KKU ENGINEERING JOURNAL 2016;43(S2):267-270 Research Article

KKU Engineering Journal

https://www.tci-thaijo.org/index.php/kkuenj/index

The strength analysis of an agriculture truck chassis using finite element method

Jakkree Wichairahad*, Pairat Kaewsarn, Wiparat Nisapai, Sirintra Tan-Intara-Art and Waraporn Chanwiang

Faculty of Engineering, Chaiyaphum Rajabhat University, Chaiyaphum 36000, Thailand.

Received April 2016
Accepted June 2016

Abstract

The objective of this research was to analyze structural strength of agriculture truck based on basic global load case using finite element (FE) analysis software. The chassis of an agriculture truck made from Anan Karn Chang Agriculture Truck in Chatturat district, Chaiyaphum province, Thailand, was chosen for the study. The three-dimensional beam element type was applied in the study. The analysis was simplified based on static load and linear elastic material behavior assumption. There are four types of basic load behavior consisted of bending, torsion, longitudinal, and lateral loads considered. The results of maximum stress and deformations including construction stiffness were used as main parameters to evaluate the structural strength among load case. Regarding the results, it was found that the maximum stress occurred in torsion load was 164.57 MPa. The stress of bending load, longitudinal load and lateral load was 131.49 MPa, 147.08 MPa and 152.78 MPa, respectively. Furthermore, the bending and torsion stiffness of chassis were 7,399 N/mm and 6,415 N-m/degree, respectively.

Keywords: Agriculture truck, Chassis, Structural strength analysis, Finite element analysis

1. Introduction

Agriculture transportation using agriculture truck plays a key role in Thailand. According to statistic, number of the agriculture truck has been continuously increased [1]. The truck consists of two axles with 6 meters of length, 2 meters of width, and 1,600 kilograms of weight [2]. Entrepreneurs were required to take into consideration on strength of structure when design and manufacture. Generally, the truck structure is divided into two parts: chassis and pick-up as shown in Figure 1. The chassis carries weight of other parts such as engine, driver, and payload whereas the pick-up placed on chassis serves for carrying agriculture products.

In case of basic global load on automotive structure, it was classified into 4 forms [3-4]: bending loads, torsion loads, longitudinal loads and lateral loads.

Currently, computer aid design, manufacturing and engineering analysis was widely employed in automotive industrial especially design and structure strength analysis before making prototype. So that, while FE accuracy improvement was performed, time consuming for trial and error also were reduced.

According to computer aid engineering process using finite element analysis, there are some advantages and drawbacks when each element type was used. Moreover, there are three popular elements for structure analysis which are surface, beam, and mix-beam surface elements. Thus, strong point of the surface element is analysis accuracy. From previous studies, M.M.K Lee [5] found out that surface element was more accurate than volume element by using simulation of thin-hollow square pipe. Besides, L.P. Pet et al. [6] also showed that time consuming of the volume element process was more 10 times than surface. Structure analysis of thin-hollow square pipe with over 10 times length of cross section, there was another alternative which was beam element because time consuming had been lowered 1000 times compared to the volume [7]. Furthermore, model was more easily adjusted and modified compared to the surface. In case of the accuracy, it was presented that results of the surface element were closely the fact [8].

After having literature review, the number of researches related to strength stiffness and stability of truck structure was found that there was maximum stress especially when braking and cornering. Chinnaraj et al., [9] using quasi-static method and analyzed by software named Ansys instead of dynamics method was conducted and stress from experimental was compared. The obtained results showed that the stress using computer analysis was more than experimental with strain gage.

In 2011, Ingole and Bhope [10] investigated strength of 4-wheel and 8-ton truck using CAD 3-D Pro-E and Ansys software. The results showed that maximum stress was 75 MPa when using static analysis. While maximum stress was 150 MPa using dynamics, safety factor was 1.66.

In 2012, H. Kamal et al. [11] carries out structure of 6-wheel truck using static analysis in terms of 2 cases: bending loads when 1-front wheel climbing speed hump and torsion loads when 2-front wheel climbing speed hump. It was described that there was maximum stress occurred in case of 1-front wheel climbing speed hump due to torsion stress.

*Corresponding author. Tel.: +6681 266 2056
Email address: jakreew@yahoo.co.th
doi: 10.14456/kkuenj.2016.106


(a)


(b)

Figure 1 Agriculture truck superstructure; (a) Chassis frame, (b) Pick-up structure

R. Chandra et al. [12] analyzed strength of TATA truck model 2515EX aiming to reduce cost by comparing strength of 3 composite materials which were Carbon/Epoxy, E-glass/Epoxy and S-glass /Epoxy. It was found that all material could decrease weight and lower cost under strength regulation of mentioned truck.

