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Search and Survey

Air Brake Distributor Valve Holding Support Bracket Design and Experimental Validation for Railway Freight

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Abstract
Present work deals with design and testing of a support bracket which is used for holding air brake distribution valve of railway freight. Five different brackets are modeled (Cero 3.0 is used for modeling) and tolerance stack up analysis for fitment of the component is checked. A detailed stress distribution pattern and lateral deflection during worst case operation are evaluated through commercially available finite element package (ANSYS 14.5). The modified design for the support bracket successfully tested and installed in the wagon.

Key words: Modeling, ANSYS, Support Bracket, Stress Distribution, Structural Testing.

1. Introduction

Railway freight or passenger cars are equipped with air brake systems for the braking actions. The distributor valve is an important and major component of the air brake. A proper holding or fixing arrangement is necessary to design a wagon specific requirement for the proper positioning and functioning of the distributor valve. In the present case, a 40 feet meter gauge flat wagon is required to fit the air brake system below the wagon underframe. However, due to space constraints and deck height, the conventional fixing of the distributor valve below the underframe was a challenging task. For the present wagon, a flat deck is provided for carrying the ISO container or other commodities in bulk or loose condition. Tow-hooks are also provided for carrying various types of goods. The flat loading area is fully open and easily accessible even for covered wagon after removing the cover. There are several variants of track gauge as well as bogies [1] are available for different railway operating agencies. Worldwide 40% of total transported goods are carried using flat wagons [2]. Present flat wagon (as shown in figure 1) capable of carrying one 40 feet standard container (12.2 m) or two 20 feet (6.1 m). The container can be stacked in a single or double deck depending on the vertical permissible limit

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of particular railway norms. Other commodities in semi-finished or finished condition can also be transported in this wagon. The standard air brake system for this type of wagon was provided by Knorr-Bremse AG which is a Germany based braking system manufacturers for railway and commercial vehicles. Major components of the air brake consist of a 12-inch brake cylinder, DRV450 distributor valve with 2 relays, and a 250-liter air reservoir apart from other mandatory accessories. The typical air brake arrangement system for present wagon is shown in figure 2. The loading pattern will be different for carrying various type of product this required a specific air braking system. Therefore, it is mandatory to design a suitable braking support bracket to withstand the brake cylinder force during the worst loading condition and also for maximum braking load condition under maximum speed of the operator. Longitudinal dynamics of heavy freight trains were determined by Belforte et al. [3] using numerical and experimental techniques. Zhang and Dhanasekar [4] presented an excellent work on the dynamics of railway wagons considering braking actions. Iwnicki et al. [5] summarized the challenges during the design and manufacturing of railway freight wagon for maximum specified speed and superior curve negotiation. Vrtanoski and Smileski [6] reported a meaningful work on dynamic testing of innovative railway brake systems for freight wagons. The concept of a distributed regenerative braking system for freight trains was reported by Pyper and Heyns [7].

Campbell [8] patented his invention on adjustable air brake hose support for railway vehicles while Eason and Khatchadourian [9] invented the hybrid support bracket for railcar air brake hose. Recently Das and Agarwal [2] reported the camber test and torsional stability test process of flat wagon. In another work, Das and Agarwal [10] have presented an experimental work on compression, tension, and lifting stability test for a meter gauge flat wagon. Das et al. [11] also reported impact stability test on railway freight transport. However, the wagon specific requirement for fitting the air brake system under the wagon is needed to study for specific case wise. The support bracket needs to design and test for the desired performance of the distributor valve of the braking system during braking actions. The wagon specific model and design of such a support brackets are rare in the open literature.

The solebar will experience an unbalanced load during cant deficiencies. Hence, the same unbalanced load will be experienced by the support bracket. In this present paper the modeling, designing, and experimental testing of the stress data and lateral deflection considering the worst condition has been demonstrated. The data from experimental tests are captured in the data acquisition system. Experimental results are analyzed and discussed. Also possible recommendations are given for the fitment of the designed support bracket.

