STRUCTURAL IMPROVEMENT OF RIVER TRASH COLLECTOR SYSTEM (RTCS) FOR CONVEYOR TYPE MECHANISM

MOHD SAIFUL IKHWAN BIN ISMAIL
B092010329

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MANUFACTURING) WITH HONOURS – BMKM

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Mohd Saiful Ikhwan Bin Ismail

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MOHD SAIFUL IKHWAN BIN ISMAIL

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DECLARATION

I declare that this “Structural Improvement of River Trash Collector System (RTCS) For Conveyor Type Mechanism” is the result of my own research except as cited in the references. The chosen item has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MOHD SAIFUL IKHWAN BIN ISMAIL

Date : 19 JANUARY 2024

APPROVAL

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

Signature : ....

Supervisor Name : MOHD FARIDUDDIN BIN MUKHTAR

Date : 19 JANUARY 2024

DEDICATION

This report is dedicated to the pursuit of innovation and excellence in engineering, and to the collective spirit of collaboration and determination that fuelled its realization. It is with heartfelt appreciation that I dedicate this work to my family, whose unwavering support and encouragement have been a source of strength throughout this journey.

To my friends, whose camaraderie and understanding provided moments of respite and inspiration, I extend my gratitude. Your belief in my capabilities and shared enthusiasm for the challenges faced in this endeavour have been invaluable.

To the mentors and educators who have imparted knowledge and guidance, shaping not only my technical skills but also my approach to problem-solving and critical thinking, I offer my deepest thanks.

This dedication is a tribute to the collaborative efforts of the project team, whose diverse expertise and commitment to excellence have been instrumental in realizing the goals of this endeavour. Each member's dedication has left an indelible mark on the project's success. May this work stand as a testament to the collective passion for advancement and the tireless pursuit of solutions that contribute to the betterment of our community and environment.

ABSTRACT

The Malacca River is one of the rivers affected by pollution in the world. Floating trash in rivers poses a significant threat to water quality. This paper aims to shed light on the urgent need for floating trash collectors as a viable solution to combat the growing problem of river pollution. This research scope is revolving around the study of the main body structure of the River Trash Collector System (RTCS) for its structural integrity. It involves a comprehensive review of existing literature on conveyor systems and an in-depth analysis of the RTCS's current structural design, focusing on strength and weight considerations. The research intends to propose new improvements for optimizing the main frame, considering functionality, feasibility, and its durability. The proposed improvements encompass structural design changes, material modifications, improvements to the lifting mechanism and connectors, and additional measures aimed at advancing its overall performance and longevity. The outcomes will contribute to recommendations for enhancing the structural integrity of the system, offering practicality for conveyor system design and optimization in the material usage.

ABSTRAK

Sungai Melaka merupakan salah satu sungai yang terjejas akibat pencemaran. Sampah terapung di sungai menimbulkan masalah kepada kualiti air. Kertas kerja ini bertujuan untuk memberi penerangan tentang keperluan mendesak untuk pengaut sampah terapung sebagai penyelesaian yang mampu untuk menangani masalah pencemaran sungai yang semakin meningkat. Skop kajian ini berkisar dalam kajian struktur rangka utama Sistem Pemungut Sampah Sungai (RTCS) untuk integriti strukturnya. Ia melibatkan semakan menyeluruh terhadap literatur sedia ada mengenai sistem penghantar dan analisis mendalam terhadap reka bentuk struktur semasa RTCS, berfokuskan kepada pertimbangan kekuatan struktur dan jisim. Penyelidikan ini berhasrat untuk mencadangkan penambahbaikan baharu untuk mengoptimumkan bingkai utama, fungsi, kebolehlaksanaan dan ketahanannya. Penambahbaikan yang dicadangkan merangkumi perubahan reka bentuk struktur, pengubahsuaian bahan, penambahbaikan pada mekanisme angkat dan penyambung, dan langkah tambahan yang bertujuan untuk memajukan prestasi keseluruhan dan jangka hayatnya. Hasilnya akan menyumbang kepada cadangan untuk meningkatkan integriti struktur sistem, menawarkan kepraktisan untuk reka bentuk sistem penghantaran dan pengoptimuman dalam penggunaan bahan.

ACKNOWLEDGEMENTS

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

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LIST OF SYMBOLS AND ABBREVIATIONS

UNESCO	-	United Nations Educational, Scientific and Cultural Organization
PPSPM	-	Perbadanan Pembangunan Sungai dan Pantai Melaka
MIG	-	Metal Inert Gas
RTCS	-	River Trash Collector System
CAD	-	Computer-aided design
SLS	-	Selective laser sintering
3D	-	3 Dimension
mm	-	Millimetre
EDM	-	Electrical Discharge Machine
FEA	-	Finite element analysis
VON	-	Von Mises Stress
URES	-	Resultant Displacement
ESTRN	-	Equivalent Strain
FoS	-	Factor of Safety
MK	-	Mark

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CHAPTER 1

INTRODUCTION

1.1 Background

The Malacca River, located in Malaysia, is a historically significant waterway that has played a vital role in the growth and development of the city of Malacca (Tye, 2017). The river stretches approximately 10 kilometres from its source in the outskirts of the city and flows through the heart of Malacca, eventually reach into the Strait of Malacca.

Malacca River has long been regarded as the lifeblood of the city, serving as a major trade route during the height of the Malacca Sultanate in the 15th century. It facilitated the transportation of goods and connected the city to other parts of the region. Over the centuries, the river has witnessed the rise and fall of empires, colonial occupation, and the transformation of Malacca into a UNESCO World Heritage Site (UNESCO, 2008).

However, despite its rich historical and cultural significance, the Malacca River has been facing a growing problem of river pollution in recent years. The rapid urbanization, industrialization, and population growth in the surrounding areas have put immense pressure on the river, resulting in its deteriorating water quality and increasing pollution levels (HUA, 2017a).

One of the primary contributors to the pollution of the Malacca River is the indiscriminate disposal of solid waste (HUA, 2017a). The riverbanks and surrounding areas are often littered with plastic bottles, food wrappers, and other non-biodegradable materials. These items are frequently washed into the river during rainfall, leading to the accumulation of floating trash.

Industrial activities along the river's banks have also contributed to the pollution (The Straits Times, 2019). Discharge of untreated wastewater, chemicals, and effluents from factories and industrial units find their way into the river, further degrading its water quality.

These pollutants not only contaminate the water but also pose a significant threat to aquatic life and the overall ecosystem.

Moreover, agricultural runoff containing fertilizers, pesticides, and sediment from nearby plantations also enters the river, adding to its pollution (FAO, 2021). The excessive use of chemicals in agriculture and the inadequate implementation of sustainable farming practices have resulted in the degradation of water quality and the loss of biodiversity within the river.

The increasing river pollution in the Malacca River has had adverse effects on the environment, public health, and tourism (Khatun, 2021). The presence of floating trash and polluted water diminishes the aesthetic appeal of the river, negatively impacting the tourism industry, which is an important economic driver for the city. Additionally, the contaminated water poses health risks to communities living along the riverbanks, as well as to the marine life dependent on the river ecosystem (Afroz & Rahman, 2017).

Efforts have been made to address the issue of river pollution in the Malacca River (Zikri, 2020). The local government has implemented various initiatives to raise awareness, promote responsible waste management, and regulate industrial discharge. However, a more comprehensive and sustainable solution is needed to tackle the increasing pollution levels effectively.

The implementation of floating trash collectors, along with improved waste management practices, regular monitoring of water quality, and stricter enforcement of environmental regulations, can help alleviate the problem. By proactively intercepting and removing floating trash, these devices can contribute to restoring the health and vitality of the Malacca River, ensuring its long-term sustainability as a vital natural and cultural asset for the city and its residents.

1.2 Problem Statement

Rivers play a vital role in the ecosystem, providing habitats for numerous species and serving as a source of drinking water, irrigation, and transportation (McMillan, 2022). Unfortunately, rivers around the world are facing an increasing problem, which is accumulation of floating trash. The presence of litter and debris not only disrupts the ecological balance but also poses numerous challenges to human health, water quality, and the overall well-being of riverine communities. Considering these concerns, this project aims to shed light on the urgent need for floating trash collectors as a viable solution to combat the growing problem of river pollution. The escalating issue of floating trash in rivers presents several critical challenges that demand immediate attention and effective intervention.

Figure 1 A PPSPM worker collecting various types of garbage thrown into Melaka River. Credit: Melaka Hari Ini (Jamal, 2021).

Environmental Impact

Floating trash in rivers significantly affects the ecological balance and poses a threat to biodiversity. As non-biodegradable materials such as plastics and microplastics accumulate, they introduce toxins into the water, degrading water quality and poisoning aquatic life. The ingestion of plastic by fish and other organisms can disrupt their growth, reproduction, and survival, ultimately leading to a loss of biodiversity within river ecosystems.

Figure 2

Water Contamination

The presence of floating trash in rivers poses a significant risk to water quality. As the debris decays, it releases harmful chemicals and toxins into the water, compromising its suitability for human consumption and agricultural use. Contaminated water can lead to the spread of waterborne diseases (WHO, 2022), affecting the health and well-being of communities living along the riverbanks and relying on its water for various purposes.

Aesthetic and Recreational Value

Rivers are not only essential for ecological health but also contribute to the aesthetics and recreational value of an area. The accumulation of floating trash not only degrades the natural beauty of the river but also discourages recreational activities such as boating, fishing, and swimming. This diminishes the potential economic benefits derived from tourism and negatively impacts the overall quality of life for local communities.

Flood Management

Floating trash in rivers exacerbates the problem of flooding by obstructing natural water flow (Honingh et al., 2020). Debris can clog river channels, bridges, and other infrastructure, impeding the smooth passage of water during heavy rains and causing overflow. This situation increases the risk of flash floods, property damage, and loss of life, particularly in areas prone to flooding. Effective trash collection measures can mitigate these risks and enhance flood management strategies.

Figure 3 Example of trash clogging.

Long-term Environmental Sustainability

Addressing the issue of floating trash in rivers is not just a short-term problem; it requires a sustainable approach. The accumulation of plastic waste and other pollutants in rivers contributes to the larger global problem of marine pollution. Without efficient measures to intercept and remove this waste before it reaches the oceans, the detrimental impact on marine ecosystems, including coral reefs, marine life, and coastal areas, will persist.

1.2 Research Objective

The primary objective of this research is:

1) To study the structural frame of RTCS model that holding its conveyor system and floating mechanism.
2) To analyse the current frame of the RTCS relative to its strength and weight.
3) To propose new improvements and optimization for RTCS.

1.3 Scope of Research

This research scope is revolving around the study of the structural frame of the River Trash Collector System (RTCS) for material handling. It involves a comprehensive review of existing literature on conveyor systems and an in-depth analysis of the RTCS's current structural design, focusing on strength and weight considerations. The research intends to propose new improvements for optimizing the RTCS structural frame, considering functionality, feasibility, and its durability. The proposed modifications will be subjected to simulation studies and physical testing to validate their impact on strength and overall performance. The outcomes will contribute to recommendations for enhancing the structural integrity of the RTCS, offering practicality for conveyor system design and optimization in the material usage.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will concentrate on background research and a review of the literature for the entire project by employing articles, conference abstracts, books, research papers, and journals to do the research. This include on water pollution issues, structural design, pontoon, mounting component's material, and 3D printing software that has been used to design the Labah Air. With the aid of a literature review, it will be simpler to comprehend the entire project, learn more about the research, and be able to make project-related judgements.

2.2 Water Pollution Issue at Malacca River

According to a 2012 assessment from the Department of the Environment, 195 rivers out of 278 are declared contaminated (Wei & Yong, 2021). Malacca River in Malacca state is one of the instances. Malacca state, which is well-known as a tourist destination and was classified as a UNESCO historical and heritage site in July 2008, was shocked by river water pollution in the Malacca River, which has resulted in the loss of a variety of aquatic species due to water toxicity.

Water pollution in Malacca River is caused by a variety of sources, including waste pollutants and excrement waste. It will contaminate the river's water and degrade its quality. According to a study undertaken by (Afroz & Rahman, 2017), stated that the river's water quality has deteriorated substantially due to waste pollution. As a result, the objective 9 of the Water Acts of 1920, the Sewage Service Act of 1993, and the Sewage and Industrial Effluent Act of 1979 is to prevent any foreign materials from entering the river without authorization, to improve sewage treatment, and to always maintain water quality service.

A cleaning boat is currently being used to remove the debris**.** *Figure 4* shows a cleaning boat with a space at the stern and a net to catch floating rubbish. Only one watercraft driver and three other collectors are required for this method. To prevent clogging, large waste were collected into the receptacle once a day. The whole process should take less than

3 hours. According to local sources, collected rubbish has been recorded more than 5 tonnes every week.

