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농장차의 프레임 구조 해석

The Analysis of Frame Structure in Farm Vehicle

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〈Abstract〉

An agriculture machines are subjected to different loads conditions. Due to this loads variations there will be certain deformations and stress which affect the performance of the electric vehicle in adverse manner. The purpose of this paper is to analyze the total deformation and stress of the electric farm vehicle middle frame based on the finite element method. The proposed electric farm vehicle has lifting and dumping capability. Therefore, in this research four operational condition such as normal condition, dumping condition, lifting condition, and lifting-dumping condition was analyzed. In this research, the design for whole frame structure is elaborated. According to the mechanical characteristics of the frame, materials are selected and manufacturability requirements are limited. Based on ANSYS 15 software, the finite element model of electric farm vehicle is established to carry out static analysis on full-loaded conditions. The simulation results shows that the proposed design meet the strength requirements and displacement requirements. The maximum deformation 0.53611 mm and maximum stress 30.163 MPa occurred at lifting-dumping condition.

Keywords : Electric farm vehicle, Finite element method, Structure analysis.

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1. Introduction

An electric farm vehicle is an important tool in agriculture modernization. With the rapid development of economy in Korea, electric farm vehicle is widely used in agriculture area. According to the market demand, in this research a small sized electric vehicle with lift and dump capability was developed. This vehicle can be used to transport goods from the farm to the warehouse. The vehicle was design with total load capacity 300 kg. The structural analysis is one of important step in the development process such as in [1-5].

2. System Overview

The developed electric vehicle is shown in Fig. 1. The dimension of the cart was calculated optimally to maximize the capacity and the material strength.

The vehicle has ability to lift up and to dump the load. The cart was design with total body weight 300 kg and total load capacity 300 kg. For lifting and dumping, 2 hydraulic cylinders with diameter 50 mm were used. In normal condition the height of trunk is 770 mm, but in lift condition the height of trunk is 1240 mm. The operational conditions of the vehicle are shown in Fig. 2. The proposed vehicle parts are shown in Fig. 3.

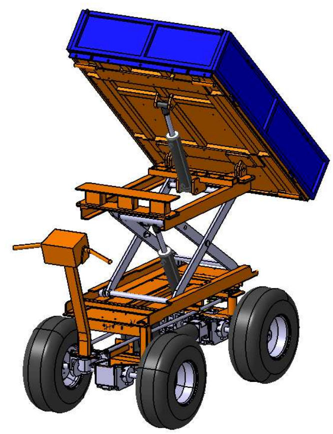
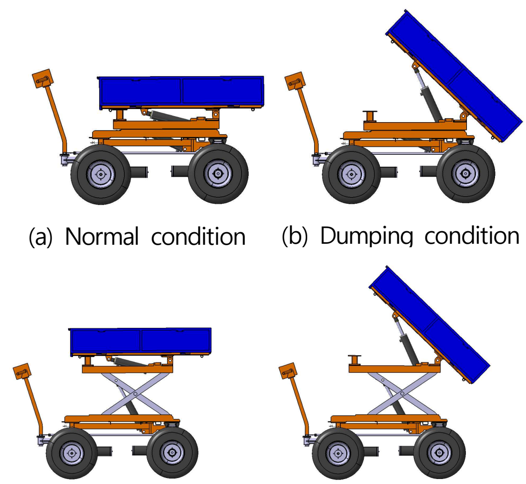


Fig. 1 Proposed design of electric farm vehicle.



(a) Normal condition (b) Dumping condition

(c) Lifting condition (d) Lifting-dumping condition

Fig. 2 Operation condition.

This research focus on displacement and stress on the middle frame since this part is most effected part during lift and dump operation.

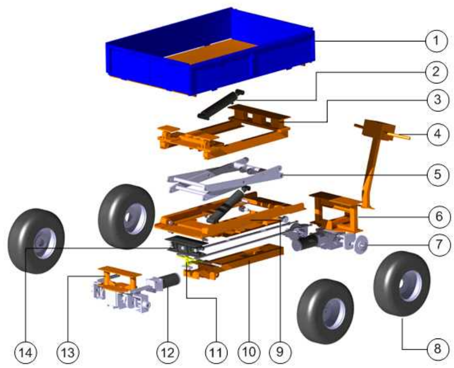


Fig. 3 Vehicle parts.