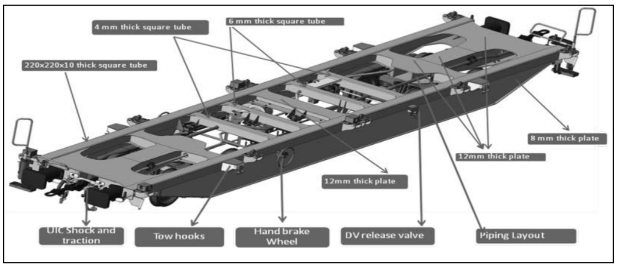

Figure 1: Container/ goods carrying 40' flat wagon

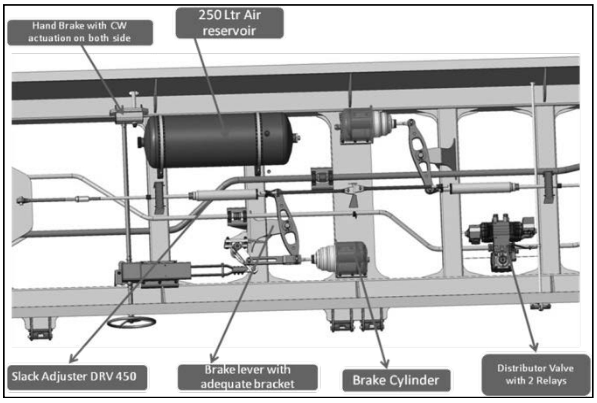

Figure 2: Knorr-Bremse AG recommended Air Brake system components for the present wagon

2. Model preparation

The support bracket used for holding the air brake distribution valve of the present flat freight wagon is modeled using the modeling software Creo 3.0. The support bracket is placed in the cross solebar (2nd from right seeing from bottom) as shown in figure 2. The support bracket has 4 numbers of plates where plate 2 is used twice and other plate is used once. The details of the usage of the plate are shown in figure 3 and table 1. The material used for the plate is SS355J0, which maximum stress withstanding capability is 355 MPa. The weather resistance grade (SS355J0W) of the same material is not used as the brackets system will be under the top cover plate of the wagon and it will not directly expose to the rain.

3. Numerical Stress Analysis

The cross solebar and the support bracket (modeled in Creo 3.0) is imported in ANSYS 14.5 software. The analyzed model is modified in ANSYS and SHELL 63 has been chosen to model the shell model of the bracket. SHELL 63 having 6 DOF per node capable of taking both bending and in-plane normal loads. These types of SHELL structure are also capable to accommodate the stress stiffening and large deflection. The real constraint is used for converting the shell model to a model with different thicknesses of the plate along with sole bar. The shell model has meshed with fine mesh. The mesh size is finalized after a mesh sensitivity study. The analyzed model has 6334 elements (as shown in figure 5). The boundary condition of the model is simulated by arresting all degrees of freedom for both end of the cross sole bar and a worst Case load (50 kN) from the brake cylinder is applied laterally (axial to the brake cylinder) to the support bracket (plate3). The total force (50 kN) is divided equally on the projected diameter wise (half of the node of the hole periphery) which bears the brake cylinder pressure (as shown in figure 6).

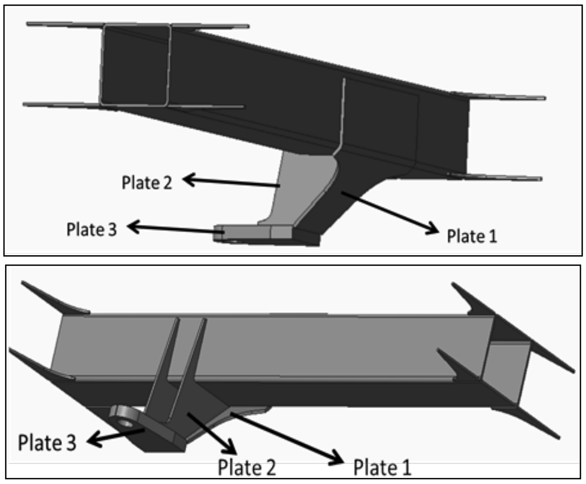

Figure 3: Different view of 3D Model prepared using Creo 3.0

Table 1: Plate number and material grade

Plate No.	Number of plate	Material Grade
Plate 1	1	SS355J0
Plate 2	2	SS355J0
Plate 3	1	SS355J0