Figure 4 Malacca River's workers on a cleaning boat with a space at the stern

2.3 Structural Design

Baltimore's Mr. Trash Wheel is officially known as the Inner Harbor Water Wheel. Its design is intended to be a trash interceptor, a water vessel that removes trash from the Jones Falls River to the Inner Harbor in Baltimore, Maryland, USA (Lindquist, A., 2016). Invented in 2008 by John Kellett, Mr. Trash Wheel featuring as a giant frog-like creature with two large eyeballs. Although it has a unique appearance however, this is a brilliant design balancing between marketing factors, local attractions, and functionality. The top body as shown in ***Figure 5*** serve as a platform for its solar panel at the rear and as a roof for protection from rain and sun to their operators. Mr. Trash Wheel harness the river current to generate electricity by using the water wheel and solar panel as a backup power supply. Due to its giant wheel however, the structural design needs to be larger to maintain stability of the vessel.

Quite similar in terms of interceptor and trash boom usage, Litter Gritter as shown in *Figure 6* is developed by Osprey Initiative for similar purpose. Both projects are to clump up the floating trash using a trash boom then collect it by using interceptor. This method is relying on the current flow of the river. However, there are two major differences between them.

While Baltimore's Trash Wheel is utilizing conveyor system to transport the trash into two large container, Litter Gritter doesn't do the same. It is purely a cage paired with trash boom to trap the floating trash with no other mechanical system nor remote sensor to support. The whole frame is made of aluminium alloy parts weld together. Simplistic design yet still effective under certain circumstances. Due to its small size, it can only be operated in shallow water.

Comparing between the existing Baltimore's Mr. Wheel and Litter Gritter, Labah Air took inspiration from both inventions. Opting for more practical design, Labah Air is quite similar to Litter Gritter in structural term but is larger enough to fit a conveyor system inside. A little difference is the conveyor system has an adjustable angle and height, allowing for flexible condition of the river. This also leave some room for future improvements such as various electronic sensors, suspension and propellor system. By reapplying successful project concept into own project is also a form of innovation.

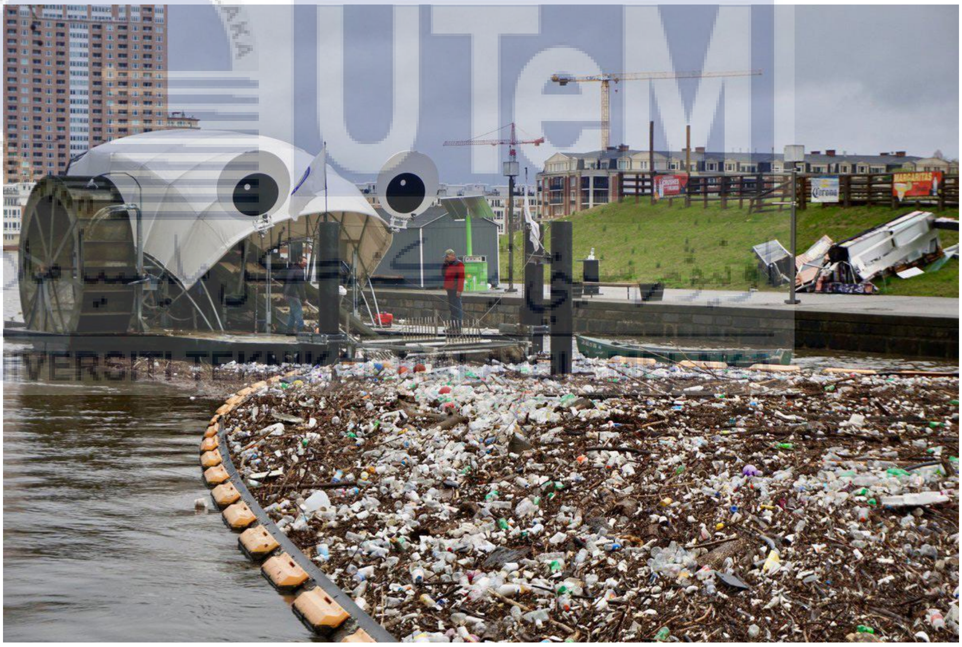


Figure 5 Baltimore's Mr. Trash Wheel

Figure 6 Litter Gritter

2.4 Pontoon

Almost every other successful research or similar project were using twin pontoon. Timo J. stated in their research journal (Ruokonen, Suuronen, Pulkkinen, & Erkinaro, 2022) that twin pontoon is advantageous as it provides stability, reduce weight and decrease wind resistance. However, reapplying it using different materials my provide a different result. Northern Baltic pontoon-trap fisheries are using mix combination of fibreglass and aluminium chute for their pontoon. Meanwhile, material used for Labah Air's pontoon are mainly FS3200PA SLS 3D printing powder material.

Figure 7 Baltic Pontoon-trap Fisheries

2.5 Conveyor system

Reviewing a journal from Universiti Sultan Zainal Abidin (Abdullah, Azizudin, & Endut, 2019), conveyor system is the primary component for the trash collector boat to collect floating rubbish and debris from surface water. Constructed using aluminium, rubber gasket and PVC pipe, wire mesh was attached along the conveyor for hauling purpose. Their system is equipped with a DC motor that enables the operator to control the speed of the conveyor at will. Additionally, a relay wireless remote control was installed into the conveyor system to control the forward and backward movement of the conveyor. The relay wireless controller has an effective range of 300 m. However, due to its intended compact size, the angle of conveyor is high and may cause difficulty during hauling operation.

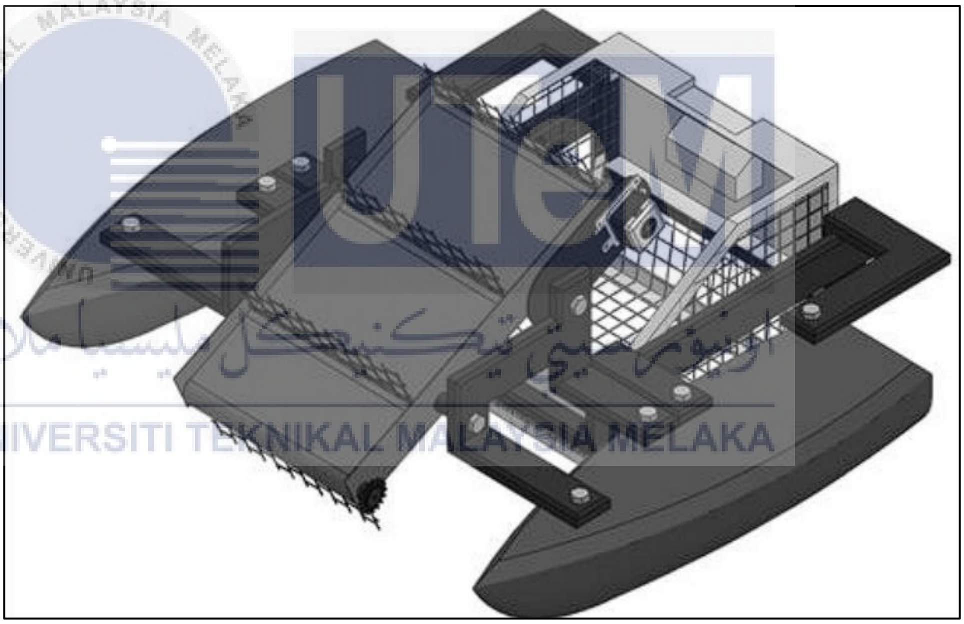


Figure 8 Isometric view design of UniSZA's Portable Trash Collector Boat

Figure 9 Miniature model of UniSZA's Portable Trash Collector Boat

Comparing this to our own Labah Air, improvement had been made to allow the conveyor not just forward and backward movement, but also upward and downward motion for preferred height, and angle adjustment for steep or slope angle. This was enabled by attaching a customized hydraulic mechanism on top of the conveyor system. The conveyor system was assembled with combination of glass prospect, nylon 3D printing powder material, and stainless steel to reduce weight while maintaining durability.

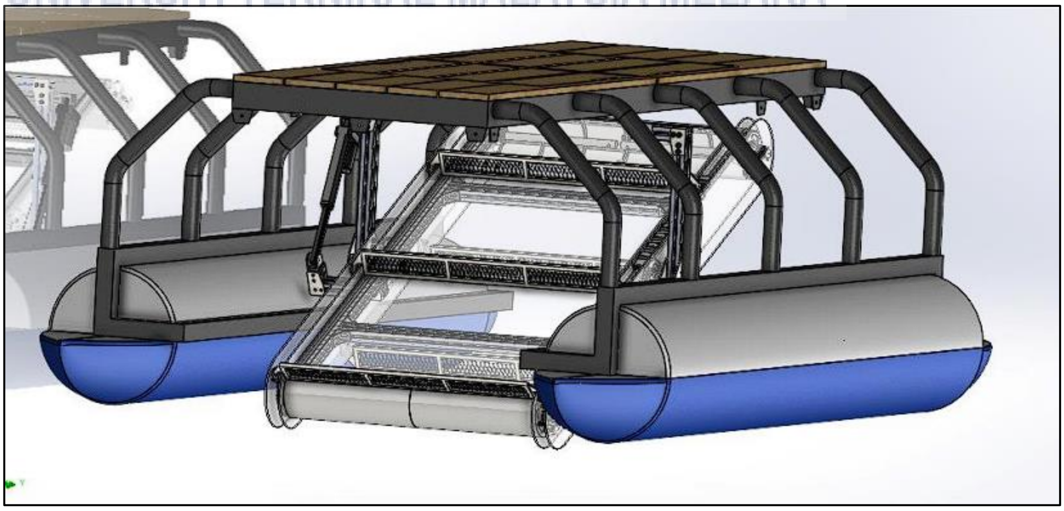


Figure 10 CAD design of Labah Air in SOLIDWORKS

Figure 11 Actual Labah Air conveyor system.

2.6 Optimization of Labah Air

2.6.1. Introduction

River pollution caused by the accumulation of trash along Malacca River poses difficulties to the PPPSM workers as mentioned in the previous chapter. To combat this issue, Labah Air have been developed to remove floating trash from water surface. To enhance the efficiency and performance of Labah Air, various optimizations can be explored. As technology advances, a continuous effort is needed to optimize these systems to improve their performance, efficiency, strength, and environmental impact. This literature review section aims to explore potential optimizations for the Labah Air based on the existing research and developments in the field.

2.6.2. Material Optimization

In terms of material optimization for the main body frame of the Labah Air, we are focusing on identifying lightweight yet durable materials. A successful model developed by Osprey Initiative LLC (Bates, 2017), showed that aluminium is a decent material since it has both criteria we needed. Since current Labah Air is using mild steel which is heavier thus, using aluminium might create a new room for improvement without compromising its structural integrity. Structural analysis will be necessary to determine its weight distribution.

2.6.3. Buoyancy

Buoyancy optimization focuses on the pontoon of the Labah Air, which directly impacts its stability and manoeuvrability. A study from Universiti Sultan Zainal Abidin (Abdullah, Azizudin, & Endut, 2019) have explored the use of fiberglass for their pontoon to reduce the weight of the system however, practical cost may be different for a larger scale project. Currently, several water tanks made from composite carbon fibre with capacity of 50 gallon each are acting as Labah Air pontoon. Incorporating additional buoyant elements or adjusting the pontoon's size and shape may be a better option to optimize buoyancy while maintaining stability.

2.6.4. Loading Capacity Optimization

Efficient trash collection is another important aspect of Labah Air optimization. Since the first version of Labah Air was developed, it has no other mean to store the collected trash other than transporting them into a towing bot. This creates additional unnecessary cost, effort, and time-consuming method.

Thus, Labah Air need to have its own method to store collected trash. For example, a litter collection basket will be able to store floating solid and filtering water on floating solids (Abdullah, Azizudin, & Endut, 2019). If large capacity is needed, a barge dumpster is another option to optimize the loading capacity of the system, allowing for maximum trash collection during each operation (Lindquist, 2016). This may result in heavier weight and need more space.

Structural design, material selection, and weight distribution all play significant roles in achieving optimal loading capacity. Furthermore, exploring efficient garbage disposal can reduce the frequency of unloading, maximizing the Labah Air's overall efficiency.

2.7 SLS Machine Farsoon SS402P

The Farsoon 402P Selective Laser Sintering (SLS) system offers state-of-the-art production capabilities to rapid prototyping and additive manufacturing users. For the most demanding applications, the 402P offers a highly productive and efficient solution.

The Farsoon SS402P industrial-grade Selective Laser Sintering (SLS) machine was utilized for this project. Farsoon model SS402P selective laser sintering (SLS) 3D printer located in SLS Laboratory FTKMP of Universiti Teknikal Malaysia Melaka (UTeM) (2°16'40.4"N 102°16'32.4"E). The external dimensions of the SLS machine are 2660mm x 1540mm x 2150mm, and it weighs 3000 kg. In the SLS chamber, the maximum build size 20 is 400mm x 400mm x 450mm, with an effective build size of 350mm x 350mm x 430mm. A CO2 laser is employed, with a maximum output of 100W and a scanning speed of 12.7m/s. Every spinning roller has a 0.3mm laser wavelength and a 0.1mm powder layer thickness (Formlabs, 2021).

