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A Review on Structural Design and Optimization of Chassis for Transport Vehicle

M. Tech. Scholar Mohan Singh, Prof. Ranjeet Kumar (Guide), Dr. R S Sikarwar (Co Guide)
Department of Mechanical Engineering,
VITS, Bhopal

Abstract- In this study, design analysis and shape optimization of ladder chassis frame is analyzed. Static analysis is performed on ladder chassis frame to find out the stress, strain and displacement in a ladder chassis due to acting loads. Solid Works software is used for the modelling of ladder chassis frame and ANSYS is used for the static analysis of ladder chassis fame. Coming to shape optimization, the cross-section of cross-members will be changed accordingly C, T & I and tested for the same.. The main goal of the work is to study the different types of chassis, find out the stress, strain and displacement under acting loads on ladder chassis, design and optimize the shape of the chassis towards the weight optimization and to study the effect of changing cross-section of cross members of ladder chassis frame with different material. It is found that the generated stresses are within the permissible limit as yield strength of A710 steel is 455 MPa so design is safe. Deformation is minimum in ladder chassis with C- section and maximum in ladder chassis with T- section. Stress is maximum in ladder chassis with T- section and minimum in ladder chassis with C- section. For weight reduction analysis, minimum weight of Ladder chassis with I-section is 749.47 kg and maximum weight of Ladder chassis with box-section is 1034.1 kg. So with regard to different cross-section of cross-member in ladder chassis, C- section is suitable for trucks.

Keywords: - Ladder chassis, t-section, Stress, Strain, box-section, Weight, cross-members, ANSYS, Solid Works.

I. INTRODUCTION

Automotive industry is one of the major industries around the globe [1]. Chassis is a central part of automotive vehicle and it carry the load of components such as engine, gearbox, clutch, fuel tank etc. These loads include the weight of each component. Therefore, chassis should be rigid enough to absorb the shock, twist, vibration and other stresses. Bending and torsional stresses are the main design consideration for the chassis apart from this it has better handling characteristics [2]. Therefore, the chassis must provide the strength needed for supporting the components to keep the ride safe. Chassis is the skeleton of vehicle and it is the load carrying structure, so it has to be designed [3].

One of the major challenges is of designing of the chassis. Design of chassis is begins with analysis of load cases [1]. There are four loads acting on chassis to be considered namely: (1) bending loads (2) torsion loading (3) combine bending and torsion loading (4) lateral loading (5) inertia forces when vehicle accelerates and decelerates.

These loads are important considerations in design of chassis because of ride safety and comfort of passengers. Nowadays automotive engineers are more interested in reducing the weight of chassis without compromising its performance. Apart from this many scholars have done the optimization of chassis. For instance, Cavazzuti et. al. [7] optimized the design of chassis. Sobieski et al. [8] have done the optimization of chassis using bending and

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torsion loading as a constraint. Sklad [9] addressed the optimization of chassis towards light weight. Sethupathi et al. [10] have done the optimization of FSAE chassis using FEA. Yasar and Brian [11] studied the effect of design parameters on chassis of car. Design was analyzed by using FEA tools with three materials namely aluminum alloy, magnesium alloy and carbon fiber. Further, design optimization was carried out by using Taguchi methodology. Paramar and Morabiya [12] analyzed the stress distribution of truck frame. Results indicate that stress intensity is minimum in "I" section than "C" section.

With the growing computing technology and fastest speed of computers trends are to reduce product development time, computer aided engineering (CAE) holds a major position in the product development cycle in the automotive industry. In order to reduce the cost of prototype, design engineers are more focused on simulations to come up with optimized design. Chassis is of the load bearing primary member of an automobile, its designing and optimization is important to ensure the automobile durability. Researchers are continuously doing their effort on the analysis of chassis subjected to various kinds of load.

Accordingly, in this study design analysis and shape optimization of ladder chassis frame is analyzed. Static analysis will be performed on ladder chassis frame to find out the stress, strain and displacement in a ladder chassis due to acting loads. Solid Works software will be used for the modelling of ladder chassis frame and ANSYS will be used for the static analysis of ladder chassis fame. Coming to shape optimization, the cross-section of cross-members will be changed accordingly C,T& I and tested for the same.

II. LITERATURE REVIEW

Yang and Chahande [1] used topology optimization methods to design light-weight automobile components. The methodology is demonstrated on different structures including a space frame, simplified truck chassis and a deck lid.

Cavajzzuti et al. [2] used topology, topometry and size optimization to design automotive chassis while satisfying the structural performance constraints as per Ferrari standards. The design when compared to the commercial Ferrari F458 chassis showed significant mass reduction.

Wang et al. [3] studied the topology optimization approach for longitudinal beam shape frames with variable cross-sections to achieve reliable chassis designs. They achieved the optimized frame which was robust and had lower mass. The shortcoming of topology optimization is, however, that the design obtained often has too complex of a shape to be manufactured. Also, high computational time is required for topology optimization approaches.

