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ANALYSIS OF RAIL-WHEEL CONTACT STRESSES USING FINITE ELEMENT METHOD IN COMPARISON WITH ANALYTICAL SOLUTION

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ABSTRACT

Contact is the principal method of applying loads between deformable solids, and therefore is present in a wide variety of mechanical components. In addition, contacts usually act as stress concentrations, and are thus probable locations for mechanical failure. Some of the most typical mechanical failures involving contact include: fretting, fretting fatigue, wear, fretting wear and false brinelling. The contact of UIC-60 and IRS-T12 rail-wheel has been analyzed by hand calculations to determine contact stresses. A three dimensional finite element model of both type of rail-wheel contact is developed in ANSYS to compare to the typical hand-calculated stresses. A vertical force is applied railway wheel & simulates the effects frictional surfaces. The results of the finite element model analysis contained herein are compared to hand calculations. Based on these results, a finite element analysis should be used if a greater level of detail is required for the analysis of the rail-wheel contact.

KEYWORDS: Contact stresses, UIC-60, IRS-T12, ANSYS

INTRODUCTION

Contact is the principal method of applying loads between deformable solids, and therefore is present in a wide variety of mechanical components. In addition, contacts usually act as stress concentrations, and are thus probable locations for mechanical failure. Contact stresses developed during the pressing action of two bodies needs careful attention since occurrences of such forces are very frequent. Gears, Ball-and-Roller bearings, wheel on rails etc are familiar examples. Considering the gears, ball & roller bearings, When two bodies with curved surfaces come into contact without any pressure or forces between them, the geometry of contact is in general either a point or a line. But in case of rail wheel system, the contact area between rail and wheel is elliptical.

Fig: Effects of contact stresses

These contact stresses are unavoidable phenomenon in railway systems. It is difficult to measure the contacting pressure due to curve on track, load applied. Wheel–rail contact is always a hot topic for railway vehicle dynamics researchers and wheel–track maintenance engineers. The determination of forces acting between wheel and rail is definitely the most important question for the study of dynamic behavior of a railway vehicle. But in case of rail wheel contact problems, the contact area is elliptical. The contact elliptical area is small so stresses developed will be higher. For the simplest model to calculate the stresses, one uses the Hertz Theory and evaluates the effect of the weight only. The theory governing the wheel/rail contact is Hertz theory. This theory describes this fact that when two solid materials are compressed to each other by vertical loads, their contact area is formed. Shape and the value of the contact area between two elastic materials are at static mode.

ANALYTICAL APPROACH

HERTZ THEORY FOR CONTACT STRESSES

Contact mechanics is the study of the deformation of solids that touch each other at one or more points. The physical and mathematical formulation of the subject id built upon the mechanics of materials and focuses on computations involving elastic and plastic bodies in static or dynamic contact. Contact mechanics is a part of mechanical engineering, it provides necessary information for the safe and energy efficient design of technical systems and for the study of tribology and indentation hardness. Principles of contact mechanics can be applied in areas such as locomotive wheel-rail contact, coupling devices, braking systems, gears in meshing & bearings.

ASSUMPTIONS IN HERTZIAN THEORY

The following assumptions are made in determining the solutions of Hertzian contact problems:

- The strains are small and within elastic limit
- The surfaces are continuous and non-conforming
- The area of contact is much smaller than characteristic dimensions of the contacting bodies.
- Each body can be considered as elastic half space

PROBLEM DEFINITION

Analysis of Rail Wheel Contact Stresses of Passenger Railway by using Hertz Theory
Total weight of railway: 51 Tons
Applied force on each wheel (F): 63.750 KN
Rail Type: UIC60 & IRS-T12
Material of rail and wheel: Steel
Modulus Of elasticity (E): 2.1×10^5 MPa ……………………. For both rail and wheel
Poisson's ratio (Υ): 0.30 & 0.20 ……………………. For both rail and wheel

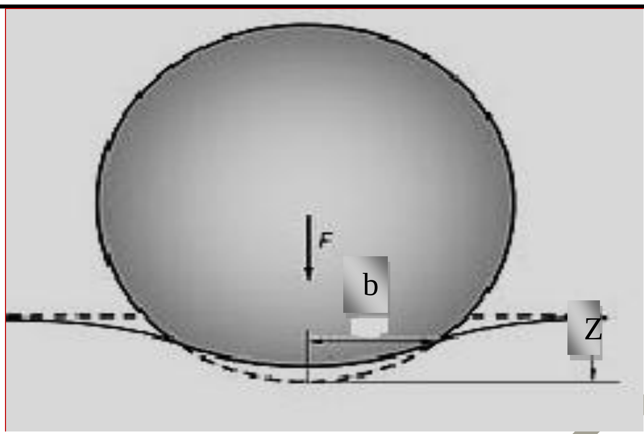

Fig: Depth below the surface & half width of contact area

Contact half width b,

$$\mathbf{b} = \sqrt{\left[\frac{2F}{\Pi l}\,\frac{(1-\Upsilon 1^2)/E1+(1-\Upsilon 2^2)/E2}{\frac{1}{d1}+\frac{1}{d2}}\right]}$$

