Modification of Stiffener Sidewall for 17 m³ Capacity Dump Truck at PT. ABC

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ABSTRACT

PT. ABC operates within the engineering and construction sector, specializing in the service and provision of advanced heavy equipment, including the DV17 type Dump Truck. This Dump Truck model features a loading and unloading body capable of supporting loads of up to several tons. However, there are noted deficiencies in the effectiveness and efficiency of the Sidewall stiffener section, which utilizes 6 supports. A modification was carried out by creating 3 variants or forms of stiffeners. The design method used is the Pahl & Beitz concept design method, with testing performed through static and dynamic simulations using Finite Element Analysis (FEA). Simulation results show that Variant 2 performed the best in both static and dynamic tests, with static simulation values showing stress at 88 MPa, strain at 0.1, displacement at 0.8 mm, a safety factor of 2.9, and a weight of 818.16 kg. The dynamic simulation for Variant 2 recorded stress at 187 MPa, strain at 0.1, displacement at 1.7 mm, and a safety factor of 1.3. When compared to the existing design by PT. ABC, Variant 2 demonstrates superior performance. The current PT. ABC design presents static simulation values of 301 MPa for stress, strain of 0.1, displacement of 4.7 mm, and a safety factor of 0.8. Dynamic simulations reveal a stress value of 411 MPa, strain of 0.1, displacement of 5.1 mm, a safety factor of 0.6, and a weight of 802.63 kg. This indicates that Variant 2 provides optimal performance and a balanced trade-off between safety and stability.

Kata kunci: Stiffener Sidewall Dump Truck, Modification, Pahl & Beitz, Finite Element Analysis, effectiveness, efficiency

INTRODUCTION

The automotive industry is a key pillar supporting the national economy. The transportation sector grew by 10.33% in the last quarter of 2023 and by 13.96% on an annual basis. In addition, the mining industry is currently experiencing rapid development in line with Indonesia's growing economy. Examples include coal, sand, gravel, stone, and soil, which are commonly used as energy sources and other mining assets. To remain competitive, mining companies must enhance productivity and efficiency while continuously improving their production processes. In mining operations, the continuity of production is highly dependent on the availability of dump trucks or loading equipment, which directly affects productivity and efficiency. Mining itself is a technology or business process that begins with geographic exploration, exploration, evaluation, extraction, processing, transportation, and finally, marketing. [1].

PT. ABC is a company operating in the engineering and construction sector, focusing on pilot services and the provision of leading heavy equipment. Additionally, PT. ABC also offers services in the maritime industry, with one of its key products being the Dump Truck. The DV17-type Dump Truck by PT. ABC is a type of loading-unloading bed that features a robust frame and is capable of withstanding loads of up to tens of tons. Constructed from lightweight steel plates welded by arc welding, this Dump Truck is lighter and has a longer lifespan. This type of Dump Truck is also used to transport overburden materials such as soil and sand, due to their higher density, which ranges from 1.2 to 2 tons per cubic meter. Poorly planned product design and the use of substandard materials can lead to several issues, such as reduced production and increased costs [2]. Based on these considerations, in order to achieve ideal conditions particularly in the production process of the truck bed. This study focuses on the deficiencies found in the stiffener section of the DV17 Dump Truck sidewall, which currently has six supports that are not yet effective. This is due to the high stress levels in the inner plate area, resulting in fractures. Therefore, modifications were made to produce stiffeners and inner plate areas with better material properties or strength, making the system more efficient and effective for transporting sand material in the Sidewall of the Dump Truck.

RESEARCH METHODOLOGY

The research methodology for the development of the Sidewall Dump Truck stiffener uses the Pahl & Beitz Design Method, which is structured in a research flowchart as shown in Figure 1.

