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ANALYTICAL INVESTIGATION OF RAIL WHEEL ASSEMBLY BY USING COMPOSITE MATERIALS

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ABSTRACT Mechanics of the rail-wheel is one of the fundamental areas of the study in the railway engineering. Complicated geometries like rail-wheel problems are solved by using Finite element analysis software. In present years, loads on axle of railway cars increase because increased in transport of goods and faster infrastructural growth. The rail-wheels are subjected to high contact stresses of alternating magnitude. In this Paper the rail wheel assembly designs in CATIA software and analysis in ANSYS software. The materials assigned for wheel high carbon steel and nickel chromium molybdenum alloy steel material. Assigned material for sleeper pad concrete and light weight concrete, track material is stainless steel. Finding which material is the best material for wheel, sleeper pad through static, modal and random vibration analysis. In this Paper the static analysis to determine the deformation, stress and strain, modal analysis to determine the deformation with respect to frequency. Random vibration analysis to determine the directional deformation. In this paper take the best material for each part of rail wheel assembly and apply the assembly of rail wheel. Static, modal and random vibration analysis for that assembly of rail wheel.

Key words: **rail wheel assembly, design, static, modal, analysis.**

(I) INTRODUCTION

A **train wheel** or **rail wheel** is a type of wheel specially designed for use on rail tracks. A rolling component is typically pressed onto an axle and mounted directly on a rail car or locomotive or indirectly on a bogie (UK), also called a truck (North America). Wheels are cast or forged and are heat-treated to have a specific hardness. New wheels are trued, using a lathe, to a specific profile before being pressed onto an axle. All wheel profiles need to be periodically monitored to ensure proper wheel-rail interface. Improperly trued wheels increase rolling resistance, reduce energy efficiency and may create unsafe operation. A railroad wheel typically consists of two main parts: the wheel itself, and the tire (or tyre) around the outside. A rail tire is usually made from steel, and is typically heated and pressed onto the wheel, where it remains firmly as it shrinks and cools. Monobloc wheels do not have encircling tires, while resilient rail wheels have a resilient material, such as rubber, between the wheel and tire.

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Fig1 Flanged railway wheel

Material of Wheel

• Steel made by Electric or Basic Oxygen process

• Steel shall be of killed quality for forged steel

• The max hydrogen content shall not exceed 3 ppm

• The max nitrogen content shall not exceed 0.007%

II. LITERATURE REVIEW

Van'tZand (1993) used FFT technique to measure and assess the dynamic characteristics of pads through impact load tests. The curve fitting method was used to fit an SDOF equation of motion to the experimental results. It was carried out at a specific frequency of 400-2000 Hz. The results was compared with another research and seemed to be in a good agreement. This method was then extended to the urban track structures (Esveld, 1997; Esveld, Kok, and De Man, 1998).

Later, Fenander (1997) studied the vertical stiffness and damping of studded rail pads on a complete track and in a laboratory test rig. Stiffness increased substantially with preload but only weakly with frequency. The fractional derivative model of their dynamic behaviour was presented in this investigation.

The 2DOF testing apparatus was developed from research done by Verheij (1982). It consisted of two steel blocks with the resilient element mounted between them. To approximate the dynamic stiffness of the pads, the stiffness of the lower spring supporting the lower block was neglected. The measurements of several new pads indicated that stiffness tends to increase slightly with frequency whilst the effect of the preload is more pronounced.

III. PROBLEM IDENTIFICATION AND METHODOLOGY

In this Paper the rail wheel assembly designs in CATIA software and analysis in ANSYS software. The materials assigned for wheel high carbon steel and nickel chromium molybdenum alloy steel material. Assigned material for sleeper pad concrete and light weight concrete, track material is stainless steel. Finding which material is the best material for wheel, sleeper pad through static, modal and random vibration analysis. In this Paper the static analysis to determine the deformation, stress and strain, modal analysis to determine the deformation with respect to frequency. Random vibration analysis to determine the directional deformation.

In this paper take the best material for each part of rail wheel assembly and apply the assembly of rail wheel.

