DEVELOPMENT AND STRUCTURAL ANALYSIS OF DUAL MOTOR ACTIVE DYNAMIC HITCH LIFT SYSTEM ON TRACTOR-SEMITRAILER COMBINATION VEHICLES

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

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A thesis submitted
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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 (Automotive) with Honours.

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Supervisor Name : *TS. MUHAMMAD ZAIDAN BIN ABDUL MANAF*

Date : 12 January 2024

DEDICATION

I hereby dedicate this piece of work to my precious parents and my trusty supervisor, Sir TS. Muhammad Zaidan Bin Abdul Manaf . They have been my rock, offering me love and support through thick and thin. I couldn't have done it without them. Much obliged for giving me the grit to wrap up my Final Year Project. Thank you so much.

ABSTRACT

The focus of this research is the development and structural analysis of dual motor dynamic hitch lift system on tractor-semitrailer combination vehicles. In response to the increasing demand for efficiency and safety in the transportation industry, this project aims to design and implement an innovative dual motor dynamic hitch lift system for tractor-semitrailer combinations. The system's development involves intricate engineering considerations to enhance the dynamic interaction between the tractor and semitrailer during various operational scenarios. By integrating dual motors, the system is designed to provide superior control and adaptability, optimizing the hitch lift mechanism's performance. The structural analysis aspect of the project involves evaluating the system's resilience under different loads, forces, and environmental conditions, ensuring robustness and reliability. The outcome of this research is anticipated to contribute significantly to the advancement of tractor-semitrailer combination vehicles, offering a more dynamic and efficient solution that can positively impact both the transportation industry and road safety standards.

ABSTRAK

Tumpuan kajian ini adalah pembangunan dan analisis struktur sistem angkat halangan dinamik dwi motor pada kenderaan gabungan traktor dan separa treler. Sebagai tindak balas kepada peningkatan permintaan untuk kecekapan dan keselamatan dalam industri pengangkutan, projek ini bertujuan untuk mereka bentuk dan melaksanakan sistem angkat halangandinamikdwi motor yang inovatif untukkombinasi traktor dan separatreler. Pembangunan sistem melibatkan pertimbangan kejuruteraan yang rumit untuk meningkatkan interaksi dinamik antara traktor dan separa treler semasa pelbagai senario operasi. Dengan menyepadukan dwi motor, sistem ini direka untuk menyediakan kawalan dan kebolehsuaian yang unggul, mengoptimumkan prestasi mekanisme angkat halangan. Aspek analisis struktur projek melibatkan penilaian daya tahan sistem di bawah beban, daya, dan keadaan persekitaran yang berbeza, memastikan keteguhan dan kebolehpercayaan. Hasil penyelidikan ini dijangka menyumbang secara signifikan kepada kemajuan kenderaan gabungan traktor-separailer, menawarkan penyelesaian yang lebih dinamik dan cekap yang boleh memberi kesan positif kepada kedua-dua industri pengangkutan dan standard keselamatan jalan raya.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I went through a lot during this process, both academically and in terms of my personality. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My utmost appreciation goes to my main supervisor, Sir TS. Muhammad Zaidan Bin Abdul Manaf, from Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding and providing priceless insights will forever be remembered.

Finally, my deepest gratitude goes to all my family members. It would not be possible to write this thesis without their endless support, especially my beloved parents. Finally, I'd like to thank everyone who helped, supported, and inspired me to begin my studies.

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LIST OF SYMBOLS AND ABBREVIATIONS

DHIL	-	Dynamic Hitch Lift
FEA	-	Finite Element Analysis
VMS	-	Von Mises Stress
mm	-	Millimeter
m^2	-	Square meter
e+8	-	Mega
e-3	-	Mili
cm^3	-	Centimeter cubic

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CHAPTER 1

INTRODUCTION

1.1 Background

The redistribution of weight or forces between the wheels or axles while the vehicle performs various maneuvers such as accelerating, braking, or turning is referred to as load transfer in the context of automobiles. It happens because of the vehicle's inertia and dynamic forces. Load transfer mechanisms in vehicles refer to the ways in which forces or loads are redistributed among the wheels or axles during various driving conditions. These mechanisms are crucial for understanding and analyzing vehicle dynamics, as they directly impact traction, stability, and handling. The tractor-semitrailer type, in particular, plays a vital role in the national economy. It transports enormous goods for a variety of economic sectors, including domestic, petroleum, and construction. However, because to the cargo bulk, there is a significant weight differential between the tractor body and the semitrailer body. These features contribute to the tractor-semitrailer's excessive longitudinal load transfer (Güleryüz & Başer, 2021) The load is transported between the semitrailer body and the tractor body via the hitch connection in a tractor-semitrailer. The longitudinal load transfer happened disproportionately during abrupt braking compared to fast acceleration, resulting in an extra axle load in the front most axle. (Tseng & Hrovat, 2015). The extra axle weights reduce braking effectiveness, increasing braking distance. Furthermore, the cargo will absorb the loads, resulting in cargo body damage. In the worst-case situation, the cargo is more likely to be dislodged and crash into the driver's cabin. Passive and active approachesmight be used to address longitudinal load transfer concerns. The manual cargo arrangements on the semitrailer by repositioning the load around the center of gravity are the passive technique. This strategy, however, is inefficient due to the many types of cargo form, size, and weight. It will not respond well to abrupt acceleration and forceful braking. As a result, the idea is to use an active system that can lower longitudinal load transmission dynamically (Tseng & Hrovat, 2015).

A previously active hitch system was developed to counter the pitch moment produced by the load transfer. It produced counterforce to create a counter pitch moment resulting in reducing the pitch moment and load transfer. The actuator dynamically absorbs the load transfer energy by producing the counter vertical force. The response causes the active hitch system to adjust the hitch table heights dynamically. The active hitch lift device uses the jack-type lifting mechanism to produce the vertical force. The actuator comprises a power screw and lifting mechanism. The power screw will jack the lifting mechanism up to produce the counterforce. The counterforce will reject the incoming load transfer and prevent the trailer from diving during harsh braking. After testing the active hitch model via simulation software, the data gathered concluded some flaws on the structural design model as the structure that connected the motor and the top plate tended to bend and the motor also has not enough power to overcome the massive hitch force. (Abdul Manaf et al., n.d.).

1.2 Problem Statement

The active dynamic hitch lift device underwent significant improvement as identified by (Abdul Manaf, Hudha, Bakar, et al., n.d.-b) wherein a notable enhancement involved the strategic placement of a single motor beneath the top plate. However, this revised design exposed certain structural vulnerabilities, particularly evident in the middle arm support and the square screw of the power motor. These components demonstrated a susceptibility to bending under the substantial hitch force during braking. Notably, the central positioning of a lone motor proved insufficient in counteracting load transfer, prompting the need for a more effective solution. To address these issues, a novel fifth wheel hitch model has been proposed, integrating dual motors to enhance power distribution and balance. Furthermore, recognizing the structural weaknesses, an imperative aspect of this redesign involves augmenting the material strength to ensure the overall robustness of the model, thereby fortifying its capability to withstand the forces exerted during hitching and braking maneuvers.

1.3 Research Objective

The primary objective research of this project is as follows:

1. To investigate the forces acting on the hitch joint on tractor-semitrailer vehicle via simulation software (TruckSim)

2. Develop a new dynamic hitch lift system with a dual motor to counteract the load transfer via CAD software (Catia V5R21)

3. To determine the stress and displacement of the dual motor active DHIL system model by using finite element analysis via CAD software (SolidWorks)

1.4 Scope of Research

1. Conduct a braking test simulation to investigate the force distributions on the axles and hitch joint of the tractor-semitrailer.
2. To create a new fifth wheel hitch that is equipped with dual motor active dynamic underneath the top plate of the hitch.
3. To analyze the structural strength of the dual motor dynamic hitch lift design by investigating the stress and displacement on the parts especially the screw of power motor and middle arm support.

1.5 Research Methodology

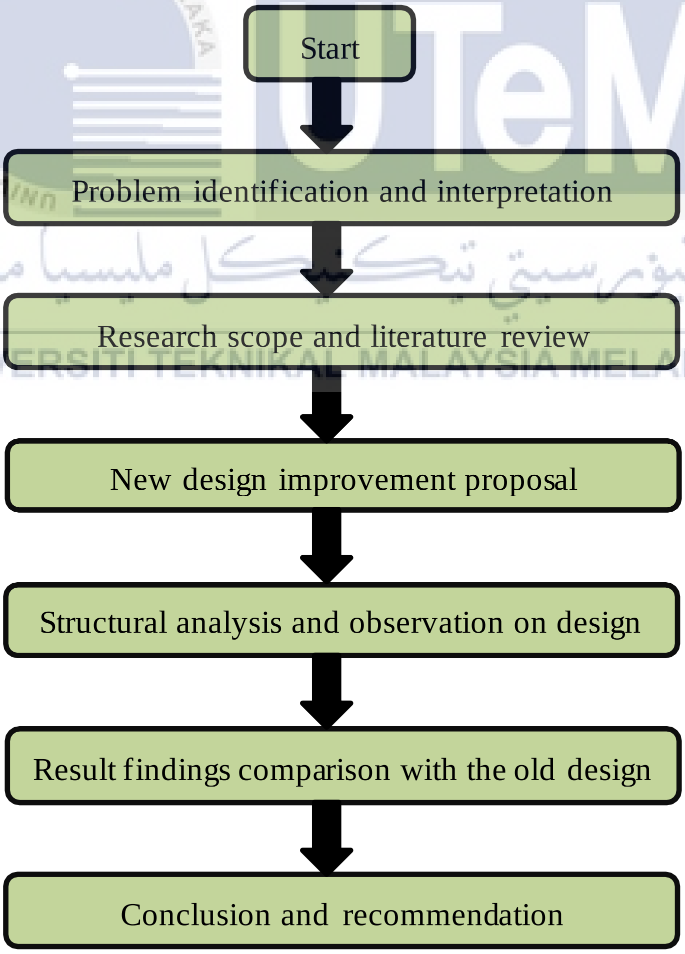


Figure 1.1 Flowchart of project plan

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter delves into a thorough investigation of the impact of load transfer on axle load, delving into insights gleaned from the research contributions of prior scholars as documented in various journals. The focal point is not only to elucidate the consequences of load transfer but also to propose and discuss viable solutions for its prevention or mitigation. Additionally, the chapter extends its scrutiny to encompass load transfer analysis specifically within the context of tractor-semitrailer configurations. Furthermore, it delves into a comprehensive stress analysis applied to a structural model, aiming to provide a holistic understanding of the intricate dynamics involved in load transfer phenomena, thereby contributing valuable insights to the broader field of transportation and structural engineering.

2.2 The Effect of Load Transfer on Axle Load

Load transfer has a substantial impact on axle loads, and knowing this effect is critical for analyzing vehicle dynamics and assuring optimal performance and safety. Based on (Doumiati et al., 2009) written journal, load transfer redistributes a vehicle's weight between its axles during various driving circumstances and maneuvers such as braking, accelerating, and turning. Weight moves from the rear axle to the front axle while braking. This increases the weight on the front axle while decreasing the load on the rear axle. The quantity of load transfer is determined by elements such as the weight distribution of the vehicle, braking force, center of gravity height, and suspension parameters. This weight transfer has an impact on the vehicle's braking capability and stability. If the front axle becomes overloaded while braking hard, it may limit rear wheel traction and cause the car to slide or lose control. Weight moves from the front axle to the rear axle during acceleration. The load on the rear axle rises, while the weight on the front axle falls. This load transfer has an impact on the vehicle's traction and stability during acceleration. When the rear axle gets overloaded during rapid acceleration, it can limit front wheel traction and impair the vehicle's ability to steer and retain control. Centrifugal force transfers load from the inside wheels to the outside wheels during cornering. As a result, the weight on the outside wheels increases while the load on the interior wheels and their corresponding axles decreases. Load transfer while cornering influences vehicle handling and stability. Uneven axle load distribution can provide uneven forces on the tires, decreasing traction and potentially producing understeer or oversteer situations.

Load transfer also has an impact on tire loads, and unequal load distribution can lead to uneven tire wear, lower traction, and poor handling. Excessive load transfer can overburden certain axles or tires, potentially resulting in early wear, longer stopp ing distances, and poor vehicle control. It is critical to consider vehicle design, suspension characteristics, weight distribution, and load-carrying capability when evaluating the influence of load transfer on axle loads. Computer models and vehicle testing assist optimize suspension systems and weight distribution to provide balanced axle loads and optimal vehicle performance. Load transfer must be managed properly to preserve stability, handling, and braking performance. It entails constructing weight-distribution suspension systems, optimizing weight distribution inside the vehicle, and conforming to axle load restrictions set by laws. Engineers may design cars with improved safety, stability, and overall performance on the road by studying and assessing load transfer impacts on axle loads.

2.3 Load Transfer Analysis for Tractor Semi-Trailer Longitudinal Model

According to the paper written by (Abdul Manaf, Hudha, Samin, et al., n.d.) the experiment or simulation is used to do a longitudinal load transfer study on the tractor-semitrailer. Because of its quick findings and low cost, many researchers used simulation to build and optimize vehicle models. The tractor-semitrailer is simulated utilizing a mathematical model technique in the simulation procedure. To model the vehicle as a rigid body subject to internal and external forces, a series of equations of motion are constructed. There are three types of simplified vehicle models that are typically employed in vehicle dynamic analysis: longitudinal models, lateral models, and vertical models. The longitudinal modelling approach was used because of its capacity to analyze vehicle reactions during longitudinal acceleration and braking. The simplified modelling technique has the advantage of allowing the model to be customized to meet specific design requirements. This allows for the development of a reduced model, which reduces calculation time. By verifying the model with an industrial standard vehicle dynamic software such as TruckSim or an actual vehicle, the produced vehicle model will be able to reflect the real vehicle system. The hitch joint model must be modular in order to effectively represent and examine the suggested strategy for reducing longitudinal load transmission. The size of the longitudinal load transfer between the tractor unit and the semitrailer unit may thus be simply calculated. The truck and semitrailer models are built using a 12 DOF longitudinal model that starts with the vertical force equation on the wheels. TruckSim software is used to validate the model by performing abrupt acceleration and hard braking tests. At the end of each test, a longitudinal load transfer analysis is given to investigate the impact of excessive load transfer on vehicle performance.

2.4 Bending Load Analysis

The bending load analysis on a structural model involves evaluating the response of the model when subjected to bending forces. This analysis is crucial for assessing the structural integrity, strength, and performance of various components, such as beams, columns, or other load-bearing elements (Naseem et al., 2020). By understanding the behavior of the structure under bending loads, engineers can make informed design decisions and ensure that the structure can safely withstand the applied loads. The model includes important geometric details, such as dimensions, cross-sectional properties, and boundary conditions. The analysis involves applying external loads, such as forces or moments, which induce bending within the structure. During the analysis, key parameters are evaluated, including bending stresses, deflections, and reactions at the supports. The bending stresses are calculated based on the applied loads, the structural properties, and the geometry of the cross-section. These stresses are critical in determining if the material can withstand the bending forces without exceeding its allowable stress limits. Deflections, or deformations, are also assessed during the bending load analysis. Excessive deflections can affect the structural performance, cause aesthetic concerns, or compromise functionality. Evaluating deflections helps ensure that the structure remains within acceptable limits and maintains its intended functionality. Furthermore, the reactions at the supports are determined to understand the load distribution within the structure. These reactions are essential for evaluating the stability of the structure and assessing the load-bearing capacity of the supports or connections. In summary, bending load analysis on a structural model is a vital step in the design and evaluation process. It provides crucial information about the bending stresses, deflections, and support reactions, enabling engineers to make informed decisions regarding the structural integrity and performance of the analyzed component or structure.

2.5 Research Gap

While the literature review has provided valuable insights into the effect of load transfer on axle load, load transfer analysis for tractor semi-trailer longitudinal models, and bending analysis, a noticeable research gap emerges concerning the dynamic aspects and real-world scenarios. The existing studies predominantly focus on static load conditions, potentially overlooking the dynamic forces encountered during actual operational scenarios such as acceleration, deceleration, and turning. Dynamic load transfer, influenced by factors like road irregularities and sudden maneuvers, remains a critical yet less explored aspect. Additionally, there might be a gap in the literature concerning the integration of advanced structural analysis methods, such as finite element analysis (FEA), to capture the intricate dynamics of tractor-semitrailer systems comprehensively.

2.6 Summary

The literature reviews drawn from various journals have provided valuable insights into the conceptual frameworks and methodologies employed by previous researchers, enhancing the understanding, and laying a foundation for the completion of this project proposal. These sources have not only contributed to a nuanced comprehension of the dynamics and structural considerations related to tractor-semitrailer combination vehicles but have also offered innovative concepts and effective methodologies. By referencing these scholarly works, the project proposal gains a solid theoretical foundation and practical knowledge that informs the improvement of the active dynamic DHIL system's design. The integration of concepts and methods from these reputable sources ensures that the proposed enhancements to the DHIL system align with industry best practices and advancements. The wealth of knowledge extracted from the literature reviews serves as a guiding framework, enabling the project to build upon the successes and insights of previous researchers while addressing the identified gaps and limitations in the existing design.

CHAPTER 3

LOAD TRANSFER ANALYSIS

3.1 Introduction

The purpose of this chapter is to establish a firm foundation to meet the study's objectives by offering a complete and extensive analysis of the technique employed in the experiment. The major focus of this discussion will be on evaluating load transfer dynamics on a tractor-semitrailer while conducting braking maneuvers. The chapter begins with a detailed discussion of the preliminary phases, followed by the modelling of braking testing using a range of semitrailer weights within the TruckSim software platform. This simulation represents the fundamental phase, and it reflects the delicate interplay between velocity, load conditions, and the load transfer dynamics that result from the interaction of these three variables. Following that, the chapter discusses the execution and analysis of the simulations, which demonstrate the complexities inherent in the tractor-semitrailer's dynamic behavior when subjected to braking conditions. The simulations are based on details processes as shown in the flowchart in Figure 3.1 below.

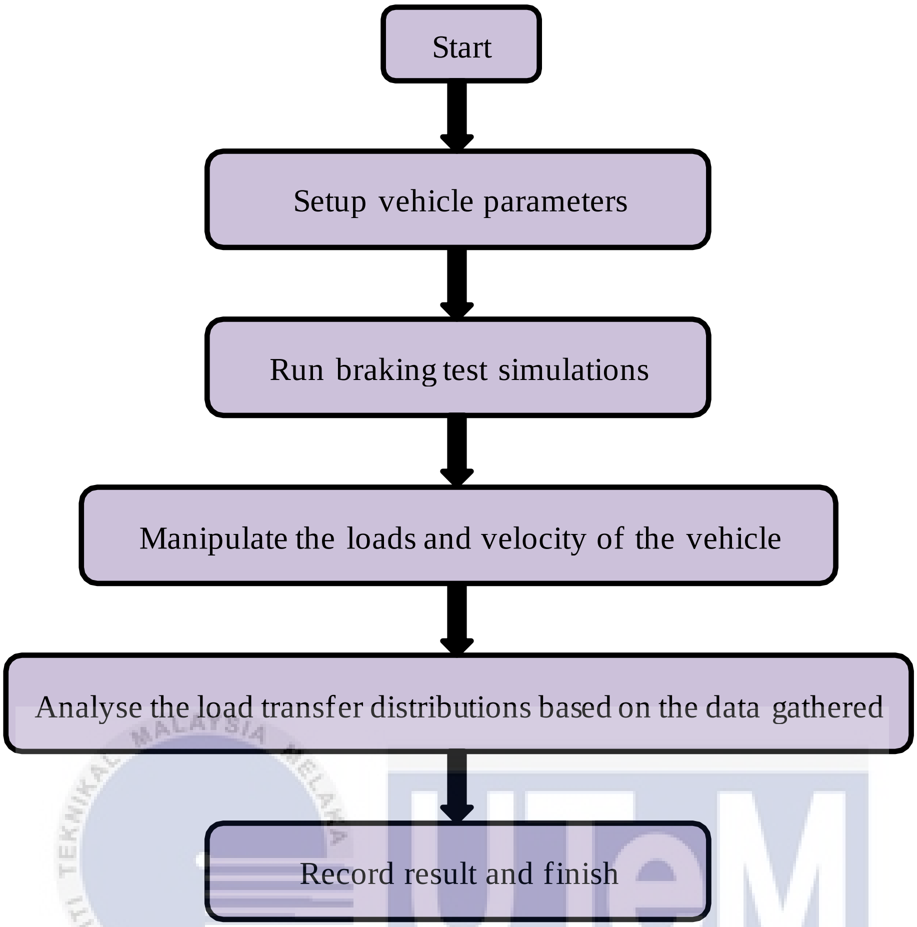


Figure 3.1 Flowchart for load transfer analysis (objective 1)

3.2 Vehicle Parameters

It is critical to understand the tractor semitrailer specifications before undertaking a braking test including longitudinal load transfer. These factors include several variables that have a substantial impact on braking performance and vehicle stability. Understanding key elements, such as tractor weight distribution, gear ratio, tire properties, and overall vehicle dynamics, allows one to precisely estimate brake behavior and plan for probable impediments. A thorough grasp of these characteristics ensures that the deceleration test is carried out in a controlled and exact way, allowing for accurate evaluations of longitudinal load transfer, and improving the vehicle's overall safety and performance

3.3 The Braking Test Simulation in Various Load and Velocity of Semitrailer via Trucksim Software

The brake test simulation on the tractor semitrailer was performed using TruckSim software under varied load and velocity situations. The purpose of this test is to assess a tractor semitrailer's braking performance under changing velocity and load situations. The first parameter is used to calculate weight transfer on the tractor semitrailer during braking. The simulation began by increasing the weight of the tractor semitrailer cargo from 10,000 kg to 30,000 kg, with a 10,000 kg increment between each increment. The speed varies from 60 km/h to 100 km/h, with a variation of 20 km/h between each speed. When a tractor and a semitrailer are hooked together, cargo is transferred between the tractor and the semitrailer, which is known as a hitch joint.

