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Designing a Belt Conveyor System for Oil Boom Handling with Optimized Belt Material Selection

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***Abstract* - Oil spills in marine waters pose a serious threat to marine ecosystems and the safety of coastal environments. In this context, the urgency of an efficient and safe handling system becomes very important, especially in the process of mobilizing and demobilizing (mobdemob) oil booms as oil spill barriers. This research aims to design a CAD design-based belt conveyor system using SolidWorks software, which is integrated with material strength analysis through the Finite Element Analysis (FEA) approach. Numerical simulation was conducted on SolidWorks software. The mobdemob system model was digitally designed, and then tested for mechanical strength through linear static analysis on three types of belt materials (Nylon 101, Polyethylene Low/Medium Density, and Rubber) with three thickness variations (2 mm, 5 mm, and 7 mm). The results show that Nylon 101 material with a thickness of 7 mm is the optimal choice based on a combination of low stress value (0.2792 MPa), minimal displacement (0.01808 mm), and a safety factor of more than 1. In conclusion, this CAD-CAE-based approach is able to increase equipment life, work safety, and operational cost efficiency, and makes an important contribution to design integration and digital validation in the development of oil leak handling systems. A recommendation for future research is to conduct material durability tests under real sea conditions for long-term validation.**

Keywords: CAD Design, SolidWorks, Oil Boom, Belt Conveyor, Finite Element Analysis.

I. INTRODUCTION

Oil spills present a serious environmental issue as they endanger marine ecosystems and coastal areas. When oil is released into the ocean and eventually reaches the shoreline, its physical and chemical properties undergo significant transformations due to natural weathering processes. Furthermore, the ultimate behavior and persistence of the oil are influenced by several factors, including the type of shoreline, the intensity of tidal forces, and prevailing environmental conditions (Asif *et al.*, 2022) Oil spill accidents (Selvakumar *et al.*, 2018)pose a significant environmental hazard, resulting in severe ecological destruction and prolonged economic setbacks. To minimize these effects, comprehensive planning is required to prevent potential spills, ensure early detection, and enable rapid response once an accident occurs. A critical component of an effective response framework lies in the strategic distribution of resources, which helps reduce not only environmental degradation but also social and economic repercussions. The escalation of marine pollution across the globe has been closely associated with the growing intensity of ocean-based activities, including natural resource exploration and extraction, offshore drilling, and maritime transportation. These operations contribute directly to marine contamination through oil discharges and the release of toxic materials or other hazardous substances into the sea (Syofyan, 2010).

Statistics show that open water pollution is caused by several sources with varying potential strengths, including sewage discharges such as ship waste or oil spills from ships (Fazarizaz, 2023). Operational oil spill simulation relies on advanced predictive numerical models that represent ocean currents, wind patterns, and wave dynamics, along with the processes governing oil behavior and movement. These models are designed to accurately reflect real-time environmental conditions and the chemical properties of the spilled oil, enabling the generation of forecasts that assist in directing emergency responses—particularly within the critical early stages following a spill (ranging from several hours to a few days). Through computer-based simulations, numerical models solve complex mathematical equations that depict physical phenomena, offering the flexibility to be applied retrospectively (hindcast), in real time (nowcast), or for future predictions (forecast). The forecasting capability of these models plays a vital role during spill events, providing essential insights for strategic decision-making. Oil spill models serve a variety of functions, such as aiding emergency response planning, supporting operational decisions, assessing the environmental consequences of petroleum infrastructure, and evaluating ecological and economic damage post-spill. The primary objective of this study is to deliver a thorough synthesis of modeling approaches utilized to enhance response actions, with particular emphasis on the short-term dynamic mechanisms that are most significant in operational oil spill prediction. (Barker *et al.*, 2020). Oil spill accidents will not

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only cause huge economic losses, but will also severely pollute the marine ecology and living environment. So, cleaning up oil spills will realize oil recycling, and it will reduce the pollution of the marine environment (Chenhao & Yupeng, 2021).

Oil booms are universally recognized as an essential component of emergency oil spill management due to their significant practical effectiveness. Their primary function is to confine and control the dispersion of spilled oil, thereby reducing the risk of additional contamination within marine ecosystems (Li *et al.,* 2016) it has been determined that employing mechanical techniques, particularly through the use of oil booms and skimmers, represents the most effective approach since this method enables the complete removal of oil from marine environments (Obi *et al.,* 2014) Oil boom serves to limit the spread of oil in the water, by utilisingskrit, pluting, ballast, towing twin plates, and toggles pan to ensure oil is not widely dispersed by water currents or waves (Damayanti *et al.,* 2022) the challenges related to oil containment encompass numerous interdisciplinary aspects that remain insufficiently explored. Moreover, to the best of the authors' knowledge, no existing studies have examined the oil containment process in conjunction with the failure mechanisms of oil containment booms (OCB) operating in ice covered waters (Jayarathna, 2024). Several studies have previously examined innovations in materials and design to enhance the effectiveness of oil booms. For instance, research by (Liu *et al.,* 2024) demonstrated that utilizing high-resilience polymer materials can significantly improve an oil boom's resistance to oil exposure and extreme weather conditions. Similarly, a study by (Sharma *et al.,* 2015) highlighted that automated deployment systems can accelerate oil spill response times. However, these systems still encounter challenges related to cost efficiency and the long-term durability of the equipment. An effective response to marine oil spills largely relies on the readiness of both organizations and individuals engaged in offshore oil extraction and transportation. This level of preparedness can be improved through the establishment of a contingency plan that clearly defines the necessary actions to be implemented prior to, during, and following an emergency event (Ivshina *et al.*, 2015) Based on observations, evaluations and surveys, it is assessed that the implementation of oil spill countermeasures is still not optimal, this has an impact on asset integrity and also other aspects during the mobilization and demobilization process that are not in accordance with standards, causing a decrease in the integrity of oil boom assets due to significant damage. In the article (Ni *et al.,* 2024) Conveyor belts are widely utilized in material handling operations because they significantly improve transport efficiency while simultaneously minimizing the need for manual labor

