AN INVESTIGATION OF EFFECTS OF AXLE LOAD AND TRAIN SPEED AT RAIL JOINT USING FINITE ELEMENT METHOD

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Abstract
The goal of this research is to investigate the effects of axle load and train speed at rail joint. A three-dimensional finite element analysis of a rail/wheel contact is conducted on the rail joint section of track and dynamic load is applied to develop an estimate respective stresses at the section. In Autodesk Inventor, different components of wheel/rail assembly i.e. wheel, rail, joint, bars, nuts, bolts, and washers are created separately then all components are assembled, and create a complete model of wheel/rail assembly. The finite element program ANSYS is used to model the contact analysis. This ANSYS is used to simulate the loading and boundary conditions of the rail and wheel contact for a stress analysis. Material properties are assumed to be same for rail and wheel, and considered to be bilinear kinematic hardening in ANSYS. A 3-D finite element model for element model for wheel/rail rolling contact is developed on the most critical section of rail track i.e., rail joint to calculate elastic-plastic finite element analysis and 3D stress response in the contact region. These models should be accurately calculating the 3D stress response in the contact region. The reason for this study is to investigate possible changes in rail and wheel contact design in order to improve the performance of the rail track. Obtained results indicate that the von misses stresses, the maximum shear stress and the Equivalent elastic strain are increases linearly with increasing axle load and the effect of train speed on above parameters is relatively weak.

Keywords: Wheel/Rail, Rail-Joint, Stress, contact-impact, FEA

1. INTRODUCTION

The track or Permanent Way is the rail-road on which trains run. The track or Permanent Way is the rail-road on which trains run. It basically consists of parallel rails having a specified distance in between and fastened to sleepers, which are embedded in a layer of ballast of specified thickness spread over the formation. The rail are joined each other by fish plates and bolts and these are fastened to the sleepers by various fittings like keys and spikes etc. the sleepers are spaced at a specified distance and are held in position by embedding in ballast.

Each of the components of track has a basic function to perform. The rails act as girders to transmit the wheel loads of trains to the sleepers. The sleepers hold the rails in proper position and provide a correct gauge with the help of fitting and fastenings and transfer the load to the ballast is placed on level ground known as formation. The sleepers are embedded in ballast, which gives a uniform level surface, provides drainage and transfers the load to a larger area of formation. The formation gives a level surface, where the ballast rests and takes the total load of the track and that of the trains moving on it.
A rail joint is the weakest spots in the railway track. Rail joint are used to connect the ends of two rails horizontally and vertically. The continuity of the railway track is breaks due to the existence of rail gap and difference in the height of the rail heads. Because of the above reasons rail joints are weaker than the rails and subjected to large stress.

![Fig.2 Atypical rail joint](image)

2. **FINITE ELEMENT SIMULATION COMPUTATION MODEL**

A 3-D finite element model for element model for wheel/rail rolling contact is developed on the most critical section of rail track i.e., rail joint to calculate elastic-plastic finite element analysis and 3D stress response in the contact region. These models should be accurately calculating the 3D stress response in the contact region. All the finite element models in this task are built using the commercial software ANSYS.

![Fig.-3 Finite element modeling of wheel rail set](image)

In Autodesk Inventor, different components of wheel/rail assembly i.e. wheel, rail, joint, bars, nuts, bolts, and washers are created separately then all components are assembled, and create a complete model of wheel/rail assembly. To calculate the stresses and strain at the rail joint the load and rotational velocity is being applied. After defining material properties and boundary conditions in ansys results are being evaluated and equivalent von mises stresses and equivalent elastic strain are being determined. All the material properties and data are obtained from the Indian railway.

3. **MATERIAL PROPERTIES**

- Young’s modulus : 210Gpa
- Material density : 7820kg/m3
- Yield strength : 500Mpa
- Tangent modulus : 4000Mpa
- Ultimate tensile strength : 880Mpa
- Tensile yield strength : 540Mpa
- Compressive yield strength : 540Mpa

4. **BOUNDARY CONDITIONS**

In this investigation, we select train speed \( V_0 = 30, 60, 70 \) km/h or \( 18, 36, 42 \) rad/s, and 60% of axle load or vertically downward load \( P_0 = 82.8, 71.7, 110.6 \) KN. UIC 60 rail is mainly used for FE analysis. The wheel and rail in the initial temperature and reference temperature is \( 22^\circ C \). The diameter of wheel is 918 mm. Friction coefficient is considered as 0.15, and the material density is 7820 kg/m3. Material properties are assumed to be same for rail and wheel, and considered to be bilinear kinematic hardening in ANSYS.

![Fig.-4 Loading and boundary condition](image)

![Fig.-5 Loading and boundary condition](image)
5. RESULTS

The von mises stresses, maximum shear stress and Equivalent elastic strain have been determined under the influence of axle load and train speed.

5.1 Effect of Axle Load

Under the condition of $Vo= 18$ rad/s or $30$ km/h, the effect of the $60\%$ of the axle load or vertically downward load on the von mises stress, maximum shear stress and Equivalent elastic strain is shown in fig.

<table>
<thead>
<tr>
<th>Strain in (mm/mm)</th>
<th>Second class3-tier sleeper load</th>
<th>1st class a/c load</th>
<th>Diesel locomotive WDM3 engine load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent elastic strain</td>
<td>$0.0016405$</td>
<td>$0.0018777$</td>
<td>$0.0024767$</td>
</tr>
</tbody>
</table>

5.2 Effect of Train Speed

Under the condition of $P0= 82.81$ KN the, influence of the train speed on the von mises stress, maximum shear stress and Equivalent elastic strain is shown in fig.
<table>
<thead>
<tr>
<th>Stress in (mpa)</th>
<th>18 rad/s</th>
<th>36 rad/s</th>
<th>42 rad/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Von mises stress</td>
<td>394.31</td>
<td>455.87</td>
<td>486.21</td>
</tr>
<tr>
<td>Maximum shear stress</td>
<td>222.29</td>
<td>259.38</td>
<td>277.48</td>
</tr>
</tbody>
</table>

The influence of axle load and train speed on the von mises stresses, the maximum shear stress and the Equivalent elastic strain is plotted in figs. Figures indicate that the von mises stresses, the maximum shear stress and the Equivalent elastic strain are increases linearly with increasing axle load and the effect of train speed on above parameters is relatively weak.
Fig. 16: Equivalent von-Mises stress in rail joint

Fig. 17: Equivalent elastic strain in rail joint

Fig. 18: Maximum shear stress in rail joint

Fig. 19: Equivalent Von-Mises stress in rail joint

Fig. 20: Equivalent elastic strain in rail joint

Fig. 21: Maximum shear stress in rail joint
Fig. 22: Equivalent Von-Mises stress in rail joint.

Fig. 23: Equivalent elastic strain in rail joint.

Fig. 24: Maximum shear stress in rail joint.

Fig. 25: Equivalent Von-Mises stress in rail joint.

Fig. 26: Equivalent elastic strain in rail joint.

Fig. 27: Maximum shear stress in rail joint.
6. CONCLUSIONS
A three-dimensional finite element model is used to analysis the wheel-rail contact impact at rail joint section of track. The finite element program ansys is used to model the contact analysis. This ANSYS is used to simulate the loading and boundary conditions of the rail and wheel contact for a stress analysis. The effects of axle load and train speed at rail joint are investigated in detail. The results from the present investigation are indicates that the axle load has a larger effect on the stresses and strain at the constant speed. The results also indicate that the effect of train speed is relatively weak than to the axle load.

REFERENCES