First and foremost, in the TruckSim programme, establish the tractor model, including load distribution and velocity. As indicated in Figure 3.2, the tractor model chosen is 3A Cab Over with 3A Euro Trailer and 6 axles. The desired velocity and load were then entered into the TruckSim programme before performing the braking test. Ensure that all relevant inputs and simulation settings are correctly set up.

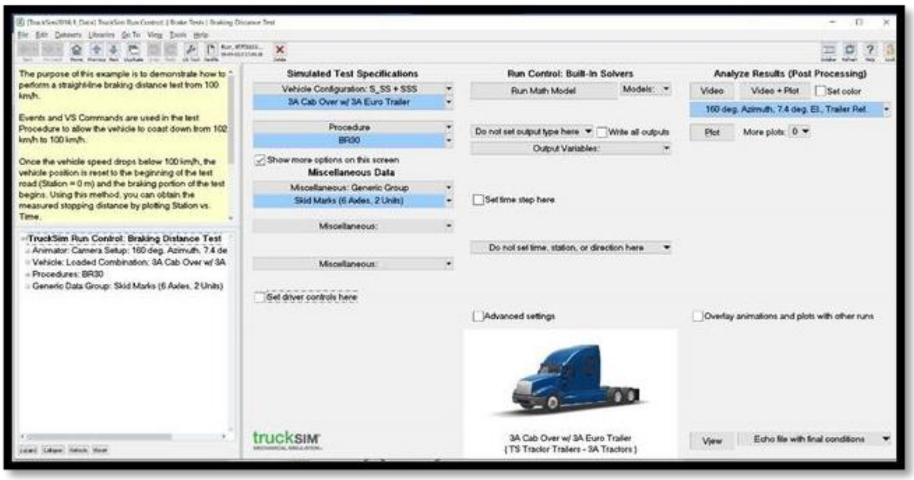


Figure 3.2 The tractor-semitrailer specifications

The semitrailer load is 10,000 kg in the first simulation. Load distribution between the truck and semitrailer is critical in load transfer. The initial speed was set at 60 km/h. The plot definitions for this simulation comprise three forces that are critical to analyze: hitch forces, longitudinal forces, and vertical force. The time taken for the braking test was set 12 seconds in the simulations.

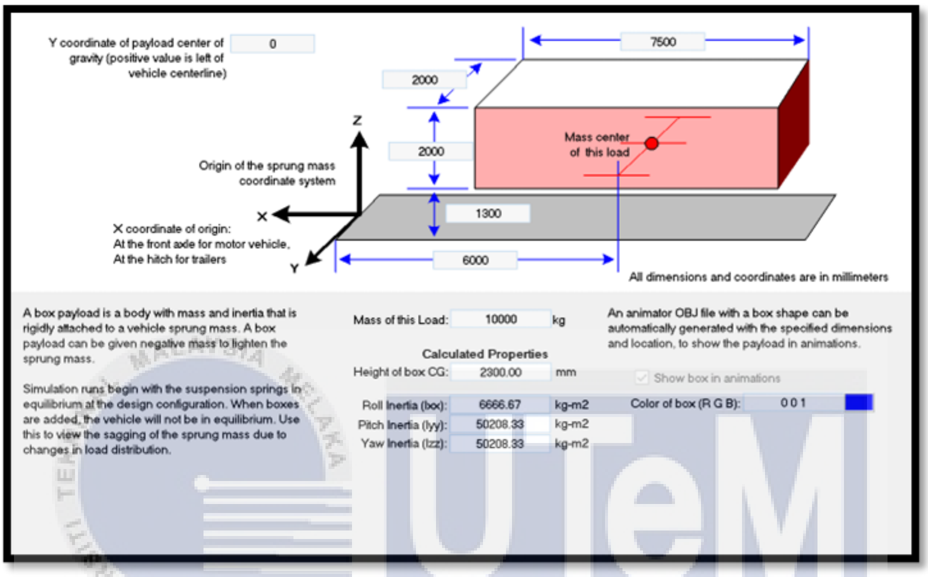


Figure 3.3 Load distribution of semitrailer on TruckSim

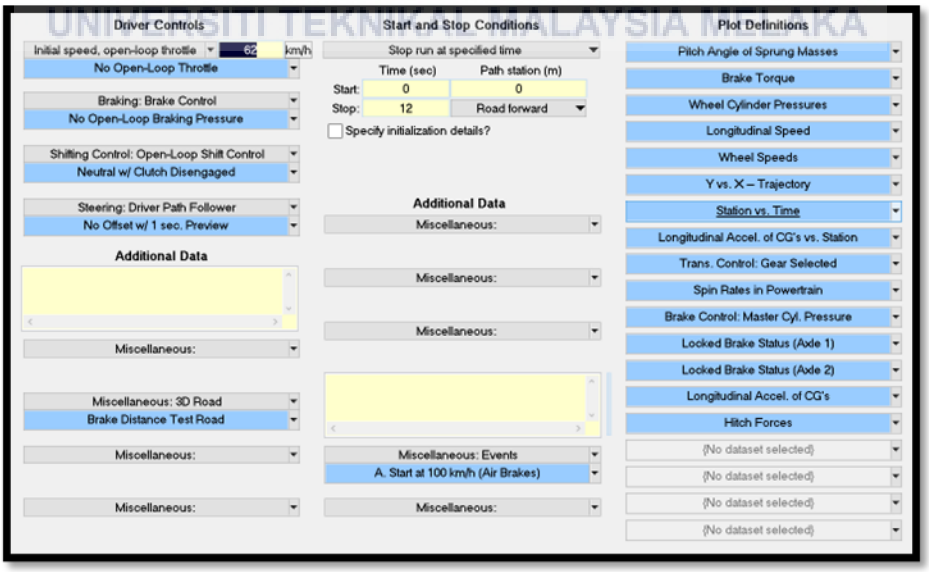


Figure 3.4 Velocity and plot definitons of tractor-semitrailer on TruckSim

3.4 Braking Test Setup

The braking test simulations in this study aim to comprehensively evaluate the performance of a combination vehicle, considering various configurations outlined in Table 5.4. The tests are conducted under the assumption of a constant brake pressure of 150 MPa applied to a combination vehicle starting at an initial speed of 60 km/h. It is crucial to note that the energy required for braking is consistent across all speed settings. The simulations are focused solely on the longitudinal deceleration of the vehicle, without any steering input, as it gradually comes to a stop. The study deliberately excludes considerations for lateral movement, ensuring a concentrated analysis of the braking dynamics in the longitudinal direction. The vehicle configurations are categorized based on the trailer size, specifically a 40-foot-long trailer with a 13.6 m wheelbase. Within this category, the trailer load conditions vary, encompassing half-laden (20,000 kg) and full-laden (30,000 kg), with an initial unladen load of 10,000 kg. Furthermore, the simulations are executed at three distinct initial braking speeds: 60 km/h, 80 km/h, and 100 km/h.

Table 3.1 List of data cases for different tractor-semitrailer configurations.

Configuration Name	Trailer Size	Trailer Load Condition	Braking Speed (km/h)	Averange Fxh (N)
BR10060	40-foot	Unladen	60 - 0	57429.5
BR10080	40-foot	Unladen	80 -0	57821.1
BR10100	40-foot	Unladen	100 - 0	61280.2
BR20060	40-foot	Half-laden	60 - 0	79721.3
BR20080	40-foot	Half-laden	80 – 0	81576.7
BR20100	40-foot	Half-laden	100 – 0	83153.1
BR30060	40-foot	Full-laden	60 – 0	101010.2
BR30080	40-foot	Ful-laden	80 – 0	104519.8
BR30100	40-foot	Full-laden	100 - 0	111001.1

3.5 The Load Transfer Analysis from The Braking Test Simulation of Tractor Semitrailer

An analysis of longitudinal load transfer in a tractor-trailer combination might give incredibly helpful information about the overall quantity of loads carried from the tractor to the semi-trailer units. The connection between hitch force and velocity may be investigated using simulation analysis to provide insight into the behavior of the towing system. Researchers can gather and examine data on attachment forces at various velocities by replicating real-world towing events. A variety of factors are considered during these simulations, including the weight and distribution of the load, the characteristics of the vehicle conducting the hauling, and the hitch system setup. To provide reliable results, the simulations will strive to reproduce the towing circumstances as closely as possible.

The analysis of hitch force and velocity in tractor semitrailer dynamics may show instances of direct proportionality, implying a linear relationship between increased velocity and hitch force. This suggests that when the vehicle speeds up, the hitch force increases proportionally and consistently. However, it is important to note that the relationship between hitch force and velocity is not always linear. Factors such as load distribution and road conditions might complicate hitch force calculations and deviate from a simple linear connection. Thus, a full study must account these extra variables, recognizing that the link between semitrailer loads and hitch force depends on various dynamic elements in real-world circumstances.

The investigation into the tractor-semitrailer's reaction to a deceleration test serves as a critical aspect of evaluating the dynamic performance and safety parameters of the vehicle under varying speeds and load conditions. The deceleration test will be conducted at three distinct speeds: 60 km/h, 80 km/h, and 100 km/h. To execute the test, the tractor-semitrailer combination will be maintained at each speed for a predefined duration, ensuring a consistent velocity before the initiation of the braking sequence. This systematic approach aims to replicate real-world scenarios encountered during road travel, where sudden deceleration is often required. The inclusion of three different speeds allows for a comprehensive analysis of the tractor-semitrailer's response across a spectrum of operationalconditions.

The influence of various loads on the semitrailer during the deceleration test introduces a crucial dimension to the research. Different loads, representing varying cargo weights, will be considered to simulate the diverse conditions that tractor-semitrailer combinations encounter in practical applications. The loads will range from partial to full capacity, providing insights into how the braking system and overall vehicle dynamics respond under different levels of payload. This aspect of the study is instrumental in understanding the system's stability, braking efficiency, and the impact of load distribution on the tractor-semitrailer's overall deceleration performance. Following the completion of each iteration of the test, a thorough longitudinal load transfer analysis is carried out to determine the effects that an excessive load transfer has on the overall performance of the vehicle. In order to contribute to a more comprehensive knowledge of the tractor-semitrailer's operating characteristics and possible areas for improvement, this detailed investigation seeks to give insights into the dynamic behavior and braking capabilities of the tractor-semitrailer over a range of speeds.

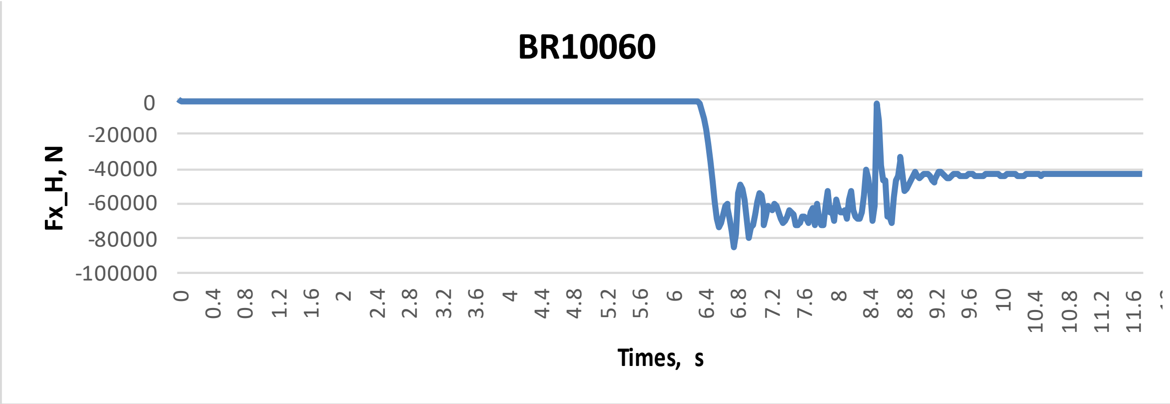


Figure 3.5 Load transfer for 10,000kg semitrailer load at vehicle's velocity of 60km/h

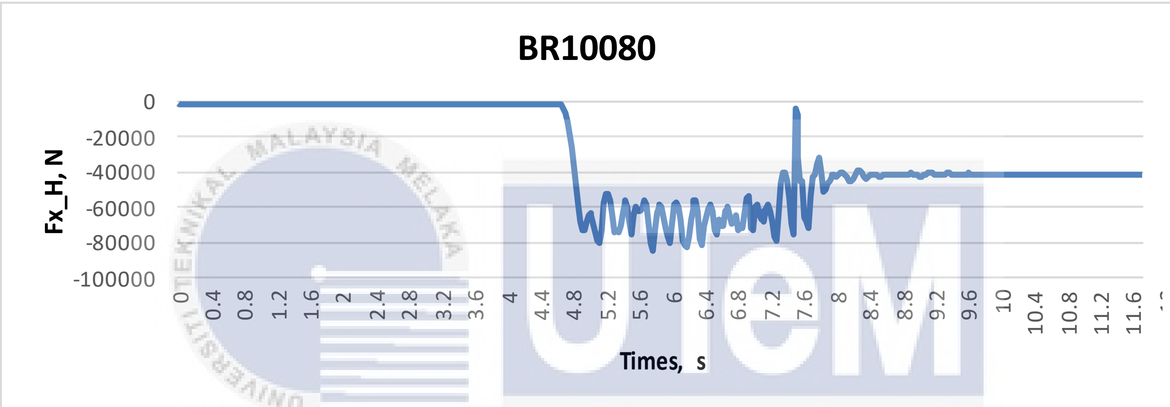


Figure 3.6 Load transfer for 10,000kg semitrailer load at vehicle's velocity of 80km/h

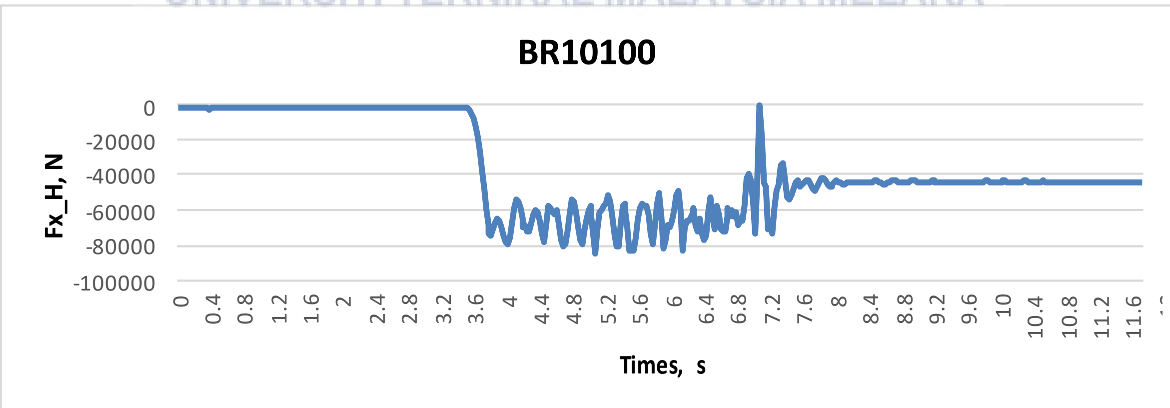


Figure 3.7 Load transfer for 10,000kg semitrailer load at vehicle's velocity of 100km/h

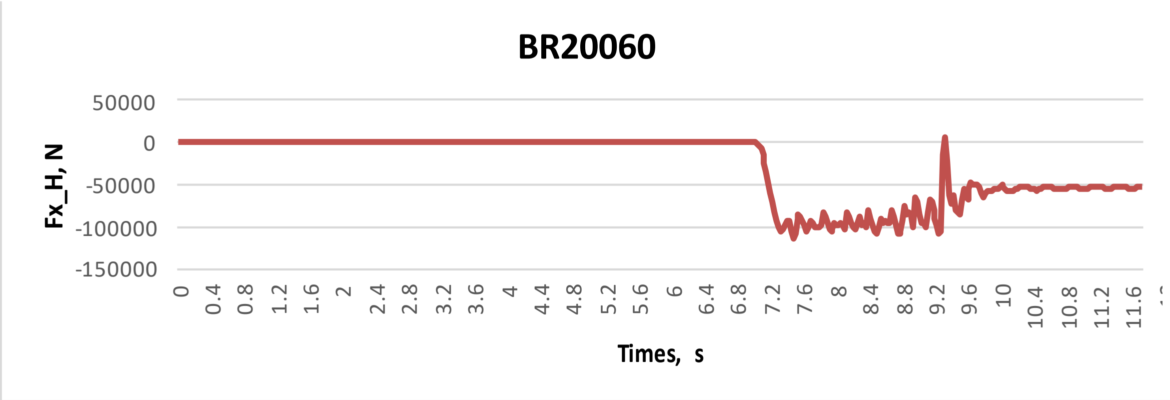


Figure 3.8 Load transfer for 20,000kg semitrailer load at vehicle's velocity of 60km/h

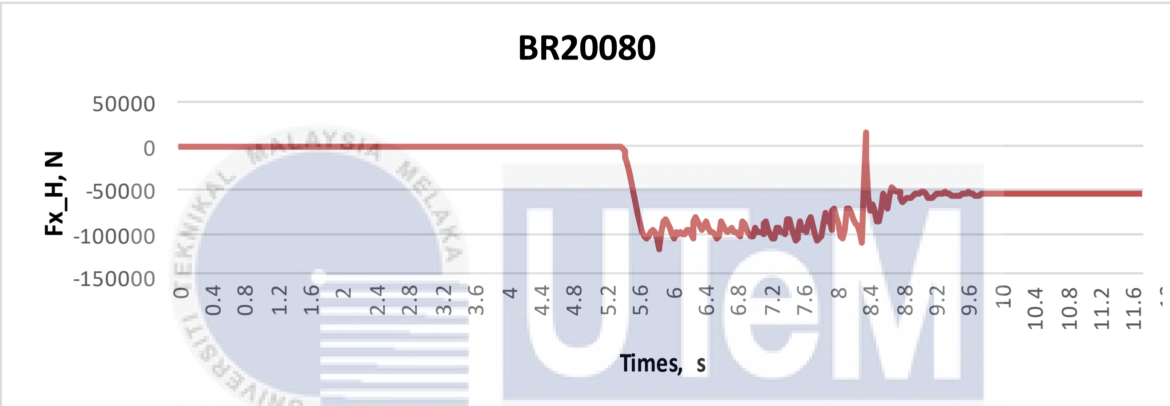


Figure 3.9 Load transfer for 20,000kg semitrailer load at vehicle's velocity of 80km/h

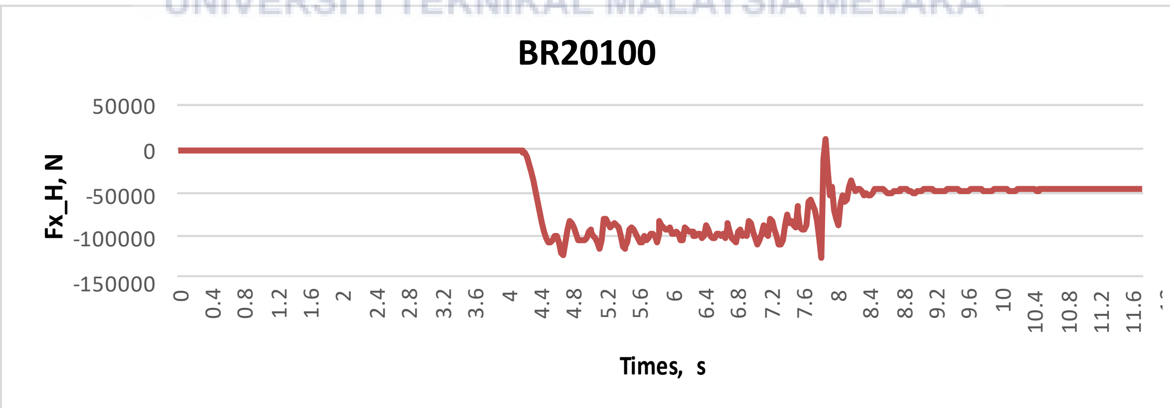


Figure 3.10 Load transfer for 10,000kg semitrailer load at vehicle's velocity of 100km/h

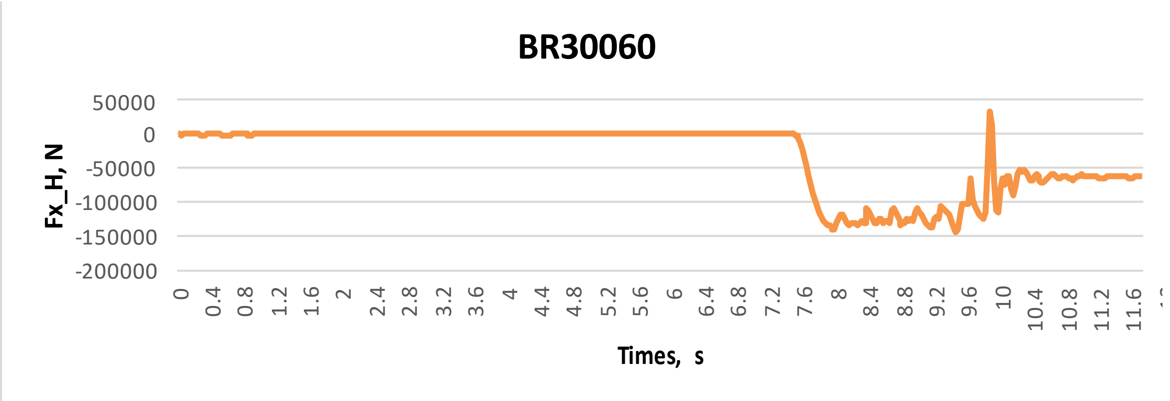


Figure 3.11 Load transfer for 30,000kg semitrailer load at vehicle's velocity of 60km/h

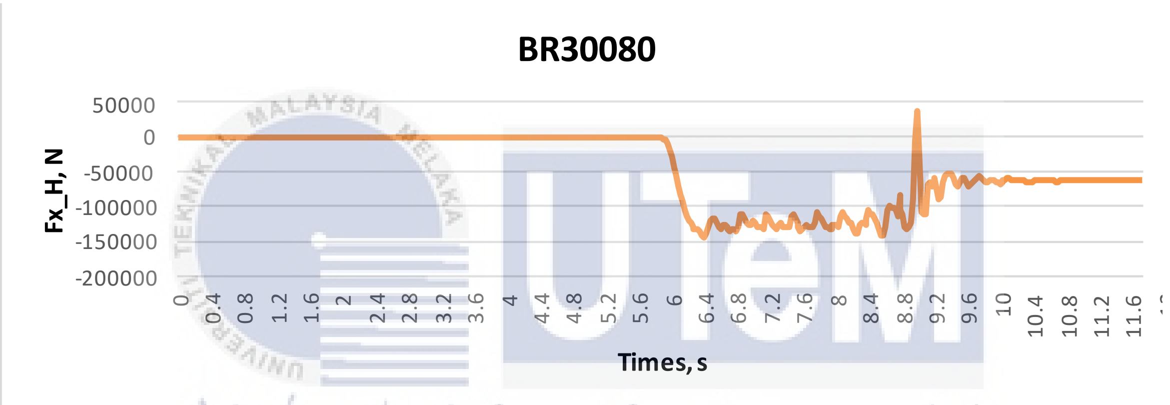


Figure 3.12 Load transfer for 30,000kg semitrailer load at vehicle's velocity of 80km/h

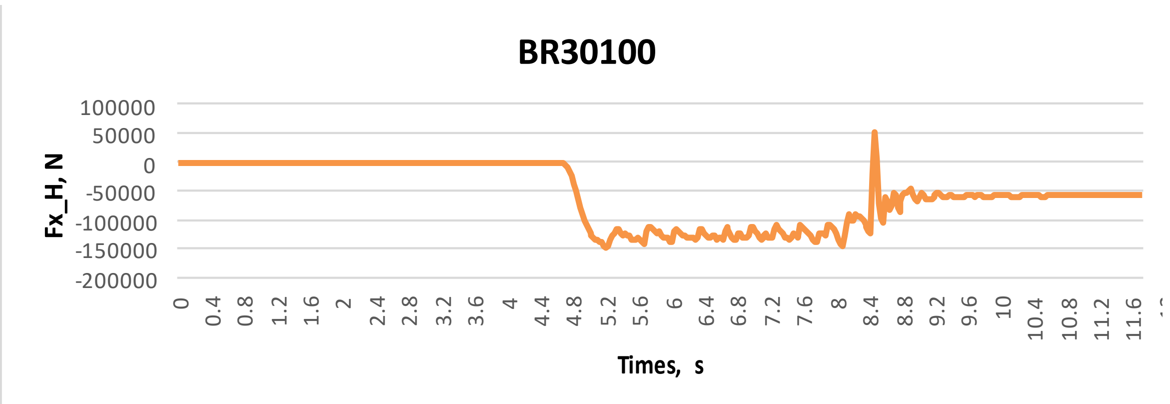


Figure 3.13 Load transfer for 10,000kg semitrailer load at vehicle's velocity of 100km/h

From the graphs in Figure 3.5 to Figure 3.13, the simulations are separated into three sets of data, with each data having three distinct velocity setups. The analysis highlights two crucial observations regarding the load transfer on the hitch of the tractor from the semitrailer and the braking performance of the tractor-semitrailer combination under varying speeds.