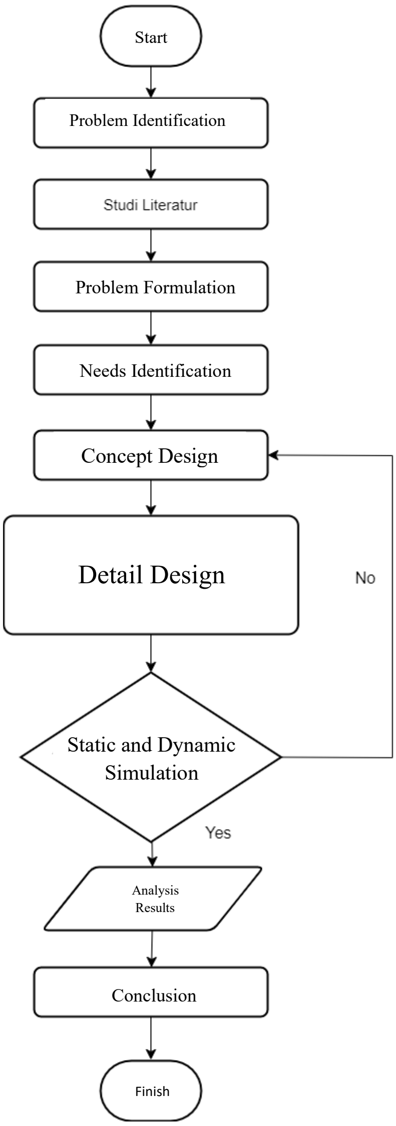

Figure 1. Research Flowchart

Problem Formulation and Needs Identification

PT. ABC has a DV17-type Dump Truck with a strong frame capable of withstanding loads of up to tens of tons. The load received by the dump truck bed is directed toward the right or left side, with the bed shape shown in Figure 2. .

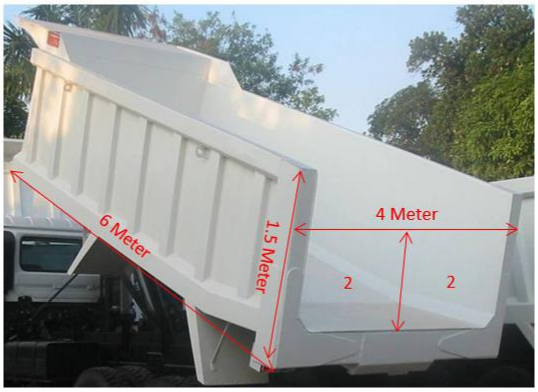

Figure 2. Dump Truck Bed of PT. ABC

The specifications of the Dump Truck bed are shown in Table 1.

Table 1. Dump Truck Bed Specifications

Item	Specifications
Length (L)	6 [m]
Width (B)	4 [m]
Height (H)	1.5 [m]
Total Load (W)	25000 [kg]

The process of identifying the Requirements for stiffeners was carried out through observation and interviews, which were then formulated and the requirements identified in Table 2.

Table 2. Needs Interpretation Based on Observation and Interview Results

No	Statement of Requirements	Interpretation of Requirements	Level of Importance
1	An easy design, manufacturing, and maintenance process	Facilitates the assembly, manufacturing, and maintenance process, with a simple construction	☆☆
2	The material utilizes metal	Using ASTM A36 metal material, which has specific characteristics due to its adequate strength and ease of formability	☆☆☆
3	An efficient and effective stiffener	The material used is in accordance with the requirements, allowing for optimal stiffener fabrication	☆☆☆

Keterangan :

☆☆☆ = High Level of Importance

☆☆ = Medium Level of Importance

☆ = Low Level of Importance

Developing the List of Requirements

Based on the Table of Requirements Interpretation from Observations and Interviews, a Demand Table was then created, which includes mandatory elements of a product (demands) and desired elements or wishes (wants)

Table 3. Table Wish and Demand

No	Design Aspects	Requirements	Level of Importance
1	Safety	Safe to Use	D
2	Estetika	The aesthetics or visual appeal of the stiffener	W
3	Material	ASTM A36 metal material	D
4	Maintenance	Ease of maintenance	W
5	Production	Easy to make or produce	D
		Simple construction	D

Keterangan :
Demand = Requirements
Whises = Expectations

Conceptual Design

The design at this stage is carried out to determine the initial design concept to be used.

Function Structure

The function structure connects the input and output of the engineering system that will perform a specific task.

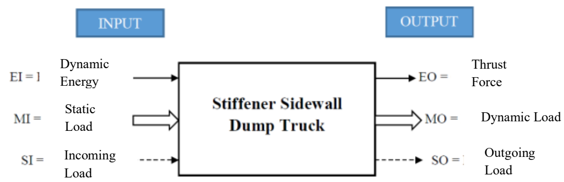

Figure 3. Function Structure

Function Tree

In the function tree, there is a detailed breakdown of the planned components, which are elaborated into several individual parts

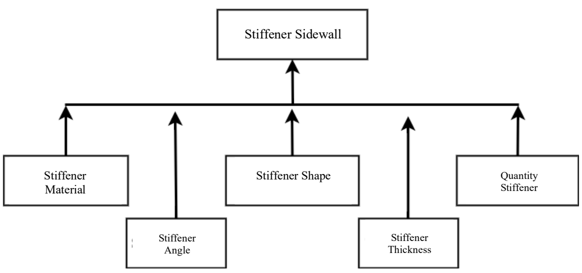

Figure 4. Function Tree

Overall Sub-Function

The overall sub-function structure of the Sidewall Dump Truck stiffener is shown in Figure 5.

