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Modelling and Numerical Analysis of Railway Wagon Wheel using Finite Element Method

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ABSTRACT: In the present work, the railway wagon wheel has been considered and optimized in terms of its modelling, design, materials, to verify its tribological behaviour under various load conditions. In real world application wheel-surface slippage causes the deformation and movement of wheel beneath the surface of track. The rail wheel assembly is assumed to operate at the designed loads. Understanding the physical interaction between rails and wheels is essential for the safety of rails. To solve this issue, a thorough analysis of the rolling contact has been conducted on train wheels to reduce the failure chances. Numerous rail-wheel-related issues, such as rail corrugation, wear, plastic deformation, rotational interaction fatigue, thermo-elastic-plastic behaviour in contact, fracture, creep, and vibration of the vehicle dynamics, are caused by the rolling contact of a wheel on a rail. As a result, despite advances in designs, materials, non- destructive inspections, fatigue propagation and failures owing to damage to railway components remain a concern for railway safety engineers.

This research aims to investigate the stress caused by increased contact load at rail wheel assembly related to stress, strain, total deformation and safety factors which are calculated by numerical study of finite element analysis (FEM) added with ANSYS simulation. The results revealed that the total deformation applied at various loads is within the limit.

KEYWORDS: FEM, Total Deformation, Rolling resistance, Equivalent Stress, Strain, ANSYS.

I. INTRODUCTION

Railways is the best, largest and highly preferred means of transport for goods and manpower in the world, especially in India. In 1825, the world's first train crossed the English countryside between Stockton and Darlington. R.M. Stephenson proposed the establishment of India's railway system (IRS) in 1844, and the East India Company (EIC) agreed. It was first initiated its service in India with 34 km from Bombay to Thane in 1853. The second, from Howrah to Hooghly, ran on August 15, 1854. Rail grades are now advised based on historical development, as railroads operate new trains with different vehicle characteristics, greater axle loads, and faster speeds. This has led to bigger wheel/rail contact forces and optimization of wheel and rail design to improve performance and minimize costs. The main source of tire rim damage has shifted from wear to fatigue. Traditional approaches to check rail-wheel contacts include Hertz's analytical method, Kalker's programs, and contact and fasts. To simplify the problem, several scientists have relied on numerical or theoretical approaches grounded in Hertz's hypothesis, which may be seen as the bedrock of all subsequent study. Static and dynamic contact stresses have been studied in detail.

This research centres on the problem's actual circumstances, including accurate boundary and loading limitations, and involves creating a well-known Finite Element Method (FEM) on a 3D rail-wheel utilizing a real-size, completed model of several components with precise profiles. This article provides a framework for selecting the current rail grades to implement long-term system enhancements.

Various researchers executed distinct types of analysis using different modelling and Analysis software's like CATIA, NX-CAD, PRO-E, SOLIDWORKS, ABACUS, ANSYS etc., with various loads. The wear phenomena in





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railway engineering, focusing on their impact on environmental costs and operational efficiency, with experimental trials and shakedown maps [1]. studied about trend Linear and Excel wear rates and compared the wear rates of different train arrangements and flange wear due to the smallest bend radius [2]. By reviewing various manufacturing industries, the implementation of Robotic systems increases productivity, reduce costs, increase efficiency, and improve product and service [3], and the China's high-speed railway system, the wheel-rail rolling contact theories, application, and future development directions, can be taken as models [4]. But, the cracks are identified early with a thorough examination of the link between wheel wear on rail and rolling stock, rail safety, and noise propagation [5]. The rail-wheel quality in terms of safety is always analysed using CAD models and FEA, with rail-wheel fatigue-life under higher axle loads due to rapid infrastructure growth in railways [6], including the study of the wheel/rail interaction of railroad cars, focusing on contact stresses under static conditions, are vital for assessing the wheel performance and predicting wear [7].

The railway firms and researchers are using virtual prototypes to predict hopper wagon dynamics using tools like AutoCAD, Pro-E, ANSYS, and Universal Mechanism, with aluminium alloy expected for future use [8]. To develop a 90-ton payload trolley fixture for the transportation of propellant in cylindrical specimens, a 2.07 m track and geared air motor power was designed using ANSYS for structural analysis in addition to manual calculations [9]. The interaction between IRS-T12 rail-wheels and UIC-60 using manual computations and ANSYS, and examined wheel behaviour under structural, thermal, and combined loads using stress analysis on a rail loco wheel with the impact of wheel including the impact of axle load and train speed on rail joint performance using a 3D finite element analysis and ANSYS program to find the von mises stresses, maximum shear stress, and equivalent elastic strain which increases linearly with enhancement of axle load [10-13].