Firstly, the direct correlation between the weight of the semitrailer and the magnitude of load transfer on the hitch is a significant finding. As the weight of the semitrailer increases, there is a proportional rise in the load transferred to the tractor's hitch. This phenomenon is in line with fundamental principles of physics, particularly Newton's third law, which dictates that every action has an equal and opposite reaction. In the context of the tractor-semitrailer system, the increased weight of the semitrailer exerts a greater force on the hitch, influencing the load distribution between the tractor and semitrailer during dynamic maneuvers such as braking.

Secondly, the observation regarding the duration for the tractor-semitrailer combination to brake aligns with the anticipated behavior of vehicles at higher speeds. The longer braking duration at greater speeds is a common characteristic attributed to the increased momentum and kinetic energy that the system needs to dissipate. At higher speeds, the vehicle possesses greater inertia, necessitating a longer period for the braking system to effectively decelerate and bring the combination to a complete stop. This observation underscores the importance of considering speed as a critical parameter in evaluating brakingperformance, emphasizing the need for efficient braking systems to handle the increased energy and forces associated with higher velocities.

3.6 Summary

The load transfer analysis conducted through the utilization of TruckSim software presents a comprehensive and dynamic examination of tractor-semitrailer behavior during braking tests under various loads and velocities. The simulation scenarios encompass d diverse combinations of load weights and speeds, allowing for a thorough exploration of the system's response to braking forces. Through these simulations, load transfer analysis becomes a focal point, offering insights into the redistribution of forces between the tractor and semitrailer components. The braking test simulations enable the identification of force distributions across the entire system, shedding light on how different factors, such as load magnitude and velocity, influence the dynamic interactions between the tractor and semitrailer during braking maneuvers. This detailed analysis, facilitated by the capabilities of TruckSim software, contributes to a deeper understanding of the load transfer dynamics in tractor- semitrailer combinations, providing essential information for optimizing braking performance and ensuring the safety and stability of these vehicles under varying operational conditions.

CHAPTER 4

DEVELOPMENT OF ACTIVE DHIL SYSTEM'S DESIGN THROUGH SIMULATION DRIVEN DESIGN

4.1 Design Improvement Proposal

The single-motor active DHIL system was originally designed (Abdul Manaf, Hudha, Bakar, et al., n.d.-b) to counteract the pitch moment caused by the load transfer. The proposed system will generate the counterforce required to achieve the counter pitch moment. As a result, the pitch moment decreases, hence lowering load transmission. The suggested actuator dynamically absorbs load transfer energy by generating a counter-vertical force. The reaction triggers the DHIL system to dynamically modify the hitch table heights. DHIL will replace a standard fifth-wheel system on the tractor chassis, as indicated in Figure 4.1.

Figure 4.1 An active DHIL actuator system installation on tractor chassis (Abdul Manaf, Hudha, Bakar, et al., n.d.-b)

Figure 4.2 shows the active DHIL actuator, which consists of a power screw and a lifting mechanism. The power screw will raise the lifting mechanism to provide counterforce. The counterforce will reject the incoming load transfer and keep the caravan from plunging during heavy braking.

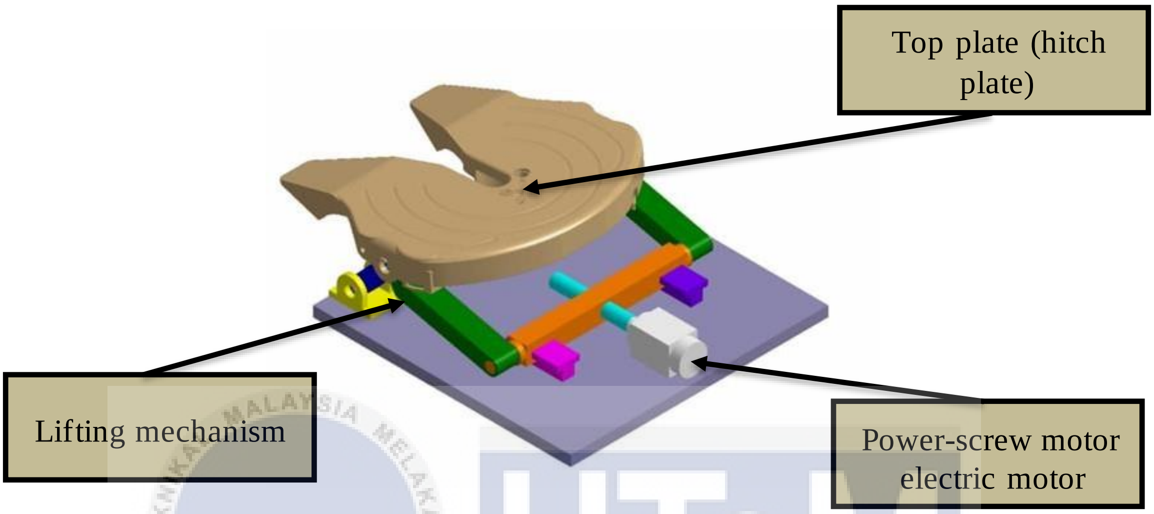


Figure 4.2 Single motor active DHIL model in isometric view (Abdul Manaf, Hudha, Bakar, et al., n.d.-b)

a) DHIL not activated b) DHIL activated

Figure 4.3The mechanism of DHIL system

Figure 4.3, a) illustrates the DHIL actuator when it is not triggered while the tractor-semitrailer travels, whereas b) illustrates the DHIL actuator in active mode when the tractor-semitrailer brakes.

The previously designed model structure was not robust enough since the middle support arm tended to slightly bend, and the screw thread and its structure of the power-crew motor has a high stress because it acts only on the center to pull the middle arm support forward while braking. Figure 4.4 shows the components that were needed to improve for a newly designed DHIL actuator.

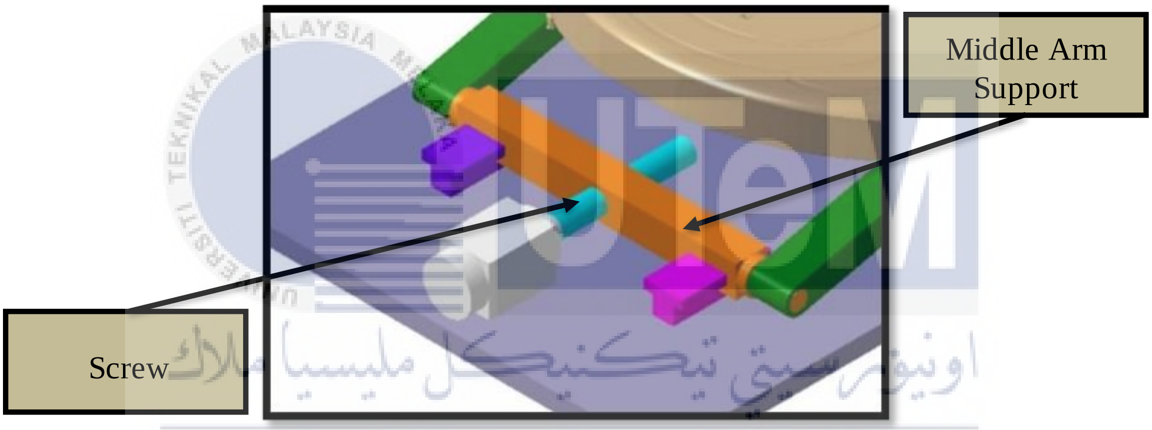


Figure 4.4 The interested parts for design improvement

4.2 New Design of Dual Motor Active DHIL System

The shortcomings identified in the previous design of the single motor active DHIL system, particularly concerning structural integrity and the power screw motor's inability to effectively counteract load transfer from the semitrailer, have prompted the proposal of a redesigned system. The novel concept revolves around the integration of a dual-motor configuration, strategically positioned on both sides of the middle arm support. This innovative approach seeks to address the limitations of the single-motor system by enhancing the power and control capabilities of the DHIL mechanism. Placing a motor on each side of the middle arm support aims to optimize load distribution, ensuring a balanced and efficient response to the dynamic forces exerted during various operational scenarios, especially when braking.

The proposed concept involves employing two motors rather than one. The first structural research revealed that the twin motor system can reduce stress and displacement on the slider. This can avoid structural failure, particularly during emergency braking. The DHIL system operates at critical emergency braking, therefore structural reliability is vital. The initial analysis discovered that the dual motor may lower stress by 81.56%, displacement by 86.04%, and strain by 47.46%, as seen in Table 4.1. Figure 4.5 further demonstrates that a dual motor design can alleviate stress at the single motor point in the center. This prevents the slider from splitting in two in the event of structural failure.

Table 4.1 Comparison of initial analysis between single motor and dual motor

Parameter	Single motor	Dual motor	% reduction
VMS (N/m^2)	8.548e5	4.708e5	81.56%
Displacement (mm)	5.396e-4	7.535e-5	86.04%
Strain	3.329e-6	1.749e-6	47.46%

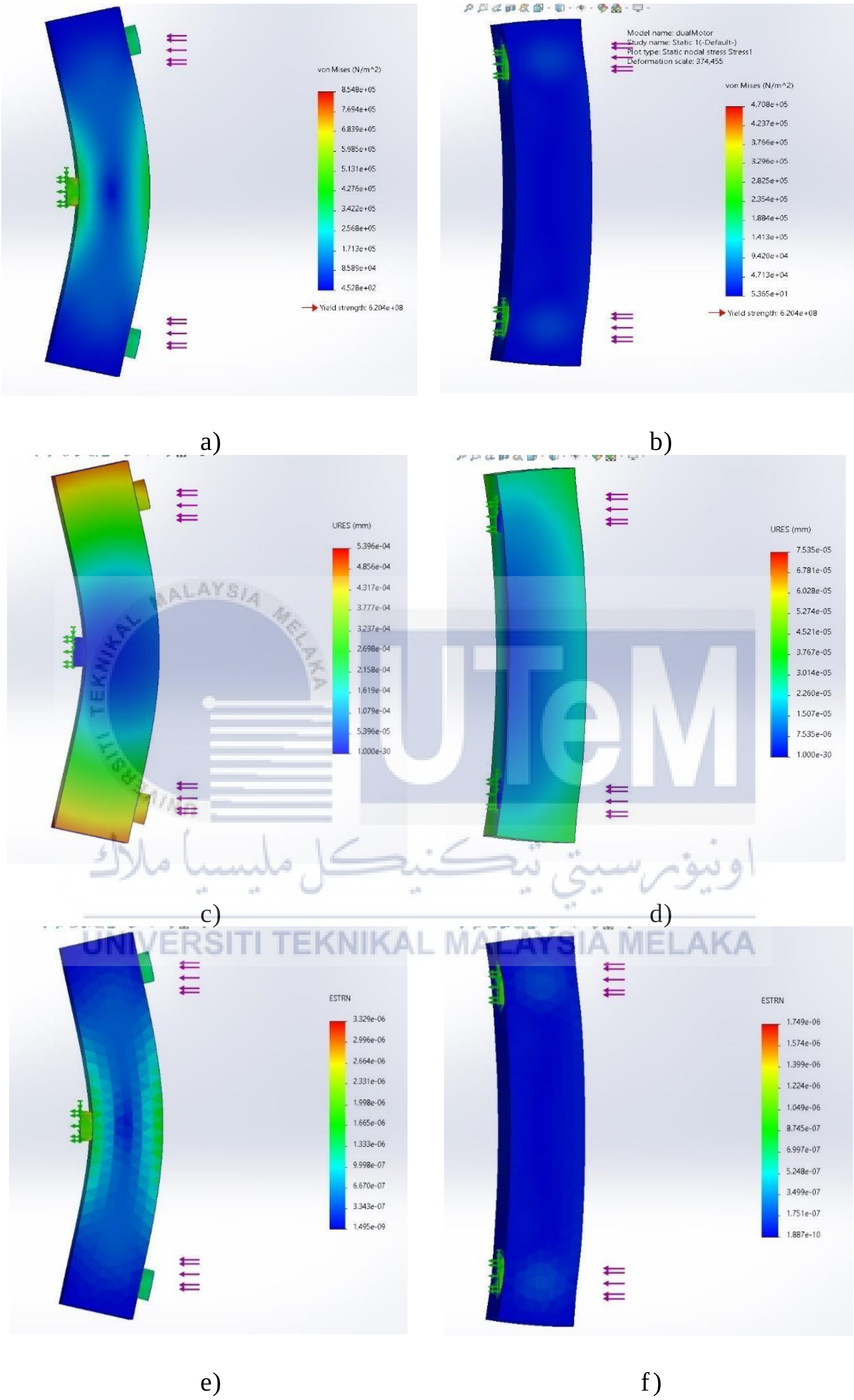


Figure 4.5 Initial analysis of single motor and dual motor (a) VMS for single motor (b) VMS for dual motor (c) Displacement for single motor (d) Displacement for dual motor (e) Strain for single motor (f) Strain for dual motor

Based on the analysis dual motor setup is proposed for DHIL system. Further analysis based various vehicle configuration presented in next chapter. This redesigned active DHIL system not only aims to rectify the structural flaws of its predecessor but also strives to significantly improve the system's overall performance, responsiveness, and adaptability in the context of tractor-semitrailer combination vehicles. Through this dual-motor approach, the proposed design seeks to achieve a harmonized and robust solution to effectively manage load transfer, enhancing the safety and operational efficiency of the tractor-semitrailer combination.

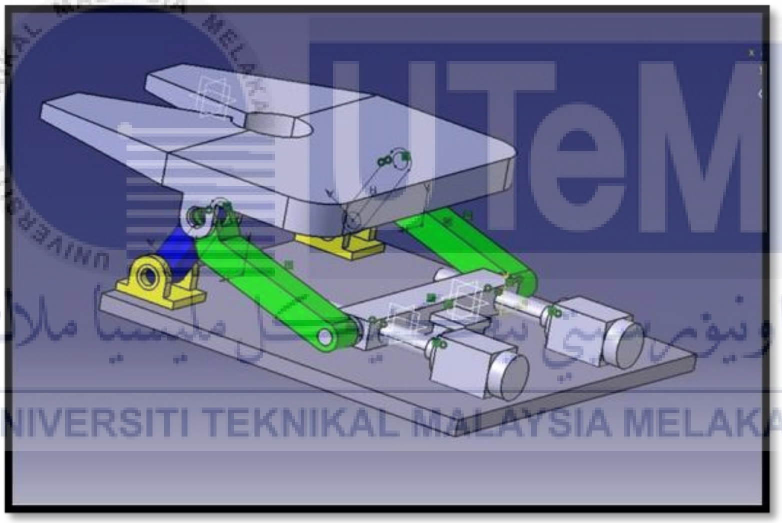


Figure 4.6 Design model of dual motor active DHIL system via Catia V5R21

Designing a new dual motor dynamic hitch lift for a tractor-semitrailer as shown in Figure 4.5 and improving its structural integrity is a promising approach to address the power and structural issues encountered with the previous design. The dual motor sy stem will provide increased power and torque compared to the previous single motor design. By having two motors working in tandem, the combined output can generate sufficient force to counter the loads transferred during various maneuvers, including braking, acceleration, and cornering. This ensures better stability and control of the tractor-semitrailer system. The power distribution between the two motors can be optimized to provide balanced and controlled lifting action.

4.3 Summary

The initial design of the single-motor active DHIL system aimed to counteract pitch moments induced by load transfers during braking, generating a counterforce to decrease pitch and lower load transmission. However, structural weaknesses were identified, with the middle support arm bending and the power screw motor experiencing high stress. In response, a redesigned DHIL system is proposed, featuring a dual-motor configuration strategically positioned on both sides of the middle arm support. This innovative approach addresses the limitations of the single-motor system by enhancing power and control capabilities, aiming for optimized load distribution and a balanced response to dynamic forces during operational scenarios, particularly braking. The dual-motor system promises increased power and torque, rectifying the shortcomings of the previous design and ensuring improved stability and control in various maneuvers. Through Catia V5R21, the design model showcases a promising solution to enhance the structural integrity and overall performance of the DHIL system, marking a significant advancement in ensuring the safety and operational efficiency of tractor-semitrailer combinations.

CHAPTER 5

STRUCTURAL ANALYSIS RESULT

5.1 Introduction

On this chapter, the design model structure will undergo Finite Element Analysis (FEA). It is a powerful engineering tool employed for structural analysis, aiming to simulate and evaluate the behavior of complex systems under various loading conditions. In the context of the proposed active DHIL system with dual motors, FEA serves as a critical methodology for assessing structural integrity and performance. Through this numerical technique, the intricate components of the DHIL system, including the frame, middle arm support, and power screw motor, are discretized into finite elements. These elements are then subjected to simulated loads and environmental conditions to predict their response, revealing stress distributions, deformations, and potential failure points. FEA enables engineers to identify structural weaknesses, optimize designs, and ensure that the dual-motor DHIL system can withstand the dynamic forces associated with load transfer during operational scenarios, such as braking events in tractor-semitrailer combinations. The results obtained from FEA contribute invaluable insights into the system's structural robustness and guide refinements in design, ensuring a resilient and reliable solution for enhancing the performance of the DHIL system.

5.2 Determine The Stress And Displacement By Using Finite Element Analysis (FEA)

The DHIL system's structural design model will be analyzed to determine von Mises stress and displacement, with a primary focus on the middle arm support and screws. The 3D model was built using actual parameters and material properties. The project is conducted based on the processes as shown in the flowchart below.

