Faculty of Industrial and Manufacturing Technology and Engineering

DESIGN AND ANALYSIS OF SABIT TERAS PREMIUM

Nur Liyana Binti Fadzil

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Disahkan oleh:

Alamat Tetap: 341 Jalan Dutamas Seroja
Taman Segambut
51200 Kuala Lumpur.

Cop Rasmi:
TS. DR. SAIFUDIN HAFIZ BIN YAHAYA
Ketua Program Sarjana Kerja Kursus / Mod Campuran
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
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Signature :

Name : NUR LIYANA BINTI FADZIL

Date : 19 January 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of supervisory committee is as follow:

Signature :

Name : TS. DR. SAIFUDIN HAFIZ BIN YAHAYA

Date : 19 January 2024

DEDICATION

Special dedicated to my dear parents, Mr. Fadzil Bin Ibrahim and Mrs. Rohani Binti Omar for granting me moral support, compassion, inspiration and patience in helping me physically and emotionally. Thank you to my precious siblings, respectable lecturers and other mates for all the encouragement, guidance and supportive in accomplishing my final year project.

Thank you for everything.

ABSTRAK

Sabit merupakan alat pertanian tradisional untuk menuai tandan buah kelapa sawit, biasanya terdiri daripada bilah logam melengkung dan pemegang kayu pendek. Sabit Teras Premium produk rekaan Teras Tegas Argotech Sdn. Bhd. mempunyai memberi kecekapan penuaian dan keselesaan pengguna. Tujuan penyelidikan ini adalah untuk mereka bentuk semula sabit bagi mengoptimumkan kelengkungannya, sekali gus meningkatkan kecekapan dan prestasi pemotongan. Penyelidikan mendalam mengenai reka bentuk Sabit Teras Premium yang sedia ada, yang difokuskan pada kelengkungan bilah, telah dijalankan dengan menggunakan pendekatan kejuruteraan terbalik dan pemodelan 3D dalam SolidWorks. Teknik Analisis Statik Linear dan Analisis Dinamik telah digunakan. Analisis Linear Static menggunakan Simulation Xpress telah dilakukan untuk menilai anjakan, tekanan, dan faktor keselamatan. Oleh itu, dengan data yang diperoleh daripada faktor keselamatan, digunakan untuk mencari keletihan menggunakan Kaedah Interpolasi Newton dan ia menunjukkan reka bentuk yang diperbaiki mempunyai keletihan yang lebih tinggi berbanding yang sedia ada. Sementara itu, Analisis Dinamik dilakukan oleh ANSYS (FLUENT) untuk menunjukkan kelajuan, tekanan, dan kelikatan yang dikenakan ke atas sabit, memberikan maklumat tentang jangka hayatnya. Semasa penilaian ini, kedua-dua reka bentuk sabit sedia ada dan yang diperbaiki telah tertakluk kepada pelbagai keadaan beban yang mensimulasikan daya penggunaan sebenar dan keletihan. Keputusan menunjukkan bahawa reka bentuk sabit yang diperbaiki mengatasi yang sebelumnya dari segi analisis linear static dan dinamik, menunjukkan kecekapan, prestasi, dan ketahanan yang lebih tinggi. Kaedah pengesahan, yang termasuk pengukuran Pekali Variasi (CV) dan Kecekapan Reka Bentuk (DE), mengesahkan bahawa reka bentuk sedia ada dan yang diperbaiki menunjukkan reka bentuk yang dioptimumkan mencapai kapasiti maksimum, meningkatkan ketepatan pemotongan dan meminimumkan usaha pengguna.

ABSTRACT

The sabit, a traditional agricultural instrument for harvesting oil palm fruit bunches, is normally made out of a curved metal blade and a short wooden handle. The current Sabit Teras Premium by Teras Tegas Argotech Sdn. Bhd. has gives harvesting efficiency and user comfort. The goal of this research is to redesign the sabit in order to optimise its curvature, hence improving cutting efficiency and performance. An in-depth investigation of the existing Sabit Teras Premium design, focused on blade curvature, was carried out utilising a reverse engineering approach and 3D modelling in SolidWorks. The techniques of analysis Linear Static, and Dynamic were used. Linear Static Analysis using Simulation Xpress been done to assess the displacement, stress and safety factor. Hence, with data get from safety factor used to find the fatigue using Newton Interpolation Method and it show the improvement design had higher fatigue than existing. Meanwhile, Dynamic Analysis done by ANSYS (FLUENT) to indicate the velocity, pressure, and viscosity exerted on the sabit, providing information about its lifespan. During these assessments, both existing and improvement sabit designs were subjected to varied loading situations that simulated actual usage forces and fatigue. The results showed that the improvement designs of sabit outperformed the previous one in terms of linear static and dynamic analysis, showing higher efficiency, performance, and durability. The validation method, which included Coefficient of Variation (CV) and Design Efficiency (DE) measurements, confirmed that existing and imprvement design shown the optimised design achieves maximum capacity, enhancing cutting accuracy and minimising user effort.

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LIST OF ABBREVIATION

2D	- Two Dimensional
3D	- Three Dimensional
DE	- Design Efficiency
CAD	- Computer Aided Design
CFD	- Computational Fluid Dynamic
CV	- Coefficient Variation
FEA	- Finite Element Analysis
FEM	- Finite Element Method
FLUENT	- ANSYS Fluid Flow
FVM	- Finite Volume Method
S_f	- Safety Factor
FFB	- Fresh Fruit Bunches
CFD	- Computational Fluid Dynamics

CHAPTER 1

INTRODUCTION

In this Chapter 1, the study is separated into five main subtopics. Starting with the background of th study, the problem statement briefly describes the study'sobjective. Furthermore, the scope and significance of the study is listed as well and Chapter 1 closes with the report organization.

1.1 Background of the Study

Palm oil, produced from the fruit of the oil palm tree or scientific name Elaeis guineensis (Saleem et al., 2022; Urugo et al., 2021) as shown in Figure 1.1, is the most frequently used vegetable oil globally, accounting for around 35% of global vegetable oil production in 2020 as mentioned by Goh (2022). Its popularity arises from its adaptability, affordability, and great yield. Palm oil is one of the most commonly used vegetable oils in the world today. Palmoil as shown in Figure 1.2 is a product of oil palm and a necessary domestic commercial productthat is consumed for diverse applications. Palm oil is found in a large diversity of items, including food such as cooking oils, margarine also cosmetics and biofuels.

Figure 1.1: Elaeis Guineensis Tree (Saleem et al., 2022)

Figure 1.2: Palm oil fruits (Urizar, 2022)

Figure 1.3 shows instances of under-ripe on the left, ripe or mature on the middle and over-ripe on the right palm oil fruit bunches. The maturity of palm oil fruit bunches can be determined simply by looking at the fruit's color. The fruit's develops from a blue-black to dark-red when ripening. Another indicator used to determine a matured palm oil bunch mention by (N. A. Mohd Basir Selvam et al., 2021) is the duration of time a matured bunch usually requires to completely ripen. It can take around 20 to 22 weeks for a bunch of fruits to mature. Typically, there could be 5 to 6 developed bunches on the tree ready to harvest.

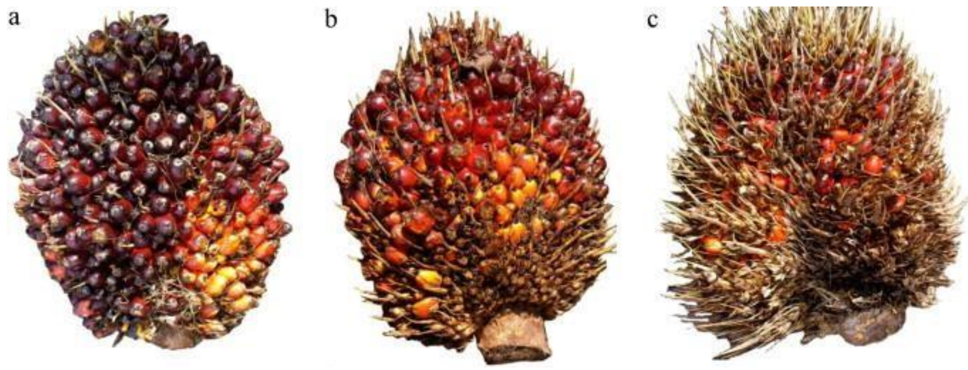

Figure 1.3: Under-ripe, ripe or mature and over-ripe palm oil fruit bunch (left to right)(N. A. Mohd Basir Selvam et al., 2021).

Palm oil revenue has expanded substantially over the past 50 years (Austin et al., 2019; Ostfeld et al., 2019). In 1970, the globe was manufacturing only 2 million tonnes. The figure now increases 35 times higher since in 2018 the world produced 71 million tonnes (Pendrill et al., 2019). Meanwhile, in 2017, according to Tan and Lim (2019) palm oil officially became one of the main and most significant vegetable oil sectors worldwide. The changein production worldwide appears in the Figure 1.4 below shown increasingin palm oil industry from 2000 to 2020 stated by Ritchie (2024).

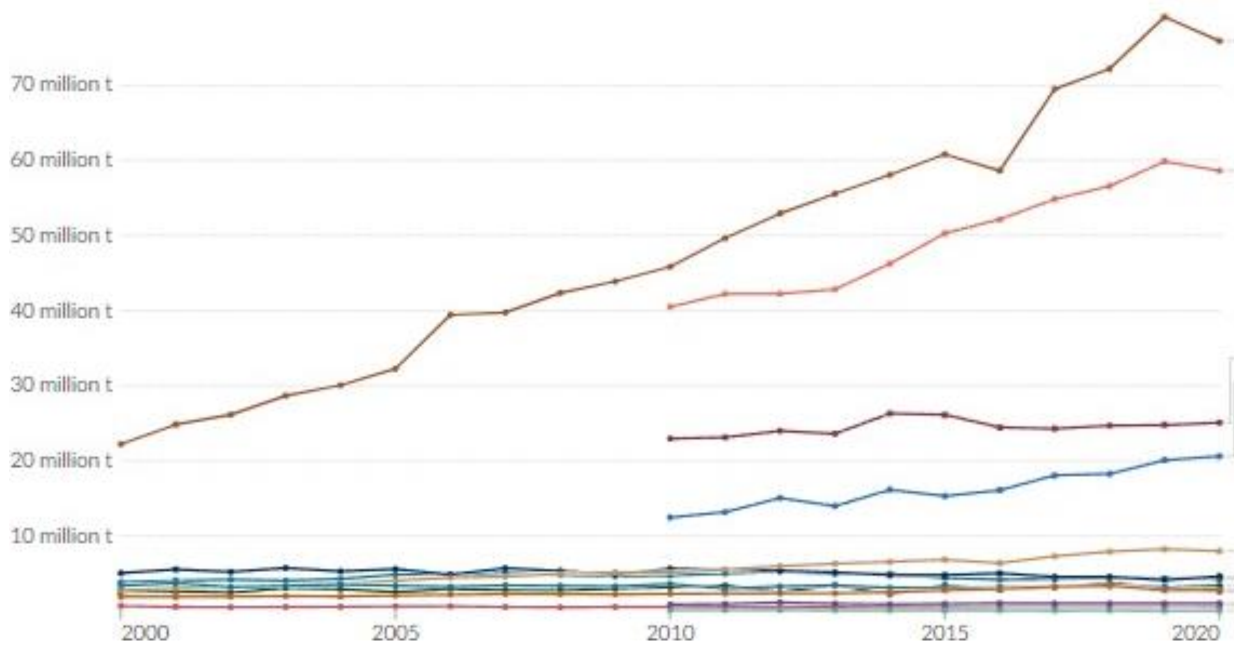

Figure 1.4: Change in Production of Palm Oil Industry since 2000 to 2020 (Ritchie, 2024)

The production of oil palm contributes significantly to hiring and investment opportunities for individuals. The palm oil-based products are placed second of Malaysia's growth revenue after petroleum-based products. Since palm oil is a recyclable resource, the value of palm oil became very apparent and the palm oil tree plantation is hugely developed in Malaysia. Besides that, (Tan and Lim, 2019) (Abubakar et al, 2021) amongall nations, the biggest and second-biggest suppliers of palm oil are Indonesia and Malaysia, exporting more than 90% of their production of palm oil, providing approximately 80% of the world's palm oil.

As a result, there is an increasing need for large manpower in the plantation sector to maintain pace with the substantial level of output in the country. The precise number of palm plantation workers in Malaysia is challenging due to the industry's widespread nature and the majority of workers being engaged in small-scale and informal plantations as mentioned by Abdullah et al. (2023).

The estimated number for the palm plantation workers in Indonesia in 2019 was 4.42 million (Abdullah et al., 2023). The large manpower in palm plantations is indicative of extensive human engagement and physical labor. Although automated cutting instruments are readily accessible, their poor utilization in the sector can be attributed to the substantial maintenance expenses associated with them. Meanwhile, traditional cutting instruments resembling the chisel and sickle are often employed by palm workers to harvest fresh fruit bunches. During the process of harvesting, the harvester will first remove the fronds in order to prevent the cutting instrument from coming into contact with the fresh fruit bunches. Figure 1.5 illustrates the process to harvest a palm oil bunch. The distance from the harvester and the palm oil bunch is considerable and it is fairly hard to tell whether the fruit bunch is either ripe or under-ripe.

Figure 1.5: The process to harvest a palm oil bunch (Tan and Lim, 2019)

Most harvesters still rely on traditional methods to harvest palm oil bunches. This approach demands a lot of energy and knowledge in detecting the ripe palm oil bunch. Present techniques involve the use of a chisel or sickle as shown on Figure 1.6 which needs human labor and is repeated. Knowledge and energy are required to achieve successful cutting. The palm oil harvesting procedure with a sickle contains a sequential sequence of phases.

Figure 1.6: Traditional Sickle and Chisel for Harvesting (Ramli et al., 2020)

A palm oil sickle is a specific cutting tool utilized for harvesting oil palm fruit. There are many sorts of palm oil sickles available, in various sizes and types, allowing harvester to buy up on the most important item for oil palm harvesting. These sickles are normally produced from high-quality steel, formed to shape, heat-treated, and then sharpened by experienced craftsmen to achieve an ideal cutting edge. The main purpose of a palm oil sickle is to cut and collect both ripe and fresh fruit bunches from the oil palm while preventing damage to the fruit or the tree. An excellent sickle is required to ensure the most return from the produced fruit bunches. Numerous manufacturers and suppliers are producing a range of palm oil sickles customized to fulfill the special requirements of oil palm harvesting. These sickles are designed with a curved blade and a small handle for ease of use in the palm oil plantation.

Furthermore, companies like Teras Tegap Agrotech Sdn. Bhd. (TTASB) in Malaysia develop and provide a wide range of sickles, chisels, hooks and more as shown on Figure 1.6 designed for plantation requirements, highlighting the importance of cutting-edge performance in harvesting oil palm equipment for a successful harvest.

Figure 1.7: Teras Tegap Product

The cutting force necessary to cut palm fresh fruit bunches and fronds varies on the size and maturity of the bunches and fronds, cutting procedures, and the cutting tool utilized. The high cutting strength demands the harvesters to exert the corresponding hand forces for cutting the fronds, resulting in substantial physical exertion that might lead to fatigue. Meanwhile, the harvesters must exert the cutting force manually and multiple cutting attempts are required to cut a frond or fresh fruit bunches in the actual palm environment. High physical effort is needed to handle the cutting tool, considering the tool's weight and the required cutting force. Furthermore, the harvesters are exposed to harsh ergonomics and repetitive cutting action when manipulating the cutting tool and chopping down the fresh fruit bunches. The extreme discomfort can have resulted fromspine loads, which produce vertebral stress and lead to numerous back problems as indicated by Glowinski et al. (2021).

1.2 Problem Statement

The study on the curvature of palm oil sickles is rather limited compared to studies focusing on the material composition and sharpness of these essential harvesting tools noted by Ling etal. (2014). While there has been outstanding focus dedicated to the creation of durable materials and the preservation of sharp cutting edges, the delicate characteristics of sickle curvature have been ignored in the current literature. This gap in study constitutes a serious restriction, as thecurvature of the sickle plays a vital role in the overall efficiency and precision of palm oil harvesting. Addressing this gap through a detailed examination of the curvature of palm oil sickles is crucial to unleash possible improvements in harvesting procedures and increase overall efficiency in the palm oil industry.

Although the agricultural product is efficiently harvested by the palm oil sickle now in use, there is plenty of opportunity for improvement. The study has indicated that there is a need for development in areas like improved curvature, sharpened cutting edges, and refined designs (Barakat and Squires, 2023) among other things. Resolving these issues could result in significant increases in harvesting efficiency. Consequently, this could lead to higher output and possibly lower labour requirements. We can increase the efficiency of the palm oil harvesting process to a new level by focusing study efforts on sickle optimisation.

The current problem lies in the lack of a systematic comparison of the *Sabit Teras Premium* and other sickles, specifically in terms of their curvature and harvesting performance. The absence of a full review impacts the identification of potential vulnerabilities in the other *sabit* design and the measurement of potential enhancements supplied by the new design. To fill this gap, there is a need for a thorough analysis using Linear Static, Fatigue and Dynamic studies to compare the curvature-related parameters and overall harvesting performance of the two *sickles*. This study seeks to provide significant insights into the efficacy of the novel design, establishing a platform for informed decision-making and prospective upgrades in palm oil harvesting procedures.

1.3 Objective of Study

The objectives for this study are stated below;

I. To identify the properties of *Sabit Teras Premium* by focusing on curvature using near Static Analysis, Fatigue Analysis.

II. To redesign the *Sabit Teras Premium* in terms of improving its optimal curvature to extensively improve the efficiency of harvesting.

III. To conduct a comparison of the improvement and existing *Sabit Teras Premium* in terms of harvesting performance, applying Linear Static Analysis, and Dynamic Analysis.

1.4 Scope of Study

This study is exclusively focused on the *Sabit Teras Premium* and precisely explores the curvature properties of both new design and existing *Sabit Teras Premium* will be performed, considering elements such as blade shape, curvature radius, and overall geometry. The primary emphasis is on conducting design modelling using SolidWorks. Furthermore, three sorts of technique assessments, including deformation tendencies under various loading circumstances using Linear Static Analysis and examining the vibrational behavior and for fatigue analysis to calculated the safety factor to ensure the *Sabit Teras Premium* design in safety mode. Next, for fatigue analysis is to study about the maximum lading to ensure the design is safe to fabricated and used. While, for dynamic responses using Dynamic Analysis, will be applied to completely examine *Sabit's* performance under different circumstances. Additionally, the study extends to design optimization, seeking to assist in the selection of the ideal design from a varied range of characteristics. This comprehensive strategy enables a full assessment of the *Sabit Teras Premium's* design, concentrating on both its geometry and performance, with the ultimate goal of boosting harvesting efficiency.

1.5 Significance of the study

The result of this study will redound to the benefit of harvester and *Sabit TerasPremium* user considering some proper ways that play a vital function in current modern days. Optimum curvature profile concept for this study will be focusing more on *sabit's* blade design in term of its attributes. A curved *sabit's* blade can better fit to the shape of palmoil bunches, allowing for easy cutting with less force compared to a straight blade. This lowersfatigue and enhances harvesting efficiency.by recognising these parameters and applying computational modeling and testing, it can build *sabit's* blades with curvature profiles that maximize cutting efficiency across varied applications.

Both design models of existing and improvement will be analysed by using linear static, fatigue, and dynamic analysis. With the right computation of displacement and pressure due to the static load, linear static analysis emits. The benefit that would be achieved from Linear Static analysis is the more prevalent deflection of the s*abit's* blade burdens, which givesthe *sabit* additional assistance while harvesting. It is more effective for higher load situations.

Fatigue is one of the methods of analysis where it takes took place due to the continuous application of pack and should be at a flat surface of the yield point and safety factor, Sf will be evaluated using appropriate tools. Fatigue analysis is useful by employing some appropriate approach for the reliability design of a *sabit* and fatigue life of *sabit*. Dynamic analysis of the s*abit's* blade design can increase the ability to harvest with less energy.

To ensure the design is valid, Design Efficiency (DE) and Coefficient of Variation (CV) will be used as standards for this study. The goal of Coefficient of Variation (CV) is to determine the stability of the improvement design. For the outcome, the larger the value of Coefficient of Variation (CV), the bigger the value of dispersion. However, Design Efficiency (DE) measures all approaches to optimize the design so that maximum capacity can be delivered.

