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Numerical simulation analysis of structural strength of portable skid for storage tank with 50.000 liters capacity

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Abstract

A *storage tank* is a container used to store fluids such as fuel, water, and chemical. Skid construction is implemented to make the tank smoothly transported while operated, such as in the mining field. Skids were assembled on the storage tank's base to sit on the ground. This study aims to design and analyze a portable skid storage tank to resist the load of 50,000 liters (392 kN) of fuel and 45 kN of mass of construction itself statically. The skid's main components are a wear plate, pad eye, and seamless pipes of schedule 40 for support, central, and base. All structure's material is 250 MPa yield strength of ASTM 36 low carbon steel. Manual calculations and Ansys simulation analysis were implemented to review the skid structure's maximum stress and safety factor. The examination included pipe support, central pipe, and pad eye. Based on the result, the highest stress of 157.88 MPa by ANSYS and 148.07 MPa by manual calculation. Therefore, the construction is safe and can handle the load of 5000 liters of fuel based on the Tresca and Von Mises criteria.

Keywords:
UL 142, storage tank, portable skid, finite element analysis

1 Introduction

The storage tank is widely used in chemical, refining, petroleum, and other industries [1]. Storage tanks have different shapes depending on the function and where the tank is placed [2]. Storage tanks generally consist of two forms, namely vertical and horizontal. This study utilizes a horizontal storage tank shape to store and supply diesel fuel with a capacity of 50,000 liters.

The storage tank requires a skid-frame holder as a supporting construction in the field [1][2]. In this study, the skid frame supported the storage tank's weight. It also facilitated the mobilization process in empty conditions so that the tank could be transported to different locations on site. Therefore, it is called a portable skid.

Many studies have been conducted on developing storage tanks in general or based on their parts. Amelia et al. (2019) analyzed the skid frame's strength for a pressure vessel of a horizontal tank with a 22,000 kg liquid load [3]. The load was assumed to be static in intensity and working force. This research used S275 JR material. Furthermore, numerical simulations are carried out using software based on the finite element method. Khanna et al. (2017) developed a design and analyzed creep by comparing the criteria of Tresca and Von Vises [4]. The simulation results showed that the Tresca criterion is more accurate than the Von Mises criterion because the Tresca criterion produces a relatively low-stress value but has a higher strain rate than the Von Mises criterion [4]. Harahap (2020) simulated the loading on the shackle using the finite element method with energy distortion criteria [5]. Based on the distortion energy, it was found that the stress that occurs is still far from the criteria for structural failure. Likewise, the deflection is slight, so the shackle is safe to use [5][6]. Satoto et al. (2017) performed a geometric comparison simulation on the pad eye [7]. The simulation was carried out by giving the same direction of force, namely a mass of 1,000 kg with a design load angle of 60° using S355J0 material. Simulations were carried out using the Solidworks software. The simulation results show that the geometry difference affects the eye pad's stress, strain, and displacement [7].

A study of the Rectangular parameters of underground tanks was carried out through stress, displacement, and pressure factors when the tank was empty or full. The simulation used the Staad Pro V81 with the finite element method [8]. Yepes et al. (2020) developed the construction of a skid and chassis of the fuel storage along with the Cummins QSK19 Cummins engine-driven HL260 M centrifugal pump. It guarantees operational autonomy for up to 12 hours continuously and can be transported to different locations using a lifting system. This study used draft recommendations from the American Institute of Steel Construction (AISC). This study used the finite element method and was simulated using Solidworks software to find the safety factor results in the design. The design was successful because the functional and safe system can be used in on-site applications [8].

Based on the background described, this study aims to design and analyze a portable skid storage tank to resist a load of 50,000 liters. The Von Mises theory states that failure will occur when the material's distortion energy per unit volume is equal to or greater than the material's distortion energy per unit volume in the yield condition [5]. Finite element analysis aims to determine the structural strength of the portable skid in the form of a simulation. The simulation in this study used ANSYS R19.2 software.

This storage tank design can be implemented in medium to big-scale companies of oil and gas or mining fields. This tank can store up to 50.000 liters of fuel and equipped with a portable skid. This skid mechanism will improve the transportation performance of this tank in the mining area.

