Jurnal Keselamatan Transportasi Jalan (Indonesian Journal of Road Safety)
Vol. 11 No. 1,Halaman: 71 – 82, Juni, 2024
Politeknik Keselamatan Transportasi Jalan

ISSN 2338-4247 (Cetak)
ISSN 2721-7248 (Online)

Numerical Analysis Of Static Structure On The Floor Frame Of The Medium Bus

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Received 13-Juni-2024; Reviewed 17-Juni-2024; Accepted 27-Juni-2024
Journal Homepage: http://ktj.pktj.ac.id/index.php/ktj
DOI: 10.46447/ktj.v11i1.586

Abstract

In the manufacturing process, the bus frame is one of the essential parts of the vehicle that supports the overall weight of the vehicle, starting from the interior and passengers inside. In this research, we will carry out a structural strength analysis of the frame using the finite element method, which focuses on the floor frame of a medium bus which receives static loading from the bus interior, including seats with the maximum passenger capacity of a medium bus. The numerical analysis uses Solidworks 2021 for the 3D design of floor frames and structural analysis of the strength of medium bus floor frames using static structural toolbar on Ansys Workbench 2018 software by varying ASTM A514, AISI 1020, and Aluminum 2014-T4 materials. The results obtained are numerical analysis using a mesh size of 27 mm. The maximum deformation, maximum equivalent stress Von Mises, and safety factor are the same location for various ASTM A514, AISI 1020, and Aluminum 2014-T4 materials. The lowest deformation of 1.5735 mm occurred when using AISI 1020 material, and the highest deformation was 1.7209 mm when using Aluminum 2024-T4 material. The maximum equivalent stress Von Mises from the front view to section A-A is 101.23 MPa on AISI 1020 material. The safety level of the design with the material is 4.8999. AISI 1020 is the most optimal material for medium bus floor frames with the highest level of safety and lowest deformation.

Keywords: maximum deformation, equivalent stress, safety factor, finite element method

INTRODUCTION

One factor influencing low safety on buses is the driver; another factor affecting the number of bus accident victims is the strength of the bus frame structure (Nugroho, 2020). The frame structure of a bus is an essential element that must be considered an absolute requirement in making a bus (Nugroho, 2020). The bus frame is the part that receives the most stress in the form of vibrations from the road, and its primary function is as a load-bearing structure (Rebaïne *et al.*, 2018).

The main frame of a vehicle is designed to withstand various loads that occur when the vehicle is moving. It is crucial to ensure that the age or service life of the vehicle becomes longer. Stress analysis is an essential aspect of engineering design because it helps determine whether a designed component can withstand the stresses and strains encountered in its operating environment. Therefore, it is necessary to analyze the structure to obtain a safe frame. The analytical method that has been developed recently uses the finite element method. This method allows engineers to predict and optimize design performance, improve product quality, reduce development time, and minimize costs associated with physical testing (Mohammed et al., 2023; Rebaïne et al., 2018)

With the importance of frame strength and the advantages of using the finite element method, many researchers have analyzed the strength of bus frames using the finite element method (Guruprasad et al., 2015; Gustomo & Anis, 2020; Kesawasidhi et al., 2022; Patrioda et al., 2023; Pravilonis et al., 2020; Widyanto et al., 2019; Yang et al., 2018). (Gustomo & Anis, 2020) analyzed the strength of the electric bus body frame using the finite element method. His research focused on the strength of the front bus body frame structure up to the passenger doors made of 6063 T6 aluminium to find the Von Mises stress, displacement and safety factor values. From the results of the analysis, the bus frame is considered very safe because it has a relatively high safety factor, namely 12.9. During the roll test, (Kesawasidhi *et al.*, 2022) examined the maximum tensile stress in the welding bus construction. The roll test is carried out to ensure that the passenger's safe space is met and that the passenger's safe space remains intact during an accident or collision. The tests on the bus frame were located at three stress points: the floor frame, wall frame and bus roof frame.

(Patrioda *et al.*, 2023) analyzed the electric bus chassis. The numerical simulation results show that the maximum total deformation of 5.3957 mm is located on the rear side of the bus, where the battery compartment segment is located. Maximum stress of 140 MPa was observed at the driveline and main frame joints, with the lowest safety factor of 1.5481. Based on the numerical simulation results, the chassis design is considered safe. Widyanto et al. 2018 analyzed bus chassis with Gray Cast Iron, AISI 4130 Alloy Steel, and AISI A514 Grade B Alloy Steel materials. Each material was tested with a thickness of 2 mm, 4 mm and 6 mm. The results showed that AISI 4130 alloy steel with a thickness of 6 mm was the optimal model because the stress and displacement were the lowest among all materials and thicknesses.

(Guruprasad *et al.*, 2015) studied the structural strength of the entire bus body on the outside and the floor plate. The results show that this project is related to the generalized finite element method modelling and analysis of important parts of the bus body for standing gravity loads, acceleration, breaking loads and collision cases. (Yang *et al.*, 2018) designed lightweight materials made from structural steel and aluminium alloy to obtain battery efficiency in electric buses. The results obtained were that by changing the bus frame structure, the weight of the bus was reduced while improving the mechanical properties according to the driving conditions applied. (Pravilonis *et al.*, 2020) reported the reliability of bus structures by varying the steel profiles used.

