A STUDY OF MODELING AND FINITE ELEMENT ANALYSIS OF AUTOMOTIVE VEHICLE WHEEL RIM ASSEMBLY FOR THE DEFORMATION AND VARIOUS STRESS DISTRIBUTION
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ABSTRACT
This paper which deals with wheel rim modelling and finite element analysis of various stress distribution. When the human race starting to use the log to transport heavy objects. The original wheels were the round slices of a log and it was gradually re–in–forced and used in this form for centuries on both carts and wagons. The distribution of stresses from the wheel hub and wheel rim is properly distributed to entire portion of wheel rim. The net result of larger deformation and more stress in one particular area, due do this failure occur. This failure can be avoided by introducing the wedge band between the hub and rim. During the finite element analysis of the wedge band, the net result of the stress distribution within the standard recommendation value of throughout the wheel rim with minimum deformation. The main objective is to determine the stress distribution and deformation on each part of the wheel rim assembly under radial load condition with linear and non - linear analysis and find out the factor of safety of the wheel rim.

KEYWORDS: Vehicle, wheel rim, FEA, Stress distribution, ANSYS simulation.

1.1 INTRODUCTION TO WHEEL RIM
The wheel is a device that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. Wheels are components working under a cyclic loading where it heavily undergoes both static loads as well as fatigue loads as wheel rim travels different load profile or terrain. Wheel is defined as a rotating load-carrying member between the tire and the hub. The main components of a wheel are the rim, the tire, the disc or the spokes. The importance of wheel and tires in the automobile cannot be challenged. Without engine, vehicle may tow but without the wheels, this is not possible. The wheel with tires takes full load condition and reduces friction and provides cushioning effects by absorbing vibration due to road surface unevenness and assist in steering control.

1.1.1 Literature Review

1.2 WHEEL RIM WITH DIMENSIONS

1.3 3D MODEL OF WHEEL RIM

Steps:
1. Go to assembly mode in CATIA. Click on existing component icon and click on product in the specification tree. Now select wheel rim base.
2. Wheel rim base is imported. Fix the component.
3. Now get the bead seat band and apply coincident constraint and contact constraint to assemble wheel rim base and bead seat band.
4. Now get the back flange and apply coincident constraint and contact constraint
to assemble wheel rim base and bead seat band and back flange.

5. Now get the wedge band and apply coincident constraint and contact constraint to assemble wheel rim base, bead seat band, back flange and wedge band.

1.4 LINEAR STATIC ANALYSIS

In linear analysis, the behavior of the structure is assumed to be completely reversible; that is, the body returns to its original deformed state upon the removal of applied loads and solutions for various load cases can be superimposed.

The assumptions in linear analysis are:

1) Displacements are assumed to be linearly dependent on the applied load.
2) A linear relationship is assumed between stress and strain.
3) Changes in geometry due to displacement are assumed to be small and hence ignored.
4) Loading sequence is not important and the final state is not affected by the load history.

The load is applied in one go with no iterations.

1.5 NON LINEAR STATIC ANALYSIS

In many engineering problems, the behavior of the structure may depend on the load history or may result in large deformations beyond the elastic limit.

The assumptions/features in nonlinear analysis are:

1) The load-displacement relationships are usually nonlinear.
2) In problems involving material nonlinearity, the stress-strain relationship is a nonlinear function of stress, strain, and/or time.
3) Displacements may not be small; hence an updated reference state may be needed.
4) The behavior of the structure may depend on the load history; hence the load may have to be applied in small increments with iterations performed to ensure that equilibrium is satisfied at every load increment.

1.6 ANALYSIS OF WHEEL RIM

The wheel rim modeled in CATIA is saved as an .IGES file. It is then imported into ANSYS using the import file command. The import file command in ANSYS can import models from CATIA in the .IGES file mode.

The element type used for the model is chosen as 8 nodded tetra elements from ANSYS element menu.

The model is then assigned the material properties like Young’s Modulus (E=2.1X10^5 N/mm^2), Poisson’s ratio (µ=.33) and Density of steel (ρ=7.85X10^3 N/mm^2). The meshing is done with the ‘mesh tool’ option in ANSYS. The total number of elements created as a result of the meshing process is 25000. Then the loading and the boundary conditions are applied to the model. The model is restrained in all degrees of freedom.

1.7 LINEAR ANALYSIS

A linear FEA analysis is undertaken when a structure is expected to behave linearly, i.e. obeys Hook’s Law. The stress is proportional to the strain, and the structure will return to its original configuration once the load has been removed. A structure is a load bearing member and can normally be classified as a bar, beam, column, or shaft.
GEOMETRY:

The model created in CATIA is imported to ANSYS and spring is inserted between wheel rim center to road surface to find out stiffness and critical damping.

MESHING:

Now, the model is meshed.

LOADING:

Loads are applied at the center of the wheel rim and it is acting downwards and at the road and is acting upward.

