Indian Journal of Engineering & Materials Sciences
Vol. 31, February 2024, pp. 84-92
DOI: 10.56042/ijems.v31i1.986

Development and validation of test rig for experimental analysis of contact behavior between rail wheel-rail and rubber tire-rail in road cum rail vehicles

Sharad K Pradhan[a], Arpit Singh Rathore[b], Shankar Sehgal[c*], Pankaj Sonia[d], Gandikota Ramu[e], Chander Prakash[f]

[a]THDC-Institute of Hydropower Engineering and Technology, Uttarakhand 249 124, India
[a,b]Mechanical Engineering Department, NITTTR , Bhopal 462 002, India
[c]Mechanical Engineering, UIET, Panjab University, Chandigarh 160 014, India
[d]Department of Mechanical Engineering, GLA University, Mathura 281 406, India
[e]Departmentof Computer Science and Engineering, Institute of Aeronautical Engineering, Hyderabad 500 043, India
[f]Centre for Research Impact and Outcome, Chitkara University, Rajpura 140 401, India

Received: 28 April 2023; Accepted: 16 January 2024

Present research attempt deals with modeling, structural analysis, fabrication of test rig and experimentations to investigate static contact behavior of 'Rubber Tire-Rail' and 'Rubber Tire-Road' combinations. Conceptual models for the test rig, rail and rubber tire with rim (178/100/R16) are developed and the contact behavior of Rubber tire-Road and Rubber tire-Rail are simulated using FEM. To establish the dimensions of the Test Rig, two stage FEM is performed. In stage-I, contact combinations viz. 'Rubber Tire-Road' and 'Rail wheel-Rail' are studied using ANSYS software without any test rig while in stage-II the same pairs with same simulation environment are analyzed with the proposed test rig. The negligible stresses and deformation in the test rig are indicators of correctness and rigidness of designed test Rig. After finding out the dimensions, the test rig is fabricated and used to perform the experimentations. Numerical and experimental investigations for 'Rubber tire-Rail/Road' combinations are carried into 3 and 2 sub categories respectively. The percentage error in experimental and simulation results are 1.82% for Contact Pressure and 14.37% for Contact Area at 30 KN load and 0.5 MPa inflation pressure. Results indicate that the developed simulated environments and test rig can be used for similar future studies.

Keywords: Contact patch, Road cum rail vehicle, Rubber tire-rail contact, FEM, Simulation, Test rig

1 Introduction

In this era of high speed, safe transport scenario and PM Gati Shakti - National Master Plan for Multi-modal Connectivity in India,[1] railway transportation is of extreme significance because of its extended load wearing potential, low charges, excessive speed, safe, ecologic capabilities and connectivity. In railway engineering, rail and rail wheel contact is one of the key areas of study. After arrival of Road cum Rail vehicles it becomes further more important due to additional involvement of contact between Rail and Rubber Tire. Rail cum road vehicle is a vehicle which can operate both on rail tracks and on a regular road. These are often converted road vehicles, keeping their normal wheels with rubber tires, but fitted with additional flanged steel wheels for running on rails. The main characteristics of road cum rail vehicles are mobility of rubber tires and rail wheels on rails, high localized deformation of rubber tires and transfer of vehicle load in static and running conditions from rail wheel and rubber tires to rails.

Understanding the manner in which the rail wheel and tire interacts with the rail and road is a very important factor that goes into assessing vehicle performance. By learning about the contact area footprint, properties such as traction, noise, ride, handling, and wear, can be understood more effectively.

The main goal of this work is to estimate experimentally and numerically the contact patch, contact pressure distribution and equivalent von misses stress at the rail-rubber tire contact interaction. In this research attempt the lateral and radial deformations of rubber tire when it on rail under various amounts of load values is also studied.