No research has been carried out that analyzes the structure of the floor frame, which is attached directly to the chassis. This frame structure is used as a place for the floor plate. The floor frame structure is fundamental because it is in direct contact with the load above it, which includes chairs, drivers, attendants and passengers.

Therefore, the analysis carried out in the current research is the strength and safety of the floor frame structure of a medium bus, so that deformation values, equivalent von misses, and safety values are obtained using the finite element method.

EXPERIMENTAL METHOD

The simulation was carried out in the Computer Laboratory, Department of Mechanical Engineering, Politeknik Negeri Banyuwangi, with the leading equipment being a personal computer with Intel Core i7-8700 Processor specifications, 8.192 GB RAM and 1.981 GB NVIDIA Quadro K420 VGA, operating on a Windows 10 system operation. A static structural toolbar on Ansys Workbench 2018 was chosen to analyze the floor frame structure. Engineering data was used to select the materials used in the floor frame, namely ASTM A514, AISI 1020, and Aluminum 2014-T4, with yield stress and tensile stress values as shown in Table 1. Geometry as an input process for 3D frame structure design drawn using commercial SolidWorks software. A detailed image of the medium bus floor frame is shown in Figure 1, with a total length of 7525 mm and a total width of 1980 mm. The model creates meshing and sets the parameters needed for the analysis. Meshing is carried out starting from sizes 27 to 36 mm. Examples of 27 mm meshing results are shown in Figures 2(A) and (B). Setup is the process of inputting data for support and loading. The support points on the floor frame are shown in Figure 3, with 12 clamp supports attached to the chassis as in the red circle. The loading point is shown in Figure 4, with a red arrow indicating the loading position and direction. This loading comes from the driver's and driver's seats and the mass of passengers with details as in Table 2 with a total mass of 3003 kg. Standard Earth Gravity includes the influence of gravitational force, and the desired solution includes Total Deformation, Equivalent Von Mises Stress and Safety Factor. The final step is the result for the analysis calculation results from the output specified in the Setup menu.

Table 1. Material specification

No	Material	Yield Stress (MPa)	Tensile strength (MPa)
1	ASTM A514	690	895
2	AISI 1020	496	889
3	Alumunium 2014-T4	324	469

The standard safety factor value follows the standard from (Mott, 2009) with the provisions: N = 1.25 – 2.0 for designing structures that receive static loads with a high level of confidence for all design data, N = 2.0 – 2.5 for designing machine elements that receive dynamic loads with an average level of confidence for all design data. N = 2.5 – 4.0 for designing static structures or machine elements that receive dynamic loading with uncertainty regarding loads, material properties, stress analysis, or the environment. N = 4.0 or more for the design of static structures or machine elements subject to dynamic loading with uncertainties regarding loads, material properties, stress analysis, or the environment.