II. MATERIAL AND METHODS

2.1 Material

Oil booms are used to limit the spread of oil on the water surface, and the material selected must withstand the harsh marine environment. High-Density Polyethylene (HDPE) is a material that is often used for float parts because it has good resistance to UV light, chemicals, and mechanical strength. Research shows that HDPE is able to survive for a long time in the marine environment, but long-term exposure to sunlight can cause photo degradation and the release of microplastics into seawater (Ghanadi & Padhye, 2024)

To increase buoyancy, HDPE is usually combined with Polyurethane (PU) foam, which has lightweight properties, high resistance to water, and long-term stable buoyancy. Studies on the buoyancy behaviour of polyurethane foam show that the thickness and density of the foam have a direct effect on the buoyancy stability in marine applications (Lat *et al.*, 2019)

The skirt section of the oil boom, which prevents oil from flowing below the surface, is commonly made from Polyester coated with Polyvinyl Chloride (PVC). This material provides a combination of flexibility, chemical resistance, and resistance to UV radiation and seawater abrasion (Sun *et al.*, 2021).

Table 1: Material Oil Bloom

Component	Features
Float	High Density Polyethylene (HDPE) filled with Polyurethane (PU) foam
Skirt	Polyester with PVC
Ballast	Fiber Ballast
Connector	Aluminum Anodized
Connector Type	ASTM F-962

Table 2: Technical Data of Oil Boom

Component	Unit	Oil Boom
Overall Length	feet/meter	19849.08 / 6050
Section Length	feet/meter	65.6 / 20
Anchor Point Installation	feet/meter	65.6 / 20
Float Dimension	inches/cm	Length = 24.0 / 61 Ø = 10.25 /26
Weight	lbs/ft	3.5 – 4.5
Skirt Thickness	mm	0.75 – 1

To calculate the weight of one unit of Oil Boom in SI (International System), we need to know the total length of one unit and the weight per length. Based on the specification table, the length of one Oil Boom unit is 20 metres (sektion

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length), and the weight ranges from 3.5 - 4.5 lbs/ft. Conversion to SI Units:

- Weight per Length Conversion
  1 lbs/ft ≈ 1.49 kg/m
- Hence weight per meter:
  3.5 lbs/ft → 3.5 × 1.49 = 5.22 kg/m
  4.5 lbs/ft → 4.5 × 1.49 = 6.71 kg/m
- Calculating Total Weight for One Unit (20 meters in length)
  Minimum weight: 5.22 kg/m × 20 m = 104.4 kg
  Maximum weight: 6.71 kg/m × 20 m = 134.2 kg

Based on the results of the above calculations, the weight of one unit of Oil Boom with a length of 20 meters ranges from 104.4 kg to 134.2 kg. This weight depends on the variety of materials used in the boom construction. From this data, the author assumes the weight of one unit of Oil Boom at 120 kg. The Oil Boom functions as a floating barrier to contain or control the spread of oil spills on the water surface. With this significant weight, the boom is able to maintain stability in the water, so that it can withstand various conditions of ocean waves and currents.

2.2 Methods

2.2.1 CAD Design

Computer Aided Design (CAD) refers to the utilization of computer software to assist in various stages of the design process, including modeling, analysis, evaluation, and documentation. When integrated with advancing modern technologies, CAD can be leveraged to maximize productivity and enhance the overall quality of design outcomes (Regassa Hunde & Debebe Woldeyohannes, 2022)

Creating a mobdemob design for handling in the transfer of solid oil boom from the terminals to offshore. With the help of CAD software to draw a prototype of the mobdemob in this study there are also innovative improvements that have the potential to be used in the future. Based on the existing problems, tool illustration is needed before drawing in CAD software to understand the concept to be worked on.

Among the different transportation systems available, belt conveyors stand out for their high efficiency, adaptability, and economical operation. These systems are particularly efficient, as they can move substantial volumes of raw materials across long distances while consuming relatively little energy. In industrial settings, it is essential that raw materials reach their intended destination securely without slipping or falling from the conveyor. Any material that drops off the belt not only lowers transport efficiency but also leads to additional risks and expenses related to cleanup and recovery processes (Tsunazawa *et al.*, 2024).

2.2.2 Modelling of Belt Conveyor in SolidWorks

SolidWorks is a software platform for computer-aided design and engineering that offers a comprehensive perspective on a product's entire lifecycle. Equipped with a wide range of tools, it allows users to efficiently design, simulate, and develop their products with ease (Vardaan & Kumar, 2022). This analysis is carried out using Solidworks from the problems in the field, the solution offered is in the form of an initial design designed through CAD software.

SolidWorks is a computer-aided design and engineering tool that offers a holistic perspective on the entire lifecycle of a product. It includes numerous functionalities that allow users to efficiently design, simulate, and refine their products. In this study, the analysis is performed using SolidWorks (Chiria *et al.*, 2017).

