DESIGN AND ANALYSIS OF WINCH FOR EXTENDABLE BUNDLE PULLER

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This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Design and Innovation)

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DECLARATION

I declare that this project report entitled "DESIGN AND ANALYSIS OF WINCH FOR EXTENDABLE BUNDLE PULLER" is the result of my own work except as cited in the references

Signature : ....

Name of Supervisor : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design & Innovative).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father This project is dedicated wholeheartedly to my beloved parents, Mrs Haslawati binti Mohamed and Mr Saiful Azman bin Amat who have been always there for me along the way to complete the study in Universiti Teknikal Malaysia Melaka and continually support me spiritual, moral, and also in term of financial.

Besides that, I would like to dedicate this project to my siblings who always help me with study, moral and also in financial support. I also like to dedicate this project to my friends who help me by giving some knowledge to complete this project.

Lastly, I would like to dedicate this project to whoever that ever exist in my life along the journey to complete my study and also my project.

ABSTRACT

Bundle pullers are useful in the power plant sector because they are used to extract the tube bundle from the heat exchanger. Bundle pullers are made up of a cradle that holds a mainframe and a power source, a sled that is attached to a tube bundle and has a hydraulic powered screw drive that pushes the sled on the mainframe, a hydraulic elevator on the mainframe that holds and adjusts the position of the tube bundle, and an extension that adjusts the length of the mainframe. Bundle pullers for extracting exchangers already have a variety of designs for the lifting frame. There are several designs that use merely a beam with a string tied to it, as well as the current design where the winch could extract the bundle tube. The goal of this project is to design a winch capable of extract a variety of tube bundles weighing up to 80 tonnes. Measurements of the bundle tube were taken as a reference for the next design of bundle puller. The maximum load that the chosen design of the winch can hold was determined using Finite Element Analysis (FEA) with ANSYS. The FEA results from the winch will decide the size of the gear and motor power to be used for the winch bundle puller.

ABSTRAK

Penarik berkas berguna dalam sektor loji kuasa kerana ia digunakan untuk mengekstrak berkas tiub daripada penukar haba. Penarik berkas terdiri daripada buaian yang memegang kerangka utama dan sumber kuasa, kereta luncur yang disambungkan pada berkas tiub dan mempunyai pemacu skru berkuasa hidraulik yang menolak eretan pada rangka utama, lif hidraulik pada rangka utama yang memegang dan melaraskan kedudukan berkas tiub, dan sambungan yang melaraskan panjang kerangka utama. Penarik berkas untuk mengekstrak penukar sudah mempunyai pelbagai reka bentuk untuk bingkai pengangkat. Terdapat beberapa reka bentuk yang hanya menggunakan rasuk dengan tali yang diikat padanya, serta reka bentuk semasa di mana win boleh mengeluarkan tiub berkas. Matlamat projek ini adalah untuk mereka bentuk win yang mampu mengekstrak pelbagai berkas tiub dengan berat sehingga 80 tan. Ukuran tiub berkas diambil sebagai rujukan untuk reka bentuk penarik berkas seterusnya. Beban maksimum yang boleh dipegang oleh reka bentuk winch yang dipilih telah ditentukan menggunakan Analisis Elemen Terhad (FEA) dengan ANSYS. Keputusan FEA daripada win akan menentukan saiz gear dan kuasa motor yang akan digunakan untuk penarik bundle win

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I would also like to express my biggest gratitude to Dato' Hj Mohd Faizal Bin Mohd Hassim who is the president of Hydrospeed Sdn Bhd for giving permission to me and my friend to analyse the old design of bundle puller at the site.

Last but not least, I would like to thanks to all my friends, my beloved parents, my siblings who always there for me and always give moral support to me in completing my study as mechanical engineering student and also to everyone who has helping me through completing the project and my journey as a student.

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CHAPTER 1

INTRODUCTION

1.1 Background

Oil refinery is an industry that uses fractional distillation to convert crude oil into more useful petroleum products such as gasoline, diesel fuel, asphalt base, heating oil, kerosene, and liquefied petroleum gas. (Kundnaney and Kushwaha, 2015).

Heat exchangers are essential in the oil and gas processing industry. They are used in the refining process, specifically in cracking units, as well as in natural gas liquefaction. Cracking is the process of dispersing the hydrocarbons that make up crude oil. A heat exchanger is a device used to transfer heat from one medium to another efficiently in order to transport and process energy (Alawa and Egwanwo, 2012).

The heat exchanger system has a significant impact on the time of the plant's turnaround. When the plant resumes normal operation following turnaround, a failing heat exchanger within a short period of normal plant operation, even if the contractor's warranty is still valid, might result in a significant financial loss due to reduced downtime or production loss.. (Saffiudeen et al., 2020)

Figure 1.1 Heat exchanger bundle tube (Industry Review, 2021).

As a result of the invention of the bundle puller, a better cleaning device for tubes in a plant was created that does not require removing the tubes from their installed positions in the plant in order to clean them. The lance drive is positioned to reduce buckling of the lance. (Cradeur and Cardone,1976)

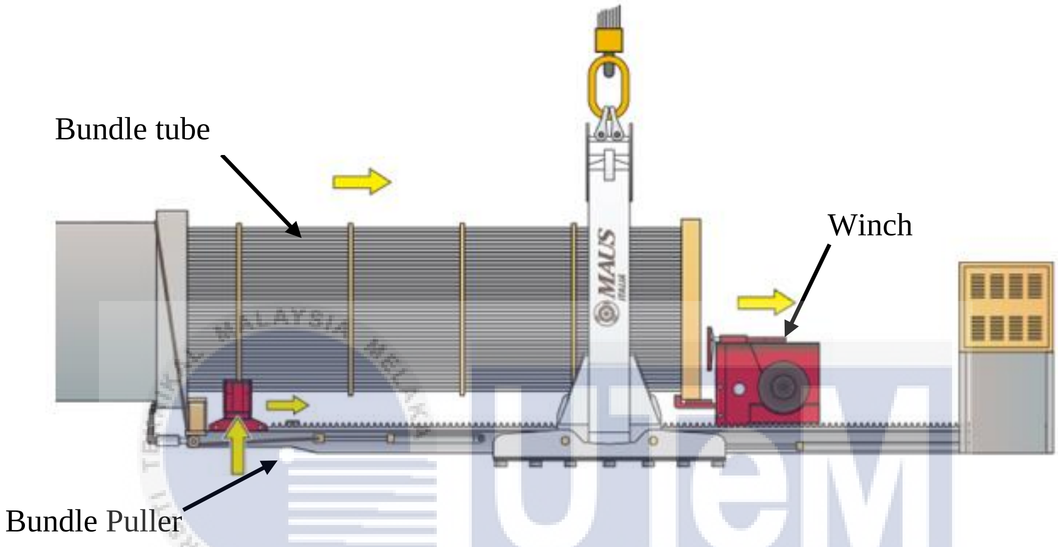

Figure 1.2 Aerial Bundle Puller (Maus,2019).

1.2 Problem Statement

Bundle Puller is one of the important products that is often used in the oil and gas industry, especially when there is a shutdown and bundle tube cleaning work needs to be done quickly and effectively. Current design bundle puller is use for the specific pulling force, length and diameter of bundle tube. To safe cost extendable bundle puller that can be used for various size of bundle tube should be designed.

In this project, 40 T bundle puller will be upgraded to 80 T bundle puller by maintain the existing engine and hydraulic accessories. Also, since the design of the balancing and main frame is extendable. The design of the winch should be considered about the additional components for extendable bundle puller.

As an improvement, it was proposed to design a winch for upgrade the existing 40T bundle puller. However, gear ratio for the winch to move and suitable gear to match with the gear rack need to be considered. Thus, a new winch system and specifications need to be designed

1.3 Objective

The objectives of this project are as follows:

1. To design winch of bundle puller that can pull until 80 tonnes bundle tube
2. To design the winch that can be used for the extendable bundle puller mainframe and balancing frame.
3. To carry out FEA analysis to ensure the new design of a winch is safe to use for 80T pulling force.

1.4 Scope of Project

- Investigate the current design and mechanisms 40 Tonne of winch
- Come out new design of winch that can come out pulling force until 80T bundle tube
- Carry out finite element analysis to the winch

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will be included study and research of published material like journals, thesis, case studies, technical document, book and online library. Generally, the purpose of their view is to analyse critically a segment of a published body of knowledge through summary, classification, approach used in their project, and any technique that used in their study, review of literature and theoretical articles. This chapter will describe topics that related of winch, winch mechanisms, gear systems, gear forces, Computer Aided Design (CAD), design, conceptual design, Optimization, Finite Element Analysis (FEA), Design Process and other relevant topic for this project. These chapters to carry out any approach that can use in drain cover frame design and analysis using Finite Element Analysis method and carry out current product design.

2.2 Definition of Winch

Winch is a type of driving equipment used to raise and lower large items. It is frequently utilised in the field of mechanical mechanisms. It is built as a pulling mechanism, with rope wound around a horizontal drum that is normally driven by a motor. According to the driving system, it is classed as an electrical winch, a mechanical drum-style winch, a mechanical capstan-style winch, a hydraulic winch, a mechanical hand-operated winch, a mechanical portable winch, or a hybrid winch. A winch is composed of numerous components, including a drum, a shaft, a rope, a winch gearbox, and a drive system. It is frequently used to tow large loads and is seen in mines and marine applications. Winches are a critical component of crane and mooring systems used to activate cable cars, lifts, and, in fact, whenever dynamic pull from a flexible rope is required. To produce a strong draw and accurate control during winching operation, it is required to modify the conventional design of winches. The purpose of this review is to identify areas for improvement in the design of winch systems in order to provide high-performance winches for a variety of technical applications. (KachareSavita2015).

A winch is designed to pull objects that are either parallel to the ground or have a very slight gradient. A hoist is required if you need to lift something out of a pit, such as a tractor. Additional brakes are included on a hoist to safeguard the safety of both the dragged item and you (Emanuel, 2014).

Winches are categorised into numerous subcategories based on their mechanism of operation. They are propelled by hydraulic, pneumatic, electrical, and mechanical systems. As a result, they are classed according to their power source as hydraulic winches, pneumatic winches, electrical winches, or mechanical winches. They are used in a number of technical applications, such as portable water well equipment, the maritime environment, on a boat or ship, on an oil rig, and for vehicle recovery. (KachareSavita,2015)

Hydraulic winches are frequently used in engineering applications. A hydraulic motor is used to drive the hydraulic winch, which is controlled by an electronic hydraulic proportional valve. When a hydraulic winch is required to follow a specific movement, the reaction speed significantly affects the control accuracy. (Entao,2011)

Hydraulic winches are often constructed with a high rated weight, making them ideal for the most difficult tasks on land and sea. This heavy-duty winch is frequently used on ships, coastlines, and docks for a variety of purposes. The winch is hydraulically powered, which enables it to transmit a high force capable of handling a considerable amount of labour. Energy efficiency is critical when selecting winches for marine applications. Hydraulic winches are the ideal choice for large ships due to the size of the hydraulic system and equipment. (Fulton et al., 2006).

The hydraulic transmission utilises oil as the working medium, communicates movement by changes in the seal volume, and transfers power via changes in the oil pressure. When several hydraulic cylinders are employed, the pressure applied at any location on a given volume of liquid can be evenly transferred in all directions, which implies that each hydraulic cylinder will pull or push at its own pace, which is determined by the pressure required to move the load. When hydraulic cylinders have the same carrying capacity range, the hydraulic cylinder carrying the lightest weight moves first, and the hydraulic cylinder carrying the heaviest load moves last. To ensure that the hydraulic cylinder moves synchronously and the load is lifted at the same speed at all points, control valves or synchronous lifting system components must be included in the system. Hydraulic winches are primarily consisting of a hydraulic motor (low or high speed), a hydraulic typically closed multi-disc brake, a planetary gearbox, a clutch (optional), a drum, a support shaft, and a frame. The hydraulic motor is very efficient mechanically, has a high starting torque, and can be provided with a variety of distributors depending on the operating conditions, or the valve group can be directly incorporated into the motor oil distributor. The drum houses the brake and planetary gearbox. The drum, support shaft, and frame are all built to meet mechanical specifications. The winch's general structure is straightforward and acceptable, with a high level of strength and rigidity. In terms of performance, the winch equipment is safe, efficient, has a large beginning torque, is stable, produces little noise, and operates reliably. (Skjong, 2014)

2.3 Winch Mechanisms

A winch is composed of multiple distinct components, each of which contributes to the accomplishment of a broader objective. A drum with a circular form that allows wire to be wrapped neatly around it. Due to a spool inside the winch, the drum of the winch can rotate in a circular motion, winding the cable in or out. To avoid tangling, a steel cable or synthetic wire will most likely be wrapped around a drum. (McBratney,2016)

A winch motor is the component of the winch that actually powers the cable, rope, or chain. Not only is the winch motor responsible for the winch's pulling force, but it also powers the cable, rope, or chain out of or onto the winch. The horsepower of the winch motor dictates the winch's pulling and lifting capabilities. Numerous big industrial-type winches are propelled by massive electric motors. These motors are connected to the winch via a series of rubber belts and pulleys. On the other hand, the winch motor is frequently a direct drive motor that is coupled to the transmission gears through a coupler. This avoids the chance of belts or gears slipping due to moisture or debris accumulation. (Kilchermann, 2021).

Whether hydraulic or electric prime movers are used, mechanical efficiency is critical for optimising a winch gearbox's performance. Certain conventional gear systems can have a mechanical efficiency of as little as 50%. In comparison, even at very low speeds, a single stage planetary gearbox unit is approximately 98 percent efficient. Additionally, by distributing loads among numerous planet gears (usually three or four), a planetary gearbox's torque capability is superior than that of alternative solutions of comparable physical size. (He, 1970).

Additionally, the gearbox enables the use of much smaller motors than would be required to move the heavy weights. For instance, if you peek inside a music box, you will notice the mechanism's gears. In a spur gear system, a smaller gear spins a larger gear. The size of the larger gear dictates the size of the object that the winch can pull. (Carral et al., 2021).

2.4 Spur Gear System

A gear is a mechanical component made up of a toothed wheel attached to a spinning shaft. Gears operate in pairs to transmit and change rotational motion and torque (turning force) without slipping, with the teeth of one gear engaging the teeth of the mate gear. If the teeth of a set of matching gears are arranged in circles or if the gears are toothed wheels, the ratios of the rotational speeds and torques of the shafts are constant. (Kia et al., 2015).

A gear is a circular wheel with teeth that rotates in conjunction with another toothed item to transmit torque or power. Spur gears are the simplest type of gear, having teeth cut parallel to the shaft to which the gear is mounted. Spur gears are used to transfer energy between parallel shafts. The spur gear has a 98-99 percent efficiency rating. (Rani, & Khalandar, 2013).

Spur gears or straight-cut gears are the most frequent type of gear. They are typically made up of parallel shafts with straight teeth placed to transfer power. When coupled in pairs, these gears convey motion and power via the parallel axes design. Depending on the application, they may be paired with another spur gear, an internal gear (as in a planetary gear system), or a gear rack (such as in a rack and pinion gear pair). Their shafts are parallel and coplanar. (Eng et al., 2018).

Spur gears have been used since ancient times. They include teeth that protrude radially and parallel to the shaft's axis. A spur gear with teeth on the exterior of a disc is referred to as an external spur gear.If the teeth are on the inner face of the disc, the gear is called an internal spur gear. In the vast majority of applications, external spur gears are used. Internal spur gears are frequently used in epicyclic gearing to achieve a small centre distance. When the pinion and gear mesh, the teeth make contact with two convex profile curves through which the driver applies tangential force to the driven gear at the radius of the pitch circle. The torque generated at the shafts is equal to the moment of the tangential force in the direction of the shaft centres. When the gearset rotates in this manner, it delivers power proportional to the torque. (Mott et al., 2018).

Table 2.1: Dimensions of gears and gearing parameter (ALIPIEV and ANTONOV, 2011)

Concept Spur Gear Calculation		
Item	Symbol	Formula
Number of teeth	z	z = d/m
Module	m	m = d/z
Pitch Diameter	d	d = m x z
Outside Diameter	de	de = m (z + 2) or de = d + 2m
Root Diameter	df	df = m (z – 2.5) or df = de – 2h
Centre Distance	dc	dc = (D + d) / 2; D = (Pitch diameter of gear)

2.5 Spur Gear Forces

Gear forces are essential in the design of gears. Gear tooth forces, in particular, impact root stress and contact stress. Root stress and contact stress, which are discussed in another notebook, dictate the size of the gears. Gear tooth forces must also be considered when designing supporting shafts and bearings. Spur gears only generate forces in the gear plane; helical gears generate axial forces as well and must be supported axially. Tangential and radial forces in the gear plane create bending moments on the supporting shafts. Axial force causes bends in the perpendicular plane. As a result, calculating gear forces is crucial in the design of shafts and bearings (Glinsky, 2020).

Between mating gears, force occurs in a direction perpendicular to the contacting surfaces. The normal force, FN, can be broken into three components: the axial force Fa, the radial force Fr, and the tangential force Ft. The tangential and radial forces in spur gears are illustrated in Figure 1.

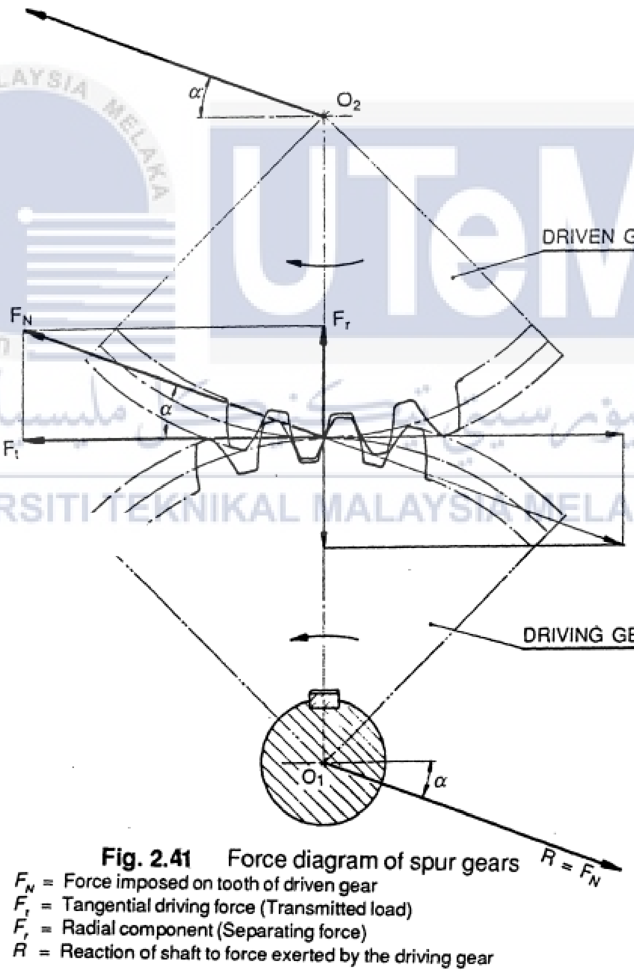

Figure 2.1 Forces on spur gears (Maitra, 2001).

Normal force is distributed along the contact line, which rotates with the gears. The sum of this scattered force must be equal to the torque applied to the gear by static equilibrium. Even if the force is dispersed, the operational pitch circle can be utilised to approximate the point of contact's average position. (Taburdagitan & Akkok, 2006).