1.6 Report Organization

Chapter 1 represents the study's introduction. This report begins by explaining the background of the study, problem statement and its objective, the study's significance, and report organization. Beginning with the basis of the study will clarify the structure of *Sabit Teras Premium* and its blade feature. Moreover, the discussion concerning the problem related to the previous *Sabit Teras Premium* will be clearly presented. The significance of the study continues in this chapter where the importance of curvature profile for *sabit* to the customer will be illustrated.

Chapter 2 cover on the background and facts about the existing *Sabit Teras Premium*, features and analysis. Furthermore, the history and variants of *sabit* contour design will be discussed in this chapters. This chapter will begins with the definition of *sabit's* blade and essential of ideal curvature profile on blade side. The explanation of the concept of curvature that is placed on *sabit's* blade contour also will be discussed in this section. The next subtopic will be followed by the overview of the *Sabit* and its feature in *sabit* terminology. Beyond that, its advantages include maximising the use of *sabit* in harvesting industry. The materials of the *sabit* that is used will also briefly explained.

Chapter 3 elaborates method involving the process flow chart and methodology of this study. This chapter will offer an introduction to the existing *Sabit Teras Premium*. Furthermore, the process flow diagram of developing the *sabit's* blade design for both existing *sabit* and improvement *sabit* design will be discussed in this chapter. Both 2D and 3D design models will be constructed by using SolidWorks Software and analysis of simulation which is linear static will be obtained for both design models. The process flow diagram for linear static, fatigue and dynamic analysis will be discussed in this chapter. For linear static analysis radiates with the correct calculation of displacement and stress due to the variations of static load using Simulation Express on SolidWorks. Hence, for dynamic analysis, by utilizing Ansys (FLUENT) software is used to test all concept models by knowing their pressure, velocity and viscosity. Meanwhile, Newton Interpolation Polynomial is used as a fatigue predictor to estimate the fatigue life of both design models and this method is utilised for fatigue analysis. During validation process, Design Efficiency (DE) and Coefficient of Variation (CV) will be applied for both existing *sabit* and improvement sabit design.

Chapter 4 describes the findings and result of the Linear Static analysis and Fatigue analysis. This chapter states about the outcomes and the comments based on the result that have been achieved. The Linear Static analysis will be undertaken by utilising Simulation Express by Solidworks Software to determine the Von Mises stress and displacement on both existing and improvement design of *sabit* models. Besides that, Newton Interpolation method is used for computing the initial pressure and safety factor value. Then, the design optimization for both models will be calculated. However, design validation process for both design models will be established by computing the Design Efficiency (DE). The reason for discovering the conversation will be presented in this chapter.

Chapter 5 presents dynamic analysis where the design model for both existing *sabit* and improved *sabit* design is analyse by utilising Ansys (FLUENT) software. Ansys (FLUENT) software applies to meet the requirement of this study by considering the velocity, viscosity and pressure in moving mode. Materials that have been picked will review existing design models as well as enhancements design models. Afterwards, calculated the safety factorto verify the design was in safety mode. The design validation for both design models will be calculated by computing the Coefficient of Variation (CV).

Chapter 6 reveals about the results and recommendation regarding all aspects of the study. This chapter outlines the conclusions in which it would be known at the end ofthe study to determine if all of the objectives havebeen encountered. An insight will established on the study of the curvature based on the outcome of analysis from the previous chapter. The comparison of existing *sabit* and improvement *sabit* design with their respective specification will be employed as supporting evidence for judging whether or not the aims have b een attained. In addition, the study relevant to the idea for recommendation will be recognised based on the results acquired for future study through the technique of analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

2.1.1 Palm Oil

Palm oil is a globally predominant edible oil, primarily produced by Indonesia and Malaysia, which are the top producers (Alamanda, 2023; Urizar, 2022). Palm oil is a widespread and extremely valuable product utilized in diverse sectors such as food, cosmetics, and biofuel production (Zahan and Kano, 2018) because rich in phytonutrients and minerals (Achaw and Danso-Boateng, 2021). Palm oil fulfils 40% of the global requirement for vegetable oil stated by Syed Hilmi and Ibrahim (2022). Palm oil is a highly widespread and commonly consumed vegetable oil that is. It serves as a primary substance in several sectors.

Palm oil originates from the pulp of the oil palm fruit known as Elaeis guineensis (Saleem et al., 2022; Urugo et al., 2021). Sehgal and Sharma (2021) stated that palm oil is derived from the soft flesh of the palm fruit and contains a high concentration of saturated fatty acids and bioactive compounds.

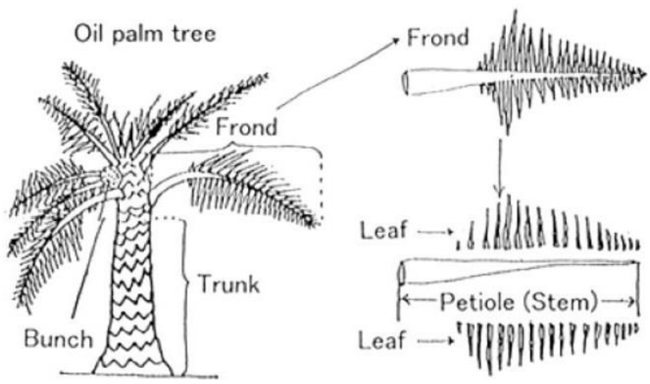

Figure 2.1: Anatomy of an Palm Oil Tree and Palm Oil Frond (Hamdan et al., 2012)

2.1.2 Important and Purpose of Palm Oil

Palm oil is a significant edible oil with diverse benefits. It has a high amount of phytonutrients, including tocotrienols, tocopherols, and carotenoids, which are responsible for its distinctive nutritional characteristics (Abasubong et al., 2023). Palm oil is renowned for its stability, making it ideal for extending the shelf life of food (Saleem et al., 2022). Furthermore, palm oil has been discovered to possess promising health advantages, such as the ability to prevent cardiovascular illnesses, diabetes, obesity, and cancers noted by Mayes (2020).

In addition, palm oil can be used for formulations made from lipids and drug delivery systems to enhance the bioavailability, solubility, and stability of medications (Efendy Goon et al., 2019). Urizar (2022) mentioned the oil palm tree, which is the source of palm oil, is an exceptionally productivecrop that contributes significantly to global vegetable oil output. In general, palm oil is essential in nutrition, the food business, and the biodiesel sector, and its use providesflexibility and advantages in several applications.

2.2 History of Harvesting

2.2.1 Harvesting for Palm Oil

The harvesting process of palm oil comprises the cutting down of FFB from the palm trees (Sunggara et al., 2023). The current harvesting procedure generally involves human effort, which can be labor-intensive and may cause injuries or damage to the FFBs (Chen et al., 2022). To overcome these challenges, there is a requirement for a separate harvesting system that can recognise and localize the FFBs (Escallón-Barrios et al., 2022). Harvesting forpalm oil includes several issues. The timing of the harvest is essential for the quality of the oil. Ripe fruits generate higher-quality crude palm oil mention by Akbar et al. (2023). Manual picking of oil palm FFBs can be labor-intensive and may cause injury or damage to the FFBs. According to Akbar et al. (2023) deal harvest time is till the sixth day after fruit detachment or separated. Alongside that, the quality of oil palm fruit depends on detachment percentage and plant age. This study done by estimating the time of the harvest cycle and the number of loose fruits.

Figure 2.2: The Pole Unit for Sickle (Silky Hayauchi 3.7m Telescopic Pole Saw (177-39) - Forestry Tools, 2024)

Traditionally, sickles have been employed for this function. However, there is a need to adapt the sickle for enhanced efficiency and productivity in palm oil harvesting. Harvesting oil palm trees using a sickle can be done in a step-by-step method. The initial stage is to attach a sickle unit to a pole unit, which can be adjusted to reach different heights of the tree (Aliuddin Bakar et al., 2018). The pole unit as shown on Figure 2.2 above is coupled to a reciprocating means unit, which provides the reciprocating motion needed for harvesting and pruning (Rahman et al., 2017). That begins with identifying ripe fruits by using the sickle to carefully cut down ripe palm oil fruits from the palm tree. The curved blade of the sickle enables for precision cutting and reduces damage to the fruit bunches. Next, trimming the palm fronds with palm oil sickles. This helps to maintain the health and productivity of the palm trees. Lastly, collecting the fruit bunches that are chopped down and transfer to the processing facility.

2.2.1 Evaluation Tool for Harvesting

Sickle harvesting tools play a key role in agricultural procedures, particularly in the harvesting of crops such as wheat, rice, and barley. The history of sickle harvesting tools as shown in Figure 2.3 is an issue that has drawn important interest in the field of archaeology. The efficacy and reliability of these technologies directly impact the productivity and quality of the harvest.

Figure 2.3: Old Sickle for Harvesting (Sickle, 2018)

One of the oldest sources of evidence for the usage of sickle harvesting tools comes from the Ohalo II locations in Northern Israel (Nelson et al., 2013) identified composite wheat harvesting tools, particularly flint blades, at this location. These tools were used for harvesting near-ripe semi-green wild wheat. The wear marks on the implements indicate that they were not used continuously and reflect two harvesting modes which are flint knives held by hand and inserts hafted in a handle. This finding provides vital insights into grain harvesting techniques that existed 8,000 years before the Natufian and 12,000 years before the formation of sedentary farming civilizations in the Near East.

While the discovery at the Ohalo II camp sheds information on the early use of sickle harvesting tools, there are still significant knowledge gaps that demand additional inquiry. Firstly, the particular approaches and methodologies applied in the employment of these technologies remain unclear. Future studies could focus on experimental archaeology to reproduce and understand the precise mechanics of sickle harvesting during this historical period. Additionally, the socio-cultural implications of the development and use of sickle harvesting equipment are not properly studied. Investigating the impact of these technologies on the organization of labor, settlement patterns, and food production systems would provide a more thorough understanding of their relevance in ancient cultures.

Moreover, the study findings presented above mostly focus on the employment of sickle harvesting tools in the Near East. There is a need for comparison studies across different locations to determine the distribution and adoption of these technologies in other parts of the world. Such study could shed insight into the diffusion of agricultural practices and technological developments connected to sickle harvesting.

In outcome, the study findings on the history of sickle harvesting tools reveal the early employment of composite wheat harvesting tools at the Ohalo II site in Northern Israel. These findings provide insights into wheat harvesting processes that lead to the formation of sedentary farming populations. However, there are still research gaps regarding the specific procedures, socio-cultural ramifications, and global proliferation of sickle harvesting equipment. Future study should try to address these gaps to better expand our understandingof the history and significance of sickle harvesting tools.

2.2.1.1 Harvesting in Malaysia

Beyond that, Zahid-Muhamad et al. (2018) investigate the current state of oil palm harvesting and highlight the transition from manual methods to more effective and mechanized approaches. They highlight the relevance of mechanization in enhancing productivity and lowering manpower requirements in the palm oil business. Saibani et al. (2015) conducted time and motion study on hand harvesting methods for oil palm fruit bunches in Malaysia. Their findings provide insights into the efficiency and usefulness of traditional manual harvesting procedures.

The traditional methods utilized for harvesting palm oil have been a subject of study in the literature. Osei-Amponsah et al. (2014) evaluate the handicraft processing industry in Ghana and examine the institutional changes that have influenced the quality of palm oil. Their study underscores the significance of conventional processing methods and the necessity for updated processes to boost the quality of palm oil. Additionally, Zahid-Muhamad et al. (2018) address the traditional methods of harvesting palm oil and underline the significance of knowing these practices in order to build appropriate mechanized technologies.

2.3 Evaluation of *Sabit*

A palm oil sickle is a specifically designed cutting implement utilized for the purpose of gathering oil palm fruit. Various sizes and styles of palm oil sickles are available, enabling clients to conveniently get this indispensable tool for oil palm harvesting. The sickles are commonly crafted from premium-grade steel, shaped through forging, subjected to heat treatment, and meticulously honed by skilled artisans to guarantee a precise cutting edge. The main purpose of a palm oil sickle is to harvest both mature and young fruit bunches from the oil palm tree without inflicting any harm to the fruit or the tree itself. An excellent sickle is crucial for maximizing the profitability of the harvested fruit bunches. a range of palm oil sickles customized to fulfill the special requirements of oil palm harvesting.

Multiple manufacturers and suppliers offer a variety of palm oil sickles that are specifically built to satisfy the unique needs of harvesting oil palm. These sickles are specifically engineered with a contoured blade and a compact grip to facilitate effortless utilization in the palm oil plantation.

In addition, companies such as Teras Tegap Agrotech Sdn. Bhd. (TTASB) in Malaysia produce and distribute a comprehensive selection of sickles, chisels, axes, and hooks specifically designed for the needs of plantations. They prioritize the significance of advanced performance in the tools used for harvesting oil palm, which is crucial for achieving a good harvest. Therefore, there is a need to continuously improve and modify sickle harvesting tools to boost their effectiveness and address constraints. This literature study attempts to consolidate existing study findings related to the redesign of sickle harvesting instruments and propose relevant future study topics.

2.3.1 Introduction of *Sabit Teras Premium*

Sabit Teras Premium, offered by Teras Tegap Agrotech, is an innovator in agricultural innovation Figure 2.4. *This Sabit Teras Premium* elevates the physical challenge with its well-constructed blade, created for outstanding efficiency and user comfort.

Figure 2.4: Sabit Teras Premium by Teras Tegap Argotech (Sabit Teras Premium Pakej A | Shopee Malaysia, 2024)

Highly constructed with a particularly curved blade, the *Sabit Teras Premium* provides clean, effortless cuts through even the toughest palm fronds and fruit bunches. Its ergonomic handle enables a comfortable grip, eliminating tiredness and strain during extended harvesting periods. Teras Tegap Agrotech, famous for its commitment to quality and craftsmanship, has poured its expertise into every detail of the *Sabit Teras Premium*. Invest in this quality tool and experience the difference great design can make palm oil harvesting.

2.3.2 Material used for *Sabit Teras Premium*

The comparison of different materials showed that spring steel is the best choice due to its structural strength and resistance to breaking undercutting force (Ozturk et al., 2018). The most suitable material for a palm oil sickle is spring steel, as it has the least structural distortion and can take immense strain without breaking according to (Ramli et al., 2020). Although aluminum is the lightest option, it is prone to corrosion (Noordin et al., 2016).Another material, SUP 9a, has been identified as acceptable for sickle blades, with an ultimate hardness of roughly 55HRC (Groman-Yaroslavski et al., 2016). Additionally, a newly created spring sickle pole called ZappIt® has been designed employing an aluminum pole. In terms of employing palm oil fuel ash (POFA) as a material, grinding it to a smaller particle size increases its quality and makes it appropriate as a pozzolanic material for cement substitution (Fullagar et al., 2021). Overall, spring steel and SUP 9a are the suggested materials for palm oil sickles.

However, Teras Tegap Agrotech selected SUP 9a as its material for their *Sabit Teras Premium*. SUP 9a also known as AISI 5160 Alloy Spring Steel has various benefits for the use of palm oil sickles. Firstly, AISI 5160 Alloy Spring Steel offers excellent resistance to corrosion, rust, and discoloration, making it suited for applications utilizing palm oil which can be corrosive (Surinlert et al., 2021). Additionally, AISI 5160 Alloy Spring Steel can be hardened to increase its surface hardness, which is critical for sickles that need to withstand wear and tear (Muhammad et al., 2015). Furthermore, spring steel has been observed to have decreased wear when sliding against cast iron in the presence of palm- biodiesel fuel, showing its good performance in such situations (Carmona-Hernandez et al., 2020). Lastly, AISI 5160 Alloy Spring Steel offers strong corrosion resistance and low-temperature hardness, making it acceptable for usage in H2S-containing conditions, which can be found in palm oil processing (Carmona-Hernandez et al., 2019).

2.3.3 Structure of Sabit Teras Premium

Sickle classified into two classes which is plain on outer blade and serrated on inside blade as stated in Figure 2.5 (Corradi and Munar, 2019; Nelson et al., 2013). Blade is the major metal section of the sickle and is built in a curved shape. It is make the blade made of AISI 5160 Alloy Spring Steel. Meanwhile, the teeth of serrated sickle made sharp for effectiveness in the field. But for Sabit Teras Premium is plain sickle type without the teeth on the blade as illustrated in Figure 2.6.

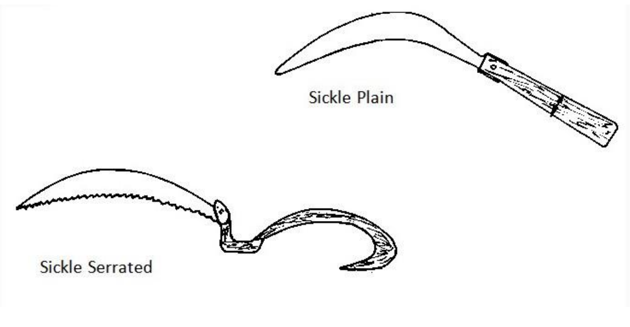

Figure 2.5: Type of Sickle Used for Harvesting (*Farm Machinery and Equipment-II: LESSON 6. REAPER AND REAPER BINDERS*, 2013)

Next, for the handle of the sickle is generally made of well-seasoned wood but for this *Sabit Teras Premium* is built from spring steel that attaches together with the blade as one part. The two holes on handle of *sabit* shown circle on Figure 2.6 is the spots to attach the poleunit or called *Pelanjak Teras* as shown on Figure 2.7. The forged end of the blade for fasteningthe handle is called tang. While, the plain or serrated edge of the inner side of the blade is called tang. Also, the plain or serrated edge of the inner side of the blade is termed cutting edge.

Figure 2.6: Sabit Teras Premium by Teras Tegap Argotech.

Figure 2.7: Pelajak Teras Produced by Teras Tegas Premium (Pelajak Teras | Shopee Malaysia, 2024)

2.4 Sabit Teras Premium's Blade

2.4.1 Effect of Curvature

The optimal curvature profile in design has a considerable effect on plenty of engineering applications. In the case of railway vehicles, an improved wheel profile design can minimize wear and fatigue in curved parts, enhancing running safety and maintenance (Song and Choi, 2022).Similarly, an ideal design technique for asymmetric rail head profiles can decrease wear on curved tracks, boosting the dynamic performance and fatigue life of railways (Choi et al., 2013).

In the field of aerodynamics, a cascade design method based on curvature optimization can reduce aerodynamic losses from non-smooth blade profiles. In the context of gear design, a new design approach using a free-form curve for the gear tooth profile can reduce bending stress and increase performance (Bhil and Singh, 2016). Other researcher Kalnahuz et al. describe a curvature control-based method for optimizing the radial stacking of gas compressor blade profiles, which enhances flow separation and minimises total pressure loss (Kalnahuz et al., 2023). Overall, optimizing the curvature profile in design can lead to increased performance, safety, and durability in many engineering applications. Therefore, curvature on blade of sabit also important in order to increase the rate of harvesting

2.4.2 Important of Curvature of Blade

The curvature of palm oil sickles is essential for effectively harvesting oil palm trees. The design and study of the sickle curvature can greatly affect the efficiency and productivity of the harvesting process. This literature study attempts to consolidate and synthesize the relevant study findings related to the redesign and analysis of the curvature of palm oil sickles. By evaluating the existing literature, this review will identify knowledge gaps and offer prospective future study areas.

Mu and Kazerounian demonstrate that altering the curvature of the blades can produce helpful relationships between input force and output force, resulting to increased cutting performance (Mu and Kazerounian, 2005). Meanwhile, an ideal matching-based technique for evaluating blade section line profile features, which can assist detect faults in the blades and advise additional processing or process optimization (Yang et al., 2015). Method for improving blade profiles utilising an integrated procedure that permits adjustment of the data through macro-functions, enabling users to optimize blade profiles without CAD experience mentioned by Ling et al. (2014).

The curve of the blade on a *sabit* used for palm oil harvesting is absolutely essential. The form of the blade impacts the cutting process and noise generation. A study indicated that *a sabit's* blade having a falciform construction, narrowing from the leg to the head of the blade, lowers noise generated during cutting (Ramli et al., 2020). Additionally, the design of the blade, including the front and rear edges, can effect the flow of fluid and reduce noise. Curved edges and recesses towards the downstream direction of fluid flow serve to decrease noise (Noordin et al., 2016). The substance of the sickle blade is also significant.