Figure 12 Farsoon SS402P Selective Laser Sintering (SLS) machine (Farsoon Technologies, 2017)

With a feeder chamber dimension of 400mm x 400mm x 450mm, the weight required to fill the FS3200PA powder is around 60kg powder. The sintering process flow for the Farsoon SS403P machine is shown in *Figure 13*, which includes the cooling stage, SLS 3D printing, and post-processing stages. Farsoon SS403P series feeder chambers are the same size as Farsoon SS402P series feeder chambers, and both are suited for FS3200PA powder material (Saffarzadeh et al., 2016).

The build cylinder will be lowered for the cooling stage, and (A) the building part will be withdrawn from the build location once it has cooled. The build cake will then be incrementally elevated (C) and sent to the breakout station (D). During the breakout process, the excess powder will be gently moved into the overflow bin for recycling. Finally, (F) the finished samples that have the best mechanical performance for the application. Then it'll be put it through a tensile test. After that, the powder cake is transported to a powder cleaning machine to remove any remaining non-sintered powder before being recycled for the next sintering session.

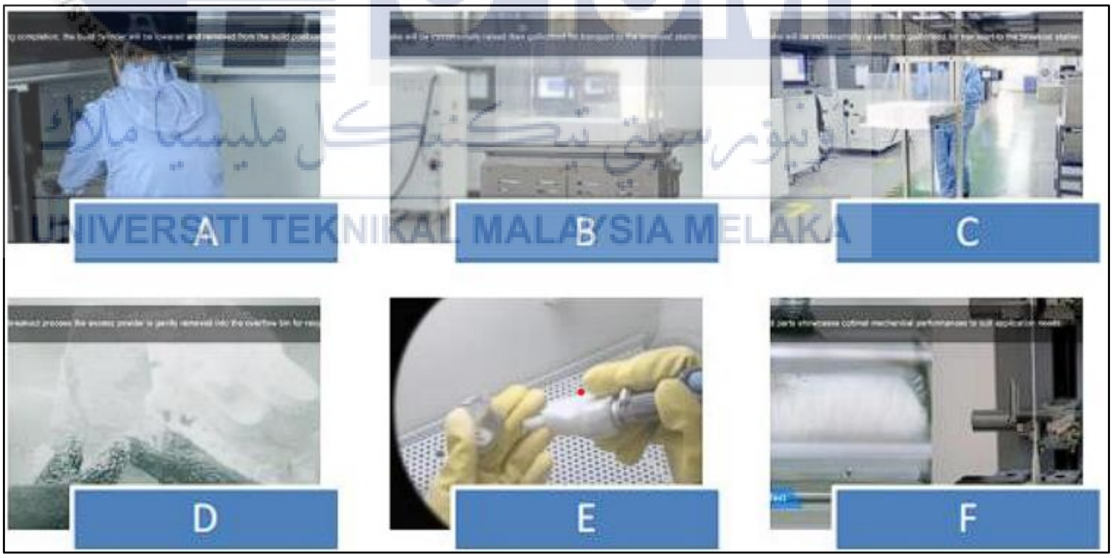


Figure 13 Sintering process flow using Farsoon SS403P machine.

2.8 Research Gap Analysis

A research gap is essentially an unanswered question or unresolved problem in a field, which reflects a lack of existing research in that space (Al-Saraf, 2022). By analysing several journals, research papers and other sources, several research gaps were identified regarding the Labah Air. These research gaps are as follows:

2.8.1 Material Optimization

Several studies in similar field to Labah Air highlights the use of different materials for various components, such as aluminium for the main body frame and fiberglass for the pontoon. However, there is lack of comprehensive analysis of different materials that can be employed for Labah Air to improve its structural integrity, weight distribution, and overall efficiency.

2.8.2 Integration of Advanced Technologies:

Although many studies have examined the mechanism of floating device on water surface, however not much that extensively discuss the integration of advanced technologies such as electronic sensors, suspension systems, and propellers, into the model. Further research is needed to explore the potential benefits and challenges of integrating these technologies to enhance the functionality and performance of Labah Air in terms of trash collection, navigation, and real-time monitoring system.

2.8.3 Comparative Analysis:

While there are studies such as from (Md Rafique & Langde, 2017) and (Abdullah, Azizudin, & Endut, 2019) that compares their own prototype with existing systems like Baltimore's Mr. Trash Wheel and Litter Gritter, there is a research gap in conducting a comprehensive comparative analysis of different designs, considering factors such as cost, efficiency, adaptability to different water environments, and also environmental impact. Such a comparative analysis would provide crucial insights for further development and improvement of Labah Air.

CHAPTER 3

METHODOLOGY

3.1. Introduction

The methodology refers to the steps involved in conducting an analysis. It is a strategy for achieving objectives through planning, data collection, investigation, and analysis to validate that the study. The research will become more organized by following the methodical approach, and the scientific route are more focused and successful because of the approach. This study will show the entire process, from field research through sample collection and analysis of the results.

3.2. Research Method

In this project, all parameters and data sample will be obtained along the Malacca River. The suggested Labah Air were intended to be compared to the traditional method, which are time intensive and do not provide real-time data.

3.3. Research Area

This study will be conducted at the Malacca River to monitor and reduce trash along the river with a collaboration with the Perbadanan Pembangunan Sungai dan Pantai Melaka (PPSPM). This device will be place in the selected region of the river to trap and collect the floating trash along the river.

Figure 14 Malacca River has been chosen as the research area.

3.4. Project Planning

To meet the objectives of the study, a project planning as in Figure 15 has been drafted. It contains 12 stages starts from field study & data collection of Labah Air at Malacca River. Conceptual design will review again until the evaluation of drag coefficient meet the required benchmark. Only then a more detailed design would be draw. Optimization of the internal structure would be done by using Altair SolidThinking Inspire. After that, the actual fabrication will be executed by using advanced and conventional manufacturing process. Field test of the Labah Air are planned to be performed at Taman Rempah Jetty, Malacca River. Result will be analysed once the field test has been performed.

3.5. Flow Chart

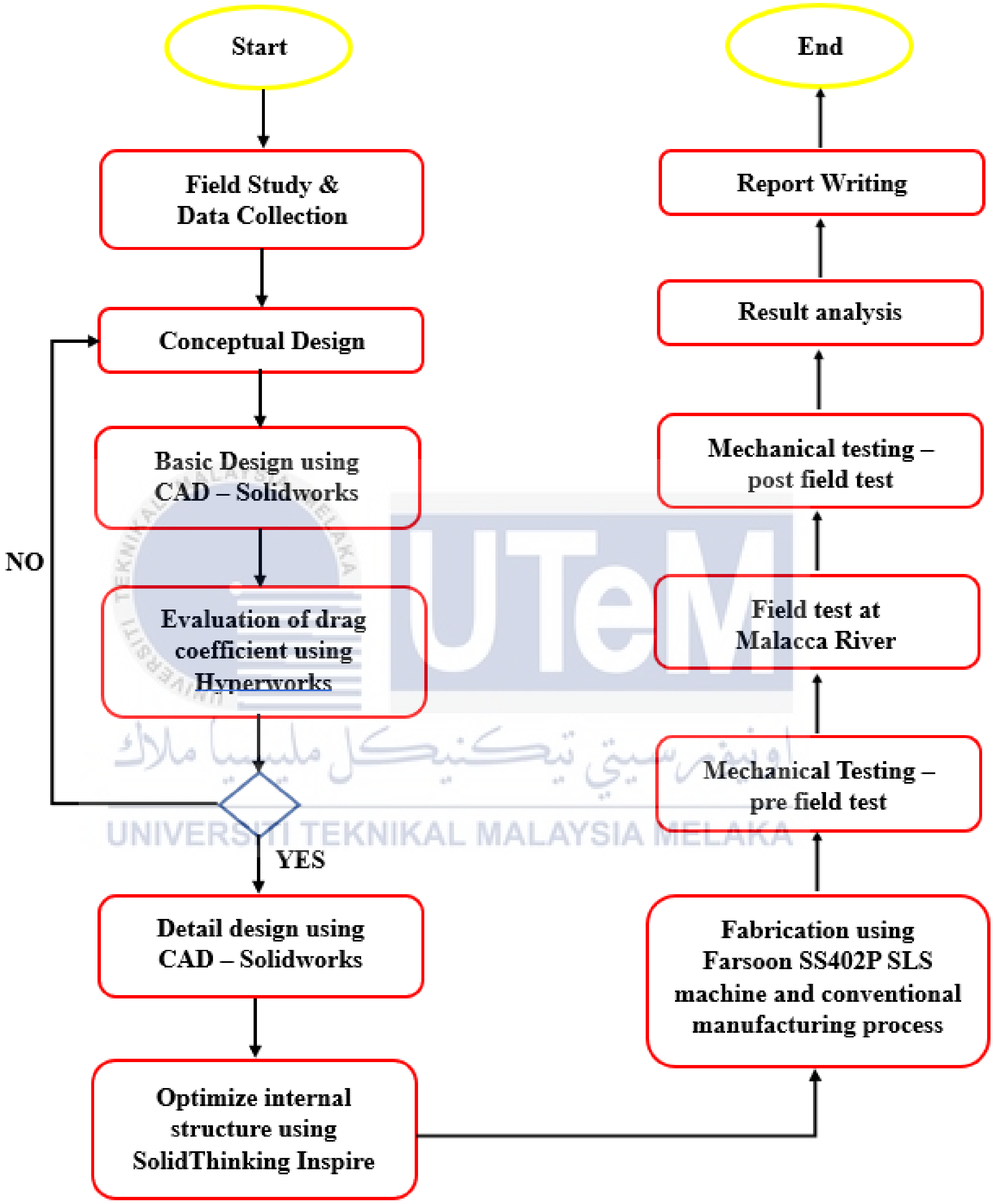


Figure 15 Flow chart of project planning

3.6. SOLIDWORK Software

3.6.1. SOLIDWORK Drawing

Sketches can be fully defined, under defined, or over defined as shown in *Figure 16*. In fully defined sketches, all the lines and curves in the sketch, and their positions, are described by dimensions or relations, or both. There is no need to fully define sketches before using them to create features. However, it should be fully defined sketches to maintain the design intent. Fully defined sketches appeared in black.

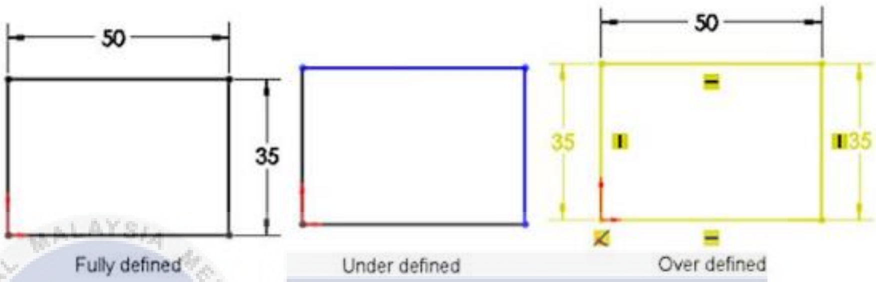


Figure 16 Different Type of Sketch

3.6.2. SOLIDWORK Part

After completing the sketching, the part will be generated through features in SOLIDWORKS. There are different types of the features such as extrude, cut-extrude, loft, shell, fillet and much more examples shown in *Figure* 17. The features must be chosen based on the design that want to generate.

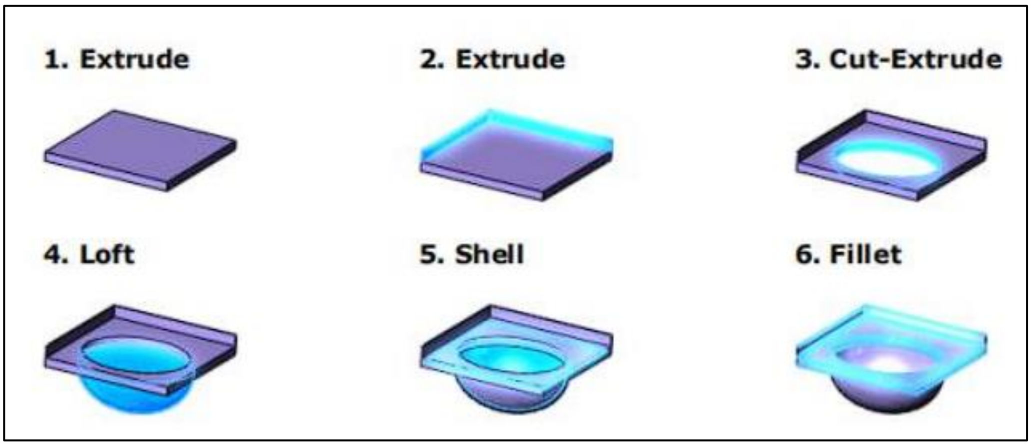


Figure 17 Type of Features in SOLIDWORKS

3.6.3. SOLIDWORK Assemble

Assembly process is used after the parts has been produced. The components in an assembly are defined in relation to each other using assembly mates. There are different types of mates such as coincident, concentric, parallel, tangent, and perpendicular as shown in *Figure 18*. SOLIDWORKS also have advanced mates such as profile centre, symmetric, width, path mate and linear or linear coupler as shown in *Figure 18*. *Figure 19* shows the complete of assemble all the parts for Labah Air top frame.

