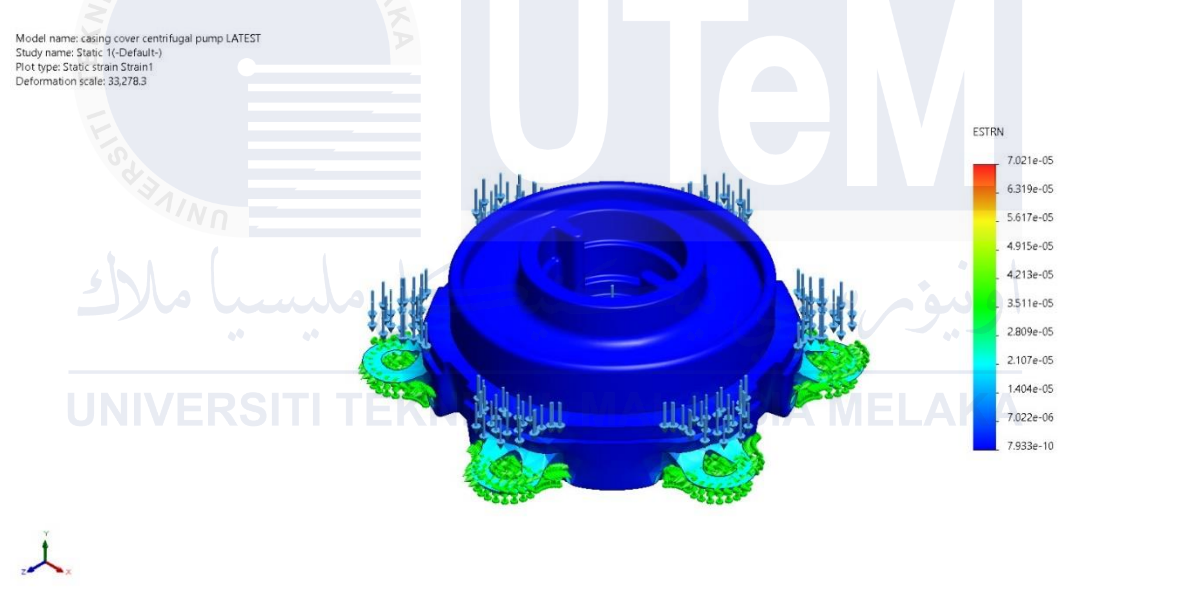
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 58	6.376e-04mm Node: 8672

casing cover centrifugal pump LATEST-Static 1-Displacement-Displacement1

Figure 4. 6 Displacement 1

Figure 4.5 depicts the stress distribution across the casing cover utilizing the von Mises stress criterion. This criterion evaluates the ability of the material to resist yielding under the action of the applied loads by computing the overall stresses at different locations. The minimum stress obtained is 1.036×10^{-2}N/m^2, located at Node 362862, in areas of minimal force concentration or away from fixtures. The maximum stress is 3.924×107^{7} N/m^2 occurring at Node 189, likely in regions where geometric transitions or load concentrations occur. Figure 4.6 illustrates how the applied loads on the casing cover affect the displacement distribution. This evaluation makes sure that the deformation of this component stays at acceptable levels so as not to interfere with other parts or render them ineffective. The minimum displacement is 0.000mm and recorded at Node 58, which is common for fixed points or areas least influenced by effects of applied forces. The largest deformation value is 6.376mm.

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	7.933e-10 Element: 147571	7.021e-05 Element: 118116



casing cover centrifugal pump LATEST-Static 1-Strain-Strain1

Figure 4. 7 Strain 1

Strain analysis, as shown in Figure 4.7, measures the deformation of the casing cover from its original dimensions. Strain is the direct measure of a material's elongation/compression under loading and affects directly the durability of the material. The minimum strain is 7.933×10^{-5}, occurring in Element 147571, situated in low-stress zones with negligible deformation. The maximum strain is 7.021×10^{-5}, located in Element 118116, corresponding to the high-stress and high-displacement regions.