2.4.1 Impact of Curvature on Shear

The curvature give impact on shear behavior among many configurations. In the context of bridge engineering, the use of narrow networks in spring steel supports affects shear stiffness and can lead to collapse prior to yielding, thereby sacrificing residual shear strength. In the analysis of peristaltic flow, the existence of curvature in a pipe leads in velocity profiles that are not symmetric about the central line (Shahzadi and Nadeem, 2016). In the study of flame propagation, it is noted that curvature generally slows down flame speeds by smoothing out wrinkled flames (Lyu et al., 2018). Additionally, surface viscosity induces shear flows in incompressible two-dimensional domains when surface curvature changes (Barakat and Squires, 2023).

The curvature of a *sabit* blade has a crucial impact in shear force during palm oil harvesting, influencing both cutting efficiency and user comfort. It is because to shear concentration. The curved contour of the blade operates like a wedge, focussing the delivered force onto a smaller area at the cutting edge. This concentration of energy provides a shearing action, cleanly separating the palm fronds and fruit bunches with less overall effort compared to a straight blade. Compare to a flat knife versus a curved sickle cut through paper, the curved blade will cut cleanly and easier due to the concentrated shear force as mention by (Kalnahuz et al., 2023).

Besides that, the ideal curvature profile also can minimised friction. The curve minimizes the blade's contact area with the substance being sliced. This decreases friction, which consumes energy and dulls the blade. Less friction equates to smoother, cleaner cuts and a sharper blade for a longer duration, decreasing the need for frequent sharpening. A well-designed curve ensures the appropriate angle for efficient shearing.

In conclusion, the curvature of a sickle blade directly effects the shearing motion during palm oil harvesting. By understanding its role in force concentration, friction reduction, cutting angle optimization, and ergonomic design, engineers and designers can develop blades that deliver both efficient cutting and user comfort, contributing to improved productivity and worker well-being in the palm oil industry.

2.5 Summary

Previous study reveals shortcomings in the *Sabit Teras Premium* that limit comfort and effectiveness. Due to its poor curvature, it requires additional labour. Furthermore, the lack of thorough failure point and stress distribution assessments raises safety issues.

A unique redesign and analytical technique is suggested to deal with these problems. Curvature optimization uses cutting-edge techniques to find the best shape for lowest effort and maximum cutting efficiency. Increased tool life can be achieved by investigating substitute materials with better wear resistance and edge retention. Behavioural information and feedback are used to improve blade design, which aims to reduce fatigue and injury hazards. Finally, fatigue and stress analysis will identify possible places of failure, guiding changes to the design to increase safety.

There is a lot of promise in this guided by data and strategy. The *revised Sabit Teras Premium* has the potential to completely transform the palm oil harvesting business by increasing worker well-being, efficiency, and safety through the optimisation of curvature and ergonomic design that improves user experience, and stress analysis that prioritizes safety.

CHAPTER 3

METHODOLOGY

This Chapter 3 shows the type of approach used for the study where it discusses the existing *sabit* design and improvement *sabit* design in terms of their blade curvature. In this chapter, there are two categories of methodologies which is the method of research and the method of analysis. For the method of research, each approach will provided with a processflow diagram where that will clarify every step that is employed in the technique. For the method of analysis, the approach discusses the analysis such as linear static, fatigue, and dynamic. This chapter starts by explaining the method of research in the next part.

3.1 Method of Research

The research scope for this study will be covered with the assiduity of existing *sabit* and improvement *sabit* design. In this study, *Sabit Teras Premium* is chosen as existing design while new curvature on blade is chosen as improvement *sabit* design since it consist of optimum curvature profile design for the study. The design modelling process for both *sabit* will be done by using SolidWorks Software where it is applicable for both 2D and 3D design models by using the available capabilities from the software.

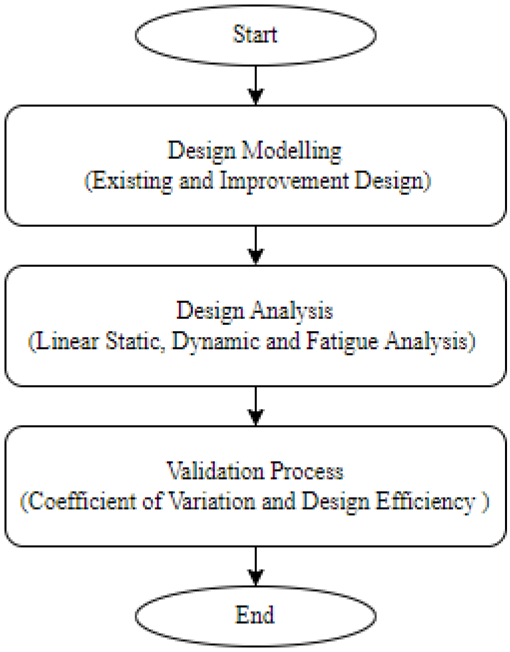

Figure 3.1: The overview of a completed process flow diagram for the study

Figure 3.1 illustrates an in-depth flow chart in this study for both design approaches. This study field will be started with the determination of *Sabit Teras Premium* as the existing design and new curvature on blade as an improvement *sabit* design. It is picked as it satisfies the fulfilment of the *sabit's* blade design for this project. Then, it will continue with the design modelling process via adopt technique reverse engineering to get existing 3D modelling of *Sabit Teras Premium* by starting with capture a clear and decent image of *Sabit Teras Premium*. By utilizing SolidWorks Software such as spline, line, extrude and other characteristics are picked as the appropriate software for the construction of 2D and 3D design models.

Following that, analysis design will represent the following phase of study where design analysis consists of linear static, fatigue and dynamic analysis for both design models. For linear static analysis, Simulation Express by SolidWorks Software and Newton Interpolation Polynomial are employed as methods for evaluating the Von Mises Stress, displacement, and initial load for both design models. Determination of fatigue is one of the statistical procedures in which it arises due to the continuous application of the load and should be at an un-elevated yield point state. The examination is related to the safety factor (Sf) for both design different kinds of existing design and improvement design studied throughout fatigue analysis.

Furthermore, for dynamic analysis is implemented the ANSYS Fluid Flow (FLUENT) module, to simulate all theory simulations by using Computational Fluid Dynamics (CFD) program. Therefore, this study describes the distribution of velocity, pressure and viscosity for existing and improvement design. CFD Analysis is done in three phases, which are pre-processing, processing and post processing. CFD also creates quantitative predictions of fluid-flow phenomena based on conservation rules like mass, momentum, and energy regulating fluid motion. The findings can be evaluated numerically as well as graphically when the problem is solved.

As a result, the study will be continued with the validation process for both existing and improvement model designs. Upon applying Coefficient of Variation (CV) and Design Efficiency (DE). The purpose of Coefficient of Variation (CV) is to determine the stability of the improvement plan. However, Design Efficiency (DE) measures all ef forts to optimize the design so that maximum capacity can be delivered.

3.1.1 Sabit's Blade Design

The sabit's blade in palm oil harvesting tools typically refers to the curved metal component of the tool attached to a short wooden handle, used to cut the oil palm fruit bunches. This curvature plays an essential function in cutting efficiency, allowing for smoother cuts with less force required compared to a straight blade. Beyond that, some curvature helps for better control and less difficult positioning when cutting around the fruit bunches.

The curved profile of the blade operates similarly to a wedge, focussing the delivered force onto a smaller area at the cutting edge. This concentration of energy provides a shearing action, cleanly separating the palm fronds and fruit bunches with less overall effort compared to a straight blade. The curved blade will cut cleanly and more easily due to the concentrated shear force compared to flat knife

3.1.1.1 Existing Design

Sabit Teras Premium is chosen as existing *sabi*t design as shown in Figure 3.2. According to the manufacturer, the *Sabit Teras Premium* offers advantages such as increased cutting efficiency owing to its enhanced blade design. Addition, *Sabit Teras Premium* has high wear resistance and reduced fatigue and injury risk. in the meantime, some users remark that the present blade might not be appropriate for all palm kinds or harvesting conditions due to its curvature on the blade.

Figure 3.2: 2D Image of Sabit Teras Premium

The initial step of creating a 2D sketch is design modelling using SolidWorks software for both 2D and 3D designs. SolidWorks is an engineering software programme for computer-aided design (CAD) that makes it potential to create 3D parts from 2D sketches. The *existing Sabit Teras Premium* models' design modelling begins with 2D design modelling and, finishes with extrude to 3D design modelling using SolidWorks software by utilizing reverse engineering technique

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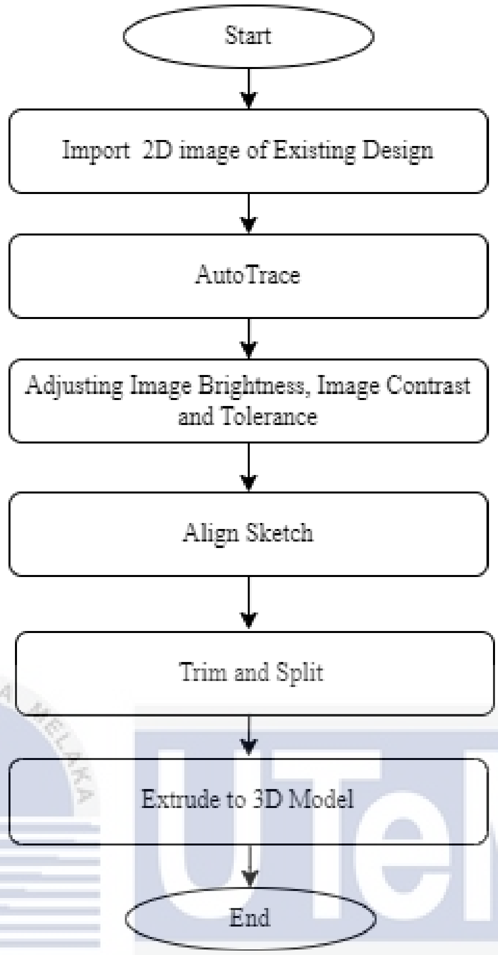


Figure 3.3: The process flow diagram of 2D and 3D design models for Existing Design

In the beginning, the design process as shown in Figure 3.3 is started by selecting a proper picture of Sabit Teras Premium. Transform the 2D image into a 3D model within SolidWorks with AutoTrace. Begin by import a high-resolution image of Sabit Teras Premiumand position it. Following by adjusting AutoTrace's Image Brightness, Image Contrast and Tolerance parameters for exact edge capture and desired sharpness of Sabit Teras Premium as shown below on Figure 3.4.

Figure 3.4: AutoTrace's Feature in SolidWorks

After tracing the picture, evaluate the curves for accuracy, then use editing tools Split and Trim to improve the shape to make sure the line matches with the line on the image of *sabit*. Sketch of *sabit* as shown in Figure 3.5 and Figure 3.6. In order to conclude the 2D sketching, delete all irrelevant and become barriers to the sketching by utilizing 'Quick Trim' entities. Next, click the 'Exit drawing' to Extrude or Pad the traced drawing to construct 3D features with the thickness of *sabit* which is 5mm, adding details like fillets and holes with extra commands. The final 3D sketch as stated in Figure 3.7. Enhance realism with surfaces, materials, and simplicity for optimized analysis or fabrication. Take all the configurations that are required in 2D drawing and click 'OK' to finalize 3D design model. Considering that image quality and manual changes are crucial, and investigating complex plugins could further refine the 3D model creation method.

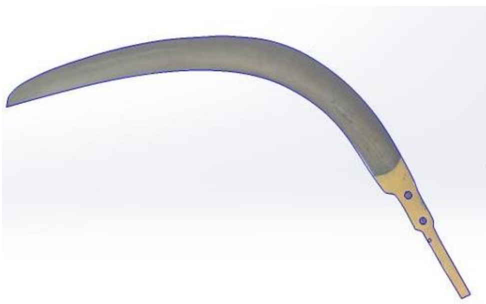


Figure 3.5: 2D Sketch of Existing Design using AutoTrace Features

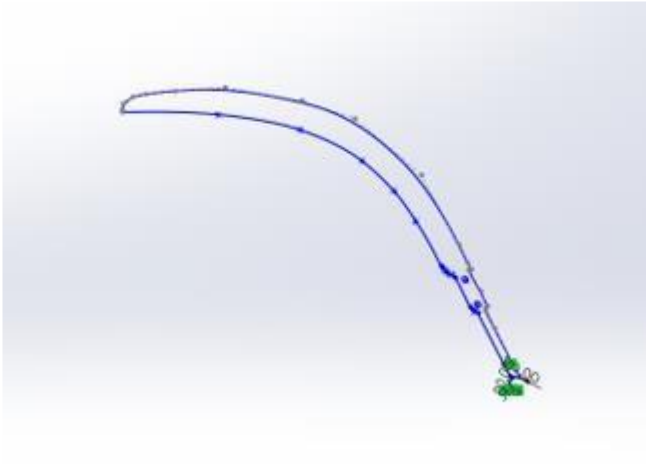


Figure 3.6: 2D Sketch of Existing Design.

Figure 3.7: 3D Sketch of Existing Design

3.1.1.2 Improvement Design

This improvement design involves redesigning the existing blade curvature and replacing it with a new, better curvature profile to enhance *sabit's* blade performance, indicating an effort to improve the blade's design. The optimum curvature profile can assist eliminate drag and increase the overall efficiency by maintaining a continuous and streamlined flow of air. Figure 3.8 reviews the process flow diagram of 2D and 3D design models for improvement design.

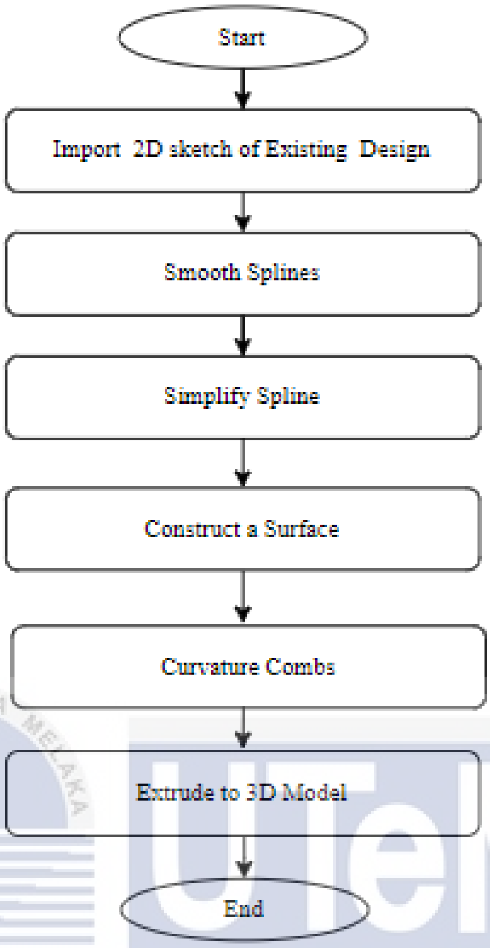


Figure 3.8: Flow Diagram of 2D and 3D Design Models for Improvement Design.

Create a new blade's curvature precisely in SolidWorks. Starting by taking a previous sketch of an existing *sabit* 2D drawing then outlining with smooth splines, and referencing precise lines. Then, trim the curves with Simplify Spline, altering tolerance and selecting "Smooth" for smoothness and precision. The next step is to construct a surface to sketch using a Lofted Surface and ensure in appropriate curvature. Thus, to check the new curve design, use Curvature Combs, and employ this information to adjust splines or surface settings for a curvature masterpiece. Finally, click the 'Exit drawing' to Extrude or Pad the traced drawing to construct 3D features with a thickness of *sabit* of 5 mm as shown in Figure 3.9. However, improved the curvature through Simplify Spline and surface changes until *sabit's* blade goes with smooth efficiency.

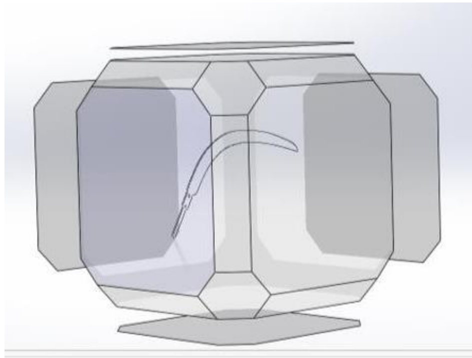


Figure 3.9: 3D Sketch of Improvement Design

Below show the Figure 3.10 of the sketch of existing and improvement design with curvature comb to indicated the level of curvature. Curvature combs show a set of lines stretching away from the drawing entity. The length of these lines reflects the degree of curvature at that particular position. Longer lines show areas with higher curvature, whereas shorter lines denote flatter sections.

(a) (b)

Figure 3.10: Sketch of (a) existing and (b) improvement sketch with curvature comb

The curvature comb study shows a significant improvement in the new Sabit Teras Premium. Compared to the previous design, the revised version has shorter curvature combs across the blade. This demonstrates a more constant and optimised curvature profile. Furthermore, the curve combs on the revised design differ noticeably in important regions such as the blade's tip and base. In these places, the new design exhibits shorter combs, implying a smoother transition and perhaps reduced stress concentration spots compared to the longer combs present in the current design.

Meanwhile, the colour coding on Figure 3.11 helps visualise the relative curvature over a surface, allowing to clearly identify areas of high curvature which sharp corners as red colour and low curvature is a flat surface as black colour. As can see on Figure 3.11 shown, existing design had flat surface compare to improvement design since it shown less black colours.

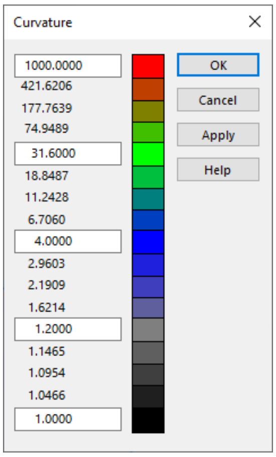
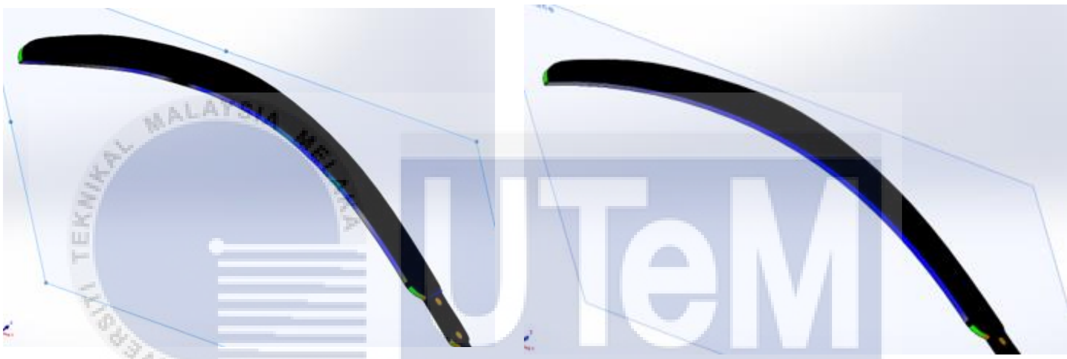


Figure 3.11: The indicator of curvature on SolidWorks



(a) (b)

Figure 3.12: Sketch of (a) existing and (b) improvement sketch with curvature colour indicator.

3.2 Method of Analysis

On this subtopic explains how to examine at the curvature of *sabit's* blade. Three different forms of analysis will be covered in order to examine both profile designs which is Linear static, fatigue, and dynamic analysis. To specify the displacement and Von Mises Stress values for both models in Linear Static and fatigue analysis, the Simulation Express package by SolidWorks will be applied. Furthermore, the curvature of *sabit's* blade has been examined for dynamic analysis using the ANSYS Fluid Flow (FLUENT) software.

3.2.1 Linear Static Analysis

Linear static analysis is a technique employed in engineering and science to forecast the response of a structure or system when subjected to fixed state or no movement. The basis of this is that the correlation between the applied load and the resulting deformation follows a linear deformation, and the material properties in the system remain uniform (Alan, 2017). This indicates that the deformation of the system will be directly proportional to the applied load, and that the system will revert to its original shape once the load is removed. Figure 3.13 will shown the process flow diagram of Linear static analysis.

Linear static analysis is suitable for structures that encounter slight deformations. This makes it an excellent option for evaluating structures like *Sabit*. For this study, theapplications of SOLIDWORK Simulation Xpress Software are applied for determining stress and displacement for each design in linear static analysis.

