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Design Analysis of a Manhole Mining Ambulance with a Hilux 4×4 WD Single-Cabin Chassis Unsing Finite Element Analysis (FEA)

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Abstract

This study aims to determine the strength and durability of ambulance manhole structures intended for emergency situations in mining areas. The research includes a literature review, direct calculation of manhole dimensions, design development, material selection, and loading simulation using SolidWorks 2021 software. The evaluated parameters are von Mises stress, deformation, and safety factor. Three variations of manhole designs and three types of materials—ASTM A500, Galvanized Steel, and JIS G34445 STKM 13B—are considered. Simulation results are presented in tabular form. The optimal design and material identified is Design 2, which exhibits von Mises stress of 3.759 MPa, deformation of 1.749 mm, and a safety factor of 8.1.

Keywords: *Ambulance, Design, Mining, Solidworks, Structure*

Abstrak

Penelitian ini bertujuan untuk mengetahui nilai kekuatan dan ketahanan struktur manhole ambulan yang akan digunakan pada area pertambangan. Manhole ini digunakan pada ambuan untuk keadaan gawat darurat. Penelitian ini terdri dari studi literatur, menghitung dimensi manhole secara langsung, pembuatan desain, pemilihan material, dan simulasi pembebanan pada desain yang ada. Simulasi menggunakan software SolidWorks 2021. Nilai yang akan di ambil adalah *von misses stress, deformation*, dan *safety factor*. Terdiri dari 3 variasi desain *manhole* dan 3 jenis material yaitu ASTM A500, Galvanized Steel, dan JIS G34445 STKM 13B. Hasil simuasi akan di tampilkan pada tabel. Desain dan material terbaik adalah desain manhole 2. Memiliki nilai von misses stress 3,759 Mpa, *deformation* nilai 1,749 mm, dan *safety factor* 8,1.

Keywords: *Ambulan, Desain, Tambang, Solidworks, Struktur*

1. Introduction

Transportation is a crucial aspect of life in Indonesia, facilitating daily activities. The growing demand for transportation parallels the increasingly complex infrastructure need, particularly in major cities serving as economic centers, education, trade, and healthcare [1]. The types and functions of transportation vary to meet human needs, encompassing both large and small vehicles [2]. Large transportation includes vehicles like buses and trucks that can carry substantial loads, while small transport consists of cars and minivans with limited capacity [3]. An example of small transport is healthcare vehicles such as ambulances, which are vital for providing medical services in remote areas [4].

One suitable vehicle for modification into a robust ambulance is the Toyota Hilux 4×4 WD Single Cabin. This pickup truck features a durable, modern design with a high, luxurious profile. It has a 2,393cc diesel engine, four-wheel drive, and EURO 4 performance, making it efficient and environmentally friendly [5]. The Hilux chassis, made from strong metal and composite materials, ensures the vehicle's structural integrity, which is crucial for supporting loads and maintaining rigidity [6].

Manhole-type heavy-duty vehicles are essential in mining areas due to the challenging terrain. These robust, box-shaped vehicles can navigate extreme conditions like rough, steep, and gravelly roads, making them suitable for mining operations [7]. Mining roads differ significantly from typical city roads, with unstable surfaces and steep inclines affecting vehicle operations and production speed [8]. Previous research has analyzed various vehicle chassis models using Finite Element Analysis (FEA) to assess stress, load-bearing capacity, and deformation under different conditions [9].

This study aims to innovate the ambulance design with a separate box frame from the Hilux cabin, creating a spacious interior to accommodate medical equipment. The research will focus on the strength and durability of the manhole structure in enduring the uneven terrain of mining roads [10]. Using Finite Element Analysis (FEA), a numerical method for solving engineering and mathematical problems related to physical phenomena, this study will analyze the structural integrity of the vehicle frame under various stress conditions [11].

2. Method

This research employs a Design-Based Research (DBR) approach. The study begins with analyzing past issues followed by a literature review. The software used for this research is

SolidWorks 2021. The manhole design involves creating three different designs using a single material [12]. Several factors are considered in selecting the best design, including strength, elasticity, stiffness, and ductility. The designs are then analyzed to observe the behavior under load and evaluated based on von Mises stress, deformation, and safety factors. Figure 1 illustrates the research process sequence [13].