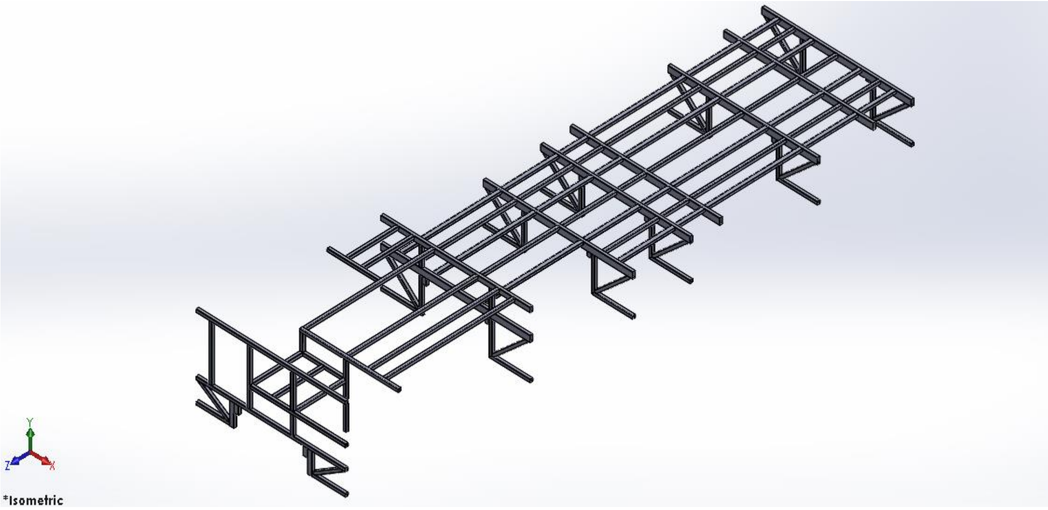
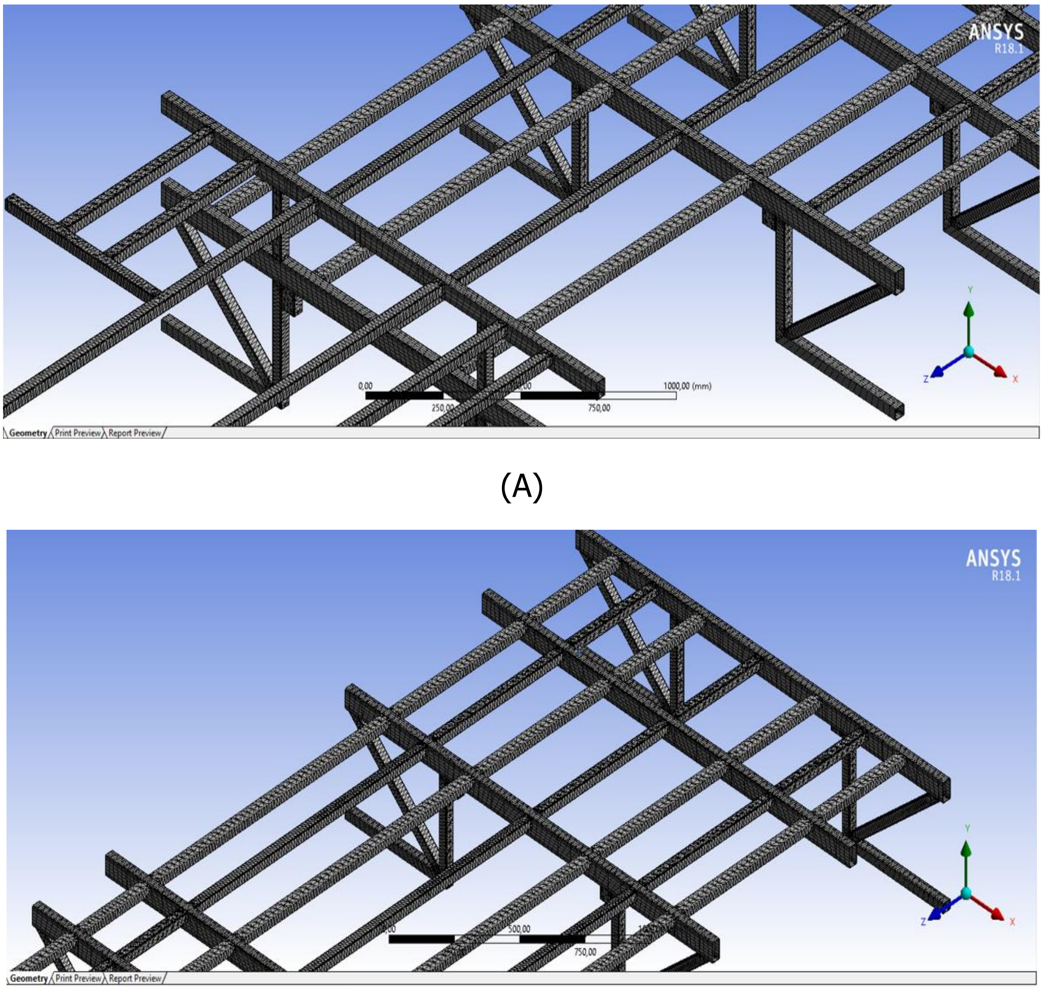


Figure 1. The 3-D design of a medium bus floor frame

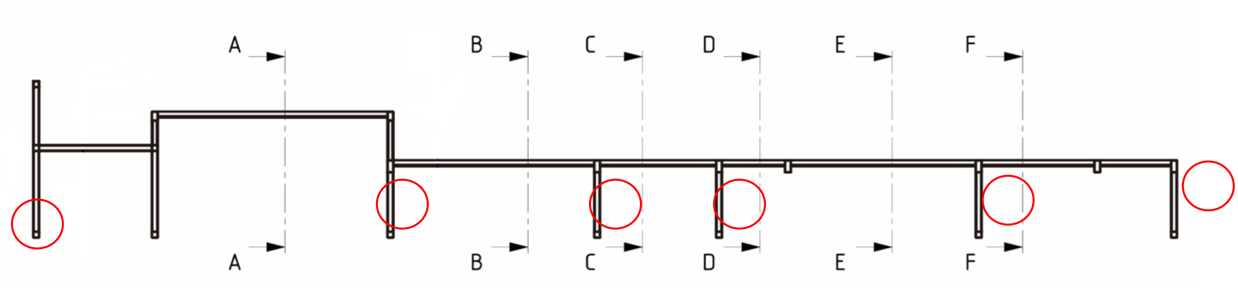


(A)

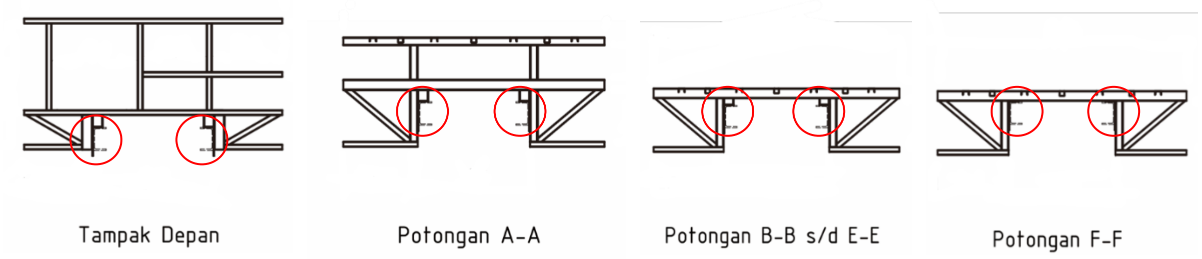
Figure 2. Meshing results: (A) from the front view to the A-A sections, (B) from the A-A to F-F sections.

