DESIGN & ANALYSIS OF RAILWHEEL FAILURE

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Abstract- *Rail wheel is the major part which helps move a train at high speeds and increased axle loads at wheel contact forces. These leads to major rim damage from wear to fatigue. This process of wear, fatigue causes fractures in wheels or tread surface material.*

These are the major causes for damage to the rail suspensions and derailment of the rail. The current study focuses on sub-surface propagation analysis which is based on the critical plane approach. Firstly, we design a geometric model of a rail wheel in AUTOCAD software.

It is made of steel R-16 and R-19 steel and tested by applied loads and boundary conditions on wheel &Axle by using the ANSYS 16.0.Now solving the model to obtain mechanical loading and thermal loading

1. INTRODUCTION:

In recent years, higher train speeds and increased axle loads have led to larger wheel/rail contact forces. Also, efforts have been made to optimize wheel and rail design to improve the performance and reduce the cost. These trends have changed the major wheel rim damage from wear to fatigue. Unlike the slow deterioration process of wear, fatigue causes abrupt fractures in wheels or the tread surface material loss.

These failures may cause damage to rails, damage to train suspensions and, in some cases, serious derailment of the train. The fatigue problem of railroad wheels is often referred to as rolling contact fatigue, which is caused by repeated contact stress during the rolling motion. Similar fatigue problems also exist in other mechanical components experiencing rolling contact loading, such as gears and bearings.

A detailed overview of the rolling contact problem of railroad wheels were given by Different failure modes have been observed for railroad wheels, such as shattered rim, vertical split rim and thermal cracking. Shattered rim failures are the result of large subsurface cracks that propagate roughly parallel to the wheel tread surface. Thermal cracking usually breaks off a piece of the wheel tread, while shattered rim can destroy the wheel's integrity and thus is more dangerous. The current study focuses on the subsurface crack propagation (shattered rim) analysis.

Most of the existing rolling contact fatigue models use a simplified stress calculation technique, such as Hertz analytical solution or simplified finite element analysis with applied Hertz contact pressure. Due to the complex geometry of the wheel/rail contact area, it is more appropriate to use a 3D finite element method to calculate stress response in the mechanical components.

2. LITERATURE REVIEW:

As per Tournay HM, Mulder JM. The transition from the wear to the stress regime wear. The influence of wheel and rail profile shape features on the initiation of rolling contact fatigue (RCF) cracks is evaluated based on the results of multi-body vehicle dynamics simulations. The damage index and surface fatigue index are used as two damage parameters to assess the influence of the different features. The damage parameters showed good agreement to one another and to in-field observations. The wheel and rail profile shape features showed a correlation to the predicted RCF damage. The RCF damage proved to be most sensitive to the position of hollow wear and thus bogie tracking. RCF initiation and crack growth can be reduced by eliminating unwanted shape features through maintenance and design and by improving bogie tracking.

As per Stone DH, Majumder G, Bowaj VS. This report details studies conducted by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), to determine the causes and behavior of shattered rim defects in wheels. Shattered rim defects are the result of large fatigue cracks that propagate roughly parallel to the wheel tread surface. They form and grow 1/2 to 3/4 inch (12–20 mm) below the tread surface. Once a shattered rim crack is formed it will grow under normal rolling loads. Therefore, the prevention of shattered rims is best accomplished by preventing crack initiation. Shattered rims tend to occur in either relatively new wheels or those that are near their condemning limit. Recent changes have been made to ultrasonic test requirements in AAR Specification M-107/208, "Wheels, Carbon Steel," to reduce the acceptable size of discontinuities. This will help reduce the occurrence of some shattered rims, but will not prevent the formation of all of them. Ultrasonic testing of returned wheels would be effective in reducing the incidence of shattered rims in wheels with thinner rims.

3. GEOMETRIC REPRESENTATION:

3.1 GEOMETRY:

Wheel is a circular device that is capable of rotating on its axis, facilitating movement or transportation whilst supporting a load (mass). Common examples are found in transport applications. A wheel, together with an axle overcomes friction by facilitating motion by rolling. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by application of another external force. More generally the term is also used for other circular objects that rotate or turn.

The train wheel is made of steel primarily to reduce rolling friction. The wheels on the train ride on a tiny contact patch, the contact area between each wheel and the track is approximately the size of a penny. The train's wheels are not just disks, there is a special ledge on each of them. The role of this ledge is very important; it lowers below rail's level and prevents the train from leaving the track. It is the lowest part of the wheel that is moving in the direction opposite to the train's heading.