Before simulation, the dimensions of the manhole are calculated directly by the analysis and literature review. The design is created using SolidWorks 2021. Three design variations are developed once the measurements are completed [11]. The material used is JIS G34445 STKM 13B. The next step is determining the points where the manhole will be subjected to loads. These points are located on the floor of the manhole. Each design variation is subjected to the same load and load points. The simulation then reveals the effects on the manhole when subjected to these loads [14]. Flowchart research is presented in **Figure 1.**

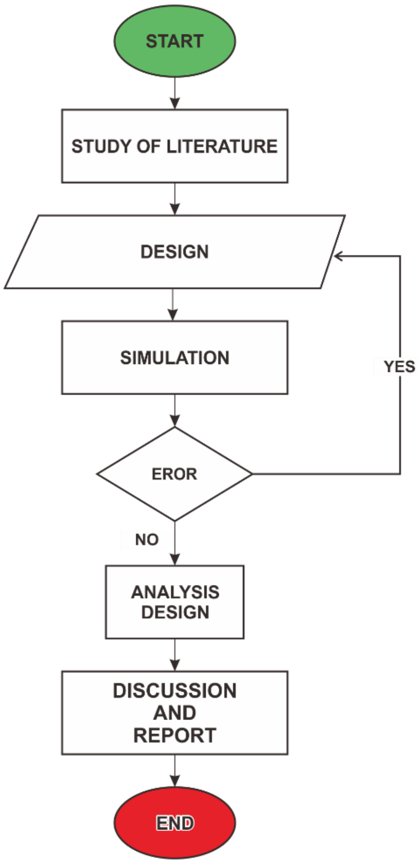

Figure 1. Flowchart Research

The flowchart illustrates the sequence of activities in this research. Initially, a literature review was conducted to gather insights from previous studies, and data on the dimensions or sizes of the manhole were collected. Following acquiring these dimensions, the design process commenced, involving the creation of three variations of manhole designs. Subsequently, simulations were performed, incorporating material properties according to JIS G34445 STKM 13B. In case of simulation errors, design adjustments were made accordingly. If no errors occurred during the simulation process, results were obtained and presented in a table containing values of von Mises stress, deformation, and safety factors for the three designs. Upon obtaining these results, a discussion of the research findings was conducted and documented in the report.

3. Result and Discussion

In this study, von Mises stress analysis, deformation, and safety factor evaluations were conducted using SolidWorks 2021 for simulation testing, which helps save time and materials in designing a manhole tool or product. The Finite Element Analysis (FEA) method was used to calculate the strength and behavior of the manhole structure **[15]**. Through FEA, values for von Mises stress, deformation, and safety factors can be determined. Below are the design variations of the manhole analyzed in this study is presented in **Figure 2.**

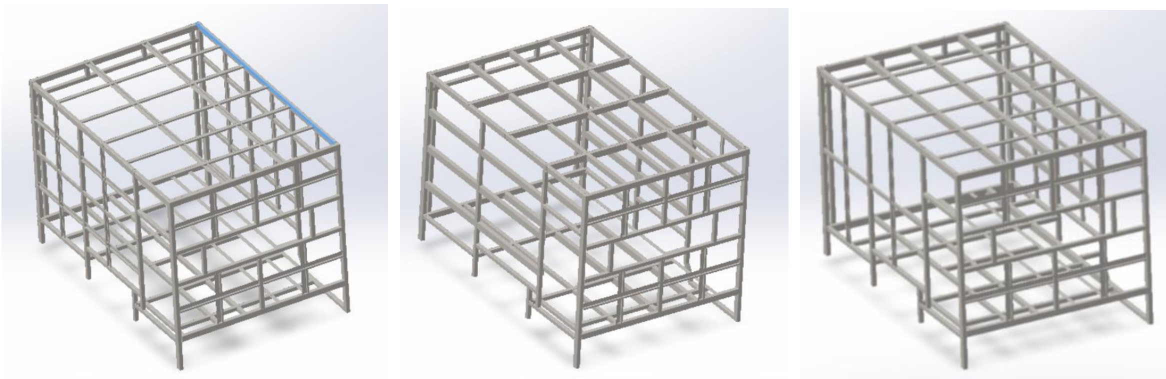

Figure 2. Design Manhole

The design shape is tailored to the tool's functional requirements and the chassis' dimensions. The material used for the manhole column is JIS G34445 STKM 13B. **Table 1** presents the mechanical properties of the JIS G34445 STKM 13B material **[16]**.

