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MODAL ANALYSIS AND STUDY OF SUBWAY BOGIE FRAME UNDER AMBIENT EXCITATION

Pushpadatta B*1

*1Head Of The Department, Department Of Mechanical Engineering, Vidyavardhaka Polytechnic, Mysuru, Karnataka, India.

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ABSTRACT

A wealth of practical cases indicates that the fatigue failure of subway bogies primarily stems from the modal resonance of the structure. If the modal characteristics of the entire vehicle, including equipment and bogies, are mismatched, rail vehicles may experience abnormal vibrations and noise. Therefore, it is imperative to conduct modal analysis and matching design for subway vehicle bogies to ensure smooth operation, reduce structural vibrations and noise, and enhance vehicle safety and ride comfort. Modal identification methods under the ambient l excitations during vehicle operation were employed to identify the modal parameters of the bogie structure before and after wheel reproofing and under different load conditions. According to the test results, wheel reproofing has minimal impact on the modal parameters of the structure, but with an increase in load, the modal frequencies of each order generally increase. This is associated with boundary constraint states, such as the increased stiffness of the bogie air spring with an increase in vehicle load. By comparing the test results with simulation analysis results of the bogie structure under free and constrained states, it is evident that simulating realistic boundary constraint conditions is crucial to ensure the accuracy of the finite element model. Based on frequency isolation criteria and vibration isolation theory, a frequency planning basis for the bogie structure was established. The study found that as the vehicle load increases, changes in the boundary conditions of the bogie affecting the elastic modal frequencies of the structure may have a certain impact on matching design, and may even better comply with the requirements of frequency management equations. This provides a new direction for subsequent scholars researching modal matching design.

Keywords: Subway Bogie, Modal Experiment, Finite Element Analysis, Modal Matching.

I. INTRODUCTION

Trains encounter Different vibration surroundings with distinct characteristics during operation, similar as periodic, arbitrary, and flash excitations, as well as combinations thereof. These different excitation types have varying impacts on outfit, potentially leading to resonance modification, frequency coupling, functional failures, fatigue damage, and strength declination. To alleviate these goods, it's critical to enhance the train's rigidity to vibration surroundings by avoiding resonance or significant modification. The dread, a crucial element icing the safety and functional quality of the vehicle, supports, attendants, and facilitates traction and retardation. Common issues include cracks at motor mount connections, antenna ray fractures, and axle box suspense observance breaks. Modal resonance is frequently the root cause of fatigue failures in shelter bugbears. Misalignment of the modal characteristics of the entire vehicle, including its outfit and bugbears, can lead to abnormal climate and noise

II. METHODOLOGY

Finite element numerical simulation and vibration testing are the primary specialized approaches presently used to gain the structural modal parameters of rail vehicles. Test modal analysis is the process of modal identification of a exploration object under laboratory conditions or functional working conditions. Grounded on whether the external excitation signal is measurable during the identification process, test modal analysis styles can be classified into two orders. originally, Experimental Modal Analysis(EMA), where the input signals of the system is controllable and measurable. The input excitation signal to the system is controllable and measurable. It involves assaying and recycling the response and excitation data to gain the frequency response function of the structure. By combining modal identification styles, the essential frequency, mode shapes, modal damping rate, and other dynamic characteristic parameters of the structure can be linked. Secondly, functional Modal Analysis(OMA), where the input signal of the system isn't measurable, and the excitation signal come from ambient excitations, with only the affair response being measurable. OMA doesn't bear measuring the

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input signal to the system. It solely relies on the affair response under ambient excitation. rather of frequency response functions, OMA replaces them withcross-correlation functions. By applying modal identification styles, the modal parameters of the structure can be linked. Compared to EMA, OMA can perform online analysis using only measured response signals, requires simpler outfit, and can identify modes that are fluently excited under functional conditions.