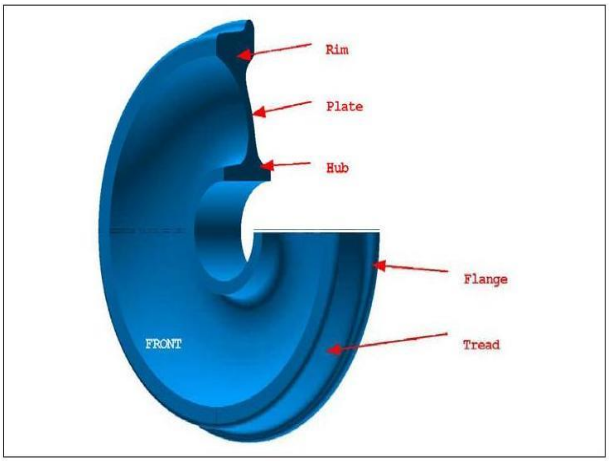


Figure 3.1: Composition of Wheel.

4. SOFTWARE OVERVIEW:

4.1 SOLIDWORKS:

Solid Works is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and was developed by a subsidiary of Dassault Systemes Solid Works corp.. Solid Works is currently used by over 3/4 million engineers and designers at more than 80,000 companies worldwide.

Solid Works is a Parasolid-based solid modeler, and utilizes a parametric feature-based approach to create models and assemblies.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. Solid Works allows you to specify that the hole is a feature on the top surface, and will then honor your design intent no matter what the height you later gave to the can. Features refer to the building blocks of the part.

They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded or cut to add or remove material from the part. Operation-based features are not sketch-based, and include features such fillets, chamfers, shells, applying draft to the faces of a part, etc.

Building a model in Solid Works usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of Solid Works means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

5. MODELING AND ANALYSIS:

5.1 MODELING:-

The Wheel and Axle is modeled in modeling software like the Solid Works in order to study the stress distribution and temperature distribution in the wheel. The wheel is integrated into five parts namely Rim, Plate, Hub, Flange and Thread. The train wheel has got a very special place in today's world because it is the only thing which runs on rails. And both rail and wheel are made up of the same material.

A Wheelset is the Wheel-Rail assembly of a railroad car. The frame assembly beneath each end of a car or locomotive that holds the Wheelset is called the bogie. The Wheelset is classified into

- Wheel
- Rail

Most wheels have a conical shape of ratio about 1 in 20. The conical shape has the effect of steering the Wheelset around curves, so that the flanges come into play only some of the time. The rails generally slant in at the same rate as the wheel conicity. As the wheels approach a curve, they will tend to follow a straighter path. This causes the Wheelset to shift sideways on the track so that the effective diameter of the outer wheels is greater than that of the inner ones. Since the wheels are joined rigidly by the axle, the outer wheels will travel further, causing the train to naturally follow the curve.

The wheel is 943 mm in diameter with a weight of 376 kg. The Axle is 2316 mm in length and weighs over 339 kg. The Wheel and Axle is modeled based on the dimensions provided by the Integral coach factory.

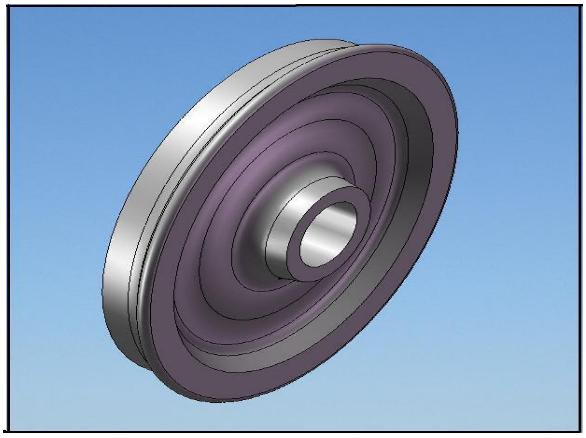


Figure 5.1: Wheel – Isometric View.

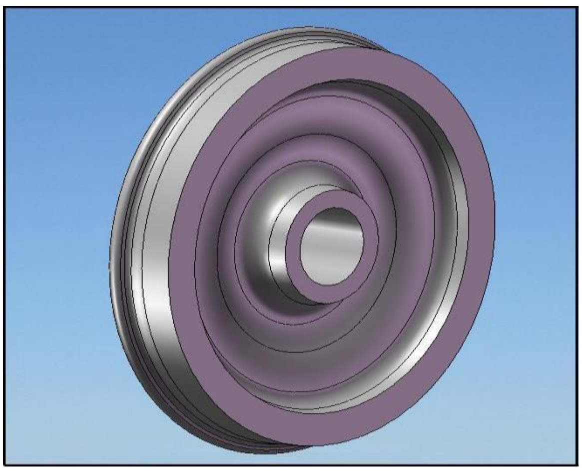


Figure 5.2: Wheel – Di-metric View.