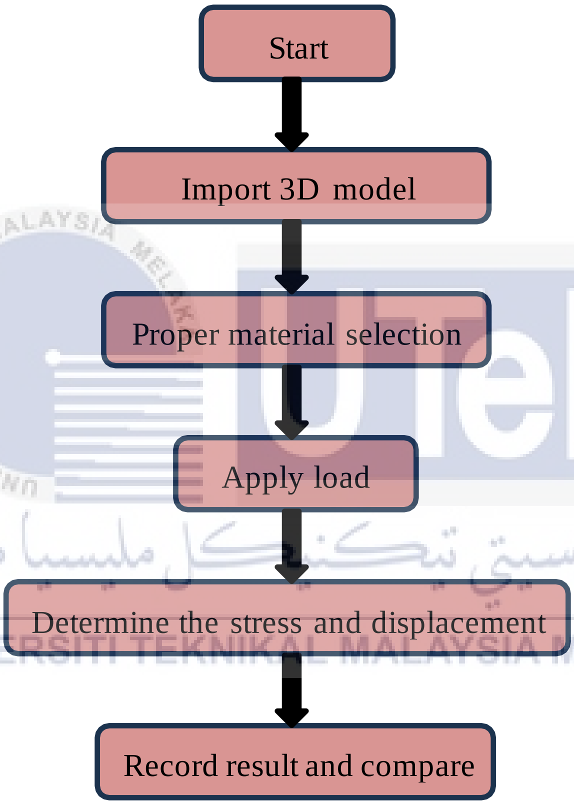
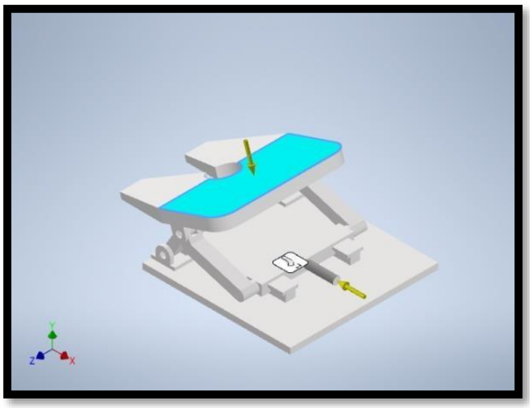
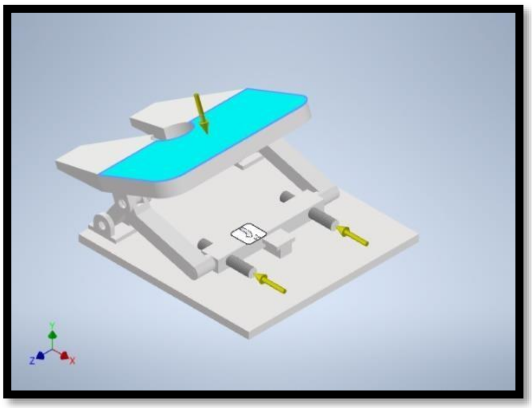


Figure 5.1 Flowchart of structure analysis (objective 3)

The 3D model for the DHIL actuator system, created in Catia V5R21 software, was imported into SolidWorks for analysis simulation. The analysis will commence after the loads have been applied to the relevant points; one on the top plate, which acts as a hitch force from the load transfer of semitrailer cargo, and the other on the screw of the power-screw motor, which functions as the motor's power output as shown in the Figure 5.2 below.





a) Forces applied on single motor active DHIL system

b) Forces applied on single motor active DHIL system

Figure 5.2 Forces applied points on DHIL design model

The appropriate materials are then chosen to ensure that the DHIL actuator can withstand huge force from the semitrailer while also allowing the screw to counteract the push forward. The material chosen is mild steel, which is often utilized in heavy -duty vehicles and components. The properties of the material were shown in Table 1.

Table 5.1 Mild steel properties

Name	Steel, Mild	
General	Mass Density	7.85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	220 GPa
	Poisson's Ratio	0.275 ul
	Shear Modulus	86.2745 GPa

The investigation into the DHIL design model places paramount importance on the critical analysis of key properties, with a primary focus on von Mises stress, displacement, and strain. Von Mises stress, derived as a scalar quantity from the stress tensor, stands as a pivotal metric, offering a comprehensive measure of the material's potential failure arising from a combination of normal and shear stresses. The assessment of von Mises stress in various components of the DHIL system is indispensable for pinpointing regions prone to failure and determining the structure's ability to withstand applied loads during operational scenarios. Complementing this, displacement analysis plays a crucial role in gauging the system's response to applied forces, elucidating how components deform or displace under diverse conditions. The integration of strain analysis into this multifaceted evaluation further enriches the assessment by providing insights into the material's elastic deformation and potential yielding. The synergistic combination of von Mises stress, displacement, and strain analyses ensures a comprehensive and holistic evaluation of the DHIL system's structural integrity and performance.

The vertical hitch force data taken from the braking test simulation in various trailer load configuration as listed in table below.

Table 5.2 Data from previous braking test simulation

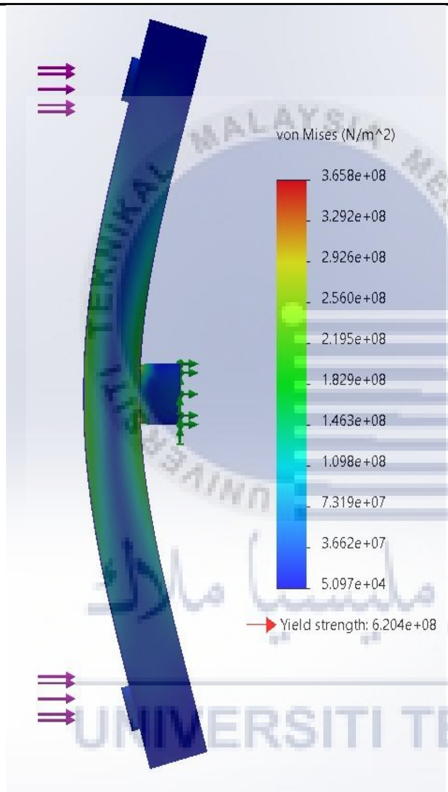
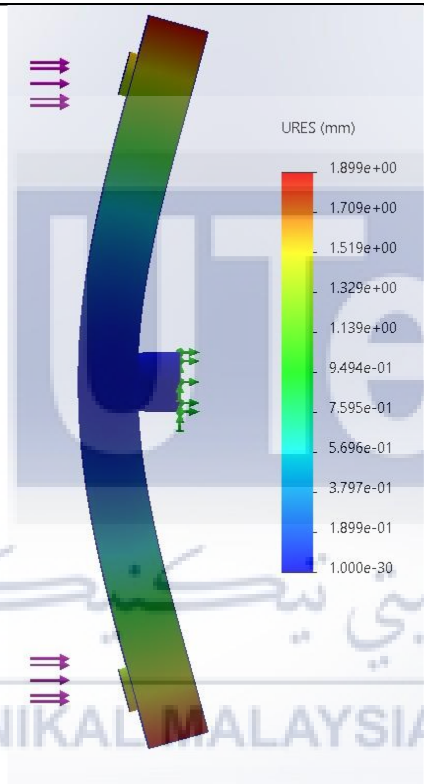
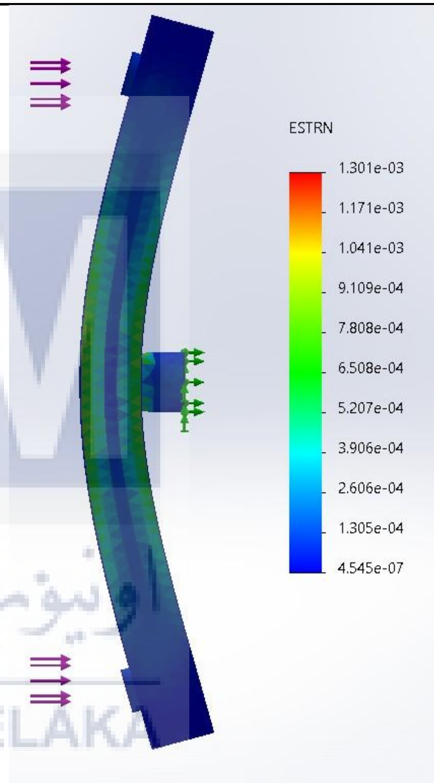
Configuration Name	Trailer Load Condition	Braking Speed (km/h)	Vertical hitch force (N)
BR10060	Unladen	60 - 0	89999
BR10080	Unladen	80 -0	90541
BR10100	Unladen	100 - 0	91567
BR20060	Half-laden	60 - 0	134100
BR20080	Half-laden	80 – 0	134267
BR20100	Half-laden	100 – 0	140233
BR30060	Full-laden	60 – 0	180272
BR30080	Ful-laden	80 – 0	180848
BR30100	Full-laden	100 - 0	181408

In the detailed scrutiny of the DHIL system model, specific attention was dedicated to critical components, notably the power screw and the middle support arm. Meticulous examination of von Mises stress, displacement, and strain values facilitated a nuanced assessment of the structural performance and behavior of these key elements under various loading conditions. Von Mises stress analysis offered crucial insights into the material's potential failure due to combined stresses, aiding in the identification of stress concentration areas susceptible to deformation or failure. Simultaneously, displacement analysis provided a comprehensive understanding of how the power screw and middle support arm responded to applied forces, unveiling potential areas of strain or deflection. This meticulous evaluation ensures a thorough understanding of the mechanical behavior of the DHIL system and serves as a foundation for informed design refinements and improvements.

5.3 Comparison Analysis Data of Previous and New DHIL Design Model On Screw and Middle Arm Support

The following analysis presents a comparative examination between the original and the newly proposed active DHIL design models, specifically homing in on the structural components of the screw and middle arm support. This study scrutinizes crucial performance metrics, including von Mises stress (VMS), displacement, and strain values, to comprehensively evaluate the efficacy of the design modifications. The investigation aims to discern the inherent strengths and potential weaknesses of both iterations, shedding light on their respective responses to loading conditions and providing valuable insights into the structural integrity and mechanical behavior of the DHIL system. Through this detailed comparison, a nuanced understanding of the design improvements and their impact on the identified parameters will be elucidated, contributing to the optimization and refinement of active hitch lift devices for enhanced functionality and reliability.

Table 5.3 The analytical result of the middle arm and screw sections of a single motor in DHIL configuration setup.

Case variations	VMS (N,m^2)	Displacement (mm)	Strain
BR10060	 Maximum: 3.658e+08 Minimum: 5.097e+04	 Maximum: 1.889e+00 Minimum: 1.000e-30	 Maximum: 1.301e-03 Minimum: 4.545e-07

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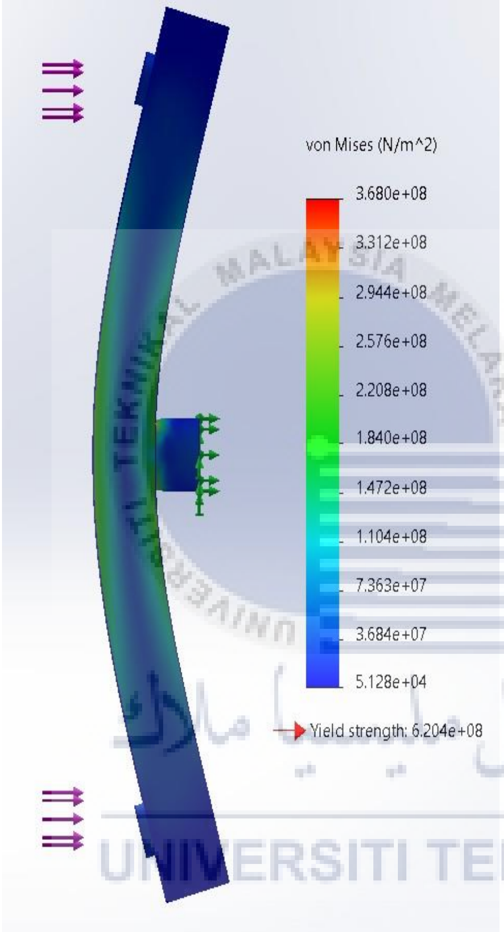
<td>

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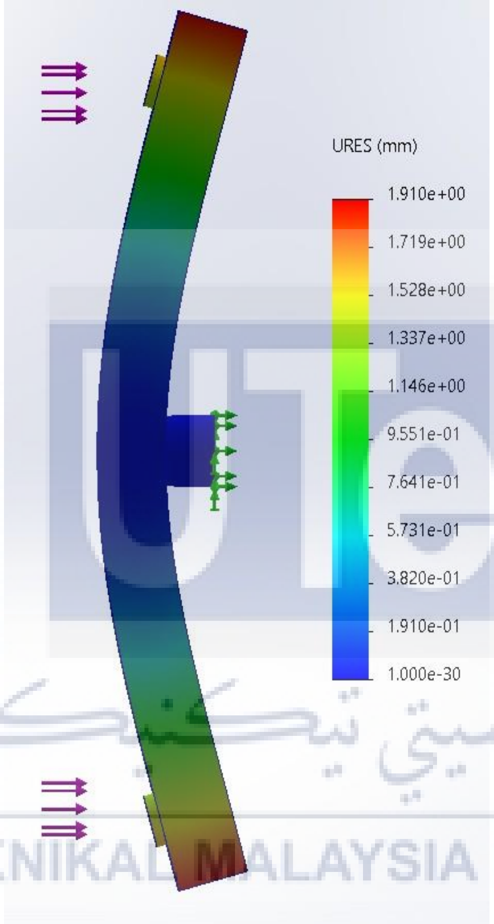
<td>

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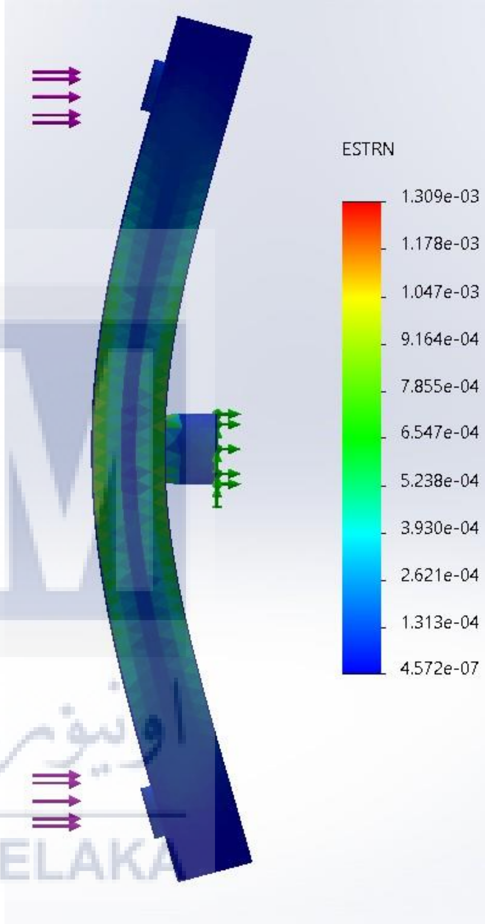
<td>

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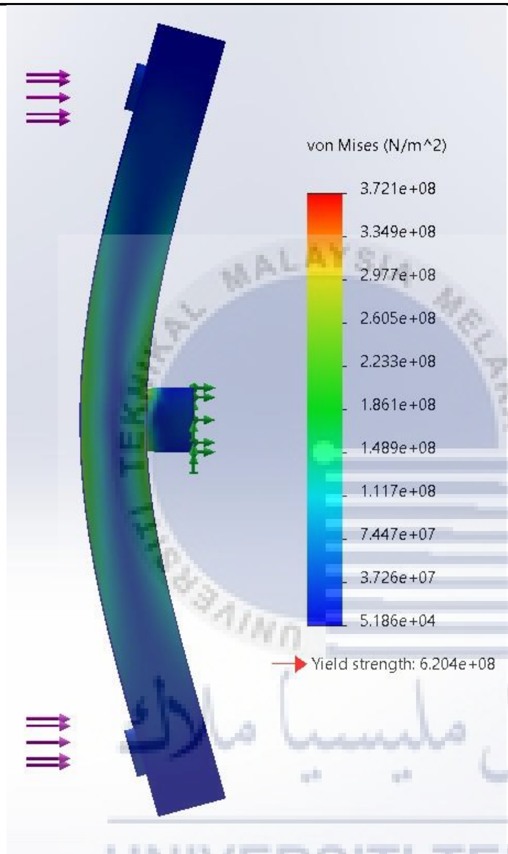
<td>

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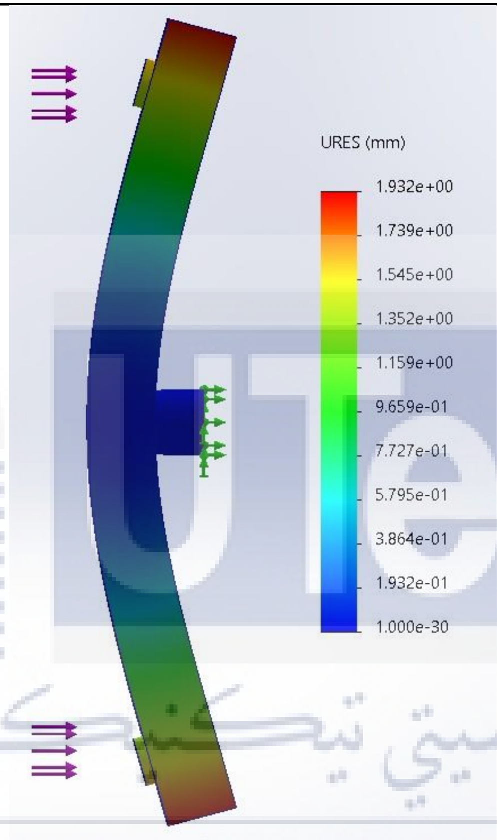
<td>

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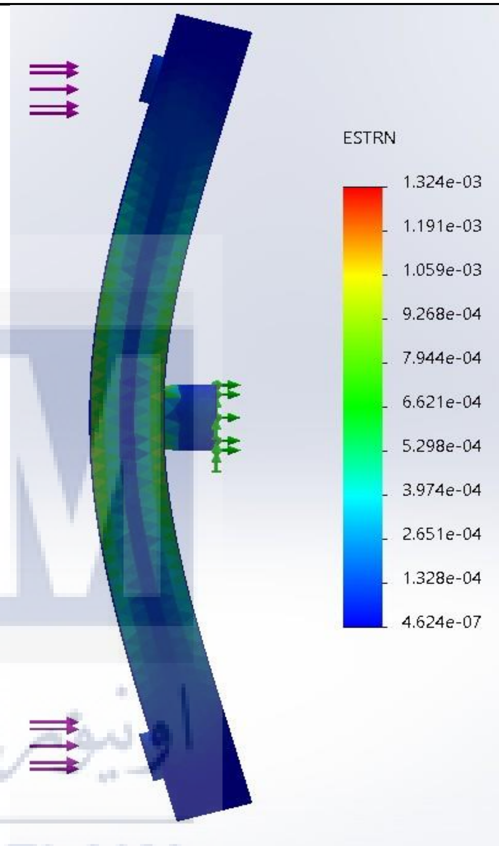
<td>