The tangential force, Ft, is perpendicular to the operating pitch circle in the transverse plane. At the pitch circle, the moment generated by the tangential force matches the torque applied. Following that, the tangential force is defined as,

$$F_t = \frac{2T}{d_p} \quad \text{(Eq2.1)}$$

When the normal force is projected in the transverse plane, the tangential force is one component; the radial force is the other component. Radial force can be calculated as follows:

$$F_r = F_t \tan \alpha_{tw} \quad \text{(Eq2.2)}$$

Axial force is one component of force in the axial plane.The tangential force is the other component.The axial force is then determined by,

$$F_a = F_t \tan \beta \quad \text{(Eq2.3)}$$

Finally, the normal force is the vector sum of all three components, with a magnitude equal to,

$$F_N = \sqrt{F_a^2 + F_r^2 + F_t^2} \quad \text{(Eq2.4)}$$

2.6 Computer Aided Design (CAD)

Computer-aided design (CAD) is a process that utilises geometrical factors to create computer models. These models often show on a computer monitor as a three-dimensional representation of a part or system of parts that may be easily modified by altering pertinent parameters. CAD systems enable designers to visualise objects in a range of different representations and to test them in a variety of real-world scenarios. (Hirz & Dietrich, 2011).

CAD originated from three distinct sources, which also help to emphasise the fundamental operations provided by CAD systems. The origins of CAD may be traced back to attempts to automate the drafting process. General Motors Research Laboratories pioneered these innovations in the early 1960s. One significant time-saving advantage of computer modelling over traditional drafting approaches is the ease with which the former may be altered or modified by altering the model's parameters. (Goel et al., 2012).

Modeling with CAD systems has a variety of advantages over using rulers, squares, and compasses in traditional drafting. For instance, designs can be modified without the need for erasing and redrawing. Additionally, similar to a camera lens, CAD systems provide "zoom" features that enable designers to magnify specific portions of a model for inspection. Computer models are often three-dimensional and can be rotated on any axis, much like a real three-dimensional model held in the hand, allowing the designer to acquire a more complete understanding of the product. Additionally, CAD systems lend themselves to creating cutaway drawings that disclose the inside geometry of a part, as well as illustrating the spatial interactions between a system of parts. (Kalay, 2004).

2.8 Finite Element Analysis (FEA)

ANSYS began as a structural mechanics finite element analysis (FEA) code. ANSYS Workbench has a tool called Design Modeler, which allows for the creation of gears using only basic drawing tools. (Mounika, 2019).

The Finite Element Method (FEM) can be used to analyse tooth contact stress and, of course, bending stress more precisely. As a result, the results of FEM can be utilised to determine the appropriateness of common calculation methods. (Bergseth, 2009)

To overcome the challenges associated with the lengthy numerical technique and the complex form of analytical equations, the finite element method (FEM) was used to analyse the deformation behaviour of different coating systems. To analyse the plastic deformation behaviour of several hard coating–substrate complexes, a FEM model was built. (Sun et al., 1995).

A sophisticated non-linear finite element method was successfully employed to precisely mimic the behaviour of gear contacts. True three-dimensional gear tooth profiles with micro-geometry adjustments were used in the models under realistic load circumstances. The effects of shaft misalignment, deflection, and assembly deflection on the contact behaviour of gear surfaces have been explored. The analysis-based optimization of the microgeometry has been proposed to reduce surface contact fatigue failure. The concept has been extremely successful in reducing surface fatigue wear on vehicle transmission gears. (Mao, 2007).

While the finite element approach is capable of providing this information, the time necessary to complete this model is considerable. To reduce modelling time, a pre-processor method such as that supplied by Pro/Engineer may be utilised to generate the geometry required for finite element analysis. One may simply construct three-dimensional gear models using Pro/API Engineer's toolset. Pro/E saves the geometry as a file, which can then be transmitted to Ansys. (Raptis et al., 2010). (Raptis et al., 2010) Additionally, the maximum stress at the gear tooth root was calculated using both computational and experimental approaches when the meshing gears were loaded at their most disadvantageous contact point (highest point of single-tooth contact-HPSTC). The numerical stress analysis is performed using the Finite Element Method (FEM), whereas the experimental stress analysis is performed using photo elasticity.

The spur gears are designed to withstand tooth bending failure, which impacts transmission error. Finite element models and solution methods are used to do accurate calculations in ANSYS, and the results are compared to those achieved using established theoretical approaches. (Shinde et al., 2020).

The gear tooth contact analyses in spur gears are carried out using finite element analysis.A general finite element model was created for the purpose of determining the contact stress in spur gears with equal geometry in both gears. Through the use of a mesh, contact elements, and an adaptive technique, FEA was used to mimic the gear tooth contact behaviour using an augmented Lagrange contact algorithm. The technique for creating a three-dimensional model in finite element software was outlined in full. Displacements, stress distributions, and strain were determined for three distinct materials at two different speeds. As a result of the results, it can be inferred that composite material gear deforms relatively little in comparison to steel and plastic materials. Additionally, the rotational speed of the spur gear has an effect on the material's behaviour, such as stress, strain, and deformation. As a result, composite materials are a superior option to steel and plastic (Rajeshkumar & Manoharan, 2017)

FEA simulations are constructed using a mesh of millions of tiny pieces that work together to form the shape of the structure being evaluated. Each of these minor elements is subjected to calculations, with the final result of the structure being the product of these mesh refinements. These approximation calculations are typically polynomial in nature, with interpolations across the small elements, allowing for the determination of values at some but not all places. The places at which values can be calculated are referred to as nodal points, and they are often located near the element's boundary. (Polly et al., 2016).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will describe in more detail the methodology that is used to carry out this project to design winch for bundle puller. Development on the winch is needed to save the time working and high operating cost. Before starting any design, the requirement for the machine needs to be considered in order to satisfy their needs.

In this project gear that controlled the winch movement and pull the bundle tube need to be analysed because the requirement is to make a design of winch that can pull bundle tubes between 10 tonnes to 60 tonnes. Site visit also have been done to have some discussion and to analyse the machine to get a good picture on how the product can be improve in term of design and also practically. The design of the winch will be done by CATIA V5 and the design will be finite element analysis by using ANSYS. The overall process will be show in flowchart in figure 3.1.

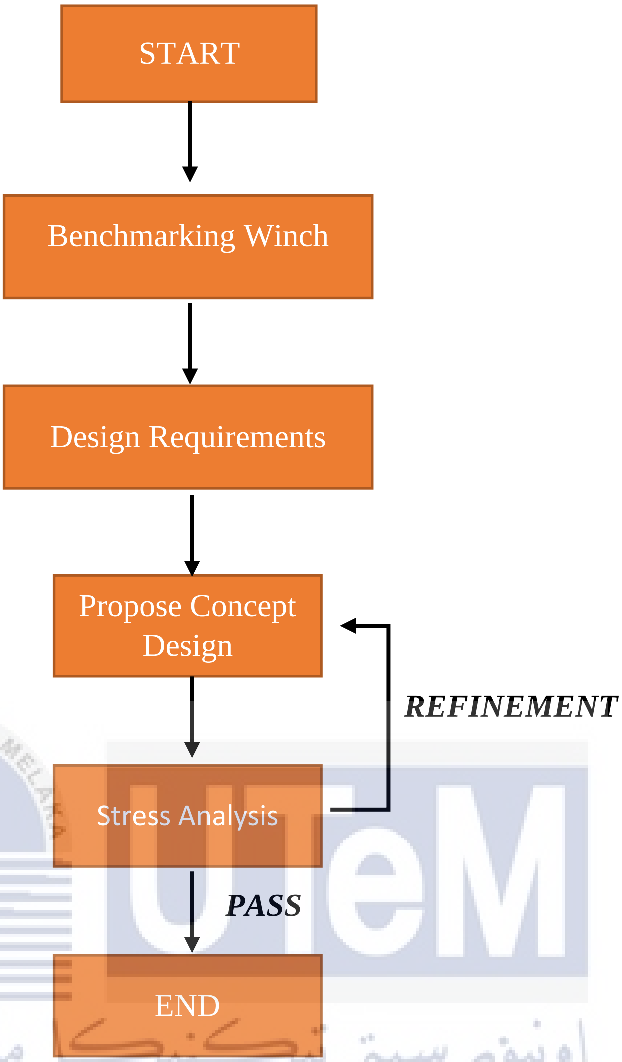

Figure 3.1: Flow chart for the methodology of this project

Based on the flow chart shown in figure 3.1, the process starts with a meeting with the supervisor to give an early briefing about the project scope and understanding the problem statement. Then, undergo a benchmarking winch by site visit at HRSB Sungai Udang to study the design and mechanism of the existing bundle puller. The aim of taking the measurement is to know more specifically the actual size of the bundle extractor and the components of the winch. This is because it is easier to come out with the ideas after completely know the measurements and components. The winch will be simulated using another engineering software called ANSYS. Through this simulation, the decision on which failure on the winch can be known and predicted. At the end of this process, report writing needs to be done after finished all the simulations.

3.2 Benchmarking Winch

Benchmarking of the winch done by site visit to the HRSB Sdn Bhd workshop was done to see the current design of the bundle puller and the winch. The purpose of the site visit is to understand how the bundle puller and winch operate and have some discussion with their staff to know the requirement they want for the new design of the bundle puller. The current design of the bundle puller is from the company named Hydrospeed Sdn Berhad. Besides, a few measurements of the current bundle puller have been recorded for guiding purpose. Figure 3.2 is the bundle puller that placed at the HRSB Sdn Bhd Workshop. Figure 3.3, and 3.4 is the part of the bundle puller's winch which is the current design of pull the bundle tube and gear compartment that will be combine in the new design.

Figure 3.2: Existing bundle puller for 45 tonnes

Figure 3.3: Winch Bundle Puller

Figure 3.4 Mechanisms of Winch

All the measurement of the bundle puller will be taken carefully to avoid from misunderstood when designing the new model of winch. Redesign the current model help to get inspiration and also to analyse the component to get a good view of the bundle puller.

3.2.1 Existing Component Winch

Benchmarking from the existing winch, engine specifications, hydraulic motor, hydraulic jack, gear rack and pinion, and chain used to move the winch were used to develop the new design.

3.2.2.1 Specification Diesel Engine Winch

From what could be discovered, the HARTZ Diesel engine 2L41C had been used in order to move the winch motor and hydraulic jack. Table 3.1 shows the Technical data HARTZ Diesel Engine.

Table 3.1 Technical data HARTZ Diesel Engine (https://www.hatz diesel.com/fileadmin/user_upload/hatz-diesel.com/betriebsanleitung/l_m/ebook_BA_LM_43340213_EN.pdf)

Technical data, performance table

	Technical data	2L41C	3L41C	3L43C	4L41C	4L42C	4L43C
Engine	Type	Air-cooled 4-stroke diesel engine with direct injection					
	Number of cylinders	2	3	3	4	4	4
	Exhaust gas after-treatment			EGR & DPF		EGR	EGR & DPF
	Bore x stroke [mm / inches]	102 x 105 4.02 x 4.13	102 x 105 4.02 x 4.13	102 x 105 4.02 x 4.13	102 x 105 4.02 x 4.13	102 x 105 4.02 x 4.13	102 x 105 4.02 x 4.13
	Displacement [l / cu.in.]	1.716 / 104.7	2.574 / 157	2.574 / 157	3.432 / 209.4	3.432 / 209.4	3.432 / 209.4
	Mean piston speed at 3000 rpm [m/s / ft/min]	10.5 / 2.067					
	Compression ratio	20.0 : 1	20.0 : 1	20.8 : 1	20.0 : 1	20.8 : 1	20.8 : 1
	Lub. oil consumption, related to full load	max. 1 % of fuel consumption					
	Oil filling max / min [l / US qts]	4.5 / 2.5 4.8 / 2.6	8.0 / 5.0 8.5 / 5.3	8.0 / 5.0 8.5 / 5.3	13.0 / 5.0 13.7 / 5.3	13.0 / 5.0 13.7 / 5.3	13.0 / 5.0 13.7 / 5.3
	Speed control · Lowest idle speed rpm	900	900	1.000	900	1.000	1.000
	· Static speed droop	approx. 5% at 3000 r.p.m.					
Installation information	Amount of combustion air at 3000 rpm approx. [1] [m³/min / cu.ft./min]	2.6 / 92	3.9 / 138	3.9 / 138	5.2 / 184	5.2 / 184	5.2 / 184
	Amount of cooling air at 3000 rpm approx. [1] [m³/min / cu.ft./min]	29 / 1.024	39 / 1.377	39 / 1.377	42 / 1.483	42 / 1.483	42 / 1.483
	Mass moment of inertia J [kgm² / lb.ft²] · SAE-flywheel 8"	0.64 / 15.2	0.65 / 15.4	0.65 / 15.4	0.67 / 15.9	0.67 / 15.9	0.67 / 15.9
	· flywheel for F+S clutch	0.49 / 11.6	0.50 / 11.9	0.50 / 11.9	0.51 / 12.1	0.51 / 12.1	0.51 / 12.1
	Starter	12 V - 2.7 kW — 24 V - 4.0 kW					
	Alternator charging current at 3000 / 1500 rpm	14 V - 60 A / 42 A — 28 V - 40 A / 28 A					
	Battery capacity [min / max Ah]	12 V - 88 / 143 Ah — 24 V - 55 / 110 Ah					
Weight	Engine with electric start 12 V or 24 V [kg / lbs.]	303 / 668	363 / 800	365 / 805 [2]	433 / 955	435 / 959	435 / 959 [2]

3.2.1.2 Specification Hydraulic Motor Winch

Figure 3.5 Sauer Danfoss OMV 630

The winch will be moved forward and backward using a hydraulic motor from the Sauer Danfoss OMV 630 series. Hydraulic pressure generated by the hydraulic pump transfers fluid energy to mechanical energy, which is used to execute the physical movement. According to the catalogue, Table 3.2 shows the hydraulic motor's technical specifications.

Table 3.2 Technical Data Danfoss OMV630 (http://danfoss.cohimar.com/pdf/omv.pdf)

Technical data

Technical data for OMV, OMVW and OMVS

Type			**OMV OMVW OMVS**	**OMV OMVW OMVS**	**OMV OMVW OMVS**	**OMV OMVW OMVS**	**OMV OMVW OMVS**
Motor size			**315**	**400**	**500**	**630**	**800**
Geometric displacement	cm^3 [in^3]		314.5 [19.19]	400.9 [24.46]	499.6 [30.49]	629.1 [38.39]	801.8 [48.93]
Max. speed	min^{-1} [rpm]	cont.	510	500	400	315	250
		int[1)]	630	600	480	380	300
Max. torque	Nm [lbf·in]	cont.	920 [8140]	1180 [10440]	1460 [12920]	1660 [14690]	1880 [16640]
		int.[1)]	1110 [9820]	1410 [12480]	1760 [15580]	1940 [17170]	2110 [18680]
Max. output	kW [hp]	cont.	42.5 [57.0]	53.5 [71.7]	53.5 [71.7]	48.0 [64.4]	42.5 [57.0]
		int.[1)]	51.0 [68.4]	64.0 [85.8]	64.0 [85.8]	56.0 [75.1]	48.0 [64.4]
Max. pressure drop	bar [psi]	cont.	200 [2900]	200 [2900]	200 [2900]	180 [2610]	160 [2320]
		int.[1)]	240 [3480]	240 [3480]	240 [3480]	210 [3050]	180 [2610]
		peak[2)]	280 [4060]	280 [4060]	280 [4060]	240 [3480]	210 [3050]
Max. oil flow	l/min [USgal/min]	cont.	160 [42.3]	200 [52.8]	200 [52.8]	200 [52.8]	200 [52.8]
		int.[1)]	200 [52.8]	240 [63.4]	240 [63.4]	240 [63.4]	240 [63.4]
Max. starting pressure with unloaded shaft	bar [psi]		8 [116]	8 [116]	8 [116]	8 [116]	8 [116]
Min. starting torque	at max. press. drop cont. Nm [lbf·in]		710 [6280]	910 [8050]	1130 [10000]	1330 [11770]	1510 [13360]
	at max. press. drop int.[1)] Nm [lbf·in]		850 [7520]	1090 [9650]	1360 [12040]	1550 [13720]	1700 [15050]

3.2.1.3 Specifications Hydraulic Jack Winch

Figure 3.6 Hydraulic Jack FCY-10150

The hydraulic jack is used to raise or lower the winch's front section in order to attach the winch hook to the bundle tube. A hydraulic jack is a device that uses force applied via a hydraulic cylinder to lift heavy loads. Hydraulic jacks lift loads using the force generated by the cylinder chamber's pressure. According to Table 3.3, the following is a description of the hydraulic jack FCY-10150.

Table 3.3 Product Description Hydraulic Jack FCY-10150 (https://yindutool.en.made-in-china.com/product/JvMnmzWEsucF/China-10t-150mm-Long-Type-Hydraulic-Jack-FCY-10150-.html)

10T 150mm Long type hydraulic jack FCY-10150

Model NO.	Tons(T)	Cylinder effective area(cm2)	Cylinder inside DIA(MM)	Cylinder Outside dia (mm)	Travel(mm)	Weight(kg)	Collapsed height(mm)	pump
FCY-10150	10	15.89	45	63	150	4.5	207	Cp-180
FCY-20150	20	33.16	65	88	150	7.7	210	Cp-700
FCY-30150	30	50.24	80	108	150	12.5	214	Cp-700-2
FCY-50150	50	78.5	100	128	150	17.5	216	Cp-700-3
FCY-100150	100	143.06	135	178	150	34	226	Cp-800

3.2.1.4 Specification Gear Rack and Pinion Winch

The gear system used on the current winch can be determined based on the observations made during the site visit. The figure 3.7 shows the gear mechanisms from the existing 40 Tons winch. These gears and pinions form the winch's backbone, allowing it to move forward or backward. The specifications for the gears and pinions used on the 40-tonne winch can be found on table 3.4 below

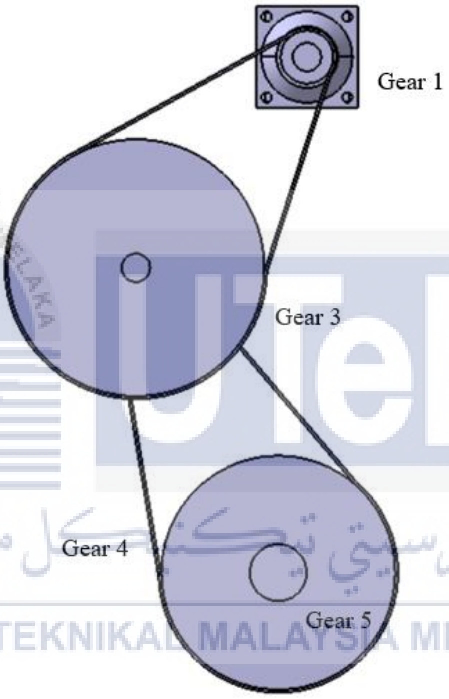

Figure 3.7 Gear Mechanisms Existing 40 Tons Winch

Table 3.4 Gear Rack and Pinion 40 Tons Winch Specifications

Gear No.	Type of Gear	Module of Gear	Size of Gear
1	Sprocket	1”	Outside Diameter = 102 mm
2	Sprocket	1”	Outside Diameter = 411 mm
3	Sprocket	1”	Outside Diameter = 102 mm
4	Sprocket	1”	Outside Diameter = 306 mm

5	Spur Gear	6	Outside Diameter = 156 mm
Rack	Gear Rack	6	60 mm x 60 mm

The detail could be referred at Appendix A for sprocket size, Appendix B for Spur Gear size and Appendix C for Gear Rack size.