Hemant Patil et al. [13] carried out structure of 6-wheel truck using C channel structure steel as chassis focusing on thickness and chassis transverse beam location then computer analysis was employed. It was found that thickness adjustment of C channel structure steel was more decreased maximum stress than chassis transverse beam location adjustment.

Hence, the objective of the study was to analyze strength of agriculture truck chassis starting up with CAD 3 D creation, defined payload, loads of other parts and acceleration as the input while strength analysis was performed using finite element method under 4 basic global load cases with computer aid engineering software. The researcher aims this study will be beneficial for the agriculturist in safety and the truck manufacturer in structure design and development procedure.

2. Material and method

The model was designed and analyzed by researchers using computer software as followed:

2.1 Computer modeling

Chassis finite element model of Jumbo Elephant agriculture truck with 700 mm. width and 5,150 mm. length manufactured by Anan Karn Chang Agriculture Truck in Chatturat district, Chaiyaphum province, Thailand, was made using computer aided design and engineering whereas the model was used by 3 D beam element with maximum element density, 362 element, 718 node and was specified chassis cross section as shown in Figure 2.

2.2 Material properties

Linear elastic homogeneous material behavior assumption was considered and available material properties were from standard testing. So that, yield stress was 245 MPa, Young modulus was 199 GPa, and Poisson ratio was 0.3.

2.3 Boundary condition

Regarding to the boundary condition and the total of 4 global load cases, they were performed as following;

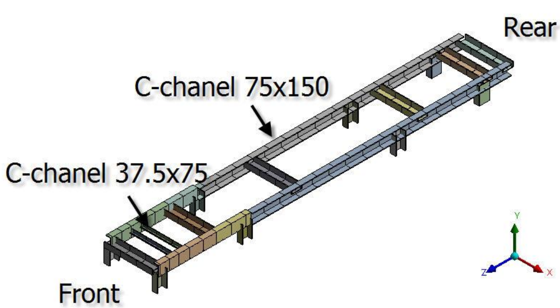

Figure 2 Agriculture truck CAD model and cross section of chassis

Bending load case; a total of 5 components consisted of the engine component of 480 N., the front console weight of 1,412 N., the driver weight of 637 N., the payload of 98,100 N. and the construction weight of 3,453 N. (from CAD simulation), was considered as a vehicle at rest including the simply support at 4 wheel hub. [3, 4]

Torsion load case; a wheel climbed a hump accidentally was considered. While the vertical displacement was applied to one wheel hub with a ramp up of 200 mm, other three wheels were attached at the ground. [3, 4]

Longitudinal load case; the acceleration or deceleration responds were carried out in longitudinal direction. From the previous studies, the severe acceleration load of 0.75g was recommended for this case. [3, 4]

Lateral load case; a lateral acceleration was used to simulate the cornering maneuver. For a severe drive, a lateral acceleration of 0.35g was employed to obtain both sides of a turning response. [3, 4]

2.4 Chassis maximum stress and stiffness

While the strength analysis was considered maximum combine stress in terms of load cases, structure stiffness was focused on 2 cases: bending stiffness (K_B) and torsion stiffness (K_T) [3-4] as displayed in Figure 3 from ratio of load, deformation and twist angle as shown in equation 1.

$$K_B = W/\delta, \quad K_T = T/\theta \tag{1}$$

Where: W –total load (N)
T –torsion moment (N-mm)
δ –deformation (mm)
θ –twist angle (degree)

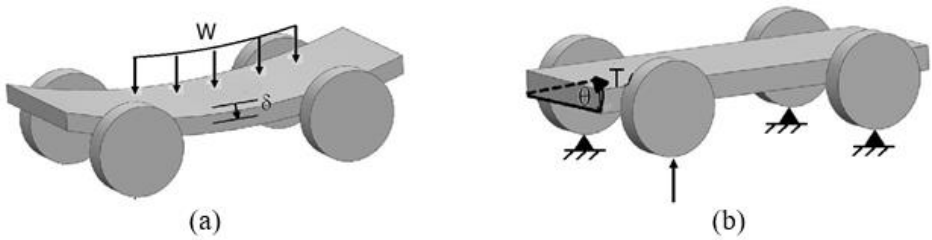

Figure 3 Structure stiffness (a) Bending stiffness, (b) Torsion stiffness

3. Results and discussions

The results were categorized into 2 parts as followed:

3.1 Chassis maximum stress

In this studied, with 3-D beam element type, the maximum stress were the combination of stress from axial force and stress from moment that called "Maximum Combine Stress". The results of simulation were shown that maximum value of combine stress of bending, torsion, longitudinal and lateral loads was -131.49 MPa (Compressive stress), +164.57 MPa (Tensile stress), -147.08 MPa (Compressive stress), +152.78 MPa (Tensile stress), respectively. The maximum stress occurred at the chassis in position of maximum moment applied as shown in figure 4. However, the maximum stress result that shown in this studied came from computer simulation. The verification can be made by attach the strain gauge on the real chassis. In addition, safety factor of structure in 4 basic global load cases, it was found that the safety factor of bending, torsion, longitudinal and lateral loads was 1.9, 1.5, 1.7 and 1.6, respectively. However, safety factor was required to consider dynamics factor included which safety factor of truck structure from previous studies could be more than 1.5 [14, 15].