3. Simulation Method

The procedure of static analysis includes following steps as shown in Fig. 4. Firstly, the 3D model of important component of the vehicle was created. In this research focused on the middle frame since this part affecting hardly by the load and lifting condition.

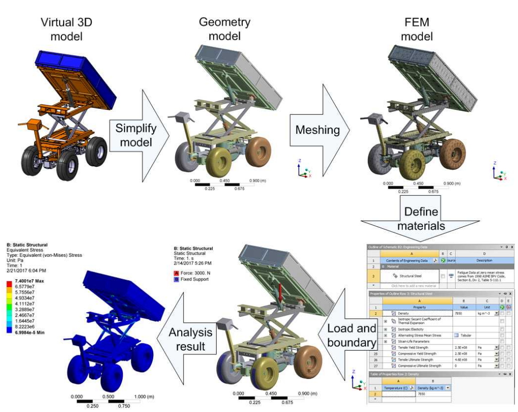


Fig. 4 Procedure of static analysis.

Secondly, the model was simplified to obtained geometry model. Thirdly, the mesh of the model was generated. Fourthly, the materials properties were defined. Fifthly, the boundary condition was defined. Finally, solve the problem, visualized and read the results. The boundary conditions for simulation in several operation conditions are shown in Fig. 5. To simulate 300 kg load condition, 3000 N force was applied to the Z axis of all operation conditions. Fix support was added to each wheel. As shown in Fig. 5, compare to the normal condition, the load support state in lifting condition is different due to the change of the cross bar. During the transition from normal condition to lifting condition, the load support on the rear side is slowly shifted from the rear end of the middle frame to the middle side of the frame. This condition affected the total deformation and the stress. The material properties for simulation is shown in Table 1.

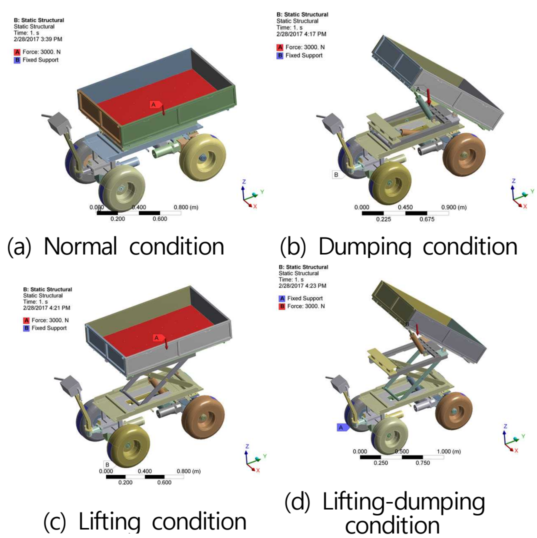


Fig. 5 Boundary condition.

Table 1. The material properties of simulation

Parameter	Value
Material	Structural steel
Density	7850 kg.m-3
Tensile yield strength	2.5E+8 Pa
Compressive yield strength	2.5E+8 Pa
Young's Modulus	2E+11 Pa

4. Simulation Result

4.1. Total deformation

The simulation result of total deformation are shown in Fig. 6 ~ Fig. 9. Fig. 6 shows the total deformation in normal condition. In this condition, the weight are spread evenly among front and rear side of vehicle, The maximum deformation 0.12034 mm occurred on the front side of the vehicle. The minimum deformation 0.048207 mm occurred on the rear side of the vehicle.

Fig. 7 shows the total deformation in dumping condition. In this condition, the weight are mostly supported by rear side of vehicle, specially on the hydraulic cylinder connector. The maximum deformation 0.28413 mm occurred on the front side of the vehicle. The minimum deformation 0.041117 mm occurred on the rear side of the vehicle.

Fig. 8 shows the total deformation in lifting condition. In this condition, the weight are spread evenly among front and rear side of vehicle, The maximum deformation 0.2332 mm occurred on the front side of the vehicle. The minimum deformation 0.089609 m occurred on the rear side of the vehicle.