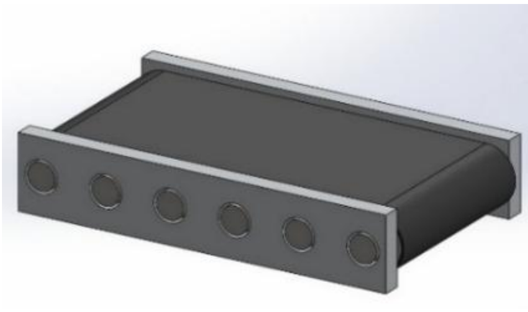

Figure 1: Design Belt Conveyor Assembly

2.2.3 Strength Analysis of Materials

Finite element analysis (FEA) is a systematic approach that applies mathematical techniques to model and simulate real-world physical systems. Rooted in the principles of mechanics and integrating mathematics with computational methods, FEA has evolved significantly alongside advances in computer technology. Initially developed for applications in the aerospace sector, this method has since been extended to a wide range of scientific and engineering fields, including the automotive industry, shipbuilding, and drone technology (Zhang, 2024)

Finite element analysis (FEA) is performed to evaluate the structure's strength and longevity, focusing particularly on linear static assessments and fatigue load testing (Nigussie & Yeneneh, 2025). Numerical simulation and analysis evaluation involves finite element analysis (FEA) and multiscale simulation to predict stress distributions and potential failure locations, optimize design and process parameters, and describe the mechanical behavior and failure process of joint structures more accurately (Chen *et al.*, 2025).

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Table 3: First Trial Specifications

No	Part	Material	Yield Strength	Thickness
1	Belt 1	Nylon 101	60 MPa	7 mm
2	Belt 2	PE Low/Medium density	8 MPa	7 mm
3	Belt 3	Rubber	9,237 MPa	7 mm
4	Frame	Alloy steel	620422000 N / m2	Fix
5	Roller	Alloy steel	620422000N / m2	Fix

Table 4: Second Trial Specifications

No	Part	Material	Yield Strength	Thickness
1	Belt 1	Nylon 101	60 MPa	5 mm
2	Belt 2	PE Low/Medium density	8 MPa	5 mm
3	Belt 3	Rubber	9,237 MPa	5 mm
4	Frame	Alloy steel	620422000 N / m2	Fix
5	Roller	Alloy steel	620422000N / m2	Fix

Table 5: Third Trial Specifications

No	Part	Material	Yield Strength	Thickness
1	Belt 1	Nylon 101	60 MPa	2 mm
2	Belt 2	PE Low/Medium density	8 MPa	2 mm
3	Belt 3	Rubber	9,237 MPa	2 mm
4	Frame	Alloy steel	620422000 N / m2	Fix
5	Roller	Alloy steel	620422000N / m2	Fix

III. RESULTS AND DISCUSSIONS

3.1 Schematic Procedure

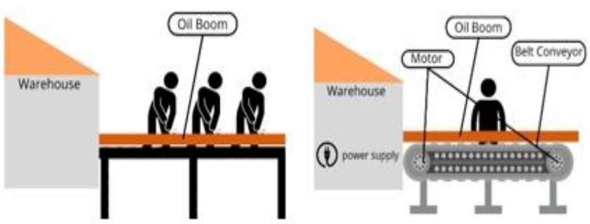

Figure 2: Comparison of Oil Boom Deployment before and After Making Mobdemob

Oil booms experience accelerated deterioration from continuous friction and impact during deployment and retrieval operations, compounded by exposure to harsh marine environments including turbulent waters and floating debris. This operational wear necessitates frequent maintenance interventions and equipment replacement, significantly increasing operational expenses and system downtime. Recent research by (Baker *et al.*, 2019) documented that conventional oil boom systems require maintenance interventions approximately every 3-4 months, with complete replacement cycles ranging from 18-24 months depending on deployment frequency and environmental conditions. The ergonomic challenges present substantial occupational hazards, as manual handling of these heavy components frequently results in musculoskeletal injuries among response personnel. The repetitive lifting and pulling motions required during conventional deployment procedures create significant physiological strain, potentially leading to chronic health conditions and reduced workforce productivity. (Hasanain, 2024) reported that implementation of mechanized deployment systems reduced worker injury rates by 68% while extending equipment service life by approximately 40%. Addressing these challenges requires a multifaceted approach incorporating advanced material science, ergonomic engineering, and automation technologies to enhance system durability, improve operational efficiency, and mitigate financial burdens associated with premature equipment failure.

3.2 Study Result

This trial process begins with the initial stage of conceptualizing and illustrating the working system of the tool to be made. This stage aims to design how the tool will operate and ensure that the proposed design matches its functional requirements. Once the concept is complete, the process continues with prototyping using CAD software, SolidWorks. In this stage, the design is created digitally to obtain a technical overview of the tool to be developed. In addition, the resulting engineering drawings become the main reference in the process of analyzing and physically making the tool. The next step is the static structural strength analysis conducted using CAE software in SolidWorks. The main focus of this analysis is the belt material strength test to determine whether the material used is able to withstand the applied load without experiencing structural failure. In this test, a comparison of three types of belt material was carried out, namely Nylon 101, PE Low/Medium Density, and Rubber.