Name	Type
Displacement1{1}	Deformed shape

casing cover centrifugal pump LATEST-Static 1-Displacement-Displacement1{1}

Figure 4. 8 Displacement 1(1)

Figure 4.8 demonstrates the deformations of the casing cover resulting from 2000 N load applied with fixed sides restricting movement. Such displacements are exaggerated for better visibility and their maximum and minimum displacement areas clearly marked. Maximum Displacements are found at locations furthest away from the fixed edges and attain a peak value of 6.376 mm. Minimum Displacement, found around the fixed zones confirming the constraint effectiveness, that is the measuring point in assessing structural performance within the design whereby deformations should remain safe and shall not interfere with any other parts that surround it. It validates and clarifies the design's reliability and highlights areas for improvement for enhancing the casing cover in this regard toward long-lasting durability and functionality in a centrifugal pump system.

Figure 4. 9 Casing cover of a centrifugal pump from sand casting

Figure 4.9 shows the casing cover of a centrifugal pump that had been produced by sand casting process. The casing cover of centrifugal sand-casting pump is shown here. By paying low cost and producing geometri-cal forms of considerable precision, sand casting was chosen as a process. This material is expected to possess sufficient durability and anti-wear index to be worn out in operation.

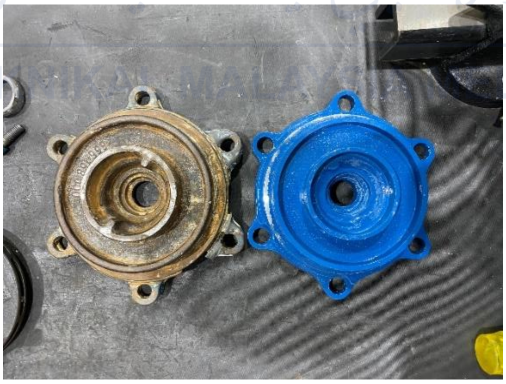


Figure 4. 10 Old casing (left) and New casing (right)

This Figure 4.10 shows an image of worn-out original casing on the left side and newly cast casing on the right side. This replacement housing has in many respects improved surface finish and dimensional harmony, resulting in much tighter sealing and operational efficiency. The low contrast shows clearly the reason for replacement: degradation to prolong the equipment life.

Figure 4. 11 Product fitted on centrifugal pump

The new casing was successfully installed onto a centrifugal pump as shown on Figure 4.11 once it was undergoing finishing process. The installation phase thus represents compatibility with the existing pump design, given that it validates the accuracy of the achieved dimensions and structural integrity established at the time of manufacture.

Figure 4. 12 Product fitted on whole machine centrifugal pump

Thus, Figure 4.12 shows the centrifugal pump with the new casing influenced into an overall operational assembly. The pump then underwent several performance evaluations, demonstrating its operability under standard operating conditions. Observations indicated improved efficiency coupled with lesser vibration, confirming the robustness of the new casing design and manufacturing process.

4.3 Summary

The case study aimed to make the casing cover of a centrifugal pump by employing SolidWorks in creating drawings for it as well as Finite Element Analysis (FEA). The main purpose was to enhance the pump structural integrity in addition to its performance and lifespan through addressing the present wear and tear matters. This involved developing a comprehensive 3D model of the casing cover in SolidWorks encompassing essential dimensions, characteristics, and parts. Materials selection based on mechanical properties, corrosion resistance and compatibility with operating environment of pump. The design changes for strengthening crucial parts as well as for improving flow dynamics by optimizing geometry of cover leading to less turbulent flow.

The FEA module was enabled to import the SolidWorks model for the structural analysis. In order to make it an accurate reflection of the real-world working conditions, the process had to define the boundary conditions, the load cases, and the material properties. So as to have a more precise analysis, especially in areas where there is high concentration of stress gradients, that decided to generate a finer mesh. The static and dynamic stress analysis helped in identifying where there may be any chances of failure whereas the thermal FEA determined how different temperatures would affect its performance.

The new casing design resulted in substantial stress reduction in important regions of the pump cover thereby making it more durable. Better performance with possible reduction in operating cost is achieved by introducing die casting method that optimizes flow properties inside the cover. Thus, the restoration increases the pump's life span since it deals with areas where both heat and force put pressure on it.

CHAPTER 5

CONCLUSION

5.1 Background

This chapter are the last part of this report. This chapter will explain the conclusion for overall chapter for this fabrication of casing cover of a centrifugal pump. In this chapter also will discussed about the recommendation of this project.