Kurdi et al. [4] compared diverse heavy-vehicle frames with different mass and torsional stiffness. The authors found an effective design with low mass and maximum torsional stiffness.

Kang et al. [5] presented the optimal design of a heavy-vehicle by applying the analytical target cascading (ATC) methodology. They solved design problems for heavy-duty truck and bus with the suspension system.

Rajasekar et al. [6] applied the genetic algorithm to optimize the chassis with various rectangular cross-sections.

Jin and Wang [7] performed the strength analysis of a simplified suspension model. The authors simplified the suspension with an equivalent beam to calculate the strength of frame under diverse load conditions.

Nelson [8] used the inertia relief analysis to estimate the impact loads on the space structure.

Morton [9] applied this method to calculate the distribution of flight load on the unconstrained helicopter rotor.

Vallejo [10] simulated a finite element model using inertia relief to predict the fatigue behavior of the heavy truck chassis.

Pagaldipti and Shyy [11] studied the influence of inertia relief on optimal designs.

Saito [12] carried out the full automobile optimization procedures with the inertia relief analysis.

Zhang and Deng [13] used the inertia relief option to perform stress analysis on the mine dump truck frame and proposed essential elements for optimization of a commercial vehicle.

Gaikwad and Ghawade [14] performed the static structural analysis of truck chassis. Chassis is modelled in Pro-E and FEM analysis has been done in ANSYS. Highest stress is found as 106.08 MPa. Further, the result of numerical simulation is bigger than 5.92% than analytical one.

Muthyala [15] made the comparative analysis of steel and CFRP ladder chassis. Further, crash analysis has been performed. Thickness optimization is performed on ladder chassis. It is observed that 7.91% weight is reduced in the combination of chassis.

Garud et al. [16] had changed the web height and thickness to study their effects on weight. CFRP was showing better results as compared to original chassis. Further, with increase in thickness, deformation and stress value decreases.

Mishra [17] designed the truck chassis with different materials. Ladder chassis is modelled in Solid Works and FEM analysis has been done in ANSYS. Result reveals that shear stresses are maximum in alloy steel chassis as compared to aluminum chassis.

Kumar et al. [18] performed the FEM analysis of truck chassis. Results indicate that highest stress occurred is 106.08 MPa. The calculated maximum stress is 95.43 MPa. The result of FEM analysis is 10% higher than that of analytical one.

Francis et al. [19] calculated the von mises stress and shear stress for chassis frame. Mild steel, aluminum alloy and titanium alloy are selected for analysis. Result indicates that von mises stress is found minimum in aluminum alloy.

Darlong et al. [20] had done the FEM analysis of ladder chassis frame under static and dynamic conditions. Result indicates that 15.22% weight reduction is achieved with a von-mises stress of 31.69 MPa.

Goel et al. [21] studied the deformation, natural frequency, and stress induced in an automotive chassis under different cross-section of cross members. Chassis is modelled in Solid Works and FEM analysis has been done in ANSYS.

III. CONCLUSION

The two key influences that determine the geometry of the chassis are indeed the form and cross section. That cross section or cross part positions will determine the frame specification for the ladder style frame. Under dynamic and static environments, multiple cross sections include differing behavior including characteristics. Various sections which are already found in various implementations include C-section, I-section, and box-section (rectangular) including circular sections. Owing to its large bending load resistance, the C-section is commonly used throughout heavy vehicles.

Compared to other sections, torsional resistance becomes lower in the C-section. Open C-sections have fast assembling, routing including convenient usability for one of the other aggregate structures. I-sections do have high shear resistance and torsion, even though there are no elements of mounting and availability. Therefore, the use of I-section as a trailer truck chassis would be reduced. The torsional resistance of the circular cross section chassis is indeed fine.

The circular section does have disadvantages, such that it is easy to craft then it is not cheap to implement. Throughout the space frame architecture used in race cars, circular segment chassis can be used in which the moment of inertia must be held low and also more structural rigidity becomes provided.

REFERENCES

[1] Yang, R. J., Chahande, A. I., “Automotive Applications of Topology Optimization,” Structural Optimization, Vol.9, 1995, pp. 245-249.

[2] Cavazzuti, M., Baldini, A., Bertocchi, E., Costi, D., Torricelli, E., and Moruzzi, P., “High-performance Automotive Chassis Design: a Topology Optimization-based Approach,” Structural and Multidisciplinary Optimization, Vol. 44, 2011, pp. 45-5

[3] Wang J., Wang T., Yang Y., Peng Z., Li Z., and Wang N., “Topology Optimization Design of a Heavy Truck Frame”, Proceedings of the FISITA

2012 World Automotive Congress. Lecture Notes in Electrical Engineering, Springer, Berlin, Heidelberg, Vol 195, pp. 219-22

[4] Kurdi, O., Rahman, R. A., Samin, P. M., "Optimization of Heavy Duty Truck Chassis Design by Considering Torsional Stiffness and Mass of the Structure," Applied Mechanics and Materials, Vol. 554, 2014, pp. 459-463.

