Stress analysis of electric bus chassis using finite element method

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Stress analysis of electric bus chassis using finite element method

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Abstract. This paper discusses stress analysis of electric bus ladder chassis. The objective of this paper is to obtain an optimum design that has less weight but strong enough to receive load from passenger and body of bus. The chassis is subjected to load which are static, dynamic and cyclic loading. Therefore, the chassis should have good properties that can withstand to those types of load. During the travel, chassis are excited by road roughness, engine, transmission and more. Stress and displacement can be obtained by using finite element method. Simulation was carried out by using commercial finite element packages Abaqus in order to find stress distribution and displacement of chassis. The material used were AISI 4130 Alloy steel, AISI A514 GRADE B Alloy steel and Grey cast iron, with variations in thickness of 2 mm, 4 mm and 6 mm. The model with the AISI 4130 Alloy steel with 6 mm in thickness was chosen as the optimum model due to the lowest stress and displacement among all materials and thicknesses.

1. Introduction

As population increased significantly, transportation system become increasingly unmanageable. Bus is an importance vehicle in transportation that can bring passenger to reach their destination. Good and strong bus is needed in order to give the best service to passengers. Chassis is a main component in an electric bus that integrates many other components such as frame structure, transmission system and battery. Current trend in bus design is to reduce weight in order to minimize fuel consumption.

Stress is an unwanted parameter in structure since it initiates failure. Therefore, it must be reduced as less as possible in order to minimize the risk of failure. Many researchers have investigated stress on chassis. Static stress analysis and displacement of chassis and other structures have been carried out using Finite Element Method (FEM) by some researchers [1-14]. Meanwhile, Sreenath S and K Kamala Kannan [15] have introduced a new approach and specific design procedure for more lightweight bus body design. Satrio Wicaksono et al. [16] did the bus roll over test in accordance with UN ECE R66 Standard. Investigation of the bus in empty and fully loaded condition showed that the superstructure of the bus is not strong enough, as the residual space safety criterion was violated.

2. Finite Element Modelling

In the finite element (FE) Analysis, the first step is to create a model of bus chassis. The truck chassis was modelled by quadratic tetrahedral elements of type C3D10 (Tet-10) solid elements. The model has 517890 number of elements for 2 mm of thickness.

Three types of material were used in this work, namely: AISI 4130 Alloy Steel, AISI A 514 GRADE B Alloy steel and Grey Cast Iron. The simulation results in term of stress and displacement were compared for all the materials to get the best material that has minimum stress and thickness.

2.1. Model of Chassis
In present work, Mercedes-benz's chassis type OF 9170 was chosen for analysis. This chassis can be categorized as ladder type. The model was drawn using Solid Works commercial packages software. The model of chassis is shown in Figure1. The model has length of 7.9 m and width of 1.01 m. The material properties of three materials are shown in Table 1.

Figure 1. Model of electric bus chassis

Table 1. Mechanical properties of materials [17]

Mechanical Property	Material		
	Grey Cast Iron	AISI 4130	AISI A 514
Density (kg/m^3)	7200	7850	7850
Ultimate Tensile Strength (MPa)	450	450	760
Tensile Yield Strength (MPa)	280	435	690
Elongation at Break (%)	0.52	21.5	18
Modulus of Elasticity (MPa)	140	190	210
Poisson's Ratio	0.211	0.27	0.27
Shear Modulus (GPa)	69	80	80

2.2. Load and Boundary Condition
The chassis model was loaded by static forces from the bus body and passengers. For this model, the maximum loaded weight of bus plus passengers is 80.000 kg. The load is assumed as uniform pressure obtained from the maximum loaded weight divided by the total contact area between cargo and upper surface of chassis as shown in Figure 2.

Boundary condition (BC) applied to this model of chassis was taken based on real condition. The BC was applied on 8 regions of a whole chassis as shown in Figure 2. The type of BC is a fixed support (the displacement and rotation not allowed in all axes).

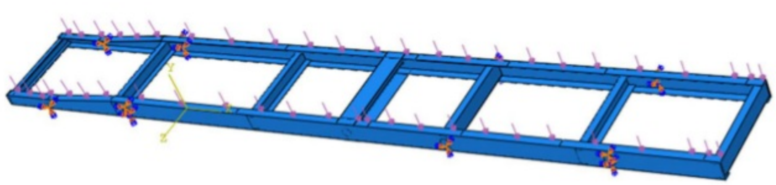

Figure 2. Load and boundary condition of model

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3. Result and discussion

Figure 3 and 4 show Von Misses stress and displacement of chassis for 6 mm thickness with material of AISI 4130 Alloy steel, respectively. Maximum stress occurred in right side of front chassis with magnitude of 202.2 MPa, while the minimum stress also occurred in the right side of front chassis but in different location. Maximum deflection occurred in the middle of one of cross section member in front of chassis with magnitude of 0.8445 mm and minimum deflection occurred at rear of chassis near the boundary condition. Based on these both results, it shows that the front of electric bus chassis is the critical part of chassis. Therefore, improvement is required such as using reinforcement or change the thickness of chassis.