3.2.1.5 Specifications Chain Winch

Table 3.5 shows the specifications of the chain used on the 40 Ton Winch as a gear connector and to move the winch

Table 3.5 Chain Specifications (https://gear.com.my/product/roller-chain/)

Dimension : inch & mm

Chain

Catalog No. ANSI No.	Catalog No. DIN ISO Nr	Catalog No. P in	Catalog No. P mm	Width Between Inner Plates W min in	Width Between Inner Plates W min mm	Roller Diam. R max. in	Roller Diam. R max. mm	Pin Diam. D max. in	Pin Diam. D max. mm	Pin Length L max. in	Pin Length L max. mm	Transverse Pitch C in	Transverse Pitch C mm	Breaking Load min Lb	Breaking Load min Kg	Weight Lb/ft	Weight Kg/m
25		1/4	6.35	0.125	3.18	0.130	3.30	0.091	2.31	0.339	8.60			990	450	0.09	0.14
35		3/8	9.525	0.188	4.78	0.200	5.08	0.141	3.59	0.510	12.95			2420	1100	0.22	0.33
40	08A	1/2	12.70	0.313	7.95	0.312	7.92	0.156	3.97	0.691	17.45			4290	1950	0.41	0.62
41	085	1/2	12.70	0.251	6.38	0.306	7.77	0.141	3.59	0.567	14.40			2640	1200	0.27	0.41
50	10A	5/8	15.875	0.375	9.53	0.400	10.16	0.200	5.09	0.856	21.75			7040	3200	0.71	1.06
60	12A	3/4	19.05	0.500	12.70	0.469	11.91	0.234	5.96	0.059	26.90			9680	4400	1.01	1.50
80	16A	1	25.40	0.625	15.88	0.625	15.87	0.312	7.96	1.390	35.30			16500	7500	0.68	2.50
100	20A	1 1/4	31.75	0.750	19.05	0.750	19.05	0.375	9.54	1.699	43.15			25300	11500	2.55	3.80
120	24A	1 1/2	38.10	1.000	25.40	0.875	22.22	0.437	11.11	2.122	53.90			35200	16000	3.76	5.60
140	28A	1 3/4	44.45	1.000	25.40	1	25.40	0.500	12.71	2.303	58.50			45100	20500	5.10	7.60
160	32A	2	50.80	1.250	31.75	1.125	28.57	0.562	14.29	2.742	69.65			59400	27000	6.38	9.50
25-2		1/4	6.35	0.125	3.18	0.130	3.30	0.091	2.31	0.691	15.00	0.252	6.40	1760	800	0.18	0.26
35-2		3/8	9.525	0.188	4.78	0.200	5.08	0.141	3.59	0.907	23.05	0.398	10.10	3970	1800	0.42	0.64
40-2	08A-2	1/2	12.70	0.313	7.95	0.312	7.92	0.156	3.97	1.254	31.85	0.567	14.40	7050	3200	0.80	1.20
50-2	10A-2	5/8	15.875	0.375	9.53	0.400	10.16	0.200	5.09	1.569	39.85	0.713	18.10	10700	4860	1.36	2.02
60-2	12A-2	3/4	19.05	0.500	12.70	0.469	11.91	0.234	5.96	1.957	49.70	0.898	22.80	15500	7040	2.02	3.00
80-2	16A-2	1	25.40	0.625	15.88	0.625	15.87	0.312	7.96	2.543	64.60	1.154	29.30	27300	12400	3.38	5.02
100-2	20A-2	1 1/4	31.75	0.750	19.05	0.750	19.05	0.375	9.54	3.108	78.95	1.409	35.80	41000	18600	5.12	7.64
120-2	24A-4	1 1/2	38.10	1.000	25.40	0.875	22.22	0.437	11.11	3.909	99.30	1.787	45.40	59500	27000	7.38	10.98
140-2	28A-2	1 3/4	44.45	1.000	25.40	1	25.40	0.500	12.71	4.228	107.40	1.925	48.90	80700	36600	9.36	13.92
160-2	32A-2	2	50.80	1.250	31.75	1.125	28.57	0.562	14.29	5.045	128.15	2.303	58.50	104900	47600	12.58	18.72
25-3		1/4	6.35	0.125	3.18	0.130	3.30	0.091	2.31	0.843	21.40	0.252	6.40	2650	1200	0.27	0.39
35-3		3/8	9.525	0.188	4.78	0.200	5.08	0.141	3.59	1.305	33.15	0.398	10.10	5950	2700	0.63	0.96
40-3	08A-3	1/2	12.70	0.313	7.95	0.312	7.92	0.156	3.97	1.821	46.25	0.567	14.40	10600	4800	1.20	1.80
50-3	10A-3	5/8	15.875	0.375	9.53	0.400	10.16	0.200	5.09	2.281	57.95	0.713	18.10	16100	7290	2.04	3.03
60-3	12A-3	3/4	19.05	0.500	12.70	0.469	11.91	0.234	5.96	2.854	72.50	0.898	22.80	23300	10560	3.03	4.50
80-3	16A-3	1	25.40	0.625	15.88	0.625	15.87	0.312	7.96	3.697	93.90	1.154	29.30	41000	18600	5.07	7.53
100-3	20A-3	1 1/4	31.75	0.750	19.05	0.750	19.05	0.375	9.54	4.518	114.75	1.409	35.80	61500	27900	7.68	11.46
120-3	24A-3	1 1/2	38.10	1.000	25.40	0.875	22.22	0.437	11.11	5.697	144.70	1.787	45.40	89300	40500	11.07	16.47
140-3	28A-3	1 3/4	44.45	1.000	25.40	1	25.40	0.500	12.71	6.154	156.30	1.925	48.90	121000	54900	14.04	20.88
160-3	32A-3	2	50.80	1.250	31.75	1.125	28.57	0.562	14.29	7.348	186.65	2.303	58.50	157000	71400	18.87	28.08

3.3 Design Winch Requirement

A discussion had been had with the HRSB company's representative to gather additional information regarding their requirements for the winch design. Table 3.6 contains all relevant information. The inputs will be analysed and utilised to help develop the design plan. The data acquired will support in the conceptual design of the winch.

Table 3.6 Customer Requirement

NO	REQUIREMENTS
1	Managed to pull up to 80 tons bundle tube
2	Maintain operation of current engines, hydraulic motors, and hydraulic jacks
3	Rectangular-shaped winch

3.3.1 Design Winch Specifications

This Product Design Specification details the function of the winch on the bundle puller. This document's objective is to ensure that the future design and development of the product meet the client's expectations. Product Design Specification for Winch Bundle Puller

A. Product identification

The winch bundle puller's function is to extract or insert the bundle tube from or into the heat exchanger.

B. Features

1. Travel distances of up to 9500mm are possible.

2. Capable of producing up to 80 tonnes of bundle tube force.

3. Capable of extracting bundles of tubes up to 12m in length.

4. Bundle tubes up to 2000mm in diameter are easily removed.

5. Winch pulling power varies from 45,000 kg up to 60,000kg

6. Hydraulic Motor-Driven

7. The winch is driven smoothly by four gears attached to the gear rack.

C. Design Dimension Limitation / Design Constrain

1.

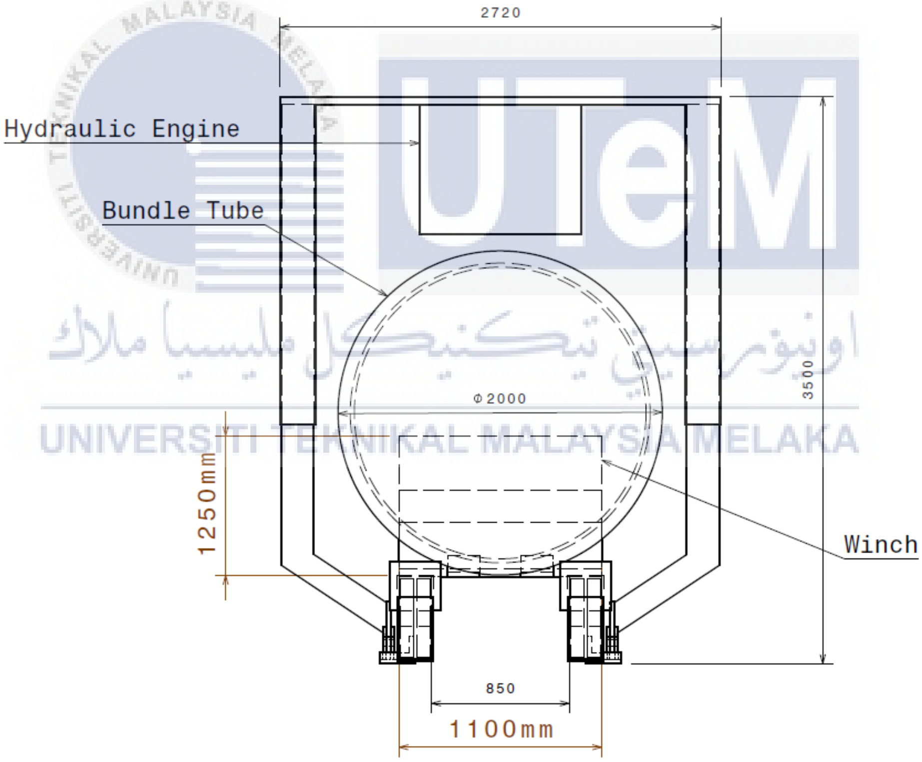

Figure 3.8 Bundle Puller from front view

2.

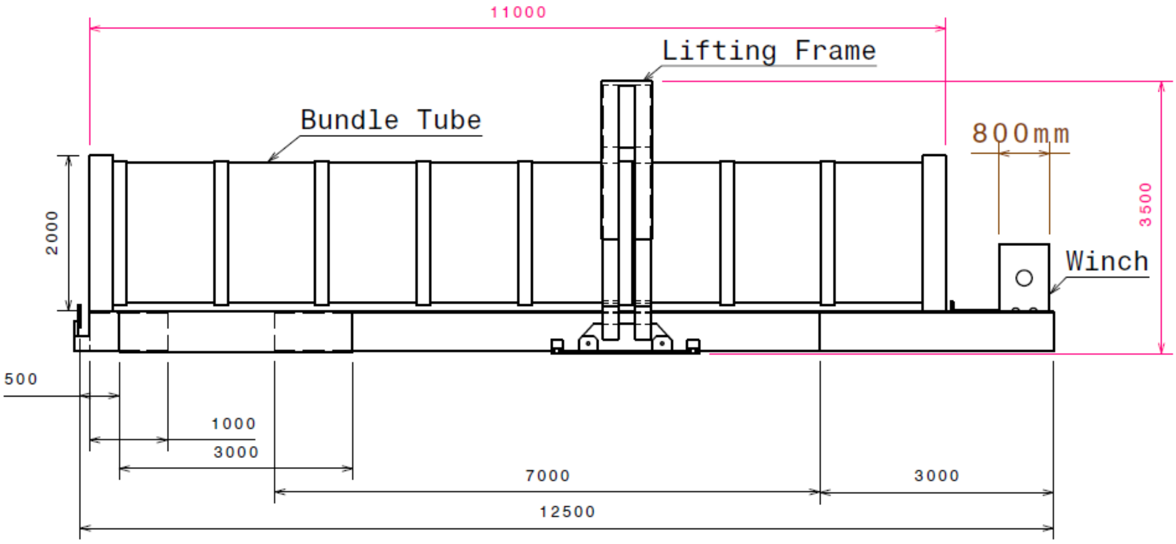

Figure 3.9 Bundle Puller from side view

Width: The winch's width should be between 1100mm and 850mm as shown in Figure 3.8

Height: The height must surpass 1000mm above the centre of the bundle tube with the largest diameter necessary for the 80 tons bundle tube as shown in Figure 3.8

Length: The winch's maximum length should be 800mm to ensure that when the bundle tube is extracted, it fits exactly on the bundle puller as shown in Figure 3.9

3.4 Concept Design Winch

This chapter will provide some recommendations or solutions, such as a proposed design for the winch, a proposed gear configuration for the winch, and a proposed material composition for the winch.

3.4.1 Propose Design Winch

The winch concept design was developed after an evaluation of the winch requirement and winch design specifications. Figure 3.10 shows the new design of the winch for 80 Tons Bundle Puller. It shows the winch's potential travel distance reaching up to 9000mm.

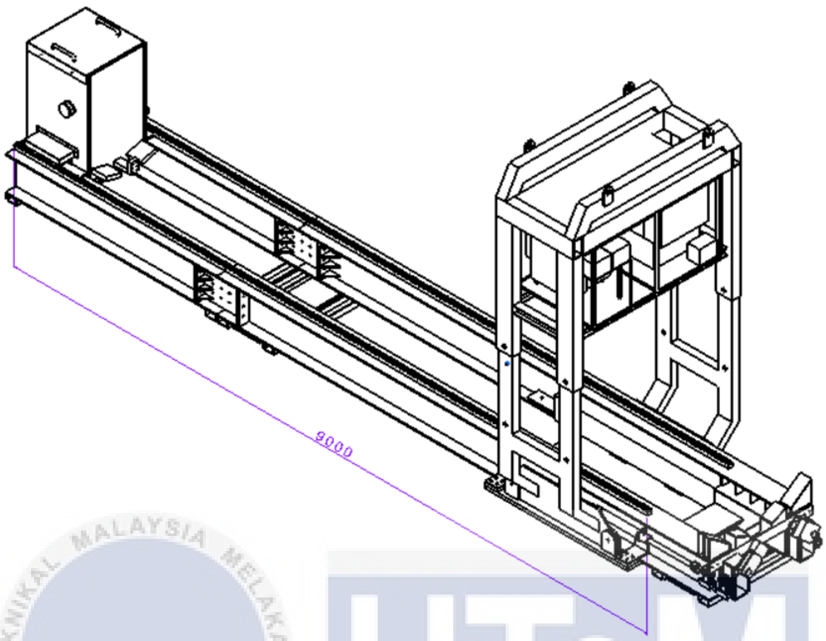

Figure 3.10 Distance travel by winch

According to figure 3.11, the total weight of the winch was also successfully decreased by 27%, from 3500 kg to 2544 kg. The objective of optimising the existing design and lowering manufacturing costs was accomplished.

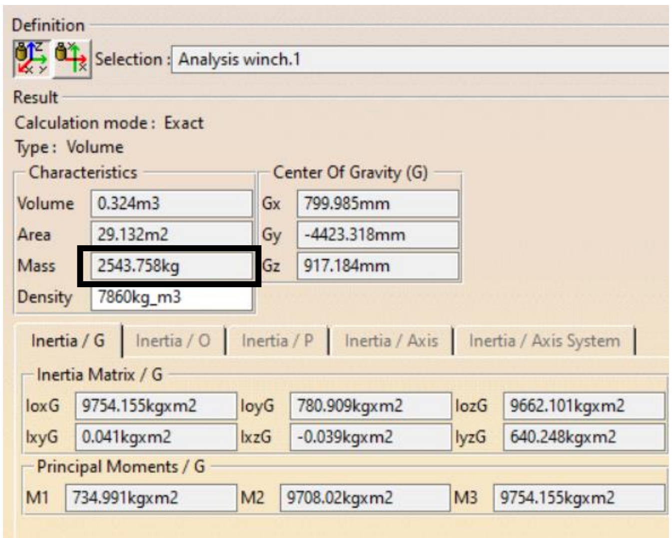

Figure 3.11 Mass and volume of the 80 Tons Winch

The new winch design fits snugly into the 80 Tons main frame bundle puller, as illustrated in Figure 3.12. Certain modifications have been done, including lowering the bottom of the winch. This is because a bigger gear was used than the current winch in order to achieve 80 tonnes of pulling power on the bundle tube. Appendices d, e, and f contain more detailed drawings.

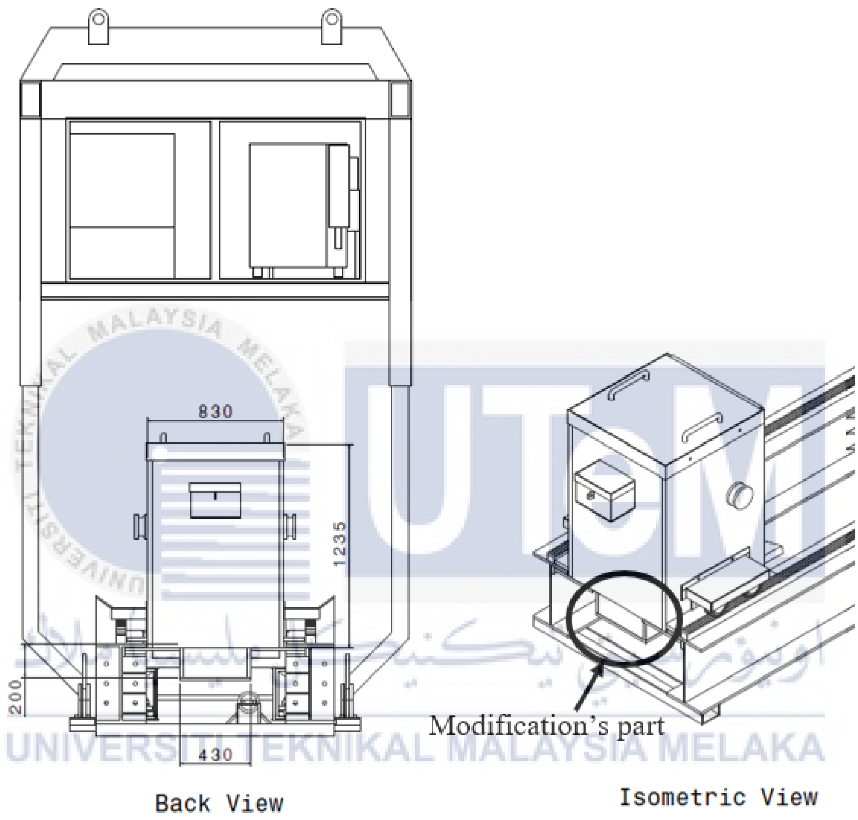

Figure 3.12 Modification of Winch Parts

3.4.2 Propose Gear Winch

Figure 3.13 shows the gear mechanism for the new design for 80 Tons Winch. According to the problem statement, the following is the gear selection for the winch that would be required to pull the winch up to 80T bundle tube. The table 3.7 illustrates the suitable selected gear. The detail could be referred at Appendix A for sprocket size, Appendix B for Spur Gear size and Appendix C for Gear Rack size.