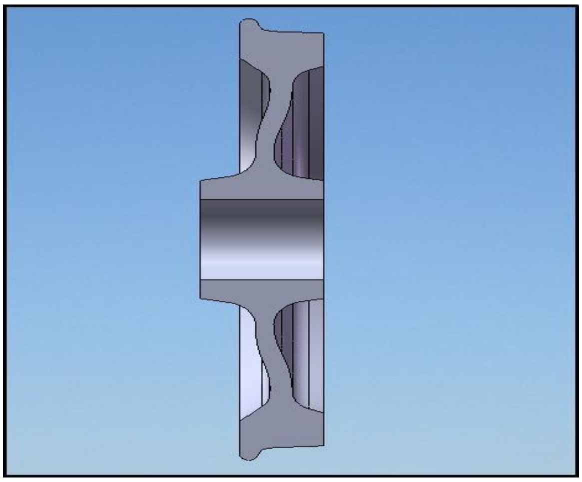


Figure5.3: Wheel –Cut Sectional View.

5.3 MESHING SPECIFICATION:

In order to conduct a finite element analysis, the structure must be idealized into some form of mesh. Meshing is a procedure of applying the finite number of elements to model. The art of successful application of this technique depends on the type of element selected. Ansys offers wide range of elements for various types of models. For e.g.: if there is a solid model, there are various types of solid elements such as SOLID 187, SOLID 95 etc. Similarly for shell model, there are various types of SHELL elements such as SHELL 93, SHELL 281 etc. Therefore in setting up a mesh the user should attempt to keep these elements in mind and keep the elements near to the basic parent element shape as far as possible.

For Structural Analysis the element type selected is SOLID187 and for Thermal Analysis the element type selected is SOLID 87.

A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

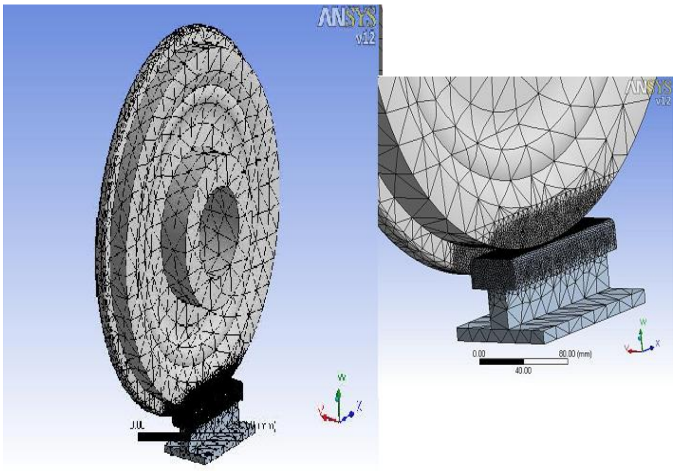


Figure 5.4: Meshed wheel from geometry

6. CALCULATION:

6.1 CALCULATION OF FORCES:

There are two types of Forces acting on the Axle. Vertical Force due to the payload. These Forces are directly transferred to the Wheel through the Axle. The nominal Axle Load is 16.25 tones and additional 40% is added as Shock Load.

Lateral Force due to track irregularities and skidding on curves. These loads are applied to the side of the Axle.

VERTICAL FORCE:

Max. Axle capacity = 16.25 tones.

Vertical Load at Rail Contact = [16.25 X 10^3] / 2 = 8125 kg = 81250 N.

Vertical Load at Rail with Shock = 81250 X 1.4 = 113750 N.

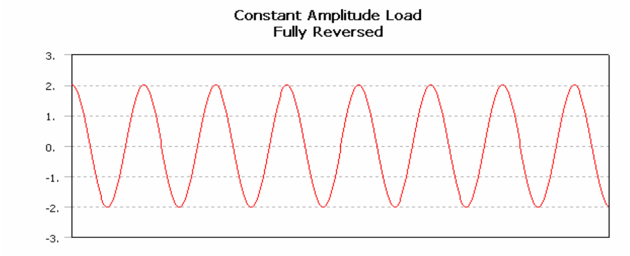
Projected Area = 130 X 119 = 15470 mm^2.
Projected Load= 113750 / 15470 = 7.3529 N / mm^2.

LATERAL FORCE:

Horizontal Lateral Load = 50% of Dynamic Load.
11375 kg = 113750 N.
Projected Area = πR^2 = π X 65^2 = 13273.22 mm2.
Projected Load = 113750 / 13273.22 = 8.5698 N / mm^2.

6.2 LOADING TYPES:

Constant amplitude, proportional loading is of constant amplitude because only one set of FE stress results along with a loading ratio is required to calculate the alternating and mean values.