Fig. 9 shows the total deformation in lifting-dumping condition. In this condition, the weight are mostly supported by front side of vehicle, specially on the hydraulic cylinder connector, The maximum deformation 0.53611 mm occurred on the front side of the vehicle. The minimum deformation 0.20741 mm occurred on the rear side of the vehicle.

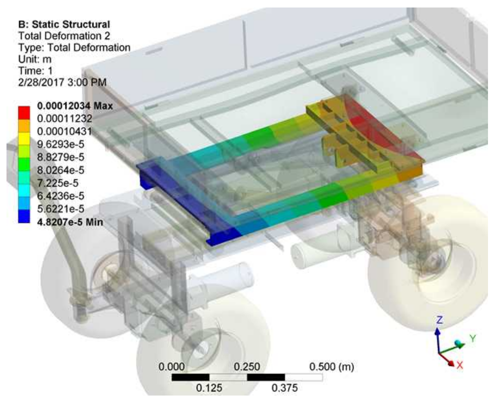


Fig. 6 Total deformation in normal condition.

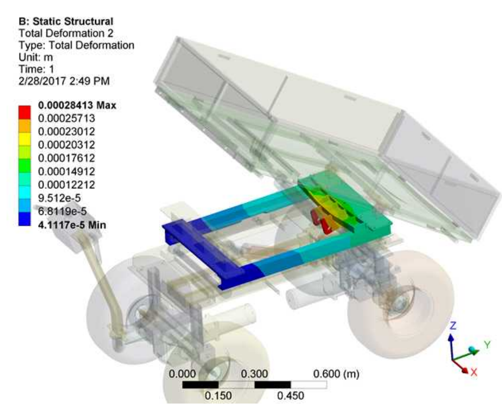


Fig. 7 Total deformation in dumping condition.

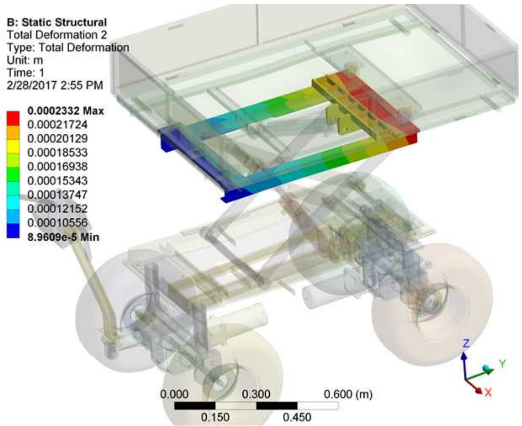


Fig. 8 Total deformation in lifting condition.

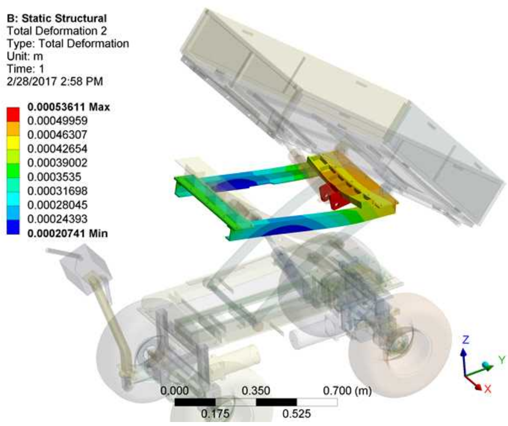


Fig. 9 Total deformation in lifting-dumping.

4.2. Stress analysis

The simulation result of stress analysis are shown in Fig. 10 ~ Fig. 13. Fig. 10 shows the stress in normal condition. In this condition, the weight are spread evenly among front and rear side of vehicle, The maximum stress 4.889 MPa occurred on the front side of the vehicle. The minimum stress is 3.0485 MPa.

Fig. 11 shows the stress in dumping condition. In this condition, the stress are mostly on front side of vehicle, The maximum stress 28.285 MPa occurred on the front side of the vehicle. The minimum stress is 1.6941 MPa.