III. MODELING AND ANALYSIS

Bogie modal test

The running modal trials on the dread frame of the shelter vehicle were conducted under four different operating conditions, including the AW0 condition before reproofing bus, the AW3 condition before reproofing bus, the AW0 condition hence reproofing bus, and the AW3 condition hence reproofing bus. also linked running modal results of the dread frame under different operating conditions were anatomized, and the posterior finite element modal computation results were validated and compared.

Testing protocol

Accelerometers were arranged on both sides of the shelter dread frame, with six detectors on each side on the side shafts. also, two acceleration detectors were placed on the strip, one located at the midpoint and the other at the connection point between the motor and the strip. Each motor on both sides was equipped with one acceleration detector. There are 18 accelerometers in aggregate. The vibration dimension points are shown in Fig. 1, the vibration dimension points are shown in Fig. 1, and the factual test point layout for the dread frame is illustrated in Fig. 2. The named accelerometers have a dimension range of ± 50 g. During the testing process, all acceleration detectors are configured to collect data synchronously, measuring both perpendicular and side vibration accelerations, with a slice frequency set at 1024 Hz. A member of stationary test signal is taken for modal identification, and the performing modal parameters are used to validate posterior finite element models. In addition, the main experimental instruments and outfit used in the test, including data accession bias and handheld accelerometer calibrators, are shown in the Table 1.

Table 1

Number	Instrument	Quantity	Model	Producer
1	Three axis accelerometer	18	-	Langs
2	Data acquisition system and analysis software	1	-	Oriental Institute
3	Portable accelerometer calibration instrument	2	JX-2A	Xinyang Wanda
4	Computer	1	ThinkPad	Lenovo

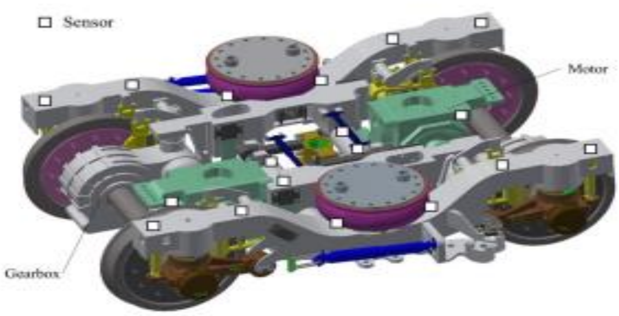

Fig. 1. Schematic diagram of the measurement points for the bogie frame vibration test.

Fig. 2. Actual test point layout for the bogie frame.

IV. RESULTS AND DISCUSSION

Test Results:

According to the statistical table of working modes for the dead frame under different test conditions, it can be observed that for the dead frame of the EMU dread, the modal frequentness corresponding to the four modal mode shapes don't differ significantly between not reproofed and reproofed wheel conditions, with variations within ± 2. Under different cargo conditions, the modal frequentness corresponding to the AW3 condition of the dead frame are generally advanced than those under the AW0 condition, which is related to the increase in cargo affecting the stiffness of the dread frame air spring and other boundary constraint countries.

Bogie Frame Structural modal analysis in simulation:

Finite Element Modal Analysis is a structural vibration analysis system grounded on finite element computations. It investigates the vibration characteristics of structures, including natural frequentness, mode shapes, and modal damping rates, by discretizing the structure and employing principles and ways of the finite element system. Generally, the process of finite element modal analysis includes the following way originally, establish the geometric model of the object under study. Ten, successionally set the material parcels, define contact connections, perform meshing, and apply boundary conditions. Eventually, conduct simulation analysis and affair the simulation results. thus, grounded on the geometric model of the shelter dread frame, finite element modal analysis is performed, considering different constraint conditions, to calculate the modal results under different constraint countries. The software used for this modal analysis is hyperactive mesh. Tis software provides three main styles for rooting eigenvalues the Power Method, the Transformation Method, and the Lanczos Method. Among these styles, the Lanczos Method combines the advantages of the former two styles. It performs well and is generally used as the dereliction system in utmost finite element software for calculating eigenvalues efficiently, without losing delicacy like the Transformation Method or the computational cost of the Power Method. Finite Element Modal Analysis is a structural vibration analysis system grounded on the finite element system. By discretizing the structure and combining the principles and ways of the finite element system, it investigates the essential characteristics of structural vibration, similar as natural frequentness, mode shapes, modal mass, modal stiffness, and modal damping.