II. MATERIALS

2.1 CHEMICAL COMPOSITIONS AND SPECIFICATIONS

In the present work, the following materials are considered for modelling and analysis in SolidWorks and ANSYS which are listed in Table-1. The nominal chemical composition of various materials and their specifications are summarized for the listed materials are mentioned in the next Table-1.

From the list of Table-1, M-I material (Medium carbon steel-1084) is the present usage material in Indian railways to fabricate wagon wheels.

MATERIAL NUMBER	MATERIAL NAME	FEATURES		
M-I (Present using Material by Indian Railways)	MEDIUM CARBON STEEL-1084	Hardened and tempered		
M-II	HIGH CARBON STEEL-1095	Hardened and tempered		
M-III	MEDIUM CARBON STEEL-1040	Hardened and tempered		
M-IV	LOW ALLOY STEEL-4140	Hardened and tempered		
M-V	ALLOY STEEL- Fe-5Cr-Mo-V			

Table-1: List of various materials used for analysis

2.1.1 MATERIAL - I: (Medium Carbon Steel – 1084)

Steels are widely used in engineering applications due to their favorable mechanical properties, which include a high strength-to-weight ratio, strength, hardness, and simplicity of machining. Steel mechanical properties vary substantially based on alloy composition and heat treatment technique. In the present railway industry, Low Carbon Steels (LCS), Medium Carbon Steels (MCS) and High Carbon Steels (HCS) are used. The chemical composition and general mechanical properties of the commonly used Medium Carbon Steels (MCS) and High Carbon Steels





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(HCS) 1084 grade are reported in Table 2.

 Table 2: Chemical Composition of Material-I (Indian Railway wheel material (in wt.%))

Elements	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Chromium	Nickel	Molybdenum	Copper
Acronym	С	Mn	Si	Р	S	Cr	Ni	Мо	Cu
Coach	0.3-0.5	0.6 - 0.8	0.7	0.03	0.03	0.15	0.25	0.06	0.25
Wheels									
Wagon	0.5-0.6	0.6 - 0.8	0.7	0.03	0.03	0.15	0.25	0.06	0.25
Wheels									

Table 3:	Specifications	of Material-I	(Indian	Railways	wheel	material)
----------	----------------	---------------	---------	----------	-------	-----------

Material	Youngs Modulus (MPa)	Poisson's ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)	Density (Kg/m3)	Coefficient of Thermal Expansion (/ ⁰ C)
MCS/HCS 1084Grade	21600	0.27 - 0.5	140000	72000	320-700	550-900	7850	0.0000012

2.1.2 MATERIAL - II: (High Carbon Steel – 1095 Hardened & Tempered)

HCS-1095 steel, a high-carbon steel, is heat-treated by hardening (heating and quenching) and tempering to obtain hardness and toughness, making it ideal for applications that require sharp edges and edge retention. The Chemical composition and specifications of material-II(HCS-1095) are listed in Table-4 and Table-5.

 Table 4: Chemical Composition of Material-II (HCS- 1095 hardened & tempered) (in wt.%)

Elements	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Iron
Acronym	С	Mn	Si	Р	S	Fe
HCS-1095 Hardened &	0.90-1.03	0.30-0.50	0.15-0.35	Max 0.040	Max 0.050	0.25
Tempered						

HCS-1095 steel is plain carbon steel, meaning it primarily relies on carbon for its strength and hardenability, with manganese and silicon present in small amounts.

Fable 5: Specifications of Material-II	(HCS-1095 Hardened & tempered)
---	--------------------------------

Material	Youngs Modulus (MPa)	Poisson's ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)	Density (Kg/m³)	Coefficient of Thermal Expansion (/ ⁰ C)
HCS-1095 (Hardened & tempered)	221800	0.29	176030	85969	1042	1480	7850	0.000007457

2.1.3 MATERIAL - III: (Medium Carbon Steel – 1040 Hardened & Tempered)

Medium carbon 1040 steel, a medium-carbon steel, typically contains 0.37% to 0.44% carbon, 0.60% to 0.90% manganese, and small amounts of phosphorus and sulfur, with the balance being iron. Heat treatment, including hardening and tempering, enhances its strength and hardness. The Chemical composition and specifications of material-II(HCS-1040) are listed in Table-6 and Table-7.





