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Light Weight Designing of Heavy Vehicle Chassis : A Review

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ABSTRACT

As the chassis being one of the heaviest components in automobile, there is a great scope in its weight optimization in order to improve the fuel economy of vehicle along with reduction in greenhouse gases emission. This review of literature shows some light on the various approaches that can be used to optimize the weight of chassis frames. These approaches are divided into two parts as based on design changes and based on material changes. From the literature survey it has found that reinforced Aluminum composites can be successfully used as a replacement for higher density Steel materials. Along with this, this study focuses on the various design approaches which provides strength to the structure without increase in its weight.

Keyword: - Chassis, lightweight, Al 6061, I section, SiC reinforcement in Al.

1. INTRODUCTION

Chassis frame plays the most important role in every automobile. It acts as a skeleton for vehicles such that almost all the important parts are attached with chassis frame. Generally it is one of the heaviest components of vehicles. Improving fuel economy is currently a topic of great interest due to the rapid rise in gasoline cost as well as new fuel economy and greenhouse gas emission standards. Weight reduction in heavy vehicles gives benefits in fuel economy, emission, handling, ride and towing capacity. Although the auto makers have deployed several technologies to improve the fuel efficiency of their vehicle, reducing the weight is still one of the approaches they prefer, not only because it improves fuel economy, but also because of the emergence of advanced materials that may result in lower cost in association with good manufacturability. Among various weight reduction strategies some are more desirable than others. Herein various design based and material based chassis weight reduction strategies are discussed.

2. DESIGN BASED WEIGHT REDUCTION STRATEGIES

The detailed Finite element analysis of the truck chassis is carried out for full frontal, offset frontal and corner impact. Based on these results behavior of chassis during vehicle crash is discussed. Characteristics of different impact cases are revealed and compared through acceleration and internal energy analyses. From this study, it is concluded that during the impact, the majority of impulse is generated along the impact direction and most of the crash energy is absorbed by thin-walled beam members and other components in the high impact zone, which undergo the most serious plastic deformation [1]. A low loader truck chassis has been designed with the beams of I cross sections. The CAD model is analyzed using tools based on finite element method and results are compared with the analytical calculations. Results show that the designed model is safe under the applied heavy loads. Also the minimum value of factor of safety suggested by Department of Structure and Transport of Australia has been achieved [2]. In this work the collapse region of a light weight chassis is optimized using robust design techniques. With the intention of maximizing energy absorption, the number, size and position of collapse triggers are determined considering factors that influence a collision in real-life situations, and cannot be controlled. An important conclusion of this work is that it is possible to satisfactorily improve, the behavior of a structure by adding collapse triggers instead of changing the materials or the general geometry [3].

In comparison with round cross section, elliptical cross section of beams makes it stiffer, also it improves the manufacturability aspects in terms of joint welding. As the chassis failure is more vulnerable under lateral stresses, so this thing should be kept in consideration during designing of chassis frame. From the modal analysis using FEA tool, we can find out the natural frequency of the chassis and make the changes accordingly in order to keep it out of the range from 4 Hz to 8 Hz to which humans are more sensitive [4]. The study depicts the optimization of tractor trolley chassis to carry maximum load. It shows the comparison between chassis designed with "C" and "I" cross sections. Also it gives a methodology to select the optimum parameters of the "C" section using orthogonal array method. The maximum deflection and stress are determined by performing stress analysis for different sections. The present work deals with the analysis of the experiment by Taguchi method. The experimental and computed results are compared and verified with 5% to 10% of difference [5]. Analysis of natural vibration frequency and dynamic mode of the frame is an important process to ensure operating capabilities of autos. The FEA software ABAQUS is used to get accurate frame stress distributions, frame deflection laws at its two ends and the middle point, and transient frame dynamics. With Transient dynamic analysis of the frame, the nodal vibration amplitude was found varying with the changed supporting positions of the frame, and in this paper efforts were made to reduce the frame vibration amplitude to achieve the most stable state of the frame. Analysis in this paper provides a reference basis for structural optimal design of the frame [6].

