Review on Structural Strength Analysis of Bogie Frame Based on Finite Element Method

Shihab Aldeen Mohammed Fadol

African Railway Center of Excellence, Addis Ababa Institute of Technology, Ethiopia

Abstract: ***The bogie frame of a railway is an important structural member for the support of vehicle loading. Much study has been carried out in experimental and theoretical domains on the prediction of the structural strength of the bogie frame. In this paper I conduct a review on bogie frame structure strength analysis based on FEM , seven publication have been examine to identify the load case condition and to address the location of maximum stress by comparing the methodology of each Arthur and the result.***

Keywords: bogie frame, structural analysis, FEM

1. Introduction

Railway industry has encountered newer stages of progress as: improved running service safety, lightweight structures, and assurance of the maximum loading capacity, reduced product design cycle and in the same time lower costs for construction, maintenance and repair. Most of the railway vehicle studies focus on the complete design process of the key structural components of the railway carriage such as bogie frames, axles, wheels and other components, which includes design procedures, assessment methods, verification and manufacturing quality requirement

Bogie is a chassis carrying wheels, suspension system, and brakes attached under the railway vehicles for running, In general, a bogie frame operate under tractive force, restoring force and propulsion receives fatigue load caused by repetitive vibration forces and landing during service. Structural analysis is a comprehensive assessment to ensure that the deformations of bogie frame structure will be adequately lower than the permissible limits, and failure of structural will not occur

1.1 Bogie

The bogie of a railway vehicle sustains the weight of the car body, controls the wheels sets on straight and curved track and absorbs the vibrations. The bogie consists of a frame, suspension system, wheels-axis sets, braking system.[1]

Bogie frame is a main structure of rail vehicle for undertaking dynamic loads from body and random vibration resulting from track irregularity. Its fatigue strength and stress distribution can effect operation safety of urban transit rail vehicle dramatically. Once the bogie frame propagates crack, fracture and other damage, it is more likely to lead to destruction under complex and strong alternating dynamic loads, and finally results in derailment. During the design period, bogie frame is designed according to some specific standards of load and operating conditions. However, the actual operating conditions may not be completely consistent with the conditions in standard, which brings the risk of bogie frame in application. Therefore, it is necessary to evaluate the fatigue strength of the bogie frame by combing experiment and simulation for better operation.[2]

1.2 Functions of Bogie Frame

Main function of bogie frame are[3]:
1) Support railcar body firmly.
2) Run stably on both straight and curved track.
3) Ensure good ride comfort by absorbing vibration generated by track irregularities and minimizing impact of centrifugal forces when train runs on curves at high speed.
4) Minimize generation of tract irregularities and rail abrasion.
5) Bogie frame have sections for holding bolster, brake arrangement, axle box guide and many other parts which are welded to the frame.
6) Withstand and/or transfer vertical loads of the superstructure with payload, lateral forces caused due to negotiating the curves and interaction between rail and wheel and longitudinal force due to drafting of the coach by the engine.

1.3 Type of bogie frame

Bogies are basically differentiated depending on the design of their frame. With external frame bogies, the frames encompass the wheelsets. From practical considerations and reasons of space, external frames are popular on narrow gauge vehicles, since otherwise the space between the frame sides would be very narrow. There are also differences depending on the position of the axle bearings. In general, they are located on the so-called stub axles, outside the wheel disks. With inner-frame bogies they lie between the wheel disks on the axles, which results in both a smaller support width and another bending stress of the wheelset.

The bogie frames can be designed in "H-form" or in "O-form" depending on the top view. The O-form, which is particularly common in external frame designs, therefore is considerably more rigid than the H-form. A variation of the H-form which allows a slight inclination of both wheelsets is the "Three-piece bogie". In this elastic bogie the two outer long sides with the axle bearings can, in addition, be rotated against the central transverse beam vertically. This has advantages if the track geometry is particularly bad as it transmits fewer pitching and rolling movements.

1.4 Forces

During bogie lifetime several external forces, both exceptional and normal service loads, act on the bogie frame, coming from the wheel-rail contact points and from the interfaces with the car body. These forces are generated from[4] :

1) Double sprung masses, including payload.
2) Track irregularities.
3) Lateral accelerations caused by curve riding.
4) Longitudinal accelerations caused by traction and braking.