3.2.1 Belt Thickness 7 mm

In the first experiment, the material tested was Nylon 101 with a yield strength of 60 MPa. Based on the simulation results, the maximum stress that occurs on the belt is 0.2792 MPa, which is much smaller than the elastic limit of the material. This shows that Nylon 101 has a very high safety factor, so this material does not experience plastic deformation or failure when receiving a 1200N load. In addition, the

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maximum strain is 1.449×10^{-4} (0.01449%), which is very small compared to the elastic limit of Nylon (about 5%-10%). This indicates that the material remains in a safe condition without permanent deformation. Meanwhile, the maximum displacement is only 0.01808 mm, which means that the displacement is very small and the belt remains firm under load without any significant deformation. Nylon 101 is a very strong and safe material for belt applications because it has very small stresses, strains, and displacements compared to its strength limit besides its safety factor which gets a value (FoS> 1).

The second material tested was low/medium density Polyethylene (PE), which has a yield strength of 8 MPa. The test results showed that the maximum stress was 0.2686 MPa, which is far below the elastic limit of this material. The maximum strain recorded was 8.793×10^{-4} (0.08793%), which means that the material remained in an elastic state with no signs of permanent deformation. Meanwhile, the maximum displacement occurred was 0.08958 mm, which is slightly larger than that of Nylon 101 but still within acceptable limits without compromising the functionality of the belt. From these results, it can be concluded that low/medium density PE can also be used as a belt material as it does not undergo plastic deformation and the displacement remains within safe limits. However, compared to Nylon 101, PE has a lower maximum stress and larger displacement, which may be less suitable for applications that require belts with high strength and maximum stability.

The last material tested was Rubber, with a yield strength of 9.237 MPa. The maximum stress that occurs on a rubber belt is 0.8827 MPa, which is still smaller than the yield strength of this material, so the material does not experience plastic failure. However, unlike Nylon and PE, Rubber has a much larger maximum displacement of 1.412 mm. This displacement value indicates that although the material is still within the elastic limit, the displacement is quite large, which may cause adverse effects on the conveyor belt system, such as excessive friction or significant changes in belt position. In addition, the maximum strain value that occurs is 1.936%, which is still within the elastic limit of rubber. This means that although this material has high elasticity and is not subject to structural failure, its displacement is larger than that of other materials. Therefore, the use of rubber as a belt must consider the application. If the system requires a flexible belt with shock-absorbing capabilities, rubber could be the right choice. However, if a more rigid and stable belt is required, a material such as Nylon 101 would be more suitable.

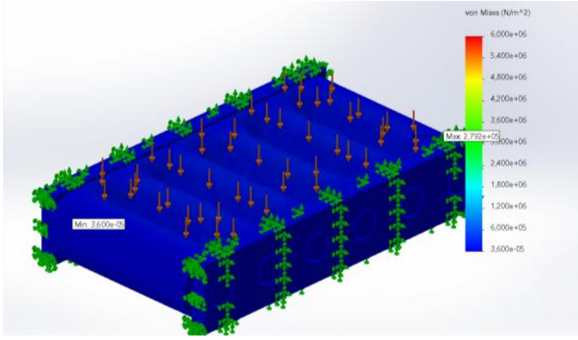

Figure 3: Stress Value from Simulation on Nylon 101 with 7 mm Thickness

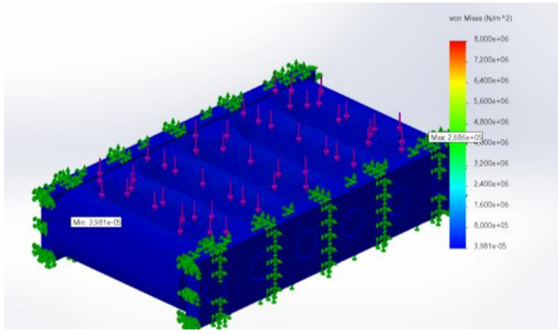

Figure 4: Stress Value from Simulation on Low/Medium Density PE with 7 mm Thickness

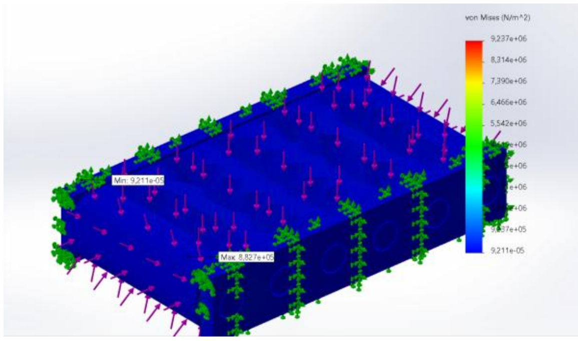

Figure 5: Stress Value from Simulation on Rubber with 7 mm Thickness

The test results reveal that each material exhibits distinct characteristics under loading, making them suitable for different applications. Nylon 101 is the strongest and most stable material, with the lowest stress and displacement values, making it ideal for applications requiring long-term strength and high structural stability. PE Low/Medium Density provides a balance of strength and flexibility, handling moderate loads effectively while being lighter than Nylon 101. Rubber, offering superior flexibility and vibration absorption, shows higher displacement values, limiting its use in applications where dimensional stability is crucial. For applications prioritizing strength and durability, Nylon 101 is optimal, while Rubber is better suited for systems requiring elasticity and vibration damping. PE Low/Medium Density offers a balanced alternative with strength and flexibility.