Conceptual design of the test rig is developed and fabricated to test the contact behavior of rubber tire-rail and rail wheel-rail one after another individually. To establish the dimensions of the Test Rig, two stage FEM is performed. In stage-I, different contact

*Corresponding author (E-mail: sehgals@pu.ac.in)

combinations viz. 'rubber tire-road', 'rubber tire-rail' and 'rail wheel-rail' are studied using ANSYS software without any test rig while in stage-II the same pairs are analyzed using same simulation environment with the proposed test rig. The negligible stresses and deformation in the test rig are indicators of the rigidness of the designed test Rig. Based on the dimensions estimated a simple and compact size testing rig is being developed to measure the contact area and contact pressure distribution experimentally. The test rig can apply a maximum load of 5 ton on rubber tire-rail/road and rail wheel-rail combinations. Carbon paper and Fuji film pressure sensitive paper are used to measure the contact area and contact pressure distribution at the interference of rail-rubber tire.

During numerical study under stage-I for validation of the Rubber tire finite element model and other boundary conditions, the investigations are performed in two phases. In first phase a reference rubber tire (255/100/R16) in contact with road is analyzed and the results are validated with the existing published experimental and simulated data,[2] and then the validated finite element tire model is used to analyze its behavior when it is in contact with rails. In second phase a new rubber tire (178/100/R16) is taken and its contact behavior with road and rail using same validated simulated environment is performed. Further, experimental study is performed on the new tire also using the developed test rig.

In order to determine the contact behavior of the rubber tire on rail and optimization of contact area and contact stress distribution, it is necessary that the existing literature related to rubber tire-rail/road, should be reviewed. Existing research efforts related to contact between rubber tire and road are available but not for rubber tire and road hence the same are reviewed in this section.

Douglas *et al*.[3] conceived multiphase project including, building an apparatus to measure contact stresses under full scale tires in contact with road, measuring contact stresses for a range of tire types, wheel loads, and inflation pressures. Anghelache *et al*.[4] studied the impact of longitudinal tread ribs on the shear stress distributions and ratios of Strain distributions inside the truck tire contact patch. Beer *et al*.[5] presented the work for measurement of three-dimensional (3D) tire pavement contact stresses using a flat bed sensor system. Zhang *et al*[6] developed an embedded, flexible local force sensor for measuring the tire local friction forces and their distributions in contact with road. Steyn *et al*.[7] investigated the relationship between pavement surface texture depth and tire/surfacing contact stress and area. Texture depth and tire/surfacing touch pressure were measured for various tire inflation pressures on 5 distinct pavement surfaces. Guo *et al*. analyzed the changing characteristics of contact stresses in the tire–pavement interface and the functional relationship between rolling resistance and the working conditions of truck-bus tires, A three-dimensional tire–pavement model is established and used to predict the distribution of contact stresses and rolling resistance under different working conditions of the tire, comprising various tire loads, inflation pressures, and velocities.[8]Gabriel Anghelache *et al*.[9] highlighted the impact of the longitudinal tread ribs on the shear stress distributions. Measurements of stress distributions have been performed in straight line rolling, for different vehicle tires, inflation pressures and rolling speeds, in traction, braking, and free rolling conditions. Gabriel Anghelache *et al*.[10] presented the original measuring equipment for tri-axial stress distribution in different rolling conditions. Two sets of stress distributions obtained through experiment and simulation, in free rolling and in braking conditions, are compared. Bo Li *et al*.[11] proposed a contact stress model for new elastic wheel on ground. Two elastomers, ground and non-pneumatic wheel, are included in the contact model, and the vertical load is applied on the interior rigid hub of non-pneumatic wheel.

Concluding remarks based on literature survey:

- The research efforts done for contact analysis of rubber tire and rail are not available but for the combination o rubber tire and road are many.
- Typical components of a radial passenger tire includes Tread area, Grooves, Shoulder, Bead, Radial plies, Steel belts, Cap plies etc. The main components are rubber and reinforcement (ply and belts).
- Two material constitutive models are used to simulate the tire: linear elastic for reinforcement and hyper-elastic for rubber. Rubber is hyper-elastic in nature and can generally be considered to be isotropic, nearly incompressible and strain rate independent. The reinforcements mainly consist of materials that can be properly represented by elastic modulus and Poisson's ratio.