3.2 Chassis bending and torsion stiffness

It was found that maximum deformation of bending, longitudinal and lateral loads was 13.6 mm, 6.95 mm and 5.45 mm, respectively. Bending stiffness was computed from equation 1 and the result was 7,399 N/mm. From previous studies, more than 3,000 N/mm was recommended results [16].

Furthermore, computation of torsion stiffness from the input as ramp up 200 mm load at left front wheel hub with fixed other 3 wheel hub, reaction force was 146,140 N, span of left to right wheel hub was 700 mm. After following Equation 1, it was found that torsion stiffness was 6,415 N-m/degree meanwhile bending stiffness was shown deformation resistance on bending load including payload [3]. In other hands, torsion stiffness was shown resistance on structure when torsion such as falling or climbing speed hump with a wheel. The recommended result of torsion stiffness from previous studies was more than 4,000 N-m/degree [16]. However, the improvement of strength and stiffness of chassis can be made by add the beam member for triangular planar shape of chassis.

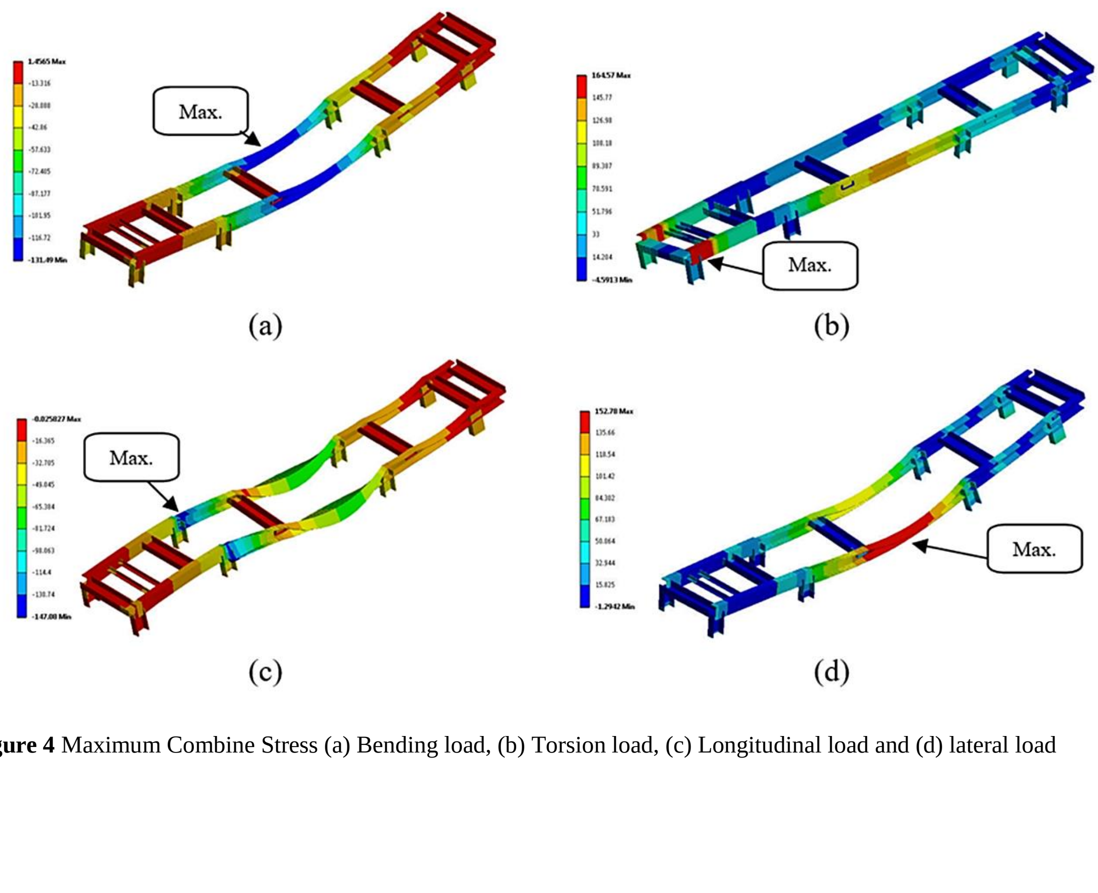

Figure 4 Maximum Combine Stress (a) Bending load, (b) Torsion load, (c) Longitudinal load and (d) lateral load