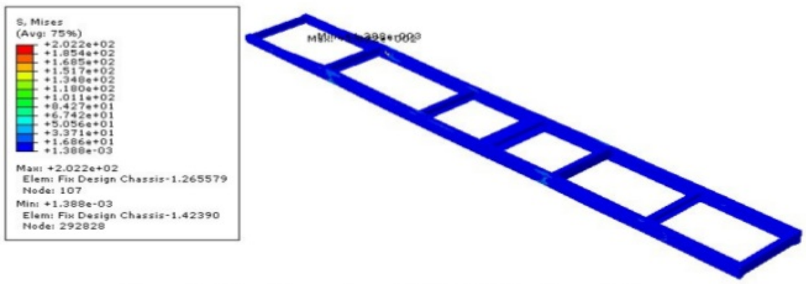

Figure 3. Von Misses stress of AISI 4130 for 6 mm thickness

The complete result of von Misses stress and displacement for all three materials and various thickness were shown in Table 2 and Table 3 respectively. According to data in Table 3, stress on the chassis is inversely proportional with the thickness of model, the thicker the model the lower the stress. The model with the AISI A 514 Grade B Alloy Steel material has the lowest stress, namely 202.2 MPa and model with Gray Cast Iron has the highest stress with magnitude of 437.9 MPa.

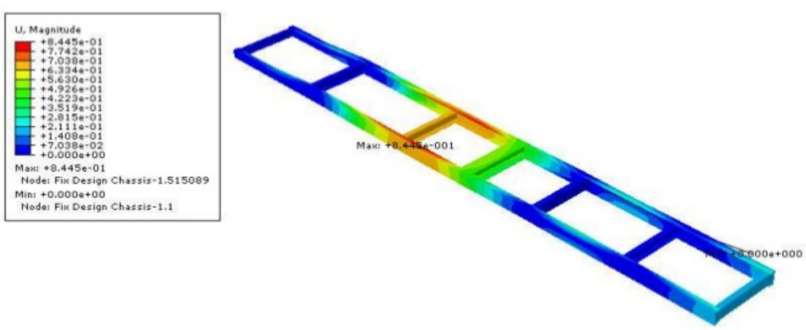

Figure 4. Displacement of AISI 4130 for 6 mm thickness

Table 2. Simulation result of Von Misses stress for all materials and thicknesses

Material	Stress (MPa)		
	2 mm	4 mm	6 mm
Grey Cast Iron	437,9	331,1	204,7
AISI 4130 Alloy Steel	431	321,9	203,1
AISI A 514 Grade B Alloy Steel	427,3	317,2	202,2

Table 3. Simulation result of displacement for all materials and thicknesses

Material	Displacement (mm)		
	2 mm	4 mm	6 mm
Grey Cast Iron	7,994	4,724	1,14
AISI 4130 Alloy Steel	5,8	3,467	0,84
AISI A514 Grade B Alloy Steel	5,2	3,127	0.76

The simulation results for displacement show the same trend with the simulation result for Von Misses stress. The thicker the model the lower the displacement. The model with the AISI A 514 Grade B Alloy Steel material has the lowest displacement, namely 0.760 mm and model with Gray Cast Iron has the highest displacement with magnitude of 7.994 mm.

The failure analysis of the model has been carried out by calculating safety factor for all models with three materials and three thicknesses. The value of safety factor was obtained by dividing the magnitude of Yield Stress for certain material with the magnitude of occurred stress for that material. The result for safety factor calculation was shown in Table 3.

Table 4. Safety factor for all materials and thicknesses

Material	Safety Factor		
	2 mm	4 mm	6 mm
Grey Cast Iron	0,64	0,84	1,367
AISI 4130 Alloy Steel	1,009	1,35	2,14
AISI A514 Grade B Alloy Steel	1,61	2.17	3,41

Table 4. shows that model with AISI A 514 Grade B Alloy Steel material and 6 mm thickness has the highest safety factor with value of 3.41. The model with Grey Cast Iron and 2 mm thickness has the lowest safety factor with magnitude of 0.64. It means that model was fail since the value of safety factor was lower than 1.

4. Conclusion

Finite element analysis on electric bus chassis model with three materials and three thicknesses has been done successfully. Based on simulation result of Von Misses stress and displacement for all the material and thicknesses, it can be concluded that model with AISI 4130 Alloy steel with 6 mm in thickness is the optimum model due to the lowest stress and displacement among all materials and thicknesses.

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