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A Review on Static Analysis of Aluminium Carbody Structure for Passenger Trains

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Abstract—**This review paper focuses on the on studying the static analysis of aluminium car body structure for passenger trains. Based on continued development and demand for passenger trains around the world, stability and safety of trains is also increasing. It is of much importance to accurately carry out a detailed evaluation of the static structural analysis of the carbody for safe operations. In this study the characteristics of these alloys based on their strength considerations when subjected to static loads using finite element methods are analyzed. Different cases of static loading are considered to replicate the actual loadings that take place. The simulation results showed that Al 6005A has better characteristics for building car body structure.**

***Index Terms*—Static analysis, Aluminium, Passenger train, Carbody, Finite element**

1. INTRODUCTION

The carbody is the load carrying structure of a rail vehicle consisting of doors, windows, Body shell, headlight and other parts. It also consists of the access panels that are watertight and withstand extreme weather conditions without leaking.

Before putting a rail vehicle into operations, certification through performing static and tests using international standards must be done. Numerical and experiments tests are used to determine the static behavior of carbody structures however experimental measurements are time consuming, expensive and cannot be applied at all stages of design [1].

Over the years, the design of rail vehicle car body has developed from a basic steel structure that meets the requirements of strength and functionality to a design which is more complex and efficient to aluminium. Aluminium enhances the way the products perform with reference to stiffness, impact absorption, strength and with the reduction of weight and conservation of space at the same time. The relevant technical specifications for static and dynamic characteristics of light weight body design must be achieved to ensure safety, comfortability and reliability of the car body structure. At this point, extensive numerical studies should be carried out for determination and improvement of static strength of lightweight rail vehicles. Finite element method is a very strong numerical tool widely used in determing the static and modes of the carbody structure accurately and whether they meet the technical requirements.

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2. REVIEW METHODOLOGY

The review involved reading literatures of the already existing work carried out by other scholars. The literature was obtained from research sites like google scholar, science direct and scopus. The target information was obtained use key words like rail vehicle carbody, static analysis, aluminium carbody and passenger rail carbody.

This involved identifying carbody specifications, performed calculations to identify the different forces acting on different carbody regions, modelling the carbody using solid works, exporting the 3D model into ansys, identification of boundary conditions, application of forces, obtaining results, discussion and drawing conclusions.

Furthermore, it involved reading the literatures of the work already done by the other different scholars and comparing their results.

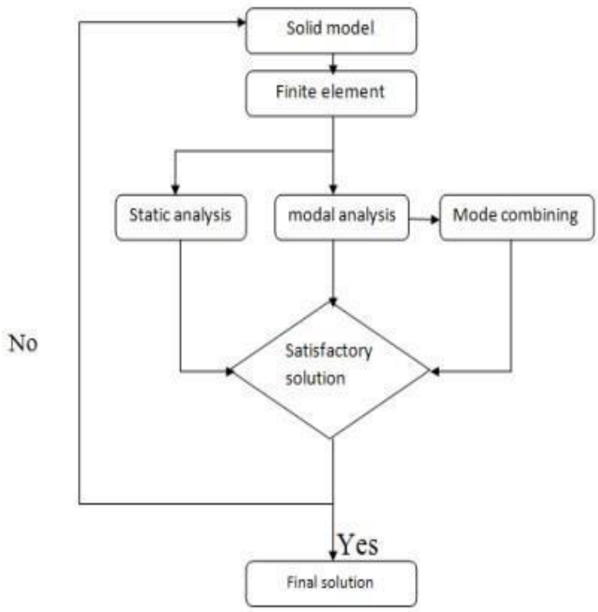

Fig 1: Showing steps for carrying out static structure analysis [2]

3. LITERATURE REVIEW

This chapter concentrates on reviewing the already existing work carried out by other scholars.