Maximum pressure p_{max},

$$p_{max} = \frac{2F}{\Pi b l}$$

Calculations of Principle stresses,

$$\sigma x = -2\gamma_1 p_{max}[\sqrt{(1+Zb^2)} - |Zb|]$$

$$\sigma y = -2p_{max}\left[\frac{1+2.Zb^2}{\sqrt{(1+Zb^2)}} - 2|Zb|\right]$$

$$\sigma z = \frac{-p_{max}}{\sqrt{(1+Zb^2)}}$$

Maximum shear stress,

$$\tau max = \frac{\sigma x - \sigma z}{2}$$

From these above expressions, we can calculate principle stresses and maximum shear stress

ANALYSIS OF RAIL WHEEL CONTACT STRESSES BY USING ANSYS

ANSYS is finite element analysis software which enables engineers to perform the following tasks:

- The solid model of rail-wheel contact model is created in CATIA V5. It is is a feature based modeling (FBM) software. Many CAD packages use FBM method. It is easy and gives model tree for completed part, so that modification at any point at any branch can be passed through whole model.

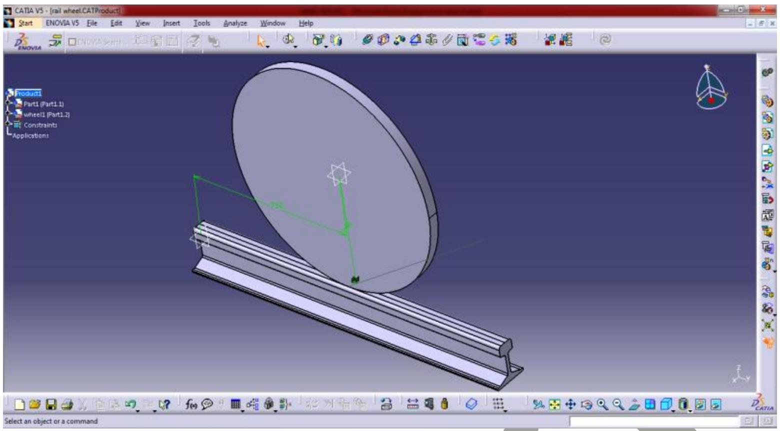

Fig: CAD model of rail-wheel contact

- The CAD model of rail-wheel contact was saved in .igs format for importing it into ANSYS workbench for the analysis purpose.
- The material used for the rail-wheel contact is structural steel which isotropic behavior. The Poisson's ratio for UIC rail was taken as 0.30 and for IRS-T12 as 0.28
- After importing geometry to Ansys workbench, connection tree is visible in which frictional contact is made between wheel and rail. Then, on clicking on contact body and target body,
- Meshing is the process in which your geometry is discretized into elements and nodes. This mesh along with material properties is used to mathematically represent the stiffness and mass distribution of the structure. The element size is determined based on number of factors including overall model size, body curvature and the complexity of the feature.

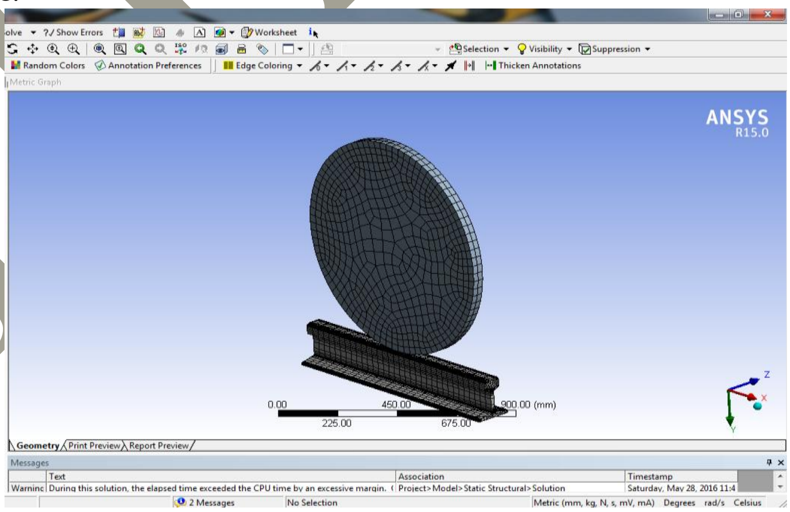

Fig: Meshed Geometry

- The boundary condition is the collection of different forces, pressure, velocity, supports, constraints and every condition required for complete analysis. Applying boundary condition is one of the most typical processes of analysis.