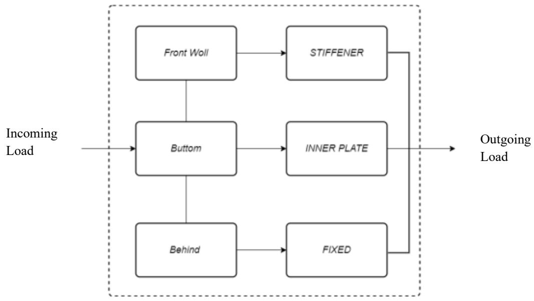

Figure 5. Overall Sub-Function

Solusi Combination of Solution Principles

After the overall function structure and its sub-functions are established, the next step is to identify solution principles to perform those sub-functions. The method used is the combination method, in which all available solutions are merged or combined in the form of a matrix. As many solution principles as possible are proposed, but they are then reanalyzed.

Table 4. Combination of Solution Principles

No	Sub-Function	Solution		
		1	2	3
1	Stiffener Material	AISI 1035 1.1	ASTM A36 1.2	
2	Stiffener Plate Material Thickness	5.5 [mm] 2.1	4.5 [mm] 2.2	3.5 [mm] 2.3
3	Stiffener Shape	Straight 3.1	Straight and Angled 3.2	Angled 3. 3
4	Quantity Stiffener	4 Pieces 4.1	12 Pieces 4.2	5 Pieces 4.3
5	Stiffener Angle	Angle 90° 5.1	Combination Angle 21° & 90° 5.2	Angle 70° 5.3
		V1	V3	V2

Description
V1 = Variant 1
V2 = Variant 2
V3 = Variant 3

RESULTS AND DISCUSSION

Detailed Design

Variant 1

This stiffener design includes only 4 stiffeners and is also equipped with 16 L-brackets on the top and bottom. It uses AISI 1035 material, and the planned plate thickness is 5.5 mm, with the stiffeners shaped as upright straight 90° or vertical forms.

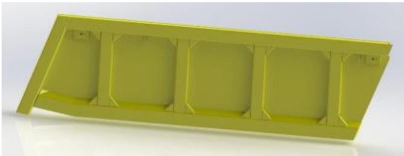

Figure 6. Variant 1

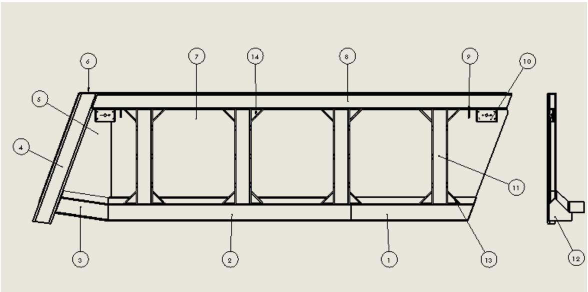

Figure 7. Component Variant 1

Table 5. Component Specification of Variant 1

No	Component Name	Material	Thickness [mm]	Weight/Pcs [kg]	Qty [Pcs]
1	*Lower Coaming 1*	ASTM A36	4.5	36.83	1
2	*Lower Coaming 2*	ASTM A36	4.	75.06	1
3	*Lower Coaming 3*	ASTM A36	4.5	15.99	1
4	*Behind Coaming*	ASTM A36	10	51.58	
5	*Inner Plate 2*	ASTM A36	6	54.72	1
6	Penutup	ASTM A36	8	1.3	1
7	*Inner Plate 1*	ASTM A36	6	383.22	1
8	*Top Coaming*	ASTM A36	6	89	1
9	*Hook*	ASTM A36	12	0.6	2
10	*Lamp Bracket*	ASTM A36	6	2	2
11	*Stiffener*	AISI 1035	5.5	16.	4
12	Penutup *Lower* C.	ASTM A36	5.5	2.0	1
13	L Siku Bawah	AISI 1035	5.5	1.6	8
Total				793.64	19

Variant 2

This variation 2 stiffener design uses ASTM A36 material, includes 12 stiffeners with a 70° slanted type, and features a horizontal stiffener in the middle section. The plate thickness used is 3.5 mm.