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Table 6: Chemical Composition of Material-III (MCS-1040 hardened & tempered) (in wt.%)

Elements	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Iron
Acronym	С	Mn	Si	Р	S	Fe
MCS- 1040	0.37-0.44	0.60-0.90	Max 0.40	≤ 0.04	≤ 0.05	Balance
(hardened & tempered)						

Table 7: Specifications of Material-III (MCS-1040 hardened & tempered)

Material	Youngs Modulus (MPa)	Poisson's ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)	Density (Kg/m3)	Coefficient of Thermal Expansion (/ ⁰ C)
MCS-1040 (Hardened & tempered)	221800	0.29	176030	85969	659.1	892.7	7850	0.000006847

2.1.4 MATERIAL - IV: (Low Alloy Steel – 4140 Hardened & Tempered)

A low-alloy 4140 steel is noted for its high tensile strength, toughness, and wear resistance due to its chemical makeup, which comprises carbon, chromium, molybdenum, manganese, and other trace elements. The Chemical composition and specifications of material-IV (Low alloy Steel 4140) are listed in Table-8 and Table-9.

Table 8: Chemical Composition of Material-IV (LA Steel 4140 hardened & tempered) (in wt.%)

Elements	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Chromium	Nickel	Molybdenum
Acronym	С	Mn	Si	Р	S	Cr	Ni	Мо
Low alloy 4140 Steel (hardened & tempered)	0.3-0.4	0.7 - 1.00	0.1-0.3	Max 0.035	Max 0.04	0.8-1.10	0.25	0.15-0.25

Table 9: Specifications of Material-IV (Low alloy 4140 Steel hardened & tempered)

Material	Youngs Modulus (MPa)	Poisson's ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)	Density (Kg/m3)	Coefficient of Thermal Expansion (/ ºC)
Low alloy 4140 Steel (hardened & tempered)	221800	0.29	176030	85969	1042	1480	7850	0.000006848

2.1.5 MATERIAL - V: (Alloy steel, Fe-5Cr-Mo-V)

Fe-5Cr-Mo-V alloy steel, often used in high-stress, high-heat environments, exhibits excellent mechanical properties including high strength, hardness, and resistance to wear and corrosion, especially at elevated temperatures. The Chemical composition and specifications of MATERIAL-V (Fe-5Cr-Mo-V alloy steel) are listed in Table-10 and Table-11.





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Table 10: Chemical Composition of Material-V (Alloy steel, Fe-5Cr-Mo-V) (in wt.%)

Elements	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Chromium	Iron	Molybdenum
Acronym	С	Mn	Si	Р	S	Cr	Fe	Мо
Alloy steel, Fe- 5Cr-Mo-V	≤ 0.15%	0.3-0.6	≤ 0.5	< 0.025	< 0.025	4.0-6.0	92-95.3	0.45-0.65

Fable 11: Specifications of	Material-V (Alloy s	teel, Fe-5Cr-Mo-V)
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Material	Youngs Modulus (MPa)	Poisson's ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)	Density (Kg/m3)	Coefficient of Thermal Expansion (/ ⁰ C)
Alloy steel, Fe-5Cr-Mo-V	221900	0.3673	267400	77854	1511	1788	7778	0.00001239





Figure 4.1: Nomenclature of RWW



(a) Cross Section of the RWW





(b) Design the desired form in (c) Pick the 2DSketch & Minimize the 2D Sketch on RWW Material





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(d) Front View of RWW(e) Sideview of RWW(f) Isometric View of RWWFigure 3.2: Modelling of Railway wagon wheel with Array of slot

IV. FINITE ELEMENT METHOD (NUMERICAL ANALYSIS)



Figure 4.1: Numerical Analysis of the Railway Wagon

4.1 DATA

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Tensile Yield Strength

1042 MPa

NOTE: By using the above nomenclature shown in section-4 (figure-4.1) the numerical analysis of the railway wagon wheel has been performed which follows the step wise procedure.

The detailed step wise calculations with its values are available in Appendix-A.

=

4.2 PROCEDURE IN ANSYS SYMULATION

STEP -1: Dividing the Elements.
STEP -2: Calculating the Area of Each Node.
STEP -3: Calculating the Average Areas.
STEP -4: Calculating the Body Force Vector.
STEP -5: Calculating the Global Stiffness Matrix.
STEP -6: Finite Element Equation.
STEP -7: Calculating Stress.
STEP -8: Calculating Reaction Forces.
STEP -9: Verification.