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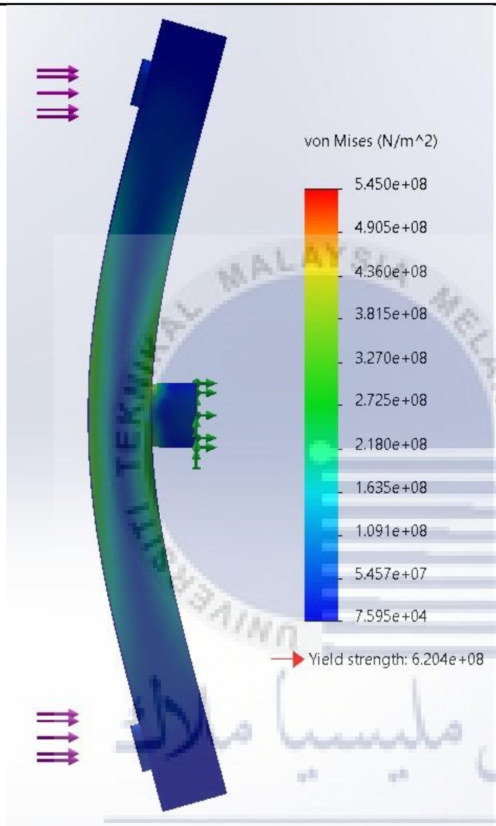
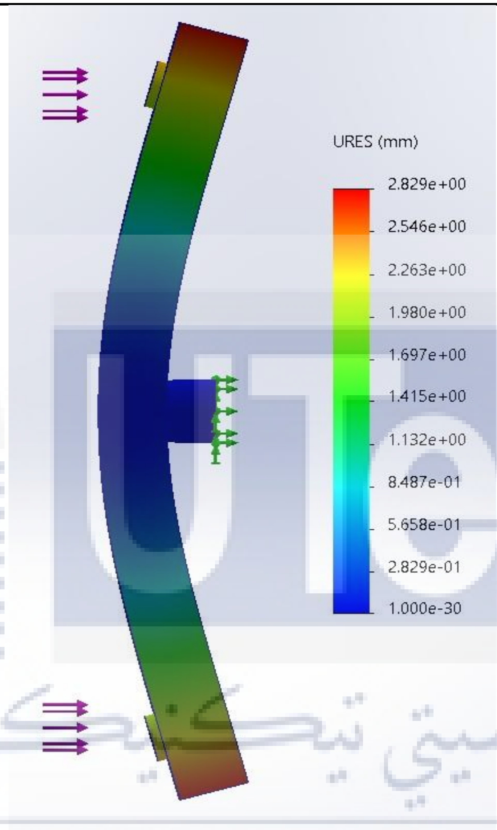
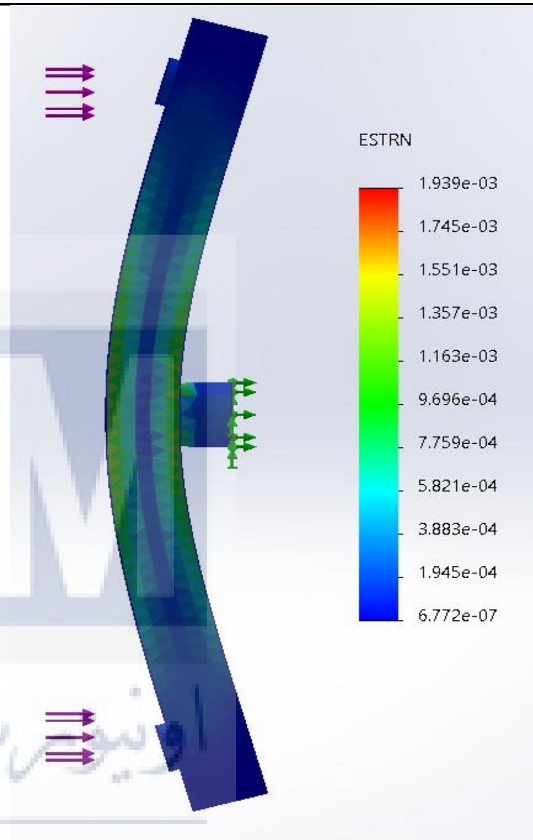
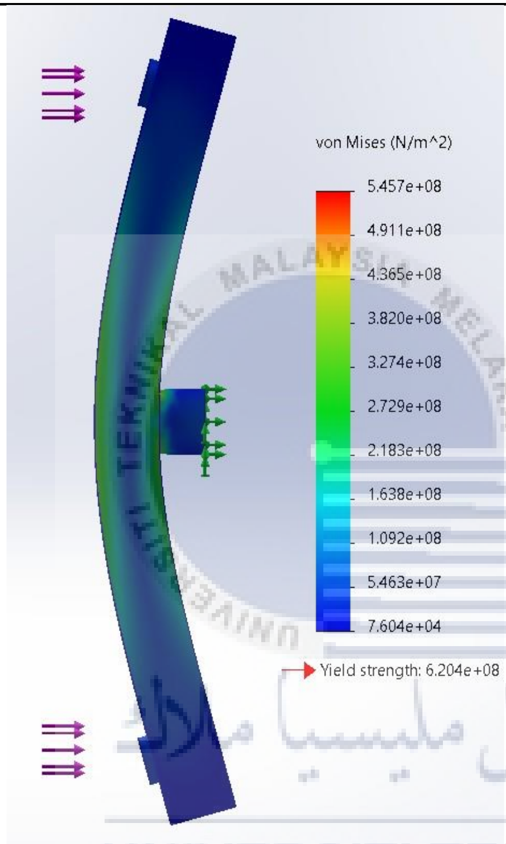
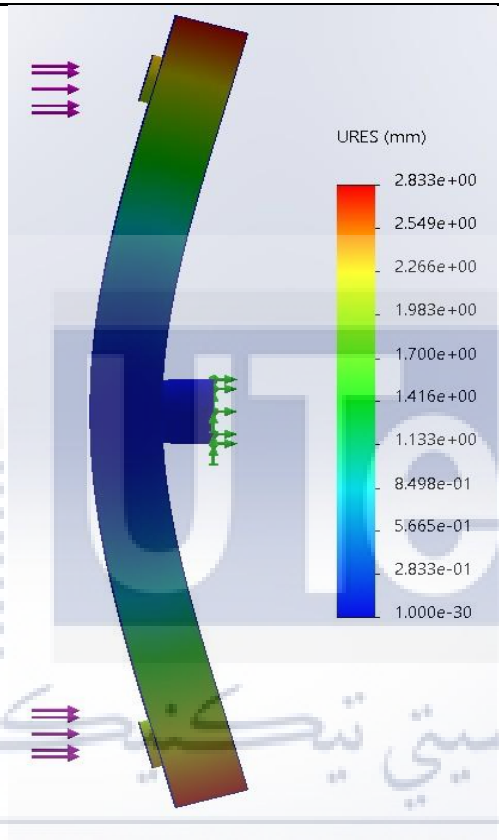
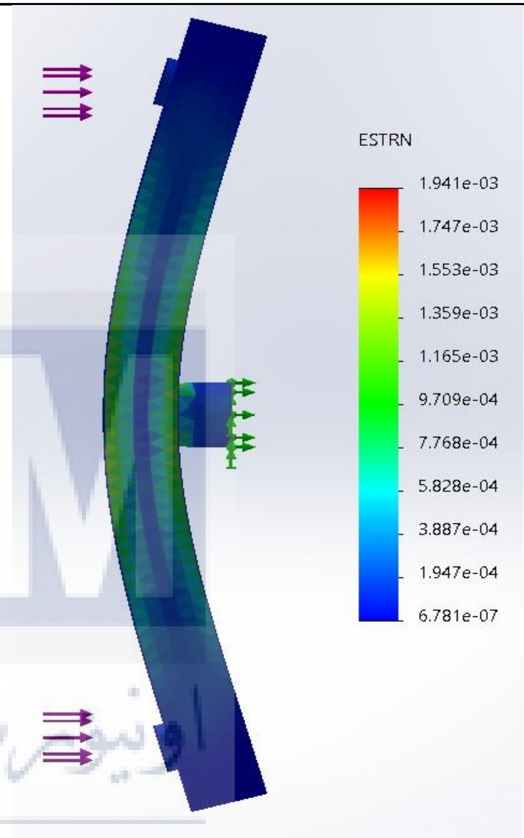
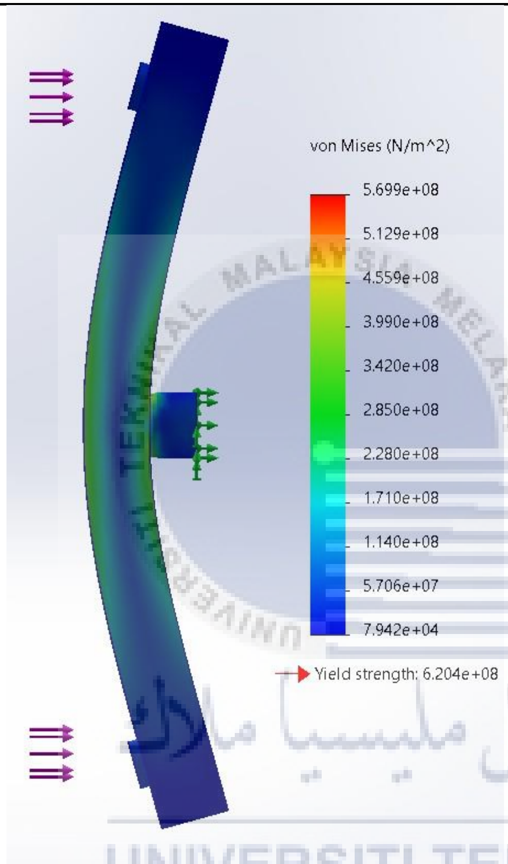
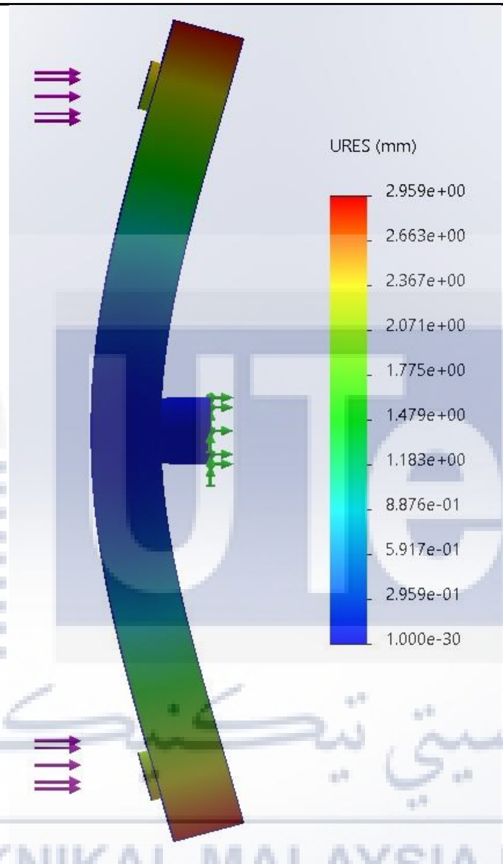
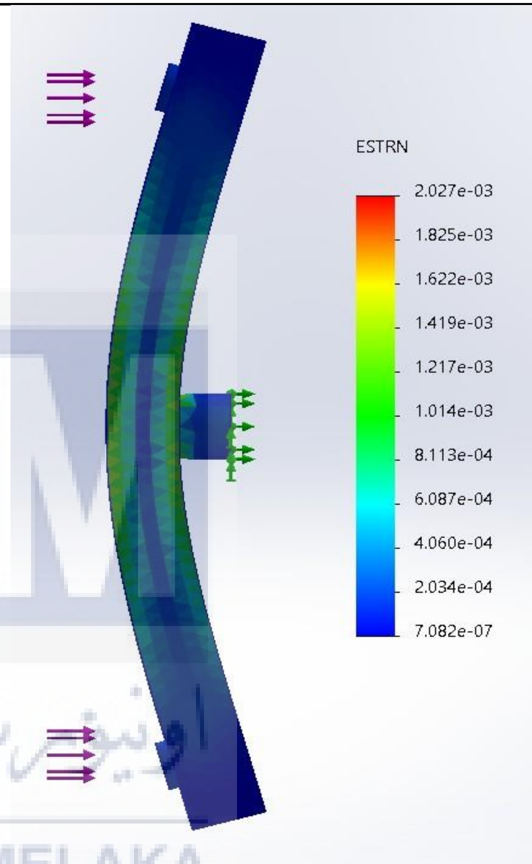
BR20060	 Maximum: 5.450e+08 Minimum: 7.595e+04	 Maximum: 2.829e+00 Minimum: 1.00e-30	 Maximum: 1.939e-03 Minimum: 6.772e-07

BR20080	 Maximum: 5.457e+08 Minimum: 7.604e+04	 Maximum: 2.833e+00 Minimum: 1.000e-30	 Maximum: 1.941e-03 Minimum: 6.781e-07

BR20100	 Maximum: 5.699e+08 Minimum: 7.942e+04	 Maximum: 2.959e+00 Minimum: 1.000e-30	 Maximum: 2.027e-03 Minimum: 7.082e-07

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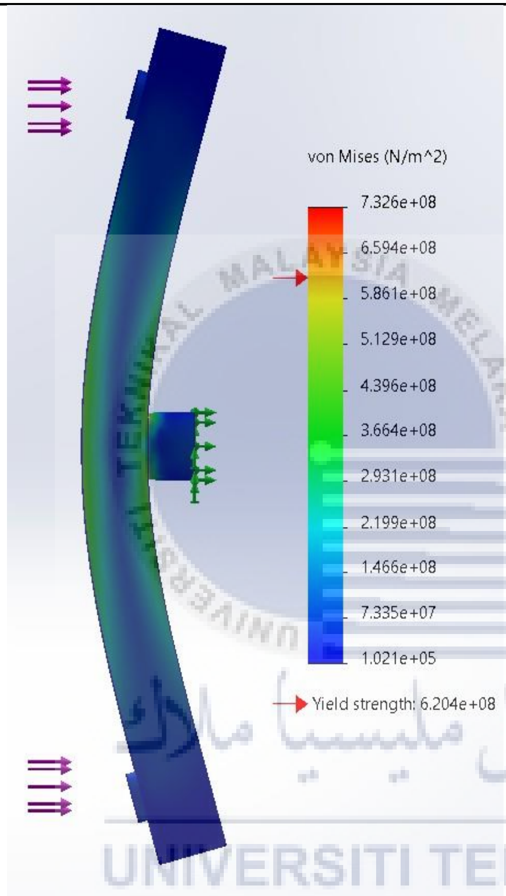
<td>

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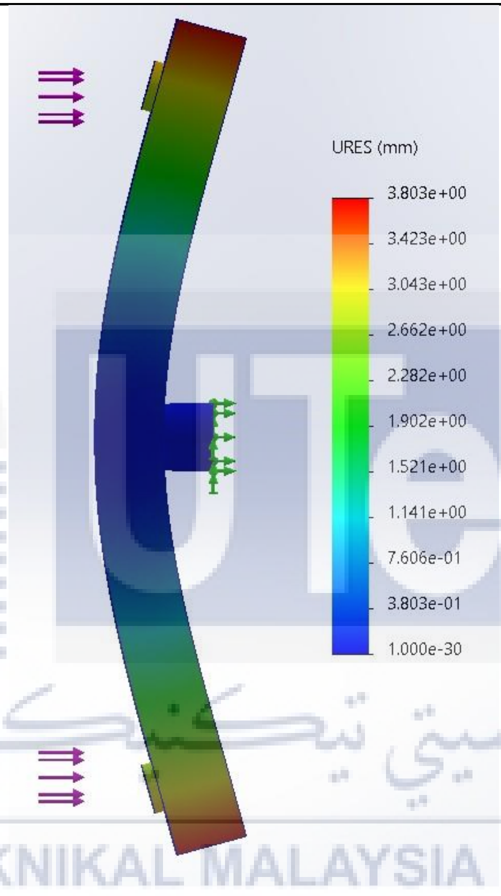
<td>

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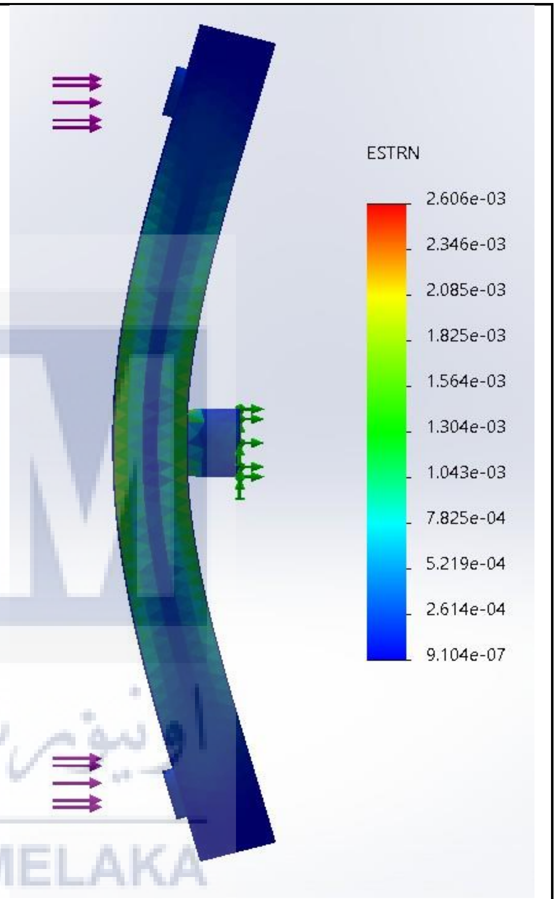
<td>

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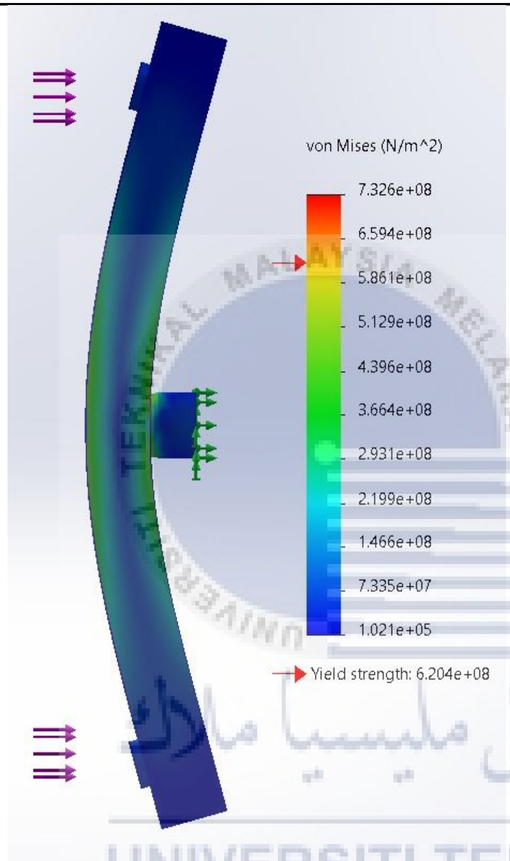
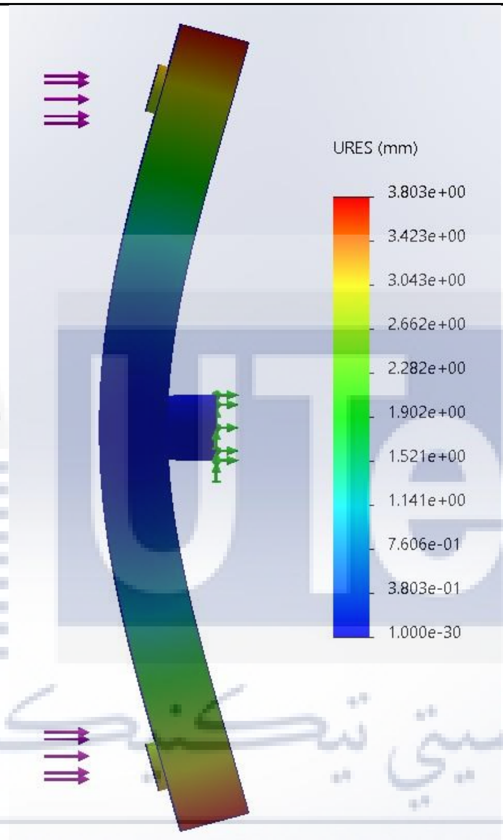
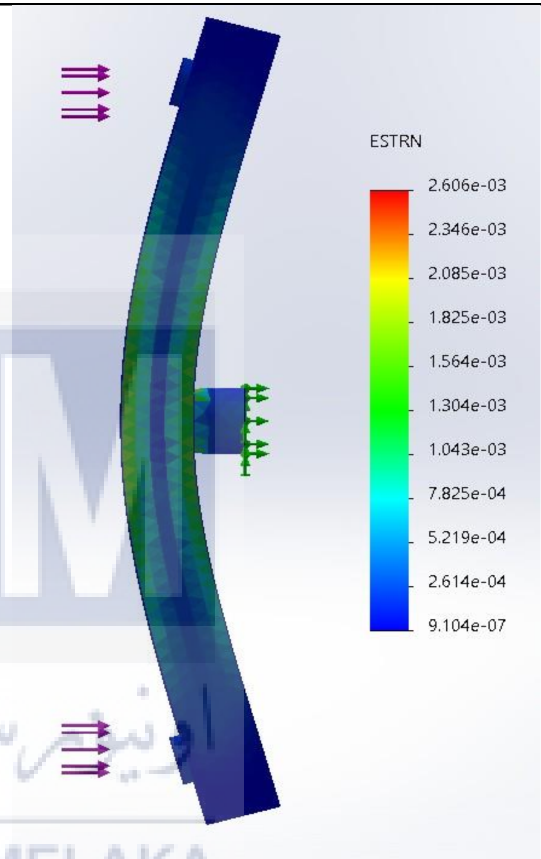
BR30080	 Maximum: 7.326e+08 Minimum: 1.021e+05	 Maximum: 3.802e+00 Minimum: 1.000e-30	 Maximum: 2.606e-03 Minimum: 9.104e-07

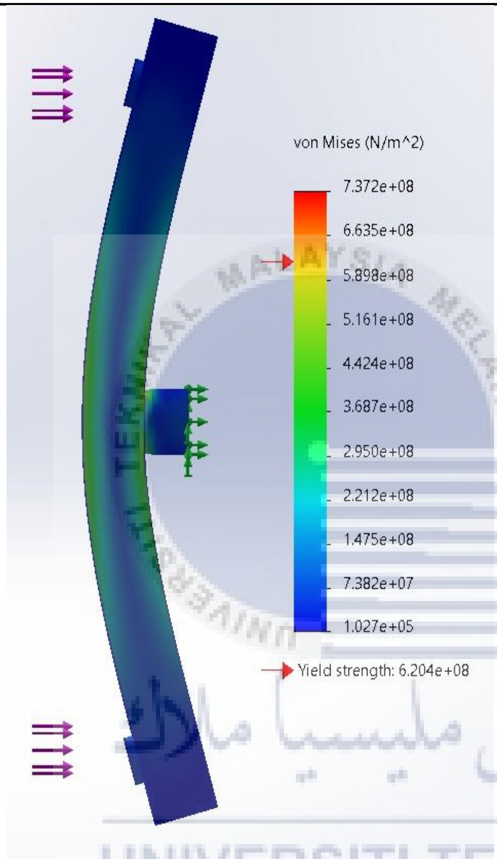
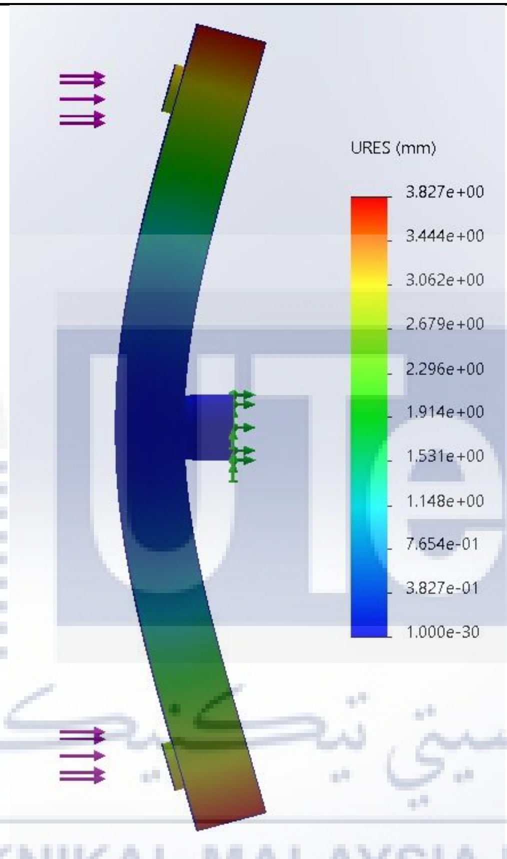
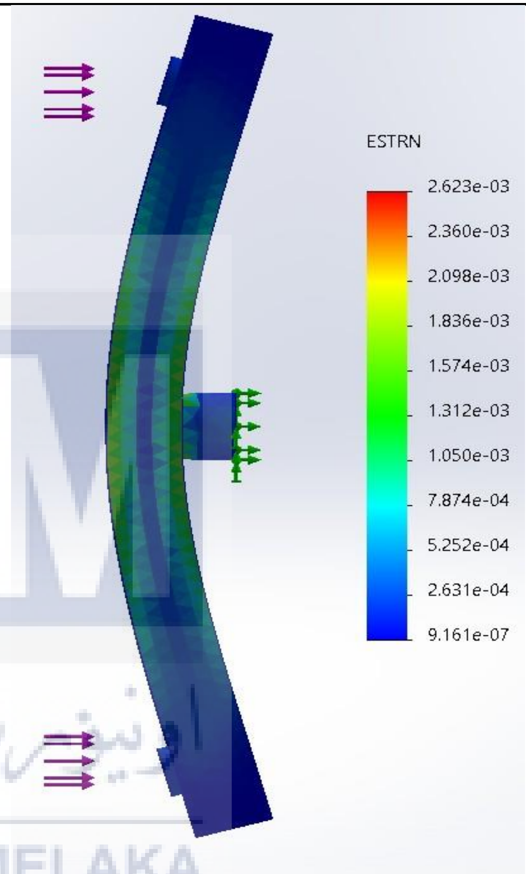
BR30100	 Maximum: 7.372e+08 Minimum: 1.027e+05	 Maximum: 3.827e+00 Minimum: 1.000e-30	 Maximum: 2.623e-03 Minimum: 9.161e-07

Table 5.4 The analytical result of the middle arm and screw sections of a single motor in DHIL configuration setup.