Tabel 2. Loading

No	**Loading**	**Amount**	**Mass (kg)**	**Total (kg)**
1	Front frame, front view to A-A section	Two chair Two person	2 × 20 2 × 71	40 142
2	Rear frame, A-A to F-F sections	31 chair 31 person	31 × 20 31 × 71	620 2201
				3003



(A)



(B)

Figure 3. (A) Side view of the support position, (B) Detail support position on each section view

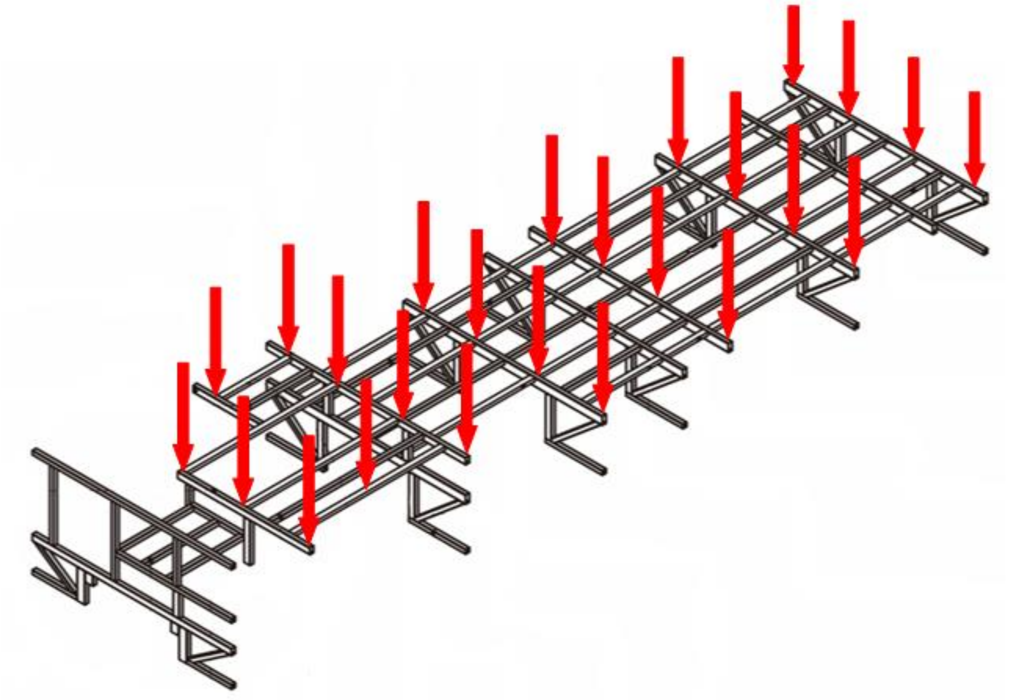
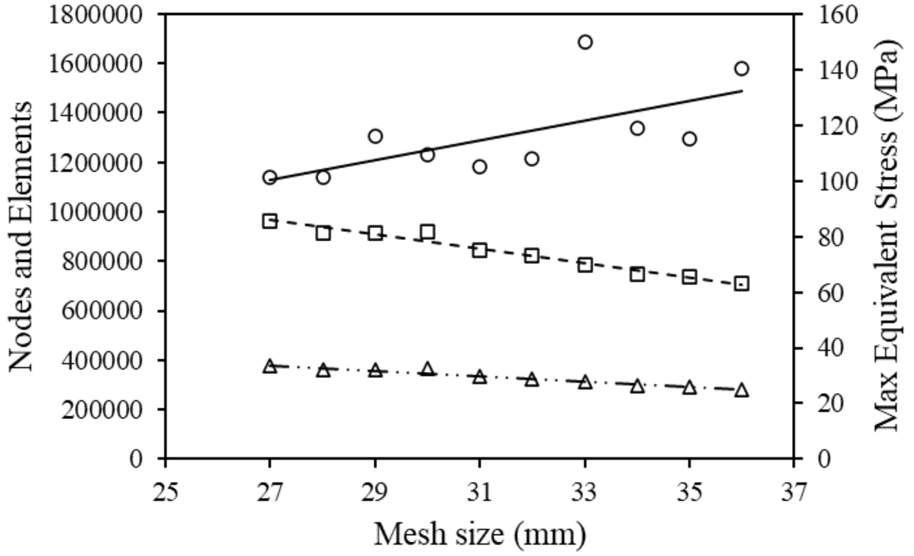