The vehicle body consists of the main load carrying structure above all truck suspension units. It includes all components that are connected to this structure and contribute directly to its strength, stiffness and stability. Due to the complexity of the forces, the carbody has needs to withstand a number of forces which include longitudinal, transverse, vertical, tensile and compressive force so the carbody is established using a shell [2].

Railway vehicle bodies shall withstand the maximum loads consistent with their operational requirements and achieve the required service life under normal operating conditions with an adequate probability of survival. The capability of the railway vehicle body to sustain required loads without permanent deformation and fracture [3]. To prove the safety of carbody Japanese industrial standards regulate load test for the prototype carbody restricting it to load tests only [4].

Different research has been done on the materials used for the rail vehicle carbodies to get the materials advantage to minimized the stress, vibration, minimize the material deformation and other related to maximize the static nature of the car and also done to reduce the weight of the vehicle body.

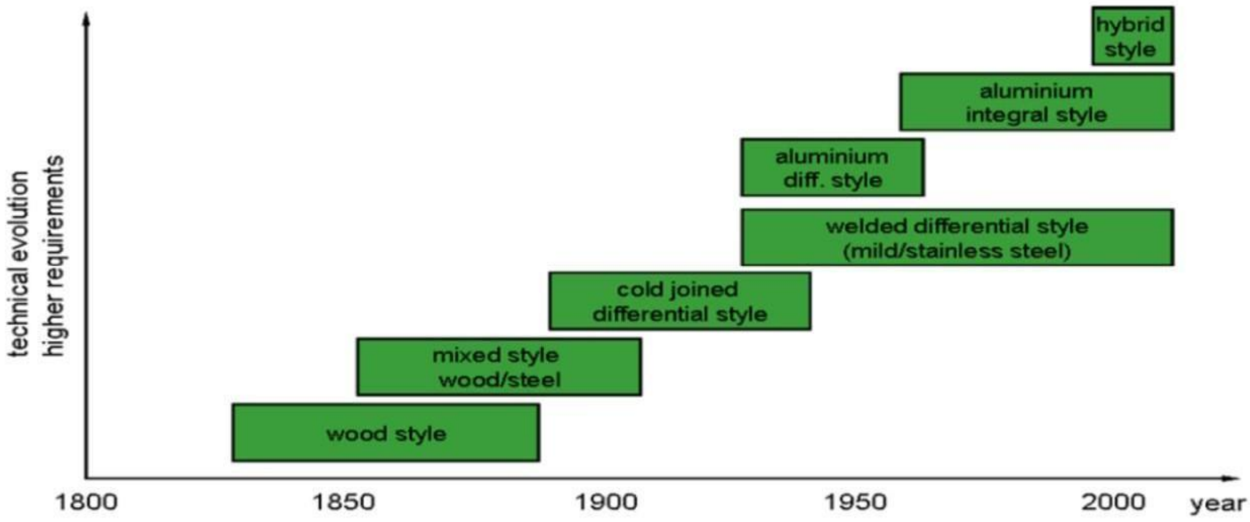

Fig 2: The show the chronology development of rail vehicle body material from the begging of the railcar to the recent history [4]

4. REVIEW

The geometry for the car body structure is displayed in the figure below. It is divided into several main components, namely underframe, side-wall, end-wall, roof, and main support beam, as shown. Aluminum is utilized for underframe, roof, side-wall, and end-wall. In this numerical simulation, two series of aluminum are considered that is Al 6061 and Al 6005. All material used is considered having bilinear isotropic behavior, in which the material properties 21.9kgf/mm^2 and 25kgf/mm^2 for Al 6005 and Al6061 respectively [6].