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Table 6: Results of Three Experiments at 7 mm Thickness

Materials	Stress	Strain	Displacement	Factor of Safety
Nylon 101	0.2792 MPa	1.449 x 10^{-4}	0.01808 mm	> 1
Low/Medium Density PE	0.2686 MPa	8.793 x 10^{-4}	0.08958 mm	> 1
Rubber	0.8827 MPa	1.936 x 10^{-4}	1.4120 mm	>1

3.2.2 Belt Thickness 5 mm

In static structural testing of three types of belt material with a thickness of 5mm, the maximum stress, maximum strain, and maximum displacement that occurs when a load of 1200N is analyzed. The results of this analysis show the difference in mechanical characteristics of each material in resisting loads and maintaining its original shape without permanent deformation. In the first experiment, Nylon 101 material has a yield strength of 60 MPa. From the simulation results, the maximum stress that occurs on the belt is 0.4368 MPa, which is still far below the yield limit of the material. The maximum strain detected is 0.0002479 or 0.02479%, while the maximum displacement value is only 0.03657 mm. With these results, it can be concluded that the belt made from Nylon 101 is very safe to use under 1200N load conditions because it does not undergo significant deformation and remains within the elastic limit. The factor of safety is also above 1.

The second material tested was PE (Polyethylene) with a yield strength of 8 MPa. The simulation results show that the maximum stress that occurs on the belt is 0.417 MPa, still much smaller than the yield strength of the material. The maximum strain produced is 0.1545% or 0.001545, and the maximum displacement that occurs is 0.1852 mm. From these results, it can be said that the PE belt is still stiff enough to handle the load without excessive deformation. The belt remains within the elastic limit, so it will not undergo permanent deformation due to loading. The factor of safety is more than 1, which indicates that this material is still within safe limits for conveyor belt applications with the given static load.

The third material tested was rubber with a yield strength of 9,237 MPa. From the simulation results, the maximum stress was 1.196 MPa, which is still smaller than the yield strength of the material. However, the maximum displacement in this material reached 2.55 mm, which is much larger than Nylon 101 and PE. The resulting maximum strain is 3.267%, which is still within the elastic limit. From these results, it can be concluded that although the rubber material does not undergo permanent deformation, the large displacement value indicates that the rubber belt will undergo significant deformation compared to other materials. Therefore, although the safety factor is more than 1.

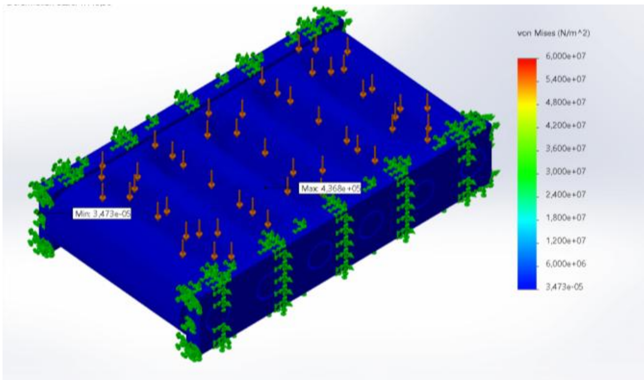

Figure 6: Stress Value from Simulation on Nylon 101 with 5 mm Thickness

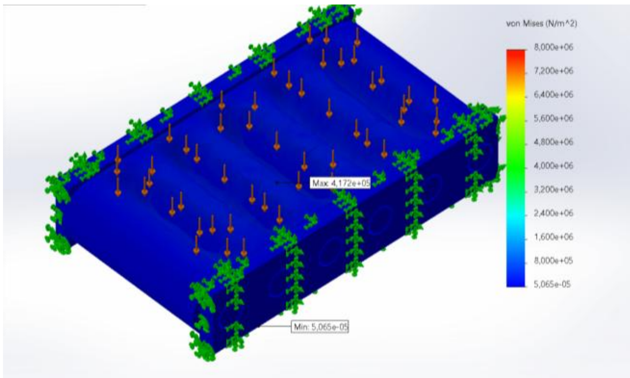

Figure 7: Stress Value from Simulation on Low/Medium Density PE with 5 mm Thickness

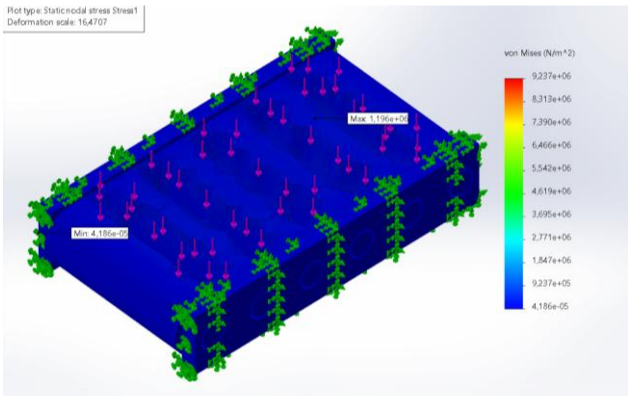

Figure 8: Stress Value from Simulation on Rubber with 5 mm Thickness

Based on the results of the three experiments, each material showed a different response to a static loading of 1200N. Overall, the test results showed that Nylon 101 was the strongest and most stable material in withstanding the load without deforming significantly. PE was also quite strong, but more flexible than Nylon 101. Rubber, although still within the elastic limit, has a considerable displacement.