Table:1 Materials

component	Material name
Wheel	High carbon steel, nickel chromium molybdenum alloy steel
Sleeper pad	concrete, light weight concrete
Track	Stain less steel
shaft	Stain less steel

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Table:2 Properties

Material	Young's modulus (MPa)	Poisson's ratio	density (g/cc)
High carbon steel	235000	0.313	8.6
nickel chromium molybdenum alloy steel	200000	0.32	7.7
concrete	3000	0.18	2.3
light weight concrete	6200	0.185	2.4
Stain less steel	193000	0.31	7.75

IV. INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

(i) INTRODUCTION TO CATIA

CATIA is an acronym for Computer Aided Three-dimensional Interactive Application. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA is a multi platform 3D software suite developed by Dassault Systèmes, encompassing CAD, CAM as well as CAE. Dassault is a French engineering giant active in the field of aviation, 3D design, 3D digital mock-ups, and product lifecycle management (PLM) software. CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

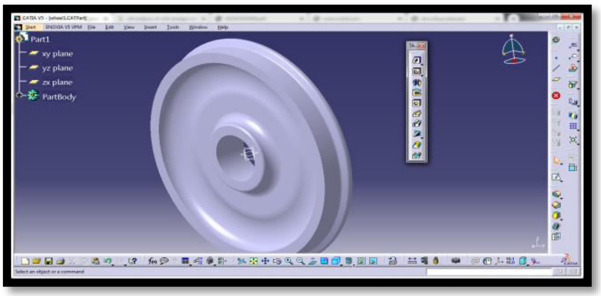

Fig 4.1 wheel

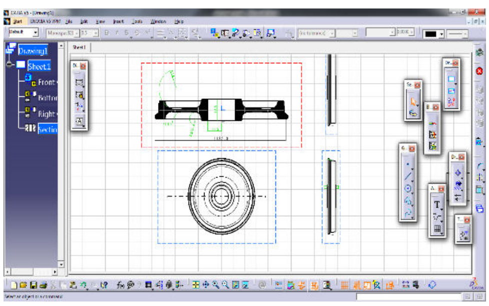

fig : 4.2 2D diagram of wheel

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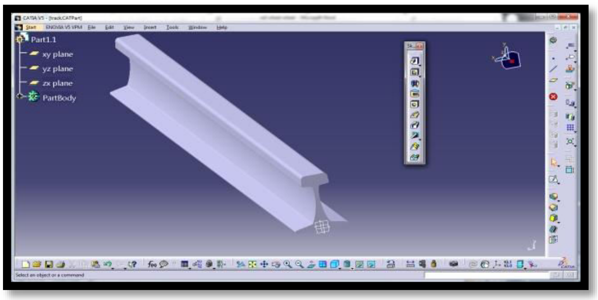