Table 1. Mechanical Properties

Property	*Point*
Mass density (Mpa)	7850
Yield strength (Mpa)	305
Elastic modulus (Mpa)	2e+11
Poisson's ratio (Mpa)	0,28
Tensile strength (Mpa)	440

3.1 Presenting research results

The table below presents the simulation results for the ambulance manhole using SolidWorks 2021. The simulation indicates that Design 2 performs the best in withstanding a load of 2000 kg, as the safety factor for this load remains within the safe category. **Figures 3**, **Figure 4**, and **Figure 5** present simulation results.

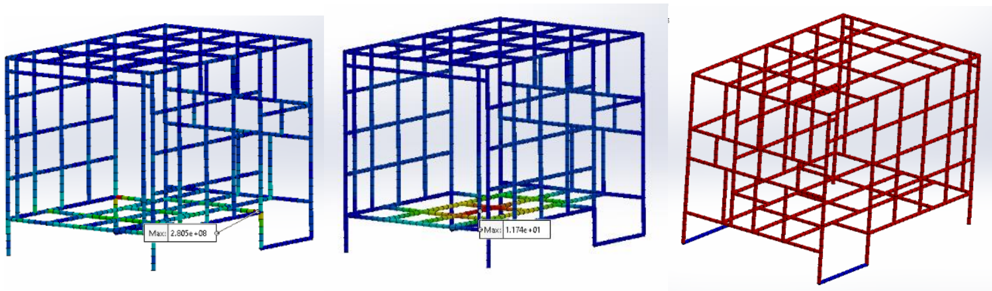

Figure 3. Simulation Results 1

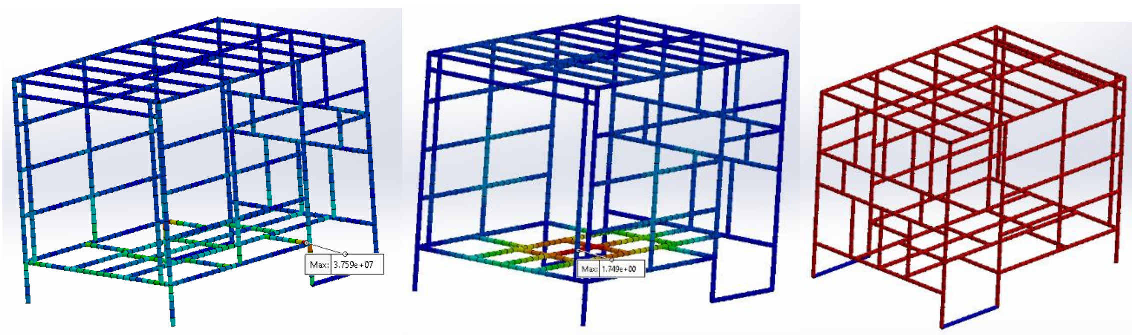

Figure 4. Simulation Results 2

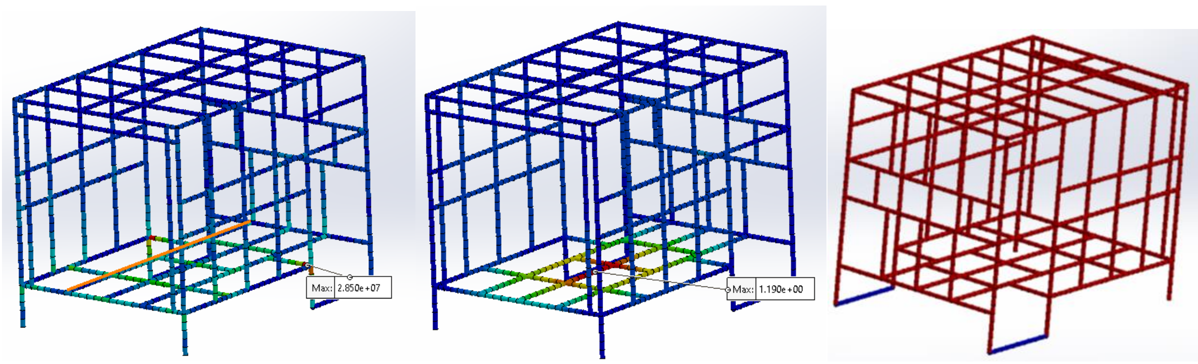

Figure 5. Simulation Results 3

The images above depict the simulation results for the three design variations, showing the values for von Mises stress, deformation, and safety factors. The color gradient on the columns or beams of the chassis illustrates these results. The simulations were conducted, yielding the following values are presented di **Table 2.**

Table 2. Simulation Result

Category	Design 1	Design 2	Design 3
Von Mises Stress (Mpa)	2,805	3,759	2,850
Deformation (mm)	1,174	1,749	1,190
Safety Factor	1,1	8,1	1

The table presents the results of the simulation for various manhole designs. As shown, the simulation results for Design 1 indicate a von Mises stress of 2.805 MPa, a deformation of 1.174 mm, and a safety factor of 1.1. The simulation for Design 2 resulted in a von Mises stress of 3.759 MPa, a deformation of 1.749 mm, and a safety factor of 8.1. In contrast, the simulation for Design 3 yielded a von Mises stress of 2.850 MPa, a deformation of 1.190 mm, and a safety factor of 1.

3.2 Discussion

The manhole simulation was performed using the Fixed Support function to ensure that the design remains stationary during the simulation. The load-bearing points are located on the surface of the ambulance manhole floor. Each manhole design was subjected to a load of 2000 N during the simulation.

a. Simulation *manhole* design 1

The simulation of manhole design 1 was conducted with fixed support applied to each side of the manhole. The load-bearing points were directed at the surface of the manhole floor. The simulation was performed using SolidWorks 2021. The results yielded a von Mises stress of 2.805 MPa, a deformation of 1.174 mm, and a safety factor of 1.1.