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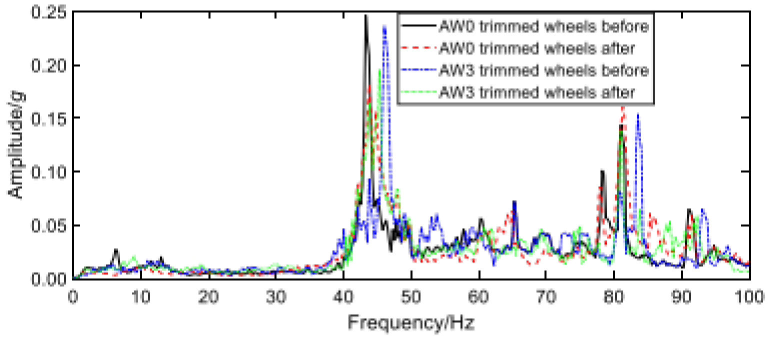
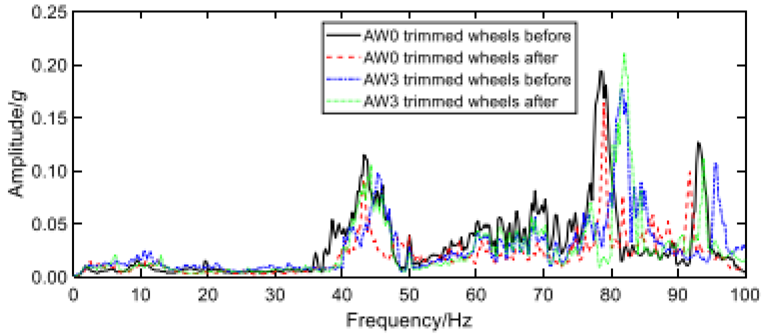


(a)



(b)

Fig. 3. Vibration spectrum of the measurement point at the end of the bogie frame under different test conditions.

Grounded on the test results, the simulated results under constrained ready- to- operate conditions for the dynamic auto dread frame are close to the test results under different lading conditions and wheelset conditions. The divagation is around 10, with a maximum divagation of 13 and an average divagation of 6.7. still, under the Free State, the results show larger diversions from the test results under different conditions, with diversions around 20, a maximum divagation of 28, and an average divagation of 23.7. This indicates that there's a significant difference in the finite element modal computation results under different constraint conditions. It's essential to pretend the factual boundary conditions as nearly as possible to insure the delicacy of the finite element model.