V. FEA IN ANSYS

John Swanson developed general purpose engineering software in the 1960s and founded Swanson Analysis Systems Inc. in 1970, resulting in ANSYS. ANSYS is a solution for the engineering industry where finite element analysis is performed by hand.

`BOUNDARY CONDITIONS

Material properties like Density, Youngs Modulus, Tensile Yield Strength and other details are shown in Figure-5.1.

In the present analysis the meshing is done by selecting the Tetrahedra element with 5mm size of the element. The meshing details like mesh quality, element size, number of nodes and other details are shown in Figure 5.2.

The contact details between rail and wheel are described in Figure-5.3. The Force and Displacement details are described in Figure -5.4 and Figure-5.5.

Common Material Proper	ties
Density	7850 kg/m ³
Young's Modulus	table(T) = 2.1245e+11 Pa
Thermal Conductivity	table(T) = 43.334 W/m.°C
Specific Heat	table(T) = 435.39 J/kg.°C
Tensile Yield Strength	1.634e+09 Pa
Tensile Ultimate Strength	1.764e+09 Pa
Nonlinear Behavior	True

Figure 5.1: Properties of Materials





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Quality

Display	
Display Style	Use Geometry Setti
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	5.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Diagonal	1992.8 mm
Average Surface Area	41661 mm ²
Minimum Edge Length	2.3362e-003 mm

Check Mesh Quality	Yes Errors
Error Limite	Annearchie Machani
Error Limits	Aggressive Mechan
Target Element Qual	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None
Inflation	
Advanced	
Number of CPUs for Pa	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Redu
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refr	No
Statistics	
Nodes	1696489
Elements	1062406



Figure 5.2: Meshing of Wheel

Scope	
Scoping Method	Geometry Selection
Contact	3 Faces
Target	2 Faces
Contact Bodies	RAILWAY WHEEL LO
Target Bodies	RAIL
Protected	No
Definition	
Type	Frictional
Friction Coefficient	0.28
Scope Mode	Manual
Behavior	Symmetric
Trim Contact	Program Controlled
Contact APDL Name	
Target APDL Name	
Suppressed	No

-	Display								
	Element Normals	No							
-	Advanced								
	Formulation	Augmented Lagrange							
	Small Sliding	Program Controlled							
	Detection Method	Program Controlled							
	Penetration Tolerance	Program Controlled							
	Elastic Slip Tolerance	Program Controlled							
	Normal Stiffness	Program Controlled							
	Update Stiffness	Program Controlled							
	Stabilization Damping Factor	0.							
	Pinball Region	Program Controlled							
	Time Step Controls	None							
-	Geometric Modification								
	Interface Treatment	Add Offset, Ramped Effe							
	Offset	0. mm							
	Contact Geometry Correction	None							
	Target Geometry Correction	None							



Figure 5.3: Details of contact information between two bodies

tails of Torce		
Scope	15.	
Scoping Method	Geometry Selection	
Geometry	1 Face	
Definition		
Туре	Force	
Define By	Components	
Applied By	Surface Effect	
Coordinate System	Global Coordinate System	
X Component	0. N (ramped)	
Y Component	-2.e+005 N (ramped)	
Z Component	0. N (ramped)	
Suppressed	No	

Figure 5.4: Details of Force application





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- Sc	ope					
Sc	oping Method	Geometry Selection				
Ge	eometry	5 Faces				
- De	finition					
Typ	pe	Displacement				
De	fine By	Components				
Co	ordinate System	Global Coordinate System				
	X Component	0. m (ramped)				
YC	Component	Free				
	Z Component	0. m (ramped)				
Su	ppressed	No				



Figure 5.5: Details of Displacement

VI. METHODOLOGY

The step-by-step procedure of simulation process is shown in Flowchart of Figure-7.1.