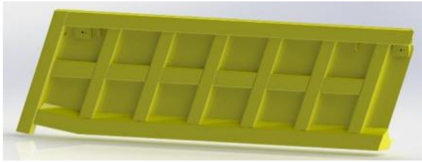

Figure 8. Variant 2

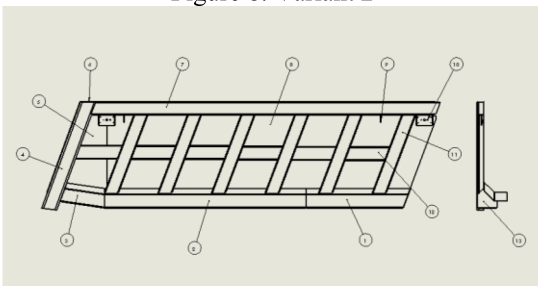

Figure 9. Component Variant 2

Table 6. Component Specification of Variant 2

No	Component Name	Material	Thickness [mm]	Weight/Pcs [kg]	Qty [Pcs]
1	*Lower Coaming 1*	ASTM A36	4,5	36.83	1
2	*Lower Coaming 2*	ASTM A36	4.5	75.0	1
3	*Lower Coaming 3*	ASTM A36	4.5	15.99	1
4	*Behind Coaming*	ASTM A36	1	51.58	1
5	*Inner Plate 2*	ASTM A36	6	54.72	1
6	Penutup	ASTM A36	8	130	1
7	*Top Coaming*	ASTM A36	6	89	1
8	*Inner Plate 1*	ASTM A36	6	383.2	1
9	*Hook*	ASTM A36	12	0,6	2
10	*Lamp Bracket*	ASTM A36	6	2	2
11	*Stiffener*	ASTM A36	35	11.36	6
12	*Stiffener* Tengah	ASTM A36	3.5	5.5	6
13	Penutup *Lower* C.	ASTM A36	45	2.03	1
Total				818.16	25

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Variant 3

In this third variant, ASTM A36 material is used. It has 5 stiffeners with a combination type—straight at 90° and slanted at 70°, with a plate thickness of 4.5 mm. Additionally, it includes 14 L-brackets on the top and bottom.

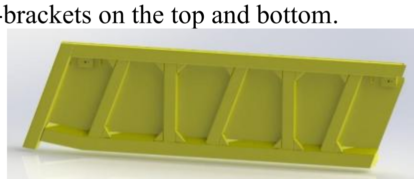


Figure 10. Variant 3

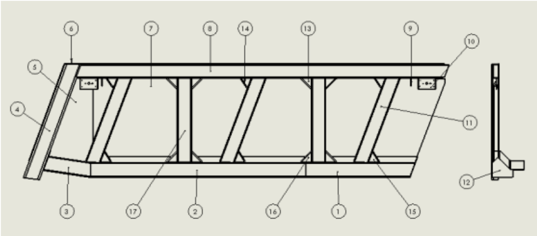


Figure 11. Component Variant 3

Table 7. Component Specification of Variant 3

No	Component Name	Material	Thickness [mm]	Weight/Pcs [kg]	Qty [Pcs]
1	*Lower Coaming 1*	ASTM A36	4.5	36.83	1
2	*Lower Coaming 2*	ASTM A36	4.5	75.06	1
3	*Lower Coaming 3*	ASTM A36	4.5	15.99	1
4	*Behind Coaming*	ASTM A36	10	51.58	1
5	*Inner Plate 2*	ASTM A36	6	54.72	1
6	Penutup	ASTM A36	8	1.30	1
7	*Inner Plate*	ASTM A36	6	383.22	1
8	*Top Coaming*	ASTM A36	12	8	1
9	*Hook*	ASTM A36	6	0.62	2
10	*Lamp Bracket*	ASTM A36	6	2	2
11	*Stiffener 70°*	ASTM A36	4.5	14.61	3
12	*Penutup Lower C*	ASTM A36	4.5	2.03	1
13	*L Siku Atas*	ASTM A36	4.5	0.95	4
14	L Siku Atas Miring	ASTM A36	4.5	0.82	3
15	L Siku Bawah Miring	ASTM A36	4.5	0.82	3
16	L Siku Bawah	ASTM A36	4.5	0.85	4
17	*Stiffener* Lurus 90°	ASTM A36	4.5	13.67	2
Total				806.24	32

PT. ABC's Sidewall

This stiffener model has a material thickness of 4.5 mm, a length of 1,302 mm, and consists of 6 stiffeners with an inclination angle of approximately 70°. The material used for the Sidewall of the Dump Truck is ASTM A36.