2 Materials and Methods

The research method used in this research is a manual computation and simulation using ANSYS R19.2 software, flowchart as shown in Fig. 1. Tresca and Von Mises criteria are used to evaluate stress. This simulation uses ANSYS R19.2 software to find a picture stress model, which is then controlled or simulated on the model to see the effect.

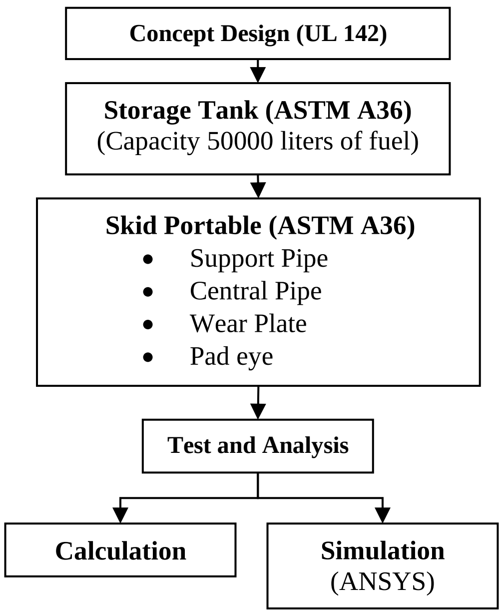

Fig. 1. Flowchart

The research steps are as follows. First, understand the load type that the portable skid will encounter. The load is a horizontal tank containing diesel fuel with a capacity of 50,000 liters. In addition, an empty horizontal tank and skid structure weigh 45 tons. The skid structure can be modeled through a 3D model created in Solidworks software.

Second, select the material and the profile used in the portable skid. This step is essential to obtain an optimum portable skid to withstand the load without structural failure. Profile selection considers the strength and convenience of transportability. At the same time, the selection of the materials considers the material's yield strength, heat resistance, and price. Thirdly, create a 3D model of a portable skid design assisted by Solidwork software, as shown in Fig. 2.

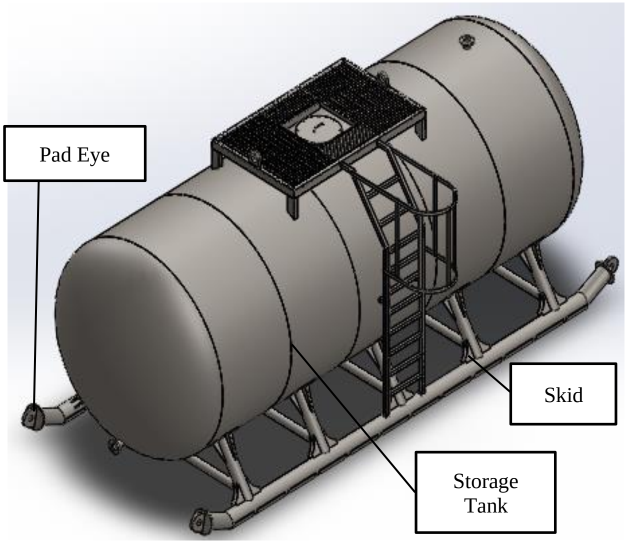

Fig. 2. Model of Tank and Portable Skid

A portable skid design should meet the requirements of light, strength, and ease to transport from one site to another. In addition, the ANSYS R19.2 simulates structure behavior during load work. The Tresca and Von Mises criteria are used to study that the portable skid structure stress must be less than the yield point of the material used. Structurals are manually analyzed to find the maximum stress value and location in the portable skid. Finally, these two computations' results are then compared to estimate the error.

Storage tanks are used in industries related to fluid type. Storage tanks have different shapes according to their function and where the tank is placed. The general shape of the storage tank is horizontal, vertical, and rectangular. The standards used for designing storage tanks also vary, such as ASME and API 650. Another standard of ground diesel tanks is UL 142. UL 142 standard tanks are designed especially for tanks that store flammable liquids such as diesel and are placed above ground level. The UL 142 standard storage tank's design requirements depend on the [9].