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<tr><th>Case variations</th><th>VMS (N,m^2)</th><th>Displacement (mm)</th><th>Strain</th></tr>
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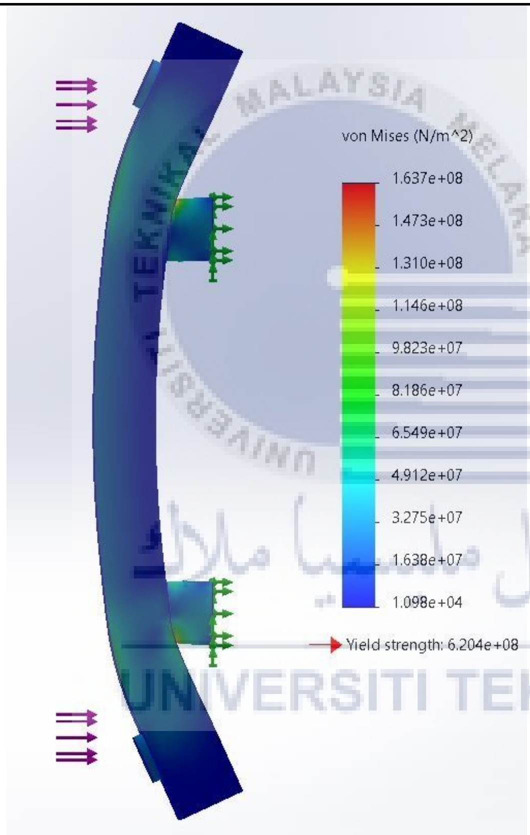

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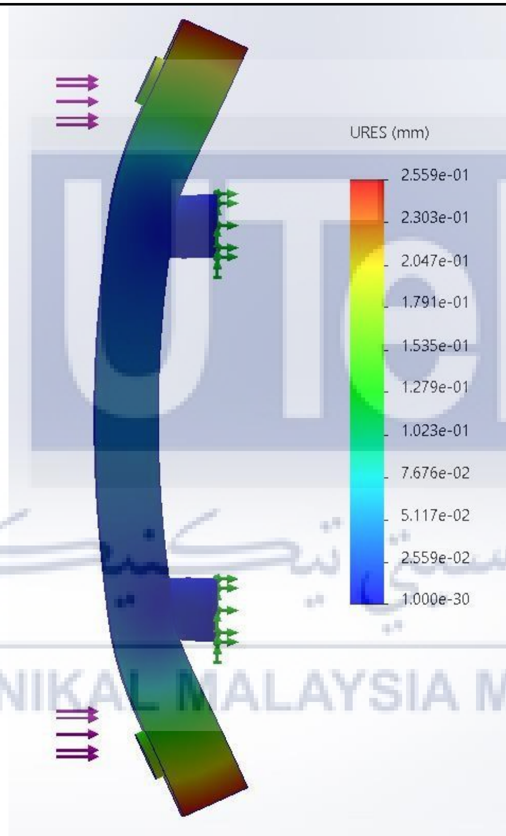

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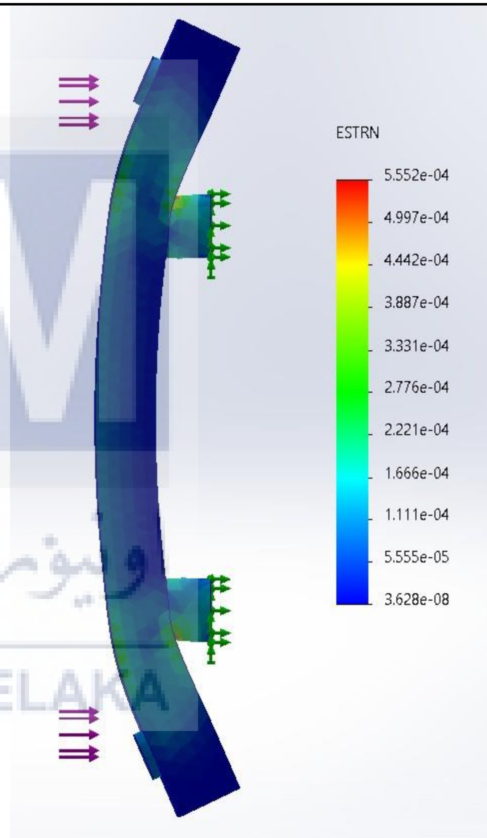

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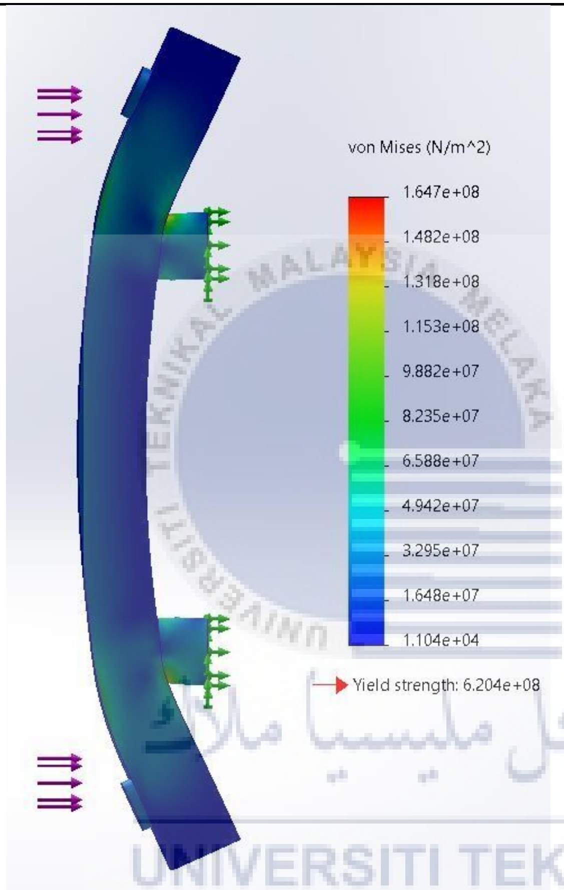
<td>

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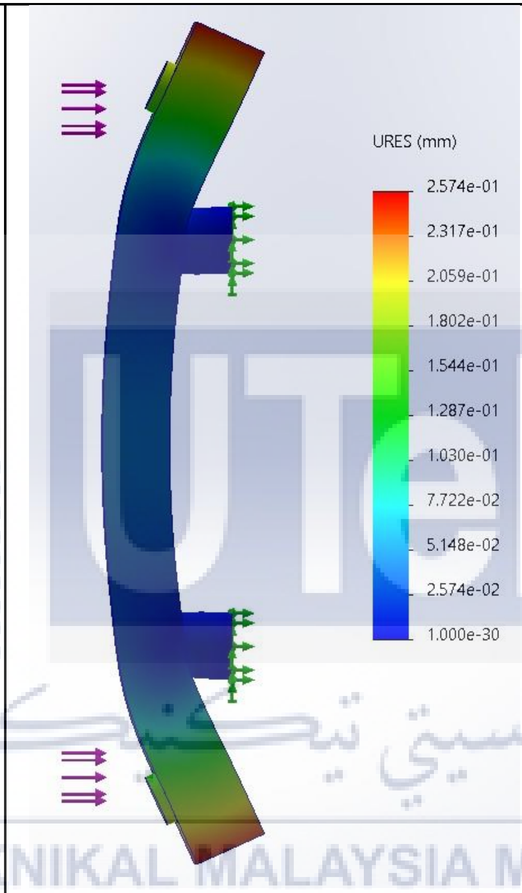
<td>

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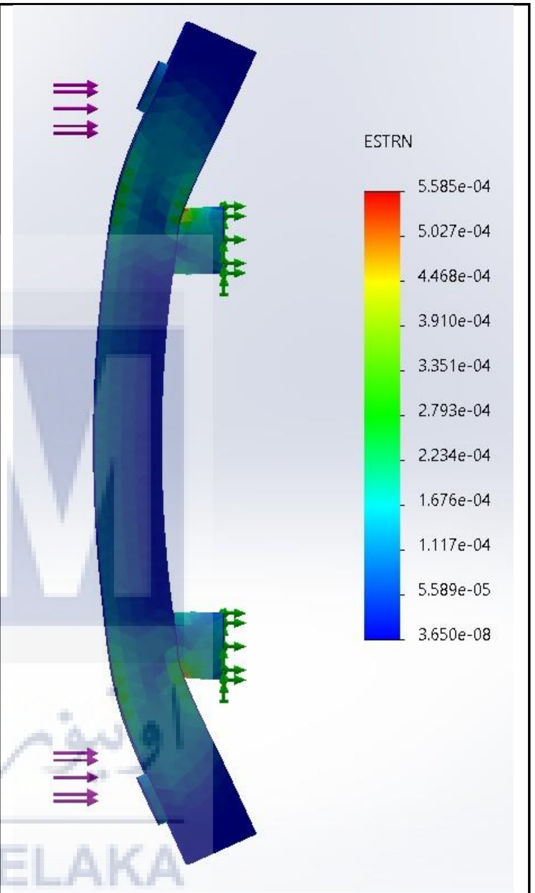
<td>

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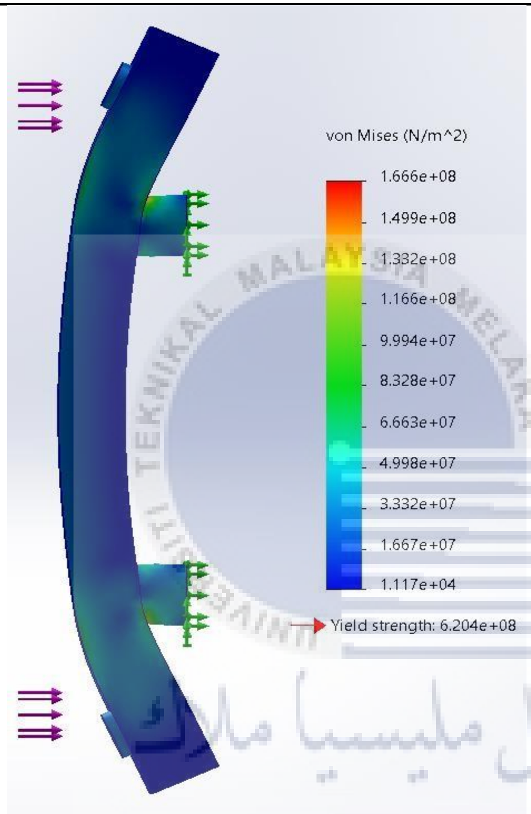
<td>

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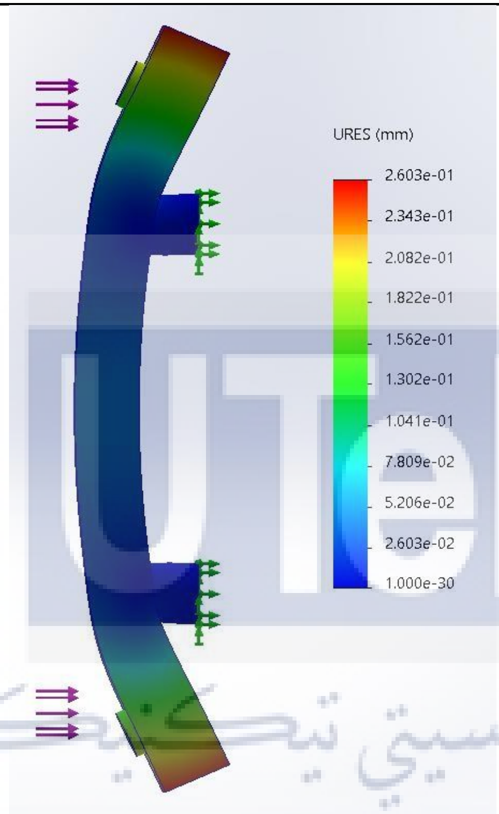
<td>

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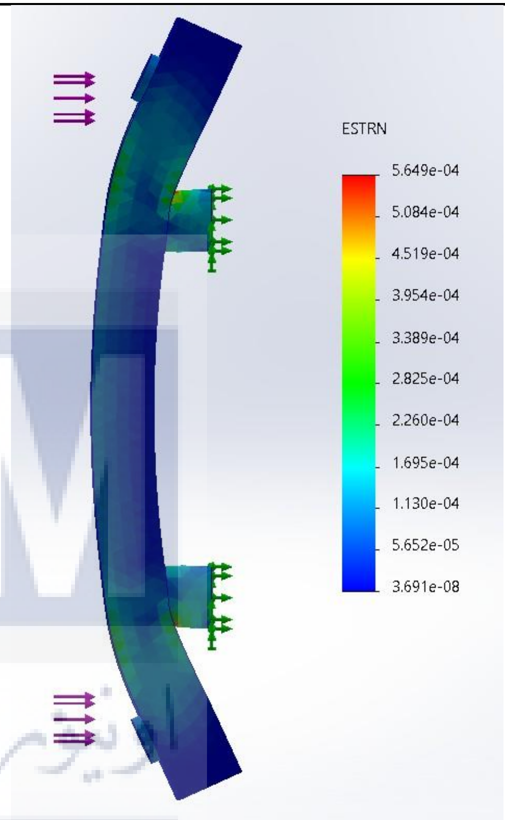
<td>

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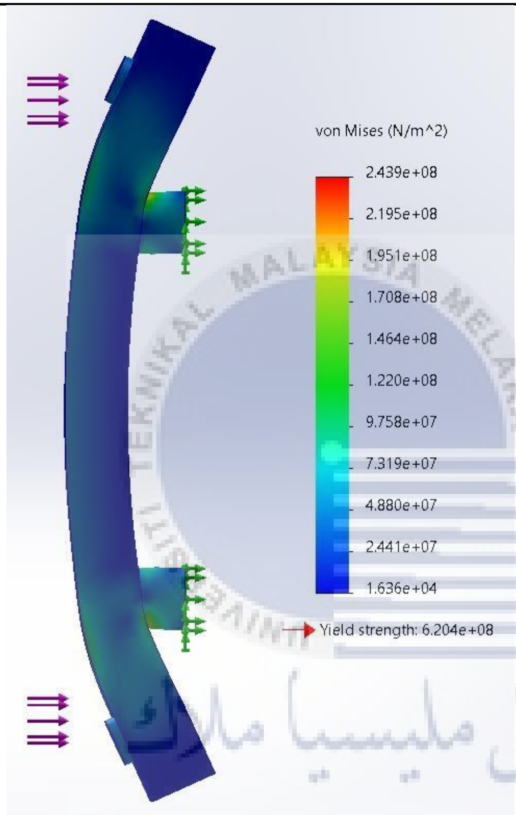
<td>

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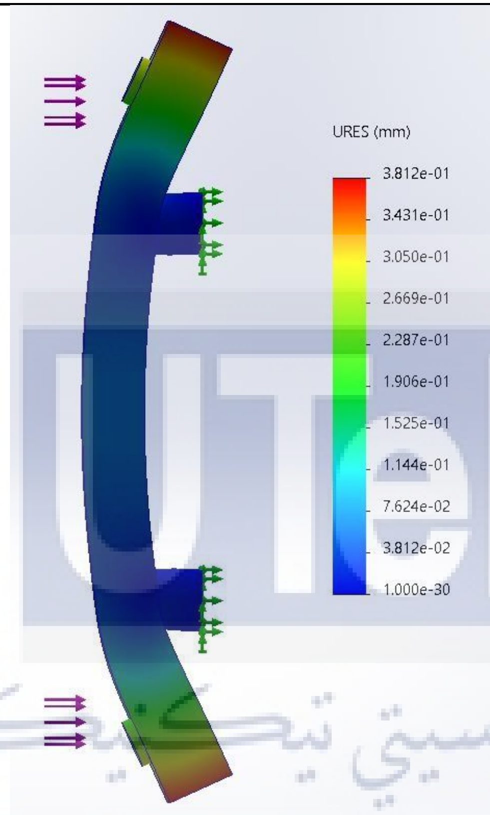
<td>

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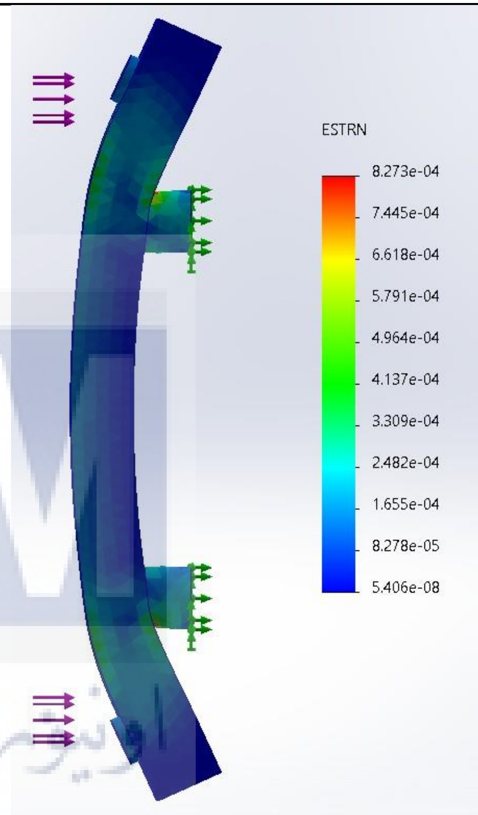
<td>