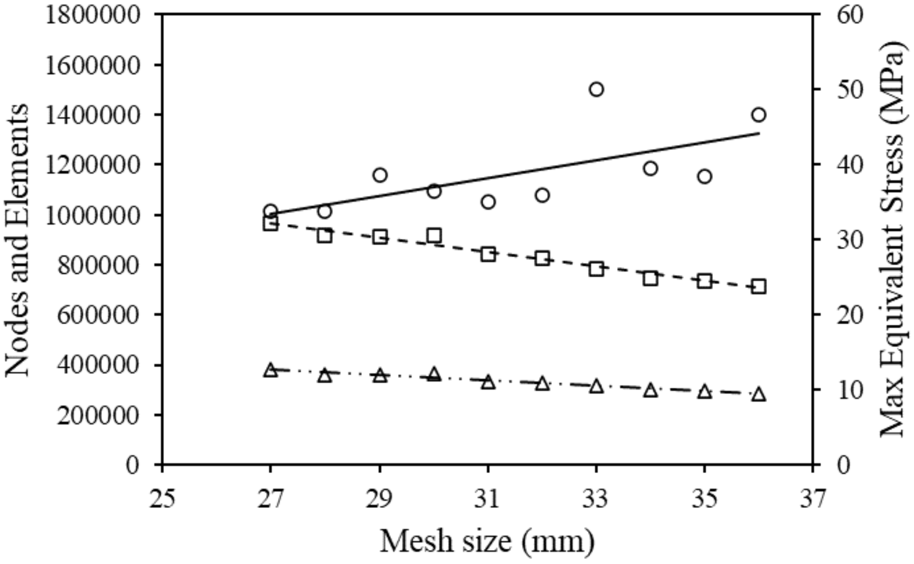
Figure 4. The distributed load on the floor frame of a medium bus

RESULTS AND DISCUSSION

Before further simulations, selecting the size by varying ten mesh sizes ranging from 27 to 36 mm is necessary. The nodes, elements, and max equivalent stress values are divided into two parts: at the front, starting from the front to the A-A piece and from the A-A section to the section F-F. There are chairs, a clerk and a bus driver at the front to A-A sections. In the A-A to F-F sections, there are bus seats and passengers. Figure 5 shows the results of changes in mesh size with a trend that as the mesh size increases, the number of nodes and elements decreases, but the max equivalent stress value tends to increase. Nodes are connecting points between elements. Max equivalent stress is a combination of nine stress values into one stress. The nine stress components include $\sigma_{XX}, \sigma_{XY}, \sigma_{XZ}, \sigma_{YX}, \sigma_{YY}, \sigma_{YZ}, \sigma_{ZX}, \sigma_{ZY}, \sigma_{ZZ}$. From the simulation results, the smallest mesh size is only 27 mm, max equivalent stress does not appear when using a mesh smaller than 27 mm. Therefore, this study used a mesh size of 27 mm.



(A)



(B)

Figure 5. (A) Maximum equivalent stress on the front view to sections A-A for various mesh sizes, (B) Maximum equivalent stress on sections A-A to section F-F for various mesh sizes

1. Total Deformation

Deformation is a change in the shape or size of an object. The results of the simulation of the medium bus floor frame after receiving the load show that the maximum total deformation from the front view to the A-A section is 1.5735 mm and 0.52449 mm for the A-A section to the F-F section. Weight comes from the number of seats, driver, internet attendant and maximum number of passengers. The total load is 3003 Kg or 29449 Newtons with the loading direction perpendicular to the Y-axis.

Maximum deformation occurs in the front view section up to section A-A because nothing in the ladder frame supports or is not attached directly to the medium bus chassis. Hence, the distance between the load and the support is more remarkable, which causes more significant deformation. The distance between the front view frame and sections A-A is 2340 mm, with a maximum total deformation of 1.5735 mm at the end of the frame.