EQUIVALENT STRESS:

Equivalent stress at the wheel rim is 32.341Mpa maximum and 0.0006835Mpa minimum.

Directional deformation:

The deformation takes place in Z-Direction is -25.131mm maximum and -27.379mm minimum.

**Calculation**

**Material Properties**

<table>
<thead>
<tr>
<th>Material used</th>
<th>Structured steel grade – II C1002 BEML standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength</td>
<td>350MPa</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>540MPa</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>2X10^5 N/mm</td>
</tr>
<tr>
<td>Density</td>
<td>7850 Kg/m^3</td>
</tr>
</tbody>
</table>

**Mass and mass distribution:**

Net Vehicle Mass 74,000kg
Rated Pay Load 91,500kg
Gross Vehicle Mass 1, 65,500kg

<table>
<thead>
<tr>
<th>Mass Distribution</th>
<th>Empty (%)</th>
<th>Loaded (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Axle, kg</td>
<td>34,780 (47%)</td>
<td>54,450 (33%)</td>
</tr>
<tr>
<td>Rear Axle, kg</td>
<td>39,220 (53%)</td>
<td>1,11,050 (67%)</td>
</tr>
</tbody>
</table>

**Free body diagram:**

\[ \sum H = 0 \]
\[ \sum V = 0 \]

Resolving Vertical Forces:

\[ R_B \times 3720 - 1623.555 \times 1860 = 0 \]
\[ R_B \times 3720 = 1623.555 \times 1860 \]
\[ R_B = (1623.555 \times 1666) / 3720 \]
\[ R_B = 811.7775 \text{ KN} \]

To find \( R_A \):

\[ R_A + R_B - 1623.555 = 0 \]
\[ R_A = 1623.555 - 811.7775 \]
\[ R_A = 811.7775 \text{ KN} \]

**DIAGRAM:**

Gross vehicle mass of the dump truck is 165500kg and it is acted at the centre of the axle the rear axle carries 67% of the load when it is fully loaded. So

\[ R_B = 165500 \times 0.67 \]
\[ R_B = 110885 \text{ kg} \]

Two wheel on each side of the wheel end so divide by 2.

\[ R_A = 110885 / 2 \]
\[ R_A = 55442.5 \text{ kg} \]
\[ R_B = 55442.5 \times 9.81 \]
\[ R_B = 54389.925 \text{ N} \]

**TO FIND VELOCITY:**

The maximum speed of the BH100 ton rear dump truck is 60km/hr.
N = 60km/hr
N = \( \frac{(60 \times 1000)}{3600} \) m/sec

V = 16.67m/sec

**AREA OF THE WHEEL RIM:**

\[
\text{Area} = \text{Area of (wedge band + rim base + bead seat band + back flange)}
\]

\[
\text{Area} = 315446 + 314402.6 + 349138 + 198469 + 19846.9
\]

\[
\text{Area} = 1375924.6 \text{mm}^2
\]

**TO FIND PRESSURE:**

\[
P = \frac{V}{\eta} \quad \ldots \ldots \quad (6.1)
\]

\[
P = \frac{543890.925}{\sqrt{75974.6}}
\]

\[
P = 0.395 \text{N/mm}^2
\]

**TO FIND THE ROTATIONAL VELOCITY:**

\[
V = R \times \omega \quad \ldots \ldots \quad (6.2)
\]

\[
\omega = \frac{V}{R} = \frac{16.6}{603}
\]

\[
\omega = 0.0275 \text{rad/sec}
\]

**TO FIND THE STIFFNESS (K):**

\[
F = K \times \delta \quad \ldots \ldots \quad (1.1)
\]

\[
K = \frac{F}{\delta}
\]

Where K is stiffness, F = load, \( \delta \) = displacement, minimum displacement assumed is 50mm.

\[
K = \frac{543890.925}{50}
\]

\[
K = 10877.8 \text{N/mm}
\]

**TO FIND CRITICAL DAMPING (C_c):**

\[
C_c = 2\sqrt{KX} \quad \ldots \ldots \quad (1.2)
\]

\[
C_c = 2\sqrt{543890.925 \times 10877.8}
\]

\[
C_c = 153835.5 \text{N-sec/mm}
\]

**TO FIND STIFFNESS (K):**

\[
K = \frac{F}{\delta} \quad \ldots \ldots \quad (1.3)
\]

Where \( \delta = 80 \text{mm} \) assumed maximum displacement of tire

\[
K = \frac{543890.925}{50}
\]

\[
K = 6798.6 \text{N/mm}
\]

Find the factor of safety:

Yield strength of the material is 350Mpa

Working stress of the material is 64.682Mpa

\[
\text{FOS} = \frac{350}{64} = 5.4
\]

Dump trucks are heavy structure, so according to standard the FOS should be

1. For static analysis the factor of safety should be more than 4
2. For dynamic analysis the factor of safety in between 1.5 to 2.5

The factor of safety should be above four so the wheel rim is safe.

**REFERENCES**


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