Another way to enhance the strength of components is to add reinforcements to the model. A failure analysis of a longitudinal stringer of a prototype vehicle has been carried out in this study. Stress analysis is carried out using finite element analysis and according to its results a reinforcement model to solve the problem is proposed. Experimental results of reinforced model are compared with numerical values and both assure the safety of modified stringer [7]. In efforts to increase the strength of a structure without increasing its weight is to modify its cross sections in such a way that it gives higher resistance to applied loadings, The "I" cross section of beams gives more stiffness against bending loads in comparison with "C" cross section. This study gives design recommendations for stainless Steel "I" sections under concentrated traverse loading [8]. This study throws some light on use of non-slender and slender high strength Steel circular hollow sections, elliptical hollow sections, square hollow sections and rectangular hollow sections [9].

3. MATERIAL BASED WEIGHT REDUCTION STRATEGIES

Use of materials having high strength and low density is a great approach to reduce the weight of an automobile part. The performance requirements and materials related to weight saving strategies for a variety of automotive chassis components have been reviewed. This study suggests two most impacting strategies of weight reduction as use of carbon fiber polymer matrix composites and continuous fiber selectively reinforced Aluminum metal matrix composites. It also supports its financial feasibility in automotive industry [10]. The financial feasibility in the use of light weight material is an aspect of most concern. A simple analysis of this problem suggests that materials costs and process represent the major obstacles to expansion of this market. On a piece cost basis, glass fiber composites typically provide weight savings compared to Steel but invoke a cost penalty whilst the converse is true in a similar comparison with Aluminum. Graphite composites offer weight savings but cost penalties compared to both metals [11]. Another study on use of composites focuses on use of composite materials E Glass Epoxy and S2 Glass Epoxy. Since the density of composite materials is less than that of Steel, the weight of chassis reduces using composite materials than Steel , also the strength of the composites is more than that of Steel . Comparing the results for all three materials, the stress value is less for E-glass Epoxy and also its weight is less compared with other two materials. This study concludes that using E Glass Epoxy is better option for frameless chassis with loads [12]. The study compares the results of finite element analysis of chassis model with E-glass epoxy and carbon epoxy as material with the base material Steel. Findings of this study show that carbon epoxy provides better strength as compare to E-glass epoxy and Steel [13].

Use of Aluminum and magnesium as substitutes of Steel is widely used approach in light weighting of heavy components. Lightweight metals may be used in the vehicle in both wrought and cast forms. Aluminum, in the form of stamped sheet, has the potential to be used extensively in vehicle structures and closures. However, compared to Steel, Aluminum is more difficult to stamp and spot weld. Magnesium, Aluminum, and metal-matrix composite castings have the potential to be used as replacements for many ferrous castings in power- train and chassis components. This article describes some of the technical issues that must be considered if the automotive industry is to utilize these lightweight materials in larger volumes [14]. Jorge along with ronny and silva give the novel procedure to help in selecting and changing the materials used for structural components of commercial vehicles. They suggest high strength cast ferrous materials as a cost competitive lightweight alternative in commercial vehicles [15].

Based on the available light weighting technologies willium and etal. selected two lightweight materials, namely Aluminum 7075-T6 and magnesium HM41A-F were for study. Based on the finite element analysis of the two design alternatives as well as the baseline Steel design for given loading and constraint conditions, they concluded that use of magnesium HM41A-F results in more weight reduction compared to Aluminum 7075-T6. The work presented in this study explores the potential weight savings achieved through designs using different material candidates to meet mechanical related requirements [16]. Rahaman and Jayahari tested the mechanical properties and wear behavior of Aluminum 6061 matrix reinforced with Steel machining chips. By comparing test results of composite with that of pure Aluminum 6061, they concluded the wear resistance improve with the use of the Steel machining chips powder as reinforcement [17]. Sivananthan, Ravi and Samuel used silicon carbide particles as reinforcement in Aluminum 6061 matrix. By varing the percentage of SiC particles in Al matrix they carried the tests for Hardness, tensile strength and compression strength and found the improvement up to 25%, 25.6% and 12% respectively in comparison with Aluminum 6061 [18]. Nagendra kumar mourya etal. experimentally studied the effect of increase in weight percentage of SiC particles in Aluminum 6061 matrix. The results showed that the rate of increase in tensile strength as well as hardness is higher than the rate of increase in density with the increase in percentage weight of silicon carbide particles in Aluminum 6061 matrix [19]. But in an another study zare and etal. contradictorily found that with the increasing amount of reinforcement of SiC in Aluminum the density of composite decreases with increase in porosity. This study also determined the thermal conductivity of composites and found it decreasing with increase in SiC percentage [20].