The other requirement for a storage tank is easy to move and handle. A portable storage tank is commonly called a portable skid tank. The main features of a skid tank are a portable skid, pad eye, and storage tank. Portable skid tanks usually contain fuel, water, and other chemicals. These materials are stored in a storage tank, as shown in Fig. 1. This storage tank is usually constructed based on specific standard requirements of the tank filler material. Another feature is the skid frame.

A skid frame is a structural combination of various sizes or profile dimensions designed to withstand the load [3]. In this study, the skid frame also makes it easier to move the horizontal storage tank so that the horizontal tank can smoothly move to other locations. According to its function, this support is called a portable skid. There are wear plates, support pipe, central pipe, base pipe, and pad eye components of a portable skid. Horizontal solar tanks require skid frames as their supporting construction; therefore, it is necessary to design.

A skid frame that can support horizontal solar tanks with a capacity of 50,000 liters without undergoing structural failure. Designing a safe design for a portable skid requires understanding the structure's mechanical behavior, such as determining the structure's stress, strain, and switching. The portable skid assembly is shown in Fig. 3 below.

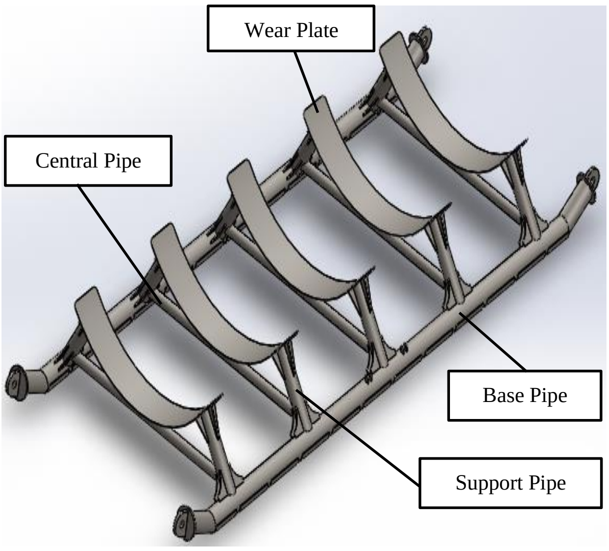

Fig. 3. Model of Portable Skid

A *pad eye* is a semicircular object made of metal and welded on a plate [7]. The pad eyes are assembled on a portable skid tank as a connection tool to a drive mechanism. The pad eye becomes a critical component because it is subjected to the whole structure load of the portable while moving from one place to another on the field. The hook tool is connected to the pad eye and a wire rope sling to pull the portable skid structure. The main priority of pad eye design is to result safely structure and not suffer damage and overstress when withdrawing the storage tank. Therefore, the pad eye can protect the storage tank during the moving. The pad eye design also should not cause errors or accidents during operation. The Pad eye is illustrated in Fig. 4.

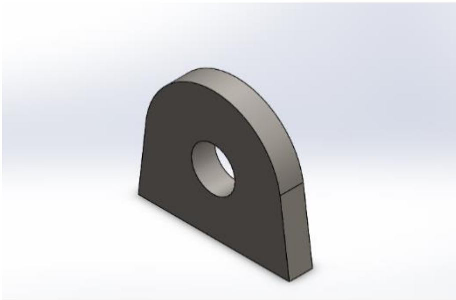

Fig. 4. Pad Eye Example

The storage tank's capacity is 50,000 liters for diesel fuel storage. This work designed the storage tank using the UL 142 standard. This standard is used for designing a stored tank for flammable liquids such as diesel fuel and placed above ground level. The UL 142 standard storage tank design considers the minimum steel thickness, maximum diameter for horizontal tanks, and connection type [10]. According to the UL 142 standard, a tank with a capacity of 50,000 liters uses a thickness of 6 mm using ASTM 36 low-carbon steel.

In this study, the load consists of the overall load of the storage tank, diesel, and fixed ladder. Based on the analysis, the total load of the horizontal tank is 45 tons. Storage tank specification is shown in Table 1.