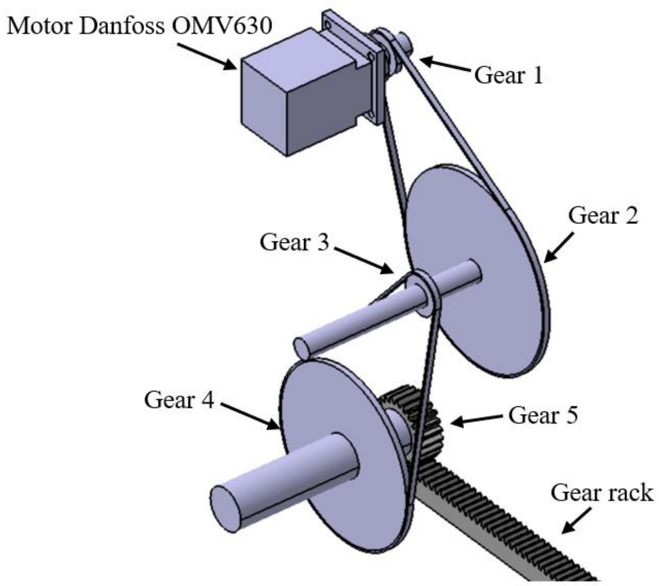

Figure 3.13 Mechanism Gear of 80 Tons Winch

Table 3.7 Propose gear selection for 80 Tons winch

No gear	Type of gear	Module Gear	Size of gear
1	Sprocket	1”	Outside Diameter = 93 mm
2	Sprocket	1”	Outside Diameter = 451 mm
3	Sprocket	1”	Outside Diameter = 93 mm
4	Sprocket	1”	Outside Diameter = 411 mm
5	Spur Gear	6	Outside Diameter = 156 mm
Rack	Gear Rack	6	(60 x 60) mm

3.4.3 Propose Material Winch

The winch will be constructed or manufactured mainly of mild steel. This is because it was a high-demand commodity in the fabrication and manufacturing industries, including the oil and gas sector. Additionally, its availability, constructability, low cost, and strength make it difficult to break. Besides that, it can be painted, primed, or galvanized to prevent corrosion and add a beautiful touch. Mild steel can be employed in circumstances that need structural steel fabrication due to its high yield strength and ease of shaping. Table 3.8 shows the ultimate tensile strength of mild steel is 450MPa.

Table 3.8 Ultimate Strength of Materials Properties, (M,2021). Mild steel: Density, strength, hardness, melting point. Material Properties. Retrieved January 6, 2022, from https://material-properties.org/mild-steel-density-strength-hardness-melting-point/)

Name	Mild Steel
Phase at STP	solid
Density	7850 kg/m3
Ultimate Tensile Strength	400-550 MPa
Yield Strength	250 MPa
Young's Modulus of Elasticity	200 GPa
Brinell Hardness	120 BHN
Melting Point	1450 °C
Thermal Conductivity	50 W/mK
Heat Capacity	510 J/g K

3.5 Stress Analysis Winch

Engineering Calculation and ANSYS Workbench software are used to do finite element analysis (FEA). As stated in the objective, the analysis will concentrate on the winch's strength to ensure that it can be utilised safely. The finite element analysis (FEA) will be used to determine the maximum stress and factor of safety. There will be a few various cases based on the boundary conditions given to the winch. The case of the winch's stress analysis is given in Table 3.9.

Table 3.9 Stress Analysis of Winch by Case

No Case	Stress Analysis Case
1	Stress Analysis Gear Winch
2	Stress Analysis Wall Thickness Winch
3	Stress Analysis Wall Thickness Winch
4	Stress Analysis on Front Hook Winch
5	Stress Analysis on Hydraulic Motor Holder Winch
6	Stress Analysis on Middle Shaft Winch

3.5.1 Case 1: Stress Analysis Gear Winch

In this case, the calculation for gear selection will be demonstrated. Figure 3.14 shows the winch's gear system; the hydraulic motor will rotate and provide torque to gear 1. The maximum torque generated from the hydraulic motor is mentioned in the technical data for the hydraulic motor in Table 3.2.

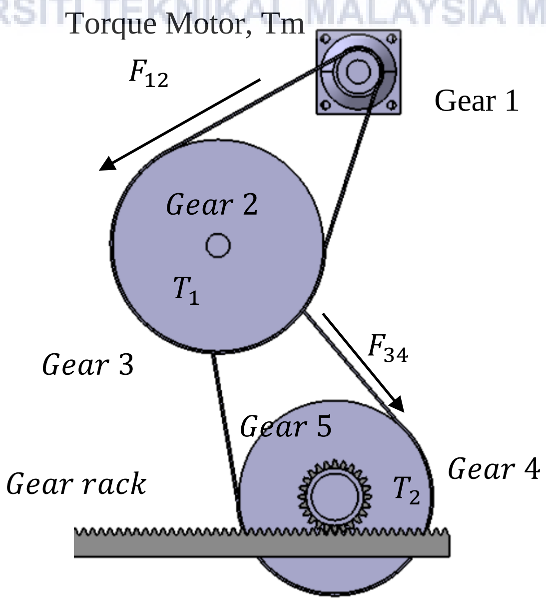

Figure 3.14 Gear System Winch

The winch's gear selection will be determined using the torque formula. Torque is a unit of measurement that indicates how much a force applied on an object causes it to rotate. The torque formula (3.1) is defined:

$$T = Fr \tag{3.1}$$

$T = Torque$

$F = force$

$r = radius\ of\ gear$

3.5.2 Case 2: Stress Analysis Wall Thickness Winch by Pulling Force 80 Tons

Case 2 is to determine the winch wall thickness's strength. Stress analysis of the thickness of the wall winch will be performed by drawing the winch to various thicknesses. The thickness study will be performed on several wall thicknesses, including 20mm, 30mm, 40mm, and 50mm. 80 tons of pulling force will be applied to the winch hinge at points B and C as illustrated in the figure 3.15 in the situation that the winch moves backward, pulling the bundle tube, and the bottom plate at point A will act as a fixed support. Chapter 4 will present the outcome of the maximum stress and safety factor analyses.

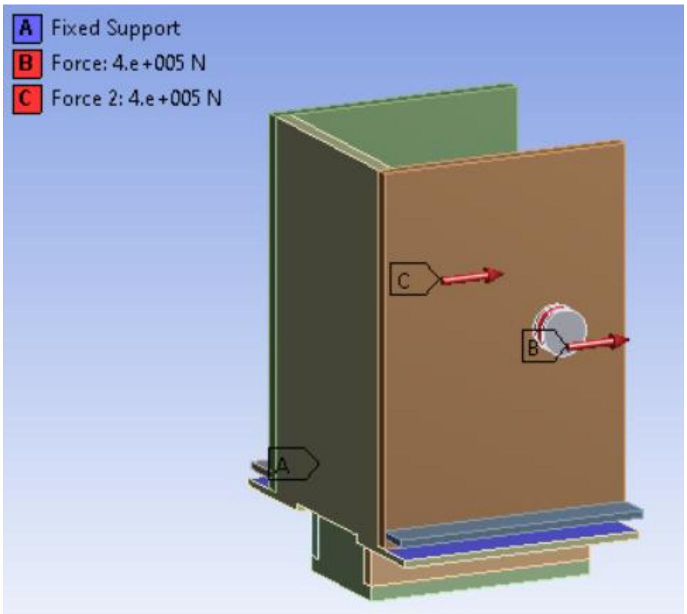

Figure 3.15 Stress Analysis Case 2 Boundary Condition

3.5.3 Case 3: Stress Analysis Wall Thickness Winch by Pulling Force 80 Tons

Case 3 is to measure the strength of the winch wall thickness. Stress analysis of the thickness of wall winch will be done by apply the pulling force to the pull the bundle tube to the different thickness. The thickness analysis will be determined by different thickness wall which 20mm,30mm,40mm and 50mm. Pulling force 80 tons will be applied to the winch hinge at point B and point C as shown in figure 3.16 as situation when the winch move backward pulling the bundle tube and the bottom plate at point A as shown in figure 3.16 will be fixed support. The result of the maximum stress and safety factor will be provided in Chapter 4.

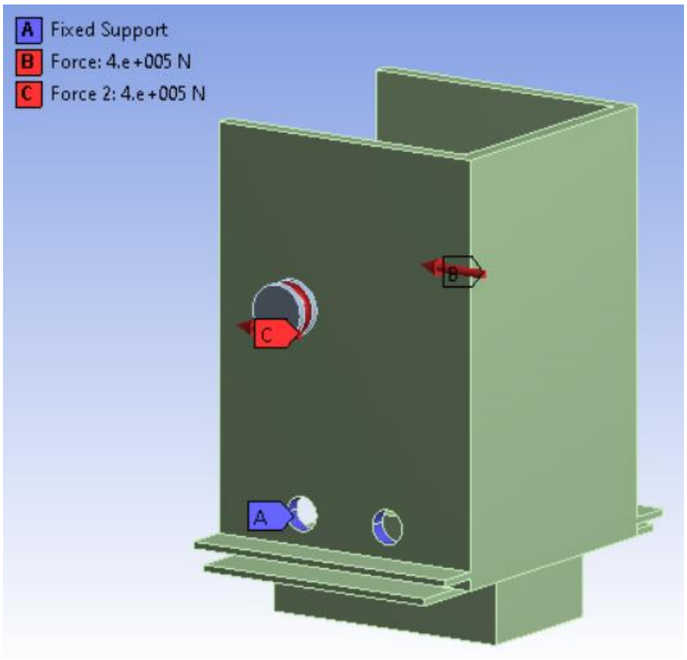

Figure 3.16 Stress Analysis Case 3 Boundary Condition

3.5.4 Case 4: Stress Analysis Wall Thickness Winch by Weight Winch

Case 4 is to determine the strength of the winch wall thickness by applying force equal to the winch's total weight to the various thicknesses. The thickness analysis will be performed on various wall thicknesses, including 20mm, 30mm, 40mm, and 50mm. In this case, 4000N of pulling force will be applied to the body winch, which is estimated to be the total weight of the 50mm winch at point A, and the bottom plate of the winch at point B will serve as a fixed support as shown in figure 3.17. The maximum stress on the wall winch as a result of applying the winch's weight load and the safety factor will be discussed in Chapter 4.

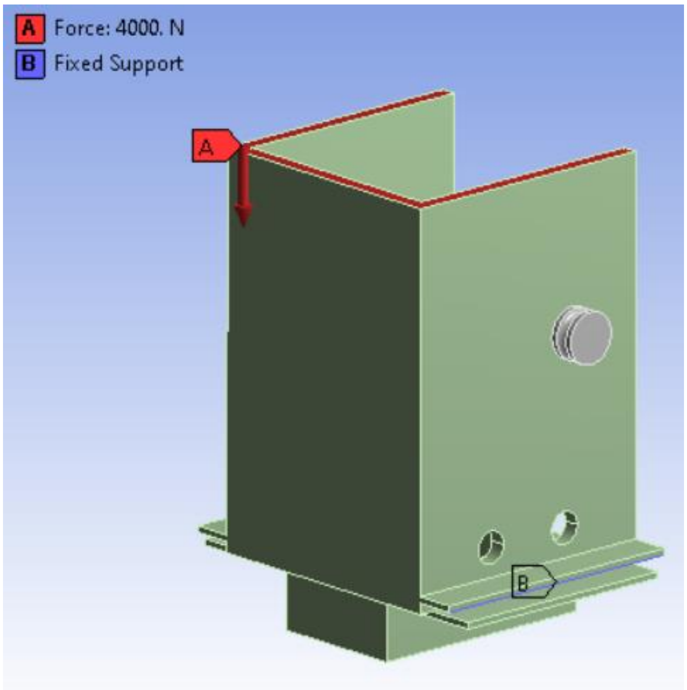

Figure 3.17 Stress Analysis Case 4 Boundary Condition

3.5.5 Case 5: Stress Analysis on Front Hook Winch

In this case the coefficient of friction occurs due to the force between the saddle and the I-beam bundle puller. These are the formula coefficient of friction (3.2).

$$F_f = \mu F_n \tag{3.2}$$

$F_f = Frictional\ force$

$\mu = Coefficient\ of\ friction$

$F_n = Normal\ force$

$F_n = 800000\ N$

$\mu = 0.21 based\ on\ Figure\ 3.23$

Table 3.10 Coefficient of Friction by Materials

Cadmium	Cadmium	Lubricated and Greasy	0.05
Cadmium	Chromium	Clean and Dry	0.41
Cadmium	Chromium	Lubricated and Greasy	0.34
Cast Iron	Cast Iron	Clean and Dry	1.1
Cast iron	Mild Steel	Clean and Dry	0.4
Cast iron	Mild Steel	Lubricated and Greasy	0.21
Carbon (hard)	Carbon	Clean and Dry	0.16
Carbon (hard)	Carbon	Lubricated and Greasy	0.12 – 0.14
Carbon	Steel	Clean and Dry	0.14

$$F_f = \mu F_n \tag{3.3}$$

$$F_f = (0.21)(800000)$$

$$F_f = 600000\text{N}$$

The thickness analysis will be determined by different thickness wall which 10mm,20mm and 30mm. Then, pulling force 600000N will be applied to the front part of the winch as shown in figure 3.18 at point A and the side of front plate will be fixed as shown in figure 3.18 at point B and point C. The maximum stress result and factor safety will be provided in Chapter 4.

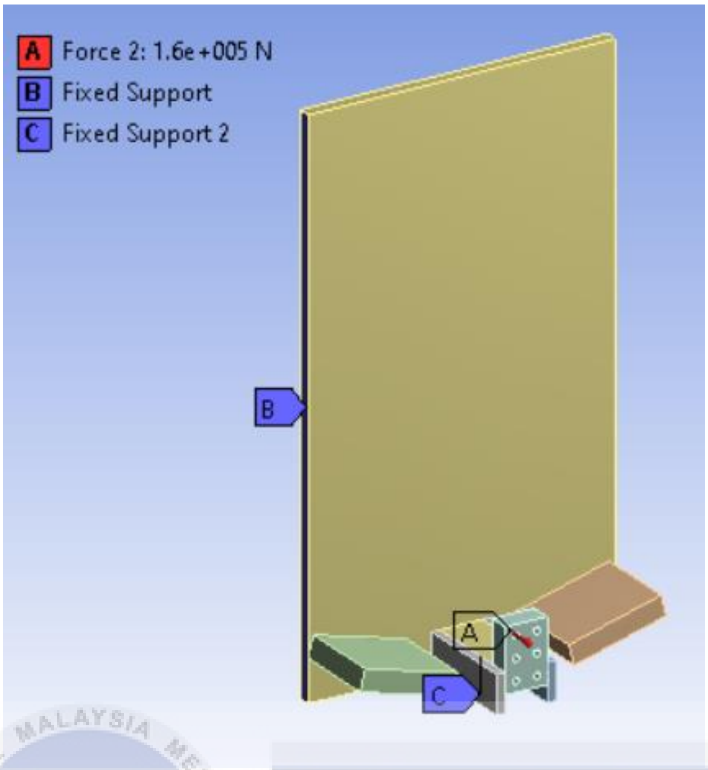

Figure 3.18 Stress Analysis Case 5 Boundary Condition

3.5.6 Case 6: Stress Analysis on Internal Front Plate Winch

This case is to study the maximum stress Internal front plate winch by applying the Frictional force which 600000N at point A and point B as shown in Figure 3.19. Other, fixed support be applied at point C as shown in Figure 3.19. The maximum stress analysis will be determined by different thickness wall which 10mm,20mm and 30mm. The maximum stress result and factor safety will be provided in Chapter 4.

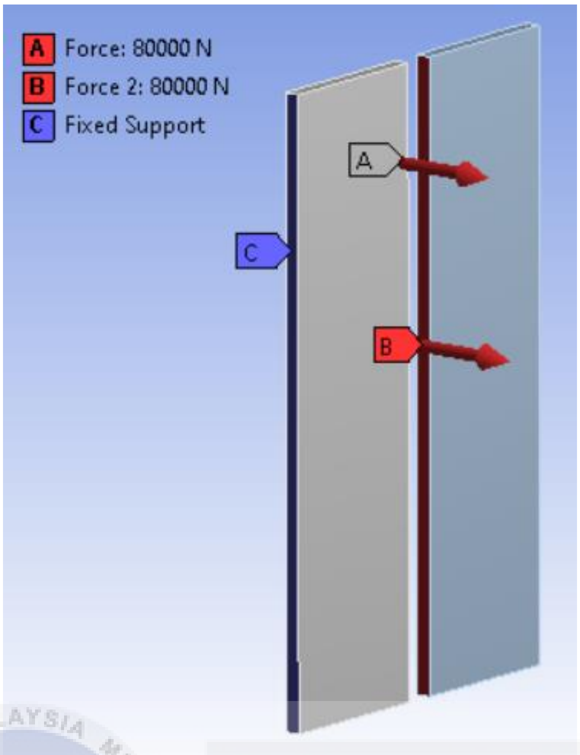

Figure 3.19 Stress Analysis Case 6 Boundary Condition

CHAPTER 4

RESULT

4.1 Result of Stress Analysis Winch

4.1.1 Result Stress Analysis Case 1

Figure 4.1 shows the gear system of the new design 80 tons winch. Torque is generated by the OMV 630 hydraulic motor and delivered to gear 1 via the Figure 4.1. Torque is created in gear 1 against gear 1 and gear 2. Following that, torque for gears 2 and 3 may be calculated from gear force 2. Then, using the torque gear 3 result, the force on gears 3 and 4 can be calculated. Following that, torque is accessible in gears 4 and 5. Finally, when torque is present on gear 5, force gear 5 is available.

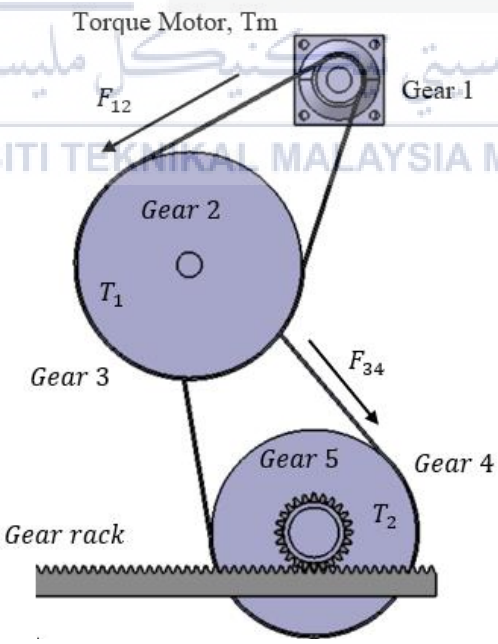

Figure 4.1 Gear System of Winch

The analysis calculation was performed to determine the maximum force applied by the gear during the winch's pull of the bundle tube and the appropriate gear size for the winch's pull. The analysis used equation 1 to calculate the force and torque values. Assuming from Table 3.2, the motor has a torque of 1660Nm, T motor = 1660Nm.

With the value of $T\ motor$ = 1660 Nm, Radius 1 = 0.0465m

$$F_{12} = {}^{T\ motor}/_{Radius\ 1} \tag{4.1}$$

$$F_{12} = {}^{1660Nm}/_{0.0465m}$$

$$F_{12} = 35699N$$

With the value $F_{12} = 35699N$, $Radius\ 2 = 0.2255m$

$$T1 = F_{12}\ x\ Radius\ 2 \tag{4.2}$$

$$T1 = 35699N\ x\ 0.2255m$$

$$T1 = 8050.1Nm$$

With the value $T1$=8050.1N, $Radius$ 3=$0.0465m$

$$F_{34} = {}^{T1}/_{Radius\ 3} \tag{4.3}$$

$$F_{34} = {}^{8050.1N}/_{0.0465m}$$

$$F_{34} = 173121N$$

With the value $F_{34} = 173121N$, $Radius\ 4 = 0.2055m$

$$T2 = F_{34}\ x\ Radius\ 4 \tag{4.4}$$

$$T2 = 173121N\ x\ 0.2055m$$

$$T2 = 35576Nm$$

With the value $T2 = 35576Nm, Radius\ 5 = 0.078m$

$$F_5 = {}^{T2}/_{Radius\ 5} \tag{4.5}$$

$$F_5 = {}^{35576Nm}/_{0.078m}$$

$$F_5 = 45.611T$$

With the value of one part of the motor $F_5 = 45.611T$,

$$2\, motor\ force = 45.61t \times 2 \tag{4.6}$$

$$2\, motor\ force = 91.22T$$

This is a calculation for a single component or side of the motor. Two motors will be used to pull the bundle tube, and the combined force of the two motors will be 91.22T, which is acceptable to pull the bundle tube with a pulling force of 80T.