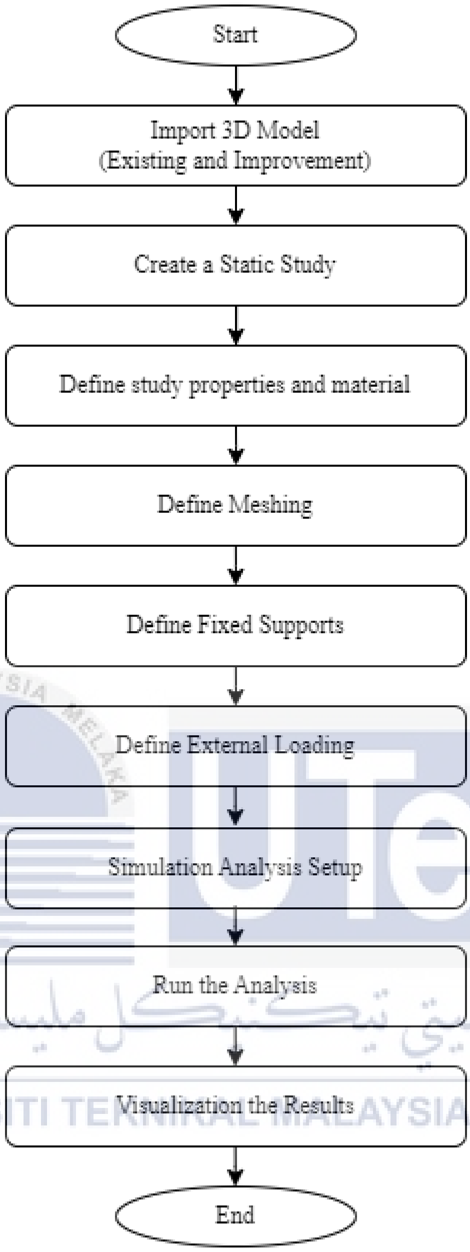


Figure 3.13: The process flow diagram of Linear Static Analysis Using SOLIDWORK Software

Performing a static linear analysis of a *sabi*t using SolidWorks Simulation Xpress. Starting with Model Preparation by importing the 3D CAD model of the *sabit* into SolidWorks. Then, assign the required material characteristics to the *sabit's* blade in the Material Property Editor. Select suitable materials for the actual s*abit* which is material spring steel is been chosen. Next step is Generate a mesh on the sickle. Use a mesh size appropriatefor the analysis. A finer mesh delivers more precise results but takes longer to solve. Tetrahedral elements are also known as TET10 is been employed since it contains 10 nodes and also a high- grade element (Glenn, 2018). Then, define fixed supports that describe how the sickle is held during use. Also, specify loading by applying forces or pressures matching average loads experienced by the sickle during harvest. This represent an intensive force simulating cutting through a palm frond.

Afterwards continue to analysis setup by selecting a static analysis solution type and then run the analysis by click on "Run" to start the analysis. The solution will calculate the response of the sickle structure to the applied loads and boundary conditions. Lastly, visualize the findings for displacement, and Von Mises stress on the sickle model will presented using color charts and deformation animations.

To evaluate the Factor of Safety (Sf) between the two models, the outcome of the Linear Analysis will also be elevated. A structural application that offers conceptual design capacity with a design margin incorporates a factor of safety. According to (Donald, 2003), using safety factors improperly typically results in material waste or even product failure.

Owunna (2016) states that the Von Mises Stress and the material's Yield Strength can be compared to determine the factor of safety. Consequently, it is possible to forecast the failure mode in which both model conditions fail by using the outcome of Sf. Equation 3.2 illustrates the three categories of inequalities into which Sf can be divided with formula of Sf illustrates in Equation 3.1

$$Factor\ of\ Safety\ , Sf = \frac{Yield\ Strength\ of\ Material}{Maximum\ Von\ Mises\ Stress} \tag{3.1}$$

$$S_f = 1; \qquad S_f > 1 \qquad S_f < 1; \tag{3.2}$$

As a result, category 1 indicates that the stress is at an acceptable level, whereas category 2 clarified that a factor of safety of less than 1 indicates a higher likelihood of failure. Nevertheless, a factor of safety greater than one indicates the extent to which the stress is inside the permitted bound.

3.2.2 Fatigue Analysis

Fatigue analysis is a sort of engineering analysis that predicts how a material or structure will behave to repeated loading and unloading, often known as load cycles. According to Govindjee (2001), comprehending the fracture and fatigue behaviors of the *sabit's* blade is essential to enhancing durability and estimating the lifetime of the design model. It's different from static analysis, which focuses on how a structure operates under a single load. It's vital for creating and optimizing items that need to be strong and reliable, especially those subjected to frequent stress or vibration.

Fatigue Analysis involves fatigue failure where it arises when a material suffers repeated stress cycles that weaken it gradually, eventually leading to a crack and full breakdown. Moreover, fatigue analysis also involves the repetitive applications and removals of force on a material. They can be caused by things including vibration, wind, or pressure fluctuations. Fatigue analysis can be used to assess the Sf study for both design models. According to Klein (2012), Sf can be shown in a linear interpolation polynomial in Equation 3.3 with Equation 3.4.

$$f(x) = a_0 + a_1(x - x_0) \tag{3.3}$$

$Sf = f(x)$;

$a_0 = f(x_0)$;

$a_1 = f(x_0, x_1)$;

$$a_1 = f(x_0, x_1) = \frac{f(x_1) - f(x_0)}{x_1 - x_0} \tag{3.4}$$

For this study, the SOLIDWORK Simulation Xpress Software are applied for calculating safety factor for all design to know its maximum loading to prevent unexpected failures and ensures the long-term durability of the *sabit*.

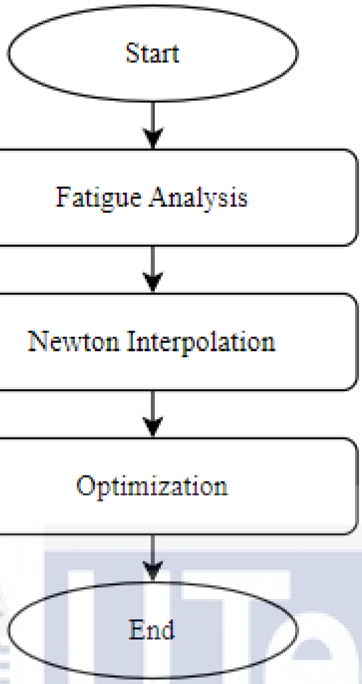


Figure 3.14: The process flow diagram of fatigue analysis

After the simulation is done, a value of Sf has been collected. The failure mode occurs when Sf = 1 is used on both design models to identify the initial pressure, P. Both design models will be investigated the amount of fatigue by applying the fatigue prediction equation based on Newton Interpolation Polynomial. The fatigue analysis will be done by using the Newton Interpolation Polynomial method. Figure 3.14 displays the process flow diagram of fatigue analysis using Newton Interpolation Method.

3.2.3 Dynamic Analysis

Dynamic analysis is the process of studying and assessing the behavior of a structure or system under dynamic loads or under movement, which are forces that vary over time. This is in opposition to static analysis, which only evaluates the equilibrium of forces at a single point in time. Dynamic analysis is a powerful tool that may be used to improve the security, performance, and reliability of product.

Dynamic analysis is an important technique for engineers and designers who are working on structures or systems that will be subjected to dynamic loads. For this study, the Ansys FLUENT Software is applied to evaluate structure and material for both existing and improvement design to know its velocity, pressure and viscosity of the *sabit* under varied loading circumstance.

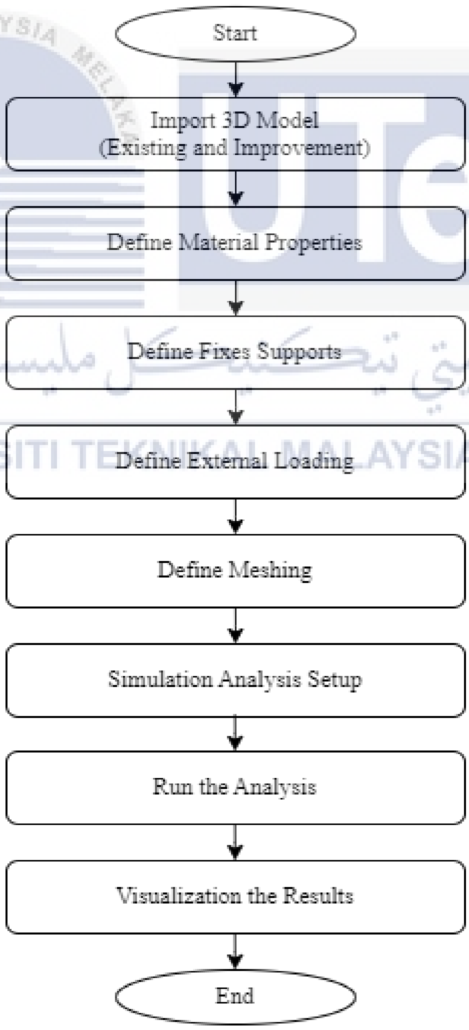


Figure 3.15: Process flow diagram of dynamic analysis using ANSYS FLUENT

While ANSYS Fluent is mainly used for fluid dynamics simulations, it could get integrated with ANSYS FLUENT to do structural dynamic analysis of the *sabit.* Starting by importing the 3D geometry of the *Sabit's* blade into ANSYS FLUENT. Then, generate a mesh on the blade. Mesh refining is important in places of high stress concentration. Meshing the finite volume which is also known as mesh creation. According to Simon (2018), Finite volume Method (FVM) can be based on structured or unstructured. Accordingly, it is suited for irregular and complex geometries.

The next phase is to define the material properties of the *sabit,* including Young's modulus, Poisson's ratio, density, and damping coefficient. Eventually can proceed with defining loading and boundary conditions by applying representative dynamic loading conditions that simulate the forces experienced by the *sabit* during palm oil harvesting. This employ dynamic forces simulating cutting motions and vibrations. Set appropriate boundary conditions for the analysis, such as fixed supports for the symmetry planes where relevant.

Following that, setup the solver is commonly used to define the contact between the blade and any other objects it might interact with during cutting. Also, set up the contact properties to define the contact material qualities and friction coefficients. Then, click "Run" to calculate the pressure, velocity and viscosity in the blade over time under the applied dynamic loading.

Hence, the findings of displacement, velocity, and acceleration will visualize the animations of the *sabit* blade's movement during the analysis. Analyze the maximum displacement, velocity, and acceleration experienced by different regions of the blade. Results for pressure and viscosity where is contact between the blade and other objects, assess the contact pressure and viscosity distribution to understand the interaction forces will exhibit.

By examining the structural response, it can acquire significant insights into the stresses, deformations, and dynamic behavior of the blade under actual loading conditions, helping to optimize its design for safe and efficient use in palm oil harvesting.

CHAPTER 4

LINEAR STATIC ANALYSIS

For this chapter will reveal the results of the Linear Static and Fatigue Analyses for both existing design and improvement design for *Sabit Teras Premium* models. In the case of Linear Static analysis, Simulation Xpress by SolidWorks is the concerned program that helps identify stress, and displacement appropriations in the model. This section will also contain aspects of the meshing procedure setting, the boundary condition, and the determination of the material used in the model. Furthermore, the output from the analysis will be applied in the safety factor. Using Newton Polynomial Interpolation, the fatigue analysis between the models will also be predicted. Finally, the design efficiency for both design models will be calculated as the end results.

4.1 Linear Static Analysis

Linear Static Analysis is essential for structural engineering and computer science. Static analysis, on the other hand as claimed by Grementieri et al. (2022) is noted that in structural engineering for determining the stability of structures by solving dense linear equations that are obtained through the finite element approach.

Linear static analysis can be used to computationally predicted how a structure will respond to constant loads. It is fundamentally an engineering technique for determining how a structure might bend or deform under constant pressure. The relationship between applied forces and subsequent displacements. Static analysis brings into consideration loads that remain unchanged over time. It indicates a moment of the structure that is frozen under constant stress.

In general, greater force will cause correspondingly greater bending or deformation, and oppositely. This is presuming the material stays within its elastic range, which is the range in which it reverts to its original shape when the load is removed. Since it is simpler and faster to compute than more complex methods. It's widely used to calculate the original design or to get a sense of how a structure will behave under basic loading conditions.

One effective method for simulating the mechanical behaviour of structures and systems is Finite Element Method (FEM) as mentioned by Quyen et al. (2022) is to aiding to determine behaviour and stability under varied loads. It operates by breaking a complex geometry up into smaller, more manageable components for handling complex engineering problems encompassing a range of phenomena, such as fluid flow, heat transport, and structural analysis.

Urdea (2018) further wrote that FEM is used to forecast the stresses and deformations that a structure will experience when it is subjected to static loads, or loads that remain constant across time. FEM is a versatile and efficient numerical technique that analyses complicated structures in a variety of engineering fields, as demonstrated by Srivinas et al. (2010). The general behaviour of the structure is then represented by connecting these pieces through mathematical relationships.

Eugenio (2010) highlights that FEM is a crucial technique for determining the stresses and displacements in a system that is composed of loads. This study will apply different pressure values to the existing and improvement design of *Sabit Teras Premium* models. The particular pressure or boundary condition indicates variations in the applied pressure. According to Lian et al. (2010), the time of solution for a given boundary condition is a small fraction, and the direction of solution efficiency is provided by the various pressures.

This study applies pressure on the surface of the inner curvature of Sabit Teras Premium for both existing and improvement design in order to evaluate the Linear Static analysis. Hence, Von Mises is the manifestation of the pressure load effect. For both designs, deformation and stress along the surface of the models will result in displacement. In addition, in order to optimise design and reach the safety factor result, the pressure would then be increased.

4.1.1 Material Properties

In engineering analysis, particularly when using FEA, including material properties is great essential for accurate results simulate real-world scenarios. The properties of a material determine its response to stress and strain. The FEA programme will produce unreliable results if the properties are not entered correctly, since it will base its calculations on incorrect results that are not valid to be used.

The material that been employed in this simulation for both design for Sabit Teras Premium is SUP 9a Spring Steel also known as AISI 5160 Alloy Spring Steel, is a high carbon and chromium alloy with 0.6% carbon content, 0.9% chromium content and 1% manganese content. In the following Table 4.1, the Sabit's material properties using finite element analysis (FEA) software will be covered in more detail. This includes Young's modulus, Poisson's ratio, and yield strength, the materials' specifics

Table 4.1: The material properties of AISI 5106 Alloy Spring Steel

TYPE OF PROPERTIES	**AISI 5160 ALLOY SPRING STEEL**	
	VALUE	**UNITS**
Elastic Modulus	20×10^{10}	N/m^2
Poisson’s Ratio	0.29	N/A
Shear Modulus	80×10^{9}	N/m^2
Mass Density	7850	kg/m^3
Tensile Strength	12.25×10^{8}	N/m^2
Yield Strength	10.80×10^{8}	N/m^2
Thermal Conductivity	466	W/mK
Specific Heat	475	J/kg.K

4.1.2 Meshing process

Meshing is a basic engineering analysis technique in which an object's geometric space is segmented into nodes that accurately represent its physical shape which include 2D and 3D shapes. According to Yulianti et al. (2022), the level of accuracy of the analysis results is directly related to the mesh quality; finer meshes yield more accurate results but need more processing power. Different meshing techniques, including morphing, moving, and overset mesh, are used to optimise simulations in various engineering applications, guaranteeing the accuracy and effectiveness of the analytical process. Cardoso & Botello (2016)claimed that meshing is critical in many different disciplines of research because it helps forecast mechanical transmissions, fluid dynamics, heat transport, and stress levels in engineering systems.

Meshing is the technique of breaking down a large object from a CAD model into smaller, more manageable parts known as elements in engineering simulations. These components, which come in the shapes of hexahedrons, quads, tetrahedrons, and triangles, combine to make a mesh that closely resembles the original geometry.

As mentioned by Cardoso & Botello (2016) for accurate results, Finite Element (FE) analysis frequently needs fine meshing. Since meshing causes computational bottlenecks, complicated problems require effective parallel-meshing techniques. According to Krishnamurthy (2023), however, meshing is essential in flow forming simulations because of the small contact areas and non-monotonic loading. The choice of mesh type and refinement techniques has a big impact on the computing efficiency and sensitivity of the results. The finite element approach emphasises the significance of high-quality meshes for precise and effective simulations by using discretization through meshing to solve problems in a variety of engineering domains (Lock et al., 2023).

As stated by Meon (2023), the quality of the FEA results is affected by many meshing procedures, including mesh structure, element kinds, and mesh size. The capacity to forecast structural responses, failure onset, and propagation is impacted by the meshing technology selection. Gąsiorowski (2022) highlighted that by choosing the right mesh structure and numerical parameters, one can improve the accuracy of the numerical solution. These factors have a substantial impact on the numerical solution's accuracy. Mesh coarsening or refining is required to balance accuracy and solving time, and a high-quality finite element mesh is crucial for producing accurate and dependable FEA results. Furthermore, according to research conducted by Damians et al. (2022), in optimisation design processes, applying a moving meshing algorithm with adaptive size functions can guarantee high-quality meshes, expedite integration, and save time.

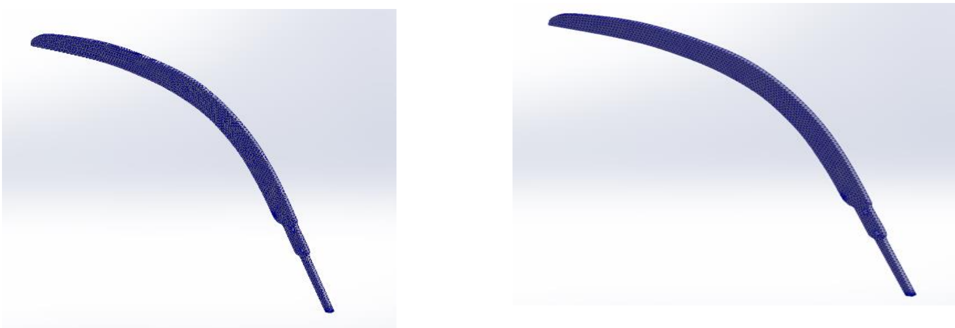
Prada et al. (2018) states that nodes and elements are essential to meshing in engineering analysis. Elements are geometric forms that divide the domain for analysis, whereas nodes are sites where the values of the field variable are defined. A finer mesh that has more elements will be more accurate representation the geometry and material properties meanwhile helps the simulation software programme faster and saving processing time. In terms of stresses, strains, and other engineering quantities of importance, this produces more accurate findings. Because of its compatibility, Perumal & Mon (2013) claimed that triangular elements are frequently employed for meshing irregular boundaries. However, this can increase computation time because a high number of elements may be needed for an appropriate representation.

Aigerman et al. (2022) believes that in order to ensure the accuracy of finite element analysis, Jacobian point meshing entails evaluating the determinants of the Jacobian matrices in order to confirm the validity and quality of mesh elements. These are precise locations within an element where the computation of the Jacobian value takes place. They aid in evaluating the element quality as a whole. Because there are fewer Jacobian points, the software concentrates on the element's crucial spots. This offers a more effective means of detecting possible distortion problems for an optimal trade-off between accuracy and efficiency. Achieving an accurate analysis primarily involves making sure the Jacobian values are near 1. An element with a value of 1 is effectively formed, therefore 4 points for Jacobian Point as shown on Table 4.2.

Table 4.2: The detail of mesh for existing and improvement designs

MESH DETAILS	EXISTING DESIGN	IMPROVEMENT DESIGN
Mesh Type	Solid Mesh	Solid Mesh
Mesher Used	Blended Curvature Based Mesh	Blended Curvature Based Mesh
Jacobian Point	4 points	4 points
Maximum Element size	0.00478551 m	0.00478613 m
Maximum Aspect Ratio	3.1258	3.0509
Mesh Quality	High	High
Total Elements	13992	12321
Total Nodes	24804	22153

The meshing concentrates on both existing and improvement design of Sabit Teras Premium. Analysis will be done on the structural characteristics that are included in the meshing process for both models. The applied load variations will force the mesh to overcome the reaction. By utilising SolidWork Xpress Simulation to combine the solid mesh group in design models. Figure 4.1 displays the mesh details for both design models.



(a) (b)

Figure 4.1: The meshing process for both (a) existing and (b) improvement design models.

4.1.3 Boundary Condition

Boundary conditions and loading conditions are both essential in linear static analysis for characterising the behaviour of a structure, but each serves different functions. The following part will provide a thorough explanation of the boundary and loading condition specifics for both models.