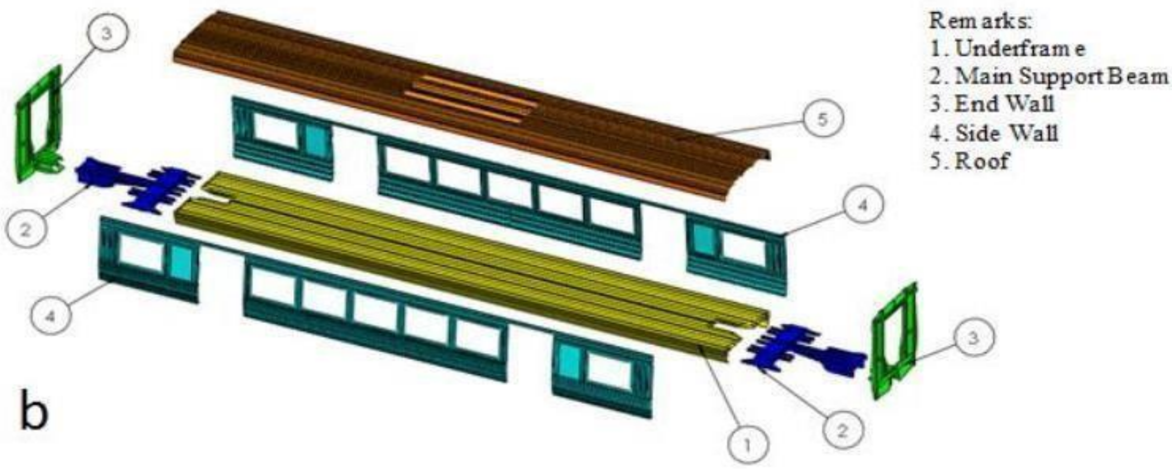

Fig 3: Showing parts of a carbody structure [5]

The vertical load due to passengers is calculated based on equation 1, which is recommended by the European Norm (EN) 12663-1:20.

$$\mathbf{P_V = k\,(P_1 + P_2)}$$

Where is vertical load, is a dynamic coefficient (1.3), P_1 is tare weight of car body and P_2 is the number of passengers times its masses

The vertical loads considered during the analysis were carbody 186000N, air conditioning 8700N, auxiliary control machine module 11000N, coupler 1810N, battery charger 2000N and total force due to passengers 410570N [6].

During application of forces, the wheels were fixed as boundary conditions and the forces applied as shown in the figure below.

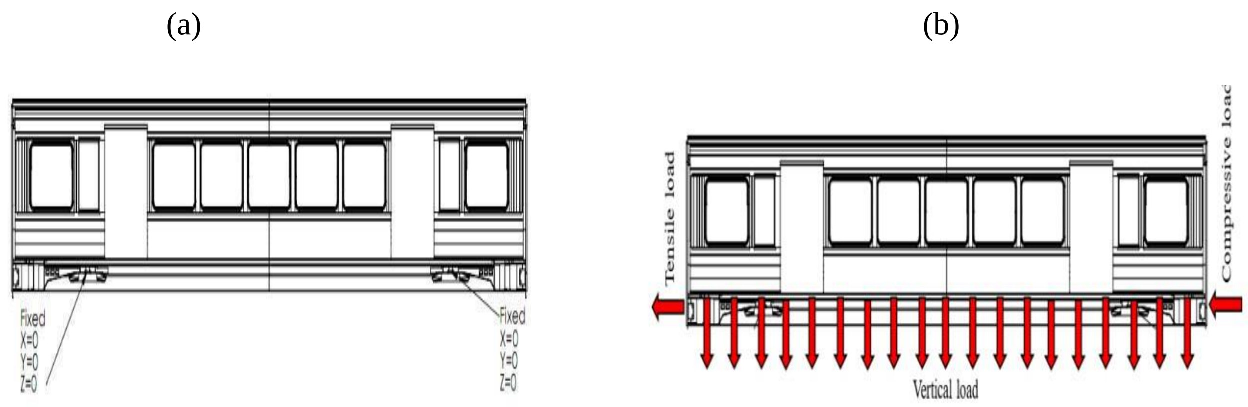

Fig 4: Figures 4a and 4b: Show boundary conditions and location of forces respectively [5]

5. LOAD CASES

The following cases were considered during application of loads

Case A: Vertical load without passengers.