5.2 Conclusion

The design and making of a customized casing cover for a centrifugal pump have been successfully achieved using SolidWorks modeling, sand casting, and milling. This study outlined various objectives from conception to final product realization to systematic planning and integration in engineering processing to achieve high quality and functional components. Besides objective fulfillment, this process revealed design innovation, material selection, and manufacturing techniques.

The first objective that is building a new casing cover for the centrifugal pump has been achieved by SolidWorks. This step made it possible to produce a thorough and highly detailed 3D model that would meet all functional and aesthetic requirements. The design phase also provided much insight into all geometric features, dimensional tolerances, and technical considerations for effective pump operation. It also helped to visualize the end product in relation to the existing components as well as the design standard. SolidWorks has broadened the horizon of making progressive improvements towards improving the design and performance of the product.

The second objective, to manufacture the casing cover through sand cast, was attained. Sand casting has proved to be a practical and economical version well oriented for a shape like the casing cover. The method comprised of designing and making molds, which were incorporated into the process so that the dimensional accuracy as well as uniformity is reflected within the product. The use of sand casting also strengthened its point as a traditional yet effective manufacturing process of making sturdy components relevant to industrial practice. The product was then post-cast to perform milling to get the requisite surface finish, dimension accuracy, and structural fit. Combining both casting and milling is testified in making quality products through the advantage of both traditional and modern manufacturing techniques.

The last objective, which involves an examination in terms of strength and durability, material type, and appropriateness with respect to student learning outcomes, was achieved thoroughly. Material selection was based on parameters such as wear, corrosion, and operational stress resistance. Tests on the fabricated casing cover found that it had mechanical strength and durability enough under the demanding conditions within a centrifugal pump. Apart from that, this project has been a good learning experience for most students who have practical exposure to design, manufacture, and evaluation processes in engineering. For these activities to be hands-on, students are allowed practical experience about real problems, preparing them for the future with problems in their professions.

In conclusion, the project hath again incorporated the design and manufacturing processes to produce a reliable centrifugal pump casing cover, fulfilling all criteria. The cover meets operational requirement and student learning through hands-on experience. Cost-effective, quality and performance methods with sand casting and machining will give the boost for future improvement in pump design and fabrication.

5.3 Recommendation

The future design of the casing cover for centrifugal pumps could increase in performance by the improvement of research in areas such as Advanced Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) for the optimization of geometry to strength and durability issues. Use of alternative fabrication methods, such as investment or die casting, could improve the surface finish and precision, while even better results could also be obtained by improving sand casting techniques.

Researching advanced materials like corrosion-resistant alloys or composites might bring better strength and durability under severe conditions. Finally, it is advised to perform detailed tests like fatigue or failure analysis, which would facilitate the understanding of a design's long-term performance and improve its contours. Such factors improve the design efficiency and the quality of the manufacture and education, by bringing in its fold innovation and excellence into future projects.

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APPENDICES

Appendix A Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	On
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\ASUS\Desktop)

Appendix B Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Appendix C Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	18.5356 mm
Minimum element size	0.926781 mm
Mesh Quality	High

Appendix D Mesh Information-Detailed

Total Nodes	423966
Total Elements	280864
Maximum Aspect Ratio	48.544
% of elements with Aspect Ratio < 3	99.3
Percentage of elements with Aspect Ratio > 10	0.00819
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:32
Computer name:	

Appendix E Sensor Details

Sensor name	Location	Sensor Details
Displacement1		Value : 3.424e-04 mm Entities :1 face(s) Result :Displacement Component :URES: Resultant Displacement Criterion :Max over Selected Entities Step Criterion : Across all Steps Step No.:1 Alert Value: NA
Stress1		Value : 5.571e+06 N/m^2 @ 0 sec Entities :6 face(s) Result :Stress Component :VON: von Mises Stress Criterion :Max over Selected Entities Step Criterion : At Specific Plot Step Step No.:1 Alert Value: NA
Displacement2		Value : 6.376e-04 mm Entities :6 face(s) Result :Displacement Component :URES: Resultant Displacement Criterion :Max over Selected Entities Step Criterion : Across all Steps

Sensor name	Location	Sensor Details
		Step No.:1 Alert Value: NA