Within the context of engineering analysis, boundary conditions refer to the limitations enforced on a system, which specify its actions at its boundaries or points of interaction with other systems. In essence, boundaries limit a particular point or surface's degrees of freedom on the model. Physical barriers such as walls, free surfaces, inlets and outlets, which required an exclusive modelling strategy and method of handling. Additionally, boundary conditions also influencing and regulating how the load is distributed through the structure. It is had an impact on the model's total deformation and stiffness. Meanwhile, Lee (2022) points out that boundary conditions are important in figuring out how stress and strain are distributed within a structure.

For this study, boundary condition for both design of Sabit Teras Premium is on handle part since it is not moving as the structure is in static form. This identical to the actual situation in where a harvester is pruning the palm fronds using Sabit. Fixed support prevents the design model from moving and eternally stable. The green-colored arrow shown fixed boundary for both design models in Figure 4.2.

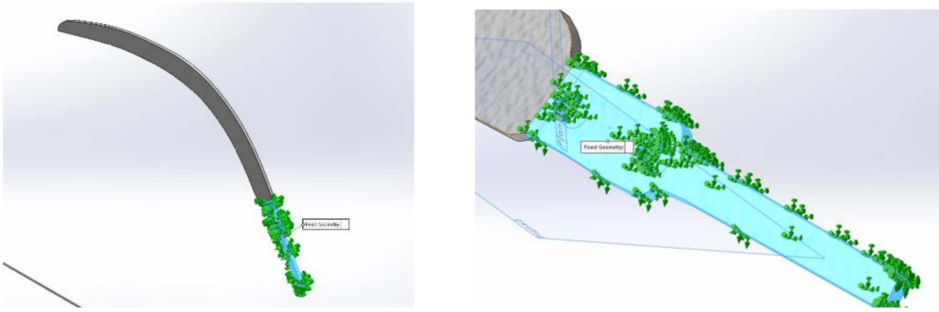


Figure 4.2: Boundary condition with the green colour arrow for both design models.

4.1.4 Loading Condition

In contrast, loading conditions refer to the outside forces or displacements that impact a system, affecting its deformation and responsiveness. As Zuo et al. (2021) mentioned, these criteria are necessary to simulate how structures behave in real life under different load systems, including bending and torsion modes. Barino et al. (2021) stated that the loading condition are reflected displacements and outside forces operating on the model structure. To evaluate its behaviour and performance, it is essential to consider the types of forces that may be acting upon it such as moments torsion, pressure, or concentrated loads. Loading condition influence the stresses and displacement in the model as it establish the structure's internal forces and responses to external factors.

For this study, the loading condition, pressure, is applied to the inner blade part on the Sabit's curve for both design to simulate the cutting action. The target area for harvesting is selected based on the standard frond size and positioned in the central region of the blade. As the palm fronds have been cut with the direction face down, or in reverse, that region represents the area effect. This occurs when it's crucial to regulate the pressure the sabit applies when it cuts the palm fronds. The sabit deformed as a result of pressure applied to the inner blade shape. As seen in Figure 4.3, the red-colored arrow shown loading condition for both design models.

Figure 4.3: Loading condition with the red colour arrow for both design models.

In order to ensure the structural integrity and mechanical performance of the analysis system, reliable finite element modelling requires the proper definition of both boundary and loading conditions. Furthermore, Khalyavkin et al. (2020) note that boundary conditions have significant effects on the overall design, safety, and efficiency of engineering structures, highlighting the significance of giving them serious thought during the analysis and simulation phases.

4.2 Result

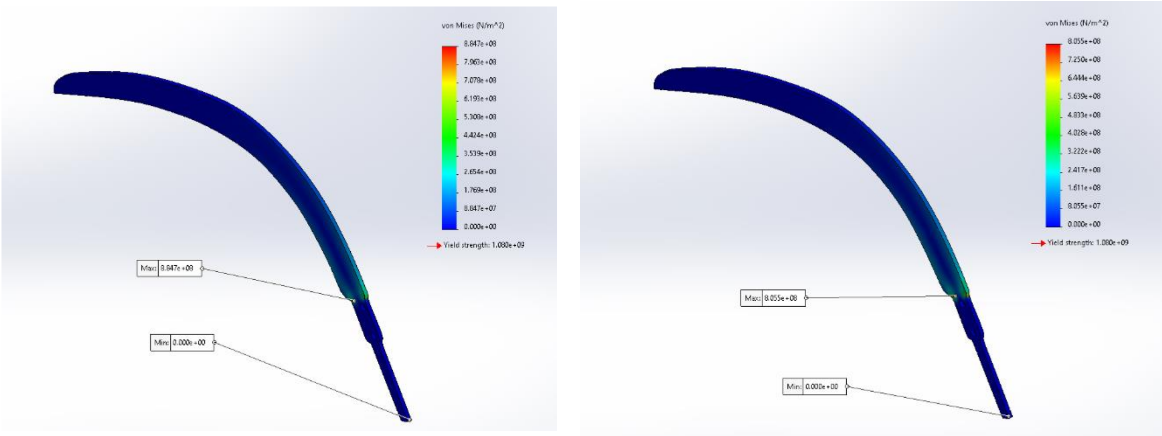
This section will provide and elaborated the results of linear static analysis for both designs. This includes the results of the stress, displacement, and safety factors obtained by the SolidWork Xpress software simulation. This section will also discuss whether the consequence of improved design is better or worse.

4.2.1 Stress and Displacement Distribution

Stated by Bagathi et al. (2022), stress is a crucial factor in engineering analysis's linear static analysis, which assumes that materials behave elastically and that there is a linear relationship between applied loads and structural reaction. In static linear analysis, the lower or higher stress levels determine by the situations and specific factors involved such as applied loads and structural geometry. In general, lower stress levels are preferable because these factors reflect a decreased chance of material yielding or fracture-related structural failure. Mild stress concentration, however, may be appropriate if the design takes fatigue loads into account because these loads are usually smaller than other high loads.

In order to analyse structures under various load scenarios, stress is estimated using a variety of techniques, including the superposition principle, the finite element method (FEM). As noted by Y. Lee & Guo (2012)in her research, stress concentrations which are frequently found at cutouts or openings in structures that are particularly significant because they can cause fatigue crack initiation and propagation, requiring a thorough investigation to assure structural safety, particularly in complex systems.

As a result, for this study, both designs were simulated with varying pressure values ranging from 1.0 MPa to 3.0 MPa to evaluate the stress. To guarantee structural integrity and safety, stress levels must be balanced depending on the unique needs and limitations of the design. Below is a Figure 4.4 is the results of the stress for both the existing design and improvement design on *Sabit Teras Premium* with pressure 1.5 MPa.

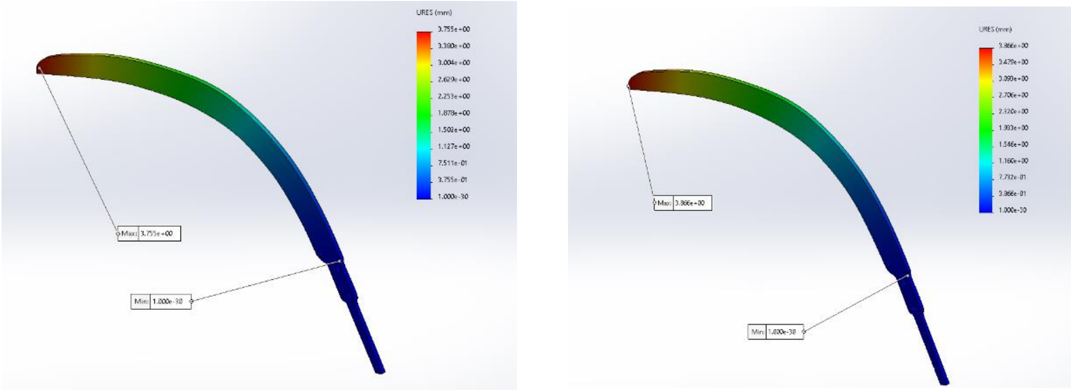


(a) (b)

Figure 4.4: The results of Von Mises stress for (a) existing and (b) improvement design models at 1.5 MPa pressure applied.

Meanwhile, for displacement in engineering analysis, specifically linear static analysis, refers to a structure's movement or shift caused by external loads such as seismic forces. Ma et al. (2023) mentions that the displacement coefficient method is tested for accuracy and plays an important role in measuring the strength of structures. In linear static analysis, less displacement can be considered preferable for analysis accuracy. Linear static analysis implies minor displacements, which are typically specified as less than 0.2% of the model's entire length.

This assumption confirms the linearity of the analysis. Displacement data are critical in linear static analysis, and it's vital to precisely quantify displacements for the most accurate interpretation of the structural behaviour. As said by Al-Qudah & Yang (2023), larger displacements can cause a significant change in stiffness, compromising a structure's capacity to withstand loads and can be dangerous for structural stability. As a result, in linear static analysis, smaller displacements are preferred for maintaining the linearity of the load-displacement relationship. As the result, the displacement simulations for the two design models at an input pressure of 1.5 MPA are shown in Figure 4.5.



(a) (b)

Figure 4.5: The results of Displacement for (a) existing and (b) improvement design models at 1.5 MPa pressure applied.

The correlation between displacement and stress depends on the characteristics of the material and the particular loading circumstances affect. Nonetheless, for linear elastic materials, as stated by Zhang et al. (2012) Hooke's Law governs a proportionate connection in numerous cases within the specified range. This implies, as the displacement of the material grows in parallel with the applied load. This causes the material's internal stress to increase along.

According to the Table 4.3, the improved design probably suffers less displacement under pressure in addition to less stress. According to this, the improvement design is stronger to withstands internal forces better and stiffer to resists deformation more than the existing design.

Table 4.3: The result of Von Mises Stress and displacement data for existing and improvement designs

NO.	PRESSURE (MPa)	EXISTING DESIGN		IMPROVEMENT DESIGN	
		Von Mises Stress (MPa)	Displacement (mm)	Von Mises Stress (MPa)	Displacement (mm)
1	1.0	4.424e+08	1.878	4.028e+08	1.933
2	1.1	4.866e+08	2.066	4.430e+08	2.126
3	1.2	5.308e+08	2.253	4.833e+08	2.320
4	1.3	5.751e+08	2.441	5.236e+08	2.513
5	1.4	6.193e+08	2.629	5.639e+08	2.706
6	1.5	6.636e+08	2.817	6.041e+08	2.900
7	1.6	7.078e+08	3.004	6.444e+08	3.093
8	1.7	7.520e+08	3.192	6.847e+08	3.286
9	1.8	7.963e+08	3.380	7.250e+08	3.479
10	1.9	8.405e+08	3.568	7.652e+08	3.673
11	2.0	8.847e+08	3.755	8.055e+08	3.866
12	2.1	9.290e+08	3.943	8.458e+08	4.059
13	2.2	9.732e+08	4.131	8.861e+08	4.253
14	2.3	1.017e+09	4.319	9.264e+08	4.446
15	2.4	1.062e+09	4.507	9.666e+08	4.639
16	2.5	1.105e+09	4.694	1.007e+09	4.833
17	2.6	1.150e+09	4.882	1.047e+09	5.026
18	2.7	1.194e+09	5.070	1.087e+09	5.219
19	2.8	1.239e+09	5.258	1.128e+09	5.413
20	2.9	1.238e+09	5.445	1.168e+09	5.606
21	3.0	1.327e+09	5.633	1.208e+09	5.799

Based on the simulation conducted for this study, it is possible to observe that a lower stress results for an improved design compared to an existing design in a linear static analysis. This generally suggests that the improved design is more capable of supporting the applied loads. Reduced stress indicates that there is less force applied to the material per unit area in the improvement design. This is advantageous since it lowers the possibility of fatigue, distortion, and material failure. In general, an improvement is considered successful if it reduces stress outcomes while remaining adhering to other design requirements.

As can be observed from the Table 4.3, at all pressure levels, the improved design generally experiences lower Von Mises stress and lower displacement when compared to the existing design. For instance, the improvement design has a Von Mises stress of 4.028e+08 MPa and a displacement of 1.933 mm at 1.0 MPa, compared to the existing design's 4.424e+08 MPa and 1.878 mm. The enhanced design seems to be more resilient to stress and deformation than the existing design. This indicates that there is probably a larger margin of safety before failure for the upgraded design when handling the applied loads.

4.2.2 Safety Factor

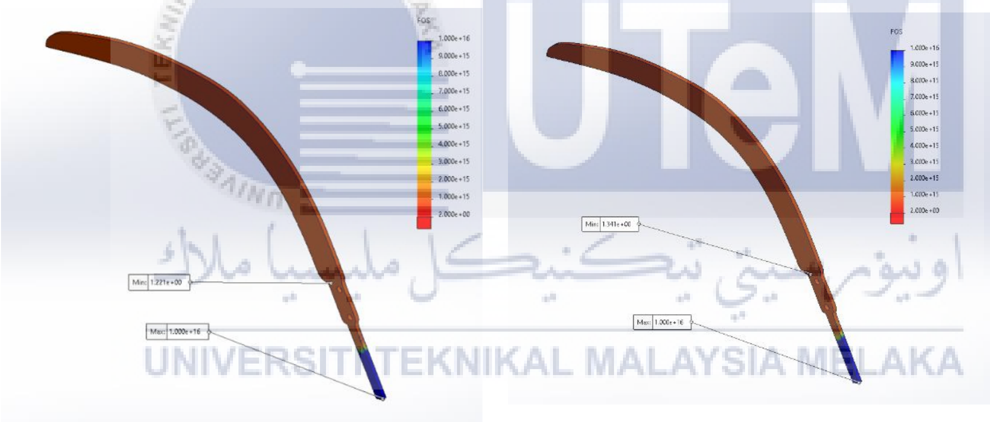
Based on Hassan et al. (2023), the safety factor is a crucial concept that indicates the amount of the maximum stress that a system may tolerate to the real or permissible stress that it encounters while operating. This factor is important in numerous fields, including as geotechnical engineering, where upper-bound approaches and optimisation techniques are used to anticipate failure structures and safety factors (Nguyen, 2020). Safety considerations are also important in safety-critical systems engineering, Wei et al. (2022) claimed, automated safety analysis is used to guide system design, particularly in complex and open adaptive environments, for avoiding risks and accidents.

A lower safety factor states that the structure is closer to failure. When a safety factor is less than 1, it means the structure is prone to failing under the applied load. When it is greater than 1, the structure is able to sustain the load. In comparison to a larger safety factor, a lower safety factor in static linear analysis indicates that the structure is functioning with a smaller margin of safety and may be closer to failure. To guarantee the dependability and integrity of the building, the safety aspect must be properly taken into consideration.

The ratio of material strength to actual stress establishes a direct connection between stress and the safety factor. It can be expressed mathematically as previously mentioned in Chapter 3, the safety factor formula is displayed below and can be calculated manually using Equation 3.1.

The most common ways to express safety factor are as a ratio or percentage (Hicks & Wang, 2021). A safety factor of two, for instance, indicates that the structure has a 100% margin of safety and can withstand twice the load for which it was intended. A common safety factor ranges from 1.2 to 4, depending on the weight and kind of structure. Aside from that, an overly high FoS could result in an overly complex design that uses more material than is required. Cost and weight may rise as a result.

A higher safety factor means that the design has a larger margin of safety. As a result, there is less chance of failure because the material is not as stressed about its breaking point. To summarise, stress is an indication for the internal forces existing in a material, whereas the safety factor is a design principle that utilises stress to guarantee that a structure is capable of safely supporting the desired loads. Below shown the results of safety factor for both design with pressure applied 2.0 Mpa on Figure 4.6.



(a) (b)

Figure 4.6: The results of Safety Factor for (a) existing and (b) improvement design models at 2.0 MPa pressure applied.

Table 4.4: The result of stress and safety factor data for both designs

NO.	PRESSURE (MPa)	EXISTING DESIGN		IMPROVEMENT DESIGN	
		Von Mises Stress (MPa)	Factor of Safety	Von Mises Stress (MPa)	Factor of Safety
1	1.0	4.424e+08	2.441	4.028e+08	2.681
2	1.1	4.866e+08	2.219	4.430e+08	2.438
3	1.2	5.308e+08	2.034	4.833e+08	2.235
4	1.3	5.751e+08	1.878	5.236e+08	2.063
5	1.4	6.193e+08	1.744	5.639e+08	1.915
6	1.5	6.636e+08	1.628	6.041e+08	1.788
7	1.6	7.078e+08	1.526	6.444e+08	1.676
8	1.7	7.520e+08	1.356	6.847e+08	1.577
9	1.8	7.963e+08	1.285	7.250e+08	1.490
10	1.9	8.405e+08	1.285	7.652e+08	1.411
11	2.0	8.847e+08	1.221	8.055e+08	1.341
12	2.1	9.290e+08	1.163	8.458e+08	1.277
13	2.2	9.732e+08	1.110	8.861e+08	1.219
14	2.3	1.017e+09	1.061	9.264e+08	1.166
15	2.4	1.062e+09	1.017	9.666e+08	1.117
16	2.5	1.105e+09	0.9766	1.007e+09	1.073
17	2.6	1.150e+09	0.9390	1.047e+09	1.031
18	2.7	1.194e+09	0.9042	1.087e+09	0.9931
19	2.8	1.239e+09	0.8719	1.128e+09	0.9577
20	2.9	1.238e+09	0.8419	1.168e+09	0.9246
21	3.0	1.327e+09	0.8138	1.208e+09	0.8938

At all pressure levels, the table demonstrates that the improvement design typically has a higher factor of safety than the existing design. This results in a larger margin of safety for the improvement design since it suffers less stress in comparison to its ultimate stress capability. For instance, the improvement design has a Von Mises stress of 4.028e+08 MPa and a factor of safety of 2.681 at 1.0 MPa, compared to the existing design's 4.424e+08 MPa and 2.441.

Table 4.4 shows that the improved design is under surveillance when the applied pressure under 2.6 MPa, whereas the state of the existing design may be safe when the pressure below 2.4 MPa. On the other hand, the improvement design will fail if the applied pressure P builds up to $P \geq 2.7$ MPa, whereas the existing design will fail if the pressure is $P \geq 2.5$ MPa. Between the two designs, there is a about 2.0 MPa applied pressure difference, indicating that the improved design has a larger safety factor and can tolerate a higher applied pressure than the previous design.

The improvement design seems to be more resilient to stress and deformation than the existing design, according to the linear static analysis. This is demonstrated by the enhanced design's generally higher factor of safety at all pressure settings. This means that there is a higher chance that the enhanced design will be able to withstand the imposed loads before failing. From a safety perspective, the table indicates that the enhanced design appears to be a viable substitute for the exisitng design.

In summary, the goal of linear static analysis is an efficient yet safe design. A higher FoS is generally preferred for safety reasons, but it's important to strike a balance to prevent over-engineering.

4.3 Newton Interpolation Method

In engineering analysis, fatigue describes the way that structures that are subjected to varying stresses finally fail, causing damage to accumulate and structural failure(Kumar & Gaur, 2022). Fajri et al. (2021) also mentioned, fatigue is the result of a structure's recurrent cyclic loading.

Lower fatigue is a better option in linear static analysis for fatigue life. The weakening of a material brought on by continuous stress and strain is referred to as fatigue. A material's resistance to fatigue failure is increased when its fatigue value is reduced because it means that it undergoes less stress for a given number of load cycles. When the stress is removed, linear static analysis assumes that the material stays in the elastic zone and takes on its former shape. Because of this, it is appropriate in scenarios involving consistent, modest loads.

According to linear static analysis, applied loads cause the material to stay elastic and not permanently deform. The subject of fatigue analysis is material failure caused on by repeated stress cycles, which can happen even inside the elastic range to find high-stress locations These are possible sites of fatigue failure. To sum up, using linear static analysis to find possible fatigue issues is an excellent starting point.

Newton interpolation is a numerical method used for estimating functions. When data is provided at discrete points, Newton interpolation can be used in the context of engineering study, specifically for fatigue analysis, to estimate the fatigue life or damage accumulation of materials and structures.