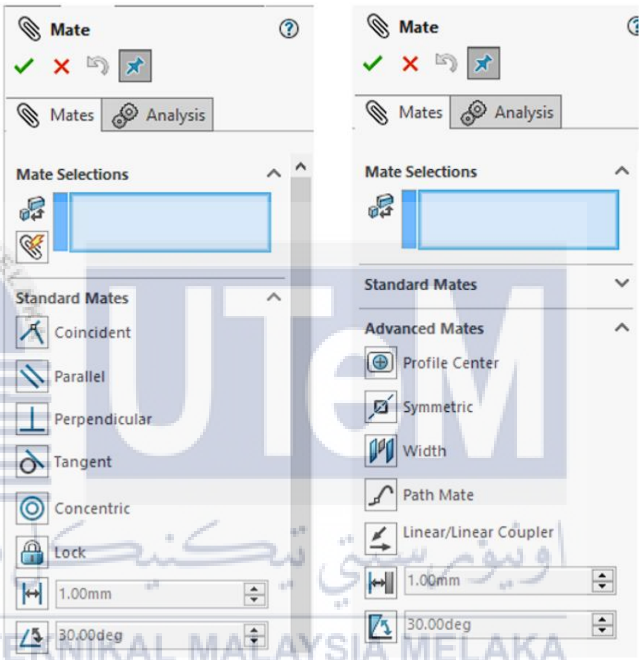


Figure 18 Type of mates and advance mates in SOLIDWORKS

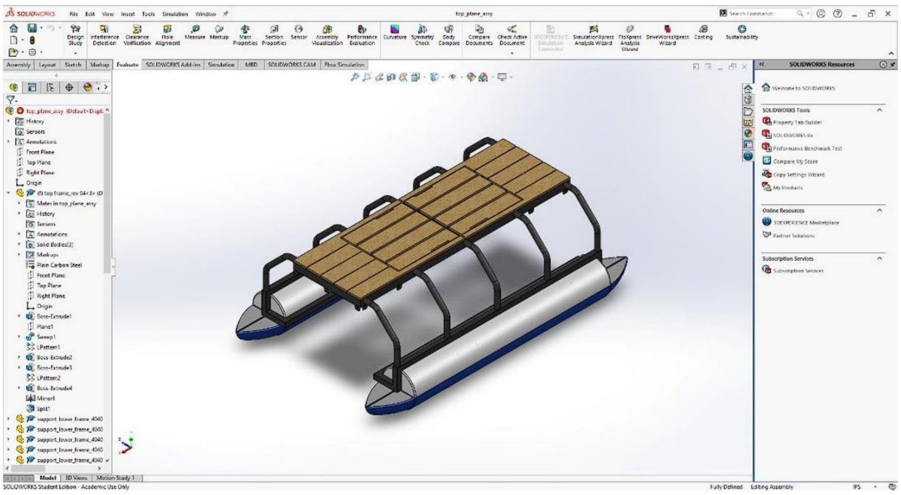


Figure 19 Drawing of RTCS MK IV top frame in SOLIDWORKS

3.7. INSPIRE solidThinking Optimize and Analysis

After completing the assembly of the Labah Air top frame in SOLIDWORKS, the analysis of the body must be done. Therefore, Altair Inspire solidThinking has been used to do the analysis of the Labah Air top frame.

First, import the file from SOLIDWORKS to Inspire. After that, identify the support as shown in *Figure 20* at the Labah Air top frame and then select the face of the body as example in *Figure 21*.

Figure 20 Support Feature in Altair solidThinking

Figure 21 Example of Face Selected in Altair solidThinking

The next step will be applying load at the Labah Air top frame. Pick the load red arrow on the Structure TAB as shown in *Figure 22* and select the face at the Labah Air top frame. Identify the value of load that want to be applied at the body example in *Figure 23*.

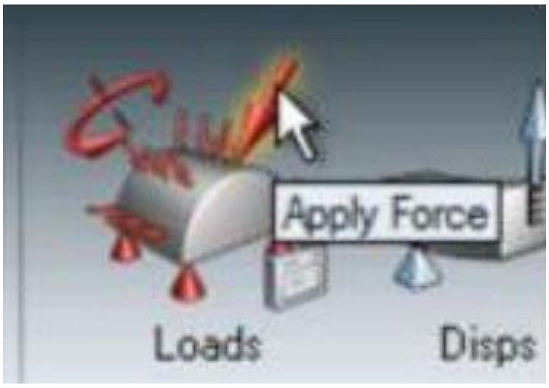


Figure 22 Load Feature in Altair solidThinking

Figure 23 Example of Face Selected in Altair solidThinking

The next step will be optimization. On the Structure TAB, click the Play Button in the Optimize icon. Enter a name for the Run and choose a minimum Percentage (%) Design Space that want to keep (default is 30%, is OK). Enter a Thickness Constraint of 20 mm and run the optimize. Note that if the Thickness Constraint is bigger, it makes a faster run, while smaller provides more detailed geometry, more accurate but takes longer time. Finally, click the Green Flag in *Figure 26*. In the resulting dialog, use the slider to add or remove geometry as shown in *Figure 27*.

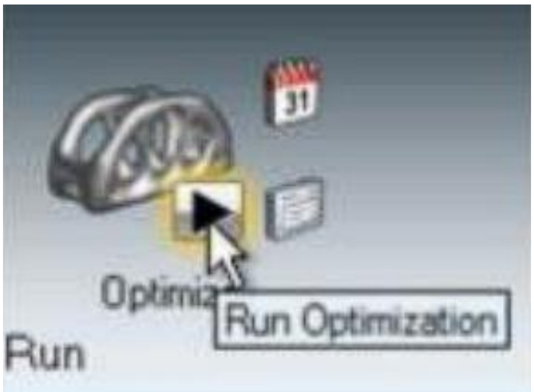


Figure 24 Optimize Feature in Altair solidThinking

Figure 25 Optimize Setting in Altair solidThinking

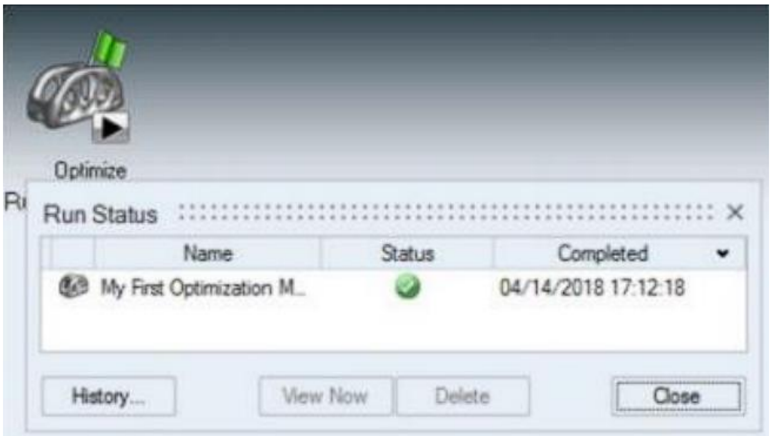


Figure 26 Status of Optimize in Altair solidThinking

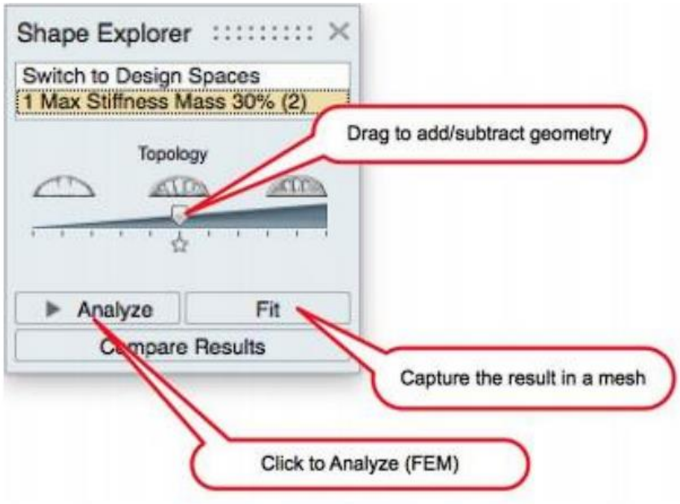


Figure 27 Resulting Dialog in Altair solidThinking

Click the Analyze button and after the analysis has finished, click the Green Flag in *Figure 28* to display the analysis result example in *Figure* 29. Different type of result may be displayed such as Displacement, Factor of Safety and Tension or Compression.

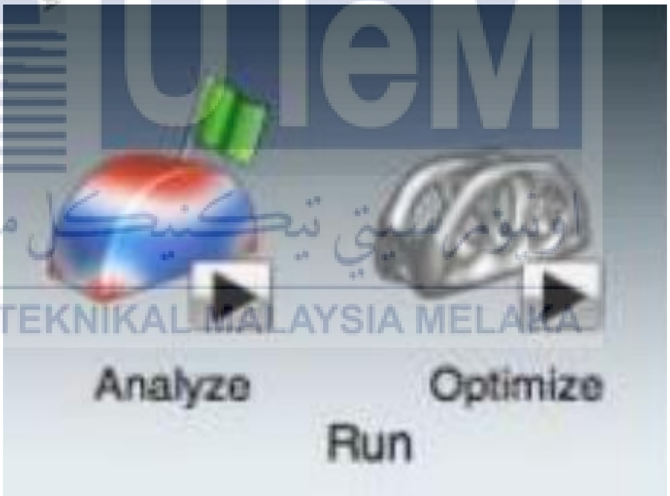


Figure 28 Analyze Feature in Altair solidThinking

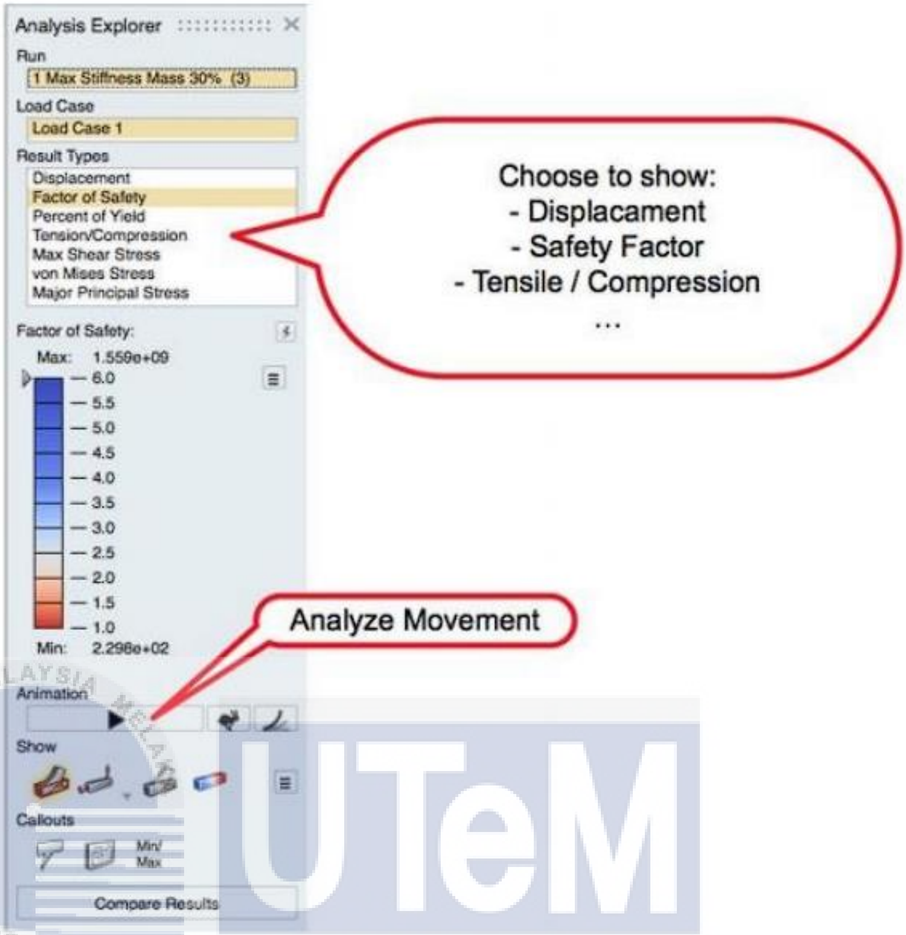


Figure 29 Result of Analysis in Altair solidThinking

3.8. SLS Machine Farsoon SS402P

The Farsoon 402P series of selective laser sintering systems gives rapid prototyping and additive manufacturing users state-of-the-art production capabilities. The 402P is an exceptional productive and efficient solution thanks to its high-performance imaging, multizone heating systems, thermal stability advances, bi-directional single-source feed system, and replaceable powder cylinders (Formlabs, 2021). Farsoon is the only selective sintering company with a single factory that oversees all areas of software, equipment, and material development. Customers benefit from one of the world's quickest, most thermally stable, and material efficient additive manufacturing technologies, which has a low cost of ownership. The SLS 3D printer employs a laser as an energy source to melt powdered plastic material and fuse it together into a 3D manufactured item. This method is part of Laser Powder Bed Fusion 38

(LPBF), one of the most advanced and dependable additive manufacturing 3D printing processes.