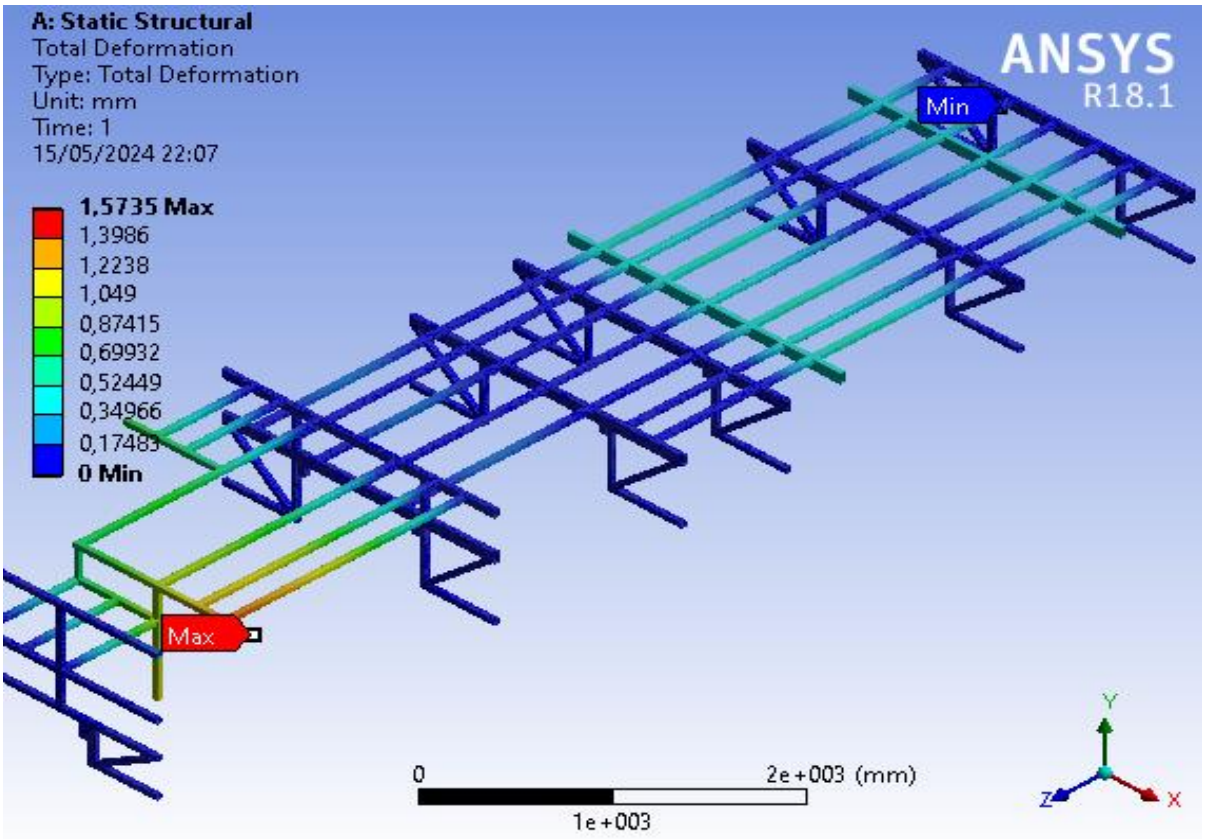


Figure 6. Total deformation for AISI 1020 material

2. Equivalent Stress

Von Mises stress is the equivalent stress value which is used to determine whether a particular material will not yield as long as the maximum Von Mises stress value does not exceed the yield strength of the material. The maximum Von Mises stress that occurs is 101.23 MPa. Compared with the material's yield strength of 496 MPa, the frame design using AISI 1020 material does not exceed the material's yield strength, so the material exposed to the load does not experience plastic deformation. Because equivalent stress is a combination of various stress components in the 3D direction, and the position where the maximum equivalent stress occurs supports the load from the driver's seat and the stairs, this causes the equivalent stress to increase.

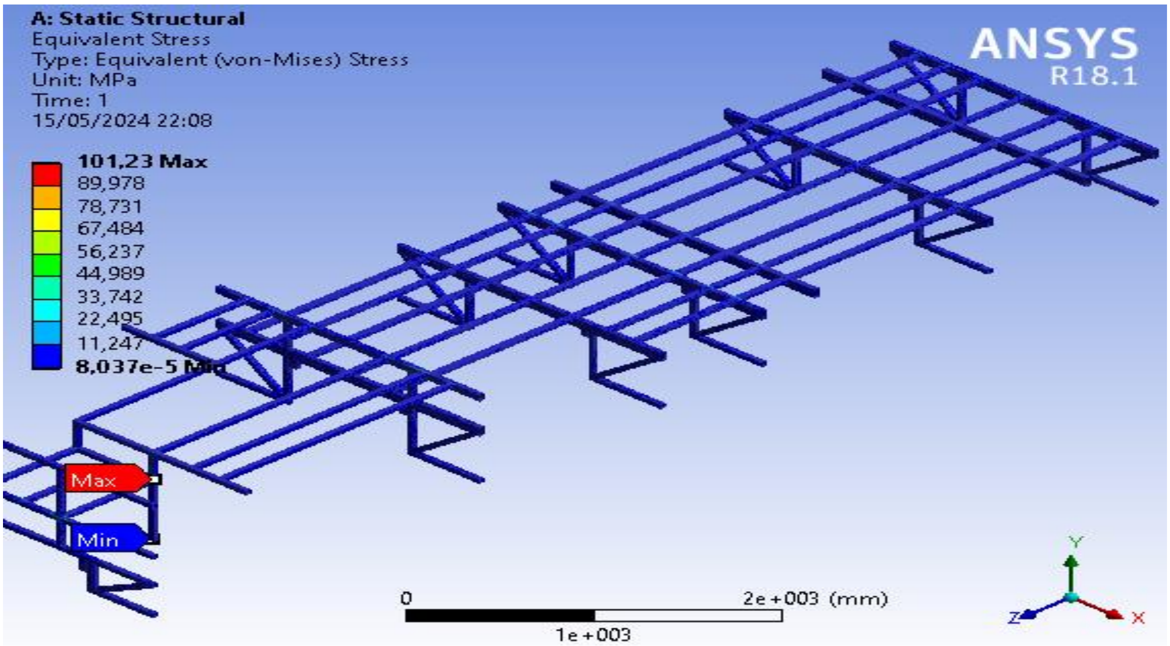


Figure 7. Equivalent Von Mises stress for AISI 1020 material

3. Safety Factor

The safety factor is a factor that shows the level of ability of a technical material to accept external loads, namely compressive and tensile loads. This factor is identical to the ratio between allowable and maximum stress. The simulation results show a minimum safety figure of 4.8999 from the front to the A-A section. This safety figure is still within the safe range for designing static structures or machine elements that receive dynamic loading with uncertainty regarding load, material properties, stress analysis, or the environment (Mott, 2009). Uncertainty regarding loads arises from varying passenger weights along with the movement of passengers on the bus.