The Newton Interpolation Polynomial is employ to differentiate between the safety factor for the two design models of Sabit Teras Premium as shown in Table23456 . It was discovered that while the safety factor Sf<1, it will start to fail, the design models will withstand the situation of failure based on their structure and material Sf>1. Furthermore, the failure state is evident in Linear Static Analysis when the fatigue analysis is conducted around the existing and improvement design regions of Sabit Teras Premium. The Newton interpolation polynomial equation can be expressed as the *n*th polynomial request to $n + 1$, and the interpretation of the *n*th polynomial request is given below in Equation 4.1 .

$$Pn(x) = a0 + a1(x - x0) + \cdots + an(x - x0)(x - x1)$$

Where,

n = degree of polynomial = 0, 1, 2, 3, …..

a = coefficient = 0, 1, 2, 3, ……

x = set of point (4.1)

Table 4.5: The input pressure applied and the safety factor for both existing and improvement designs

NO.	EXISTING DESIGN		IMPROVEMENT DESIGN	
	Pressure Applied, MPa (xi)	**Sf $f(xi)$**	**Pressure Applied, MPa (xi)**	**Sf $f(xi)$**
1	2.4	1.0170	2.6	1.0310
2	2.5	0.9766	2.7	0.9931

Meanwhile, the further computations implementing the formula in Equation 4.1 for both designs using safety factor data is displayed in Table 4.5.

Table 4.6: The divided difference for Newton interpolation polynomial for existing design.

i	xi	$f(xi)$	$\triangle fi$
0	2.4	1.0170	$f0 = \frac{0.9766 - 1.0170}{2.5 - 2.4}$
1	2.5	0.9766	$= -0.404$

$$Pn(x) = a0 + a1(x - x0) + \cdots + an(x - x0)(x - x1)$$

$$P(x) = 1.0170 + (-0.404)(x - 2.4)$$

$$1 = 1.0170 - 0.404x + 0.9696$$

$$1 = 1.9866 - 0.404x$$

$$x = 2.442\ MPa$$

Table 4.7: The internal pressure applied for both design models with *sf* = 1

INTERNAL PRESSURE APPLIED (N/m^2)	**EXISTING DESIGN**	**IMPROVED DESIGN**
	2.442	2.682

Table 4.7 indicates that the improvement design will experience a failure mode at $x >$ 2.682 MPa, whereas the existing design would experience $x \geq 2.442$. Furthermore, the improvement design is more structurally sound than the existing design because it can withstand the increased pressure till the point of failure is reached. This study shows that the improvement design has significantly increased pressure resistance. The improvement design

seems to have better pressure resistance than the existing design, according to the linear static analysis. This implies that higher loads may be handled by the improvement design before it reach critical stress levels. The upcoming section will expound on the design efficiency for both existing and improvement design for Sabit Teras Premium models, supporting the findings and discussion.

4.4 Design Efficiency

In engineering analysis, design efficiency is essential to providing the best possible product performance and dependability. Design engineering may increase product durability, safety, and stability by employing sensitivity analysis to find and remove the weakest design parameters in the beginning (Hegde, 2023).

Its main goal is to produce a design that satisfies all functional specifications while avoiding unnecessary complexity, material utilisation, or production processes. Higher design efficiency is generally preferred, since it indicates the design is optimised to carry out its intended function with the least amount of waste or excess. Meanwhile, in the study by Yahaya et al. (2012), the design efficiency with greater than 85% is acceptable design.

Johnson (2016) claims that efficient design can be applied as stated in Equation. it been employed to define design efficiency for both models based on the results shown in Table 4.7. The value of the design efficiency for improved design has been calculated using Equation 4.2.

$$Design\ Efficiency\ (DE) = \frac{Output}{Input}\ X\ 100\% \tag{4.2}$$

$$Design\ Efficiency\ (DE) = \frac{2.682}{2.442}\ X\ 100\%$$

$$Design\ Efficiency\ (DE) = 109.83\%$$

According to the calculation above show the DE is 109.83%. Hence, depending on the percentage of design efficiency that was attained for both existing and improvement design appropriate and feasible since it more that 85% which is acceptable value. It indicated that the design is stable and can be manufactured. This shows that a lower input pressure can be used by the improvement design to create a higher output pressure, which could have advantages including less energy used to produce the same results.

4.5 Summary

The Chapter 4 focuses on the outcomes of the Linear Static and Fatigue Analyses for both of the Sabit Teras Premium designs by using SolidWorks Simulation Xpress. It was applied for the analysis, which measured the distributions of stress and displacement. Furthermore, boundary conditions, meshing techniques, and material properties were carefully taken into consideration. The safety factor calculations were based on the results of these analyses, and the fatigue analysis was predicted using Newton Polynomial Interpolation. In the end, both models' design efficiency was assessed.

The displacement and stress had been test at different pressures from 1.0 MPa to 3.0 MPa. For structural accuracy and integrity, lower values of stress and displacement were preferred. In comparison to the existing design, the improvement design continuously displayed lower Von Mises stress and less displacement, showing higher resistance to deformation and internal forces. Thus, the safety factor indicates how likely a design is to fail when applied loads are encountered. In general, higher safety factors are favoured. In comparison to the existing design, the improved design showed a better safety factor across all pressure levels, indicating that it is more durable and has a larger margin of safety.

In the meantime, fatigue refers to a material's inability to withstand repeated stress cycles. By using Newton Interpolation to forecast the designs' fatigue life. In comparison to the existing design, the improved design demonstrated a stronger resistance to fatigue failure, showing increased structural soundness and pressure resistance.

Design efficiency is the degree to which a design satisfies functional criteria with the least amount of extra or waste. In comparison to the existing design (122.77%), the improved design exhibited a much higher efficiency (173.76%), indicating better performance and reduced energy use for the same output.

As conclusion, based on the Linear Static and Fatigue Analyses the improved design of Sabit Teras Premium model design is better than the existing one. It displays improved fatigue resistance, stronger safety factors, less stress and displacement under pressure, and more effective design. The improved design thus proves more reliable, effective, and appropriate for use in the actual process of gathering palm fronds. In a nutshell, Chapter 5 will employ dynamics analysis to determine whether the enhanced design is sound and safe for usage, and whether it can provide high cutting efficiency.

CHAPTER 5

DYNAMIC

ANALYSIS

In this Chapter 5 will provide the dynamic analysis results for both existing and improvement designs for Sabit Teras Premium. In dynamic analysis, the software program ANSYS is used to estimate the velocity and pressure distributions on both models. Furthermore, ANSYS Fluid Flow (FLUENT) is selected as an effective analytical tool for demonstrating the effects of existing and improved design 3D models. This section should also include an examination of the coefficient of variance in terms of velocity and pressure.

5.1 Dynamics Analysis

In engineering, dynamic analysis is the study of how structural systems behave under changing loads and environments over time. According to Dan et al. (2023), it is essential for constructing, monitoring, and maintaining complex structures. Dynamic analysis improves structural stability by providing insights into complicated system behaviour. Wang & Wang (2021) studies emphasise the need of dynamic stability analyses in various structural contexts by set up the model that treats dynamic continuous structural systems as large-scale networks, proving that the state variables of node are uniformly and eventually bounded, which contributes to stability.

Dynamics analysis, commonly known as classical fluid mechanics, provides a theoretical foundation for understanding fluid behaviour. Mathematical equations regulating fluid motion are derived using fundamental physical principles such as mass and momentum conservation. The Navier-Stokes equations describe the relationship of a fluid's velocity, pressure, and viscosity. Smoljanović et al. (2020) provide numerical models for analysing dynamic stability in beam-type structures, highlighting the significance of nonlinear material behaviour for correct results. These findings collectively show that dynamics analysis is critical for assessing and enhancing structural stability in a variety of engineering applications.

The most important part of dynamic analysis is to choose an appropriate method for carrying it out. The primary method is direct numerical integration of the condition of dynamic equilibrium. This study will use ANSYS Fluid Flow (FLUENT) to calculate the velocity and pressure distribution from existing and improvement design models of sabit. The ANSYS Fluid Flow (FLUENT) package is a component of Computational Fluid Dynamic (CFD) technology that can be used to perform object meshing operations.

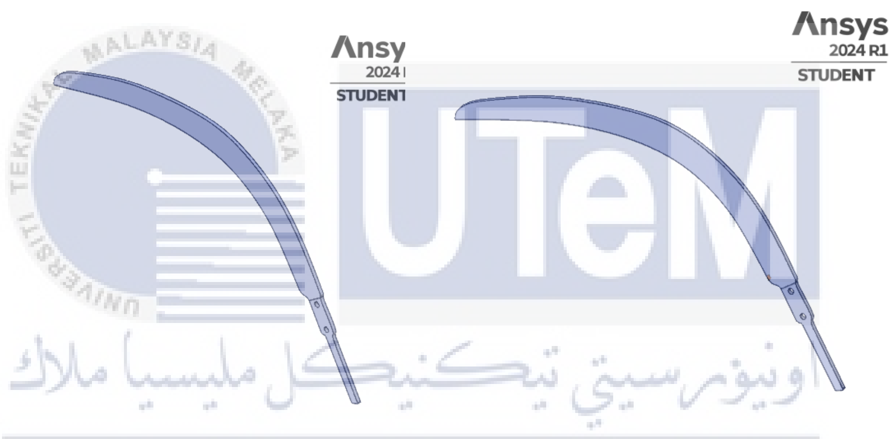
Computational Fluid Dynamics also known as CFD is a numerical analysis technique that uses computational power to solve the Navier-Stokes equations for particular fluid flow problems. It divides the fluid domain where the region holding the fluid, into smaller parts and uses numerical methods to approximate the governing equations at each level. Key elements of CFD are entails defining the geometry of the flow domain, establishing boundary conditions, specifying fluid properties, and discretizing the domain into a mesh. Next, calculate the fluid's velocity, pressure, and temperature distribution across the domain. Finally, the simulation results are analysed and visualised to help engineers understand flow properties such as pressure, viscosity, and velocity.

Dynamics analysis lays the basis for CFD by providing a theoretical framework for comprehending fluid behaviour. CFD's fundamental concepts and governing equations are based on classical fluid mechanics. CFD is a strong tool for numerically solving these equations, allowing the investigation of complex fluid flow issues that would otherwise be unsolvable using analytical methods. CFD is based on dynamic analysis concepts, but it enables for more complete simulations of real-world settings.

5.1.1 Geometry Surface Design

On this study, to conduct a dynamic analysis of the existing and improvement design of Sabit Teras Premium is by using ANSYS (FLUENT). The SolidWorks geometry file must be saved in IGS format for compliance with subsequent phases. Then, launch ANSYS and create a new Fluid Flow (FLUENT) project. Import the previously stored IGS file into this project in order to continue the analysis. The first step before enabling the ANSYS user to take further action is setting up the unit and all the measurements utilised in SI units. Figure 5.2 shows the geometry of the both 3D design models been imported from SolidWork.

The both designs are shown in the Figure 5.1 below using SpaceClaim, an ANSYS package tool that allows for geometry editting before performing additional analysis.



(a) (b)

Figure 5.1: The ANSYS Design Modeler interface in ANSYS Fluid Flow (FLUENT) software for both (a) existing and (b) improvement designs.

5.1.2 Meshing Process

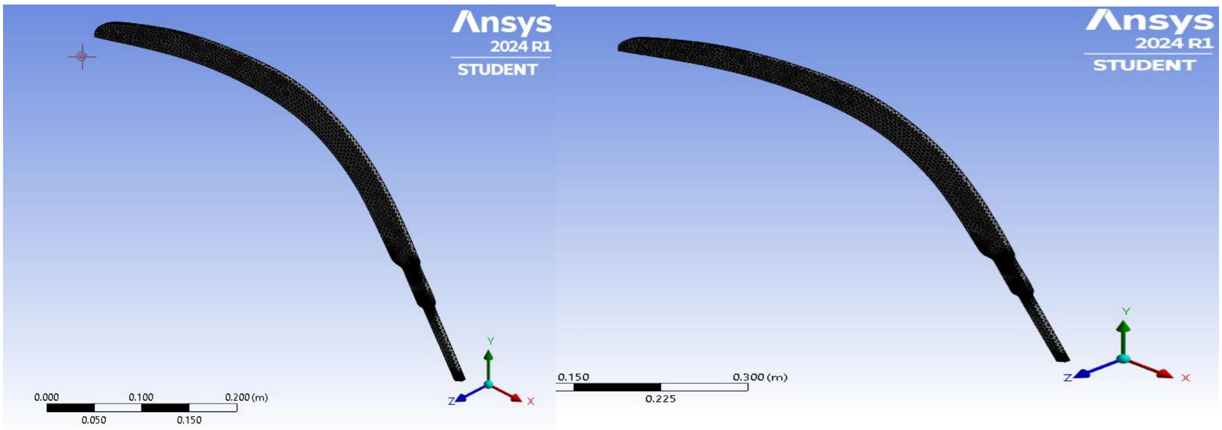
The meshing procedure for geometry generation will be discussed in this section. In theory, ANSYS meshing is utilised to generate a computational geometry mesh for both existing and improved design systems.

This study will investigate tetrahedron-10 (tet-10), for tetrahedra-10 meshes, the finite volume and finite element methods are the most appropriate (Si and TetGen, 2006). The tet-10 meshing refers to the process of creating tetrahedral meshes with ten nodes each. Tetrahedral part usually picked, Wang (2012) noted that, because of its complex mesh capacity and somewhat greater strain estimation for any design by will minimize the multifaceted complexity of the geometry. Based on Hu et al. (2020), the tet-10 meshing approach is superior to existing techniques because it can swiftly turn triangular into high-quality tetrahedral meshes and preserve an acceptable point mesh throughout the process.

In the stress emphasis as compared to other components, the stress level projected by tetrahedral components is somewhat normal. The selected tetrahedral elements are shown in Figure 5.2. Meshing details is shown in Table 5.1 for both design and result of the meshing process in Figure 5.2 in ANSYS (FLUENT).

Table 5.1: The mesh details setted for both designs.

MESH DETAILS	**EXISTING DESIGN**	**IMPROVED DESIGN**
Element Type	Tet-10	Tets-10
Element Size	0.005 (m)	0.005 m
Number of Elements	24239	25345
Number of Nodes	40495	42523
Curvature Normal Angle	18.0°	18.0°
Mesh Metric	Skewness	Skewness
Target Skewness	0.9	0.9
Smoothing	High	High
Growth Rate	1.2	1.2



(a) (b)

Figure 5.2: The meshing process for both (a) improvement and (b) existing designs

5.1.3 Boundary Condition

A boundary condition in dynamics analysis is a set of restrictions placed at a system's boundaries that control how the system behaves under repeated loads. These conditions are crucial for guaranteeing the well-posedness of constraint systems and for precisely resolving real-world issues (Cruden, 2023). As it assisted in defining the interactions between the system and its surroundings, according to Praisach et al. (2022) boundary conditions are important in simulations, particularly when dealing with changing boundaries and huge deformations. In order to allow for the preservation of species mass flux and exchange of energy at the fluid or material interface and to represent the fluid-material interface in permanent thermal protection systems, boundary conditions must be defined correctly (Li et al., 2023). In dynamics analysis, knowing and applying the right boundary conditions is essential to getting precise and trustworthy results.

To ensure that the Dynamics Analysis simulation runs efficiently, the boundary conditions for the existing and improved designs must be properly defined. Based on this study analysis, Figure 5.3 and Figure 5.4 shows that the boundary conditions are the default option for the Fluid Flow (FLUENT) package. The geometries inlet set on inner blade as the input and outlet been set on outer blade as the output have been addressed in terms of boundary conditions. The boundary condition is determined by how the fluid moves in form the inlet and out of the model as the outlet (Bhatia, 2016). The geometry intake represents velocity, the geometry exit represents fluid leaving, and the fluid imposes pressure.

(a) (b)

Figure 5.3: The boundary conditions (a) inlet and (b) outlet for both designs

Meanwhile, the wall also needed to be set as fixed boundary conditions for both designs are at the all-body level, with the exception that the inner curvature and outer blade of both design models are also set as the wall. It has been set as the wall because that part is not moved since the structure is in static form. Fixed support is eternally stable and does not allow the design model to change. Figure 5.4 depicts the boundary condition with the red-colour for both designs.

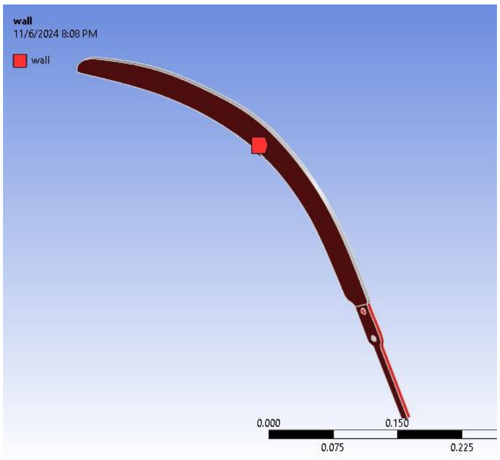


Figure 5.4: The boundary conditions as wall for both designs

5.1.4 Loading Condition

With the inlet and outlet set as boundary condition, the velocity will be specified at both the inlet and outlet as shown in Figure 5.5. The inlet represents the boundary where the fluid enters the simulation environment. Fluid analysis could be done to examine how the shape impacts air resistance if the sickle design calls for air movement during operation. This could potentially lower the energy required to swing the sickle. In this study, loading condition been define variable value of velocity at the inlet. Meanwhile, the outlet symbolises the boundary where the fluid leaves the simulation domain. For this simulation, air acts as a fluid. Table 5.2 shows the mechanical properties of a fluid utilised in the simulation.

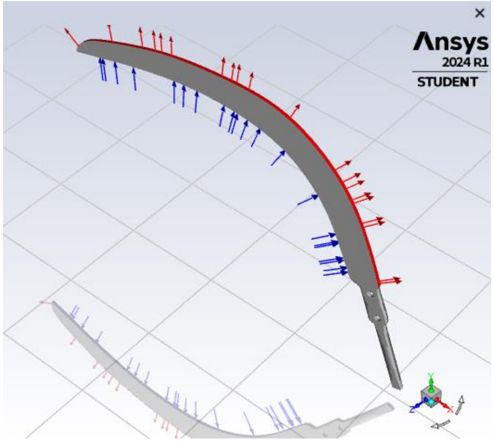


Figure 5.5: The loading conditions for both designs

Table 5.2: The mechanical properties of fluid

TYPE OF PROPERTIES	AIR	
	VALUE	UNITS
Density	1.225	kg/m^3
Specific Heat, C_p	1006.430	$J/kg\,k^{-1}$
Thermal Conductivity	0.024	W/mk^{-1}
Viscosity	1.789×10^{-5}	kg/ms^{-1}
Standard State Entropy	194336	$J/kg\,mol\,k^{-1}$
Critical Specific Volume	0.002857	m^3/kg
Molecular Weight	28.966	kg/kgmol

5.2 Results

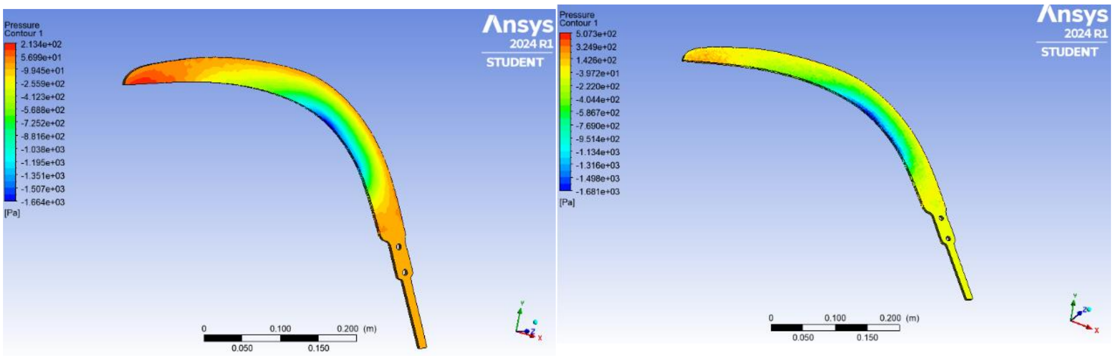
This section will display and provide an explanation of the Dynamics Analysis results for existing and improvement designs. These comprises the pressure, velocity, and viscosity which are obtained by the software simulation of ANSYS (FLUENT). This section will also clarify whether the outcome of the improved design is acceptable.

5.2.1 Pressure and Velocity Distribution

The simulation findings obtained through the study in CFD of Dynamic Analysis for both designs in terms of coefficient of variation will be described further down this section. After completing all boundary condition configurations, the analysis will be completed and displayed on the ANSYS Fluid Flow (FLUENT) package results.