Figure 12. PT.ABC Sidewall

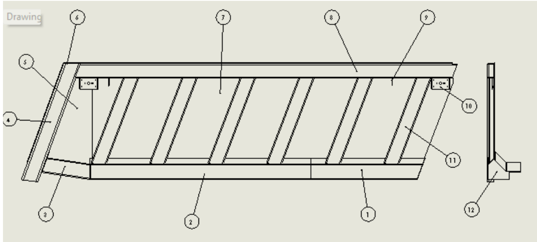


Figure 13. Component *Sidewall* PT.ABC

Table 8. Component Specification of *Sidewall* PT.ABC

No	Component Name	Material	Thickness [mm]	Weight/Pcs [kg]	Qty [Pcs]
1	*Lower Coaming 1*	ASTM A36	4.5	36.83	1
2	*Lower Coaming 2*	ASTM A36	4.5	75.06	1
3	*Lower Coaming 3*	ASTM A36	4.5	15.99	1
4	*Behind Coaming*	ASTM A36	10	51.58	1
5	*Inner Plate 2*	ASTM A36	6	54.72	1
6	Penutup	ASTM A36	8	1.30	1
7	*Inner Plate 1*	ASTM A36	6	383.22	1
8	*Top Coaming*	ASTM A36	6	8	1
9	*Hook*	ASTM A36	12	0.62	2
10	*Lamp Bracket*	ASTM A36	6	2	2
11	*Stiffener*	ASTM A36	4.5	14.61	6
12	Penutup Lower C.	ASTM A36	4.5	2.03	1
Total				802.63	19

Load

The load on the surface of the Dump Truck bed is 25,000 kg, assuming an evenly distributed load, resulting in 12,500 kg on each the right and left side of the Dump Truck.

Testing Simulation

In the static simulation test, the geometric model is defined and divided into small elements that can be analyzed using the Finite Element Method (FEA). Then, boundary conditions or constraints are applied to the model to represent how the workpiece or structure being analyzed is fixed or supported under real-world conditions.

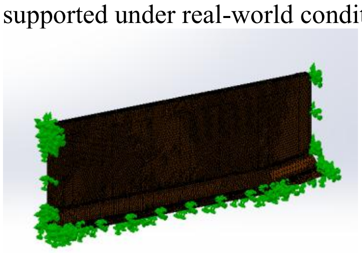


Figure 14. Fixture *Sidewall Dump Truck*

Static Testing Simulation

In the static simulation test, a loading scenario of 12,500 [kg] was applied outward or sideways by exerting external forces or pressures on the model.

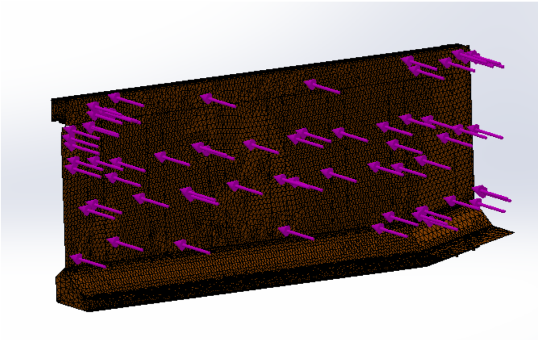


Figure 15. Pemberian Pembebanan Pada *Sidewall Dump Truck*

Static Simulation Analysis Results

The following are the results of the static load analysis process.

Table 9. Von Mises Stress Analysis Results

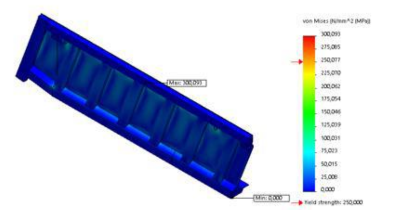
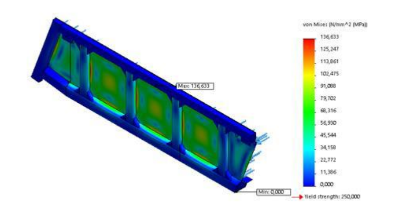
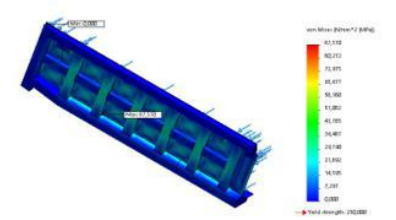
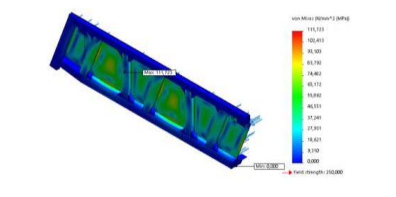
No	Desain	Stress Von Misses
1	PT.ABC	
2	Variant 1	
3	Variant 2	
4	Variant 3	