Figure 30 Farsoon SS402P Selective Laser Sintering (SLS) Machine

3.8.1. Sintering Process

After completing the assembly of the Labah Air top frame in SOLIDWORKS, the analysis of the body must be done. Therefore, Altair Inspire solidThinking will be used to do the analysis of the Labah Air top frame.

Figure 31 shows the pre-processing, SLS 3D printing, and post-processing steps of the sintering process flow for the Farsoon SS402P machine. Pre-processing involves four steps: weighing the material, using the Farsoon AllstarTM open platform interface to calculate the height specified by the Farsoon SLS programme. With a feeder chamber size of 400 x 400 x 450 mm, about 60 kg of powder is needed to fill the FS 3200PA. The powder will then be gathered and fed into the feeding chamber of the SLS machine after being completely mixed in a mixer machine. In the second stage of the printing/sintering process, the pieces are sintered using a 70-watt CO2 laser. Following the sintering procedure, the build chamber is removed from the sintering machine, and an actuator located beneath the build chamber forces the pieces and powder cake toward the acrylic enclosure, as depicted in *Figure 32*. The powder cake is brought to a powder cleaning machine to remove any non-sintered powder before being recycled for the subsequent sintering process. Then, take away all the parts that still have a sizable powder cake attached, using a removal tool such as a brush. Finally, sand blasting pressure to remove any extra powder cake that remains on the components, making them cleaner than before, in addition to using practical equipment to remove powder from components.

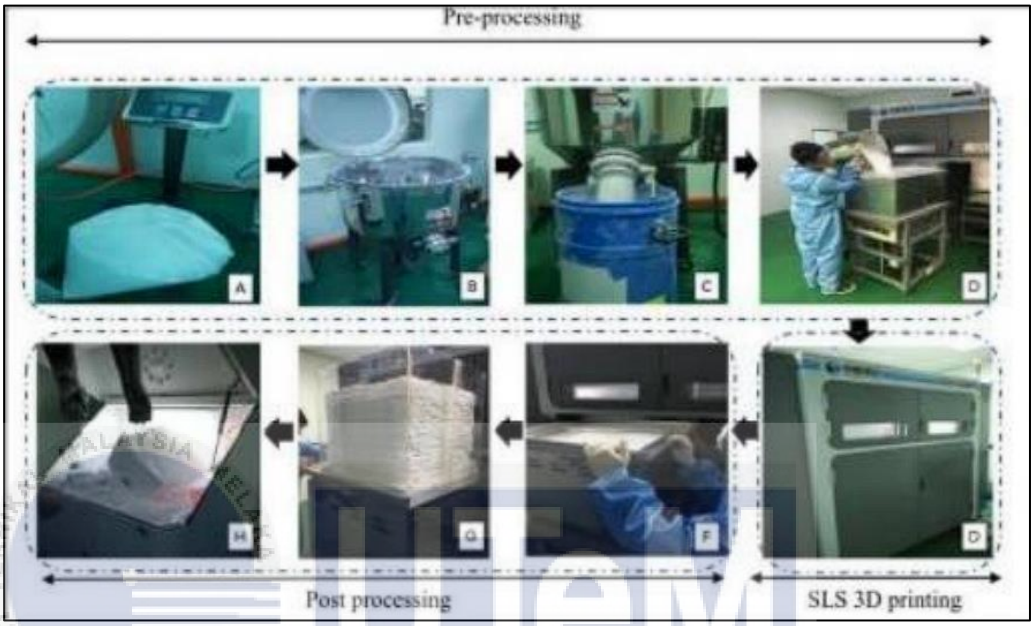


Figure 31 Pre-Processing, SLS 3D Printing and Post Processing in Sintering Process

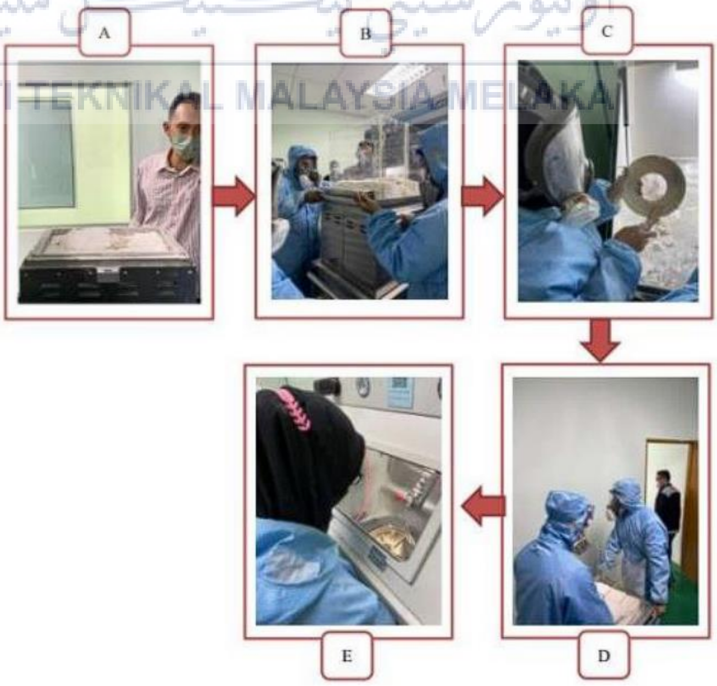


Figure 32 Sintering Process

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

In this chapter, the outcome result, equipment's specification, and discussion of the RTCS project are to be discussed. The structural frame to hold the RTCS conveyor was analysed using SolidWorks. Key area for improvement was proposed based on flaw identified during the analysis. The outcome of the result was generated after the RTCS undergo field test at Malacca River.

4.2. River Trash Collector System

4.2.1. Mechanism

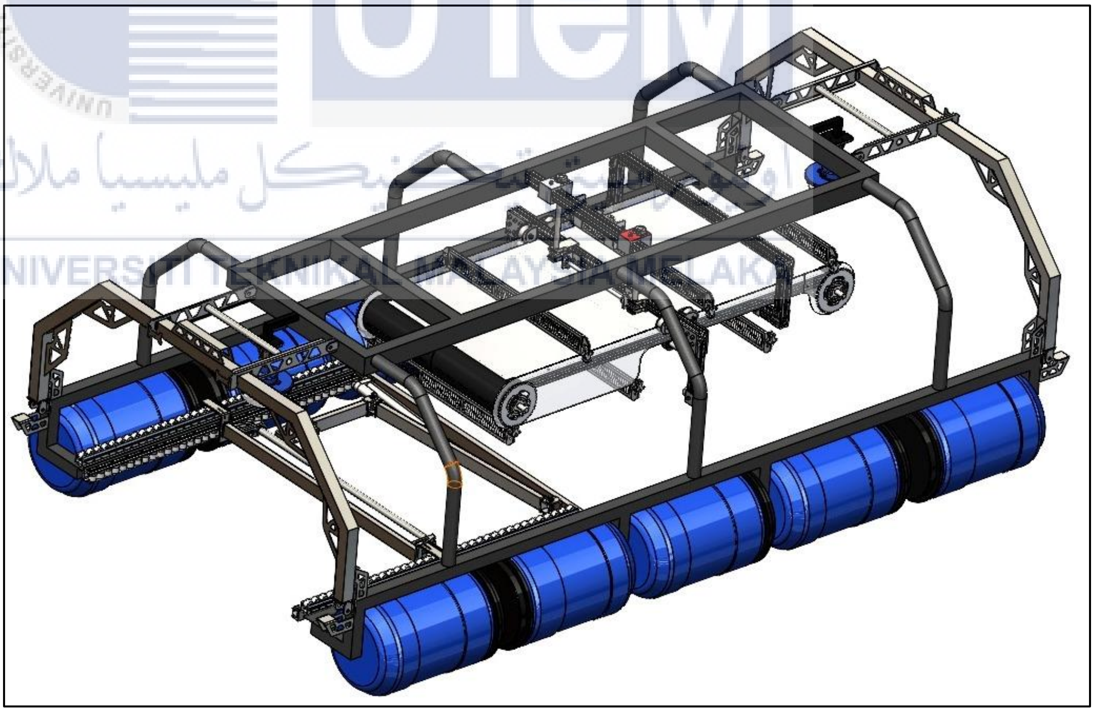


Figure 33 Internal structure of the new RTCS MK V.

The fully assembled RTCS MK V has two main purpose and several more sub-functional mechanisms that supporting the machine. It is intended to automatically be able to collect floating trash and data sampling through its sensors for continuous water quality monitoring. The approach method for this to work is by placing the RTCS right at the centre of the river between two riverbanks. Attached with a couple of trash boom, it will intercept the floating trash that swept by the current.

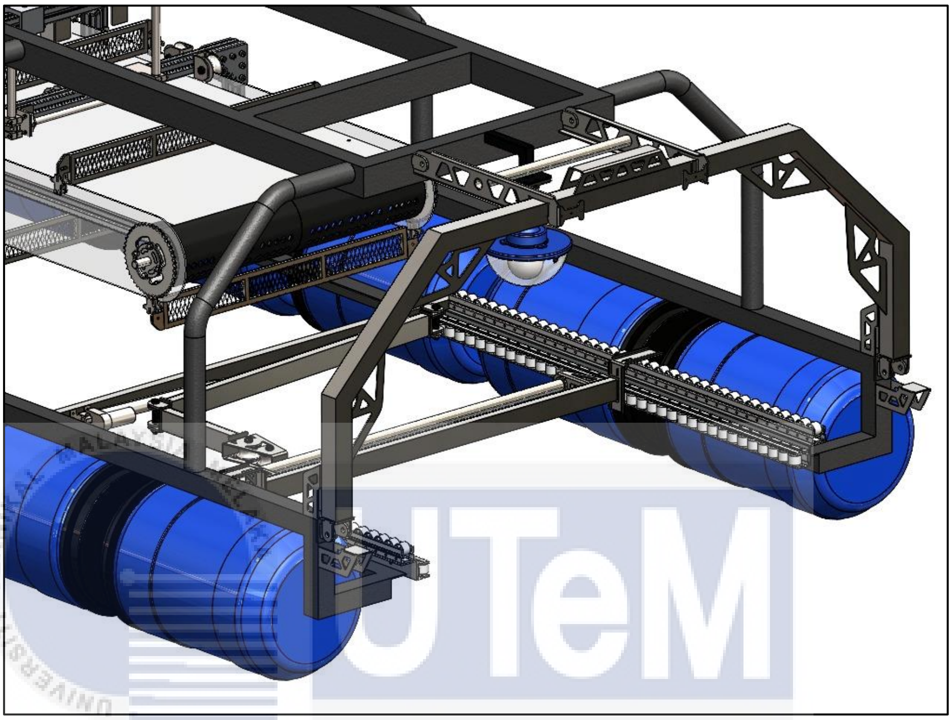


Figure 34 Front side of RTCS MK V

A hop-in mechanism at the front side of the device will guide the trash smoothly into the main conveyor belt at the centre. Powered by a single 110 hp motor, the conveyor belt then regulates the trash to the back of the machine into a storage barge. Supported by three hydraulic actuators, the conveyor system is able to adjust its angle of inclination and its height from water surface depending on the depth of the water. To solve the sustainability issue, the power source was generated from two solar panel on top of the RTCS.

However, the analysis for this research report will only be focusing on the main body frame that hold the structure together. Particularly, on how much of the load that it could handle and to determine the static factor of safety.

