Analysis of Bogie Frame Manufactured with Different Processes

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Abstract

This paper presents the analysis of bogie frame when manufactured through casting and fabrication by finite element method. The objective is to analyze effects of manufacturing over strength of the bogie frame with all its loading conditions. This is will provide us the best suited process of manufacturing for Bogie Frame.

Keywords – *Bogie Frame, Casting, Fabrication, Finite Element Analysis,*

I. INTRODUCTION

The HTSC (high traction/speed-three axle) bogie assembly support the weight of the locomotive and provide the means for transmission of power to the rails. The HTSC series truck is applied to AC transmission locomotives used in freight service. This bogie is designed as a powered "bolster-less" unit. The locomotive carbody weight is transferred directly to the bogie frame through four rubber "secondary" spring pad assemblies, which also provide yaw stiffness for tracking stability. The relatively stiff "secondary" suspension and uniform traction motor orientation improve weight transfer within the bogie for optimal adhesion performance. A soft "primary" suspension is designed to provide good ride quality and equalization of wheel set loads for operation over track irregularities.

Traction loads are transmitted from the bogie to the locomotive under frame through the pivot pin assembly Although the bogie frame itself is rigid, the soft spring design allows the end axles "yaw" freedom within the frame to position the wheelset axles to the curves center for reduced wheel and rail wear. A "traction rod" and collar/bushing attached to the journal bearing adapters and bogie frame helps control movement of the end axles and transfers driving force to the bogie frame [1].

In the development of bogie frame, the design improvement of railway vehicle was done continuously to strengthen its strength and make up for its weakness [2]. In order to save energy and material, analysis of bogie is performed for various loading conditions by B H Park, K Y Lee [3]. Various studies including the constructional study of locomotive has been carried out to have information about the dynamic properties of the bogie [4]. WANG Kun-quanv analyzes the existing status and development of heavy haul traffic in various countries, and necessity and feasibility of development on heavy load AC locomotive bogie [5].

Geoffrey Boothroyd says during design is the initial step and the important decisions are made that affect the final cost of a product in this stage and also he focuses on the occurrence manufacturing problems in the early stages of product design and development[6]. Therefore, Bogie frame can be manufactured either through Casting Process (fig. I) or Fabrication (fig. II). Both the process gives different results when carried out.

Fig. I Casting Bogie frame

Fig. II Fabricated Bogie frame

Masahiko Onosato says "Virtual Manufacturing makes it possible to estimate manufacturing processes previously without using real facilities, and therefore, Virtual Manufacturing is expected to be used for many applications in manufacturing" [7]. Hence finite element analysis of the bogie frame manufactured through the process of casting and fabrication should be done to check the results.

The main objective is to check the results of both the processes and then compare them so that the bogie produced either of the processes with best results.

II. CASTING AND FABRICATED BOGIE FRAME DETAILS

HTSC bogie frame can be manufactured through Sand Casting Process. In this process the material selected for process is Cast Steel. The chemical composition is stated in Table I.

Chemical Composition	
Carbon,%	0.25 max
Manganese, %	0.85 max
Phosphorus,%	0.05 max
Sulphur,%	0.06 max
Carbon Equivalent, %	0.40 max

TABLE I
CHEMICAL COMPOSITION OF CAST STEEL

The mechanical properties of Cast Steel used in the Casting process are stated in Table II.

TABLE **II**
MECHANICAL PROPERTIES OF CAST STEEL

Mechanical Properties	
Tensile Strength, MPA, min	435
Yield Point, MPA, min	248
Elongation at 50mm gauge length, %, min	24
Reduction of Area, %, min	36
Hardness, Brinell	137 -170

Now HTSC bogie when manufactured through Fabrication Process uses the following types of Material:

Plates: E350 C
Tubes: HFW Tube

The Chemical Composition of E 350 C is briefly described in Table III and the chemical compositions of HFW Tube are shown in Table IV.

Chemical Composition	
Carbon, %	0.20 max
Manganese, %	1.55 max
Phosphorus, %	0.040 max
Sulphur, %	0.040 max
Silicon, %	0.45 max
Carbon Equivalent, %	0.45 max

TABLE III
CHEMICAL COMPOSITION OF E 350 C

Chemical Composition	
Carbon,%	0.20 max
Manganese, %	1.30 max
Phosphorus,%	0.04 max
Sulphur,%	0.04 max
Carbon Equivalent, %	0.45 max

TABLE IV
CHEMICAL COMPOSITION OF HFW TUBE

Now, the mechanical properties of the material E 350 C and HFW tube required for the analysis are tabulated in Table V and TableVI.