- No one has proposed/developed a test rig that can perform test related to contact behavior of both rail wheel-rail and rubber tire-rail (together as well as individually).

2 Materials and Methods

2.1 Modeling of Tire, Rim, Road and Rail

A pneumatic tire is a flexible structure of the shape of a toroid, filled with compressed air. The main components are rubber and reinforcement (ply and belts). Rubber components experience large deformation as the magnitude of the applied load increases. Consequently, the linear elastic model is not suitable and hyper-elasticity becomes a better choice. Rubber had a non-linear property which was modeled by the constitutive Mooney-Rivlin equation without any consideration of a viscoelastic effect. The potential energy of deformation for the Mooney-Rivlin model for C10, C01, & D1 are adopted in this study, Table 1.

The objective of this research is to investigate the contact patch behavior of a 255/100R16 and 178/100/R16 tires with road and rail both. The properties of Rubber tire, Rim, Rail and Road are used in the simulation studies, Tables 2 and 3. The general specifications of the rubber tires and rims considered for modeling and analysis, Tables 4, 5 and 6. The rubbers in different parts of the tire are simplified to the same material. To make the process of data analysis easier, the tire is assumed to be made from natural rubber hence the tire model comprises of one radial ply, two steel belts and a rubber carcass (sidewall and tread).

The recommended rim for tires 255/100/R16 and 178/100/R16 is 5.50F. A rim comprises of two elements viz. web and flange. The flange specification of 5.50F rim is taken from the tire and rim association, Tables 5 and 6. In this study positive offset rim with offset 95 mm value is taken and the numbers of holes are 5. The rim was modeled as a linear elastic body and in contact with the bead at the end of sidewall. The rim is modeled with positive offset, Fig. 1. The standard UIC60 rail is used with cross-section area as 7670 $mm^2$and mass as 60.21 kg/m.[12]

2.2 Development of CAD model of the test rig

CAD models of this test rig are developed with rubber tire and rail wheel, Fig. 2 (a-b). In this test rig the ‘rubber tire with rail/road’ and ‘rail wheel with rail’ can be tested one at a time using a common shaft to hold either rubber tire or rail wheel. The Rail/Road is movable in upward direction with the help of hydraulic jack while the rubber tire/rail wheel remains stationary. Force applying capacity of the test rig is up to 50KN (5ton).

Based on the basic structural design equations, simulation trials and standard sizes available in the market, the dimensions of different components of the test rig are finalized. The test rig mainly consists of eight parts viz. Rail wheel (250 mm diameter with

Table 1 — Mooney rivlin parameters for rubber tire

Part	Density Kg/m^3	Young’s modulus MPa	Poisson’s ratio	C10 Mpa	C01 Mpa
Tread	1173	14	0.45	0.806	1.8
Side wall	1132	5.05	0.45	0.171	0.83
Bead core	1132	5.05	0.45	0.171	0.83

Table 2 — Elastic plastic component properties for rubber tire main components

Part	Density Kg/m^3	Young’s modulus MPa	Poisson’s ratio
Cords	7860	2.11E5	0.30
Carcass	1351	107	0.451
Inner fabric	2497	3181	.454

Table 3 — Material of rail, road and rim

Part	Density Kg/m^3	Young’s modulus MPa	Poisson’s ratio
Rail	7850	2.1E5	0.30
Rim	7860	2.1E5	0.30
Road	2300	3.0E4	0.18

Table 4 — Specification of Rubber Tires (255/100 R16 and 178/100/R16)

Size	Load index	Ply rating	Speed symbol	Diameter overall (mm)
7.00-16	118/113	14	K(110 KPH)	804

Table 5 — Specification of flange of 5.50F rim (All dimensions in this table in inch)

Flange Height FH	Radii FR1	Radii FR2	Radius location H2	Width FW	Bead Seat BW	Bead Seat HR	Well depth WD
0.875	0.38	0.615	0.572	0.48	0.940	0.28	0.219

Table 6 — Specification of flange of 5.50F rim

Size	Standard tire	Holes no.	Hole diameter(mm)	PCD (mm)	CBD (mm)	Disc thickness (mm)
5.50 F-16	7.00-16	5/6	32.5	203.20	146.00	10