b. Simulation manhole design 2

The simulation of manhole design 2 was conducted with fixed support applied to each side of the manhole. The load-bearing points were directed at the surface of the manhole floor. The simulation was performed using SolidWorks 2021. The results yielded a von Mises stress of 3.759 MPa, a deformation of 1.749 mm, and a safety factor of 8.1.

c. Simulation manhole design 3

The simulation of manhole design 3 was conducted with fixed support applied to each side of the manhole. The load-bearing points were directed at the surface of the manhole floor. The simulation was performed using SolidWorks 2021. The results yielded a von Mises stress of 2.850 MPa, a deformation of 1.190 mm, and a safety factor of 1.

The research conducted has identified the optimal design based on the simulation results obtained for each design. The highest maximum von Mises determines the best design stress and the highest safety factor for each design and its material. The selected design is the manhole part 2, which uses material JIS STKM 13B. This selection is based on the simulation results showing a von Mises stress of 3.050 MPa and a safety factor of 8.1. Essentially, the designs for manhole parts 1 and 3 can still be considered as alternative references. These designs are still viable but have lower safety factors compared to manhole part 2. Therefore, the best design is provided by manhole part 2 with material JIS STKM 13B.

4. Conclusion

The simulation utilized designs and materials with a load of 2000 N using JIS G34445 STKM 13B. Design variation 1 showed a von Mises stress value of 2.805 MPa, deformation of 1.174 mm, and a safety factor of 1.1. Design variation 2 exhibited von Mises stress of 3.759 MPa, deformation of 1.749 mm, and a safety factor of 8.1. Design variation 3 had von Mises stress of 2.850 MPa, deformation of 1.190 mm, and a safety factor of 1. These simulation results indicate that design variation 2 performs the best due to its safety factor of 8.1, making it the optimal design compared to the other variations.

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