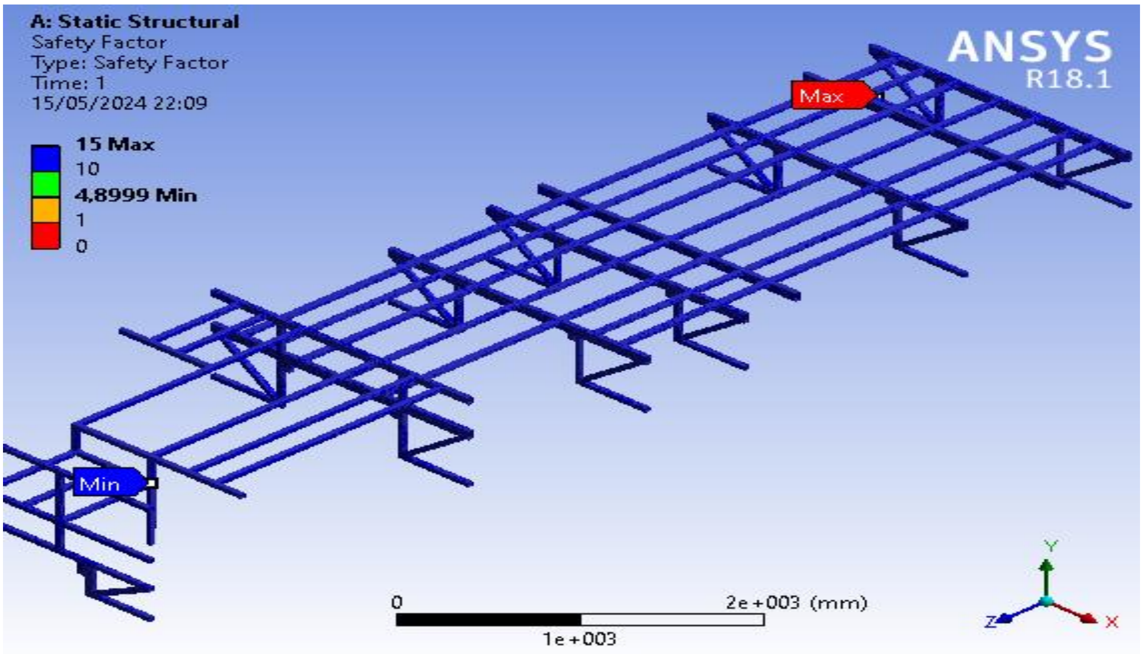
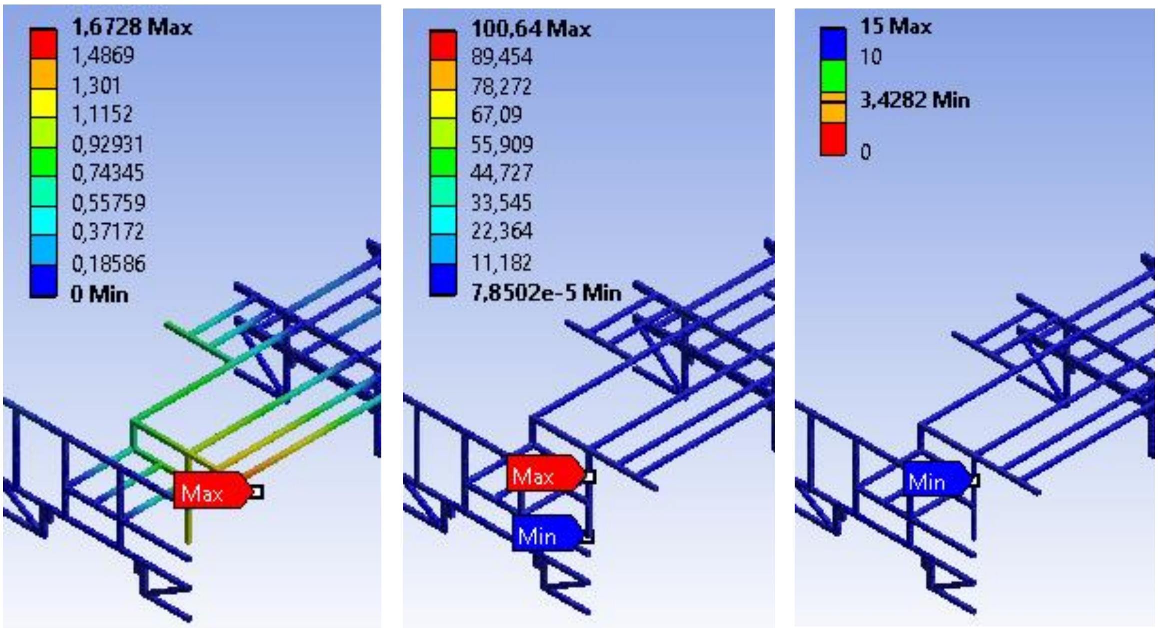
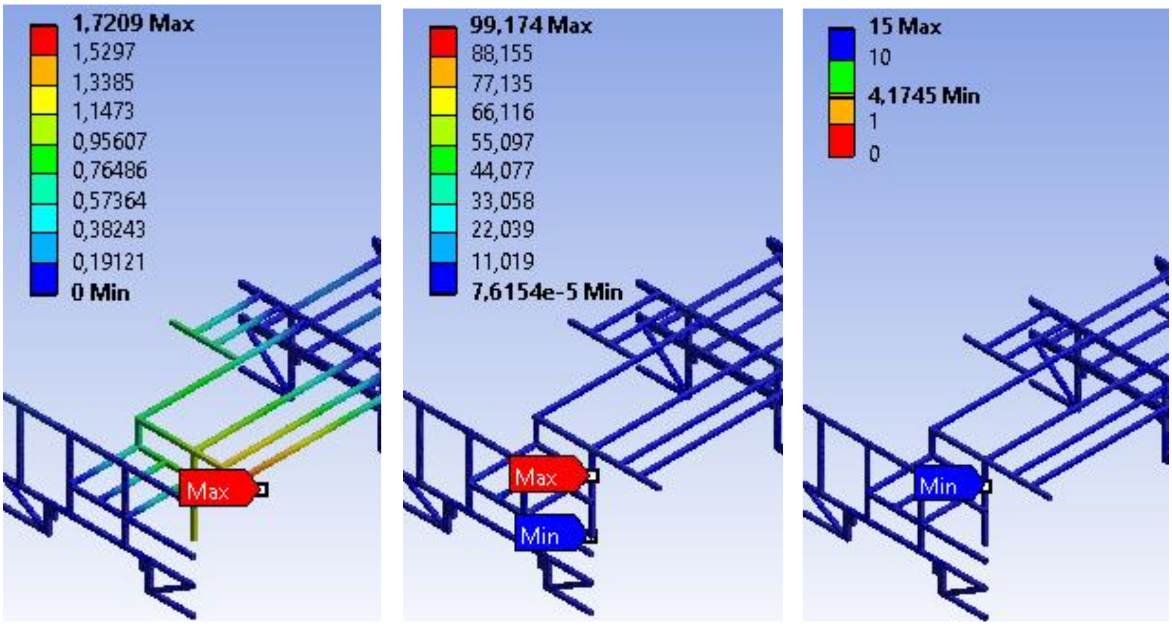