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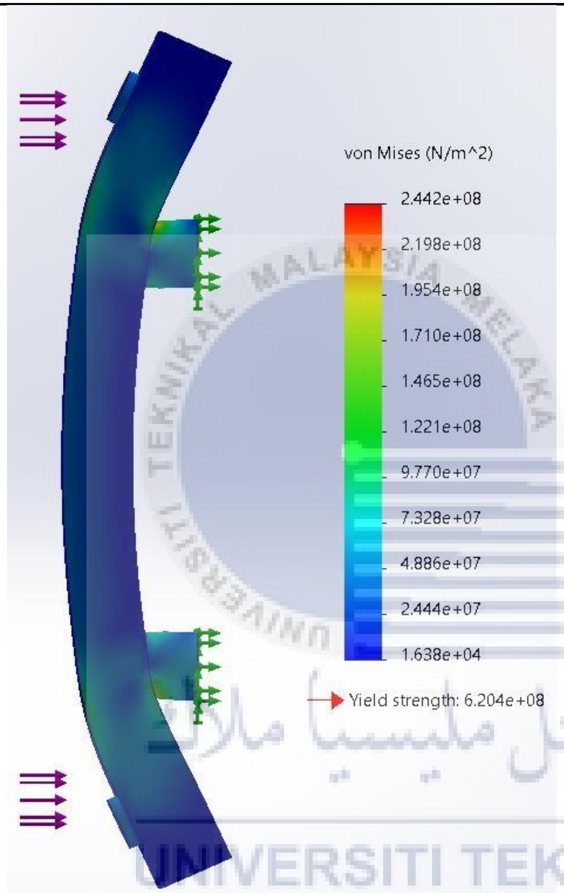
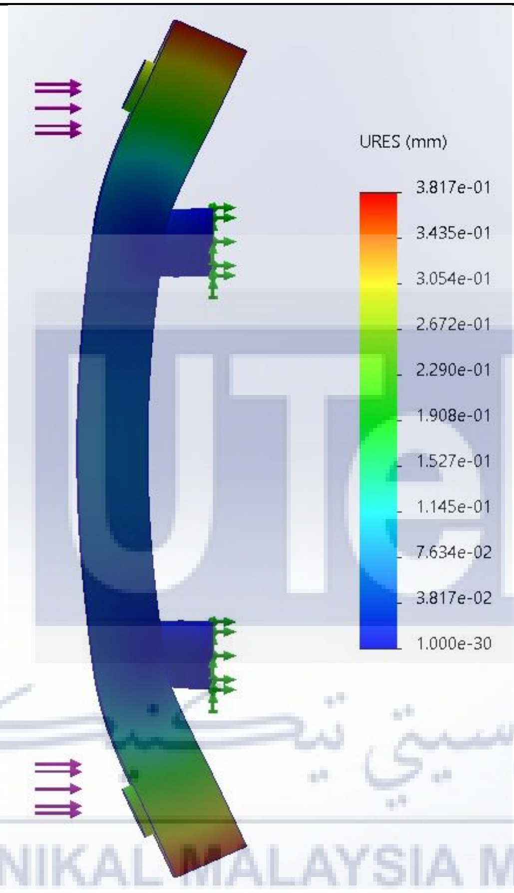
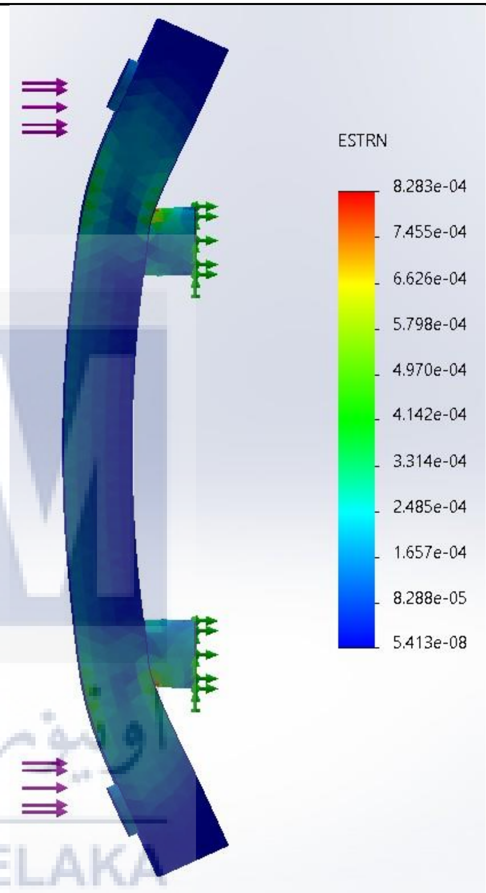
<td></td>
<td></td>
<td></td>
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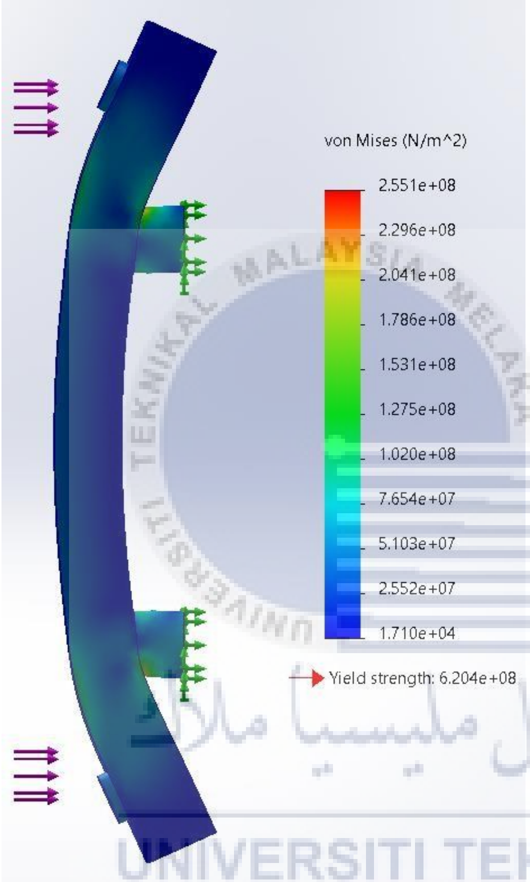
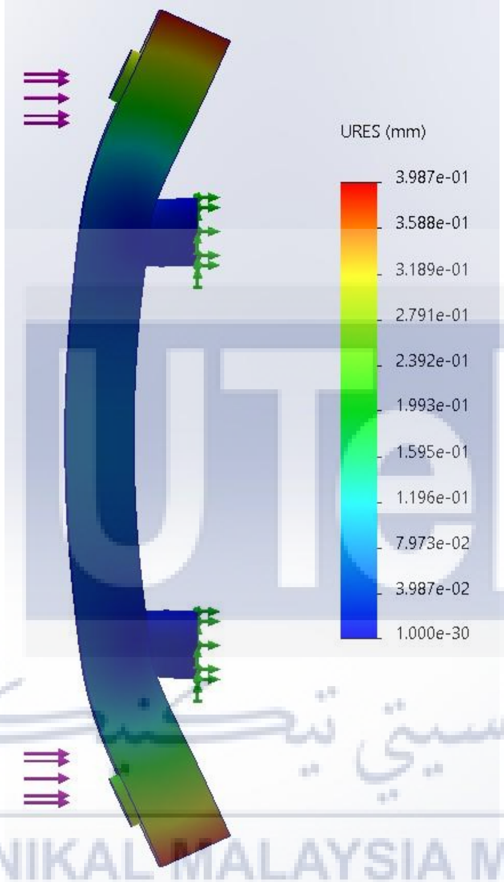
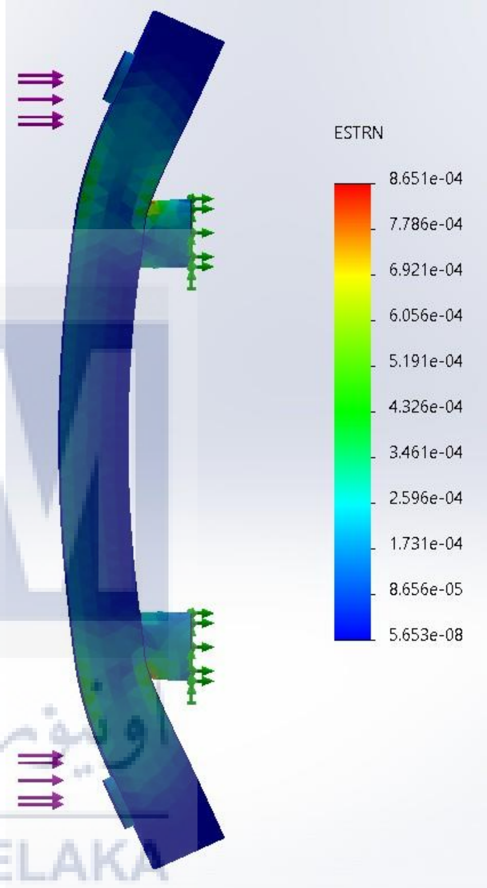
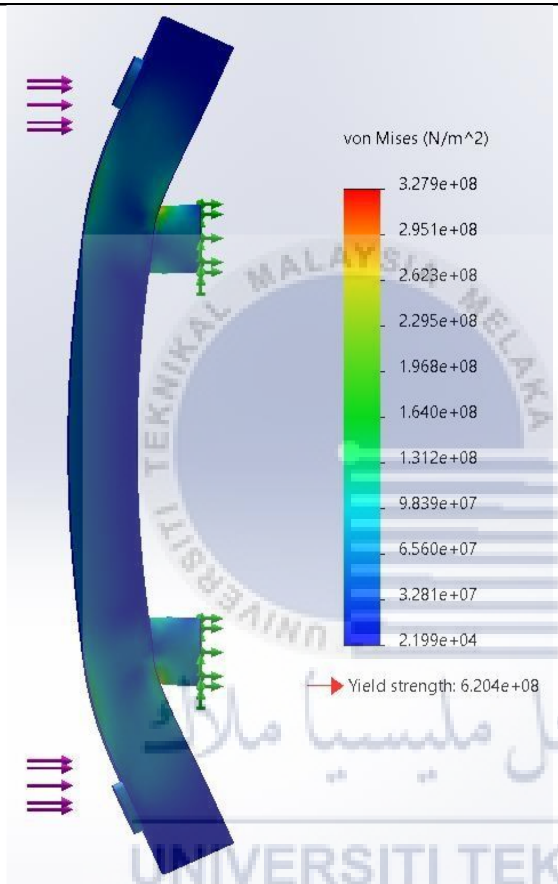
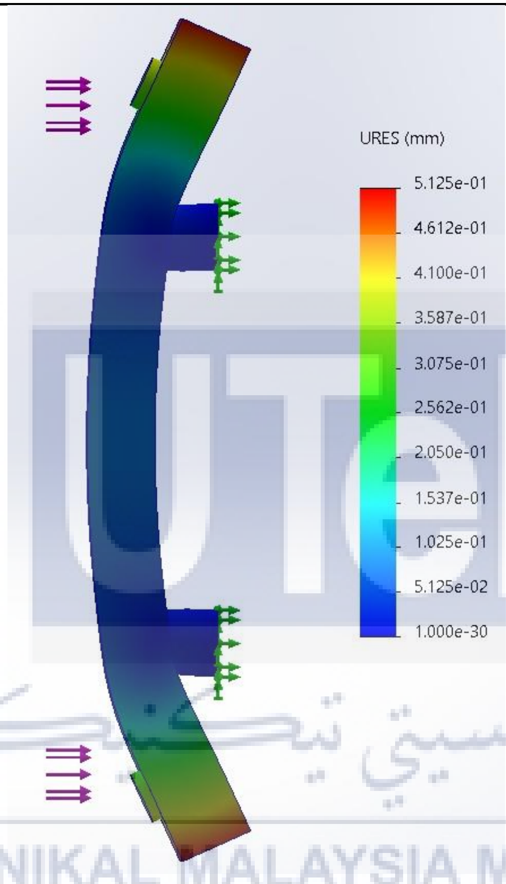
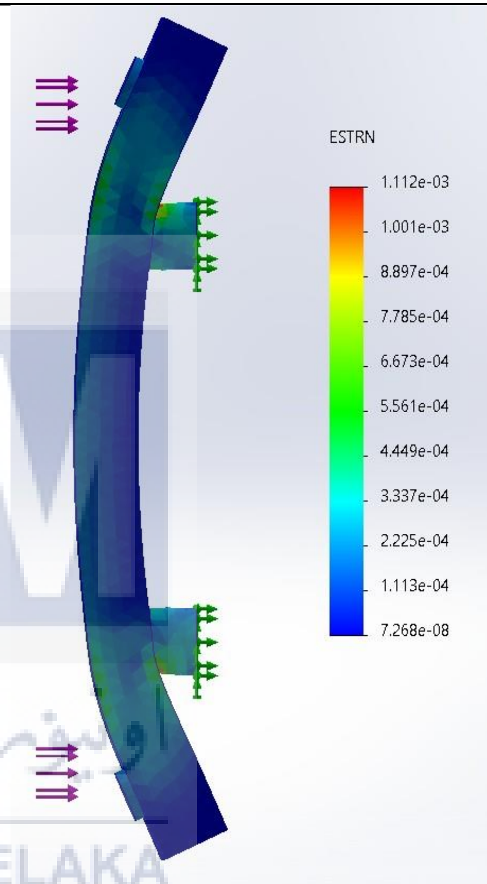
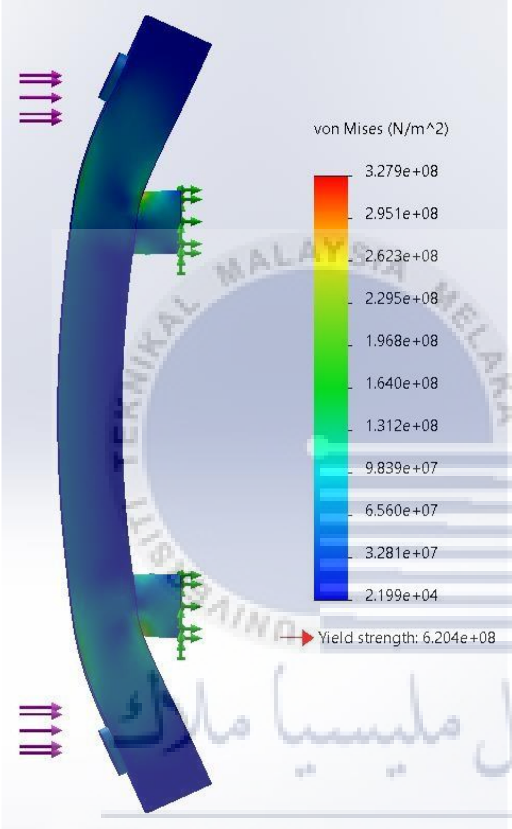
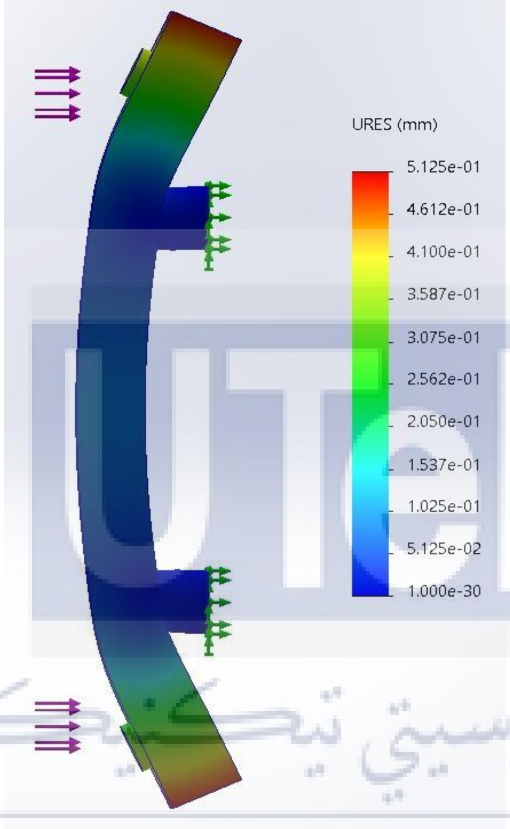
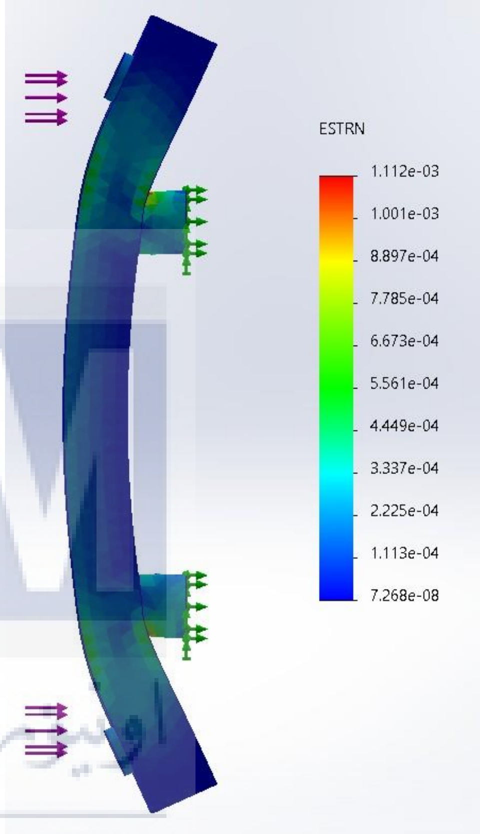
BR20100	 Maximum: 2.551e+08 Minimum: 1.710e+04	 Maximum: 3.987e-01 Minimum: 1.000e-30	 Maximum: 8.651e-04 Minimum: 5.653e-08

BR30060	 Maximum: 3.279e+08 Minimum: 2.199e+04	 Maximum: 5.125e-01 Minimum: 1.000e-30	 Maximum: 1.112e-03 Minimum: 7.268e-08

BR30080	 Maximum: 3.279e+08 Minimum: 2.199e+04	 Maximum: 5.125e-01 Minimum: 1.000e-30	 Maximum: 1.112e-03 Minimum: 7.268e-08

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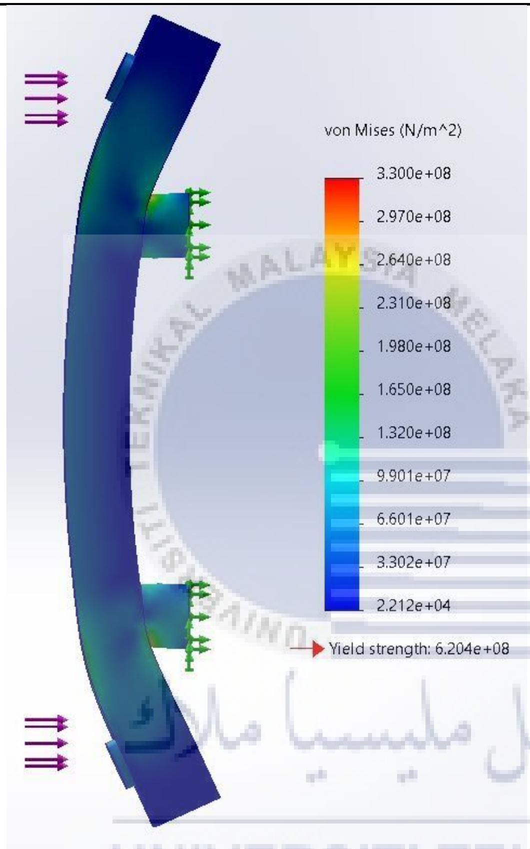
<td>

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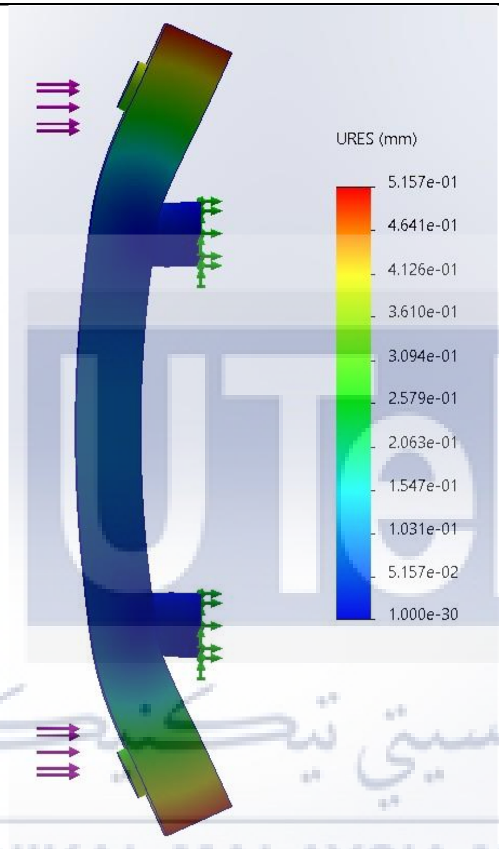
<td>

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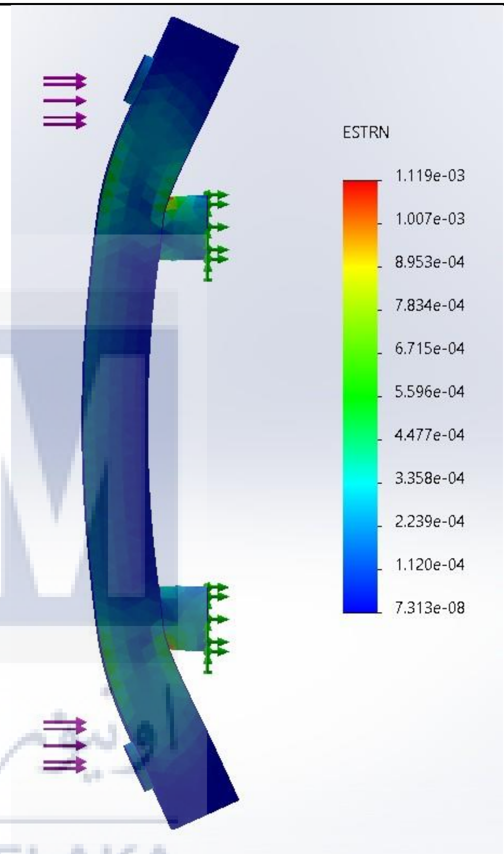
<td>

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The comparative analysis between Table 5.3 and Table 5.4 provides a detailed examination of the analytical results for the middle arm and screw sections within the DHIL configuration setup. These tables present the outcomes of von Mises stress (VMS), displacement, and strain obtained from simulation analyses conducted using SolidWorks software. In Table 5.3, the data corresponds to the single motor DHIL configuration, focusing on the structural response of the middle arm and screw under various loading conditions. On the other hand, Table 5.4 outlines the analytical results for the same sections but under the configuration of a dual motor DHIL system. This side-by-side tabulation facilitates a direct and insightful comparison of how the introduction of a dual motor setup influences VMS, displacement, and strain in the middle arm and screw components as opposed to the single motor configuration.

Table 5.5 Comparison of result values

Load and speed variations	Single motor of DHIL		Dual motor of DHIL	
	VMS (N/m^2) e+08	Displacement (mm) e+00	VMS (N/m^2) e+08	Displacement (mm) e+01
BR10060	3.658	1.889	1.637	2.559
BR10080	3.680	1.910	1.647	2.574
BR10100	3.721	1.932	1.666	2.603
BR20060	5.450	2.829	2.439	3.182
BR20080	5.45	2.883	2.442	3.817
BR20100	5.699	2.959	2.551	3.981
BR30060	7.326	3.803	3.279	5.125
BR30080	7.326	3.802	3.278	5.125
BR30100	7.326	3.827	3.300	5.157

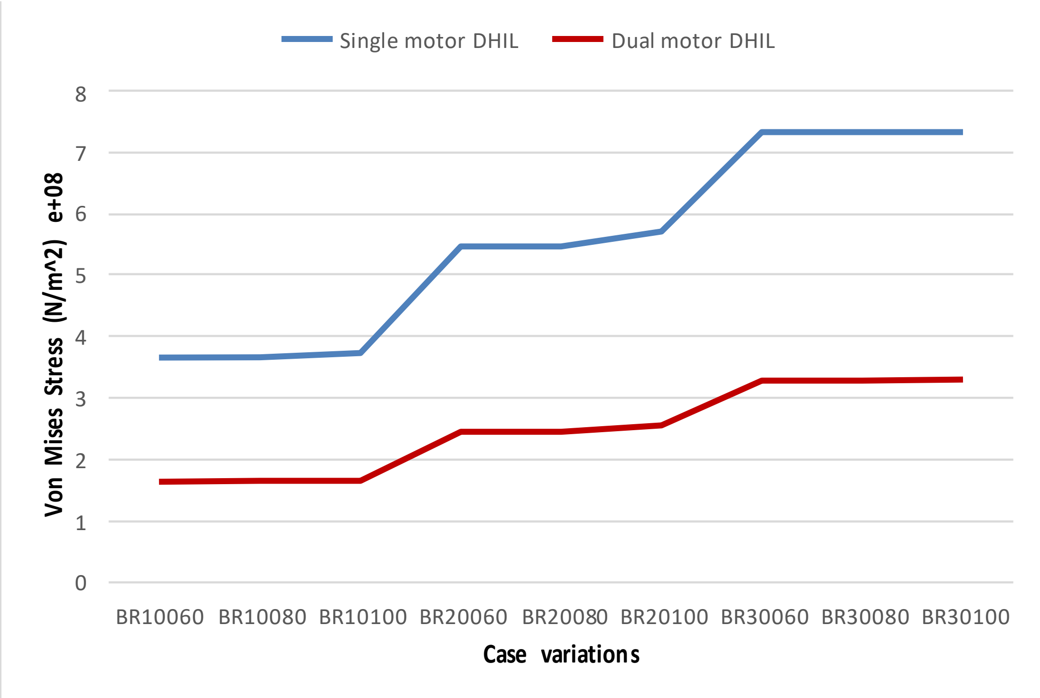

Figure 5.3 Graph of VMS against case variations for both DHIL configurations

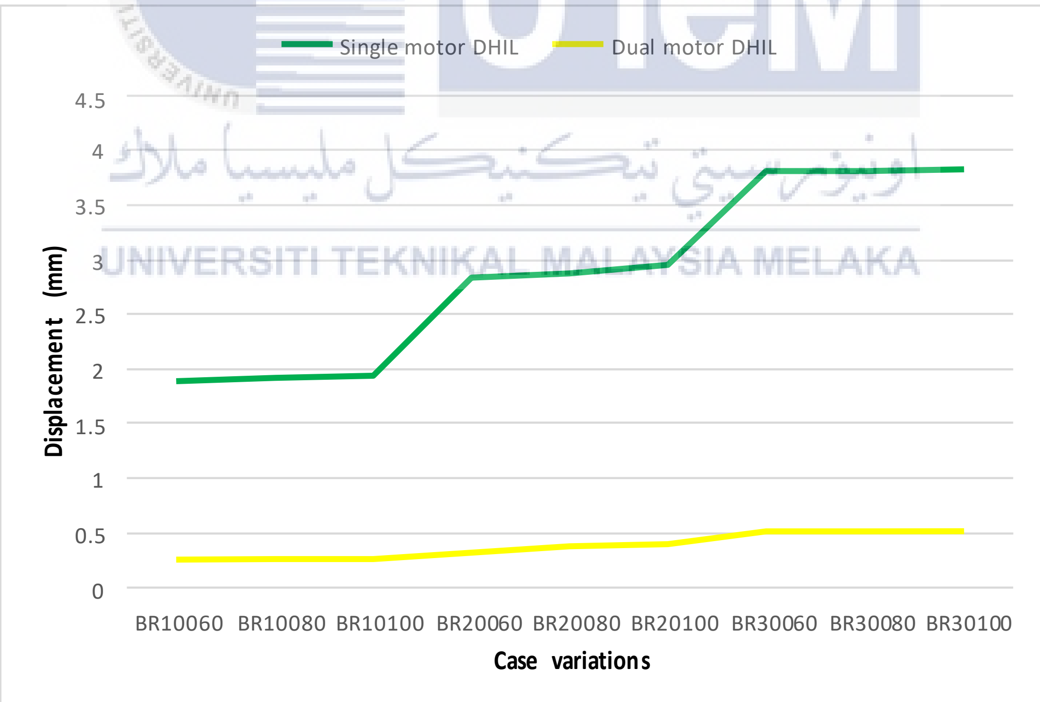

Figure 5.4 Graph of displacement against case variations for both DHIL configurations

Overall, the graphical comparison of von Mises stress (VMS) and displacement values between the single motor and dual motor active DHIL system configurations provides a compelling visual representation of their respective structural performances. As observed from the graph, it becomes evident that the dual motor configuration outperforms the single motor setup in terms of both VMS and displacement values. The VMS graph illustrates that the dual motor DHIL system experiences lower stress levels in the middle arm support and screw components compared to its single motor counterpart. This reduction in stress implies that the dual motor system is better able to distribute and handle the applied loads, leading to improved structural resilience and potentially minimizing the risk of yielding or failure. Similarly, the displacement graph indicates that the dual motor DHIL system exhibits less deformation in the middle arm support and screw components, suggesting enhanced rigidity and stability during dynamic maneuvers. These findings align with the expectation that the dual motor configuration, with its increased power and control capabilities, contributes to a more effective load distribution and management system. Overall, the graphical comparison underscores the superiority of the dual motor Active DHIL system in terms of structural performance, offering valuable insights for design optimization and the advancement of tractor-semitrailer combination vehicles.