4.1.2 Result Stress Analysis Case 2

The result is desired from the stress analysis had been done. The result available in Figure 4.2 until Figure 4.6

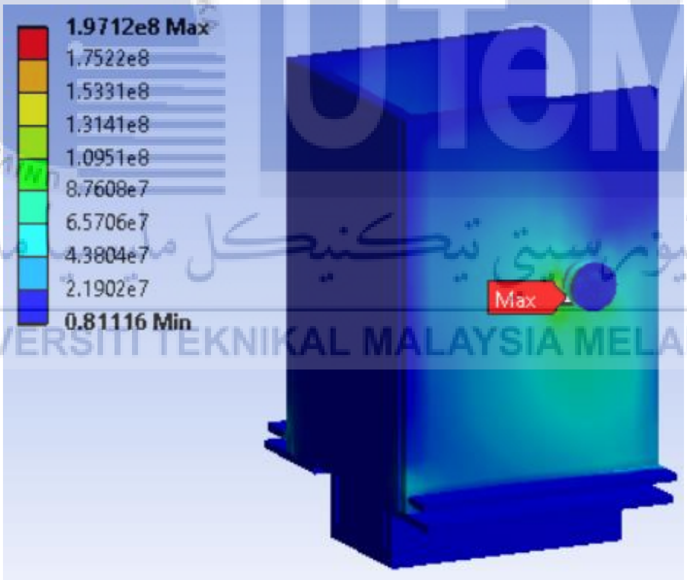

Figure 4.2 Maximum Stress for Wall Thickness 50mm

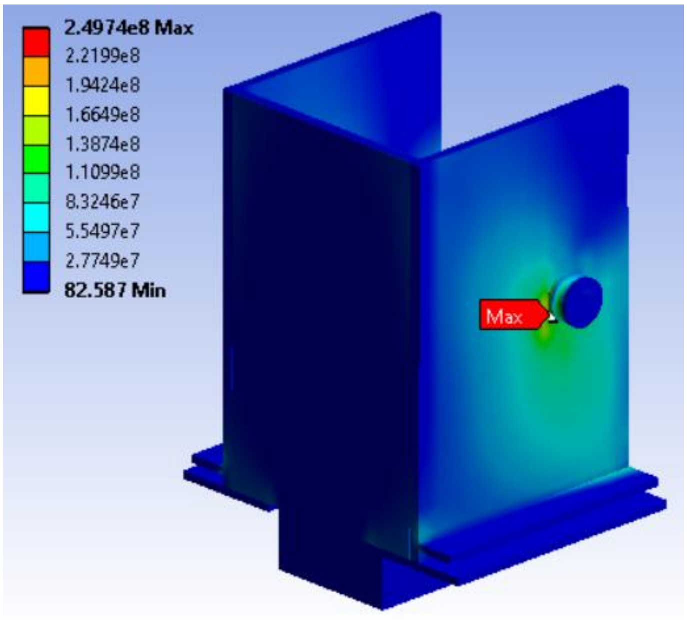

Figure 4.3 Maximum Stress for Wall Thickness 40mm

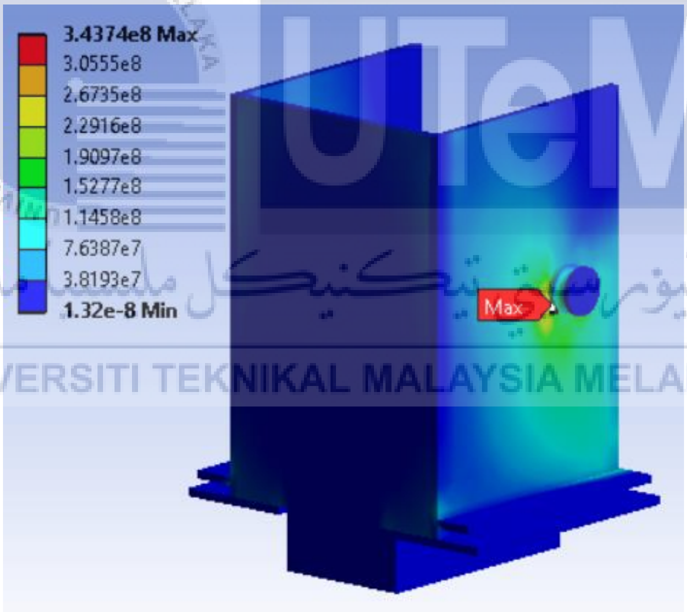

Figure 4.4 Maximum Stress for Wall Thickness 30mm

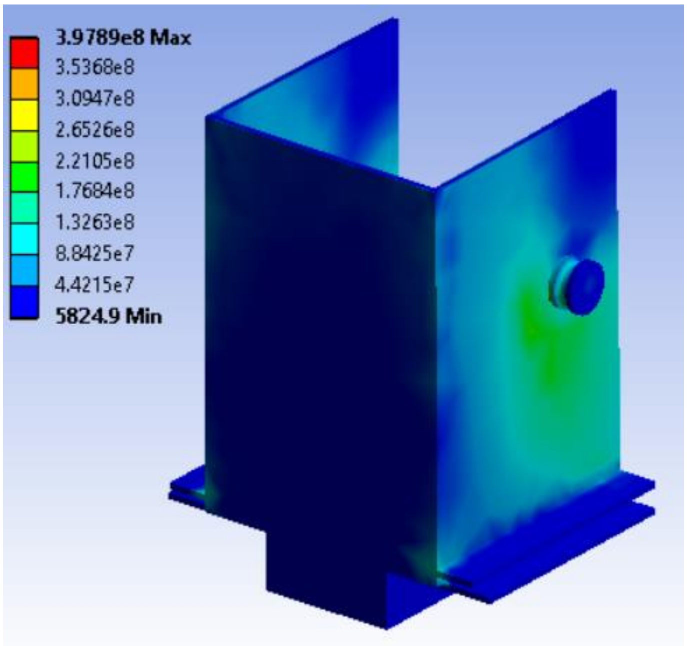

Figure 4.5 Maximum Stress for Wall Thickness 25mm

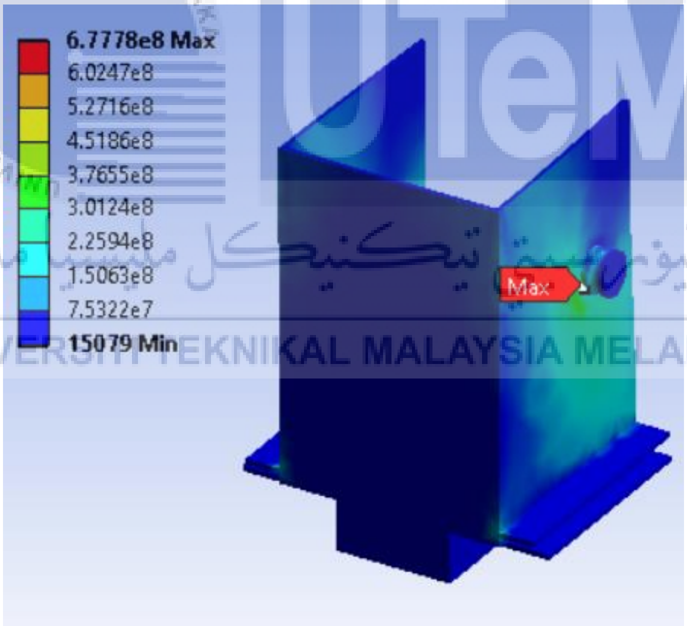

Figure 4.6 Maximum Stress for Wall Thickness 20mm

Based on Figure 4.2, the maximum stress is 197.1 MPa which can be discovered at the hinge of the winch. The safety factor for the 50mm wall thickness is about 2.28 which will to high. Other Figure 4.3 shows the maximum stress 249.7 MPa and the safety factor that was determine from stress analysis is 1.8 which will be strong to be use. Finally, based on Figure 4.4, the result of the maximum stress on wall thickness 30mm is 344 MPa and the safety factor for the stress analysis is 1.3 which will be good enough and acceptable to be use as wall thickness of the winch. The overall view for the result of these stress analysis is shown in table 4.1 below.

Table 4.1: Stress Analysis Result Case 2 for the Winch with different Wall Thickness

Force (T)	Wall Thickness (mm)	Max Stress (Mpa)	Remarks	Safety Factor
80	50	197.1	Max stress at hinge	2.28
80	40	249.7	Max stress at hinge	1.8
80	30	344	Max stress at hinge	1.3
80	25	397.9	Max Stress at hinge	1.13
80	20	677.7	Max stress at hinge	0.66

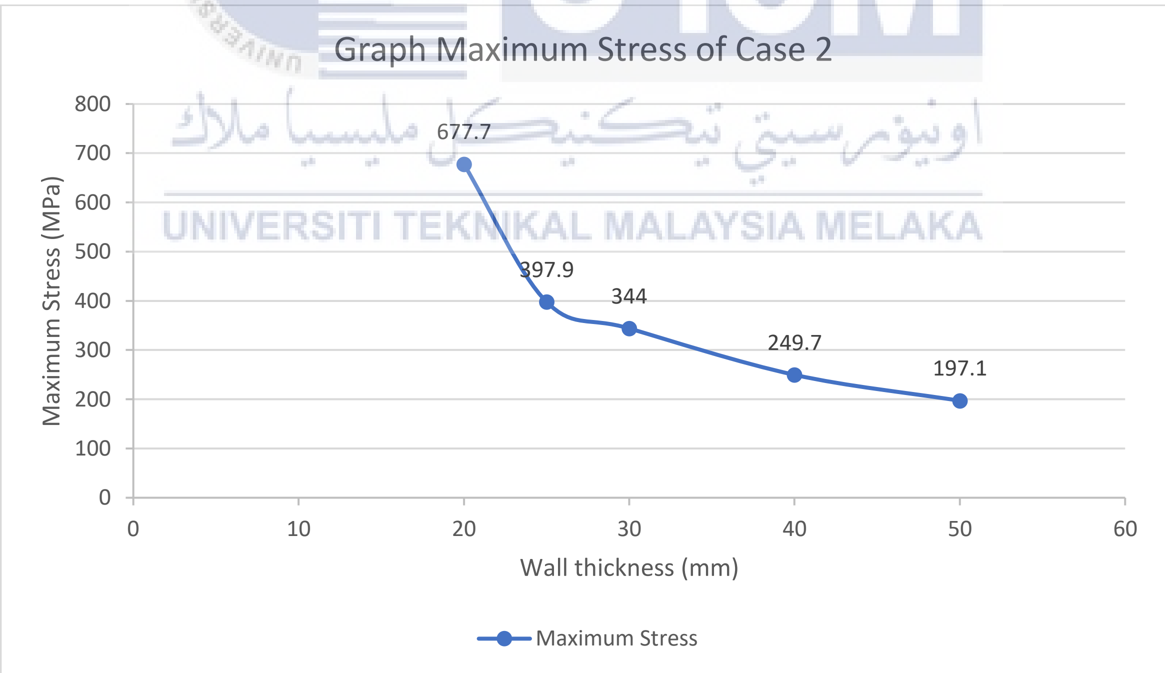

Figure 4.7 Graph Maximum Stress Analysis for Case 2

4.1.3 Result Stress Analysis Case 3

The result is desired from the stress analysis had been done. The result available in Figure 4.7 until Figure 4.11.

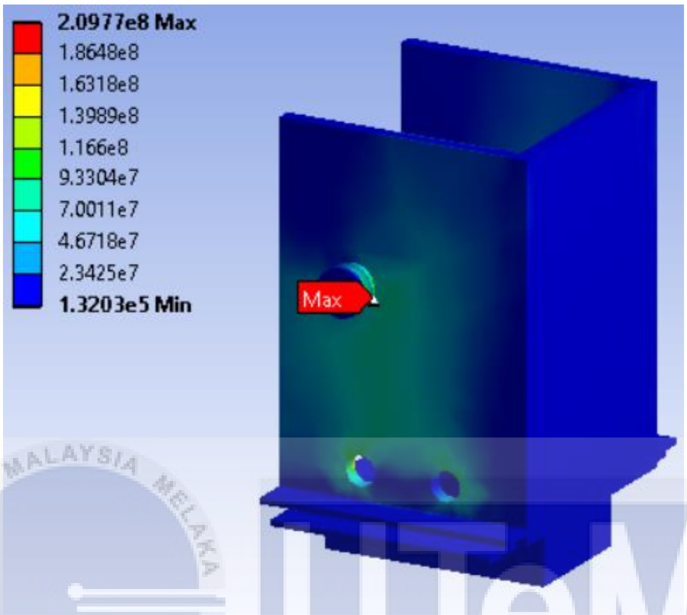

Figure 4.8 Maximum Stress for Wall Thickness 50mm

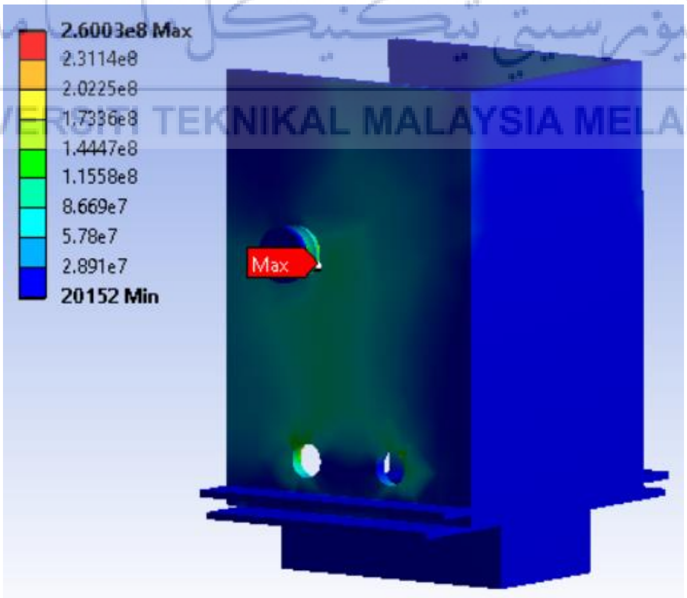

Figure 4.9 Maximum Stress for Wall Thickness 40mm

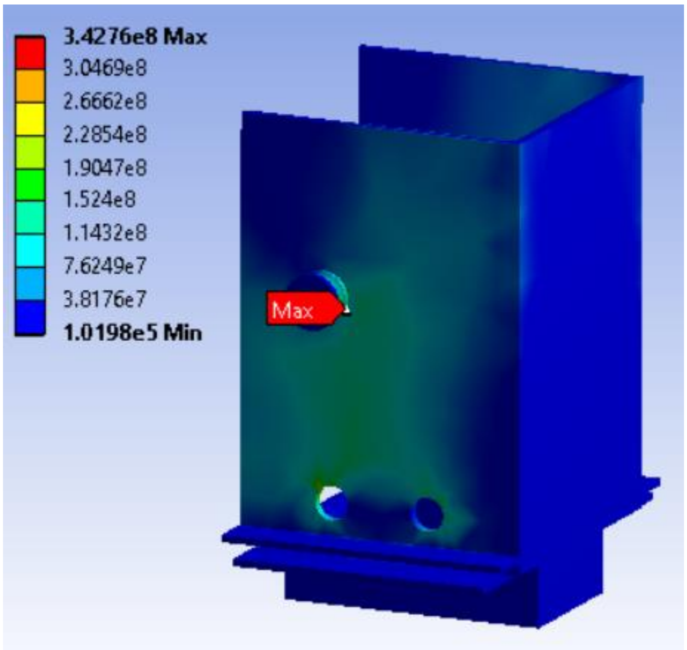

Figure 4.10 Maximum Stress for Wall Thickness 30mm

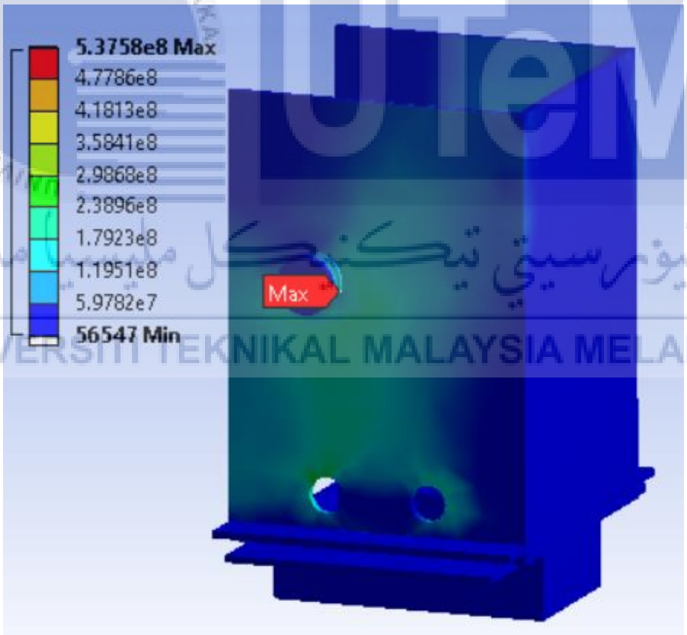

Figure 4.11 Maximum Stress for Wall Thickness 25mm

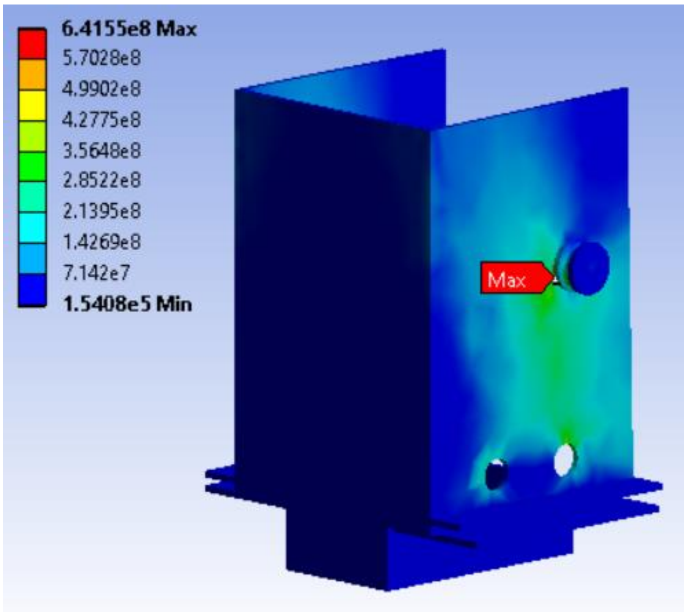

Figure 4.12 Maximum Stress for Wall thickness 20mm

According to Figure 4.7, the maximum stress is 209.8 MPa, which can be found at the winch's hinge. The safety factor for a 50mm thick wall is approximately 2.14, which is excessive. Additionally, Figure 4.8 illustrates the maximum stress of 260 MPa and the safety factor determined through stress analysis is 1.7, which is sufficient for use. Finally, based on Figure 4.9, the maximum stress on a 30mm thick wall is 342.8 MPa, and the safety factor for the stress analysis is 1.3, which is sufficient and acceptable for use as the winch's wall thickness. The results of these stress analyses are summarized in Table 4.2 below.