Figure 8. Maximum and minimum safety factors for AISI 1020 material

Using the same steps for other types of material shows that the maximum and minimum positions of deformation, equivalent von Mises, and safety factors occur at the same locations as in Figures 6 to 8. It shows that the design form has a dominant influence on the location of maximum deformation, maximum equivalent von Mises, and safety factor rather than material type. The material type will influence each structural performance's magnitude, as summarized in Table 3. The highest deformation occurred using Aluminum 2024-T4 material with a value of 1.7209 mm, and the lowest using AISI 1020 material with a deformation of 1.5735 mm. The highest equivalent stress was 101.23 MPa when using AISI 1020 material, and the lowest was 99,174 MPa when using Aluminum 2024-T4 material. The highest safety factor was 4.8999 when using AISI 1020 material, and the lowest was 6.4282 when using ASTM A588 material. These results showed that using AISI 1020 material would provide the lowest deformation and the highest level of safety. Therefore, using a floor frame design as in Figure 1, it would be better to use AISI 1020 material.



(A) (B) (C)



(D) (E) (F)

Figure 9. (A) Maximum deformation for ASTM A514 material, (B) Maximum equivalent stress for ASTM A514 material, (C) Minimum safety factor for ASTM A514 material, (D) Maximum deformation for Aluminum 2024-T4 material, (E) Maximum equivalent stress for 2024-T4 Aluminum material, (F) Minimum safety factor for 2024-T4 Aluminum material

Table 3. Structural performance of material

No	Material	Deformasi Max (mm)	Equivalent Stress Max (MPa)	Safety Factor
1	ASTM A514	1,6728	100,64	3,4282
2	AISI 1020	1,5735	101,23	4,8999
3	Alumunium 2024-T4	1,7209	99,174	4,1745

CONCLUSION

The strength analysis of the medium bus floor frame has been carried out using the finite element method with a summary of the results as follows:

1. The location of maximum deformation, maximum von Mises equivalent, and safety factor are the same for various ASTM A514, AISI 1020, and Aluminum 2014-T4 materials.
2. The lowest deformation of 1.5735 mm occurred when using AISI 1020 material, and the highest deformation was 1.7209 mm when using Aluminum 2024-T4 material.
3. Equivalent Von Mises Stress, the maximum from the Front View to Section A-A is 101.23 Mpa on AISI 1020 material.
4. The safety level of the design with materials is 4.8999.
5. AISI 1020 is the most optimal material for medium bus floor frames with the highest level of safety and lowest deformation.

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