Fig. 12 shows the stress in lifting condition. In this condition, the weight are spread evenly among front and rear side of vehicle, The maximum stress 11.22 MPa occurred on the bottom side of the frame. The minimum stress is 5.8832 MPa. Compare to Fig. 10, due to the change of the cross bar the stress on the rear frame are shifted to the middle of the frame.

Fig. 13 shows the stress in lifting-dumping condition. In this condition, the stress are mostly on front side of vehicle, The maximum stress 30.163 MPa occurred on the front side of the vehicle. The minimum stress is 6.289 MPa.

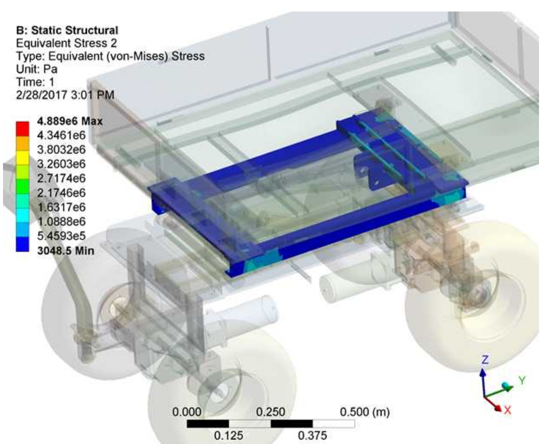


Fig. 10 Stress in normal condition.

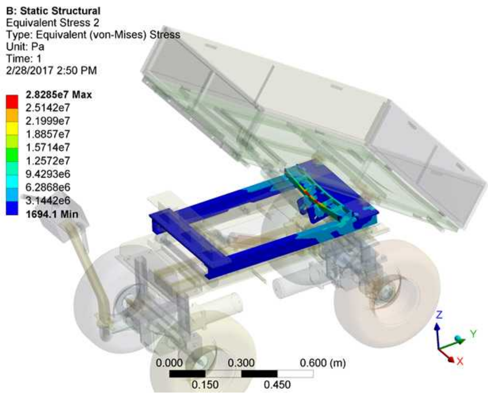


Fig. 11 Stress in dumping condition.

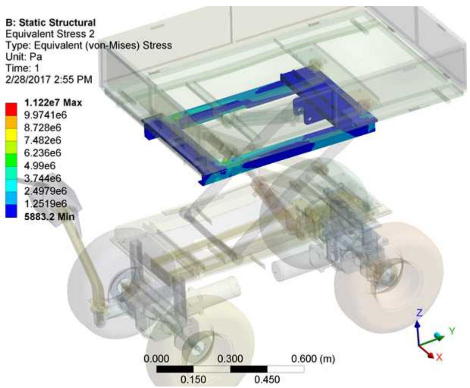


Fig. 12 Stress in lifting condition.

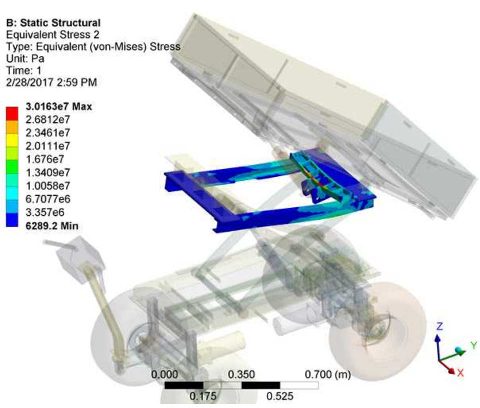


Fig. 13 Stress in lifting-dumping condition.

5. Conclusion

The analysis of electric farm vehicle was done in four operational condition such as normal condition, dumping condition, lifting condition, and lifting-dumping condition. The simulation results shows that the proposed design meet the strength requirements and displacement requirements. The maximum deformation 0.53611 mm occurred at lifting-dumping condition. The maximum stress 30.163 MPa occurred at lifting-dumping condition. In this research, the load is assumed to be a static object. However, in the real application the phenomenon in which the load tilts outward when dumping because there is water and viscosity could be occurred. Therefore, the structure analysis included the load characteristics will be interesting subject in the future research.

Acknowledgments

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