Table 1. Storage Tank Specifications

Code	UL 142
Volume	50,000 liters
Operating Pressure	3.34 psi
Empty Weight	4.25 tons
Operating Weight	45 tons

The selection of the profile on the structure is essential in a design. The structure must withstand the external load and its weight [8]. In the selection of profiles, the principles of material mechanics are applied to determine the stresses experienced by the structure and to ensure that the structure is strong enough to support the exceeding loads. This research chooses a pipe profile which has strong enough to withstand horizontal tank loads and structure.

Furthermore, the pipe profile can easily facilitate moving in the field above the ground and is easily manufactured.

Based on the UL 142 standard, the prospective material used for the portable skid is ASTM 36. This material is equated to facilitating the welding process in fabrication. ASTM 36 material has adequate quality and a relatively lower price [11][12]. In addition, ASTM 36 has a higher silicon content than other carbon steels, such as ASTM 106 and ASTM 53, so ASTM 36 material has good heat resistance. Moreover, ASTM 36 material has a higher yield strength value of 250 MPa, while ASTM 106 and A53 material has a yield strength of 240 MPa. Therefore, ASTM 36 material has better elasticity properties when subjected to load [13][14]. Table 2 presents the characteristics of the ASTM 36 material used in the study.

Table 2. ASTM A36 Material Properties

Property	Value
Elastic Modulus	2 x 105 MPa
Shear Modulus	75 GPa
Mass Density	7800 kg/m^3
Tensile Strength	400 – 550 MPa
Yield Strength	250 MPa

The pipe used in this research is a seamless pipe with schedule 40. The seamless pipe was selected because it is more robust than welded pipe. Because of the seamless, this pipe is also more resistant to high temperatures. The SCH 40 type was selected because it has sturdy properties and good elasticity.

The load type worked in the portable skid is a distribution load, which means each pipe has an evenly distributed load. The distribution load comes from a horizontal tank structure containing diesel fuel with a capacity of 50,000 liters. The load can be simulated with 3D software. The distributed load is 45 tons—calculations for the pipe that supports the tank using statically indeterminate with the cross method. The first step in the calculation is to determine the primary moment in the structure, then determine the stiffness factor of the structure and then calculate the distribution factor. The next step is to calculate the overall moment using the cross method. After getting the value of the moment, a calculation is carried out to find the reaction of the forces. Calculations are written in Eq. 1-4. From these calculations, the reaction in the pipe that supports the tank is 180,934.34 N.

$$M = \frac{F \times L}{12} \quad (1)$$

$$K = \frac{4 \times E \times I}{L} \quad (2)$$

$$DF = \frac{4 \times E \times I}{K \times L} \quad (3)$$

$$\Sigma MA = 0, \ \Sigma M = 0 \quad (4)$$

Where F is force (N), L is the distance (mm), K is stiffness factor, DF is distribution factor, E is elasticity (GPa), I is the moment of inertia (mm^3)

The buckling force in the pipe is also calculated to determine the safety of the support pipe. The buckling force must be greater than the reaction force acting on the pipe. The stress that occurs must not exceed the yield strength of the ASTM 36 material because it will cause fracture or cracking. Pad eyes are installed in the portable skid, which attaches the sling to the portable skid.

Pad eyes on the portable skid consist of two, each on the right and left. In pad eye design, it is necessary to know the total tensile load, namely the horizontal tank but in an empty state or not filled with diesel and other components.

The portable skid design was carried out with the size shown in Fig. 5 and Fig. 6. The total length is 7,743 mm, and the width is 3,068 mm.

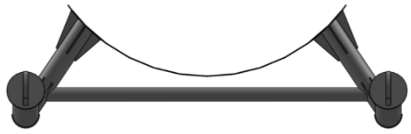

Fig. 5. Front View of Proposed Portable Skid

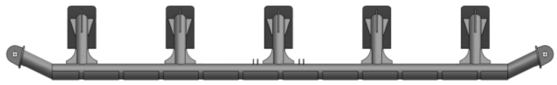

Fig. 6. Side View of Proposed Portable Skid

A profile with predetermined dimensions is the first step to manufacturing a portable skid. In this process, the dimensions must be within the specified tolerances. If the dimension is not in the range, corrective actions will be implemented so that the dimensions are within the range tolerances. The next step is to assemble one component with another component. Assembling components is an essential process in this work. Therefore, reliable and safe portable storage tanks are produced.