TABLE V
MECHANICAL PROPERTIES OF E 350 C

Mechanical Properties	
Tensile Strength, MPA, min	490
Yield Point, MPA, min	350
Elongation at gauge length $5.65\sqrt{S_0}$, %, min	22
Internal Bend Diameter	2t

TABLE VI
MECHANICAL PROPERTIES OF HFW TUBE

Mechanical Properties	
Tensile Strength, MPA, min	430
Yield Point, MPA, min	275
Elongation at gauge length $5.65\sqrt{S_0}$, %, min	20
Internal Bend Diameter	3t

All the above properties are verified during mechanical testing. For mechanical testing of Cast steel, the test bar are to be cast integrally and heat treated by casting and all its properties should confirm to Truck Frame and Bolster Cast steel[8]. Similarly the properties of material for fabrication process confirms to IS: 2062 [9] and IS: 3601[10].

III. EVALUATION OF STRENGTH OF BOGIE FRAMES

A. Structural integrity of Bogie frames

The evaluation of strength for bogie frame was performed as per the assembly load details of locomotive.

The static structural analysis of the bogie frame was done using Ansys v14.0 Workbench, a finite element analysis program.

Fig. III shows the geometric model used for structural integrity analysis of bogie frame (casting model).

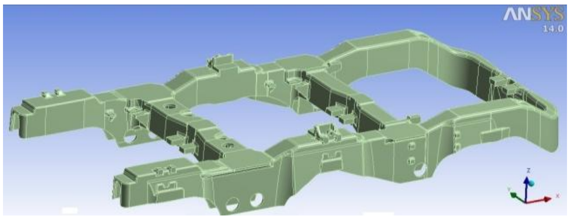

Fig. III Solid Modelling of Casting Bogie Frame

Fig. IV shows the FE model used for structural integrity analysis of bogie frame (fabricated model).

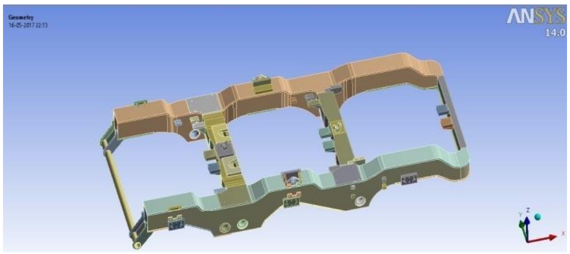

Fig. IV Solid Modelling of Fabricated Bogie frame

For finite element analysis the properties of Cast Steel for Casting Bogie and E 350 C and HFW tube for fabricated bogie are fed into Engineering material Section. During pre processing stage i.e., before meshing the materials are assigned to their respective models and parts.

After meshing the nodes and elements in the Casting model are 186318 and 50203 respectively whereas the nodes and elements in the fabricated model are 189356 and 50568 respectively.

Now the equivalent stress and total deformation is analyzed with load of 125 T equally distributed over four parts and fixing the parts where wheel and axle assembly is fixed.

Fig. V and Fig. VI shows the casting and fabricated bogie frame model with the loads and fixing supports.

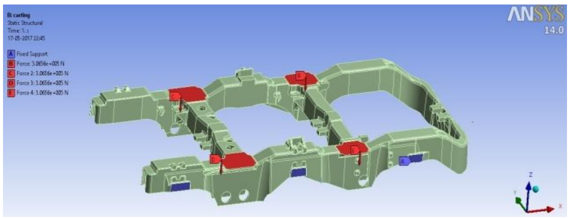

Fig. V Supports and Load Details of Casting Bogie Frame

In the above figures the red spotted areas are showing the areas where the load of 125 T is equally distributed where as the blue spotted areas are showing the fixed supports.

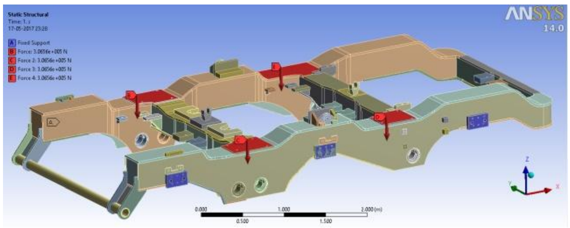

Fig. VI Supports and Load Details of Fabricated Bogie Frame

B. Strength of Bogie frames

In order to evaluate the strength of bogie frame, stress results of static analysis were used.
Fig VII and Fig VIII show the stress results of Casting Bogie Frame.

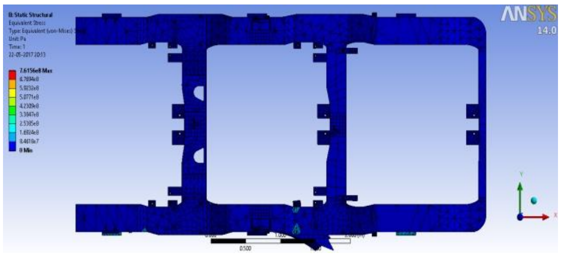

Fig. VII Stress Results of Casting Model

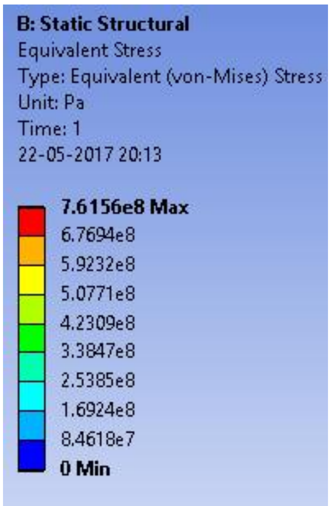

Fig. VIII Stress Results of Casting Model

Above results show that the casting model produces maximum stress results which are not acceptable.