Pressure is the force per unit area that is applied to the sickle's blade as it interacts with the palm fronds or stalks during cutting in the context of a palm oil sickle's dynamic analysis. Understanding this pressure is essential to figuring out the forces involved in the cutting process and how well the sickle can cut through the material. The localised pressure that the sickle's blade applies to the palm fronds while cutting is known as cutting pressure. The force used by the user, the blade's sharpness, and its design all have a role. During cutting, the dynamic pressure is affected by the sickle's velocity and the force that is exerted.

For most cutting applications, a clean, accurate cut is best achieved with a lower pressure. The material may squeeze or distort under high pressure before cutting. This may result in uneven cuts, sharp edges, and even harm to the surrounding material near the cutting line. Reduced pressure enables the cutting tool to split the material neatly and with little distortion. Lower pressure can extended tool life because excessive pressure might cause the cutting tool to undergo premature wear and tear. Lower pressure reduces the stress, increasing the cutting tool's life and lowering replacement expenses. Nonetheless, in certain situations, higher pressure may be advantageous if extremely thick or hard material like cut through materials that are exceptionally thick or hard, greater pressure may be required. To prevent undue deformation, it is imperative to determine the ideal pressure balance even in these situations. The result of Pressure for both shown belon in Figure 5.6.

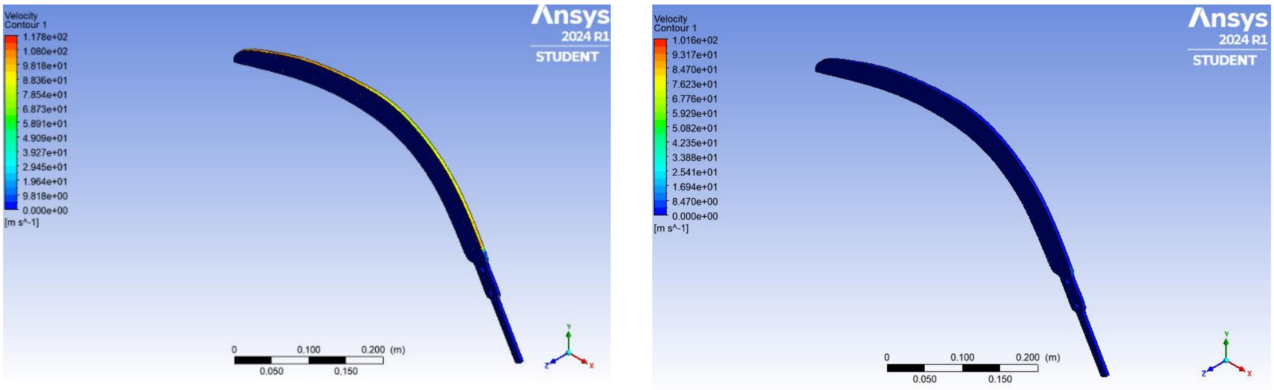


(a) (b)

Figure 5.6: Velocity vector for (a) existing and (b) improvement designs at inlet velocity = 100 ms^{-1}

Velocity in the context of a palm oil sickle's dynamic analysis is the rate at which the blade of the sickle travels when slicing through the palm fronds. The force applied to the material, the cutting efficiency, and the general efficacy of the operation are all significantly influenced by this velocity. The sickle's cutting velocity is the rate at which it moves its blade when cutting. Both the sickle's design and the user's swing or pull motion have an impact. The effectiveness with which the velocity is converted into cutting action can be influenced by the blade's form and sharpness

In general, cutting fronds (leaves or branches) from a tree with a medium to low cutting velocity is preferred than higher velocity. Here are the advantages of lower cutting velocity is the blade to move through the frond more smoothly, reducing tearing and shredding. This is particularly important for delicate fronds and when a smooth, completed cut is required. Furthermore, lower velocity minimises the chance of causing damage to the tree's surrounding tissue. This is critical for maintaining the tree's general health and supporting adequate recovery following the cut. A slower cutting velocity provides more control and precision throughout the cutting operation. This is critical for making precise cuts and preventing unintended harm. Most frond-cutting applications require a medium to low cutting velocity to ensure clean cuts, minimise tree damage, and maintain process control. Below the the result for velocity for both designs on Figure 5.7.



(a) (b)

Figure 5.7: The velocity for (a) existing and (b) improvement designs at inlet velocity = 100 ms^{-1}

In dynamic analysis, lower pressure usually refers to lower dynamic pressure, which rises with velocity and reaches a maximum known as Max Q. Lower dynamic pressure indicates less stress on the system, which may be advantageous depending on the application. Higher dynamic pressure, on the other hand, indicates more kinetic energy inside a fluid, which might be useful in certain applications. The decision between lower and higher pressure is based on the analysis's individual requirements and objectives. For this study the lower pressure is required for more smooth cutting. The results data for dynamics analysis with output pressure and velcity shown in Table 5.3 with velocity applied from 50 m/s until 150 m/s.

Table 5.3: The result max pressure and max velocity for both designs using ANSYS (FLUENT)

INPUT VELOCITY (m/s)	EXISTING DESIGN		IMPROVEMENT DESIGN	
	Max Pressure (Pa)	Max Output Velocity (m/s)	Max Pressure (Pa)	Max Output Velocity (m/s)
50	127.967	58.752	63.861	50.874
60	187.027	70.578	87.175	61.031
70	253.786	82.296	113.794	71.186
80	338.770	94.126	143.799	81.338
90	432.445	105.991	177.174	91.489
100	535.165	117.716	213.370	101.638
110	654.667	129.705	252.526	111.786
120	783.523	141.591	294.675	121.932
130	922.441	153.434	339.793	132.078
140	1071.640	165.373	387.597	142.224
150	1237.960	177.283	437.902	152.370

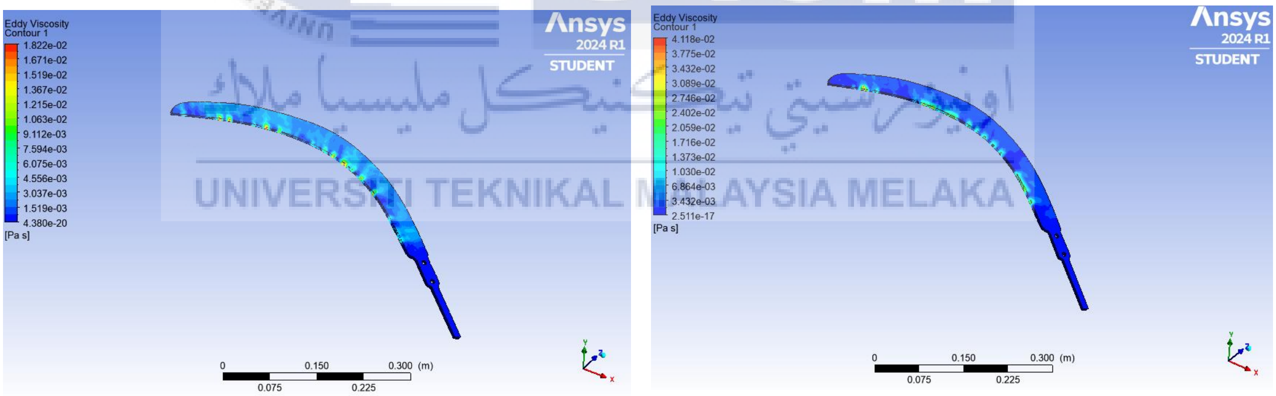
The outcomes of the dynamic analysis for both design models using ANSYS Fluid Flow (Fluent) are displayed in Table 5.3. The obtained results demonstrate that the improvement design generates low pressure and high velocity. This assertion is consistent with the Bernoulli's Principle, which, as Figure 5.6 and Figure 5.7 illustrates, states that high velocity happens at low pressure. Nonetheless, the max pressure applied to the sabit in the improvement design decreased linearly, but the highest pressure in the existing design which is 535.165 Pa while improvement design with 213.370 Pa.

Lower pressure means less force is required to push the blade through the bunches of palm fruits. This results in less physical strain while harvesting and easier cutting. Furthermore, a slower blade movement indicated by a lower velocity gives the user more control over the cut and reduces the possibility of unintentional injury to the fruit or palm tree. Table 5.3 illustrates how the improved design results in reduced pressure and velocity on 535.156 Pa and 117.716 m/s when compared to the existing design on 213.370 Pa and 101.638 m/s with both 100 m/s velocity applied. Conclusion, the improvement design is better compared to existing in term of pressure and velocity.

5.2.2 Viscosity

Viscosity is an inherent property of a fluid. It represents the internal friction between the fluid molecules that resist their movement past each other. Lower fluid viscosity is usually regarded as beneficial in dynamic analysis. Fluids with a lower viscosity provide less flow resistance, enabling smoother motion and possibly better efficiency and performance. Benefits including improved heat transmission, decreased friction, and improved system performance can result from choosing the proper low viscosity liquid.

For this study, the idea of external fluids and their viscosity becoming relevant under particular circumstances, as Figure 5.8 depicts the situation where external fluids interact with sabit. Thus, while viscosity isn't a major issue when cutting dry fronds, it might become an issue if the sickle comes into contact with liquids while in use. Water may coat the sickle's blade and function as an external fluid if it is utilized in a moist environment. Even with its low viscosity, water can nevertheless because some drag force when the sickle travels through the moist surroundings.



(a) (b)

Figure 5.8: The viscosity for (a) existing and (b) improvement designs at inlet velocity = 100 ms^{-1}

Lower viscosity is usually preferable for cutting sickle palm fronds as the sickle passes through a fluid, less drag is produced by lower viscosity fluids, such as water. This results in easier cutting that requires less effort from the user, which reduces fatigue and boosts productivity. Hence, the user can control the sickle more effectively during cutting because there is less drag. This minimises the chance of slipping and hurting the user and enables more accurate cutting. Also, when cutting, a low-viscosity fluid is less likely to make the sickle feel "sticky" or clog up. Cleaner cuts and more seamless operation are guaranteed. Over time, this may result in decreased cutting efficiency and greater user fatigue. The results for both designs of viscosity in dynamics analysis were displayed in Table 5.4.

Table 5.4: The result viscosity for both designs using ANSYS (FLUENT)

INPUT VELOCITY (m/s)	**VISCOSITY (Pa.s)**	
	EXISTING DESIGN	**IMPROVED DESIGN**
50	0.086426	0.00862
60	0.09549	0.01051
70	0.11390	0.01241
80	0.13263	0.01433
90	0.15181	0.01627
100	0.17011	0.01823
110	0.18840	0.02234
120	0.20718	0.02267
130	0.22604	0.02465
140	0.24501	0.02694
150	0.26410	0.02925

The data in the table clearly demonstrates that improved design had the lower viscosity with 0.01823 Pa.s compare to existing design with 0.17011 Pa.s when 100m/s input velocity applied. This scenario will lead to enhanced cutting performance, minimized drag forces while cutting where can leads to a more effortless cutting process. It also will led to a significant improvement in cutting speed.

5.3 Coefficient of Variation (CV)

In engineering analysis, the Coefficient of Variation (CV), commonly referred to as the normalised root mean square deviation (NRMSD) or relative standard deviation (RSD), is a statistical measure that is used to assess the relative dispersion of a set of data around its mean. Meanwhile, Arachchige et al. (2022) mentioned CV is an essential statistical measure that's utilised to evaluate the relative dispersion of data, especially when the distributions are normal. It is more effectively grasp a dataset's dispersion of data points in relation to its mean by using the CV. It makes it possible to compare dataset variability consistently even when their scales or units differ. It is a useful tool for assessing the consistency of data related to real-world processes and the accuracy of measuring devices (Seeletse & Miyambu, 2017).

The CV value can be determined by divided the data's standard deviation (SD) by the mean and multiply the result by 100% to get the CV and a percentage, as provided in Equation 234. A low CV usually less than 20% indicates that the data points are organised closely around the mean, implying great consistency and reliability. A high CV generally more than 30% implies a greater variety of data points around the mean, implying more variability in the dataset.

$$Coefficient\ of\ Variation\ (CV) = \frac{Standard\ Deviation}{Mean} X\ 100\% \tag{5.1}$$

Furthermore, the statistical values for both designs will be shown on Table 5.5 and Table 5.6 with an example of calculation for coefficient of variation is provided by applying Equation (5.5) for pressure for the existing Sabit design.

$$Coefficient\ of\ Variation\ (CV) = \frac{371.9609}{595.0355} \text{ x } 100\%$$

$$Coefficient\ of\ Variation\ (CV) = 62.51\%$$

Table 5.5: The statistical values of pressure for both design models

PRESSURE		
	EXISTING DESIGN	**IMPROVED DESIGN**
STANDARD DEVIATION	371.9609	125.2107
MEAN	595.0355	228.3332
COEFFICIENT OF VARIATION	62.51%	54.83%

Table 5.6: The statistical values ofvelocity for both design models

VELOCITY		
	EXISTING DESIGN	**IMPROVED DESIGN**
STANDARD DEVIATION	39.3138	33.6608
MEAN	117.8952	101.6316
COEFFICIENT OF VARIATION	33.34%	33.12%

In general, a sickle design with a lower coefficient of variation (CV) is desirable. A lower CV indicates higher consistency in the Sabit's crucial dimensions and qualities across multiple units. This consistency results in a more stable design that functions predictably. As shown in Table 234, the improved design yields a lower CV result for both pressure and velocity than the existing design with 7.68% lower than existing for CV for pressure. Meanwhile, improved design's CV IS 0.22% lower than existing design for CV for velocity.

5.4 Summary

Chapter 5 displays the results of the dynamic analysis for both the Sabit Teras Premium designs, using ANSYS Fluid Flow (FLUENT). This chapter describes the dynamic analysis's methodology and conclusions, including the meshing procedure, boundary conditions, velocity and pressure distributions, and coefficient of variation (CV).

Dynamic analysis focuses on how structural systems behave over time in different settings and loads. The study models and analyses the pressure, velocity and viscosity distributions on both the designs using ANSYS Fluid Flow (FLUENT) using Computational Fluid Dynamics (CFD), which sheds light on fluid behaviour and system stability.

The dynamic analysis's conclusions are highlighted in the results section, which also includes information on the coefficient of variation, pressure, and velocity distributions. In comparison to the existing design, the improved design showed reduced maximum pressures at all input velocities. Lower pressure extends tool life, reduces the possibility of material deformation, and allows for better cutting.

On the other hand, the improved design displayed more constant velocity distributions, indicating enhanced cutting control and efficiency. Last but not least, the improved design performed better when cutting since it had viscosity that proved much lower at different input velocities than existing design.

Meanwhile for the Coefficient of Variation (CV), shown improved design had lower CV values for pressure and velocity, indicating increased consistency and dependability. In the improved design, the CV for pressure was 54.83%, as instead of 62.51% in the existing design. Hence, the velocity CV for the revised design was 33.12%, while the existing design's value was 33.34%.

In summary, in terms of pressure, velocity, and viscosity distributions, the dynamic analysis shows that the Sabit Teras Premium's improved design surpasses the existing design. Because of the improved design's lower maximum pressures, more constant velocity distributions, and less drag forces, cutting efficiency and tool longevity are increased. Higher consistency and reliability are also shown in the upgraded design's reduced coefficients of variation, which makes it the better option for the Sabit Teras Premium.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study's goals were effectively met by a number of analyses that were centred on the Sabit Teras Premium tool. according to the first goal of Chapter 1's description, which is to determine Curvature Properties. Utilising both fatigue and near-static analyses, the curvature characteristics of the current Sabit Teras Premium were thoroughly determined. This analysis offered insightful information about the tool's capabilities and its drawbacks.

The second goal is to redesign for Optimal Curvature, which was achieved by using the curvature research findings and redesigning the Sabit Teras Premium with an emphasis on optimising curvature using SolidWorks software. This redesign sought to dramatically increase harvesting efficiency.

Finally, the last objective is to compare the performance of existing and improved designs to determine which is better.A full comparison of the revised Sabit Teras Premium and the previous version was carried out using Linear Static Analysis and Dynamic Analysis. This comparison enabled a clear evaluation of the efficiency gains realised by the redesign.

This study gives useful data on the Sabit Teras Premium because it effectively met all three objectives. The investigations found areas for improvement in the previous tool's curvature, which influenced the creation of a rebuilt version with optimised curvature. The comparison showed that the modified Sabit Teras Premium has the potential to significantly improve harvesting efficiency.

6.2 Recommendation

Some recommendations for future researchers to examine to determine which materials are appropriate for Sabit Teras Premium or other harvesting tools. Material testing should be a major component of this research, with a variety of materials being thoroughly tested to ascertain their resilience to rust and wear as well as their longevity and sharpness preservation. In order to assess the performance and efficacy of the most promising materials, field trials will be used in actual harvesting scenarios. Hence, evaluating the long-term durability as well as the initial cost of employing certain materials to determine their economic feasibility.

Furthermore, futher research by focusing on ergonomics of Sabit Teras Premium in order to lessen users' pain and suffering while harvesting. Creating ergonomically prototypes and including real users into the design process to guarantee the comfort and effectiveness of the products. By carrying out research that employs both subjective input and objective measures, such as joint stress and muscle activity, to assess user discomfort and fatigue levels when utilising various designs. Researchers can make a substantial contribution to the creation of harvesting equipment that are more effective, long-lasting, and easy to use by focusing on these areas.

6.3 Sustainability

Calculations are made to compare the two design models and assess which is more sustainable. The upgrade's design has a greater level of efficiency and dependability than the existing design of Sabit Teras Premium, according to the results. The investigation has revealed that the improved design has a greater sustainability rating than the existing design. This is because, in Linear Static analysis, the design efficiency of improved design is significantly higher than that of existing design. When the design efficiency is higher than 85%, as previously said in Chapter 4, the design is accepted. Additionally, compared to the existing design, the improved design's CV value in the dynamic analysis done in Chapter 5 is significantly reduced. The design of the improved design is stronger and stable when the CV value is lower.