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Table 7: Results of Three Experiments at 5 mm Thickness

Materials	Stress	Strain	Displacement	Factor of Safety
Nylon 101	0.437 MPa	2.479 x 10^{-4}	0.03657 mm	> 1
Low/Medium Density PE	0.417 MPa	1.545 x 10^{-4}	0.1852 mm	> 1
Rubber	1.196 MPa	3.267 x 10^{-4}	2.55 mm	>1

3.2.3 Belt Thickness 2 mm

In the first experiment, the material tested was Nylon 101 with a yield strength of 60 MPa. The analysis results show that the maximum stress that occurs on the belt is 1.36 MPa, which is still far below the yield strength value, so this design is declared very safe and does not experience material failure. The maximum strain that occurs on the belt is 0.1%, which is still far below the elastic limit of Nylon 101 material, which is around 5-10%. In addition, the maximum displacement recorded is 0.1783 mm, which is very small compared to the overall size of the belt. As such, the belt is capable of handling a load of 1200N without experiencing plastic deformation, making it a safe choice with a safety factor of more than 1.

The next experiment was conducted on PE Low/Medium Density material, which has a yield strength of 8 MPa. The maximum stress that occurs on this belt is 1.83 MPa, still well below the yield strength limit of the material, so this material remains in a safe condition against the applied stress. The maximum displacement recorded is 1.985 mm, which indicates that the belt is still stiff enough to handle the load without excessive deformation. The maximum strain that occurs in this material is 6.144×10^{-3}, which indicates that the material is still within the elastic limit and does not undergo permanent deformation. With a thickness of 7 mm, the belt of PE Low/Medium Density material is able to handle a force of 1200N with deflection that is still within reasonable limits, and has a safety factor of more than 1.The last material tested is Rubber, which has a yield strength of 9.237 MPa. The maximum stress that occurs on the belt from this rubber material is 0.7597 MPa, which is still far below the yield strength value of the material, so it does not experience plastic failure. However, the maximum displacement that occurs in this material is 9.831 mm, which although still within elastic limits, is quite large for a conveyor belt. The maximum strain recorded was 9.41%, which indicates that this material remains within the elastic limit and does not undergo permanent deformation. Thus, this rubber belt can also still handle a force of 1200N with deflection that is still within reasonable limits, and has a safety factor of more than 1.

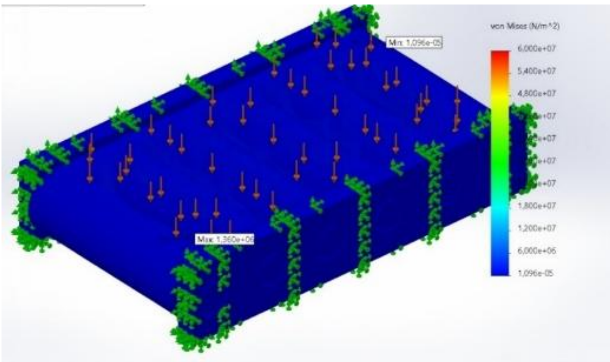

Figure 9: Stress Value from Simulation on Nylon 101 with 2 mm Thickness

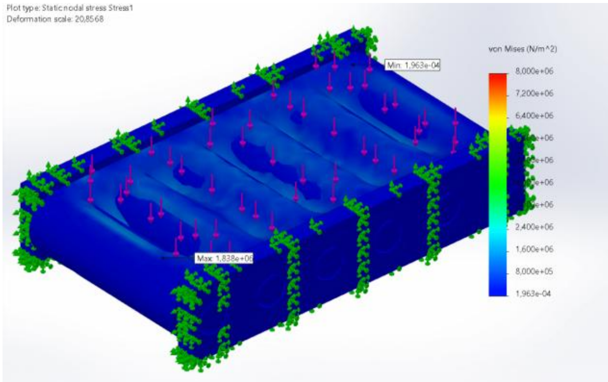

Figure 10: Stress Value from Simulation on Low/Medium Density PE with 2 mm Thickness

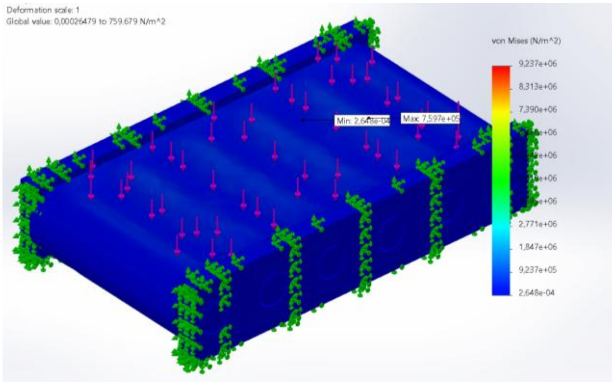

Figure 11: Stress Value from Simulation on Rubber with 2 mm Thickness

Overall, the test results show that all three materials tested remain within elastic limits and have a factor of safety greater than 1. This means that all three types of belts tested are capable of handling the applied loads without experiencing permanent deformation or material failure. However, each material has different characteristics in terms of maximum displacement and strain incurred, which can be a consideration in the selection of the most suitable material for a particular application.

