Effect of Manufacturing Process on Reliability of Bogie Frame

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ABSTRACT
The objective of this study is to analyse the effect of manufacturing process on the reliability of bogie frame. This reliability analysis is made through evaluating the fatigue life of casting and fabricated bogie frame of locomotive through finite element method. The casting bogie frame is made with the material Cast Steel whereas the fabricated bogie frame is made with the material E 350C and HFW tube. The results show that bogie frame made through the fabrication process is more reliable with comparison to the bogie frame manufactured through casting process.

Keywords-- Bogie Frame, Fatigue, Manufacturing Process, Reliability

I. INTRODUCTION
HTSC (High Tensile Steel Cast) Bogies are three-axle bolster-less bogie with two-stage suspension with helical coil springs in primary stage and rubber compression springs in secondary stage of suspension. The weight of WDP – 4 locomotive car body in which the HTSC bogie fitted is transferred directly to the bogie frame through four rubber “Compression” spring assemblies. The bogie frame is supported on axles through “soft primary” suspension consisting of twelve single helical coil springs, two springs mounted on each axle box, to provide ride quality and equalization of wheel-set loads.

Reliability of Bogie frame is its ability to perform the required function, under given environmental and operational conditions and for a stated period of time [1]. For the development of bogie, the fatigue strength of a bogie frame is an important design criterion [2]. Fatigue life analysis requires various factors that can be evaluated numerically [3].

As simulation is a powerful tool for analysing process performance; its ability is limited by the availability of accurate input information [4]. Therefore, Reliability Analysis of Bogie frame manufactured through casting and fabrication processes by fatigue life through finite element method is carried out.

Researches have been made in reliability and its importance in the product development. In the same context Simon Minderhoud exercises for improving the quality of product by focusing more on the process management aspects as the product creation process can be improved to better adjust to the market requirements [5].

R. Jianga and D.N.P. Murthyb analyzes that the reliability of manufactured products can differ from the desired design reliability due to variations in manufacturing quality. [6]

Amandeep Singh, Zissimos P. Mourelatos and Jing Li discover that Reliability is an important engineering requirement for consistently delivering acceptable product performance through time and also explains that all costs depend on quality and/or reliability [7].

F. Kimura tells it is important to achieve appropriate product reliability with minimum resource consumption. In the total product lifecycle there exist various kinds of disturbances which may deteriorate product quality and functionality [8].

II. ANALYSIS SETTINGS FOR CASTING AND FABRICATED BOGIE FRAME
2.1 Material specification
HTSC bogie can be manufactured either through Casting and or through Fabrication Process. The material in both the processes is different. In Casting the material selected is Cast steel whereas the material for fabricated bogie is E 350 C and HFW tube. The chemical compositions of materials are specified in Table 1.
### Table 1: Description of Chemical Composition of materials

<table>
<thead>
<tr>
<th>Element</th>
<th>Casting Bogie</th>
<th>Fabricated Bogie</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>Mn</td>
<td>0.85</td>
<td>1.55</td>
</tr>
<tr>
<td>P</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>S</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>Si</td>
<td>-</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Analysis requires mechanical properties of the material hence the required mechanical properties of the materials used in casting process of bogie frame are specified in Table 2.

### Table 2: Mechanical Properties of Cast Steel for Casting Bogie

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th>E 350 C</th>
<th>HFW Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, MPA, min</td>
<td>435</td>
<td>430</td>
</tr>
<tr>
<td>Yield Point, MPA, min</td>
<td>248</td>
<td>275</td>
</tr>
<tr>
<td>Elongation at 50mm gauge length, %, min</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Reduction of Area, %, min</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Hardness, Brinell</td>
<td>137 -170</td>
<td></td>
</tr>
</tbody>
</table>

All the above properties were obtained through the specification EMS 22 [9].

Similarly the mechanical properties of E 350 C which are used as the material for plates and HFW tubes are specified in Table 3.

### Table 3: Mechanical Properties of E 350 C and HFW Tube for fabricated Bogie

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th>E 350 C</th>
<th>HFW Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, MPA, min</td>
<td>490</td>
<td>430</td>
</tr>
<tr>
<td>Yield Point, MPA, min</td>
<td>350</td>
<td>275</td>
</tr>
<tr>
<td>Elongation at gauge length $5.63\sqrt{S_0}$, %, min</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>Internal Bend Diameter</td>
<td>2t</td>
<td>3t</td>
</tr>
<tr>
<td>Hardness, Brinell</td>
<td>170</td>
<td>170</td>
</tr>
</tbody>
</table>

These properties are obtained from IS: 2062 [10] and IS: 3601[11]

### III. Evaluation of Fatigue Life

#### 3.1 Loading Details.

Finite Element Modelling of Bogie frame made through Casting and fabricated process requires solid modelling and are shown in Fig. 2(a) and Fig. 2(b). Solid modelling of both the bogie frames is slightly different.
Both the type of Bogie Should with stand the load of 125 T as per the assembly details of Locomotive WDP 4. Hence analyses have been made considering this load over the frame.

3.2 Pre-processing of Model

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

FEA meshes the geometric model to finite element model converting the solid model to elements and nodes to perform the analysis. Therefore, in this case too meshing of the models has been done. 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.

3.3 Fatigue Analysis

The fatigue analysis of bogie frames can be performed by using S – N curves obtained in above process. For analysis, different criterions are proposed i.e

a. Gerber line: A parabolic curve joining Endurance limit on the ordinate to ultimate stress on the abscissa.
b. Soderberg line: A straight line joining Endurance limit on the ordinate to yield stress on the abscissa
c. Goodman line: A straight line joining Endurance limit on the ordinate to ultimate stress on the abscissa

Now since the Goodman line is safe from design considerations hence it is preferred for the fatigue life analysis.

Fig. 3(a) and fig. 3(b) shows the good man diagram for Cast steel and E 350 C.

Using the Good man diagram fig. 3(a) the fatigue analysis for Casting Bogie frame is shown in fig. 4(a) and 4(b).

Fig. 4(a) and fig. 4(b) Fatigue life analysis of Casting Bogie Frame
Similarly the fatigue analysis carried out using Good man diagram fig. 3(b) for fabricated bogie frame is shown in fig. 5(a) and Fig. 5(b)

**Fig. 5(a) Fatigue life analysis of Fabricated Bogie Frame**

**Fig. 5(b) Fatigue life data of Fabricated Bogie Frame**

IV. RESULTS AND DISCUSSIONS

Analysis of casting and fabricated bogie frame produces the result that minimum life at which the model will start deforming will be 1053.3 cycles where as for fabricated bogie it is 10346 cycles.

Despite of these results there are some more facts that are to be considered:
- Weight of fabricated Bogie is lesser than the weight of casting bogie.
- Lesser weight of fabricated bogie also contributes to life of bogie frame and which leads to greater life of locomotive.
- Manufacturing Cost of a Casting Bogie is higher than Fabricated Bogie.

V. CONCLUSION

Manufacturing process of the product has the great impact on its Reliability. As it is seen the performance and life cycle of product changes when the manufacturing process changes. Therefore, the fabricated bogie frame is more reliable than the casting bogie frame in all respects.

REFERENCES

[12] ASTM E739 – 10: Standard Practice for statistical analysis of linear or linearized stress life (S - N) and strain life (𝜀- N) Fatigue data