REFERENCES

Abasubong, K. P., Gabriel, N. N., Adjoumani, J.-J. Y., Okon, A., & Udo, M. T. (2023). *The Importance and Utilization of Palm Oil as a Fish Oil Replacement in Aquaculture* (pp. 273–299). https://doi.org/10.1007/978-981-19-7451-9_11

Abdullah, N. A., Mohamad Shaberi, M. N., Nordin, M. N. A., Mohd Ripin, Z., Razali, M. F., Wan Mamat Ali, W. M. A., Awang, B., & Ridzwan, M. I. Z. (2023). Field measurement of hand forces of palm oil harvesters and evaluating the risk of work-related musculoskeletal disorders (WMSDs) through biomechanical analysis. *International Journal of Industrial Ergonomics*, *96*, 103468. https://doi.org/10.1016/J.ERGON.2023.103468

Achaw, O.-W., & Danso-Boateng, E. (2021). Manufacture of Crude Palm Oil and Refined Palm Oil. In *Chemical and Process Industries* (pp. 195–211). Springer International Publishing. https://doi.org/10.1007/978-3-030-79139-1_7

Akbar, A. R. M., Wibowo, A. D., & Santoso, R. (2023). Investigation on the Optimal Harvesting Time of Oil Palm Fruit. *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, *12*(2), 524. https://doi.org/10.23960/jtep-l.v12i2.524-532

Al-Qudah, S., & Yang, M. (2023). Large Displacement Detection Using Improved Lucas–Kanade Optical Flow. Sensors, 23(6), 3152. https://doi.org/10.3390/s23063152

Alamanda, A. E. (2023). Peran Pemerintah dalam Optimalisasi Pelaksanaan Peremajaan Tanaman Kelapa Sawit. *Wajah Hukum*, *7*(1), 73. https://doi.org/10.33087/wjh.v7i1.1129

Aliuddin Bakar, M., Firdaus Abdul Rashid, N., & Syahlan, S. (2018). Comparison of an effective working hour and harvesting cost between manual harvesting (chisel and sickle) and mechanised harvesting (CKAT and motorised cutter) in oil palm plantation. *International Journal of Engineering & Technology*, *7*(2.29), 282. https://doi.org/10.14419/ijet.v7i2.29.13333

Aigerman, N., Gupta, K., Kim, V. G., Chaudhuri, S., Saito, J., & Groueix, T. (2022). Neural jacobian fields. ACM Transactions on Graphics, 41(4), 1–17. https://doi.org/10.1145/3528223.3530141

Arachchige, C. N. P. G., Prendergast, L. A., & Staudte, R. G. (2022). Robust analogs to the coefficient of variation. Journal of Applied Statistics, 49(2), 268–290. https://doi.org/10.1080/02664763.2020.1808599

Austin, K. G., Schwantes, A., Gu, Y., & Kasibhatla, P. S. (2019). What causes deforestation in Indonesia? *Environmental Research Letters*, *14*(2), 024007. https://doi.org/10.1088/1748-9326/AAF6DB)

Bagathi, S. R., Pawar, V. K., Gummal, S. R., & Chebolu, S. (2022). Case study of Stress Calculation using Stress Superposition Method for Linear Analysis. International Journal for Research in Applied Science and Engineering Technology, 10(3), 1112–1120. https://doi.org/10.22214/ijraset.2022.40824

Barakat, J. M., & Squires, T. M. (2023). Curvature and shape relaxation in surface-viscous domains. *Physical Review Fluids*, *8*(5), 054001. https://doi.org/10.1103/PhysRevFluids.8.054001

Bhil, A. R., & Singh, M. K. (2016). Design of Gear Tooth Profile Using Free Form Curve for Optimum Stresses. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2813284

Cardoso, V. E., & Botello, S. (2016). Parallel Meshing for Finite Element Analysis (pp. 156–168). https://doi.org/10.1007/978-3-319-32243-8_11

Carmona-Hernandez, A., Vazquez-Velez, E., Uruchurtu-Chavarin, J., Gonzalez-Rodriguez, J. G., & Martinez-Gomez, L. (2019). Use of an imidazol synthetized from palm oil as a corrosion inhibitor for a supermartensitic stainless steel in H_2S. *Green Chemistry Letters and Reviews*, *12*(1), 89–99. https://doi.org/10.1080/17518253.2019.1578997

Carmona-Hernandez, A., Vazquez-Velez, E., Uruchurtu, J., & Gonzalez-Rodriguez, J. G. (2020). Effect of Flow Condition on the H2S Corrosion Inhibition of a Supermartensitic Stainless Steel with a Gemini Surfactant. *Journal of Bio- and Tribo-Corrosion*, *6*(4), 122. https://doi.org/10.1007/s40735-020-00420-4

Chen, Z., Elsaid, S., Sim, D. Y. Y., Maul, T., & Liao, I. Y. (2022). Detection of Oil Palm Fresh Fruit

Bunches (FFBS) with Computer Vision Models. *2022 International Conference on Mechanical, Automation and Electrical Engineering (CMAEE)*, 86–91. https://doi.org/10.1109/CMAEE58250.2022.00023

Choi, H.-Y., Lee, D.-H., Song, C. Y., & Lee, J. (2013). Optimization of rail profile to reduce wear on curved track. *International Journal of Precision Engineering and Manufacturing*, *14*(4), 619–625. https://doi.org/10.1007/s12541-013-0083-1

Cruden, B. A. (2023, June 12). On the Fluid Dynamics Boundary Condition in Ablating or Blowing Flows. AIAA AVIATION 2023 Forum. https://doi.org/10.2514/6.2023-3614

Corradi, G., & Munar, E. (2019). The Curvature Effect. *The Oxford Handbook of Empirical Aesthetics*, 510–532. https://doi.org/10.1093/OXFORDHB/9780198824350.013.24

Damians, I. P., Noghretab, B. S., Olivella, S., & Gens, A. (2022, June 26). Numerical Mesh Sensitivity Works Performed to Analyze Advective Gas Flow in a Compact Clay. All Days. https://doi.org/10.56952/ARMA-2022-0679

Dan, D., Liao, X., & Han, F. (2023). A Dynamic Analysis Method for Complex Cable Systems Based on Dynamic Stiffness Method. Prestress Technology, 27(01), 15–29. https://doi.org/10.59238/j.pt.2023.01.002

Efendy Goon, D., Sheikh Abdul Kadir, S. H., Latip, N. A., Ab. Rahim, S., & Mazlan, M. (2019). Palm Oil in Lipid-Based Formulations and Drug Delivery Systems. *Biomolecules*, *9*(2), 64. https://doi.org/10.3390/biom9020064

Escallón-Barrios, M., Castillo-Gomez, D., Leal, J., Montenegro, C., & Medaglia, A. L. (2022). Improving harvesting operations in an oil palm plantation. *Annals of Operations Research*, *314*(2), 411–449. https://doi.org/10.1007/s10479-020-03686-6

Fajri, A., Prabowo, A. R., Muhayat, N., Smaradhana, D. F., & Bahatmaka, A. (2021). Fatigue Analysis of Engineering Structures: State of Development and Achievement. Procedia Structural Integrity, 33, 19–26. https://doi.org/10.1016/j.prostr.2021.10.004

Fullagar, R., Hayes, E., Chen, X., Ma, X., & Liu, L. (2021). A functional study of denticulate sickles and knives, ground stone tools from the early Neolithic Peiligang culture, China. *Archaeological Research in Asia*, *26*. https://doi.org/10.1016/J.ARA.2021.100265

Gąsiorowski, D. (2022). Impact of the Finite Element Mesh Structure on the Solution Accuracy of a Two-Dimensional Kinematic Wave Equation. Water, 14(3), 446. https://doi.org/10.3390/w14030446

Glowinski, S., Bryndal, A., & Grochulska, A. (2021). Prevalence and risk of spinal pain among physiotherapists in Poland. *PeerJ*, *7*, e11715. https://doi.org/10.7717/PEERJ.11715/SUPP-3

Grementieri, L., Tech, Z., & Finelli, F. (2022). StAnD: A Dataset of Linear Static Analysis Problems. https://doi.org/10.48550/ARXIV.2201.05356

Groman-Yaroslavski, I., Weiss, E., & Nadel, D. (2016). Composite Sickles and Cereal Harvesting Methods at 23,000-Years-Old Ohalo II, Israel. *PLOS ONE*, *11*(11), e0167151. https://doi.org/10.1371/JOURNAL.PONE.0167151

Hamdan, M., Sabudin, S., Faizal, M., & Raghavan, V. R. (2012). *Experimental studies on oil palm frond drying using swirling fluidized bed dryer*. 1212–1219. https://doi.org/10.1063/1.4704339

Hassan, R., Ibrahim, A., & Ahmad, Z. (2023). Factor of Safety (pp. 75–77). https://doi.org/10.1007/978-981-19-2697-6_7

Hegde, V. (2023). Sensitivity Analysis on Reliability Prediction. 2023 Annual Reliability and Maintainability Symposium (RAMS), 1–4. https://doi.org/10.1109/RAMS51473.2023.10088211

Hicks, J. W., & Wang, T. (2021). Safety factors as a 'design' principle of animal form and function: an historical perspective. Journal of Experimental Biology, 224(22). https://doi.org/10.1242/jeb.243324

Hu, Y., Schneider, T., Wang, B., Zorin, D., & Panozzo, D. (2020). Fast tetrahedral meshing in the wild. ACM Transactions on Graphics, 39(4). https://doi.org/10.1145/3386569.3392385

Kalnahuz, A., Melnyk, V., Solarov, O., Sirenko, Y., & Chyrva, A. (2023). *A Curvilinear Blades Profile of Accelerating Devices* (pp. 54–63). https://doi.org/10.1007/978-3-031-32774-2_6

Khalyavkin, A., Makeev, S., Salamekh, A., & Ivanovskaya, A. (2020). Analysis of boundary conditions in design circuits influence on the shaft line operating state. E3S Web of Conferences, 217, 03006. https://doi.org/10.1051/e3sconf/202021703006

Krishnamurthy, B. (2023). Influence of mesh in modelling of flow forming process. 1583–1592. https://doi.org/10.21741/9781644902479-171

Kumar, S., & Gaur, V. (2022). Advances in Fatigue Prediction Techniques. In Advances in Fatigue and Fracture Testing and Modelling. IntechOpen. https://doi.org/10.5772/intechopen.99361

Lee, Y. (2022). Assessment of Loading and Boundary Conditions in Finite Element Analysis Simulation for Clenching of Teeth. Korean Journal of Computational Design and Engineering, 27(3), 301–309. https://doi.org/10.7315/CDE.2022.301

Lee, Y.-L., & Guo, M. (2012). Pseudo Stress Analysis Techniques. In Metal Fatigue Analysis Handbook (pp. 61–87). Elsevier. https://doi.org/10.1016/B978-0-12-385204-5.00002-1

Li, G., Duan, G., Liu, X., & Wang, Z. (2023). Boundary conditions. In Moving Particle Semi-Implicit Method (pp. 71–96). Elsevier. https://doi.org/10.1016/B978-0-443-13508-8.00005-6

Ling, J., Du, X., Wang, S., & Wang, Z. (2014, June 16). Relationship Between Optimum Curved Blade Generate Line and Cascade Parameters in Subsonic Axial Compressor. *Volume 2B: Turbomachinery*. https://doi.org/10.1115/GT2014-25799

Lock, C., Hassan, O., Sevilla, R., & Jones, J. (2023). Meshing using neural networks for improving the efficiency of computer modelling. Engineering with Computers, 39(6), 3791–3820. https://doi.org/10.1007/s00366-023-01812-z

Lyu, J., Xin, J., & Yu, Y. (2018). Curvature Effect in Shear Flow: Slowdown of Turbulent Flame Speeds with Markstein Number. *Communications in Mathematical Physics*, *359*(2), 515–533. https://doi.org/10.1007/s00220-017-3060-1

Ma, Z., Liu, P., Choi, J., & Sohn, H. (2023). Structural displacement estimation using high-sampling acceleration and temporally-aliased low-sampling vision measurements. In P. Fromme & Z. Su (Eds.), Health Monitoring of Structural and Biological Systems XVII (p. 47). SPIE.

https://doi.org/10.1117/12.2646413

Mayes, S. (2020). *The History and Economic Importance of the Oil Palm* (pp. 1–8). https://doi.org/10.1007/978-3-030-22549-0_1

Meon, M. S. (2023). Finite Element Analysis of Low-Velocity Impact Carbon Fiber-Reinforced Polymer (CFRP) Composite Laminate Emphasizing on Meshing Technique. 43–51. https://doi.org/10.4028/p-9hbg70

Muhammad, T., Fuadi, Z., Fazmi, K., & Husaini, H. (2015). Wear Characteristic of Stainless Steel 304 Sliding against Cast Iron under Lubrication Environment of Palm Biodiesel Fuel. *Applied Mechanics and Materials*, *758*, 107–111. https://doi.org/10.4028/www.scientific.net/AMM.758.107

Mu, Z., & Kazerounian, K. (2005). Optimum Geometric Design of the Edge Curves for Cutting Blades. *Mechanics Based Design of Structures and Machines*, *33*(2), 173–183. https://doi.org/10.1081/SME-200067060

Nelson, T. C., Doukakis, P., Lindley, S. T., Schreier, A. D., Hightower, J. E., Hildebrand, L. R., Whitlock, R. E., & Webb, M. A. H. (2013). Research Tools to Investigate Movements, Migrations, and Life History of Sturgeons (Acipenseridae), with an Emphasis on Marine-Oriented Populations. *PLOS ONE*, *8*(8), e71552. https://doi.org/10.1371/JOURNAL.PONE.0071552

Nguyen, H. C. (2020). Safety Factor and Failure Mechanism in Geotechnical Engineering: A Numerical Study (pp. 121–129). https://doi.org/10.1007/978-981-15-0886-8_10

Noordin, M. N. A., Hudzari, R. M., Azuan, H. N., Zainon, M. S., Mohamed, S. B., & Wafi, S. A. (2016a). Development of Standard Approach for Sickle Blade Manufacturing. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(5), 740. https://doi.org/10.18517/ijaseit.6.5.960

Noordin, M. N. A., Hudzari, R. M., Azuan, H. N., Zainon, M. S., Mohamed, S. B., & Wafi, S. A. (2016b). Development of Standard Approach for Sickle Blade Manufacturing. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(5), 740.

https://doi.org/10.18517/ijaseit.6.5.960

Ostfeld, R., Howarth, D., Reiner, D., & Krasny, P. (2019). Peeling back the label—exploring sustainable palm oil ecolabelling and consumption in the United Kingdom. *Environmental Research Letters*, *14*(1), 014001. https://doi.org/10.1088/1748-9326/AAF0E4)

Ozturk, C., Aka, I. B., & Lazoglu, I. (2018). Effect of blade curvature on the hemolytic and hydraulic characteristics of a centrifugal blood pump. *The International Journal of Artificial Organs*, *41*(11), 730–737. https://doi.org/10.1177/0391398818785558

Pendrill, F., Persson, U. M., Godar, J., & Kastner, T. (2019). Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition. *Environmental Research Letters*, *14*(5), 055003. https://doi.org/10.1088/1748-9326/AB0D41)

Perumal, L., & Mon, T. T. (2013). Linear-spline element for meshing of irregular boundaries. International Journal of Computational Science and Engineering, 8(4), 376. https://doi.org/10.1504/IJCSE.2013.057300

Prada, D. M., Galvis, A. F., Alcântara, A. C., & Sollero, P. (2018). 3D Boundary element meshing for multiscale bone anisotropic analysis. European Journal of Computational Mechanics, 1–18. https://doi.org/10.1080/17797179.2018.1524054

Praisach, Z.-I., Adeljan, D., Pîrșan, D. A., & Gillich, G.-R. (2022). A new approach for imperfect boundary conditions on the dynamic behavior. Analecta Technica Szegedinensia, 16(1), 56–61. https://doi.org/10.14232/analecta.2022.1.56-61

Quyen, N. T., Quoc, N. T., Tru, N. D., Gomes, A. J. P., & Ferreira, F. B. N. (2022). An Alpha Finite Element Method for Linear Static and Buckling Analysis of Textile-Like Sheet Materials. Solid State Phenomena, 333, 211–217. https://doi.org/10.4028/p-1415q2

Rahman, A., Mohamaddan, S., Abdul Majid, N. A., Andrew-Munot, M., Razali, N. T., Md Deros, B., & Ahmad Bakri, S. R. (2017). Simple Arm Muscle Model for Oil Palm Harvesting Process. *MATEC Web of Conferences*, *87*, 02015. https://doi.org/10.1051/matecconf/20178702015

Ramli, A. S., Shuib, A. R., Mohd Bakri, M. A., Mohd Azaman, M. I. H., Md Radzi, M. K. F., Ahmad, M. R., Mohd Khalid, M. R., & Jahis, S. (2020a). Mechanical static structural analysis of CANTAS sickle blade. *Advances in Agricultural and Food Research Journal*, *1*(1). https://doi.org/10.36877/aafrj.a0000095

Ramli, A. S., Shuib, A. R., Mohd Bakri, M. A., Mohd Azaman, M. I. H., Md Radzi, M. K. F., Ahmad, M. R., Mohd Khalid, M. R., & Jahis, S. (2020b). Mechanical static structural analysis of CANTAS sickle blade. *Advances in Agricultural and Food Research Journal*, *1*(1). https://doi.org/10.36877/aafrj.a0000095

Sabit Teras Premium Pakej A | Shopee Malaysia. (2024.). Retrieved 20 January 2024, from https://shopee.com.my/Sabit-Teras-Premium-Pakej-A-i.331269841.5562389913

Saleem, A., Naureen, I., Naeem, M., Tasleem, G., Ahmed, H., Farooq, U., & Ali, T. (2022). Effect of Palm oil and Their Main Compounds in the Management of Cardiovascular Disease Risk Factors. *Scholars Bulletin*, *8*(2), 59–65. https://doi.org/10.36348/sb.2022.v08i02.002

Seeletse, S. M., & Miyambu, G. R. (2017). Construction and Application of a Statistical Test for Coefficient of Variation on Normal Distributions. American Journal of Applied Sciences, 14(11), 1024–1030. https://doi.org/10.3844/ajassp.2017.1024.1030

Sehgal, S., & Sharma, V. (2021). Palm/Palm Kernel (Elaeis guineensis). In *Oilseeds: Health Attributes and Food Applications* (pp. 145–161). Springer Singapore. https://doi.org/10.1007/978-981-15-4194-0_6

Shahzadi, I., & Nadeem, S. (2016). Impact of curvature on the mixed convective peristaltic flow of shear thinning fluid with nanoparticles. *Canadian Journal of Physics*, *94*(12), 1319–1330. https://doi.org/10.1139/cjp-2015-0508

Smoljanović, H., Balić, I., Munjiza, A., Akmadžić, V., & Trogrlić, B. (2020). Analysis of dynamic stability of beam structures. Acta Mechanica, 231(11), 4701–4715. https://doi.org/10.1007/s00707-020-02793-6

Silky Hayauchi 3.7m Telescopic Pole Saw (177-39) - Forestry Tools. (2023). Retrieved 20 January 2024, from https://www.forestrytools.com.au/products/silky-hayauchi-3-7m-telescopic-pole- saw-177-39

Song, C.-Y., & Choi, H.-Y. (2022). Multi-Objective Profile Design Optimization to Minimize Wear

Damage and Surface Fatigue of City Train Wheel. *Applied Sciences*, *12*(8), 3940. https://doi.org/10.3390/app12083940

Sunggara, K. D., Yuniar Rahman, A., & Istiadi. (2023). Fault Detection of Oil Palm Harvesting Using Yolo V4. *2023 International Conference on Computer Science, Information Technology and Engineering (ICCoSITE)*, 838–842. https://doi.org/10.1109/ICCoSITE57641.2023.10127674

Surinlert, P., Chuenoppakun, P., & Ruammaitree, A. (2021). Increase in surface hardness of stainless steel through graphene growth on stainless steel surface by chemical vapor deposition using waste vegetable oil as a carbon source. *Journal of Physics: Conference Series*, *1719*(1), 012111. https://doi.org/10.1088/1742-6596/1719/1/012111

Syed Hilmi, S. M. H., & Ibrahim, N. H. (2022). Sustainability and oil palm practices. *Proceedings of 2022 AOCS Annual Meeting & Expo*. https://doi.org/10.21748/PYUG9768

Tan, Y. D., & Lim, J. S. (2019). Feasibility of palm oil mill effluent elimination towards sustainable Malaysian palm oil industry. *Renewable and Sustainable Energy Reviews*, *111*, 507–522. https://doi.org/10.1016/J.RSER.2019.05.043

Urdea, M. (2018). Static linear analysis for trusses structure for supporting pipes. IOP Conference Series: Materials Science and Engineering, 399, 012051. https://doi.org/10.1088/1757-899X/399/1/012051

Urizar, A. (2022). Palm oil basic steps to process this oil. *Proceedings of 2022 AOCS Annual Meeting & Expo*. https://doi.org/10.21748/DGLU5386

Urugo, M. M., Teka, T. A., Teshome, P. G., & Tringo, T. T. (2021). Palm Oil Processing and Controversies over Its Health Effect: Overview of Positive and Negative Consequences. *Journal of Oleo Science*, *70*(12), ess21160. https://doi.org/10.5650/jos.ess21160

Wang, C., & Wang, Y. (2021). Stability analysis of discretized structure systems based on the complex network with dynamics of time-varying stiffness. Mathematical Methods in the Applied Sciences, 44(17), 13344–13356. https://doi.org/10.1002/mma.7629

Wei, R., Jiang, Z., Guo, X., Mei, H., Zolotas, A., & Kelly, T. (2022). Designing critical systems with iterative automated safety analysis. Proceedings of the 59th ACM/IEEE Design Automation Conference, 181–186. https://doi.org/10.1145/3489517.3530434

Yang, S., Tang, Y., & Zhao, Y. F. (2015). A new part consolidation method to embrace the design freedom of additive manufacturing. *Journal of Manufacturing Processes*, *20*, 444–449. https://doi.org/10.1016/J.JMAPRO.2015.06.024

Yulianti, S., Samuel, S., Nainggolan, T. S., & Iqbal, M. (2022). Meshing generation strategy for prediction of ship resistance using CFD approach. IOP Conference Series: Earth and Environmental Science, 1081(1), 012027. https://doi.org/10.1088/1755-1315/1081/1/012027

Zhang, D. L., Wang, B. W., & Liu, F. (2012). Stress and Displacement Analysis with Multiple Loads. Applied Mechanics and Materials, 190–191, 1266–1268. https://doi.org/10.4028/www.scientific.net/AMM.190-191.1266

Zuo, Z., Yang, G., Wang, Z., Wang, H., & Jin, J. (2021). Effect of Boundary Conditions on the Mechanical Behavior of the Geogrid–Soil Interface. Applied Sciences, 11(21), 9942. https://doi.org/10.3390/app11219942