Fig 4.3 track

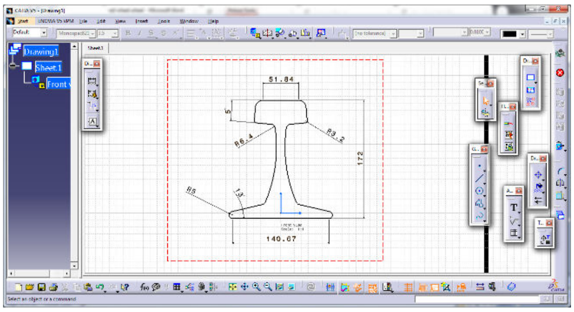

fig 4.4 2d of track

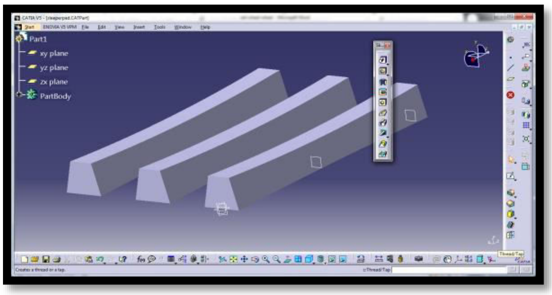

Fig 4.5 sleeper pad

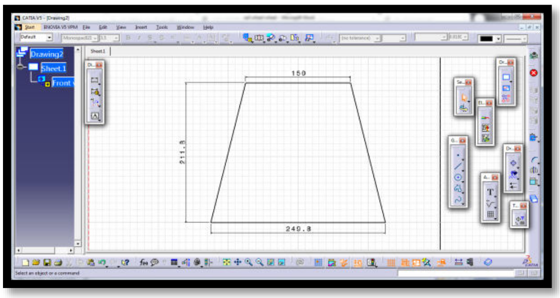

fig 4.6 2D of sleeper pad

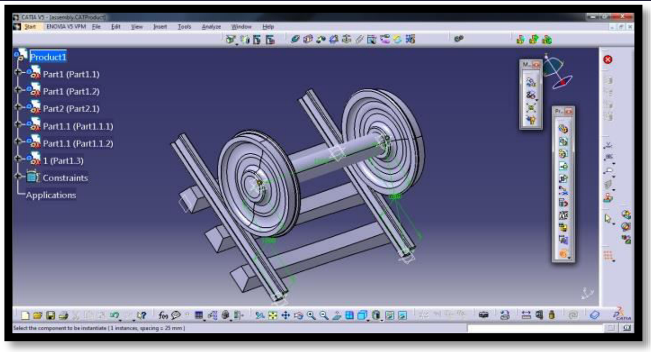

Fig 4.7 assembly of rail wheel

V. INTRODUCTION TO FEA

Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

Magneto static analysis overview

Magneto static analysis is used to design or analyze a variety of devices such as solenoids, electric motors, magnetic shields, permanent magnets,

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magnetic disk drives, etc. Generally, the quantities of interest in magneto static analysis are magnetic flux density, field intensity, force, torque, inductance, and flux linkage.

Quick Field can perform linear and nonlinear magneto static analysis for 2D and rotationally symmetric models. The program is based on a vector potential formulation. The following options are available for magneto static analysis:

- **Material properties**: air, orthotropic materials with constant permeability, ferromagnets, current carrying conductors, and permanent magnets. *B-H* curves for ferromagnets can be defined in a Curve Editor.
- **Loading sources**: current density, uniform external field, and permanent magnets.
- **Boundary conditions**: Prescribed potential values (Dirichlet condition), prescribed values for tangential flux density (Neumann condition), and constant potential constraint for zero normal flux conditions on the surface of superconductor.
- **Postprocessing results**: magnetic potential, flux density, field intensity, forces, torques, magnetic energy, flux linkage, self and mutual inductances.
- **Special features**: A postprocessing calculator is available for evaluating user-defined integrals on given curves and surfaces. The magnetic forces can be used for stress analysis on any existing part (magneto-structural coupling). The magnetic state of the media calculated using the demagnetization curves of all the involved materials can be remembered for future use. In particular, it allows for calculation of self- and mutual differential inductances of multi-coil systems.

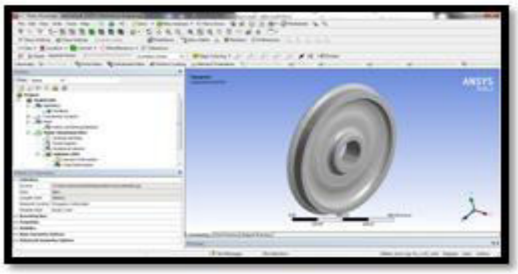

Fig 4.8 Imported Model

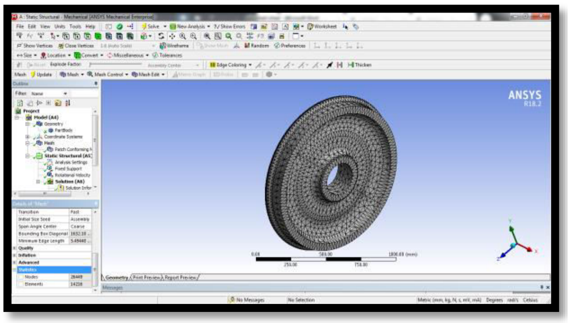

Fig 4.9 Meshed model

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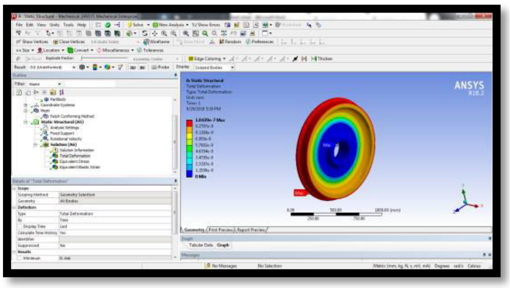