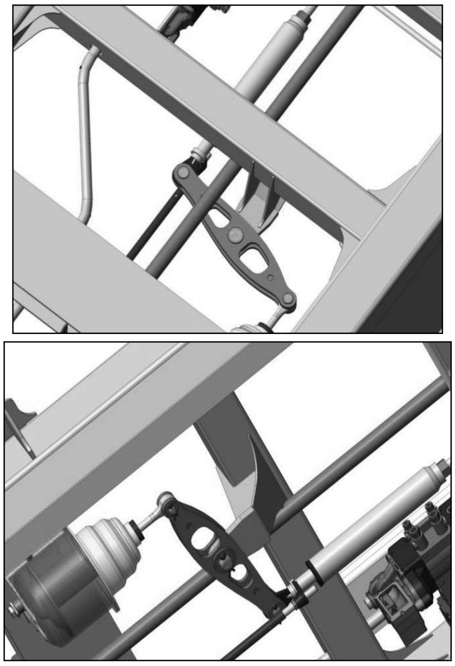

Figure 4: Fitment of the support bracket in the cross solebar with brake cylinder and brake lever

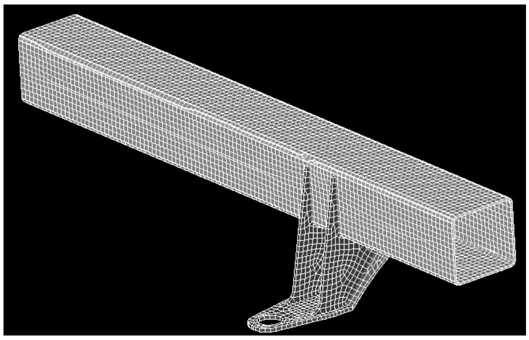

Figure 5: Finite element mesh prepared in ANSYS for numerical stress analysis

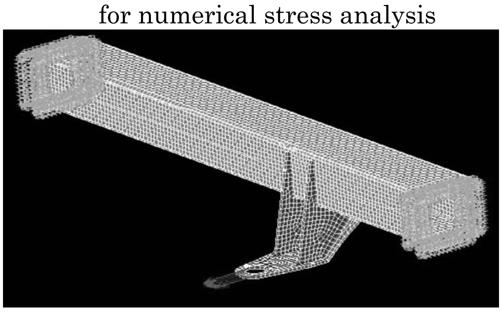

Figure 6: Boundary Conditions are applied using ANSYS

Table 2: von Mises stress in critical section with different design options and plate thickness of the support bracket

Design Options	Plate No.	Plate thickness in mm	von Mises stress MPa in the critical section of the support bracket
Design 1	Plate 1	15	381
	Plate 2	15	
	Plate 3	15	
Design 2	Plate 1	20	355
	Plate 2	20	
	Plate 3	15	
Design 3	Plate 1	15	321
	Plate 2	10	
	Plate 3	20	
Design 4	Plate 1	15	297
	Plate 2	10	
	Plate 3	25	
Design 5	Plate 1	15	267
	Plate 2	10	
	Plate 3	30	

Five different sets of design (design 1 to design 5) with different plate thickness (as shown in table 2) is analyzed for the worst-case brake cylinder force (50 kN). The maximum von Mises stress of the analyzed model is determined as depicted in table 2. The maximum critical stress in terms of von Mises stresses for the design 1 to design 5 are captured as 381 MPa, 355 MPa, 321 MPa, 297 MPa, 267 MPa, respectively. The von Mises stress distribution pattern considering design 1 is shown in figure 7. While the same stress distribution pattern is depicted for design 2 and design 5 in figure 8 and figure 9, respectively.

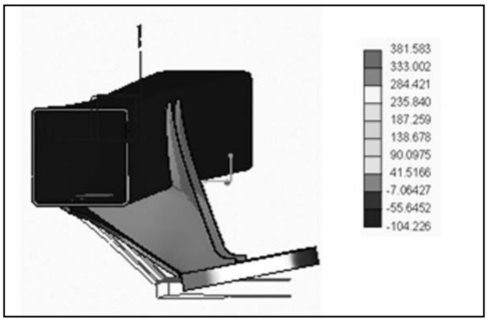

Figure 7: von Mises stress (MPa) distribution for Deign 1 of the support bracket with maximum brake cylinder load 50KN