Apart from this Fig. IX and Fig. X shows the deformation due the maximum stress developed.

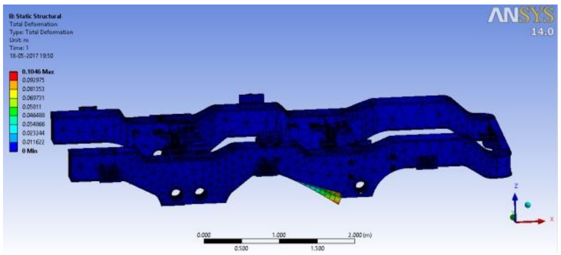

Fig. IX Deformation due to Stresses Developed.

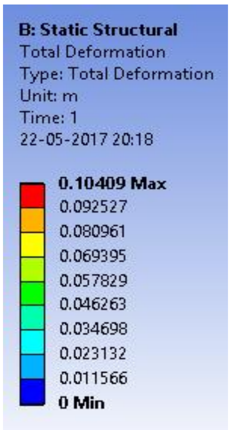

Fig. X Deformation Result due to Stress Developed

This maximum deflection produced is 104 mm which is not acceptable.

Now, the stress result for the fabricated bogie is shown in fig. XI and fig. XII.

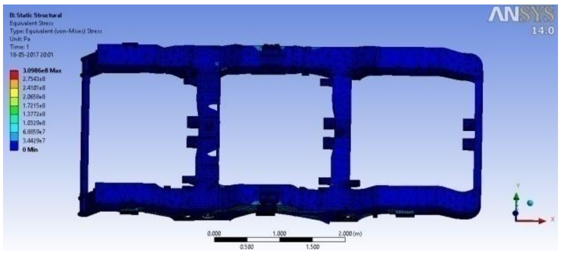

Fig. XI Stress Results of Fabricated Model

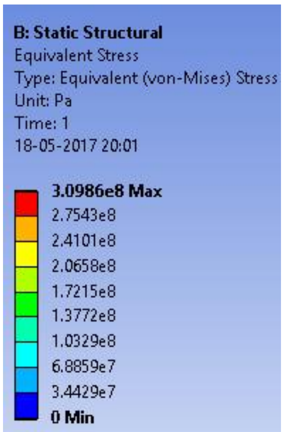

Fig. XII Stress Results of Fabricated Model

The above results shows that the maximum stresses developed are below the yield stress of the material hence the model developed is safe.

Also, the Total Deformation shown in Fig. XIII and Fig. XIV at maximum stress developed are acceptable.

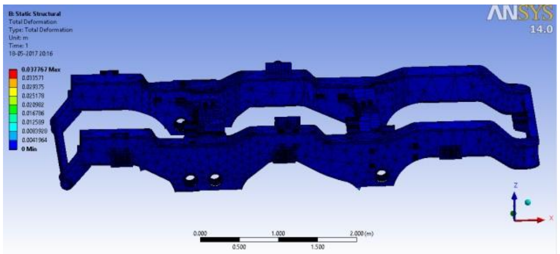

Fig. XIII Deformation due to Stresses Developed.

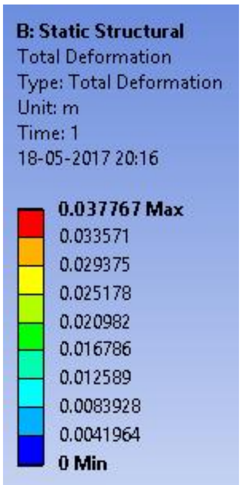

Fig. XIV Deformation Result due to Stress Developed.

IV. RESULT AND DISCUSSION

All the above results show that manufacturing process plays a very important role in deciding the strength of the product. Apart from this there are some differences in both the processes:

- The weight of the casting Bogie is 6.5 T whereas the weight of fabricated model is 5.5 T which shows fabrication model is lighter than casting model.
- The chances of defects in the casting process are more than fabrication.
- The Defects arises in casting cannot be easily rectified or sometimes the product gets rejected due to its defects.
- Preparation of model through casting is a time taking process whereas the fabrication of the same product can be completed in multiple steps and in less time.

All these factors also make fabrication process more suitable than the casting process.

V. CONCLUSION

The structural integrity of a Fabricated Model of HTSC Bogie frame has produced the better results than the casting bogie frame under external loading conditions. Also the benefits of fabricated bogie frame are more. Hence fabricated bogie frame should be preferred over casting bogie frame.

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