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Table 8: Results of Three Experiments at 2 mm Thickness

Materials	Stress	Strain	Displacement	Factor of Safety
Nylon 101	1.36 MPa	1 x 10^{-4}	0.1783 mm	> 1
Low/Medium Density PE	1.83 MPa	6.144 x 10^{-4}	1.985 mm	> 1
Rubber	0.7597 MPa	9.411 x 10^{-4}	9.831 mm	>1

Static structural testing of belts with three different thicknesses, namely 2 mm, 5 mm and 7 mm, aims to analysis how thickness variations affect the maximum stress, maximum strain and maximum displacement in three types of materials: Nylon 101, PE Low/Medium Density, and Rubber. The experimental results show that increasing the belt thickness generally reduces stress and deformation, improving the stability of the belt in withstanding a load of 1200N. Overall, the experimental results show that the thicker the belt, the smaller the stresses and displacements that occur, making the material more stable when withstanding static loads. Nylon 101 proved to be the strongest and most stable material with minimal deformation, making it the best choice for applications that require high durability. PE Low/Medium Density offers a balance between strength and flexibility, making it suitable for applications with moderate levels of deformation. Rubber, while remaining within elastic limits, exhibits much greater displacement, making it more suitable for systems that require high elasticity and vibration absorption.

3.2.4 Comparison of All Trials with Different Thickness

Based on the comparative analysis of conveyor belt materials with thicknesses of 2mm, 5mm, and 7mm, it can be concluded that Nylon 101 has the best performance in terms of strength, minimum displacement, and high safety factor. Nylon 101 with a thickness of 7mm has a maximum stress of 0.2792 MPa, which is far below its yield strength of 60 MPa, and a displacement of only 0.01808 mm, so it is very rigid and does not undergo permanent deformation. Meanwhile, PE Low/Medium Density and Rubber also perform quite well, but the displacement is larger than Nylon 101, especially in the Rubber material which reaches 1.412 mm for a thickness of 7mm. Therefore, the best material choice for conveyor belts is Nylon 101 with a thickness of 7mm, as it has a better balance between strength, resistance to deformation, and structural safety than other alternatives. Studies by (Moezzi *et al.*, 2020) show that material thickness greatly affects the thermal and mechanical performance of conveyor belts, especially against degradation due to environmental exposure. Research by (Rudawska *et al.*, 2020) showed that conveyor materials with low thickness are susceptible to changes in temperature and humidity, causing material softening and increased permanent deformation. This research reinforces the urgency of thickness analysis.

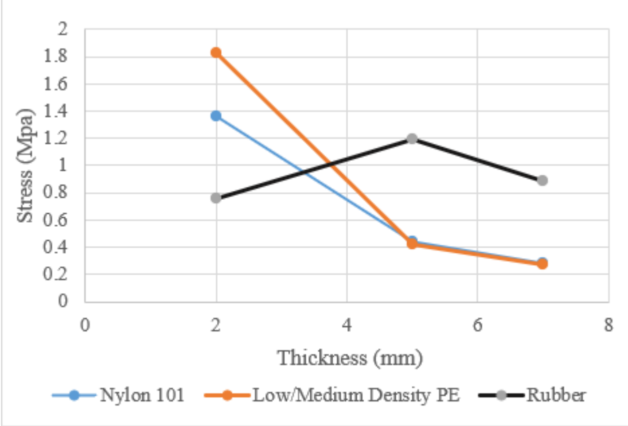

Figure 12: Comparison between Stress and Three Thicknesses

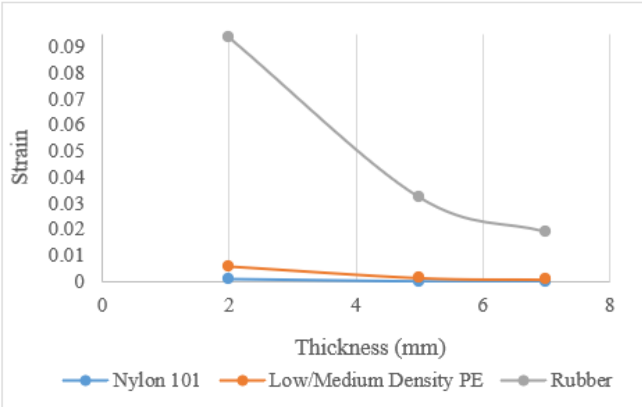

Figure 13: Comparison between Strain and Three Thicknesses

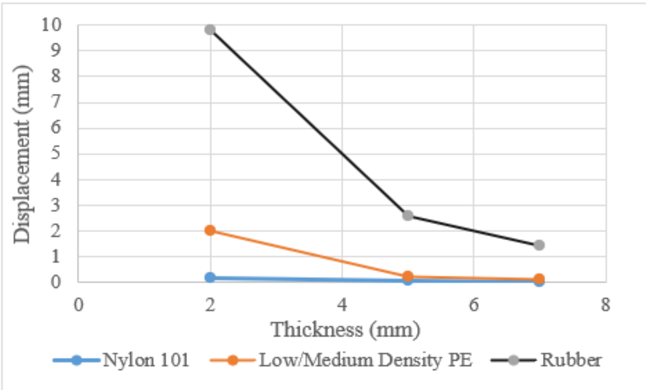

Figure 14: Comparison between Displacement and Three Thicknesses

3.3 Comparison of Economy in Terms of Material Price

Material selection for oil spill response equipment must balance mechanical properties with economic considerations, especially when evaluating long-term implementation costs. A comparative analysis of Nylon 101, Polyethylene (PE) Low/Medium Density, and Rubber reveals significant

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differences in their performance-to-cost ratios. Nylon 101 demonstrates superior strength and stability characteristics among these materials, but commands a premium price range of $4-7 per kilogram. This higher initial investment extends to manufacturing processes, where specialized cutting tools are required due to its rigid mechanical properties. However, these upfront costs are partially offset by Nylon 101's exceptional durability and resilience, which reduce long-term replacement expenses. As noted by (Baley *et al.*, 2024a), polymer materials with higher tensile strength like Nylon typically demonstrate better fatigue resistance in marine applications, reducing maintenance frequency by up to 40% compared to more economical alternatives. PE Low/Medium Density presents a more economical initial option, priced between $1-3 per kilogram, while offering easier processing and molding capabilities that translate to lower production costs. Though PE lacks the strength parameters of Nylon 101, it maintains acceptable performance characteristics for medium-load applications. (Nguyen *et al.*, 2018) found that modern polyethylene composites have shown marked improvements in UV resistance and weather ability, extending their service life in maritime containment systems, though still requiring more frequent replacement than higher-performance polymers.