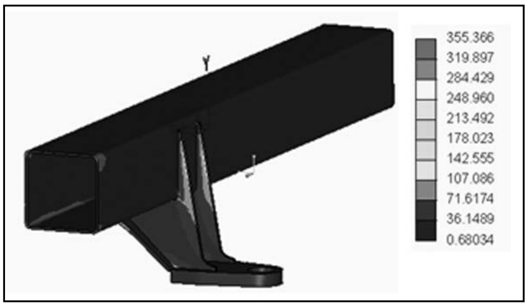

Figure 8: von Mises stress (MPa) distribution for Design 2 of the support bracket with maximum brake cylinder load 50 kN

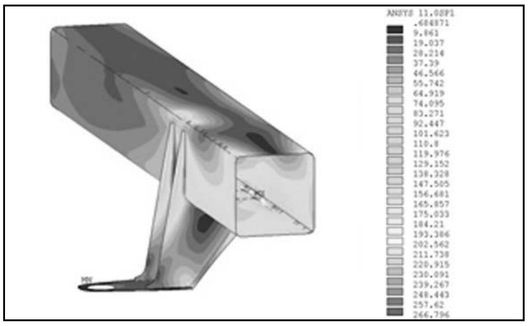

Figure 9: von Mises stress (MPa) distribution for Deign 5 of the support bracket with maximum brake cylinder load 50 kN

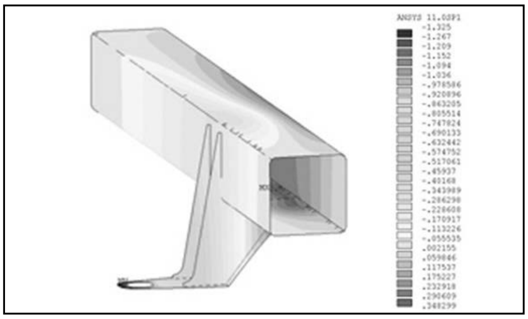

Figure 10: Lateral deflection in mm for Deign 5 of the support bracket with maximum brake cylinder load 50 kN

The present analyzed model is not considered with stress concentration due to the welding joints between plates. For the present model the worst case the safe stress concentration is considered as 1.25. Considering the stress concentration factor 1.25 the safe design is considered as design 5 which gives maximum stress as 333 MPa. The lateral deflection for the safe design (design 5) is captured in figure 10. The maximum lateral deflection of 1.325mm is observed. For all the design options the lateral deflection is provided in table 3. The least lateral deflection of 1.325mm is observed for design 5 cases.

Table 3: Lateral deflection in mm with different design options and plate thickness of the support bracket

Sl. No.	Design Options	Lateral deflection in mm
1	Design 1	6.243
2	Design 2	4.237
3	Design 3	3.025
4	Design 4	1.873
5	Design 5	1.325

4. Experimental SET UP for the test

The Wagon is placed on track under standard conditions. There were two types of tests carried out on the wagon brake cylinder. The first one is the extension force applied on the brake cylinder and the other one when the brake cylinder is pulled back with the same force. The data is captured for both the cases through strain gauges. Wagon equipped with strain gauges of 120 Ohms having length of 10 mm as seen in figure 11 and with a 60-channel DAQ for recording the stress and deformation measured through strain gauges. The deformations (in µm/m) are measured using unidirectional linear strain gauges (called strain gauges) of 10 mm grid length and a resistance of 120 Ω. The measurement signal is conditioned by a Data acquisition unit (MGC PLUS of HBM, Germany& Quantum X- MX 840 2 Nos.) and sampled at 300Hz with auto Filtering (with 4th order Butter Worth low-pass filter). A total of 61 strain gauges are glued to the Wagon. They are located in the selected position of the wagon. The position of the strain gauge in the support bracket is shown in figure 12. The constraints are computed by Hooke's law for elastic deformations by the relation: $\sigma = \varepsilon E$. Where, σ is the stress in MPa, ε is the relative elongation without unit, and E is Young's modulus in MPa).