Case B: Vertical load considering full passengers.

Case C: Vertical load including compressive and tensile loads without passengers.

Case D: Vertical load including compressive and tensile loads with full passengers.

6. RESULTS AND ANALYSIS

6.1 Von misses results from ANSYS

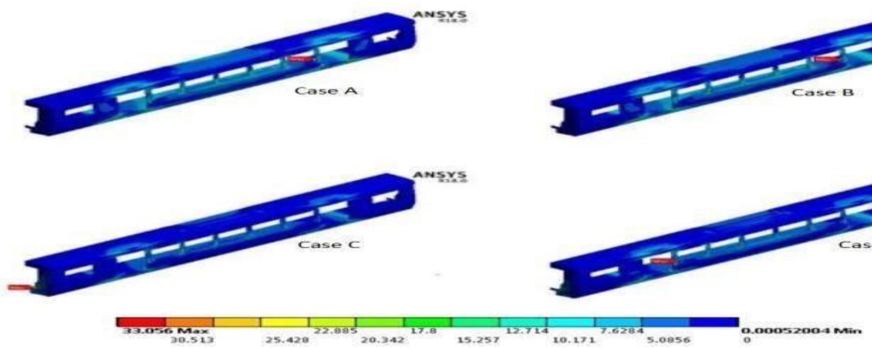

Fig 5: Distribution of von misses under various loading cases for AL6061[5]

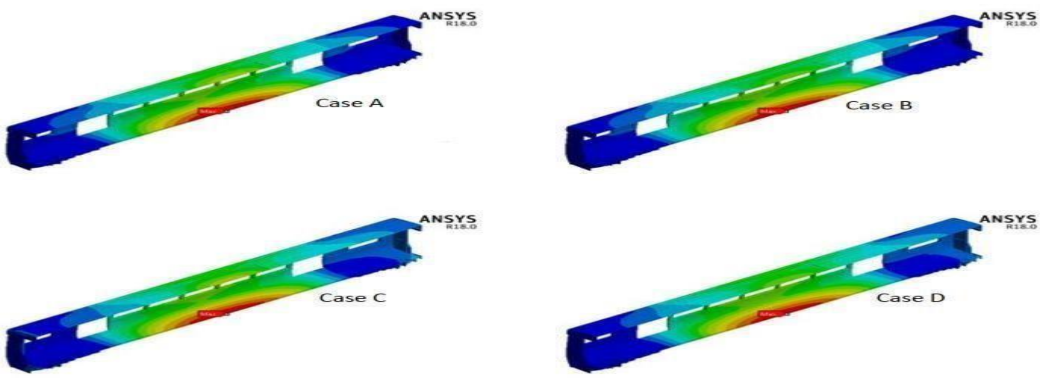

Fig 6: Distribution of von misses stress under various loading cases for Al 6005 [5]

The von misses stresses obtained ranged from 21.084MPa to 39.298MPa for Al 6005a and 18.907MPa to 33.056MPa for Al 6061 having a factor of safety ranging from 8.19 to 15.27 for all the cases.

6.2 Total deformation results

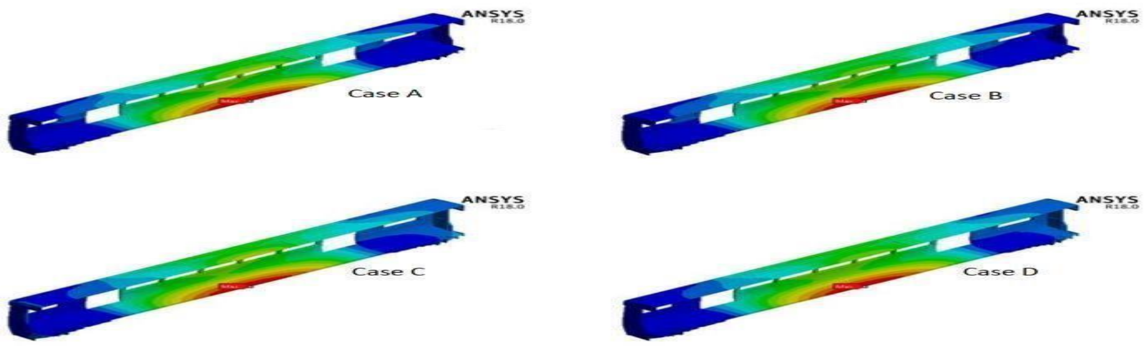

Fig 7: Total deformation results under various load cases for AL6061[5]