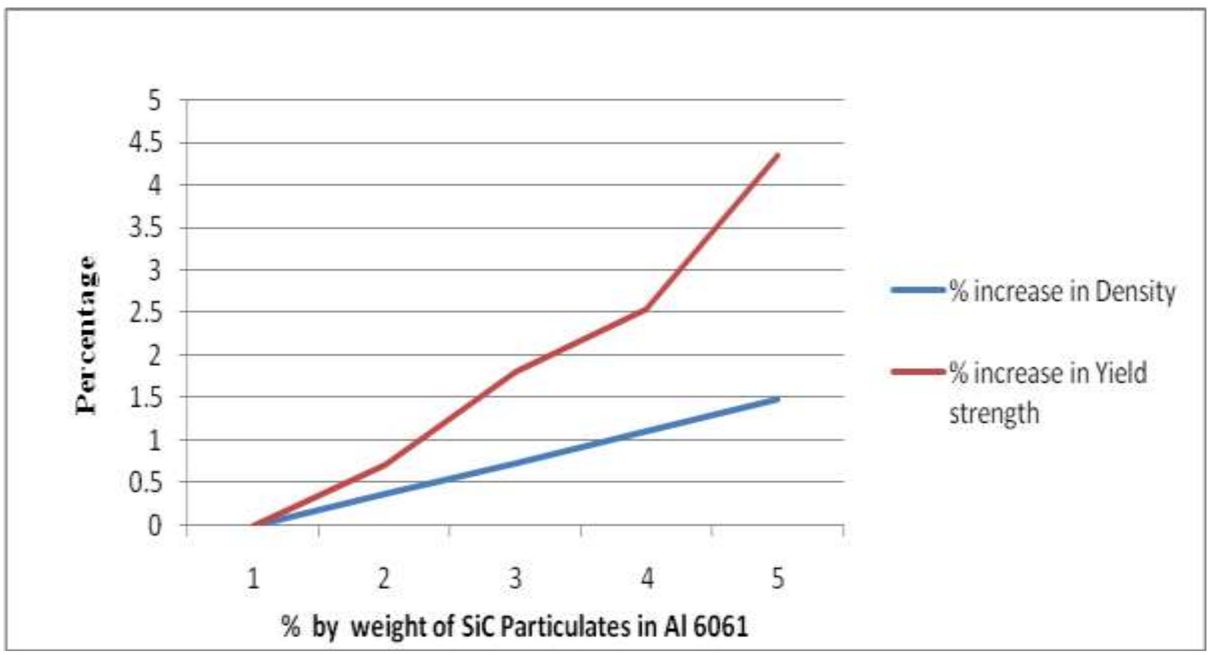

Figure 1 : Comparison between percentage increase in density and percentage increase in yield strength with percentage increase in sic particulates in Al 6061 matrix.

4. CONCLUSIONS

The use of low density high strength material for the chassis frame can reduce its weight by sufficient amount. Composites of Aluminum 6061 as matrix material and Steel chips particles or SiC particulates as reinforcements shows enormous increase in tensile strength and hardness as compared to increase in weight. Also the I section, hollow circular, elliptical, square and rectangular sections for chassis frame give it better strength in comparison with solid circular or C section.