[5] Kang, N., Kokkolaras, M., Papalambros, P.Y., Yoo, S., Na, W., Park, J., Featherman, D, "Optimal design of commercial vehicle systems using analytical target cascading", Structural and Multidisciplinary Optimization, Vol. 50, 2014, pp. 1103–1114.

[6] Rajasekar, K., Saravanan, R., and Dhandapani, N. V., "Design and Optimization of Variable Rectangular Cross Section Chassis for On-Road Heavy Vehicles", International Journal of Vehicle Structures & Systems, Vol 8, 2016, pp. 11-16.

[7] Jin, C., Wang, P., "A method for truck frame strength analysis with simplified suspension model", Proceedings of SAE-China Congress 2015, Vol. 364, 2015, pp.485-492.

[8] MSC Patran 2014 User's Guide.

[9] MSC Nastran 2014 Quick Reference Guide.

[10] Liao, L., "A study of inertia relief analysis", Proceedings of the 52nd AIAA/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference. AIAA, Denver, CO,April2011, pp.1–10

[11] Nelson, M. F., Wolf Jr., J. A., "Use of Inertia Relief to Estimate Impact Loads", Proceeding of International Conference on Vehicle Structural Mechanics, April 1977, pp. 149-155.

[12] Morton, M. H., Kaizoji, A., "Effects on Load Distribution in a Helicopter Rotor Support Structure Associated with Various Boundary Configurations", 48th Annual Forum Proceedings of the American Helicopter Society, Vol. 1, 1992, pp. 629-

[13] Vallejo, R., "Full Frame Fatigue Test on Heavy Trucks and their Set up Using Finite Element Simulation," SAE Technical Paper 2008-01-2667, 2008

[14] Pagaldipti N, Shyy Y.K., "Influence of Inertia Relief on Optimal Designs" Proceedings of the 10th AIAA/ISSMO multidisciplinary analysis and optimization conference, AIAA, Albany, NY, Sep, Vol 1, 2014, pp. 616–621

[15] Saito, T., Hiraomoto, J., Urabe, T., "A study of optimization for automotive parts and structures by using inertia relief", 11th World Congress on Structural and Multidisciplinary Optimization, Sydney, Australia, 2012

[16] Zhang, J. F., Deng, L., "Analysis on Strength of the Frame of a Mine Dump Truck," Applied Mechanics and Materials, Vol. 590, 2014, pp. 130-134.

[17] M. Zehsaz, F. Vakili Tahami and F. Esmaeili, "The Effect Of Connection Plate Thickness On Stress Of Truck Chassis Eith Riveted And Welded Joints Under Dynamic Loads", Asian Journal of Applied Sciences, ISSN 1996-3343, Volume No. 2, Issue No. 1, 22-35,2009.

[18] Sen Zheng , Kai Cheng , Jixin Wang, Qingde Liao, Xiaoguang Liu, Weiwei Liu, "Failure Analysis Of Frame Crack On A Wide-Body Mining Dump Truck", Engineering Failure Analysis, Science Direct, Elsevier, Engineering Failure Analysis 48 (2015) 153–165.

[19] Chen Yanhong, Zhu Feng, "The Finite Element Analysis And The Optimization Design Of Theyj3128-Type Dump Truck's Subframes Based On Ansys", SciVerse Science Direct, Elsevier, Procedia Earth and Planetary Science 2 (2011) 133 – 138.

[20] A.N. Savkin, A.S. Gorobtsov, K.A. Badikov, "Estimation Of Truck Frame Fatigue Life Under Service Loading", Science Direct, Elsevier, Procedia Engineering 150 (2016) 318 – 323.

[21] Mohd Azizi Muhammad Nor, Helmi Rashid, Wan Mohd Faizul Wan Mahyuddin, Mohd Azuan Mohd Azlan, Jamaluddin Mahmud, "Stress Analysis Of A Low Loader Chassis", Elsevier Ltd. Sci Verse Science Direct Procedia Engineering 41 (2012) 995 – 1001.

[22] Cicek Karaoglu, N. SefaKuralay, "Stress Analysis of A Truck Chassis with Riveted Joints", Finite Elements in Analysis and Design 38 (2002) 1115–1130, 2002 Elsevier Science B.V.

[23] Yuan Ren, Yongchang Yu, Binbin Zhao, Chuanhui Fan, He Li, "Finite Element Analysis and Optimal Design for the Frame of Sx360 Dump Trucks", Science Direct, Elsevier, Procedia Engineering 174 (2017) 638 – 647.

[24] RoslanAbd Rahman, Mohd Nasir Tamin, OjoKurdi, "Stress Analysis Of Heavy Duty Truck Chassis As A Preliminary Data For Its Fatigue Life Prediction Using Fem", Jurnal Mekanikal, December 2008, No.26, 76- 85.