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Optimization of Bogie Frame in Indian Railway

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Abstract

Our project was carried out at “Integral Coach Factory Chennai” at shell division in shop no 21. Our project is entitled as Optimization of Bogie Frame in Indian Railway. The bogie frame is an important and integral member of bogie. The main purpose of the bogie frame is to withstand and/or transfer the various forces acting on it. Each coach under frame requires two Body frame. An attempt to optimize the current conventional sleeper bogie frame and to compare already optimized Fiat bogie frame with the conventional bogie frame is done in this project. Optimization of the conventional sleeper frames is done by making changes in their side structural member’s cross section. Currently the side member in conventional sleeper frames are in shape of I section, which has been converted into channel section. Fiat bogie frames are currently imported in India from Germany. In this project we are recommending the usage of the better bogie frame in keeping the view of increased safety. This comparison will be made by analyzing the behavior of the frames under static load conditions using analysis software. Modeling and analysis will be done using PRO-E and ANSYS respectively. Both the frame will be first modeled using modeling software PRO-E. The solid model will be then imported to ANSYS by saving the file in IGES format. Using the boundary and load conditions, finite element analysis will be done. The results obtained for the frames will be compared to find the optimized model. In total, by adopting better frame which give less deflection and less induced stress value, the safety and operation at higher speed can be insured in addition to reduction of weight that happen in case of Fiat frame.

Keywords: ANSYS, Body Frame, Conventional Frame, Fiat Frame, H Beam, Indian Standard Column, I Section, Pro/e, Static Analysis

1. Introduction

1.1 General Description about Bogie Frame

The bogie frame is an important and integral member of bogie in ICF rail coach. The bogie in coach construction plays a vital part since factors like safety, speed and comfort mainly depend on the bogie on which the coach body is loosely mounted. The main purpose of the bogie frame is to 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.

The conventional bogie frame is made of heavy plate sections fabricated to form “H” type frames consisting of two side frames, two transoms, two headstocks and four longitudinal. The Fiat bogie frame consists of two side frames connected by means of two circular cross section. The material used is mild steel, (IS 2062, fe410wc) and the frames are fabricated by employing CO₂ welding techniques.

It supports the bogie bolster, wheel arrangement, primary, secondary suspension and it provides pivoting action while accepting the curves. It bares entire load of the coach and transmit to the wheel through side bearers the tractive effect which is transmitted through centre pivot pin both static and dynamic loads while running.

1.2 Functions of Bogie Frame

- The main purpose of the bogie frame is to 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.
- To have flexibility in the wheelbase, two bogies are provided per coach, which are pivoted at two points by members called centre pivot.
- Bogie frame have sections for holding bolster, break
arrangement, axle box guide and many other parts which are welded to the frame.

1.3 Location of Body Frame
Body frame is located as shown in the Figure 1 below in a bogie. Each coach under frame requires two bogie one for the front chassis and another for the back chassis of a coach. Bogie frame consists of many sections for accommodating many parts of the bogie as shown in Figure 1.

1.4 Problem Identification
With the constant need of ensuring safety and fast movement of the passengers and raw materials, ICF has embarked on the process of replacing old aging bogies with the new and high speed bogies without compromising safety of the passengers.

So they decided to introduce Fiat bogies which can operate at higher speed and are stronger than the conventional one apart from being of less weight.

But ICF imports these coaches from Germany. They currently lack the necessary technical skills to manufacture these coaches. So, this paper is an attempt to help them in gauging the effectiveness of the new bogies by conducting static structural analysis on bogie frame and proving the advantage it have over the conventional frames.

Apart from these, a new type of frame is being studied too, having converted the conventional frame I section into box section, which can be easily slipped into manufacturing mode if found suitable because of the similarity it have with the current bogies.

1.5 Loads Acting on Each Frame
Given:
- Gross weight of the coach = 52 tonnes
- Weight of the two bogies = 11.8 tonnes
- Furnished body weight = 40.2 tonnes
- With 20% shock load = 12.06 tonnes

Load distribution:
- Loads on body bolster per coach = furnished body weight + shock load
  = 40.2 tonnes + 12.06 tonnes
  = 52.26 tonnes

- Loads per body bolster = Loads on body bolster per coach/2
  = 52.26 tonnes/2
  = 26.13 tonnes

- For single side bearing = 52.26 tonnes/4
  = 13.08 tonnes.

