Vibration Analysis of a Heavy Duty Vehicle King-pin and the Study of its Effects on King-pin Life

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Abstract - Heavy duty vehicles always undergo to heavy loading and hard impacts while running. It often produces vibrations which are due to the bad road conditions, high engine speed or sudden jerks while running on road. Hence the produced vibrations may impact on the king-pin working and its life. We always measure the vibrations in terms of frequency and here the also the vibrating frequency is taken into consideration for entire study. The amount of maximum frequency produce in the king-pin and its assembly should not exceed the natural frequency of king-pin so that it will be safe.

Also it is very important to have maximum natural frequency of king-pin to avoid its failure. But it's totally dependent on the metallurgy of king-pin and its flexibility. When the vibrating frequency reaches more than the natural frequency, there are the chances of failure. Slight increment of frequency will reach the harmonic frequency and at this frequency king-pin will get damaged. Failure of king-pin wills accruse at the resonance frequency which is slightly greater than the harmonic frequency value.

In this paper the vibration/Modal analysis of king-pin is carried out with the help of FEM tool (ANSYS 14.5) and studied for the failure chances of the king-pin. CAD model is prepared in CATIA V5R19 software and further converted into STEP format for importing into ANSYS software. Conclusive statement is written on the basis of vibration analysis results study.

Keywords: King-pin, Natural Frequency, FEM Tool, Resonance Frequency

1.INTRODUCTION

While no current-era automobile front suspension incorporates a physical kingpin, the axis defined by the steering knuckle pivot points acts a “virtual kingpin” about which the wheel turns. This virtual kingpin is inclined toward the centreline of the vehicle at an angle called the kingpin angle. Virtual or physical, the kingpin angle may also be referred to by its acronym KPA, kingpin inclination (KPI), or steering axis inclination (SAI), and remains a fundamental vehicle design parameter. On most modern designs, the kingpin angle is set relative to the vertical, as viewed from the front or back of the vehicle, and it is not adjustable, changing only if the wheel spindle or steering knuckles are bent.

The kingpin angle has an important effect on steering, making it tend to return to the straight ahead or centre position because the straight ahead position is where the suspended body of the vehicle is at its lowest point. Thus, the weight of the vehicle tends to rotate the wheel about the kingpin back to this position. The kingpin inclination also contributes to the scrub radius of the steered wheel, the distance between the centre of the tyre contact patch and where the kingpin axis intersects the ground. If these points coincide, the scrub radius is zero.

Figure 1 shows the pin installed in between hub axle and beam axle. Bushings are attached on the hub axle for the hub movement. King pin is fixed on beam axle and bush is attached on both sides for proper turning. Thrust bearing is also attached on the king pin which protect king pin from damage while sudden shock is imposed on wheel.

1.1. King-pin CAD Model

To prepare the CAD model of King-Pin few commands from sketcher module and part module are utilized. Figure 2 shows the CAD model of King-Pin, which is developed in CATIA v5R19 software. Circle, Rectangle, Axis etc commands from sketcher and pad, shaft, groove and fillet etc commands are utilized from part module. Height, Diameter, groove-depth are taken from reverse engineering process.
1.2 Vibration Analysis of King-pin

Meshing of king-pin is one of the important procedures for performing vibration analysis. Figure 2 shows the meshed view of king-pin. It is simply the small solid pieces called elements which are connected with each other through some known points called as nodes. These elements are having identical shape. In this analysis 3D tetragonal element is used with 3mm maximum size. It is the primary step which always needs to perform to do any FEA analysis. Table 2 shows the total number of nodes and elements formed by meshing process.

![Figure 2: CAD model of King-Pin](image)

### Table 2: Nodes and Elements

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus (E)</td>
<td>2.1e5 MPa</td>
</tr>
<tr>
<td>Poisson's Ratio (µ)</td>
<td>0.285</td>
</tr>
<tr>
<td>Density (ρ)</td>
<td>7865 kg/m³</td>
</tr>
</tbody>
</table>

Table 1: Properties of 20MnCr5 for Structural Analysis.

3. Boundary Conditions

To simulate the proper physical condition, loads and fixed displacement are to be attached properly. In case of King-Pin, it is fixed at the centre of the pin where it actually comes in contact with axle bush. For this project King-Pin used in heavy duty vehicle like bus is considered. Hence the load which is to be applied on King-Pin is considered including thrust and torque. The total load applied in case of steering of wheel and torque applied is calculated by using formula. Hence the Actual Boundary Conditions are as follows.

![Figure 4: Boundary Conditions applied on King-Pin for Vibration](image)

4. Result Analysis

Figure 5 shows the first mode of vibration where the maximum possible deformation is 46 mm at 2447 Hz. This frequency is very high and not achievable in any condition by the vehicle. Also we know that, such high deformation is not possible as it is located inside the shackle or hub. These vibrations will be absorbed by the attached vehicle parts.

![Figure 5: Deformation in Mode](image)
Higher the frequency, safer the object is the main theme of vibration analysis. Reaching till 6th mode of vibration, natural frequency crosses 8000Hz. Hence King-Pin is safer than any other part in suspension system.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Frequency (Hz)</th>
<th>Total Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2447</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>2450</td>
<td>46</td>
</tr>
<tr>
<td>3</td>
<td>2531</td>
<td>46</td>
</tr>
<tr>
<td>4</td>
<td>2533</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>7947</td>
<td>46</td>
</tr>
<tr>
<td>6</td>
<td>8008</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 3: Tabulated Results for Vibration Analysis

5. CONCLUSION

By observing analysis results, it is clear that the natural frequency of king-pin is very high (8008 Hz) which much capable to sustain any vibrations which could be generated in heavy duty vehicle. The entire frequency mode has sufficient frequency value. Also the deformation value is large and achieving this deformation is not possible. Hence the king-pin is safe from vibrations generated in heavy duty vehicle. The king-pin is having required flexibility and vibrations do not affect the life of king-pin.

REFERENCES

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