4.3. Project’ Specification and Analysis

4.3.1. SolidWorks Model Information

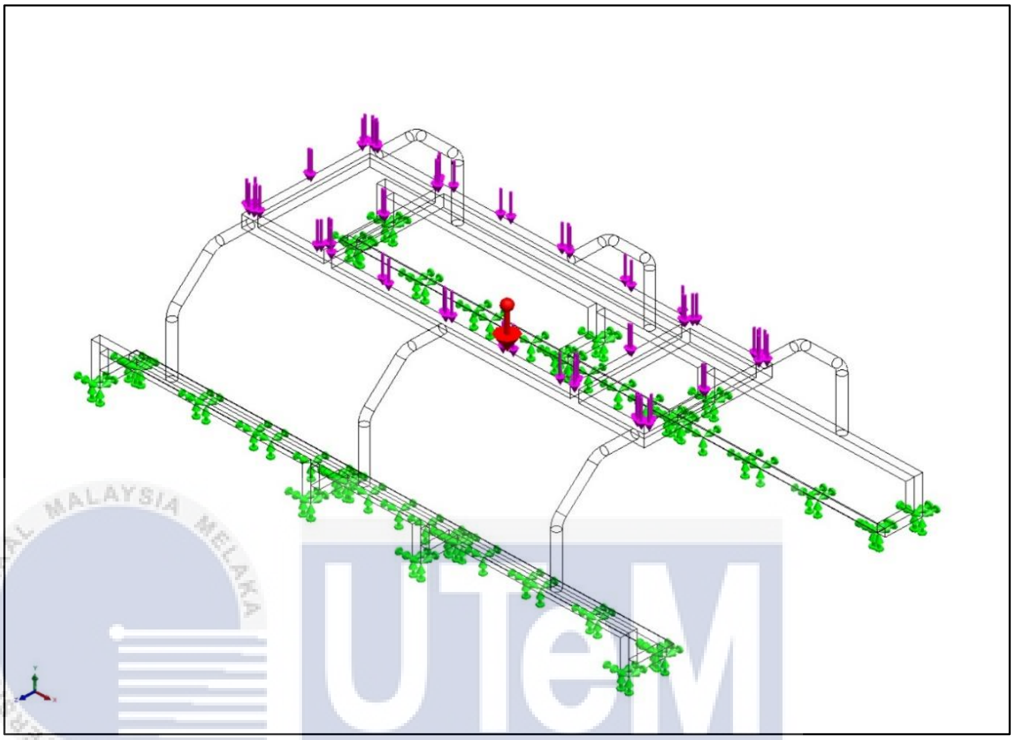


Figure 35: Model name: top frame rev 05

Table 1 Basic Model Information Table

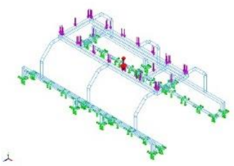
Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude6 	Solid Body	Mass:526.419 kg Volume:0.0674896 m^3 Density:7,800 kg/m^3 Weight:5,158.9 N	D:\All project\Projects\RTCS mk IV small scale\top frame_rev 05.SLDPRT Jan 4 11:24:14 2024

Table and figure above show the basic information for the model that been used to analysed using SolidWorks Simulation. Factor such as mass, volumetric value, density, and weight is several parameters that must be included.

4.3.2. Study Properties

Table 2: Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
In plane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (D:\All project\Projects\RTCS MK V small scale)

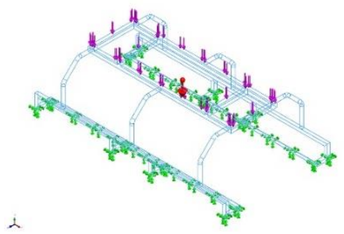
Table 3: Unit Parameter

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

Table in 4.3.2 above is the configuration settings and parameters that were used in this study. Several irrelevant properties were turned off.

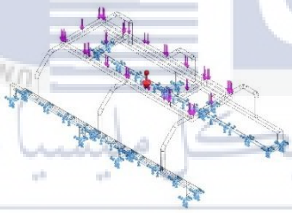
4.3.3. Material Properties

Table 4 Material Properties used for RTCS main frame body.

Model Reference	Properties	
	Name:	**Plain Carbon Steel**
	Model type:	**Linear Elastic Isotropic**
	Default failure criterion:	**Unknown**
	Yield strength:	**2.20594e+08 N/m^2**
	Tensile strength:	**3.99826e+08 N/m^2**
	Elastic modulus:	**2.1e+11 N/m^2**
	Poisson's ratio:	**0.28**
	Mass density:	**7,800 kg/m^3**
	Shear modulus:	**7.9e+10 N/m^2**
	Thermal expansion coefficient:	**1.3e-05 /Kelvin**

4.3.4. Loads and Fixtures

Table 5 Load and fixture constraint configuration.

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **2 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**0.0684834**	**6,562.34**	**-0.344146**	**6,562.34**
Reaction Moment (N.m)	**0**	**0**	**0**	**0**

.

Table 6 Load and gravity configuration.

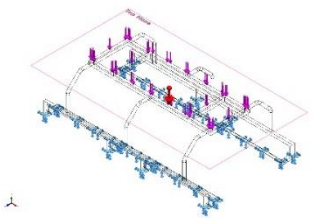
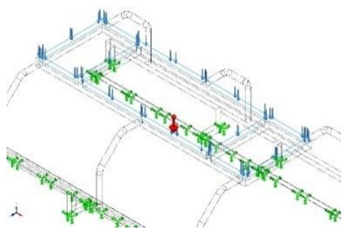
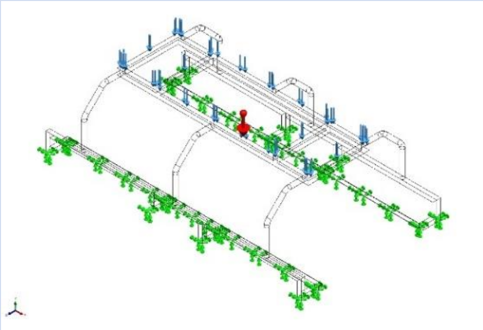
Load name	Load Image	Load Details
Gravity-1		**Reference: Top Plane** **Values: 0 0 -9.81** **Units: m/s^2**
Force-1		**Entities: 1 face(s)** **Type: Apply normal force** **Value: 1,400 N**

Table above show the fixtures and loads configuration that was set for the RTCS main body frame. It was meant to define the environment of the model. Each restraint or load condition was represented by an icon in the Simulation study tree. The Fixture Property Manager feature in SolidWorks allows to prescribe zero or non-zero displacements on vertices, edges, or faces for use with static, frequency, buckling, dynamic and nonlinear studies. The provides support for context-sensitive options in defining restraints.

Thus, 1400N was applied to RTCS contact surface as normal force with -9.81 m/s^2 of gravitational force value. When applied with said information, the software will simulate and generate the proportional value for resultant force and reaction force as shown in the Table above.

4.3.5. Interaction Information

Table 7: Interaction Information

Interaction	Interaction Image	Interaction Properties
Global Interaction		**Type:** **Bonded** **Components:** **1 component** **Options:** **Independent mesh**

4.3.6. Mesh Information

Table 8 Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	29.5165 mm
Tolerance	1.47582 mm
Mesh Quality	High
Total Nodes	56219
Total Elements	28148
Maximum Aspect Ratio	29.204
% of elements with Aspect Ratio < 3	80.4
Percentage of elements with Aspect Ratio > 10	3.36
Percentage of distorted elements	0
Time to complete mesh (hh;mm;ss):	00:00:05

4.3.7. Resultant Forces

Table 9: Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.0684834	6,562.34	-0.344146	6,562.34

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.62792	3,649.52	21.4911	3,649.59

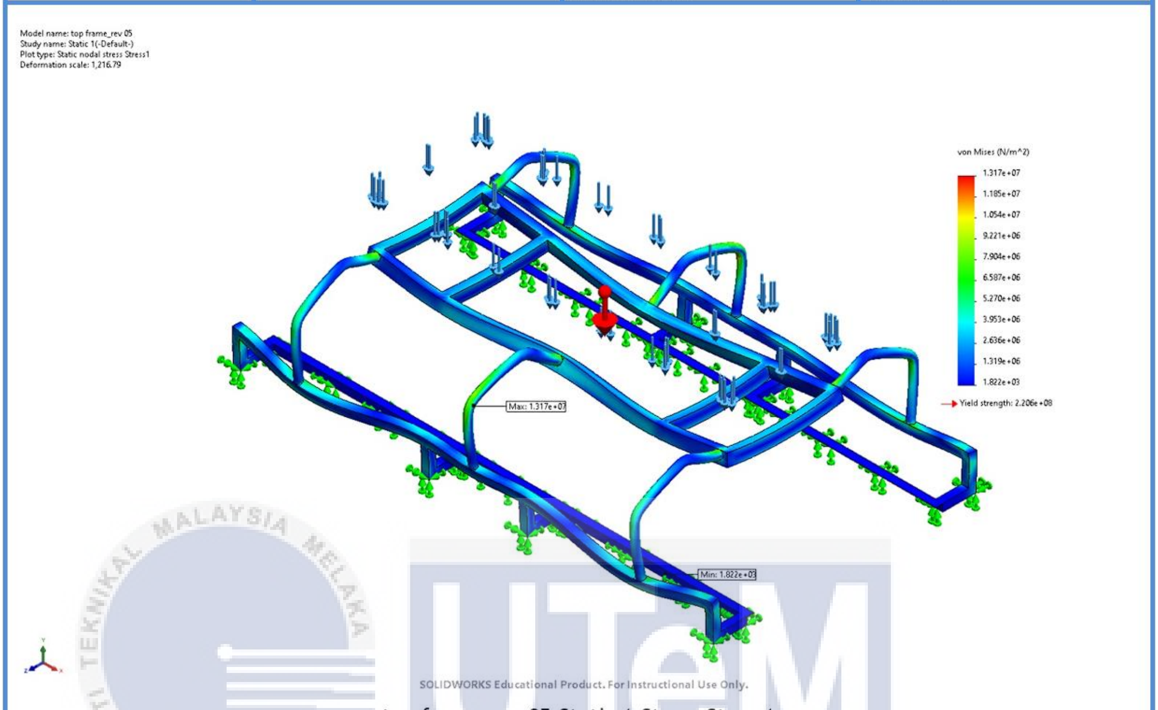
Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

4.3.8. Study Results and Analysis

Table 10: Von Mises Stress

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.822e+03N/m^2 Node: 19296	1.317e+07N/m^2 Node: 80



top frame_rev 05-Static 1-Stress-Stress1

Table above shows a projected result of the RTCS main frame model when subjected to load above its maximum limit. Evaluation using SolidWorks Von Mises Stress Simulation for static stress found that the frame will undergo deformation at various node point.

Visual representation of the stress levels within the component is shown in color-coded, with three sections representing the stress levels: minimum, maximum, and node. The minimum section displays the lowest stress levels within the component marked by blue colour, while the maximum section shows the highest stress levels marked by red. The node section represents various of mixed stress levels throughout the frame component.

Based on the static stress simulation result, it was found that symmetrical corner and the welded point has the highest stress level. This create a pattern of key areas where the structural integrity is weak and mechanical failure will most likely prone to occur first.

Crack in welded spots on the same areas had occurred in history during the development of the previous RTCS version so, there are some possibilities that it may happen again.