As well as other typically exceptional events, for instance:

1) Exceptional pay-loads.
2) Buffer impacts.
3) Minor derailments.

Taking into account all the listed sources the norm defines formulas and coefficients to evaluate the values of the single forces to apply in the calculation process. Groups of these forces, combined in load cases, allow simulating the majority of static and fatigue stress condition on the bogie frame when it is operated on the reference vehicle

1.4.1 Vertical Forces

Vertical forces come from sprung masses. For the typical passenger and locomotive applications, the loads produced by a vertical acceleration of 1.4g on the sprung masses, including the exceptional payload shall be directly applied on the interfaces between bogie frame and secondary suspension. For freight applications different values and application points have to be considered as a consequence of different geometries of frame

1.4.2 Transversal Forces

Transversal forces come from each axle. These forces are generated by wheel-rail contact forces in curve riding. The formula takes into consideration the Proud' Homme limit for the sum of the transversal forces and it is the same for all the categories of railway bogies. In the numerical calculations the constraints are normally applied on the axles and the loads on the bogie-car body interface, putting attention to replicate the load scheme of this connection

1.4.3 Longitudinal Forces

Longitudinal exceptional forces are caused from Traction and Braking in curve riding

1.4.4 Forces of a Potential Collision

The impact forces generate most severe stress state on the longitudinal connection between bogies and car body. This load is caused due to the impact of the car body which induced a longitudinal acceleration of 3g and 5g for locomotives applicable at the center of the gravity of the bogie

1.5 Bogie frame structure strength assessment:

Generally the assessment of the Bogie frame structure strength includes three aspects, namely, the role is to determine the load, static strength analysis and assessment, analysis and evaluation of the fatigue strength, According to the UIC 615-4 or, JIS E4207regulations we can calculate the appropriate supernormal load, simulated operational load and special operational load. Supernormal load when the maximum load operations may occur; simulate actual operating load refers to the load operations occur frequently; special operational load refers to the load frame by a special device caused [3]

The bogie frame supports heavy static and dynamic loads, such as the vertical loads generated by the body of the vehicle, braking and accelerating loads and twisting loads induced by track twisting. Bogie frames usually weigh from 1 to 2 tons. There are several standards for strength evaluation of the conventional bogie frame such as JIS E 4207, UIC 615-4[1]

2. Literature Survey

Regarding the distribution of stresses and strains in a bogie frame, **(Liliana et al)** [5] used three-dimensional finite element method. The model build by SOLIDWORKS software the bogie frame was modeled with 3D tetrahedral elements finite element mesh consisting of 23593 elements and 47486 nodes he found that The identified critical areas are on the top surface of the frame in the vicinity of the applied vertical load and also at central openings The maximum value of the stress obtained with the numerical analysis is 205 MPa

(Wang et al) [2] In his paper he used Solid45 element to carry on the simulation. Considering computational accuracy and speed for large structure, the bogie frame is divided into 383384 nodes and 217068 elements. Hefound outthat the maximum stress is less than the yield strength and the bogie frame always works within the material elastic range, where the maximum static stress located near the air spring seat is 119 MPa under static load condition. The structural strength analysis of bogie frame are calculated for load cases according to JIS E4207 standard, respectively. Based on these results of structural strength analysis, practical operation situation and expert's engineering experience, five critical stress locations have been identified: 1. the welding location between cross beam and gearbox bracket; 2. the welding location between cross beam and longitudinal beam; 3. the welding location between cross beam and traction motor bracket; 4. the welding location around air spring seat; 5. the welding location around braking unit bracket