6.3 STRUCTURAL ANALYSIS:

The loads and boundary conditions are applied to the model and the model is solved for results. It is found that the Maximum Displacement due to mechanical loading is 0.0769 mm and the Von Mises Stress is 1330 N/mm^2.

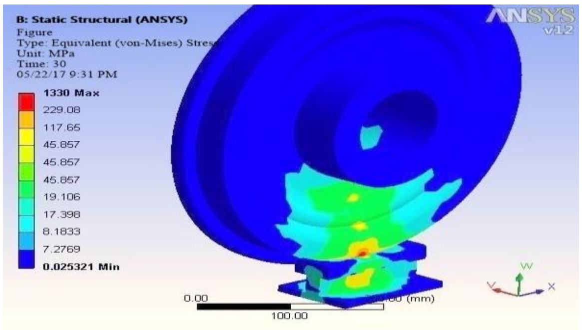


Figure 6.1: Equivalent Stress

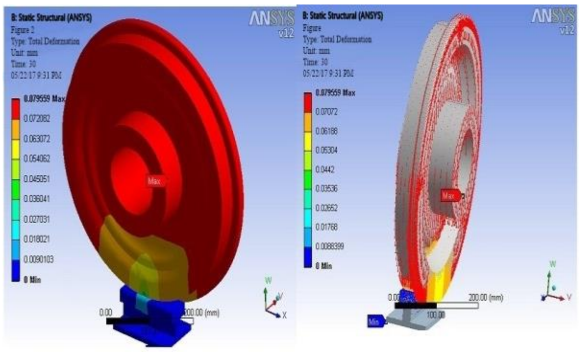


Figure 6.2: Total Deformation

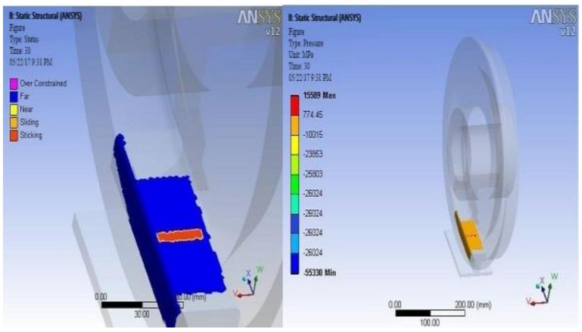


Figure 6.3: Total Deformation

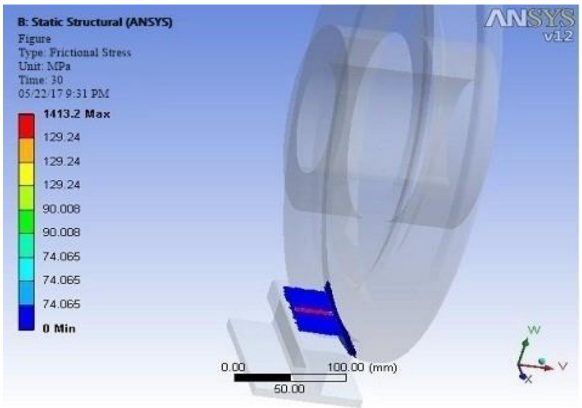


Figure 6.4: Pressure

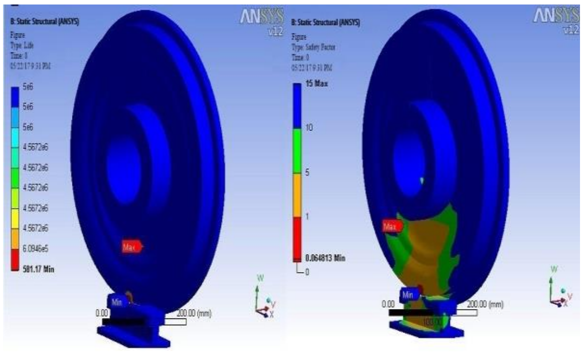


Figure 6.5: Life and Safety Factor

7. CONCLUSION

A multi axial fatigue life prediction model is developed in this paper, which is based on the critical plane approach. Unlike most of the previous critical plane-based models, the current critical plane not only depends on the stress state but also explicitly depends on the material properties. The new multiaxial fatigue model is applied to the fatigue initiation life prediction of wheel/rail contact problem. Nonlinear finite element analysis is used for stress computation and a sub-modeling technique is used to improve the efficiency and accuracy. The stress history is then used to calculate the fatigue life. A numerical example is implemented and compared with field observation of failure pattern. The effect of several parameters, namely wheel diameter, vertical loads, material hardness, fatigue strength and material ductility, on the fatigue damage in railroad wheels is studied using the proposed model.

8. REFERENCES

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