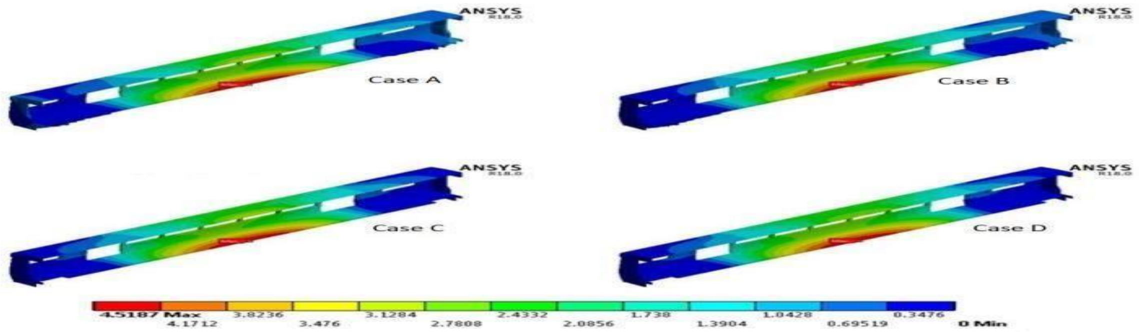

Fig 8: Total deformation results under various load cases for AL6005 [5]

The total deformation results ranged from 2.9298mm to 3.9846mm for Al 6061 and 3.242mm to 4.5187mm for Al 6005 for all the cases and the maximum stress occurs at the window area.

(a) (b)

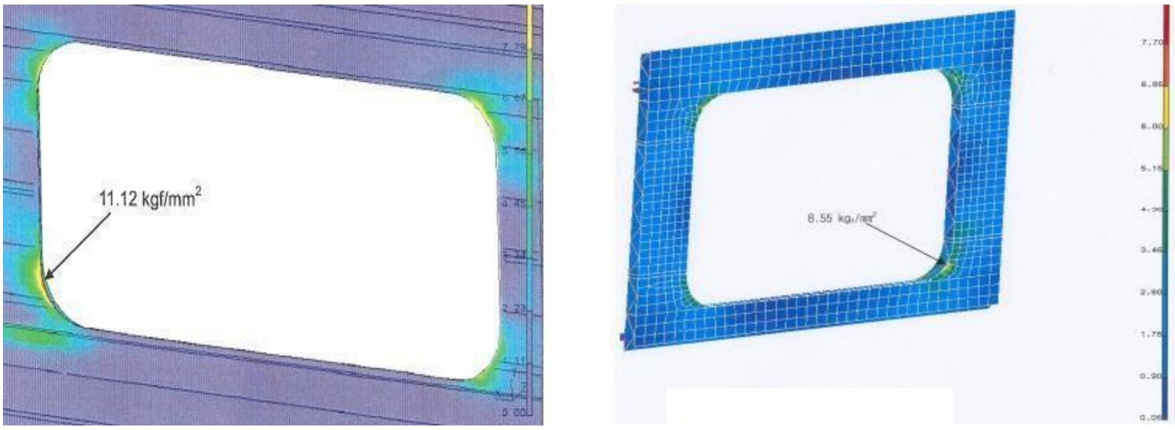

Fig 9a and 9b: Showing maximum stress distribution at the window [6][7]

6.3 Discussion of results

By following the LRT design report made by Central Corridor Light Rail Transit (CCLRT), which explains that the maximum deflection limit that occurs in the car body construction of LRT is 0.375 in or 9.525 mm. Thus, the car body construction of the rail vehicle is safe if the total deformation is less than the maximum deflection limit allowed according to the report.