Fig 4.10 Deformation of high carbon steel

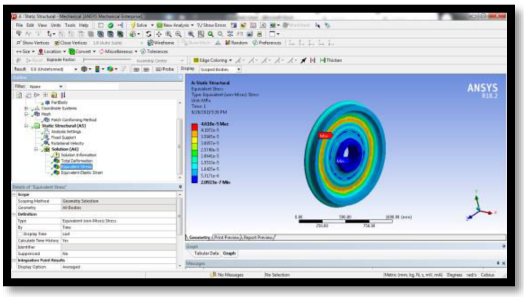

Fig 4.11 Stress of high carbon steel

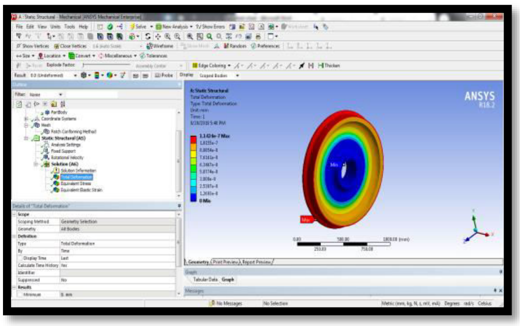

Fig 4.12 Deformation of nickel chromium molybdenum alloy steel

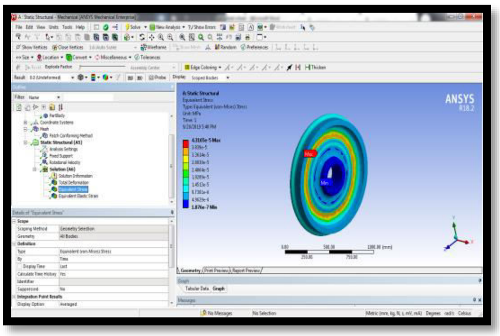

Fig 4.13 stress of nickel chromium molybdenum alloy steel

STATIC ANALYSIS OF SLEEPER PAD

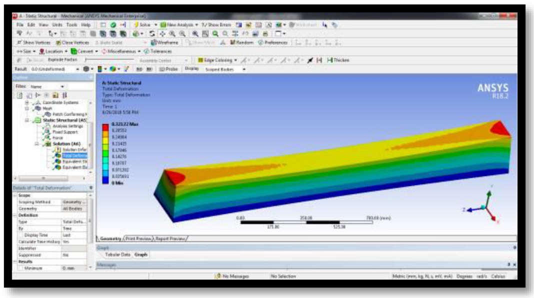

Fig 4.14 Deformation of concrete

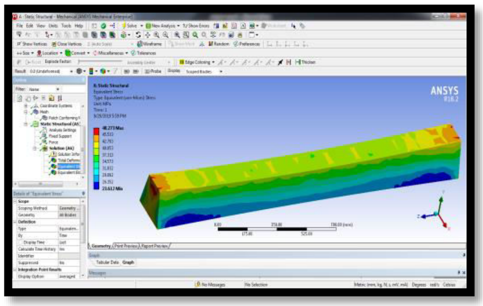

Fig 4.15 Stress of concrete

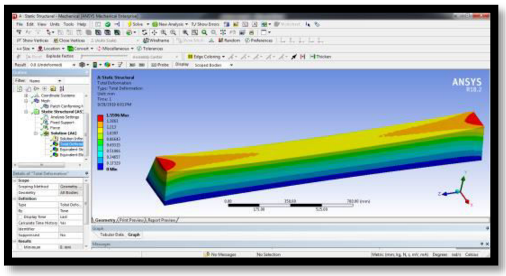

Fig 4.16 Deformationof light weight concrete

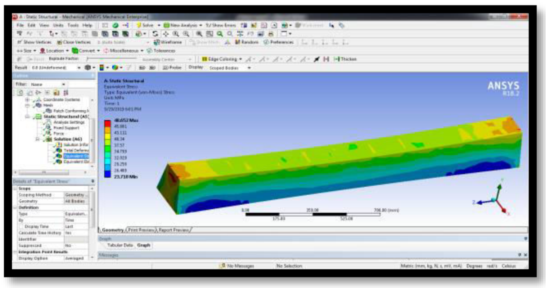

Fig 4.17 Stress of light weight concrete

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VI. RESULTS AND DISCUSSIONS

Table:3 Static analysis of wheel

Material	Deformation (mm)	Stress (Mpa)	Strain
High carbon steel	1.043e-7	4.618e-5	1.978e-10
Nickel chromium molybdenum steel	1.1424e-7	4.3165e-5	2.1725e-10

Table:4 Static analysis of sleeper pad

Material	Deformation (mm)	Stress(Mpa)	Strain
concrete	0.32122	48.273	0.0016091
Light weight concrete	1.5596	48.652	0.0078471