The joining method in this assembly uses a welding process. Therefore, the component should have the same or similar material to facilitate a good joining result. The weld thickness, length, and stresses on the weld affect the strength of the weld itself. A strong weld is defined when the maximum stress in the weld does not exceed the shear stress in the filler weld used. Therefore, it is necessary to consider whether parameters must be met in welding because the welded joint will affect the overall fabrication.

3 Results and Discussion

The portable skid is simulated and calculated based on the Von Mises criteria. The simulated and calculated are implemented based on the result of the design. The proposed portable skid is in a 3D model, as shown in Fig. 5 and Fig. 6. The next step is to calculate numerically and perform a simulation using the ANSYS R19.2 software and compare.

The material used in this work is ASTM 36 material. The load is placed based on the actual condition in the field. The total load applied to the portable skid is 45 tons, so each pipe is assumed to receive the same load from the storage tank with the value in Eq. 1.

Each pipe receives a load of 36,186.88 N with the direction of the compression force towards the earth. The result of the simulation using the Von Mises criteria is shown in Fig. 7. This simulation will be compared with the results of manual calculations.

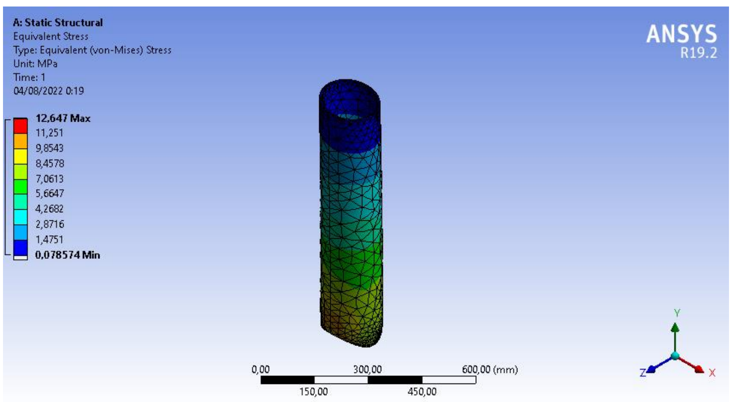

Fig. 7. Result of Von Mises for Support Pipe

Fig. 7 shows the maximum distortion energy stress of the support pipe with calculation is 10,6 MPa, and Von Mises with simulation is 12,6 MPa. The error between calculation and simulation is 19.4 %. This maximum value is smaller than the yield strength of ASTM 36, which is 250 MPa. The maximum distortion energy value should not exceed the yield strength of the material itself because it can cause structural failure in the portable skid. Another result shown in Fig. 8 is the maximum distortion on the central pipe.

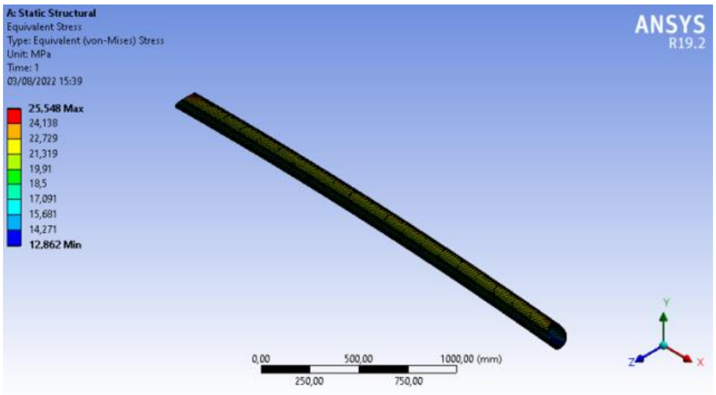

Fig. 8. Result of Von Mises for Central Pipe

Fig. 8 shows that the maximum distortion energy stress of the central pipe with calculation is 26.7 MPa, and Von Mises with simulation is 25.5 MPa. The error between calculation and simulation is 4.4 %. This maximum value is smaller than the yield strength of ASTM 36, which is 250 MPa. The maximum distortion energy value should not exceed the yield strength of the material itself because it can cause structural failure in the portable skid.