Table 4.2: Stress Analysis Result Case 3 for the Winch with different Wall Thickness

Force (T)	Wall Thickness (mm)	Max Stress (Mpa)	Remarks	Safety Factor
80	50	209.8	Max stress at hinge	2.14
80	40	260	Max stress at hinge	1.7
80	30	342.8	Max stress at hinge	1.3
80	25	537.6	Max Stress at hinge	0.8
80	20	641.6	Max stress at hinge	0.7

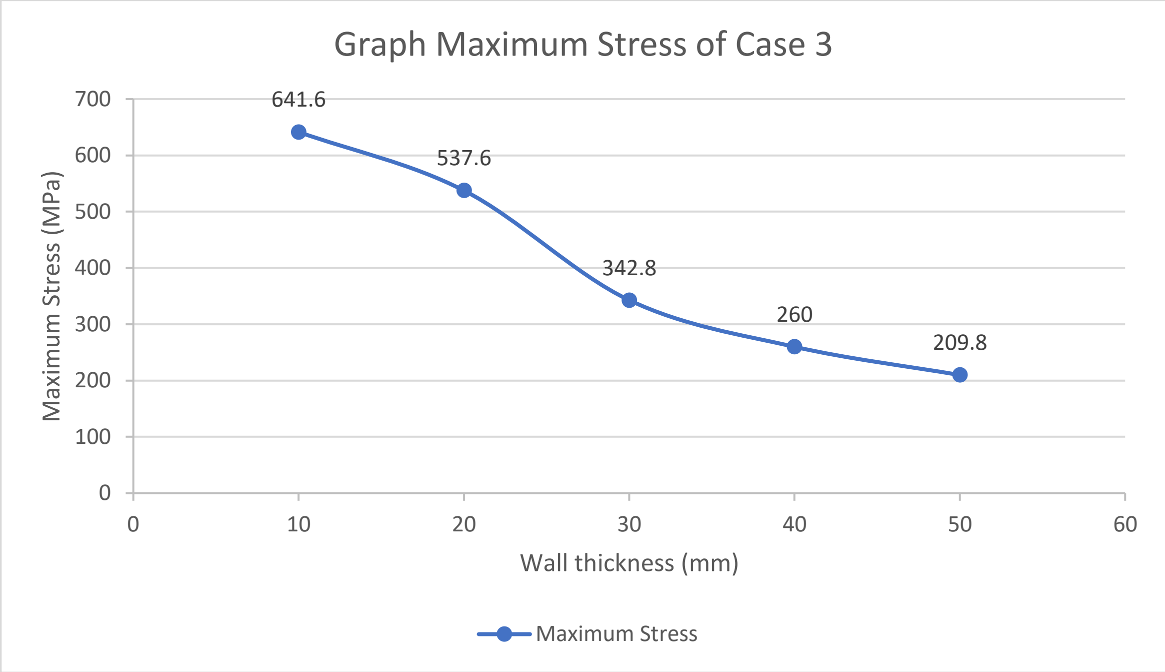

Figure 4.13 Graph Maximum Stress Analysis for Case 3

4.1.3 Result Stress Analysis Case 4

After the stress analysis of the winch already done, there are a few results from the analysis will be shown on Figure 4.12 until Figure 4.15. The result below will show the equivalent (von-Mises) stress on the model winch. The analysis was done for 4 times which are from wall thickness 50 mm to 20 mm.

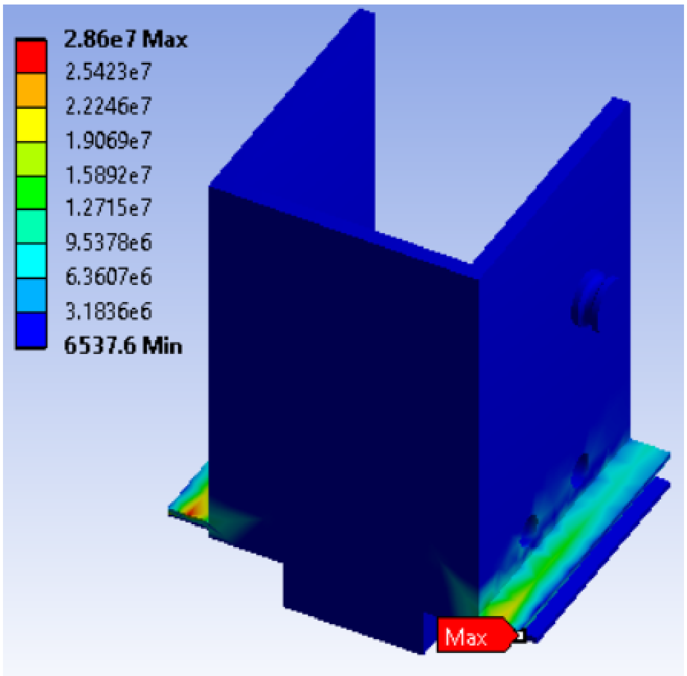

Figure 4.14 Maximum Stress for wall thickness 50mm

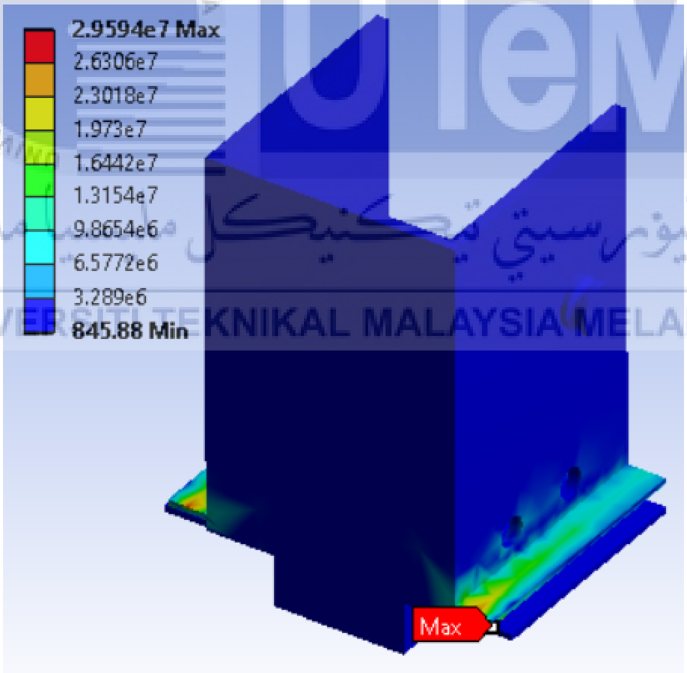

Figure 4.15 Maximum Stress for wall thickness 40mm

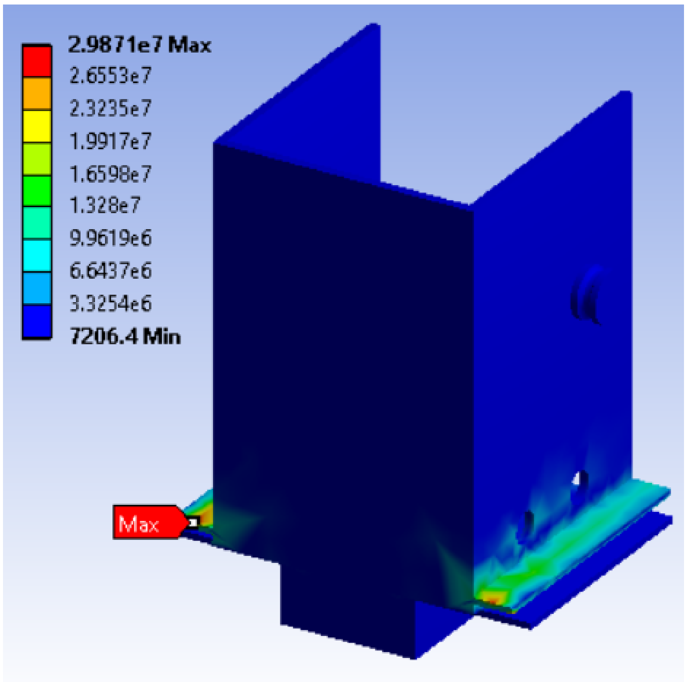

Figure 4.16 Maximum stress for wall thickness 30mm

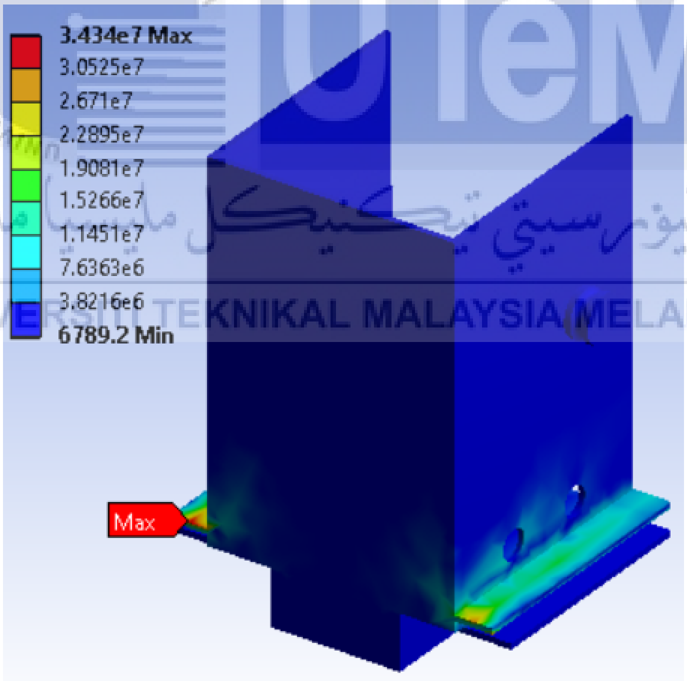

Figure 4.17 Maximum stress for wall thickness 20mm

According to Figure 4.12, the maximum stress at the winch's bottom plate is 28.6 MPa. A 50mm thick wall has a safety factor of approximately 15.7, which is excessive. Additionally, Figure 4.13 illustrates a maximum stress of 29.6 MPa and a safety factor of

15.7, which is also quite high. Finally, as illustrated in Figure 4.14, the maximum stress on a 30 mm thick wall is 29.9 MPa, and the stress analysis safety factor is 15. This demonstrates that a wall thickness of 30mm is both safe and acceptable for use as the wall thickness of the winch. Table 4.3 summarizes the results of these stress analyses.

Table 4.3: Stress Analysis Result Case 4 for the Winch with different Wall Thickness

Force (N)	Wall Thickness (mm)	Max Stress (MPa)	Remarks	Safety Factor
40000	50	28.6	Max stress at bottom plate	15.7
40000	40	29.6	Max stress at bottom plate	15.2
40000	30	29.9	Max stress at bottom plate	15
40000	20	34.3	Max stress at bottom plate	13.1

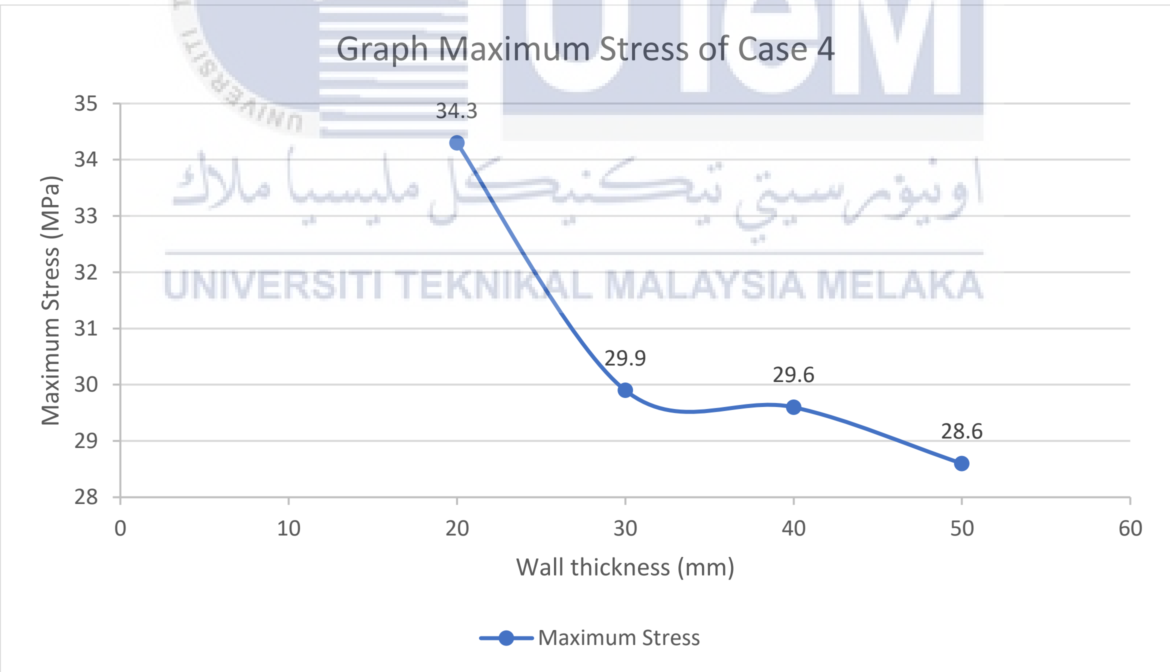

Figure 4.18 Maximum Stress Analysis for Case 4

4.1.5 Result Stress Analysis Case 5

Following the stress analysis of the front hook winch, a few of the analysis's research results will be provided on Figure 4.16 until Figure 4.18. The equivalent (von-Mises) stress on the model winch is shown in the result below. The analysis was repeated three times with wall thicknesses range of 30 mm to 10 mm.

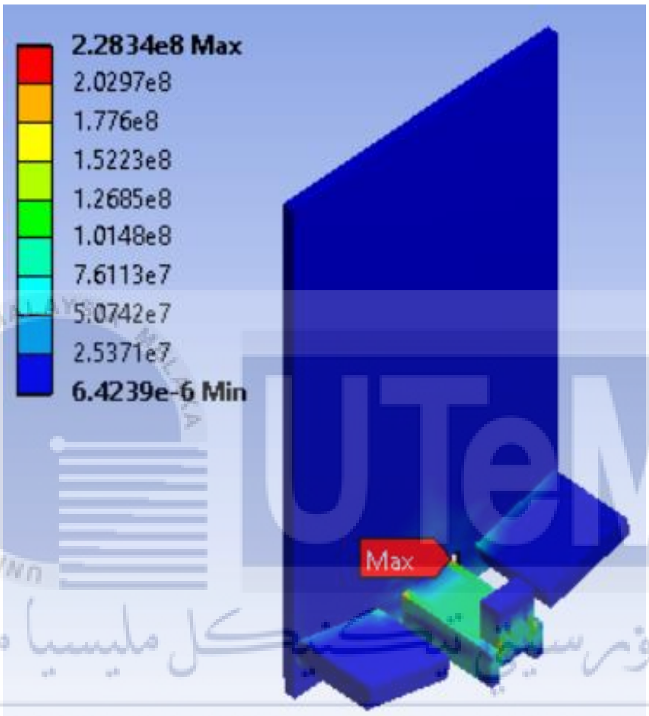

Figure 4.19 Maximum stress for wall thickness 30mm

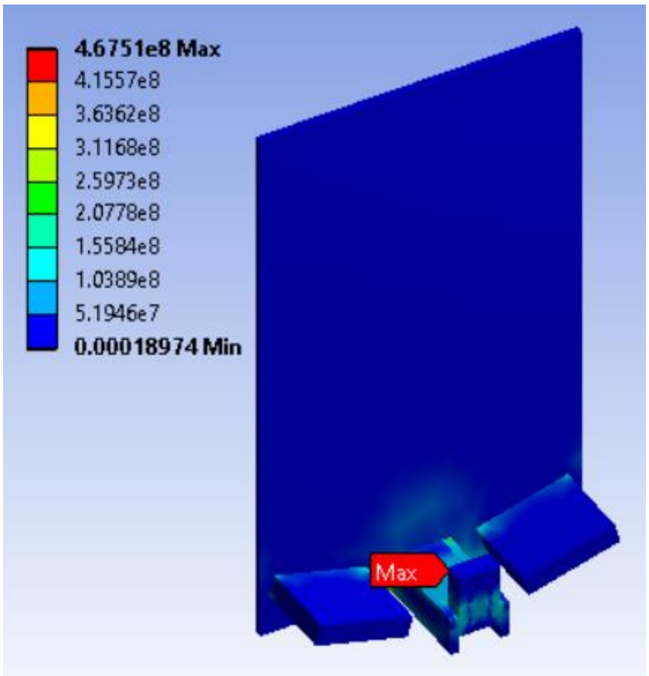

Figure 4.20 Maximum stress for wall thickness 20mm

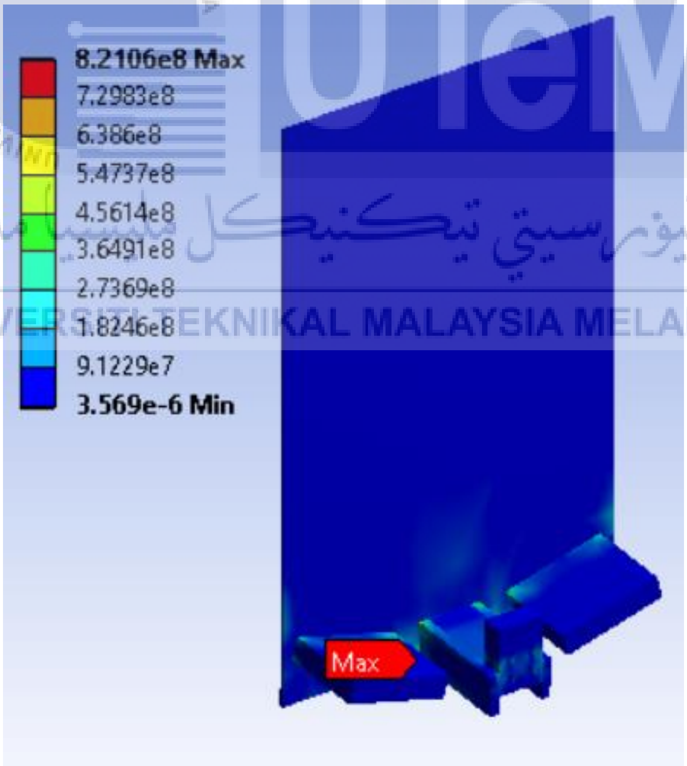

Figure 4.21 Maximum stress for wall thickness 10mm

The maximum stress at the winch's middle plate, as shown in Figure 4.16, is 228.3 MPa. A 30mm thick wall has a safety factor of about 1.9, which is satisfactory for use as the winch's wall thickness. Furthermore, Figure 4.17 depicts a maximum stress of 467.5 MPa and a safety factor of 0.9, both of which are quite low. Finally, as illustrated in Figure 4.18, the maximum stress on a 10 mm thick wall is 821.1 MPa, with a safety factor of 0.5 for stress analysis. This demonstrates that a wall thickness of 10mm is unsuitable for use as the winch's wall thickness. The results of these stress analyses are summarized in Table 4.4.