50 mm axle diameter), UIC60 standard rail, Rubber tire, Basic supporting structure, Pedestal bearing, Shaft and Loading unit. The Loading unit consists of 5-ton hydraulic jack with in-built pressure gauge. This pressure gauge is calibrated to shows the amount of force applied. Supporting structure consists of base plate of thickness 8 mm and C-section cross section pillars. The rail is modeled using UIC60 standard rail.[12] The slope of the rail taken in this study is 1: 20.[13] The Tire, cylindrical roller bearing, axel, Plummer block and iron C-section channel data are also modeled using standards.

3 Results and Discussion

3.1 Finite element based contact analysis

This section deals with simulation of the contact behavior of rubber tire in contact with rails and road respectively. A reference rubber tire[2], along with rim, with and without test rig is analyzed to investigate and validate its contact behavior with road. The Finite Element Method and ANSYS software are used to obtain these static contact behaviors. The aim is to understand the stress and deformation levels in the proposed test rig, so as to ensure that it will act as a rigid structure and should not contribute in the stress and deformation values of the contact pairs. To ensure the rigidity of the proposed test rig, all the simulation cases of contact viz. rubber tire-road and rubber tire-rail are performed with and without test rig. The material properties of different components of the test rig are taken for finite element analysis, Table 7.

Fig. 1 — Rim (5.50 F) cross section.

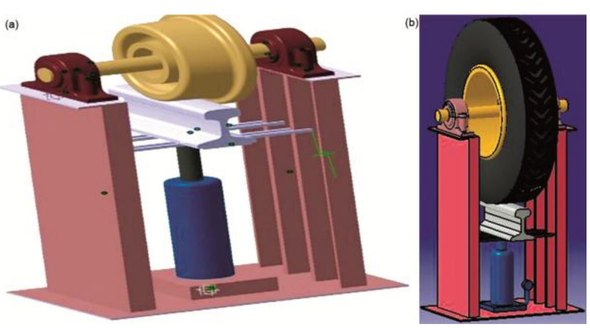

Fig. 2 (a) — Test rig with rail wheel, & (b) test rig with rubber tire.

The aim is to evaluate numerically the performance of a stationary rubber tire on rails so that the corresponding performance parameters like equivalent stress, deformation and contact patch can be predicted. This study focuses rubber tire–rail interface to estimate rubber tire deformation with respect to the contact region and the resulted contact stress distributions at the rail to enable the designer to improve both the construction of the tire and the control system, taking into account the wheel dynamics. Three case studies are taken for numerical investigation.

1) Simulation of contact behavior of a reference rubber tire and road without test rig at 30000 N and inflation pressure of 0.5 MPa.
2) Simulation of contact behavior of ref. rubber tire and road with test rig at 30000 N and inflation pressure of 0.5 MPa.
3) Simulation of contact behavior of new rubber tire and rail with test rig at 30000 N and inflation pressure of 0.5 MPa.

3.1.1 Case-1: Reference rubber tire and road interaction (without test rig) -

In this study, the road is modeled as a non-deformable flat surface to achieve better computation efficiency. This assumption is considered reasonable because the Tire deformation is much greater than the road deflection when wheel load is applied on the Tire

TABLE 7 — UTILIZED MATERIAL LIST FOR THE TEST-RIG

Part name	Modulus of elasticity (MPa)	Poisson's ratio	Density (Kg/m^3)
Rail	2.1E+5	0.3	7850
Rail Wheel	2.1E+5	0.3	7850
Plummer Block	1.1E+05	0.28	7200
C-Section Iron Channel	2.1E+5	0.3	7850
Base Plate	2.1E+5	0.3	7850

and transmitted to the road surface. Understanding the manner in which the tire interacts with the road is a very important factor that goes into assessing vehicle performance. The reference rubber tire[2], is placed in contact with road and numerical study is performed to examine the contact behavior under 30000 N load and 0.5 MPa inflation pressure without test rig. A program-controlled hybrid meshing was done with 3d solid element of hexahedral, tetrahedral & pyramid shape. solid 186, solid 187, beam 188 types of elements are used.