In terms of loading cases A, B, and D, the stress is concentrated at the corner of the window that may lead to failure and therefore attention should be paid to the corner of the window, even the value of stress concentration is still in a safe area [7].

Tab 1: Showing a range of von misses stress and deformation values of the two types of aluminium

Type of Aluminium	**Stress (Mpa)**		**Deformation (mm)**	
	Maximum	**Minimum**	**Maximum**	**Minimum**
Al 6005	39.298	21.084	4.5187	3.242
Al 6061	33.056	18.907	3.9846	2.9298

The maximum von Mises stress within Al 6005a is larger than that within Al 6061 because Al 6005a has lower yield strength rather than Al 6061 (230 MPa to 275 MPa). Thus, the utilization of Al 6005a to replace Al 6061 for constructing the car body is a better choice.

7. CONCLUSION

In this study, in reviewing the safety concerning the structural bodies of a railway vehicle made from aluminum, the vertical loading test was carried out and the following was determined.

- As a result of the static analysis, upon the application of the vertical loading, the maximum stress of the aluminum vehicle occurred in the lower area at the corner of the window. The stresses measured after the loadings were within the allowable stress. Thus, we conclude that the vehicle made from aluminum is therefore safe in its degree of strength.
- Working with the finite element models saves cost and time during the development processes of railroad vehicles, materials and complex simulations can be performed easily at all stages of design.

8. RECOMMENDATIONS

Carbody structures made of aluminium should be preferred to steel structures because they are light weighted which helps saving the amount of energy required to run the train since they also meet the safety requirements for the operation.

9. ACKNOWLEDGMENT

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10. REFERENCES

[1] C. Baykasoglu, E. Sunbuloglu, S. E. Bozdag, F. Aruk, F. Toprak, and A. Muğan, ‘Numerical Static and Dynamic Stress Analysis on Railway Passenger and Freight Car Models’, *Int. Iron Steel Symp.*, no. April, pp. 579–586, 2012.

[2] N. Xie, Y.-H. Lu, Z. Feng, and T.-L. Chen, ‘Fatigue strength research on aluminum alloy car body for railway vehicle based on finite element analysis method’, in *2015 International Conference on Material Science and Applications (icmsa-15)*, 2014, pp. 885–891.

[3] E. Credit, T. C. Number, A. Year, C. One, C. Two, and C. Three, ‘Addis Ababa Institute of Technology School of Mechanical and Industrial Engineering Course description ’:, no. ChEg 5243, pp. 4–5, 2013.

[4] S. Il Seo, C. S. Park, K. H. Kim, B. C. Shin, and O. K. Min, ‘Fatigue strength evaluation of the aluminum carbody of urban transit unit by large scale dynamic load test’, *JSME Int. Journal, Ser. A Solid Mech. Mater. Eng.*, vol. 48, no. 1, pp. 27–34, 2005, doi: 10.1299/jsmea.48.27.

[5] A. Syaifudin, E. M. Nurfadillah, A. R. Farid, and A. Windharto, ‘Strength consideration on car body of light rail transit making from aluminum extrusion’, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1034, no. 1, p. 012025, 2021, doi: 10.1088/1757-899x/1034/1/012025.

[6] W. Kim and K. Choe, ‘A Study on Structural Strength in Carbody Structure of an Express Train Sung-Cheol Yoon’, vol. 418, pp. 101–104, 2010, doi: 10.4028/www.scientific.net/KEM.417-418.101.

[7] S. Yoon, C. Jeon, and J. Kim, ‘Structural Strength Evaluation of a Carbody by Finite Element Analysis and Load Test’, vol. 358, pp. 2728–2731, 2007, doi: 10.4028/www.scientific.net/KEM.353-358.2728.

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