Table 10. Strain Analysis Results

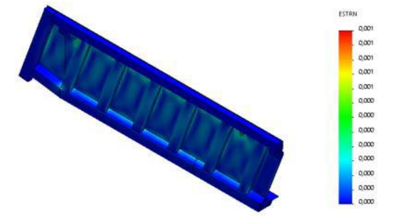
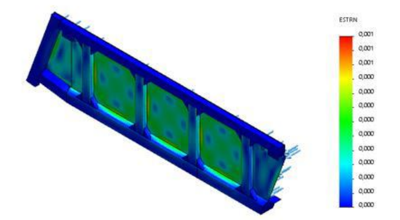
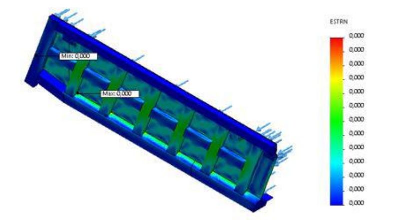
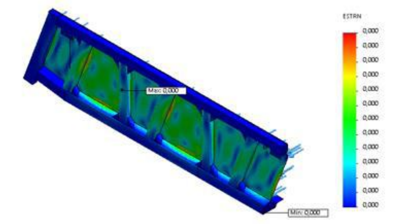
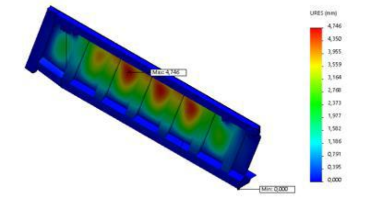
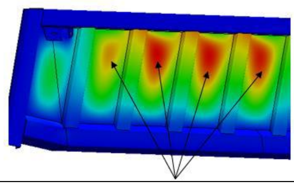
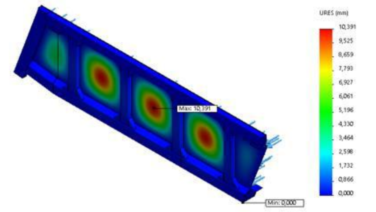
No	Desain	Strain
1	PT.ABC	
2	Variant 1	
3	Variant 2	
4	Variant 3	

Table 11. Displacement Analysis Results

No	Desain	Displacement
1	PT.ABC	 
2	Variant 1	

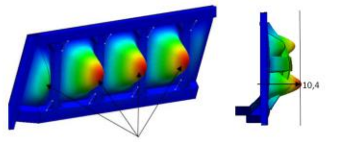
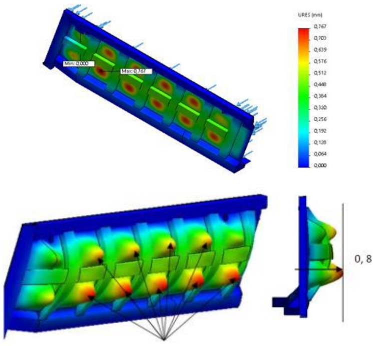
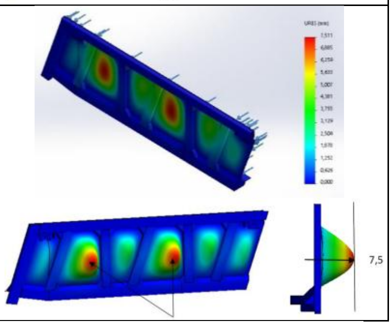
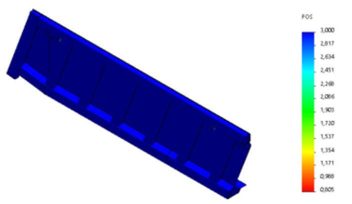
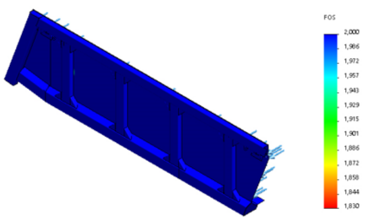
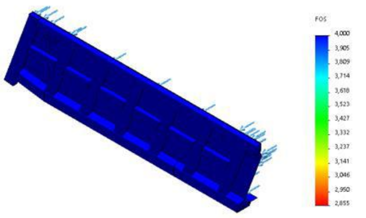
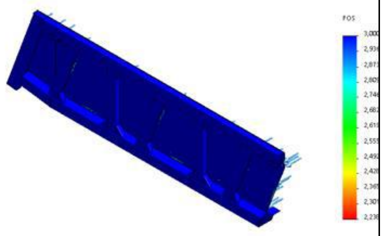
No	Desain	Displacement
		