1.6 Analysis of Bogie Frame
- Steps involved
  - Modelling in Pro/e.
  - File Menu → Import IGES → Click ok.
  - Main Menu → Preference → check “Structural” → ok.
  - Main Menu → Preprocessor → Element Type → Add/Edit/Delete → Click “Linear” element type → ok.
  - Main Menu → Preprocessor → Element Type → Add/Edit/Delete → click add → give required values → Click ok → close.
  - Main Menu → Preprocessor → Material Props → Material Models → “Structural” → double click “Linear”
→ double click “Elastic” → double click “Isotropic” → Input EX (YOUNGS Modulus) → Input PRXY (Poisson’s Ratio) → ok.

- Main Menu → Preprocessor → Meshing → Mesh Tool → ”Mesh” → click “Pick All”.
- Main Menu → Solution → Define Loads → Apply → Structural → Displacement → On Areas → Pick the fixed end area by mouse click → Click “ok” → Choose “All DOF” and put “0” as the value → Click “ok”.
- Main Menu → Solution → Define Loads → Apply → Structural → Force/Moment → On Key points → Pick points on the edge → Click “ok” → Choose “FY” as the direction and Input -5 into the value → Click “ok”.
- Main Menu → Solution → Current LS → Click “ok” → Click “yes”.
- Main Menu → General Post processor → Plot Results → Deformed shape.
- Main Menu → General Post processor → Plot Results → Contour Plot → Nodal Solution.

1.7 Input Parameters

1.7.1 Conventional Frame

Element type – solid 10 nodes 92.
Vertical load – 65400 Newton at each BSS bracket.

Table 1.

| Sl. No. | Description         | Values  |
|--------|---------------------|---------|
| 1      | Poisson’s Ratio     | 0.33    |
| 2      | Young’s Modulus (N/mm²) | 2.1 x 10⁵ |
| 3      | Tensile Strength (N/mm²) | 480     |
| 4      | Yield Strength (N/mm²) | 340     |
| 5      | Density (Kg/mm³)    | 7.85 x 10⁻⁶ |

2. Fiat Frame

Element type – Shell 63.
Load – 130000 N at each secondary suspension.

Table 2.

| Sl. No. | Description         | Values  |
|--------|---------------------|---------|
| 1      | Poisson’s Ratio     | 0.33    |
| 2      | Young’s Modulus (N/mm²) | 2.1 x 10⁵ |
| 3      | Tensile Strength (N/mm²) | 420     |
| 4      | Yield Strength (N/mm²) | 220     |
| 5      | Density (kg/mm³)    | 7.85 x 10⁻⁶ |

3. Optimized Frame

Element type – Solid 10 nodes 92.

Load – 65400 at each BSS bracket.

Table 3.

| Sl. No. | Description         | Values  |
|--------|---------------------|---------|
| 1      | Poisson’s Ratio     | 0.33    |
| 2      | Young’s Modulus (N/mm²) | 2.1 x 10⁵ |
| 3      | Tensile Strength (N/mm²) | 480     |
| 4      | Yield Strength (N/mm²) | 340     |
| 5      | Density (Kg/mm³)    | 7.85 x 10⁻⁶ |

Figure 2. Conventional model.

Figure 3. Fiat model.

Figure 4. Optimized frame.
Figure 5. Nodal solution of conventional frame.

Figure 6. Fiat frame.
4. Results of Analysis

The value of maximum induced stress obtained through analytical method in three cases are little lesser than the value obtained from ANSYS analysis\cite{10,11}. This is because: here only side frame is considered as beam but in ANSYS the whole frame is analyzed. So, the load acting on the one side frame is also impacting the other side frame, as there is transfer of load through the cross member. Hence, stress produced in one side frame studied individually is less than the ANSYS value obtained for whole frame.

| Frame Property | Conventional Frame | Fiat Frame | Optimized Frame |
|----------------|--------------------|------------|-----------------|
| Deformation (D<sub>mx</sub>) mm | 0.684498 | 0.172349 | 0.46767 |
| Maximum induced stress (s<sub>mx</sub>) N/mm$^2$ | 145.398 | 100.998 | 135.66 |

5. Conclusion

- Deflection and maximum stress induced in Fiat bogie frame is comprehensively lesser than that of conventional bogie frame. The claim of Fiat bogie frame being better suited for higher speed and load is justified.
- Deflection produced in optimized bogie frame for the same load is much lesser than that of conventional bogie frame in spite of maximum induced stress being only just lesser. Hence, optimization of conventional bogie frame is done.
- Among three kind of bogie frame discussed here, the Fiat bogie frame is found to be most suitable as maximum induced stress as well as deflection produced is lesser than both the model, but as Fiat is not an Indian design and till now not in manufacturing stage, optimized model can be also tried with some careful changes as these types of frames with little alteration are currently used for suburban train.

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