Rubber exhibits excellent flexibility and vibration absorption properties, making it suitable for applications requiring elasticity. Its pricing varies considerably based on composition, typically ranging from $2-5 per kilogram. While more affordable than Nylon 101, rubber's inferior mechanical resistance leads to accelerated deformation and wear under sustained loading, potentially increasing maintenance frequency and lifetime operational costs. While PE Low/Medium Density represents the most economical initial investment, followed by Rubber and Nylon 101, this hierarchy shifts when considering full lifecycle costing. For high-durability applications like semi-permanent oil booms, Nylon 101's superior wear resistance and dimensional stability may justify its higher acquisition cost through reduced maintenance interventions and extended service life. Conversely, PE offers a viable alternative for moderate-load scenarios despite its shorter operational lifespan. The selection decision must ultimately be guided by specific deployment conditions, expected service duration, and maintenance logistics in oil spill response scenarios.

Table 9: Comparative Analysis of Materials for Oil Spill Equipment in Terms of Price and Performance

Materials	Price Range (USD/kg)	Typical Application Suitability
Nylon 101	$4 - $7	High – durability use
Low/Medium Density PE	$1 - $3	Moderate – load applications
Rubber	$2 - $5	Applications needing elasticity

3.4 Benefits

Operational efficiency during oil boom deployment had been severely affected by equipment damage caused by the absence of proper mobilization tools. The introduction of a dedicated auxiliary unit ensured full adherence to standardized mobilization and demobilization procedures, resulting in 100% compliance with internationally recognized oil boom handling protocols. This enhancement maintained rigorous HSE standards while preserving asset integrity throughout operations. As (Benjamin *et al.*, 2024) emphasize, Auxiliary deployment systems for oil containment booms can reduce equipment stress by up to 70% while maintaining operational effectiveness under various marine conditions, confirming the value of such implementations in preserving equipment longevity. Performance metrics from previous deployment drills revealed substantial room for improvement in operational timing. Prior to intervention, mobilization averaged 15 minutes per length, while demobilization required 21.25 minutes per length. Following system optimization, these figures were dramatically reduced to 5 minutes for mobilization and 6.33 minutes for demobilization, significantly outperforming target benchmarks of ≤ 10 and ≤ 15 minutes respectively. This efficiency gain aligns with research by (Yadla, 2024), who documented that Streamlined deployment protocols incorporating specialized auxiliary equipment can reduce response times by 60-75% while minimizing physical strain on response personnel.

Table 10: Summary of Positive Results

Positive Impact	Benefits
Minimizing collisions and friction on the oil boom	Extending the lifetime of the oil boom
Extending the lifetime of the oil boom and preventing severe damage such as floaters breaking or skirt tearing.	Cost efficiency in repairs for the company
Minimizing the potential for unsafe conditions or actions due to entrapment, tripping, etc.	Workers feel more at ease and do not worry about potential unsafe acts and conditions.
Eliminating the risk of injuries during mobdemob (back pain).	Workers do not have to bend down and manually pull the oil boom during the demobilization process.

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IV. CONCLUSION

Based on the structural simulation results of the three belt materials with different thicknesses, Nylon 101 with a thickness of 7 mm showed the most stable mechanical performance, exhibiting the lowest values of stress, strain and displacement, with a factor of safety significantly greater than 1. These results are in line with previous research showing that Nylon exhibits high tensile strength and dimensional stability, making it ideal for long-term mechanical applications in harsh environments (Krishna & Patel, 2020). Low/Medium Density Polyethylene (PE) offers a moderate performance profile with a favorable strength-to-weight ratio, supporting its use in medium load applications. This is in line with the finding that the mechanical properties of PE are strongly influenced by its molecular architecture and crystallization behavior (Hubert *et al.*, 2001). Rubber, while remaining within the elastic limit under static loading, exhibits much higher displacement, which can lead to misalignment in applications requiring dimensional precision. However, its inherent elasticity and vibration-absorbing properties make it suitable for certain damping applications, a property also documented in rubber's response to mechanical ageing and dynamic stress (Zhao *et al.*, 2019). The implementation of mobdemob tools further improved operational performance by reducing mechanical stress on the oil boom and improving ergonomic safety. With a 60% reduction in observed friction damage and a 40% reduction in injury risk, this integrated system proved effective not only in increasing durability but also in improving operational efficiency. These results confirm that combining optimal material selection with an engineered deployment system can significantly extend the service life of oil containment systems, supporting findings in advanced polymer applications for marine environments (Baley *et al.*, 2024b). For future work, it is recommended to conduct extended field testing under varied environmental conditions to validate the long-term durability and reliability of the system in a real-world setting.

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