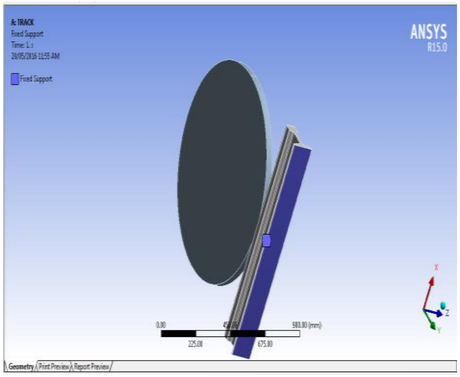

Fig: Fixed Support

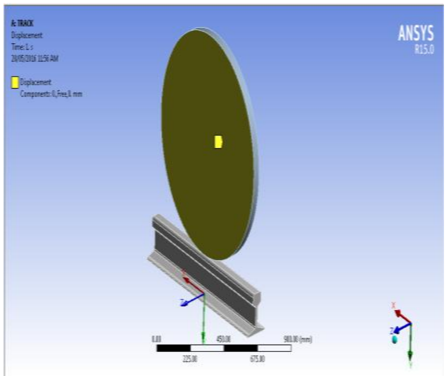

Fig: Displacement

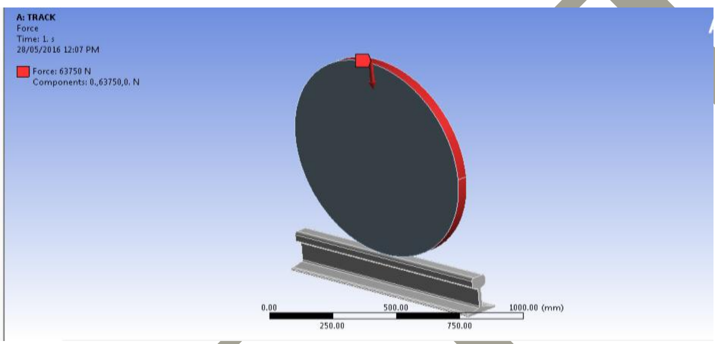

Fig: Load Applied On Wheel

- In structural analysis, after specification of meshing, material properties, boundary conditions and application of loads, solution is obtained in terms of principle stresses i.e. stresses in X, Y, Z direction and Maximum shear stress.

RESULTS AND DISCUSSION

Following table shows the results obtained in the analytical solution and ANSYS solution. The importance of these results is to correlate results obtained in two methods with each other and to check how results satisfy the research objective.

Table: Comparison between analytical and FEA results

Types of stresses (For load 63750 N)	UIC 60 Rail-wheel		IRS-T12 Rail-wheel		% of difference between analytical and FEA	
	Analytical	FEA	Analytical	FEA	UIC 60 Rail-wheel	IRS-T12 Rail-wheel
Stresses along X direction (MPa)	94.65	90.462	87.14	78.639	4.42 %	9.75 %
Stresses along Y direction (MPa)	120.23	117.47	118.60	104.19	2.29 %	10%
Stresses along Z direction (MPa)	255.25	234.29	246.44	224.34	8.21%	8.96%
Maximum Shear stress (MPa)	80.3	76.812	79.65	72.334	4.34 %	9.18 %

CONCLUSION

In this chapter, the main conclusions are drawn from the results obtained in the research.

- In this research, the UIC-60 & IRS-T12 rail-wheel were considered as nonlinear models and principle stresses and maximum shear stress were calculated for different Poisson's ratio.
- A comparative study has been made between UIC-60 & IRS-T12 rail-wheel.
- From the results and discussion, it is concluded that contact stresses developed in IRS-T12 rail-wheel are less than UIC-60 rail-wheel which shows suitability of IRS-T12 rail-wheel on the basis of strength.
- IRS-T12 rail-wheel is having higher corrosion resistance and more life than UIC-60 rail-wheel
- Also, IRS-T12 rail-wheel is having less failure chances as compared to UIC-60 rail-wheel due to less contact stresses developed.

FUTURE SCOPE

- The work could be done by considering thermal stresses developed between rail and wheel.
- The work could be done by changing the cross section of rail, wheel and contact length

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