Fig. 4. Finite element model of Bogie Frame

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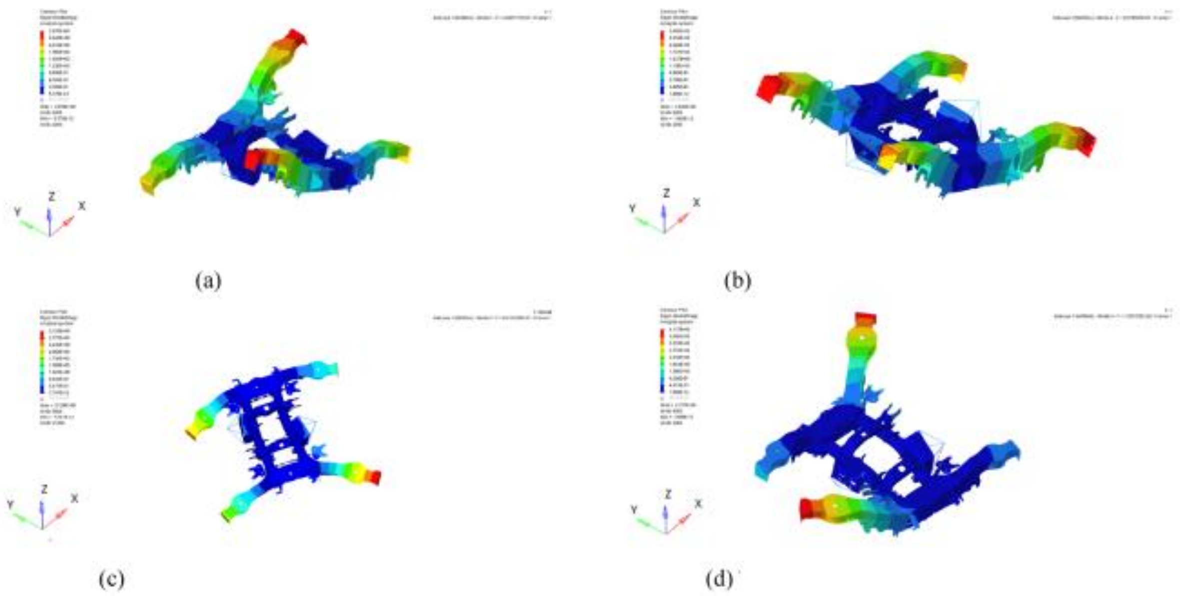

Fig. 5. Modal shape diagram of bogie frame

V. CONCLUSION

For the shelter dread frame, there's little difference in modal frequentness for frame torsion, side bending of the side shafts, perpendicular bending of the frame cross shafts, and distortion of the vertical aeroplane of the side shafts between the conditions " before wheel reproofing " and " after wheel reproofing. " Variations in these modal frequentness are within ± 2, indicating that the wheelset has minimum impact on the modal characteristics of the dread frame. Under different lading conditions, the modal frequentness corresponding to the " AW3 after wheel reproofing " condition are generally advanced than those for the " AW0 before wheel reproofing " condition. This is attributed to the increased cargo affecting the stiffness of the dread air springs and other boundary constraint countries. Under colorful lading and wheel reproofing conditions, the simulated results of the dread frame in the constrained state nearly match the test results under different conditions, with disagreement of roughly 10, a maximum divagation of 13, and an average divagation of 6.7. still, in the Free State, the simulation results diverge significantly from the test structures under different conditions, with disagreement of around 20, a maximum divagation of 28, and an average divagation of 23.7. Tis indicates that there are significant differences in finite element modal computation results under different constraint conditions, and sweats should be made to pretend realistic boundary constraint states to insure the delicacy of the finite element model. Combining frequence insulation criteria and vibration insulation proposition can give a base for the frequence planning of the dread frame. When the vehicle cargo increases, changes in the boundary conditions of the dread affect the elastic modal frequentness of the frame. Tis may have counteraccusations for modal matching design and could more satisfy frequence operation Equations. This provides a new direction for farther exploration by other scholars in modal matching design. Despite furnishing useful perceptivity into the modal characteristics of the dread frame, there are several limitations that need to be conceded. originally, the cargo conditions used in the trials(similar as AW0 and AW3) are specific and may not completely represent the cargo distribution encountered in all vehicle cargo surroundings. Secondly, the disagreement between the simulation results and the experimental results indicate that the current finite element model may not fully capture all the intricate details of the factual dread frame. also, while this study focuses on the conditions ahead and after wheelset reproofing, it does n't consider other factors that might impact the modal characteristics, similar as wheel periphery differences. Compared to applicable former studies, the results of this study have a certain degree of generality, particularly regarding the relationship between modal frequentness and cargo changes. still, given the differences between different vehicle models and manufacturers, the direct operation of the study's results may bear adaptations grounded on specific circumstances. To enhance the general connection of the exploration findings, unborn studies could consider a wider range of boundary conditions and more complex models to more directly reflect real world operating condition.

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