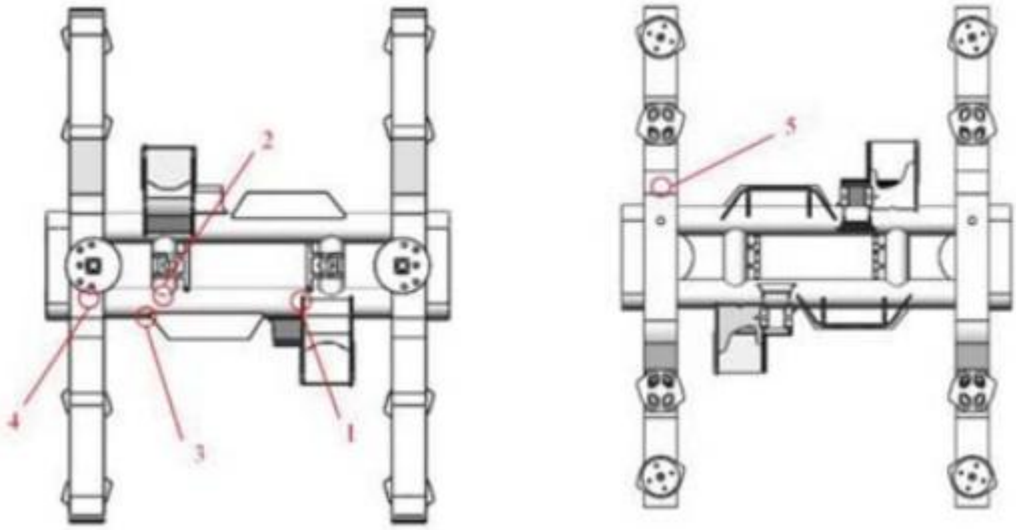

Figure: Show the five critical stress locations

(Seo et al) [6] In his paper driving bogie for electric vehicle was used as case study Transverse forces were applied at the lateral buffers, and the 1st springs were constrained. For the modeling, shell elements were used. The number of elements was 51,811, and the number of nodes was 47,356.The main frame material of the bogie is SM490A, the transom pipe is STKM18B, and the bracket is made from SS400. It found that the maximum stress occurred on the bracket attached under the side frame, the maximum stress of 125 MPa from the result of finite element analysis occurred on the connection between the side frame and the bracket. On transverse load, the maximum stress occurred at the point which is located on the upper side frame, which was the compressive stress. The maximum tensile stress occurred on the connection between the side frame and the bracket. The maximum stress occurred on the connection between the frame and the bracket. The stress that occurred under exceptional loads was less than the yield strength, which was considered to be safe **(Amol B. Sapkal and Saurabh S. Sirsikar)**[7]They used16.25t bogie as case study which is used in Indian Railways ICF, they analyzed the results and found out that Maximum deformation of 0.0311 mm occurs at tip section of blade and Maximum stress developed on bogie frame is 97.5 N/mm2, the critical region of bogie frame is between primary suspension and secondary suspension requires careful attention.

(Bharadwaj) [4] He conducted Stress analysis using ANSYS Mechanical APDL software to compare tow type of bogies used in LHB (Linke Hofmann Busch) coaches the FIAT bogie and CASNUB Bogie, The results obtained from Stress analysis of both the bogie frames are compared. It is observed that:

1) In all the four load cases, maximum Von mises stress induced in the New CASNUB bogie frame structure is less than the maximum Von mises stress induced in FIAT bogie frame structure.
2) In Potential collision with normal service load case, Stresses induced in FIAT Bogie frame are very high resulting in the failure
3) New CASNUB bogie frame can withstand high impact forces.
4) In Potential collision with normal service load case, there is 90.23 percentage decrease in the stresses induced in New CASNUB bogie frame when compared with the FIAT bogie frame

3. Summary

Paper	Type of vehicle	CAD software	FEM software	Type of element	Number of element	Number of node
[5]	Carriage bogie	SOLIDWARK	SOLIDWARK	3d tetrahedral	23593	47485
[2]	Urban rail vehicle(Q 345)	Soild45	Soild45	Not define	217068	383384
[6]	bogie used in an electric vehicle	Not define	ANSYS	Shell element	51811	47356
[7]	ICF coaches	CATIA	ANSYS	default	55598	109337
[4]	FIAT and CASNUB	ANSYS Mechanical APDL	ANSYS Mechanical APDL	Not define	Not define	Not define

4. Conclusion

Structure strength analysis is an optimum method to predict the weakest area in bogie frame it help designer to take measurement to strength the weak point by change the design or the material of the frame as we found that the maximum stress found between primary and secondary suspension.

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