3	Variant 2	
4	Variant 3	

Table 12. Safety Factor Analysis Results

No	Desain	Safety Factor
1	PT.ABC	
2	Variant 1	
3	Variant 2	

No	Desain	Safety Factor
4	Variant 3	

Dynamic Simulation Testing

This dynamic load simulation is used to predict the response of a Sidewall Dump Truck structure when subjected to time-varying loads. The simulation employs a loading scenario of 12,500 [kg] applied outward or sideways, along with natural vibrations at a natural frequency closest to 110 Hz. This allows for a comprehensive and focused analysis, identifying potential resonance issues and ensuring the structural integrity of the Sidewall Dump Truck under dynamic loading conditions.

Dynamic Simulation Analysis Results

The following are the results of the dynamic load analysis process.

Table 13. Stress Von Misses Analysis Results

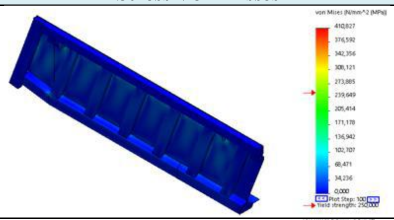
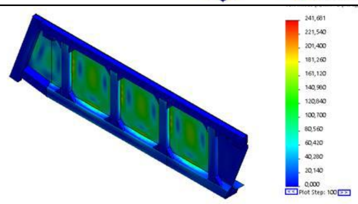
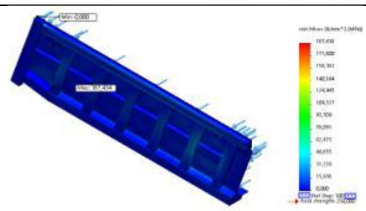
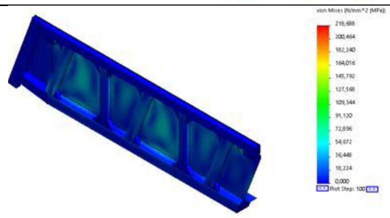
No	Desain	Stress Von Misses
1	PT.ABC	
2	Variant 1	
3	Variant 2	
4	Variant 3	