Table 4.4 Stress Analysis Result for Case 5 with different Wall Thickness

Force (N)	Wall Thickness (mm)	Max Stress (MPa)	Remarks	Safety Factor
160000	30	228.3	Max stress at middle plate	1.9
160000	20	467.5	Max stress at middle plate	0.9
160000	10	821.1	Max stress at side plate	0.5

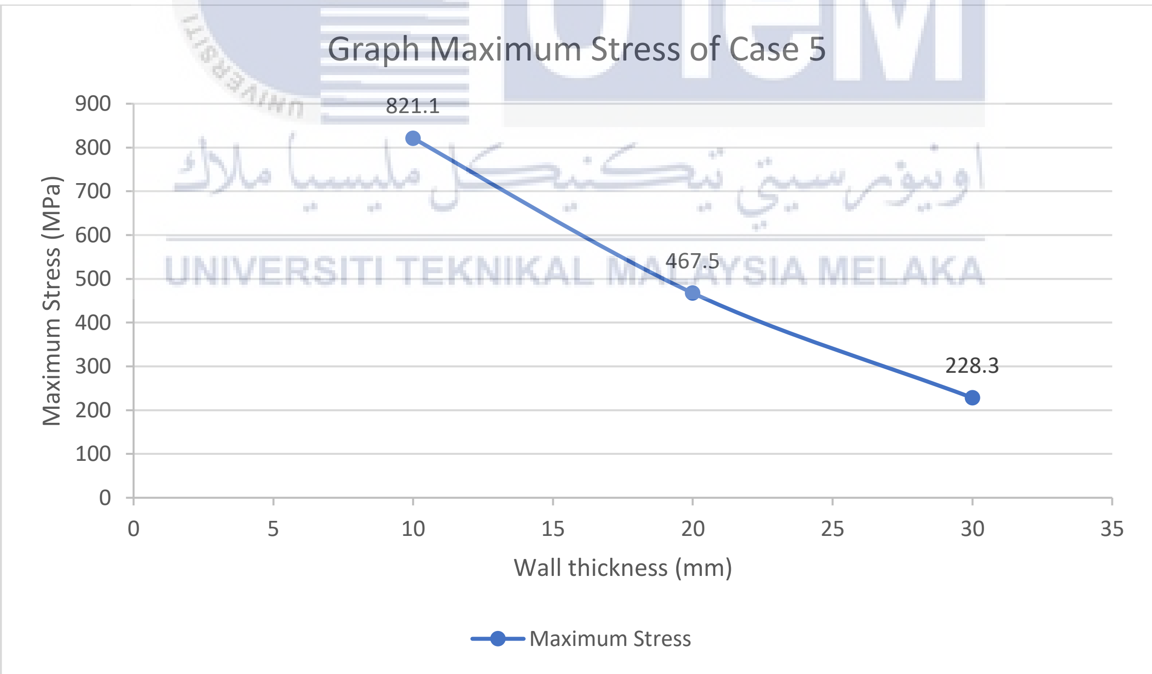

Figure 4.22 Graph Maximum Stress Analysis for Case 5

4.1.6 Result Stress Analysis Case 6

Following the stress analysis of the internal plate winch, a few of the analysis's research results will be provided on Figure 4.19 until Figure 4.21. The equivalent (von-Mises) stress on the model winch is shown in the result below. The analysis was repeated three times with wall thicknesses range of 30 mm to 10 mm

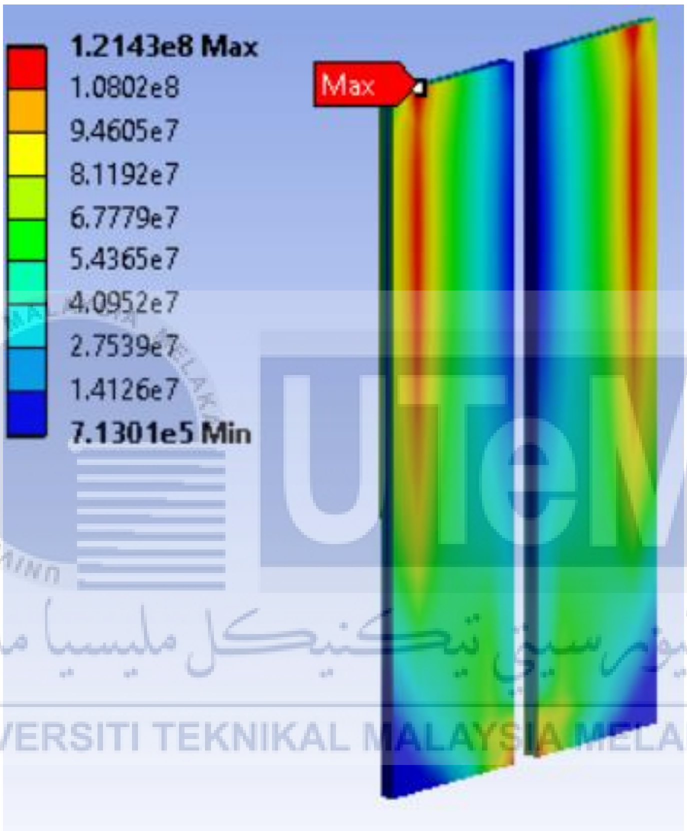

Figure 4.23 Maximum stress for wall thickness 30mm

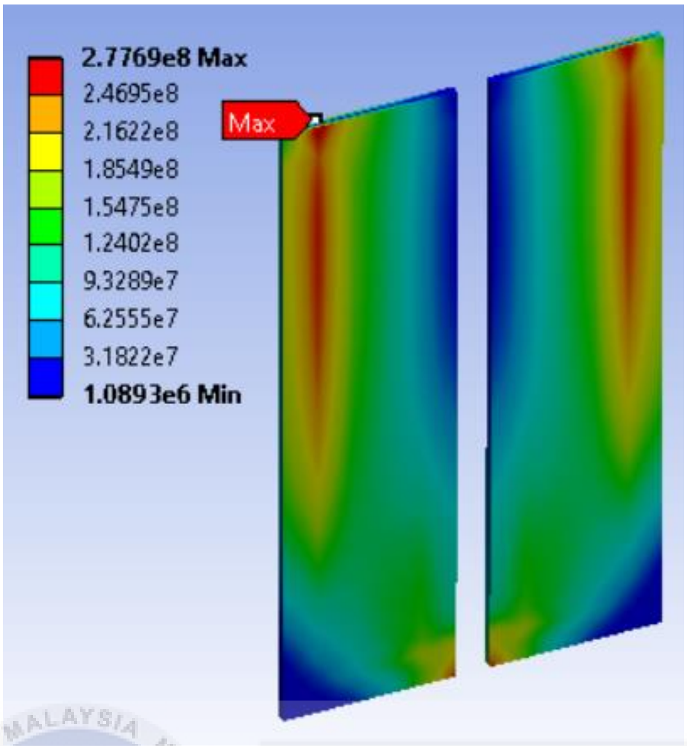

Figure 4.24 Maximum stress for wall thickness 20mm

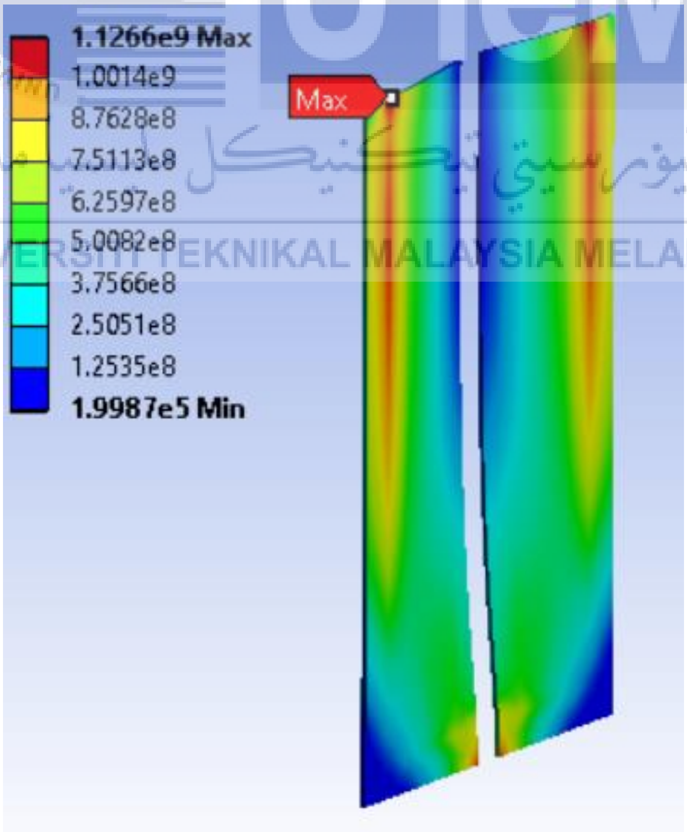

Figure 4.25 Maximum stress for wall thickness 10mm

The maximum stress at the winch's top plate, as shown in Figure 4.19, is 121.4 MPa. A 30mm thick wall has a safety factor of about 3.7, which is very high for use as the winch's wall thickness. Furthermore, Figure 4.20 depicts a maximum stress of 277.7 MPa and a safety factor of 1.6, which is good and acceptable. Finally, as illustrated in Figure 4.21, the maximum stress on a 10 mm thick wall is 1126.6 MPa, with a safety factor of 0.39 for stress analysis. This demonstrates that a wall thickness of 10mm is unsuitable for use as the winch's wall thickness. The results of these stress analyses are summarized in Table 4.5.

Table 4.5 Stress Analysis Result for Case 6 with different Wall Thickness

Force (N)	Wall Thickness (mm)	Max Stress (MPa)	Remarks	Safety Factor
160000	30	121.4	Max stress at top plate	3.7
160000	20	277.7	Max stress at top plate	1.6
160000	10	1126.6	Max stress at top plate	0.39

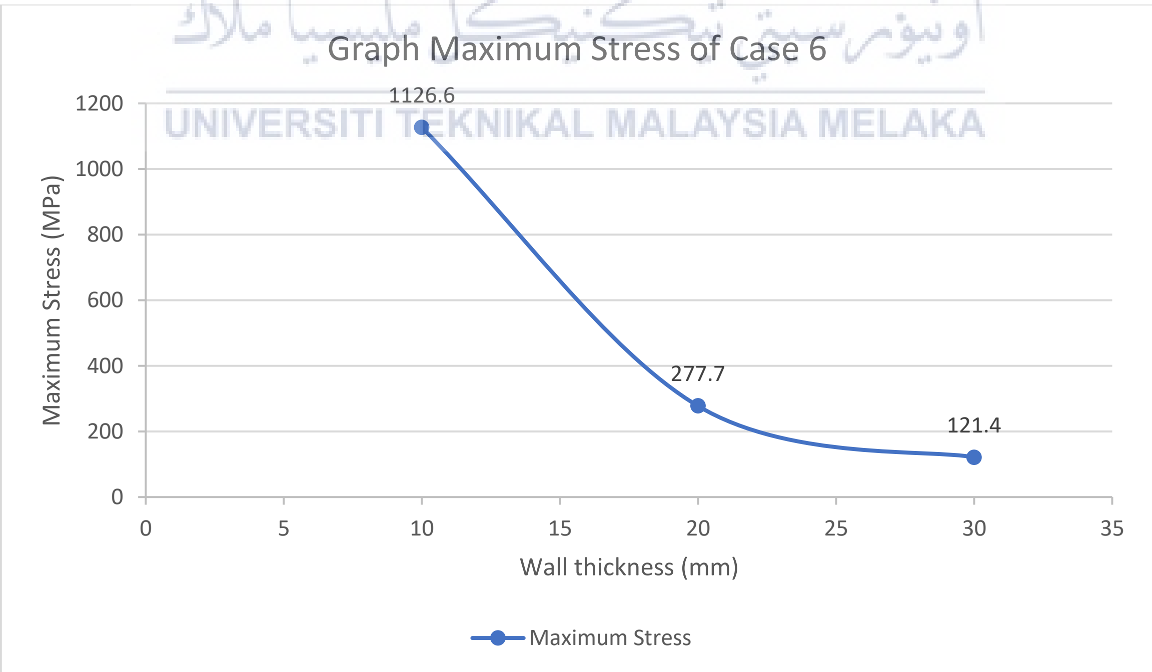

Figure 4.26 Graph Maximum Stress Analysis for Case 6

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The project to design winch of bundle puller that can pull until 80 tonnes bundle tube had been achieved. Based on the benchmarking winch and winch design specifications the design of 80 tons winch could be used for the extendable bundle puller mainframe and the balancing frame. Design of the 80 tons winch were successfully analysed by using the ANSYS Workbench software which is the frame and the tank. The analysis done was based on the expected real case scenario.

The strength of the winch was analysed to withstand the pulling force 80 Tons. As presented by the result shown in previous chapter, all the objective are successfully achieved. The highest maximum stress for the winch is on Case 2 which is 344 MPa and the safety factor is 1.3 which is acceptable enough to be use. As conclusion, the result of the analysis has proved that the final design of 80 tons winch can be use in real situation and good to be fabricate.

5.2 Recommendations

According to the research conducted, there are some recommendations that may be made to simplify the winch manufacturing process. At first, additional analysis of the design of the 80 tons winch is required. For instance, shaft and chain selection analysis. Finally, the material selection process should be investigated so that the winch's endurance can be increased even further.

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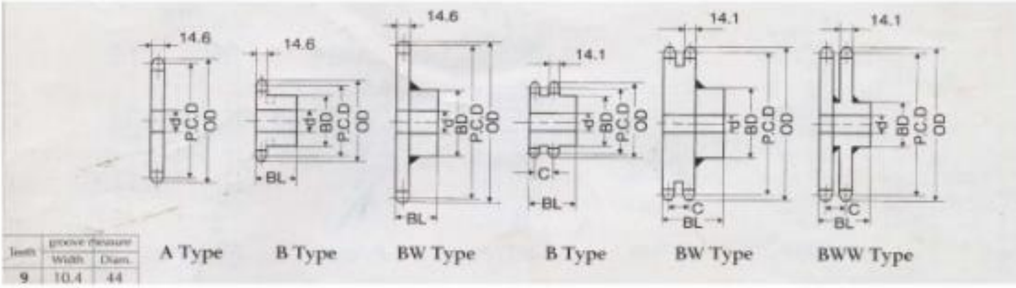
Appendix A

80 SPROCKETS

8

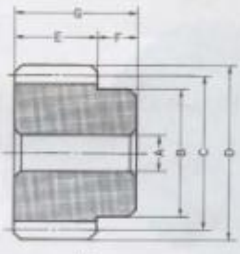


No. of Teeth	Outside Diam. OD	Pitch Diam. P.C.D	Bottom or Caliper Diam.	Stock Bore	TYPE "B" SINGLE STRAND HUB Diam. BD	TYPE "B" SINGLE STRAND HUB Length Thru Bore BL	TYPE "B" SINGLE STRAND BORE Min.	TYPE "B" SINGLE STRAND BORE Max.	TYPE "B" SINGLE STRAND Wt. kg	TYPE "B" SINGLE STRAND Material	TYPE "A" Stock d	TYPE "A" Wt. kg	TYPE "A" Material	TYPE "B" DOUBLE STRAND HUB Diam. BD	TYPE "B" DOUBLE STRAND HUB Length Thru Bore BL	TYPE "B" DOUBLE STRAND BORE Min.	TYPE "B" DOUBLE STRAND BORE Max.	TYPE "B" DOUBLE STRAND Wt. kg	TYPE "B" DOUBLE STRAND Material
9	85	74.27	57.27	16.5	*58	40	18.5	35	0.87										
10	93	82.19	66.31	16.5	52	40	18.5	32	1.02		18.5	0.60		58	63	23	35	2.00	
11	102	90.15	73.36	16.5	60	40	18.5	38	1.25		18.5	0.73		60	63	23	38	2.50	
12	110	98.14	82.26	16	67	40	18	45	1.60		18	0.85		69	63	25	46	2.70	
13	118	106.14	89.48	16	77	40	18	51	1.90		18	1.00		80	63	25	55	3.40	
14	127	114.15	98.27	16	77	40	18	51	2.15		18	1.16		88	63	25	60	3.90	
15	135	122.15	105.62	20	93	40	22	63	2.30		22	1.30		95	63	25	63	4.40	
16	143	130.20	114.32	20	93	40	22	63	2.50		22	1.50		100	71	25	66	5.40	
17	151	138.23	121.76	20	93	40	22	63	2.95		22	1.70		100	71	25	66	6.00	
18	159	146.27	130.39	20	93	40	22	63	3.15		22	1.90		120	71	25	80	7.50	
19	167	154.32	137.91	20	93	40	22	63	3.40		22	2.10		120	71	25	80	8.00	S45C
20	176	162.37	146.49	20	93	40	22	63	3.60		22	2.35		130	71	25	89	9.00	
21	184	170.42	154.06	20	93	40	22	63	3.85		22	2.57		130	71	25	89	9.50	
22	192	178.48	162.60	26	107	45	28	75	5.00		28	2.82		117	71	35	80	8.80	
23	200	186.54	170.22	26	107	45	28	75	5.23		28	3.10		117	71	35	80	9.30	
24	208	194.60	178.72	26	107	45	28	75	5.50	S45C	28	3.35		117	80	35	80	10.50	
25	216	202.66	186.38	26	107	45	28	75	5.80		28	3.65		117	80	35	80	11.10	
26	224	210.72	194.84	26	107	45	28	75	6.10		28	3.95		117	80	35	80	11.70	
27	233	218.79	202.54	26	107	45	28	75	6.40		28	4.25							
28	241	226.86	210.98	26	107	45	28	75	6.75		28	4.60		117	80	35	80	13.50	
29	249	234.93	218.70	26	107	45	28	75	7.10		28	4.93							
30	257	243.00	227.12	26	107	45	28	75	7.40		28	5.30		117	80	35	80	14.20	
31	265	251.07	234.86	26	107	45	28	75	7.80		28	5.63							
32	273	259.14	243.26	26	107	45	28	75	8.15		28	6.00		117	80	35	80	16.50	
33	281	267.21	251.03	26	107	45	28	75	8.50		28	6.40	SS41						
34	289	275.29	259.41	26	107	45	28	75	8.90		28	6.80							
35	297	283.36	267.19	26	107	45	28	75	9.30		28	7.20		117	80	35	80	17.90	
36	306	291.43	275.55	26	117	50	28	80	10.60		28	7.60		117	80	35	80	19.00	
37	314	299.51	283.36	26	117	50	28	80	11.00		28	8.00							S35C
38	322	307.58	291.70	26	117	50	28	80	11.40		28	8.50		127	80	40	89	21.00	
39	330	315.66	299.52	26	117	50	28	80	11.90		28	8.90							
40	338	323.74	307.86	26	117	50	28	80	12.40		28	9.40		127	90	40	89	23.70	
41	346	331.81	315.69	26	117	50	28	80	12.80		28	9.90							
42	354	339.89	324.01	26	117	50	28	80	13.30		28	10.30		127	90	40	89	26.00	
43	362	347.97	331.86	26	117	50	28	80	13.80		28	10.80							
44	370	356.04	340.16	26	117	50	28	80	14.30		28	11.40							
45	378	364.12	348.02	26	117	50	28	80	14.90		28	11.90		127	90	40	89	28.40	
48	403	388.36	372.48	26	117	50	28	80	15.80		28	13.50		127	90	40	89	32.00	
49	411	396.44	380.56	26							28	14.08							
54	451	436.84	420.96	26	117	50	28	80	20.00	SS41 BW type (Welding way)	28	17.10		127	90	40	89	38.50	SS41 (Welding way)
60	500	485.33	469.45	26	117	50	28	80	23.10		28	21.10		127	90	40	89	46.20	
64	532	517.65	501.77	26							28	24.05							
65	540	525.73	509.70	26	127	63	28	89	24.80		28	24.80		127	90	40	89	52.00	
66	548	533.82	517.94	26							28	25.58							
70	581	566.15	550.27	26	127	63	28	89	32.10		28	28.80		127	90	40	89	65.00	
75	621	606.56	590.54	26	127	63	28	89	36.20		28	33.10							
80	662	646.97	631.09	26	137	71	28	95	42.90		28	37.60							
84	694	679.31	663.43	26							28	41.50							
90	743	727.80	711.92	26							28	47.60							