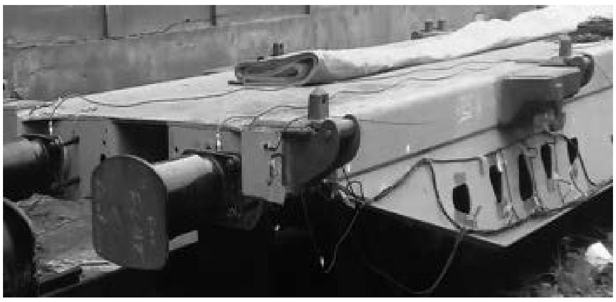

Figure 11 : The flat wagon equipped with strain gauge for capturing the strain

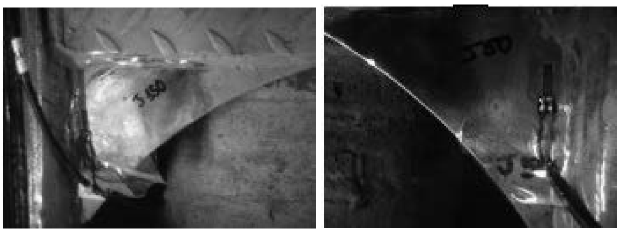

Figure 12 : Support bracket equipped with strain gauge for capturing the strain

The distributor valve of the air brake system of the wagon released and the maximum worst-case brake cylinder load through the piston is applied on the brake lever, this force is taken by the support bracket. The wagon was inspected visually after each data captured to check for any permanent deformation. The critical location stress value for the lever bracket arrangement has been captured with the help of a strain gauge considering the brake cylinder force 50KN. The lateral deflection also measured for the worst brake cylinder force. Both the data are illustrated in table 4.

Table 4: Design Data (Design 5) Vs Experimental data comparison deflection (mm) and von Mises stress (MPa) of the support bracket

Numerical Analysis Results		Results from Testing	
deflection (mm)	von Mises stress (MPa in the critical section	deflection (mm)	von Mises stress (MPa in the critical section
1.325	267	1.410	279.5

5. Results and Discussions

The lever bracket arrangement has been analyzed for maximum critical stress and deflection with 50 kN Brake force both numerically and experimentally. For numerical simulation, five different sets of designs with different plate thicknesses have been analyzed. The bracket is manufactured and installed in the wagon based on design 5. The wagon is tested as per the test program prescribed by EN 12663-2:2010 standard. During the testing of the wagon, the maximum stress in the critical location of the bracket is captured along with the lateral deflection. Stress data has been captured during testing of the wagon performance by strain gauges. The lateral deflection is also noted after applying the worst brake cylinder force. The maximum von Mises stress in critical location is observed as 381MPa, 355MPa, 321MPa, 297MPa, 267MPa for design 1, design 2, design 3, design 4, and design 5, respectively. While the maximum lateral deflection is observed as 6.243mm, 4.237mm, 3.025mm, 1.873mm, and 1.325mm for design 1, design 2, design 3, design 4, and design 5, respectively. The maximum stress level observed by testing is 4.6% higher than the designed stress but well within the permissible limit (355Mpa). Lateral deflection captured from actual testing is 4.4% higher than the computer-simulated lateral deflection.

6. Conclusions

During this modeling, numerical stress analysis and experimental method a suitable design process is established to determine the suitable bracket support for the given air brake arrangement to withstand the air brake cylinder pressure. Based on the design and testing of the present support bracket, the following outcomes can be outlined.

a. A common methodology for modeling and design of support bracket is developed. This process can be used for other type of wagons for specific use and specific braking system.
b. This will act as general guidelines for the wagon manufacture to design and test the support bracket considering worst-case braking load. This will ensure the required life of the components and safe operation during braking actions.
c. The design engineer can take proper safety measures due to maximum brake cylinder pressure by the operating railways for a given set of the braking regime.
d. For the present case, the five sets of designs have been modeled and design 5 is taken as safe design. The individual stress for the critical location for five different sets of design has been captured numerically. It has been shown that the plate 3 has a major influence to reduce the critical section stresses as well as the lateral deflection.
e. The maximum stress level observed by testing is 4.6% higher than the designed stress but well within the permissible limit (355Mpa).
f. Lateral deflection captured from actual testing is 4.4% higher than the computer-simulated lateral deflection.
g. The modified design for the bracket support successfully installed in the wagon after satisfactory testing.

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