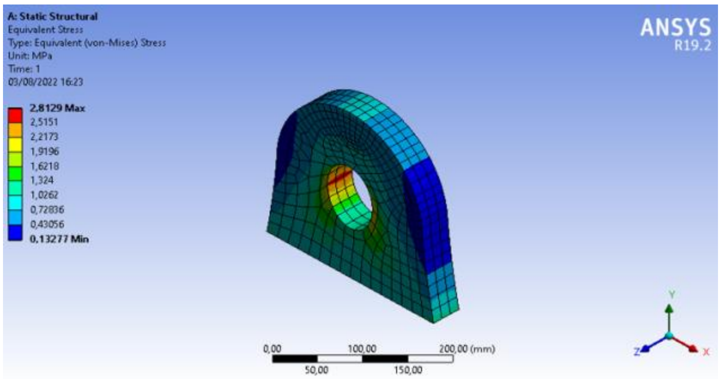

Fig. 9. Result of Von Mises for Pad Eye

Fig. 9 shows that the maximum distortion energy stress of the pad eye with calculation is 2.83 MPa, and Von Mises with simulation is 2.8 MPa. The error between calculation and simulation is 1 %. This maximum value is smaller than the yield strength of ASTM 36, which is 250 MPa. The maximum distortion energy value should not exceed the yield strength of the material itself because it can cause structural failure in the portable skid.

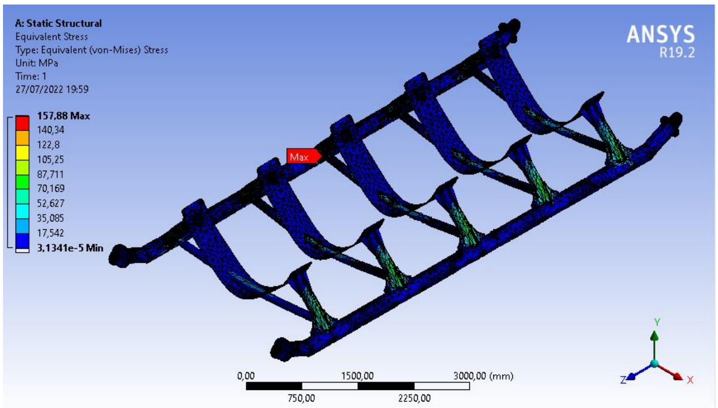

Fig. 10. Result of Von Mises for Assembly Skid

Fig. 10 shows that the maximum distortion energy stress of the assembly skid with calculation is 148,07 MPa MPa, and Von Mises with simulation is 157,88 MPa. The error between calculation and simulation is 6,2 %. This maximum value is smaller than the yield strength of ASTM 36, which is 250 MPa. The maximum distortion energy value should not exceed the yield strength of the material itself because it can cause structural failure in the portable skid. These two kinds of results will be combined, and the error value will be calculated in Table 3 below.

Table 3. Comparison between Computation and Simulation

Comp.	Manual Calculation	Sim.	%Err.
Pipe Support	10.16 MPa	12.6 MPa	19.4
Central Pipe	26.7 MPa	25.5 MPa	4,4
Pad Eye	2.83 MPa	2.8 MPa	1
Assembly Skid	148.07 MPa	157.8 MPa	6.2

4 Conclusions

A portable skid tank is designed to withstand a load of 45 tons, so it must have good structural strength. The portable skid has a length of 7,743 mm and a width of 3,068 mm. The profile selected in this study is a seamless pipe with a schedule 40 type with minimal function and price parameters but can withstand horizontal tank loads. The material selected in this study is ASTM 36 with parameters of heat resistance, yield strength, and ease of assembly process. The simulation shows that the value of the Von Mises criteria is 157.88 MPa, which means the structure can still be used without failure because the value is below the yield strength of ASTM 36 material, which is 250 MPa. This fuel storage tank with a portable skid can be an alternative design to be placed and moved in the field area. Attached with a portable skid, it is practical and easy to move in mining and oil and gas onshore muddy environments.

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