https://gear.com.my/product/sprockets/

Appendix B

SPUR GEARS 35



B

Spur Gear *m6* Material : S45C (Steel) 20° Pressure Angle Face width: 60mm

Catalog No.	Z	AH7	B	C	D	E	F	G	(Type) Weight-kgf
SS6 - 12	12	25	55	72.0	84.0	60	28	88	(B) 2.0
SS6 - 13	13	25	58	78.0	90.0	60	28	88	(B) 2.5
SS6 - 14	14	25	60	84.0	96.0	60	28	88	(B) 2.8
SS6 - 15	15	25	70	90.0	102.0	60	28	88	(B) 3.4
SS6 - 16	16	25	75	96.0	108.0	60	28	88	(B) 3.9
SS6 - 17	17	25	78	102.0	114.0	60	28	88	(B) 4.4
SS6 - 18	18	25	80	108.0	120.0	60	28	88	(B) 5.0
SS6 - 19	19	25	90	114.0	126.0	60	28	88	(B) 5.8
SS6 - 20	20	25	100	120.0	132.0	60	28	88	(B) 6.5
SS6 - 21	21	28	105	126.0	138.0	60	28	88	(B) 7.5
SS6 - 22	22	28	110	132.0	144.0	60	28	88	(B) 8.1
SS6 - 23	23	28	115	138.0	150.0	60	28	88	(B) 8.9
SS6 - 24	24	28	120	144.0	156.0	60	28	88	(B) 9.8
SS6 - 25	25	28	125	150.0	162.0	60	28	88	(B) 10.5
SS6 - 26	26	28	130	156.0	168.0	60	28	88	(B) 11.4
SS6 - 27	27	28	135	162.0	174.0	60	28	88	(B) 12.1
SS6 - 28	28	28	140	168.0	180.0	60	28	88	(B) 12.7
SS6 - 30	30	30	150	180.0	192.0	60	28	88	(B) 15.1
SS6 - 32	32	30	150	192.0	204.0	60	23	83	(B) 18.0
SS6 - 34	34	30	150	204.0	216.0	60	23	83	(B) 19.0
SS6 - 35	35	30	150	210.0	222.0	60	23	83	(B) 19.0
SS6 - 36	36	30	150	216.0	228.0	60	23	83	(B) 22.0
SS6 - 38	38	30	150	228.0	240.0	60	23	83	(B) 23.0
SS6 - 40	40	30	150	240.0	252.0	60	23	83	(B) 24.0
SS6 - 42	42	40	150	252.0	264.0	60	23	83	(B) 27.0
SS6 - 44	44	40	150	264.0	276.0	60	23	83	(B) 30.0
SS6 - 45	45	40	180	270.0	282.0	60	23	83	(B) 31.0
SS6 - 46	46	40	180	276.0	288.0	60	23	83	(B) 34.0
SS6 - 48	48	40	180	288.0	300.0	60	23	83	(B) 35.0
SS6 - 50	50	40	180	300.0	312.0	60	23	83	(B) 37.0

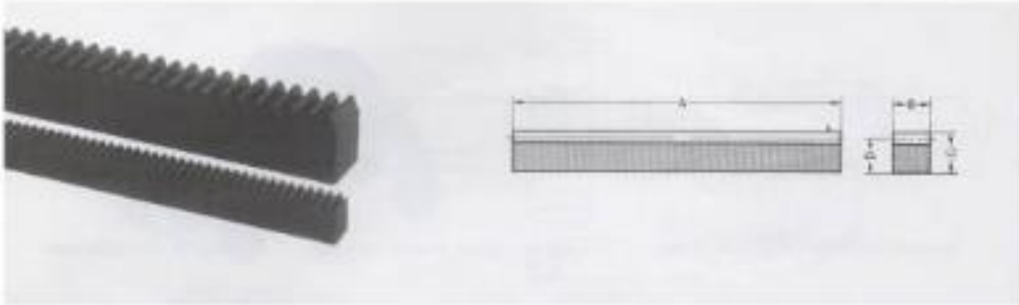
Spur Gear *m8* Material : S45C (Steel) 20° Pressure Angle Face width: 75mm

Catalog No.	Z	AH7	B	C	D	E	F	G	(Type) Weight-kgf
SS8 - 12	12	28	75	96.0	112.0	75	35	110	(B) 4.8
SS8 - 13	13	28	80	104.0	120.0	75	35	110	(B) 5.8
SS8 - 14	14	28	85	112.0	128.0	75	35	110	(B) 6.6
SS8 - 15	15	28	90	120.0	136.0	75	35	110	(B) 7.6
SS8 - 16	16	28	100	128.0	144.0	75	35	110	(B) 8.9
SS8 - 17	17	28	105	136.0	152.0	75	35	110	(B) 10.0
SS8 - 18	18	28	110	144.0	160.0	75	35	110	(B) 12.0
SS8 - 19	19	28	120	152.0	168.0	75	35	110	(B) 13.0
SS8 - 20	20	28	130	160.0	176.0	75	35	110	(B) 15.0
SS8 - 21	21	30	140	168.0	184.0	75	35	110	(B) 17.0
SS8 - 22	22	30	150	176.0	192.0	75	35	110	(B) 19.0
SS8 - 23	23	30	155	184.0	200.0	75	35	110	(B) 20.0
SS8 - 24	24	30	160	192.0	208.0	75	35	110	(B) 22.0
SS8 - 25	25	30	170	200.0	216.0	75	35	110	(B) 24.0
SS8 - 26	26	30	170	208.0	224.0	75	35	110	(B) 28.0
SS8 - 27	27	30	170	216.0	232.0	75	35	110	(B) 30.0
SS8 - 28	28	30	180	224.0	240.0	75	35	110	(B) 33.0
SS8 - 30	30	30	180	240.0	256.0	75	35	110	(B) 36.0

https://gear.com.my/product/spur-gear/

Appendix C

40 RACKS

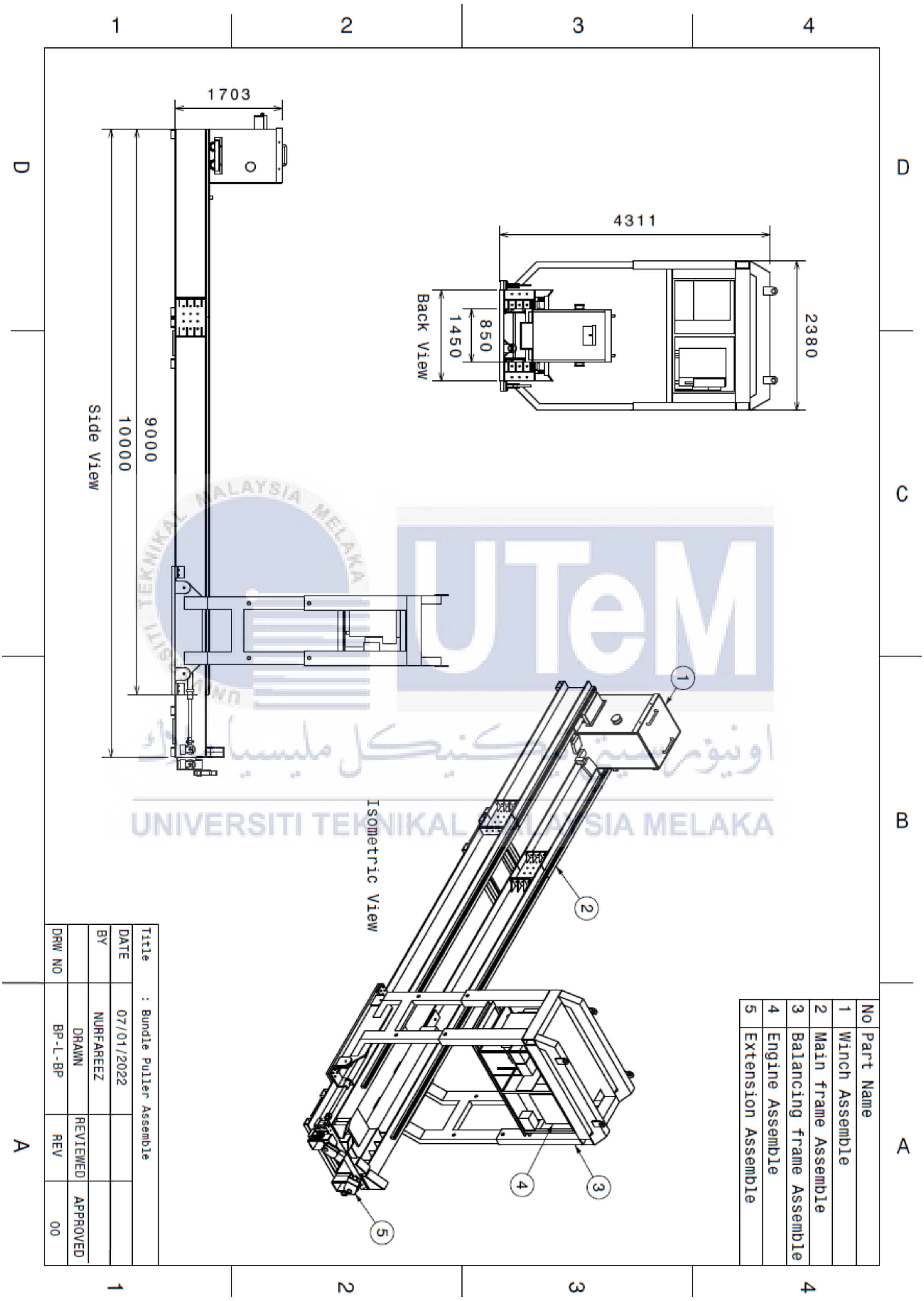


(All c/w blackening) Material : S45C-D (Steel) 20° Pressure Angle Racks (m1-m6)

Catalog No.	m	B	C	D	Over All Length (A)
SR 1 - 1000 - 1010	1.0	10	10	9.0	1000 mm
SR 1 - 1000 - 1012	1.0	10	12	11.0	
SR 1 - 1000 - 1015	1.0	10	15	14.0	
SR 1 - 1000 - 1515	1.0	15	15	14.0	
SR 1.5 - 1000 - 1515	1.5	15	15	13.5	1000 mm
SR 1.5 - 1000 - 1520	1.5	15	20	18.5	
SR 2 - 1000 - 2020	2.0	20	20	18.0	1000 mm
SR 2 - 1000 - 2025	2.0	20	25	23.0	
SR 2.5 - 1000 - 2525	2.5	25	25	22.5	1000 mm
SR 2.5 - 1000 - 2530	2.5	25	30	27.5	
SR 3 - 1000 - 3030	3.0	30	30	27.0	1000 mm
SR 3 - 1000 - 3035	3.0	30	35	32.0	
SR 4 - 1000 - 4040	4.0	40	40	36.0	1000 mm
SR 4 - 1000 - 4045	4.0	40	45	41.0	
SR 5 - 1000 - 5050	5.0	50	50	45.0	1000 mm
SR 6 - 1000 - 6060	6.0	60	60	54.0	1000 mm

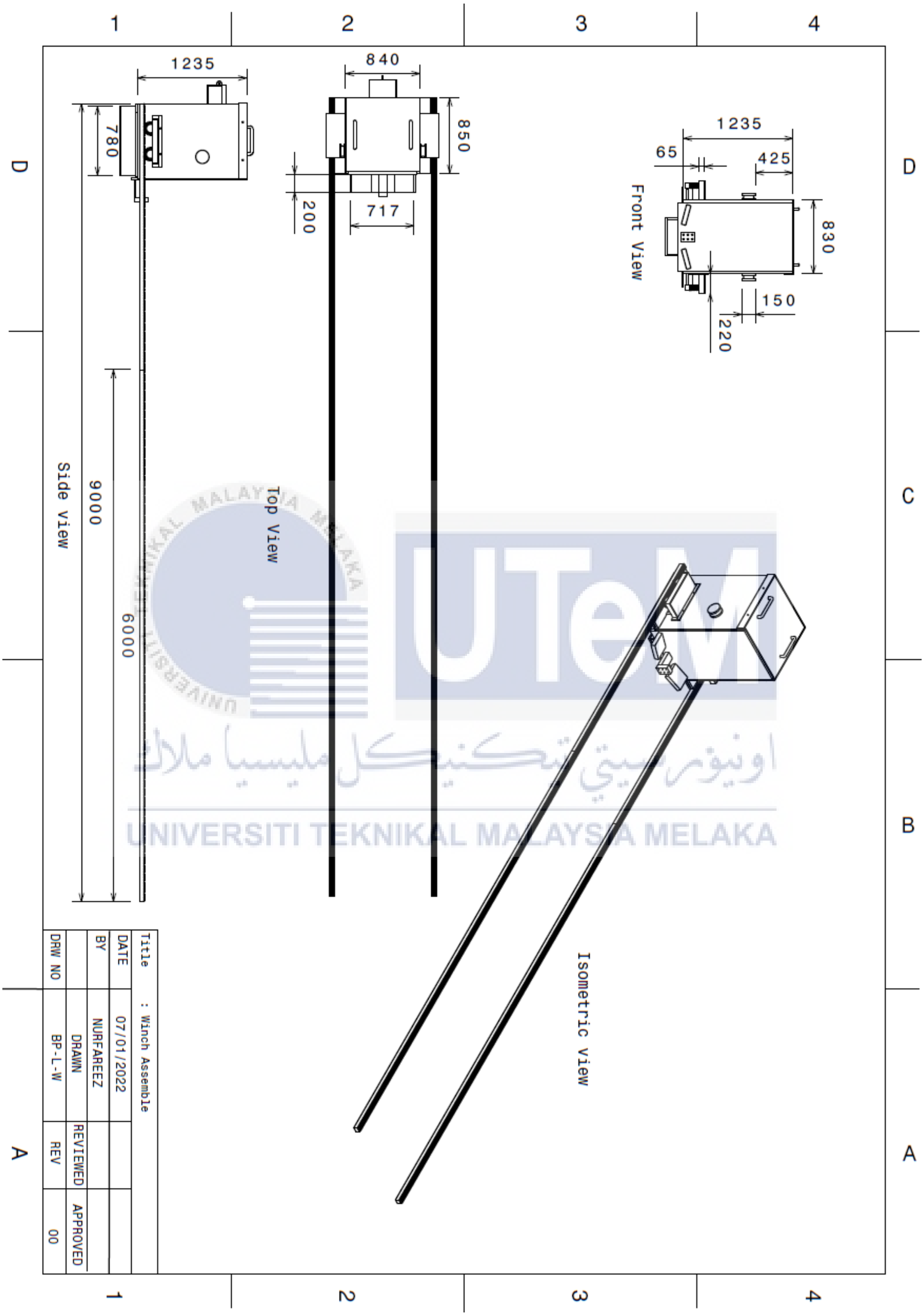
https://gear.com.my/product/rack-gear/

Appendix D



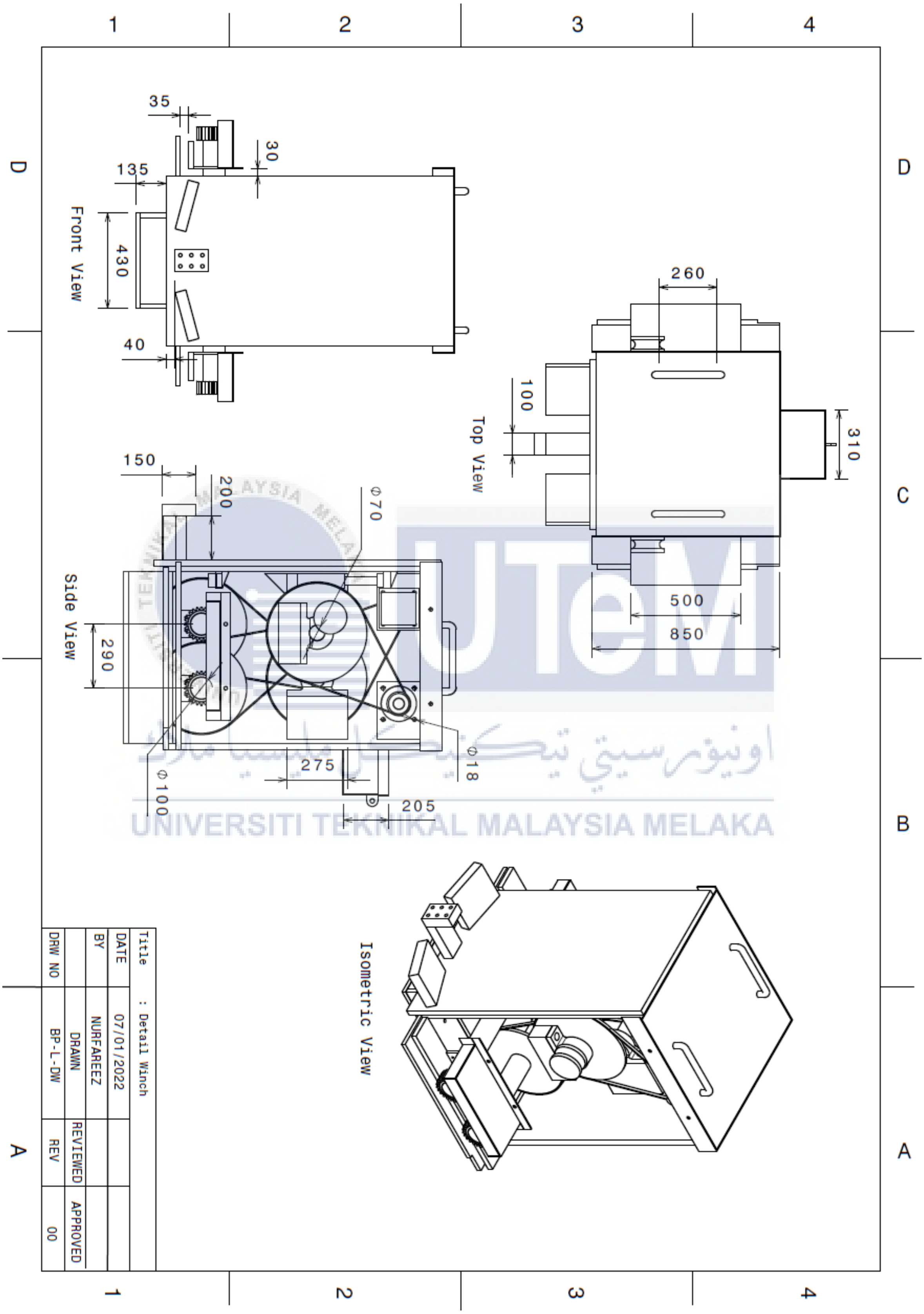
1703
9000
10000
Side View
4311
2380
850
1450
Back View
Isometric View
No Part Name
1 Winch Assemble
2 Main frame Assemble
3 Balancing frame Assemble
4 Engine Assemble
5 Extension Assemble
Title : Bundle Puller Assemble
DATE 07/01/2022
BY NURFAREEZ
DRAWN
REVIEWED
APPROVED
DRW NO BP-L-BP
REV 00

Appendix E



Side view
Top View
Front View
Isometric view
1235
840
850
780
200
717
9000
6000
65
425
830
150
220
Title : Winch Assemble
DATE 07/01/2022
BY NURFAREEZ
DRAWN
REVIEWED
APPROVED
DRW NO BP-L-W
REV 00

Appendix F


Front View
Top View
Side View
Isometric View
Title : Detail Winch
DATE 07/01/2022
BY NURFAREEZ
DRAWN
REVIEWED
APPROVED
DRW NO BP-L-DW
REV 00