5.4 Summary

The structural performance of both the old and newly modified active DHIL system models was carefully evaluated using SolidWorks software, with a particular emphasis on the screw and middle arm support components. The original design, which used a single motor arrangement, was compared against a revolutionary two motor configuration coupled to the middle arm support. The analysis focused on crucial characteristics such von Mises stress (VMS), displacement, and strain levels. Surprisingly, the research found consistently lower values for VMS, displacement, and strain in the newly designed DHIL system, indicating a significant improvement in structural performance. This reduction in stress and deformation implies that the modified model is more resilient and has better structural integrity.

CHAPTER 6

CONCLUSION

6.1 Conclusion

In conclusion, this study embarked on a comprehensive exploration of the efficacy of a dual motor configuration for the active DHIL system compared to its single motor counterpart. The research unfolded in sequential steps, starting with a meticulous investigation into the forces acting on the hitch joint of a tractor-semitrailer vehicle, employing simulation software (TruckSim). Subsequently, a new DHIL model featuring a dual motor was meticulously designed using CAD software (Catia V5R21), with the intention of mitigating load transfer effectively. The culmination of the study involved subjecting the newly developed dual motor DHIL system to finite element analysis, conducted through CAD software (SolidWorks), to assess stress and displacement. The successful achievement of the primary research objectives underscores the study's effectiveness in providing a theoretical foundation and empirical evidence supporting the superiority of the dual motor configuration. The comprehensive approach, integrating simulation, design, and finite element analysis, has not only deepened our understanding of load transfer dynamics but has also laid the groundwork for the advancement of tractor-semitrailer combination vehicles through the implementation of a more robust and efficient dual motor active DHIL system.

6.2 Recommendation

Based on the study's outcomes, it is recommended to proceed with the implementation and testing of the dual motor DHIL system in real-world scenarios. Conducting physical tests and validation on prototype models will validate the simulation and analysis results, ensuring that the dual motor configuration indeed outperforms the single motor system in terms of load transfer, stress distribution, and displacement control. Additionally, ongoing monitoring and data collection during field tests will contribute to refining the design and optimizing the dual motor DHIL system for practical applications. Collaborating with industry stakeholders and manufacturers to integrate the improved DHIL system into tractor-semitrailer combinations could lead to advancements in vehicle safety, stability, and overall efficiency. Moreover, disseminating the research findings through publications and presentations will contribute to the broader knowledge base in the field of tractor-semitrailer dynamics and load management systems. Ultimately, the successful accomplishment of the project's objectives positions the dual motor DHIL system as a promising advancement in the realm of active hitch lift technologies for enhanced performance in the transportation industry.

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Naseem, S., Perdahcıoğlu, E. S., Geijselaers, H. J. M., & van den Boogaard, A. H. (2020). A New in-Plane Bending Test to Determine Flow Curves for Materials with Low Uniform Elongation. *Experimental Mechanics*, *60*(9), 1225–1238. https://doi.org/10.1007/s11340-020-00621-5

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APPENDICES

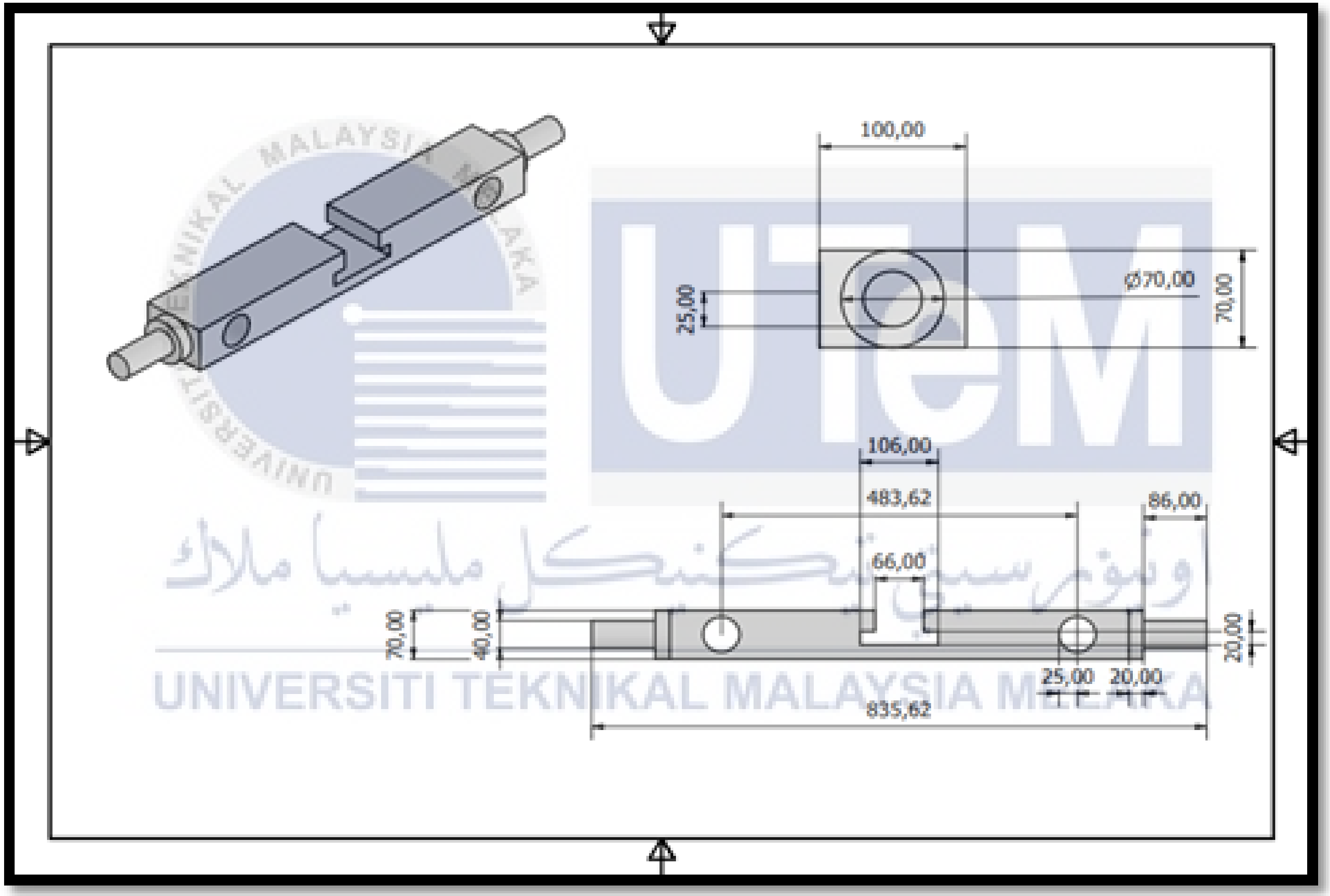
Appendix A Gantt Chart for FYP I

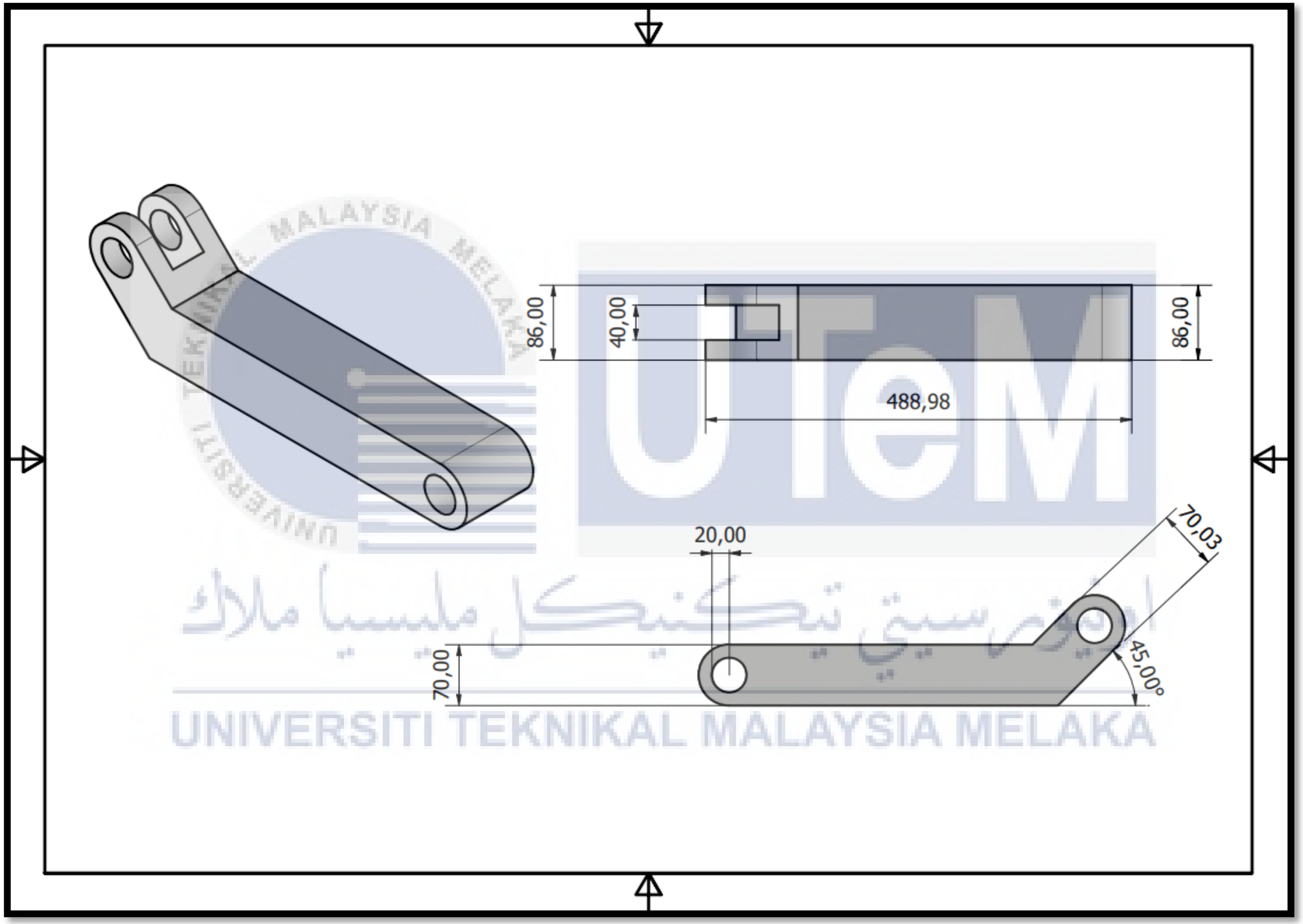
TASK ID	TASK	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
1.0	**INTRODUCTION**														
1.1	Background														
1.2	Problem Statement														
1.3	Research Objective														
1..4	Research Methodology														
2.0	**LITERATURE REVIEW**														
2.1	Introduction														
2.2	The Effect Of Load Transfer On Axle Load														
2.3	Load Transfer Analysis														
2.4	Bending/Stress analysis														
2.5	Summary														
3.0	**LOAD TRANSFER ANALYSIS**														
3.1	Introduction														
3.2	Vehicle Parameters														
3.3	Braking Test Simulation in Various Loads														
3.4	Load Transfer Analysis From The Simulation														
3.5	Summary														

Appendix B Gantt Chart for FYP II

TASK ID	TASK	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
4.0	**DEVELOPMENT OF DUAL MOTOR ACTIVE DHIL SYSTEM**														
4.1	Design Improvement Proposal														
4.2	New Design of active DHIL system with dual motor														
4.3	Summary														
5.0	**STURTURAL ANALYSIS RESULT**														
5.1	Introduction														
5.2	Finite Element Analysis (FEA)														
5.3	Comparison Analysis Data														
6.0	**CONCLUSION**														
6.1	Conclusion														
6.2	Recomendation														
Final Report Submission															
Final Presentation															

Appendix C Parts Dimension

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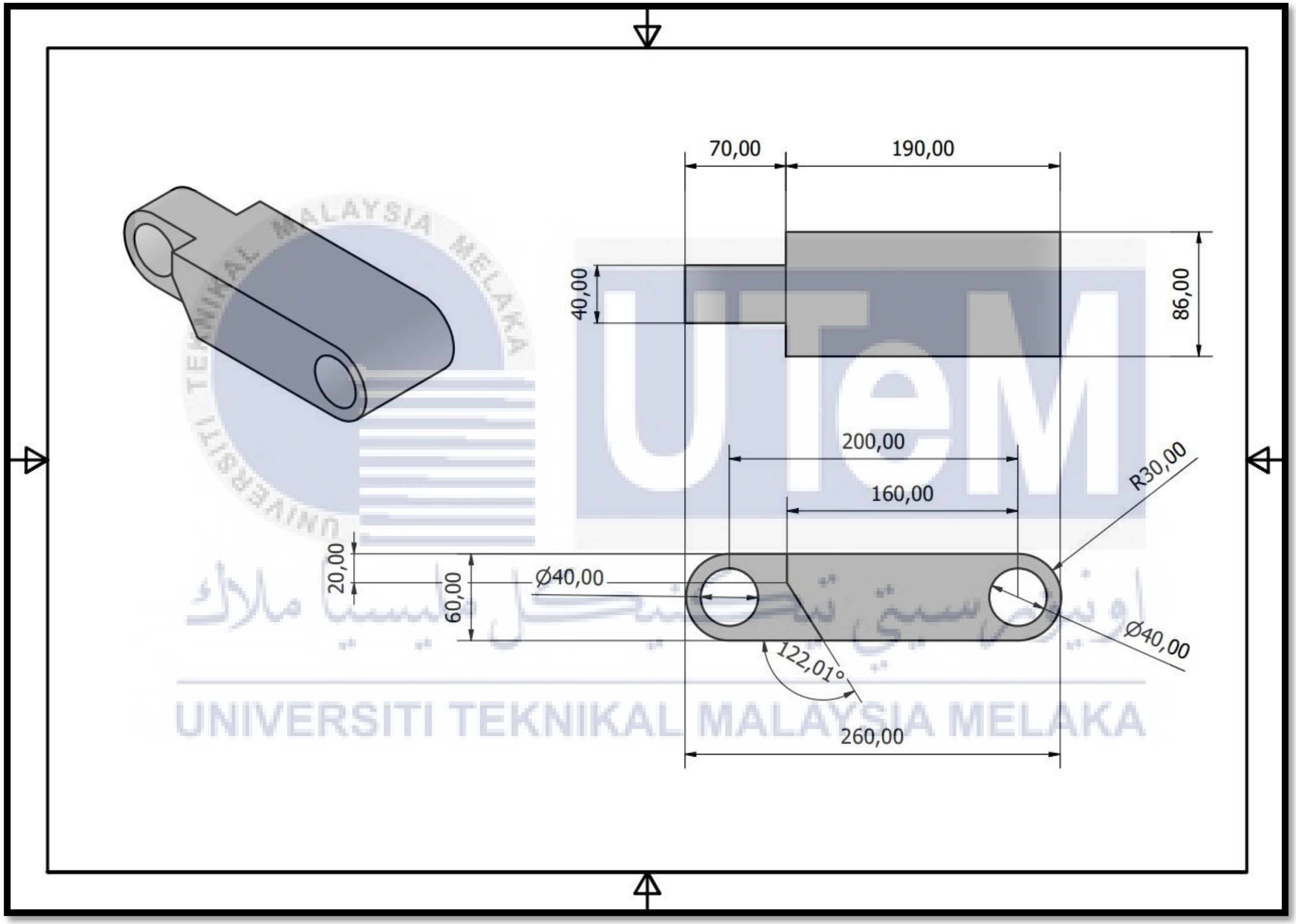
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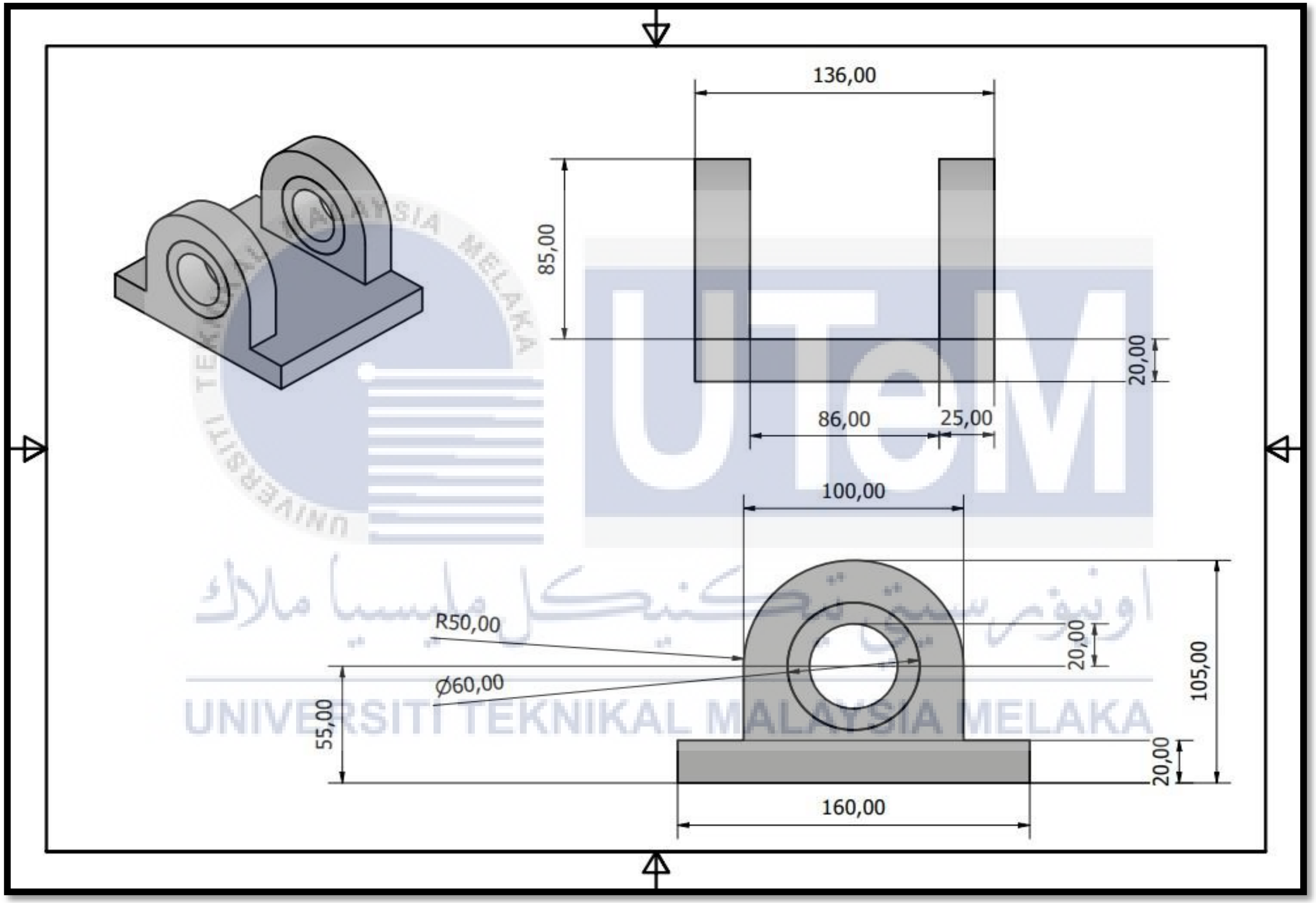
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Appendix D Turnitin Report

MUHAMMAD ARIF SYAMIM BIN MAZLAN

ORIGINALITY REPORT

7%	6%	2%	5%
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