4. Conclusions

This study was strength analysis of Jumbo Elephant agriculture truck chassis manufactured by Anan Karn Chang Agriculture Truck in Chatturat district, Chaiyaphum province, Thailand, using finite element analysis with computer aided engineering software. The 3 D beam element was used under linear elastic homogeneous material behavior assumption with 4 basic global loads including bending, torsion, longitudinal and lateral loads. It was found that maximum stress on chassis under torsion load was 164.57 MPa and safety factor was 1.5. Considering chassis deformation, maximum deformation on bending load was 13.6 mm. In terms of bending and torsion stiffness, 7,399 N/mm and 6,415 N-m/degree were found respectively. So that, the results were consistent with the recommended results from previous studies which could be more than 3,000 N/mm for bending stiffness and more than 4,000 N-m/degree for torsion stiffness. The researcher aims this study will be beneficial for the agriculturist in safety and the truck manufacturer in structure design and development procedure.

5. Acknowledgements

The research fund was supported from Chaiyaphum Rajabhat University and the researchers would like to thank Anan Karn Chang Agriculture Truck in Chatturat district, Chaiyaphum province, Thailand for kind cooperation and providing information related to agriculture truck and sincerely thank Assistant Professor Dr.Supakit Rooppakhun from School of Mechanical Engineering, Institute of Engineering, Suranaree University of Technology for any suggestion on using finite element analysis.

6. References

[1] Transportation Statistics Group, Planning Division, Department of Land Transport [Internet]. Statistics of registered vehicles across the country [updated 2014 December 31; cited 2015 February 19]. Available from: apps.dlt.go.th/statistics_web/vehicle.html

[2] Ministerial Regulation Issue 11 (B.E.1982) under Vehicles Act B.E. 1979 (1982, 11 May). Government Gazette Issue 99, Article 65, Page 72-75. [InThai].

[3] Brown JC, Robertson AJ, Serpento ST. Motor Vehicle Structures: Concepts and Fundamentals [disseration]. Butterworth-Heinemann: Oxford University; 2002.

[4] Smith JH. An Introduction to Modern Vehicle Design [disseration]. Butterworth-Heinemann: Oxford University; 2002.

[5] Lee MMK. Strength Stress and Fracture Analyses of Offshore Tubular Joints using Finite Elements. Journal of Constructional Steel Research 1999;51:265-286.

[6] Pey LP, Soh AK, Soh CK. Partial implementation of compatibility conditions in modeling tubular joints using brick and shell elements. Finite Elements in Analysis and Design 1995;20:127-138.

[7] Stigliano G, Mundo D, Donders S, Tamarozzi T. Advanced Vehicle Body Concept Modeling Approach Using Reduced Models of Beams and Joints. Proceedings of International Conference on Noise and Vibration Engineering; 2010 Sept 20-22; Heverlee, Belgium. Leuven: KU Leuven; 2010.

[8] Alcala E, Badea F, Martin A, Aparicio F. Methodology for the accuracy improvement of FEM beam type T-junctions of buses and coaches structures. International Journal of Automotive Technology 2013;14(5):817-827.

[9] Chinnaraj K, Sathya M, Prasad, Lakshmana Rao C. Experimental Analysis and Quasi-Static Numerical Idealization of Dynamic Stresses on a Heavy Truck Chassis Frame Assembly. Applied Mechanics and Materials 2008;13-14:271-280.

[10] Ingole NK, Bhope DV. Stress analysis of tractor trailer chassis for self weight reduction. International Journal of Engineering Science and Technology 2011;3(9):7218-7225.

[11] Kamal Asker H, Salih Dawood T, Fawzi Said A. Stress Analysis of standard Truck Chassis during ramping on Block using Finite Element Method. ARPN Journal of Engineering and Applied Sciences 2012;7(6):641-648.

[12] Ravi Chandra M, Sreenivasulu S, Altaf Hussain S. Modeling and Structural analysis of heavy vehicle chassis made of polymeric composite material by three different cross sections. International Journal of Modern Engineering Research 2012;2(4):2594-2600.

[13] Patil BH, Kachave SD, Deore ER. Stress Analysis of Automotive Chassis with Various Thicknesse. IOSR Journal of Mechanical and Civil Engineering 2013; 6(1):44-49.

[14] Vidosic JP. Machine Design Project. New York: Ronald Press; 1957.

[15] Kurdi O, Rahman R, Tamin MN. Stress analysis of heavy duty truck chassis using finite element method. Proceedings of the 2nd Regional Conference on Vehicle Engineering & Technology; 2008 July15-17; Kuala Lumpur, Malaysia.

[16] Murali G, Subramanyam B, Naveen D. Design Improvement of a Truck Chassis based on Thickness. Proceedings of 2013 Altair Technology Conference; 2013 July 18-19; Pune. India.