Table:5 Modal analysis of wheel

Material	Mode shapes	Deformation(mm)	Frequency (Hz)
High carbon steel	1	2.9606	132.33
	2	2.96	132.46
	3	1.9439	185.84
Nickel chromium molybdenum steel	1	3.6672	126.71
	2	3.0666	126.83
	3	2.0144	177.91

Table:6 Random vibration analysis results

Material	Axis	Deformation(mm)
High carbon steel	X-Axis	131.7
	Y-Axis	14.173
	Z-Axis	14.153
Nickel chromium molybdenum steel	X-Axis	183.55
	Y-Axis	19.835
	Z-Axis	19.806

Table:7 Modal analysis of sleeper pad

Material	Mode shapes	Deformation(mm)	Frequency (Hz)
concrete	1	12.051	1064.7
concrete	2	12.056	1064.8
	3	6.4436	1169.9
Light	1	12.229	2393.5

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weight concrete	2	12.234	2393.8
	3	6.6018	2630.2

Table:8 Random vibration analysis results of sleeper pad

Material	Axis	Deformation(mm)
concrete	X-Axis	0.027789
concrete	Y-Axis	0.0086094
	Z-Axis	0.0022348
Light weight concrete	X-Axis	0.00032938
	Y-Axis	0.00010355
	Z-Axis	2.3105e-5

By observing the above results the wheel component materials are high carbon steel and nickel chromium molybdenum alloy steel. From the static analysis the less stress and more deformation for nickel chromium molybdenum alloy steel. From modal analysis more deformation and less frequency for nickel chromium molybdenum alloy steel. From modal analysis more deformation and less frequency for nickel chromium molybdenum alloy steel. By observing the above results the sleeper pad component materials are concrete and light weight concrete. From the static analysis the less stress and more deformation for light weight concrete. From modal analysis more deformation and less frequency for light weight concrete From modal analysis more deformation and less frequency for light weight concrete. In assembly of rail wheel taken materials for assembly components. Wheel- nickel chromium molybdenum alloy steel. Sleeper pad- light weight concrete.

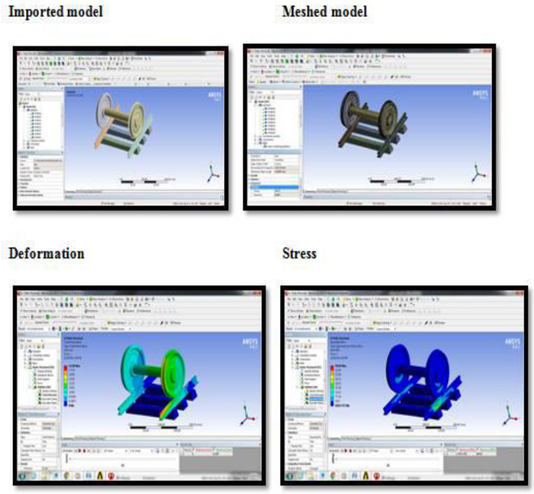

Fig 4.18 STATIC ANALYSIS OF ASSEMBLY OF RAIL WHEEL

Table:9 Static results of assembly of rail wheel

Deformation (mm)	Stress (MPa)	Strain
3.1189	349.82	0.0043065

Table:10 Modal analysis results of assembly of rail wheel

Mode shapes	Deformation (mm)	Frequency (Hz)
1	1.0657	28.702
2	1.5337	36.051
3	1.9006	55.082

Table:11 Random vibration analysis

Direction	Deformation(mm)
X	48.539
Y	20.108
Z	9.4829

By observing above results the assembly of rail wheel with stand the load. So our design is safe.

V. CONCLUSION

By observing the above results the wheel component materials are high carbon steel and nickel chromium molybdenum alloy steel. From the static analysis the less stress and more deformation for nickel chromium molybdenum alloy steel. From modal analysis more deformation and less frequency for nickel chromium molybdenum alloy steel. From modal analysis more deformation and less frequency for nickel chromium molybdenum alloy steel. By observing the above results the sleeper pad component materials are concrete and light weight concrete. From the static analysis the less stress and more deformation for light weight concrete. From modal analysis more deformation and less frequency for light weight concrete From modal analysis more deformation and less frequency for light weight concrete. In assembly of rail wheel taken materials for assembly components Wheel- nickel chromium molybdenum alloy steel. Sleeper pad- lightweight concrete. By observing above results the assembly of rail wheel with stand the load. So our design is safe.

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