Table 14. Strain Analysis Results

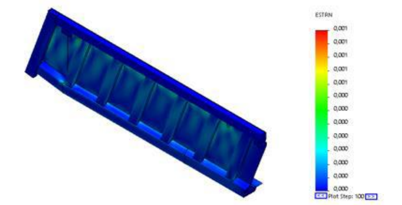
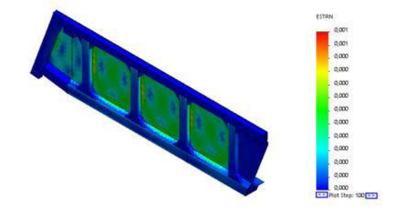
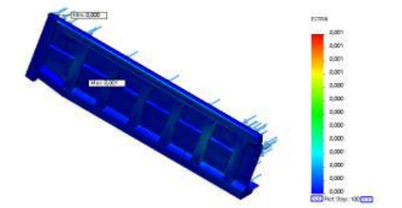
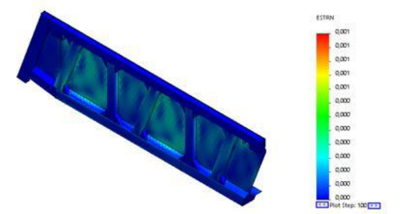
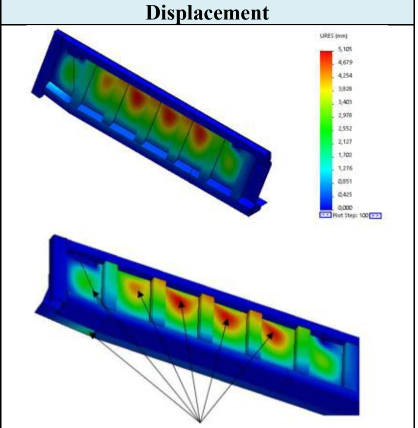
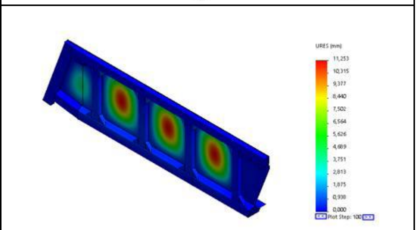
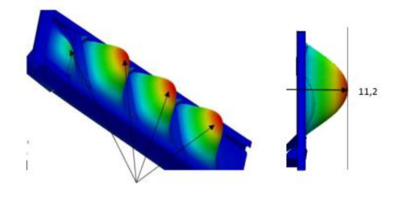
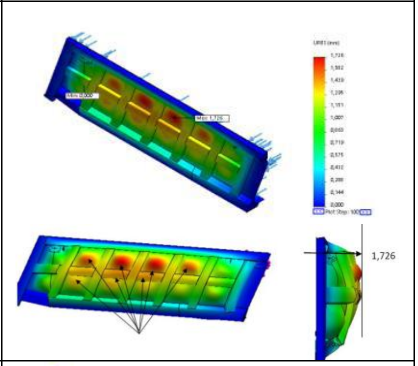
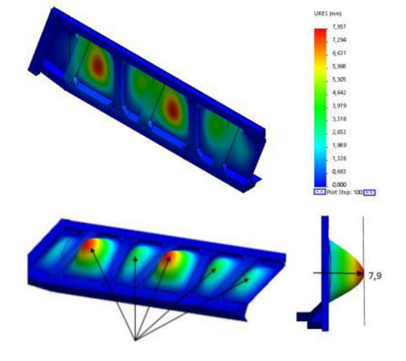
No	Desain	Strain
1	PT.ABC	
2	Variant 1	
3	Variant 2	
4	Variant 3	

Table 15. Displacement Analysis Results

No	Desain	Displacement
1	PT.ABC	
2	Variant 1	 
3	Variant 2	
4	Variant 3	

Discussion of the Analysis Results from Static and Dynamic Simulation Testing

Based on the static simulation results of the Sidewall Dump Truck from PT.ABC, variants 1, 2, and 3 using the finite element method, variant 2 is determined to be the best. Variant 2 has the highest safety factor of 2.9, with a very low displacement value and minimal stress levels due to a more evenly distributed load.

Table 16. Static Simulation Analysis Results

Design	Stress [MPa]	Strain	Displacement [mm]	Safety Factor	Weight [kg]
PT.ABC	301	0.1	4.7	0.8	802.63
Variant 1	137	0.1	10.4	1.8	793.64
Variant 2	88	0	0.8	2.9	818.16
Variant 3	112	0	7.5	2.2	802.63

Based on the dynamic simulation results of the Sidewall Dump Truck from PT.ABC for variants 1, 2, and 3, variant 2 is identified as the best option. The stress distribution on the Sidewall Dump Truck is more uniform, resulting in lower Von Mises stress and displacement, and it also has the highest safety factor.

Table 17. Dynamic Simulation Analysis Results

Design	Stress [MPa]	Strain	Displacement [mm]	Safety Factor	Weight [kg]
PT.ABC	411	0.1	5.1	0.6	802.63
Variant 1	242	0.1	11.2	1.0	793.64
Variant 2	187	0.1	1.7	1.3	818.16
Variant 3	219	0.1	7.9	1.1	802.63

CONCLUSION

The design concept of the modified stiffener for the DV17 Sidewall Dump Truck unit was carried out systematically using the Pahl & Beitz method and the Finite Element Analysis (FEA) method to verify the strength and stability of the modified stiffener design. The modified stiffener configuration for the 17 m³ Sidewall Dump Truck owned by PT. ABC resulted in Variant 2, which delivers optimal performance with a balanced emphasis on safety and stability. Variant 2 features 12 inclined stiffeners at a 70° angle made of ASTM A36 steel with a plate thickness of 3.5 mm, along with a central horizontal stiffener. This configuration provides the advantage of even load distribution and improved material flexibility. Based on the static simulation, Variant 2 shows a stress value of 88 MPa, zero strain, and the highest safety factor of 2.9, with a very low displacement of 0.8. In the dynamic simulation, Variant 2 demonstrates a stress of 187 MPa, strain of 0.1, displacement of 1.7, and an adequate safety factor of 1.3.

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