Figure-6.1: Flow Chart of Simulation Process in ANSYS





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VII. EXPERIMENTAL RESULTS





(a) Load Application of 200000N

(b) Total Deformation (at 200000N)



(c) Equivalent (von-mises) Stress (at 200000N)

(d) Equivalent Elastic Strain (at 200000N)

Figure-7.1: Outcomes of Simulation Analysis

7.1 STATIC STRUCTURAL ANALYSIS BY APPLYING FORCE:

Table-12: Outcomes of Structural Analysis by simulation

	WHEE									-	-
S.NO	TVDE	MATERIAL	ANALYSIS DETAILS	100000N	150000N	200000N	250000N	300000N	350000N	400000N	500000N
	TIFE			Max	Max	Max	Max	Max	Max	Max	Max
	MACTED	HIGH CARBON STEEL 1095	Total Deformation in (mm)	0.08665	0.12176	0.15353	0.18445	0.21232	0.23893	0.26425	0.31326
1		(Hardened & Tempered) Wheel	Equivalent Elastic Strain in (mm)	0.0045261	0.0049687	0.0052236	0.0054531	0.0054388	0.0053342	0.005387	0.0056499
		without slots	Equivalent Stress in (Mpa)	890.78	976.25	1060.6	1108.2	1111.3	1082.2	1112.7	1158.2
	MODIFIED WHEEL	HIGH CARBON STEEL 1040	Total Deformation in (mm)	0.085252	0.12323	0.15707	0.1885	0.21827	0.24627	0.2728	0.32278
2		(Hardened & Tempered) Wheel	Equivalent Elastic Strain in (mm)	0.0043105	0.0050047	0.0053383	0.0053539	0.005333	0.0054001	0.0053767	0.0053566
		With slots	Equivalent Stress in (Mpa)	861.57	1004.6	1075.5	1102.8	1107.7	1115.3	1116.1	1098.8
		Alloysteel, Fe-5Cr-Mo-V	Total Deformation in (mm)	0.08309	0.1202	0.13729	0.18356	0.21237	0.23953	0.26513	0.31319
3			Equivalent Elastic Strain in (mm)	0.0041369	0.0052991	0.0062369	0.0070587	0.007705	0.0082242	0.0083635	0.0087641
			Equivalent Stress in (Mpa)	830.22	1078.6	1282.2	1461.1	1603.1	1717.4	0.1741.1	1822
			Total Deformation in (mm)	0.0852226	0.1232000	0.1569700	0.1882300	0.2177400	0.2454600	0.2716500	0.3208600
4		(Hardened & Tempered)	Equivalent Elastic Strain in (mm)	0.00043095	0.0055025	0.0064631	0.0072311	0.0075912	0.0076839	0.0078434	0.0080906
		(nalueneu & lempereu)	Equivalent Stress in (Mpa)	861.65	1116.5	1325.2	1493.5	1563.8	1587.7	1622.6	1673.7





0.1232000

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0.124

0.123

7.2 GRAPH COMPARISION OF TOTAL DEFORMATION:



0.122 0.121 0.12 0.12 0.12 0.12 0.12 0.1202 0.119 0.118 HCS-1095 HCS-1095 Alloy steel, LOW ALLOY (Master Modified Fe-5Cr-Mo-V STEEL 4140 Wheel) Wheel

Total Deformation (mm) Vs Load (N)

0.12323

(b) Load at 150000N

(a) Load at 100000N



(c) Load at 200000N



(e) Load at 300000N



(d) Load at 250000N









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(g) Load at 400000N

(h) Load at 500000N (i)

7.3 GRAPH COMPARISION OF EQUIVALENT ELASTIC STRAIN:



(a) Load at 100000N



(c) Load at 200000N

(b) Load at 150000N



(d) Load at 250000N

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(e) Load at 300000N



(f) Load at 350000N



(g) Load at 400000N

(h) Load at 500000N









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(c) Load at 200000N



(d) Load at 250000N



(e) Load at 300000N



(g) Load at 400000N



(f) Load at 350000N



(h) Load at 500000N





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7.5 ROTATIONAL SPEED ANALYSIS:

Table-13: Outcomes of Various Rotational Speed Analysis by simulation

	WUED										rotationa	LSPEED						
S.NC		MATERIAL	ANALYSIS DETAILS	100 ra	ad/s	150	rad/s	200	rad/s		250 ra	ad/s	300 r	ad/s	350 r	ad/s	400 r	ad/s
	TIPE			Min	Max	Min	Max	Min	Max		Min	Max	Min	Max	Min	Max	Min	Max
	MACTED	CARBON STEEL	Total Deformation in (mm)	0	0.13299	0	0.29922	0	0.53194		0	0.83116	0	1.1969	0	1.6291	0	2.1278
1		1040 Hardened and	Equivalent Bastic Strain in (mm)	1.9923E-08	0.000214	4.4826E-08	0.00048228	7.9691E-08	0.00085739	1	.2452E-07	0.0013397	1.793E-07	0.001929	2.4405E-07	0.0026257	3.1876E-07	0.0034295
		tempered (Wheel	Equivalent Stress in (Mpa)	0.0039138	45.519	0.08806	102.4	0.015655	182.07		0.024461	284.49	0.035224	409.67	0.047944	557.6	0.062621	728.3
		•																
	MACTED	CARBON STEEL	Total Deformation in (mm)	0	0.13299	0	0.29849	0	0.53194		0	0.83116	0	1.1969	0	1.6291	0	2.1226
2		1095 Hardened and	Equivalent Bastic Strain in (mm)	1.992E-08	0.000214	0	0.00044973	1.992E-08	0.00085739	1	.2452E-07	0.0013397	1.793E-07	0.001929	6.1013E-06	0.0026257	6.1013E-06	0.0031981
	WHEEL	tempered (Wheel	Equivalent Stress in (Mpa)	0.0039138	45.519	0.0090906	95.324	0.015655	182.07		0.024461	284.49	0.035224	409.67	0.047944	557.6	0.047944	677.86
		•																
	Modified	CARBON STEEL	Total Deformation in (mm)	0	0.14056	0	0.31627	0	0.56225		0	0.87852	0	1.2651	0	1.722	0	2.2515
3		1040 Hardened and	Equivalent Bastic Strain in (mm)	1.2318E-08	0.000329	2.7715E-08	0.00074081	4.9271E-08	0.001317	7	7.6986E-08	0.0020578	1.1086E-07	0.0029632	1.5089E-07	0.0036852	1.9708E-07	0.0036459
	WHEEL	tempered	Equivalent Stress in (Mpa)	0.0024226	69.938	0.0054509	157.36	0.0096904	279.75		0.015141	437.11	0.021803	629.45	0.029677	782.05	0.038762	771.97
		•	•															
	Modified	CARBON STEEL	Total Deformation in (mm)	0	0.14056	0	0.31627	0	0.056225		0	0.087852	0	1.2651	0	1.717	0	2.249
4		1095 Hardened and	Equivalent Bastic Strain in (mm)	1.2318E-08	0.000329	2.7715E-08	0.00074081	4.9271E-08	0.001317	1	7.6986E-08	0.0020578	1.1086E-07	0.0029632	0	0.0040418	1.9708E-07	0.005268
		tempered	Equivalent Stress in (Mpa)	0.0024226	69.938	0.0054509	157.36	0.0096904	279.75		0.015141	437.11	0.021803	629.45	0	858.48	0.038762	1119
	Modified	Allowstool Ep 50r	Total Deformation in (mm)	0	0.13786	0	0.31019	0	0.55145		0	0.86164	0	1.2408	0	1.6888	0	2.2058
5		Millysieei, re-Jui-	Equivalent Bastic Strain in (mm)	7.6597E-09	0.000341	1.7234E-08	0.00076827	3.0639E-07	0.0013658	4	1.7873E-08	0.0021341	6.8937E-08	0.0030731	9.3831E-08	0.0041828	1.2256E-07	0.0054632
		IVIO-V	Equivalent Stress in (Mpa)	0.0007527	72.551	0.0016935	163.24	0.0030106	290.2		0.0047041	453.44	0.0067738	652.93	0.0092199	888.75	0.012042	1160.8
							-											
	Modified	l awallay Qool	Total Deformation in (mm)	0	0.14052	0	0.31616	0	0.56207		0	0.87823	0	1.2646	0	1.7213	0	2.2483
6		1140	Equivalent Bastic Strain in (mm)	3.0784E-07	0.000329	6.926E-07	0.00074056	4.9255E-08	0.0013166		7.696E-08	0.0020571	1.1082E-07	0.0029623	1.508E-07	0.004032	1.9702E-07	0.0052662
		4140	Equivalent Stress in (Mpa)	0.0024226	69.938	0.0054509	157.36	0.0096904	279.75		0.0151410	437.11	0.021803	629.45	0.029677	856.74	0.038762	1119

7.6 GRAPH COMPARISION OF TOTAL DEFORMATION ON ROTATIONAL SPEED:



(a) Speed at 100 rad/s



(b) Speed at 150 rad/s



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7.7 MODAL ANALYSIS:



S.NO	Carbon steel 1095 Hardened and tempered	FREQUENCY	REQUENCY in (Hz) 134.86 134.87 196.62 279.1 519.92 740.66 740.67 1142.7 1142.7	MODALANALYSIS		S.NO	S.NO	MATERIAL	FREQUENCY in (Hz)		MODAL ANALYSIS	
				MAXIMUM	MASTER wheel (Without Slots)						MAXIMUM	
		in (Hz)		DEFLECTION in							DEFLECTION in	
				(mm)							(mm)	
1		134.86		2.8823				127.92		2.8863	1	
2		134.87		2.8824			2	Carbon steel 1095 Hardened and tempered	127.92	TOTAL DEFORMATION	2.8862	1
3		196.62		1.9116			3		190.22		1.9113	Modified
4		279.1		3.1656			4		276.85		3.1714	wheel
5		279.1		2.4083			5		276.85		3.1714	
6		519.92		1.9465			6		472.29		1.9712	
7		740.66		3.3569			7		740.42		3.365	
8		740.67		3.3568			8		740.43		3.3654	
9		1142.7		2.4079			9		1084.9		2.1524	
10		1142.7		2.4083			10		1084.9		2.1542	
		FREQUENCY		MAXIMUM							MAXIMUM	
S.NO	IO MATERIAL	in (Hz)	DEFORMATION	DEFLECTION in	MASTER wheel (Without Slots)		S.NO	MATERIAL Carbon steel 1040 Hardened and tempered	FREQUENCY in (Hz)	DEFORMATION	DEFLECTION in	Modified wheel
				(mm)							(mm)	
1		134.86		2.8830			1		127.73		2.8857	
2	Carbon steel 1040 Hardened and tempered	134.87		2.8824			2		127.73		2.8857	
3		196.62		1.9116			3		190		1.9106	
4		279.1		3.1655			4		276.76		3.1715	
5		279.1		3.1656			5		276.77		3.1716	
6		519.92		1.9465			6		472.19		1.9712	
<u></u>		740.66		3.3569					740.19		3.3653	
8		740.67		3.3568			8		740.32		3.3655	
9		1142.7		2.4079			9		1084.6		2.1556	
10		1142.7		2.4083			10		1084.6		2.1559	
											BAAMIBAI IBA	
SNO	MATERIAL	FREQUENCY		DEELECTION in			SNO	MATERIAL	ERECHENICY in (Hz)		DEFLECTION in	
10.100		in (Hz)		(mm)			0.110				(mm)	Modified wheel
1	Low alloy steel 4140 Hardened & Tempered	127.04	TOTAL DEFORMATION	2,8863	Modified wheel		1		130.74	TOTAL DEFORMATION	2 9060	
2		127.95		2.8862			2	Alloysteel, Fe-5Cr- Mo-V	130.74		2.9059	
3		190.25		1 9113			3		193.7		1 9264	
		276.9		3 1714			4		274.91		3 2007	
5		276.9		3.1714			5		274.91		3,2007	
6		472.37		1.9712			6		463.64		1.9795	
7		740.55		3.365			7		735.46		3.4092	
8		740.55		3.3654			8		735.46		3 4095	
9		1085		2.1524			9		1080.8		2,1105	
10	1	1085.1	1	2.1542			10	1	1080.9		2,1106	
<u> </u>	l		I					J		I		

VIII. DISCUSSIONS

Railway wagon wheel research investigates novel materials and designs in an effort to improve wheel-rail contact, minimize noise and wear, increase safety, and maximize performance. Both the modified wheel-in and the original profile were investigated, and the material used in the inner construction was optimized. The results obtained from these two (numerical and simulation) studies are observed, including the stresses and displacements against the wheel. The points to be noted are.,

- There is minimal change in strain, stress, and total deformation, when the load varies.
- The total deformation, strain, and stress vary relatively little due of natural frequency fluctuations in modal analysis.
- As the force changes, the overall deformation, strain, and stress hardly change.





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IX. CONCLUSION

After investigating a Indian Railway wagon wheel by modelling, simulation, and numerical analysis the below conclusions are extracted, which are,

- a) The design railway wagon wheel was optimized in terms of design and materials, which results optimized conditions to fabricate the wheel.
- b) The railway wheel design gets reduced in terms of weight to reduce stress, weight optimization for railways involves evaluating different grades of alloy steel and carbon steel under identical boundary conditions.
- c) The present work reveals the weight reduction of the railway wheel using alloy wheels lowered by about 5%.

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