5. REFERENCES

[1]. Yucheng Liu, "Development and evaluation of a finite element truck chassis crash model", "International Journal of Crashworthiness", Vol. 15, No. 1, February 2010, page no.107–113.
[2]. Mohd Azizi Muhammad Nor etal., "Stress Analysis of a Low Loader Chassis ", "International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012) ", page no. 1877-7058.
[3]. Augusto Millán Gardea & José Carlos Miranda Valenzuela, "Topological optimization of automotive structures under impact using robust design", Computer-Aided Design and Applications 2015.
[4]. Balaguru S, Elango Natarajan, Ramesh S, Muthuvijayan B, "Structural and modal analysis of scooter frame for design improvement", "International Conference on Advances in Materials, Manufacturing and Applied Sciences", Proceedings 16 (2019) 1106–1116 .
[5]. R. V. Patil , J. U. Marathe, A.P.Tadamalle, Dr. Y. P. Reddy, "Optimisation of tractor trolly chassis using orthogonal array method", "International Conference on Advancements in Aeromechanical Materials for Manufacturing (ICAAMM-2016)." Proceedings 4 (2017) 8796–8805.
[6]. Yuan Ren, Yongchang Yu, Binbin Zhao, Chuanhui Fan, He Li, "Finite Element Analysis and Optimal Design for the Frame of SX360 Dump Trucks", "13th Global Congress on Manufacturing and Management, GCMM 2016 ",Procedia Engineering 174 (2017) 638 – 647 .
[7]. V. Veloso, H. S. Magalhaes, G. I. Bialhao, E. S. Palma, "Failure investigation and stress analysis of a longitudinal stringer of an automobile chassis" Engineering Failure Analysis 16 (2009) 1696–1702.
[8]. G.B.dosSantos⁎,L.Gardner, "DesignrecommendationsforstainlessSteel I-sectionsunderconcentrated transverse loading", "Engineering Structures" 14March2019.
[9]. Xiaoyi lan, Junbo chen, Tak-ming chan, Ben Yang, "The continuous method for the design of high strength Steel tubular sections in bending", "Journal of constructional Steel research" 160 (2019) 499-509.
[10]. D.M. Baskin, "A Perspective on Future Automotive Chassis Component Materials", "Materials Technology Advanced Performance Materials", 16 September 2016
[11]. C.D. Rudd & C F. Johnson, "Current Trends In North American Lightweight Vehicle Manufacture", "Materials Technology Advanced Performance Materials", 16 September 2016.
[12]. Mooli Harish, K. Bhaskar, "Modelling And Analysis Of A Heavy Vehicle Chassis By Using Materials E-Glass Epoxy & S-2 Glass", "International Journal of Recent Technology and Engineering", ISSN: 2277-3878, Volume-7, Issue-6, March 2019.
[13]. Priyanka Ranu , Rajeev Singh Chauhan, Dr. V.N. Bartaria, "Mathematical Modelling and Analysis of Automotive Chassis with Composites Materials Using Fem", "International Journal for Research in Applied Science & Engineering Technology" ISSN: 2321-9653 Volume 5 Issue VI, June 2017.
[14]. G. S. Cole and A. M. Sherman, "Lightweight Materials for Automotive Applications", "International Metallographic Society Symposium on "Microstructural Characterization of Light- weight Materials for Transportation", Montreal, July 24-25, 1994.
[15]. Jorge Santos, Ronny M. Gouveia, F. J. G. Silva, "Designing a new sustainable approach to the change for lightweight materials in structural components used in truck industry" "Journal of Cleaner Production", 164 (2017) 115-123.
[16]. Gergis William, Mark S. Shoukry and Jacky C. Prucz West Virginia University, "Analysis of Lightweighting Design Alternatives for Automotive Components", "SAE International by Univ of Nottingham - Kings Meadow Campus," Tuesday, September 11, 2018.
[17]. Md Sumair Ur Rahman, L Jayahari, "Study of mechanical properties and wear behavior of Aluminum 6061 matrix composites reinforced with Steel machining chips", "ICMPC_2018" Proceedings 5 (2018) 20117–20123.
[18]. S. Sivananthan, K. Ravi, C. Samson Jerold Samuel, "Effect of SiC particles reinforcement on mechanical properties of Aluminum 6061 alloy processed using stir casting rout", "International Conference on Recent Trends in Nanomaterials for Energy, Environmental and Engineering Applications." 2019.
[19]. Narendra kumar mourya etal., "Investigation of mechanical properties of Al 6061/SiC composite prepared through stir casting technique" "2nd International Conference on Computational and Experimental Methods in Mechanical Engineering", 2019.
[20]. Reza zare, Hassan sharifi, mohammad reza saeri, morteza taebi, "Investigating the effect of SiC particles on the physical and thermal properties ofAL6061?SiC_P composite", "journal of alloy and compounds",2019, page no 520-519.