Table 11 Resultant Displacement

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1221	2.776e-01mm Node: 4844

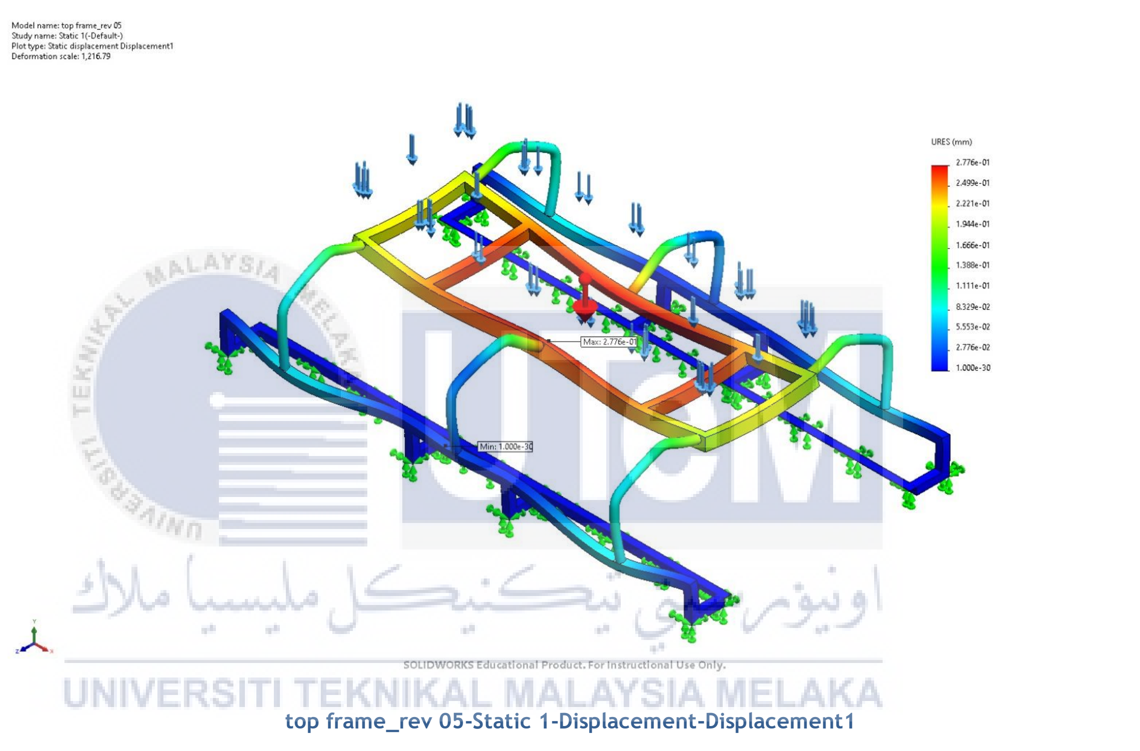


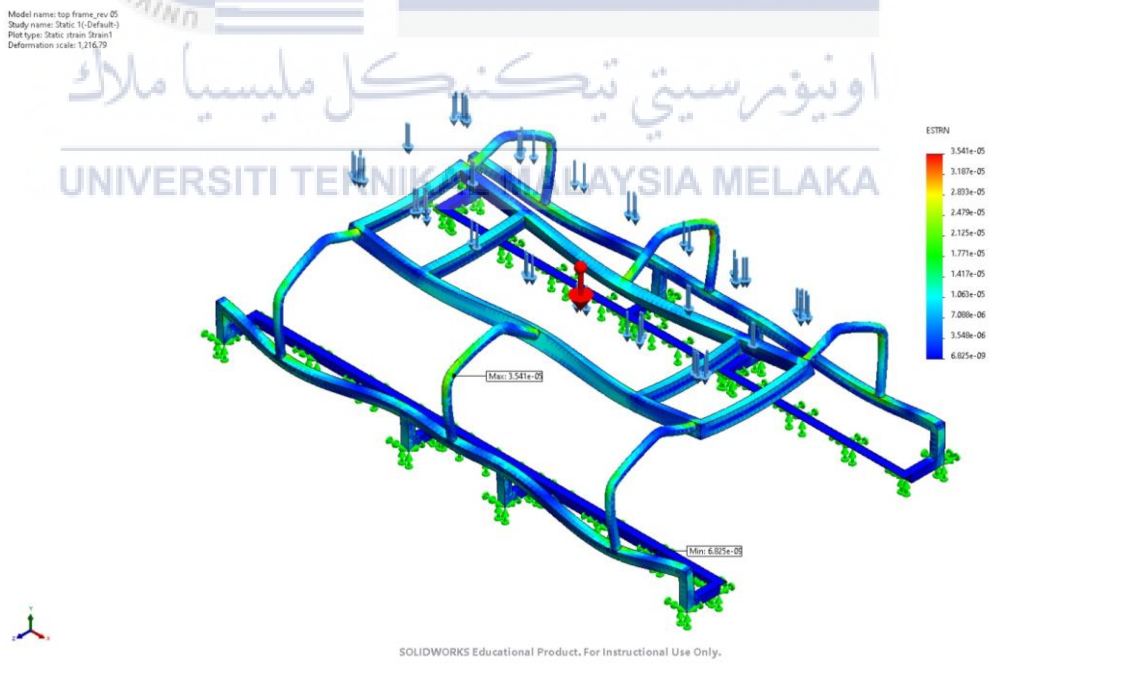
Table above shows a predicted result of the RTCS main frame model when subjected to load exceeded its maximum limit. SolidWorks Resultant Displacement Simulation was utilized to evaluate the displacement level and major deformation was found at the centre of the frame.

Visual representation of the stress levels within the component is shown in color-coded, with three sections representing the displacement levels: minimum, maximum, and node. The minimum section displays the lowest displacement level within the component marked by blue colour, while the maximum section shows the highest stress levels marked by red. The node section represents various of mixed stress levels throughout the frame component.

Based on the static displacement simulation result, it was found that highest displacement area occurs from the centre of the frame. This result was already expected as for the current design of the main frame, the lifting component that holding the conveyor are concentrated at the centre top area of the frame. Thus, resulting in a small area of load distribution. However, the result might be different if tested underwater as the density and buoyancy factor may affect the outcome to positive side. Unfortunately, the outcome is still unknown as there has not been a test with controlled environment to replicate the condition yet.

Table 12 Equivalent Strain

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.825e-09 Element: 20097	3.541e-05 Element: 25723



top frame_rev 05-Static 1-Strain-Strain1

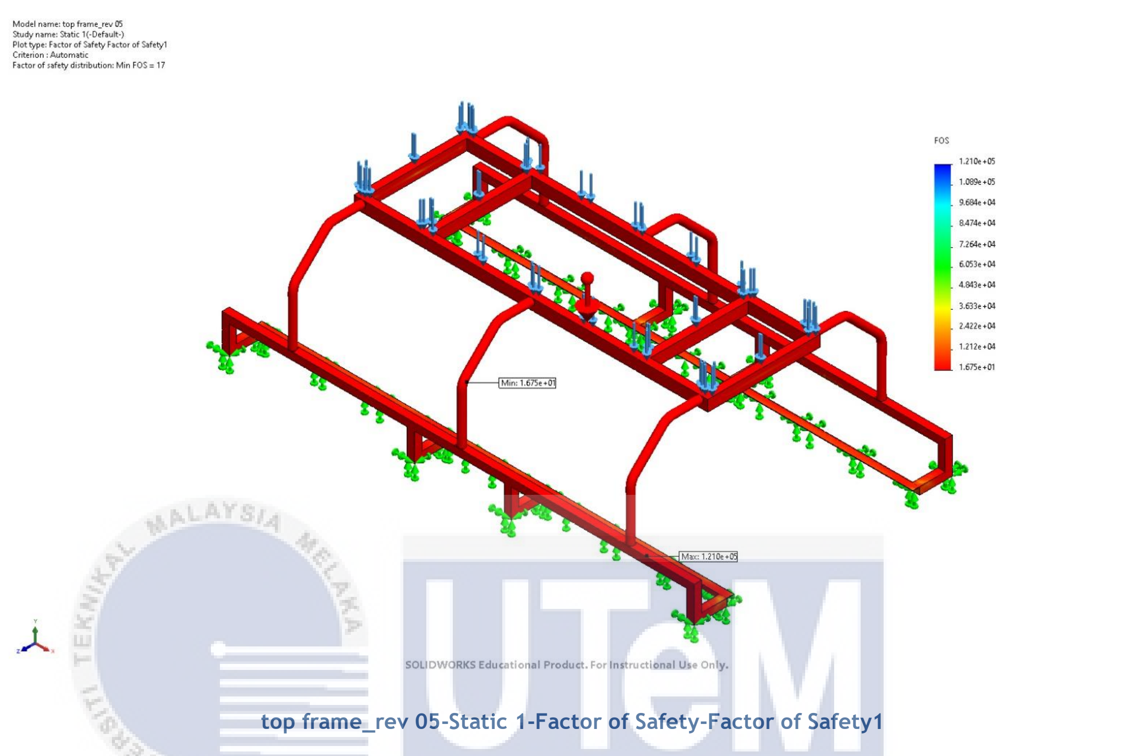
Table above shows a simulation result of the RTCS main frame model when subjected to static strain above its maximum limit. SolidWorks ESTRN: Equivalent Strain Simulation was used for the purpose of static stress evaluation and a similar deformation ratio as the Von Mises Stress Simulation result was found.

Visual representation of the stress levels within the component is shown in color-coded, with three sections representing the strain levels: minimum, maximum, and node. The minimum section displays the lowest strain levels within the component marked by blue colour, while the maximum section shows the highest strain levels marked by red. The node section represents various of mixed strain levels throughout the frame component.

Similar to the stress test, symmetrical corner where the welded point of contact has the highest strain level. This exposes a pattern of flaw in structural integrity various key areas where mechanical failure will most likely prone to occur first. However, unlike the stres load, strain load in this model is likely to cause bending due to metal fatigue especially with plain carbon steel. Installation of angled beam or steel rod adjacent to the highlighted area as support might mitigate the effect of deformation.

Table 13 Factor of Safety

Name	Type	Min	Max
Factor of Safety1	Automatic	1.675e+01 Node: 80	1.210e+05 Node: 19296



The Factor of Safety is a crucial parameter in engineering design and analysis. It is defined as the ratio of the material's ultimate strength to the maximum stress experienced in the structure during operation. The formula for calculating the Factor of Safety (FoS) is:

$$FoS = \frac{Maximum\ Stress}{Ultimate\ Strength}$$

A factor of safety less than 1.0 at a location indicates that the material at that location has failed. While FoS of 1.0 at a location show that the material at that location has just started to fail. FoS larger than 1.0 at a location indicates that the material at that location is safe.

In this case, the SolidWorks simulation results for the RTCS main body frame model indicate a minimum FoS of 1.67×10^{1} and a maximum 1.21×10^{5}.

This value represents the minimum margin of safety in the structure. A FoS of 1.67×10 1 suggests that the structure can withstand a load 16.7 times greater than the maximum expected load during operation. This is considered a healthy safety margin, indicating that the structure is robust and unlikely to fail under normal operating conditions.

The maximum FoS of 1.21×10^{5} is exceptionally high, signifying a substantial safety margin. This indicates that the main body frame model can endure extreme loads well beyond the anticipated operational stresses. This large safety factor enhances confidence in the structural integrity and reliability of the RTCS under various conditions.

Having a wide range between the minimum and maximum FoS values is generally positive, as it suggests a robust design that can handle a variety of loading scenarios. However, it's important to consider other untested factors such as material properties, manufacturing tolerances, buoyancy, and real-world conditions to ensure the design's practical viability.

In conclusion, the SolidWorks simulation results for the RTCS main body frame model demonstrate a structurally sound design, with both minimum and maximum FoS values indicating a high level of safety and reliability in the structure under different loading conditions.

4.4. Improvement and Optimization

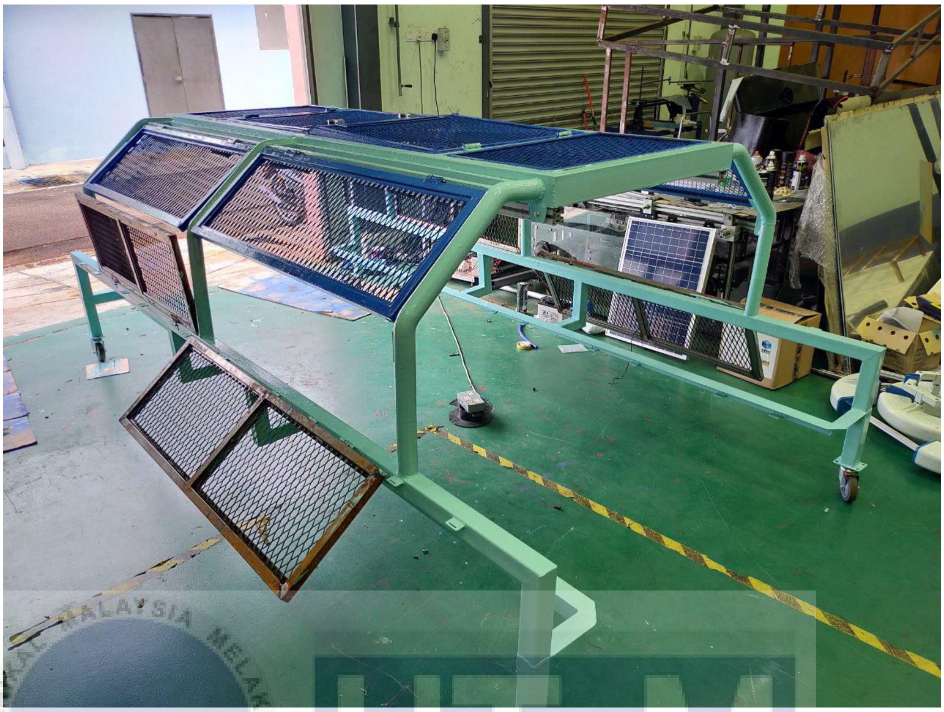


Figure 36 RTCS MK IV previous paint work, without undercoat.

The enhancement and optimization efforts undertaken for the River Thrash Collector System (RTCS) encompassed structural design changes, material modifications, improvements to the lifting mechanism, and additional measures aimed at advancing its overall performance and longevity.

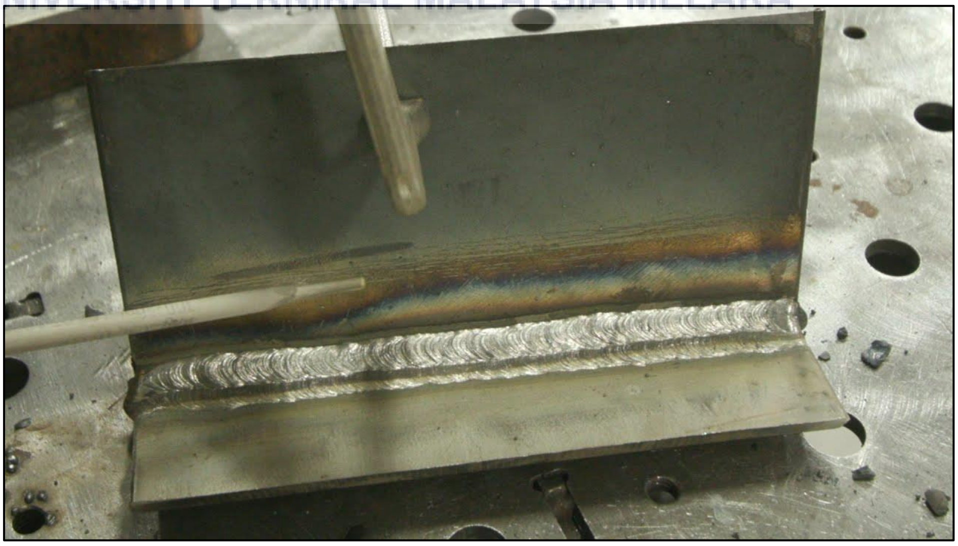


Figure 37: Welded joint part

In terms of structural design, critical load-bearing joints and areas requiring maximum rigidity underwent welding process for enhanced structural stability. Welding was judiciously employed in regions where a permanent and robust connection was essential to withstand high stress and operational loads. This selective use of welding ensures a secure and durable bond in key structural elements, contributing to the overall integrity of the RTCS. It was meant so the main frame was treated as one single rigid component when exposed to stress-strain test, it can attain more strength and durability.

Figure 38: Supporting mounting elements for RTCS

In terms of strength and durability, pivotal alteration involving the adjustment of the supportive mounting elements were implemented as shown in ***Figure 38*** above. This modification aimed to further enhance the structural integrity of RTCS, strengthening its overall robustness and load-bearing capacity. By strategically changing the type of support element employed, the structure's ability to withstand operational stresses was significantly improved while still be able to maintain its modularity.

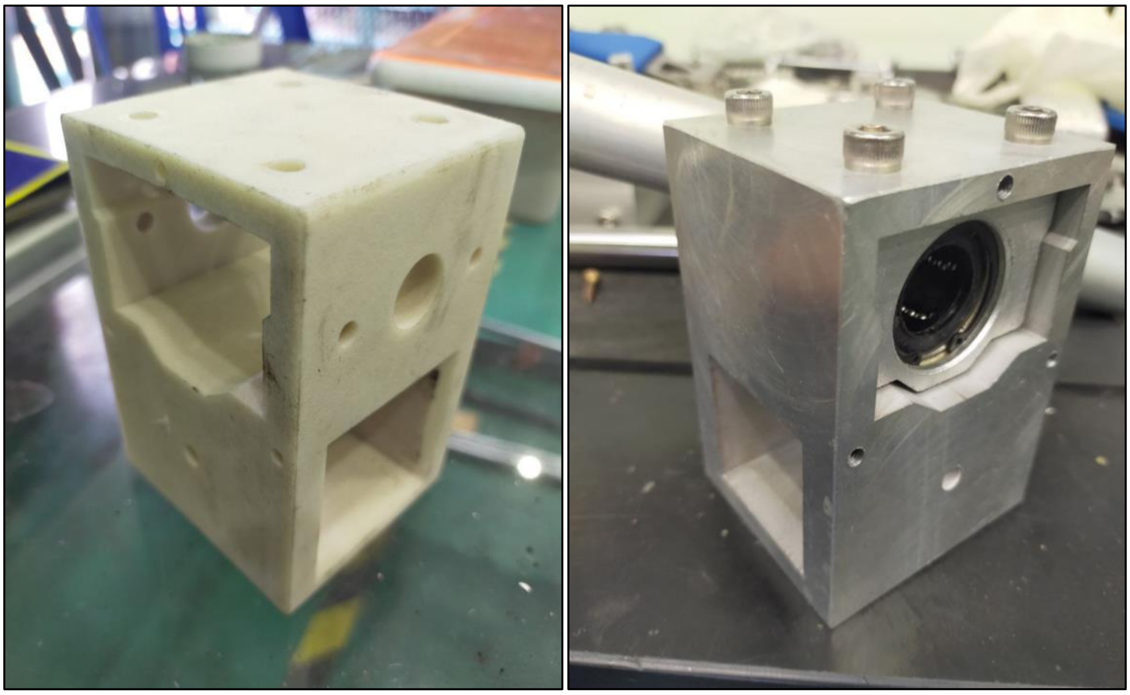


Figure 39: Shaft mounting block, left picture was SLS 3D printed, and right picture is stainless steel wire-cut.

Figure 40: 50mm round bar shaft (left picture is mild steel, and right picture is AISI 431)

Material modifications played a vital role in the optimization process. Specific components, particularly those responsible for mounting various parts, underwent a material transition from 3D printed SLS material to wire-cut stainless-steel blocks. 50mm mild steel solid shaft has been used in previous version of RTCS MK IV broke and failed when put into load test. Thus, it was changed to 50mm stainless-steel solid round bar shaft. This shift not only addressed concerns related to material strength but also contributed to the overall durability and longevity of the RTCS.

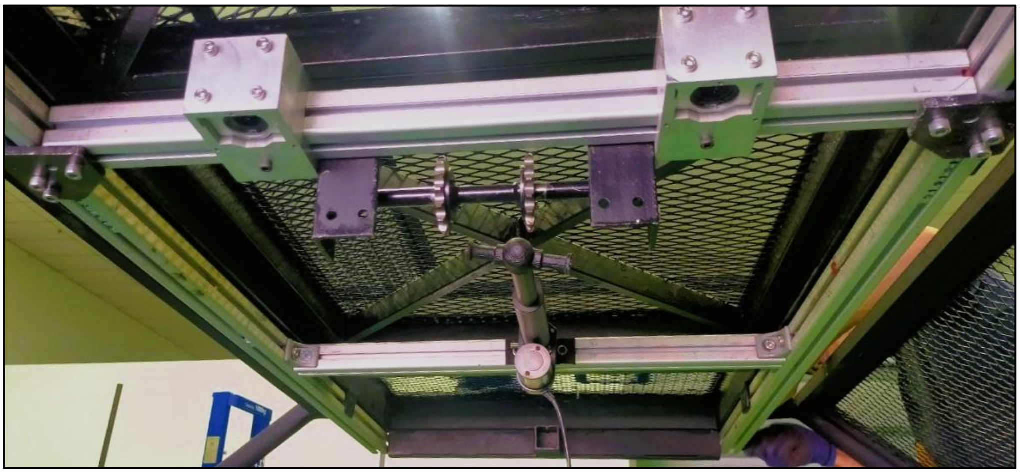


Figure 41 Integrated RTCS lifting mechanism.

The lifting mechanism shown in figure 41 above underwent a comprehensive rework to achieve better efficiency and stability. This included the removal of excess or extended lengths in the lifting mechanism, resulting in reduced weight and improved weight distribution. The redesigned lifting mechanism, positioned below the frame's roof and equipped with two actuators, not only lightened the overall load but also created additional space within the structure for future improvement.

Figure 42: M8 Stainless Steel Bolts

Figure 43: M6 Carbon Steel Bolts

As part of the optimization process, careful consideration was given to the connectors used in the RTCS. Specifically, the size and material of the bolt connectors were modified from M6 carbon steel to M8 stainless steel with anti-corrosion properties. This adjustment not only ensured a more secure connection but also mitigated the risk of corrosion, enhancing the system's longevity and performance.

Acknowledging the potential exposure to harsh environmental elements, a specialized corrosion-resistant coating was applied to critical components, particularly those in contact with water or corrosive agents. This strategic enhancement enhances the longevity of the RTCS, ensuring prolonged service life even in demanding operating environments.

These comprehensive improvements and optimization measures collectively contribute to a more efficient, stable, and robust River Thrash Collector System (RTCS). The combination of structural enhancements, material modifications, adjustments to the lifting mechanism and connectors, along with the incorporation of advanced corrosion resistance coating, underscores a commitment to excellence in design, operational effectiveness, and environmental resilience.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In the culmination of our comprehensive exploration into the improvement and optimization endeavours for the River Thrash Collector System (RTCS) main body structure, this chapter stands as a reflective synthesis of the transformative process undertaken. As we navigate through the findings, conclusions, and future prospects, it becomes evident that the meticulous improvements made to the RTCS are not only a testament to engineering ingenuity but also represent a conscientious response to the dynamic challenges posed by river thrash management. This section encapsulates the key outcomes, draws connections between the implemented changes and their impact, and sets the stage for forward-looking recommendations that will further propel the RTCS into a future of enhanced efficacy, sustainability, and adaptability.

5.2 Conclusion

Malacca River in Malaysia faced severe pollution from urbanization and industrialization, severely impacting water quality, the environment, and tourism. RTCS proposed a comprehensive solution by providing floating trash collectors, where it can make efficient waste management with continuous water quality monitoring for a sustainable recovery. However, previous RTCS version need improvement in terms of its structural design, strength, weight, functionality, and optimization. Enhancements in these areas are crucial to ensure the effectiveness of the RTCS, allowing it to be more impactful in revitalizing the health and sustainability of the Malacca River ecosystem.

Examination on the RTCS's structural frame holding its conveyor system reveal some flaw in material and design used. Utilizing SOLIDWORKS, analysis with Von Mises Stress, Resultant Displacement, Equivalent Strain, and Factor of Safety, identified key areas for improvement for the frame's strength and weight. The proposed improvement encompasses changes in structural design to enhance strength, material modifications for increased robustness, weight reduction through a reworked lifting mechanism, and the optimization of the conveyor system, with addition of anti-corrosive coating.

To summarize, the main body of River Thrash Collector System (RTCS) underwent comprehensive enhancement and optimization measures, including structural design changes, material modifications, and improvements to the lifting mechanism and connectors. The selective use of welding and modifications to supportive mounting elements strengthened the RTCS, creating a singular, rigid main frame for increased structural stability. Material changes, such as transitioning to stainless-steel blocks and upgrading the shaft material, addressed the material strength concerns with improved durability. The reworked lifting mechanism, able to reduce weight, improved weight distribution, and created additional space for future improvements. Several other small yet crucial components changes had ensured a secure connection and mitigating the risk of deterioration due to potential challenging environmental exposure.

5.3 Recommendation

This study has discovered some flaw on RTCS main structure and had proposed several improvements based on the analysis made with SolidWorks. However, this analysis was done with simulations in controlled environment without considering outside factors in real situation. Thus, it is recommended that a structured program of continuous testing and simulation was establish in the near future to ensure the ongoing reliability and resilience of the RTCS. This involves subjecting the RTCS to various stress scenarios, environmental conditions, and operational loads under field test setting where external factor such as buoyancy and density of water must be considered as well as the unpredicted current flows and weather. This probably will allow researchers to monitor the RTCS's performance, identify potential weak points, and iteratively refine the design to be more dynamic and adaptable to its real-world performance.

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APPENDICES

Appendix 1 Gantt Chart PSM 1

ACTIVITY	PLAN	PLAN DURATION	ACTUAL START	ACTUAL DURATION	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title Selection	1	1	1	1														
Planning and Research	2	2	2	2														
CHAPTER 1																		
Background, Problem Statement	3	2	3	3														
Objective, Scope	3	3	3	3														
CHAPTER 2																		
Literature Review	3	6	3	11														
Research Gap	10	2	13	1														
CHAPTER 3																		
Research Method and Area	4	1	4	2														
Project Planning	5	2	5	2														
Flow Chart	5	2	5	2														
Solidwork Software	7	2	7	3														
ALTAIR SolidThinking	7	3	8	4														
SLS 3D Printing	7	3	8	5														
CHAPTER 4																		
Introduction	10	1	12	1														
Others																		
Elog Book Weekly	1	12	1	13														
Report Progression	1	12	1	13														

Appendix 2 Gantt Chart PSM 2

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Briefing	1	1	1	1														
Experimental Setup	2	2	2	2														
CHAPTER 4																		
Early Simulation Test	3	2	3	2														
SolidThinking Optimization	4	2	4	2														
Component Fabrication	4	4	5	3														
Improvement Implementation	5	5	6	6														
Failure and Error Correction	7	5	8	6														
Final Simulation Test	11	2	12	2														
Post Simulation Analysis	12	2	12	2														
Result Verification	13	2	12	2														
Poster Presentation	14	1	14	1														
CHAPTER 5																		
Conclusion	12	2	13	2														
Recommendation	12	2	13	2														
Others																		
Weekly Weekly Logbook	1	14	1	14														
4 Pages Summary	12	3	13	2														
PosterMaking	10	4	11	3														

Appendix 3 Turnitin Report