A finite element model of the reference rubber tire and road is developed, Fig. 3. After post processing the analysis results related to total deformation, von-mises stresses, frictional stresses and contact patch are obtained, Figs 4, 5 and 6.The maximum stress and deformation recorded in the tire with 30000 N load and 0.5 MPa inflation pressure is of the order of 267.59 MPa and 54.67 mm respectively while the length and width of the rectangular contact patch are 282.5 mm and 254 mm respectively.

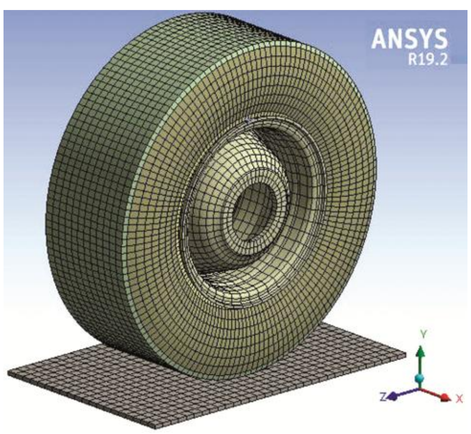

Fig. 3 — Meshing of rubber tire and road.

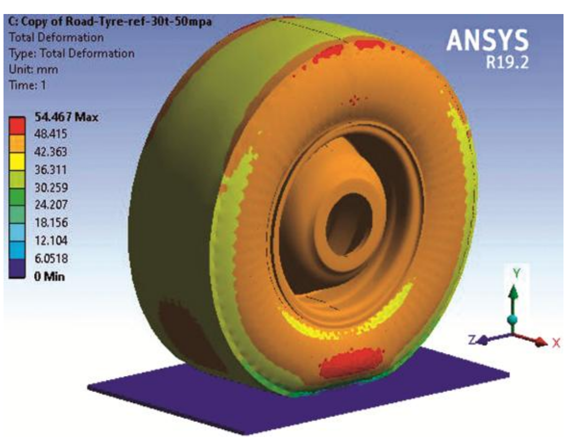

Fig. 4 — Total deformation of rubber tire with road.

3.1.2 Case-2: Reference rubber tire and road interaction (with Test Rig)

In this case study the same reference tire and road are used but along with the proposed test rig. So that the obtained results can be compared with Case-1 for validation of test rig dimensions thereby ensuring the rigid body contribution of test rig in terms of stress, strain and deformation. A finite element model of the complete assembly is developed, Fig. 7. The assembly is analyzed again at 30000N load and 0.5 MPa inflation pressure and the results i.e. total deformation, von-mises stresses, frictional stresses and contact patch (Fig. 8) are obtained.The maximum stress and deformation recorded in the tire is of the order of 192.31 MPa and 46.376 mm respectively while the length and width of the rectangular contact patch are 250.63 mm and 254 mm respectively. The reduction in stress and deformation values related to the tire is due to the fact that some part of strain energy is being absorbed by the proposed test rig.

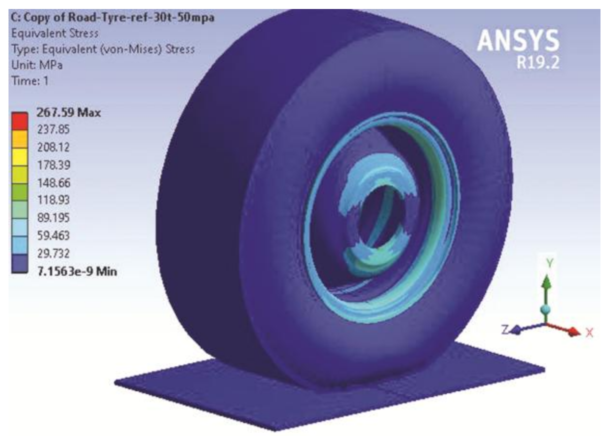

Fig. 5 — Von-Mises stress distribution in rubber tire with road.

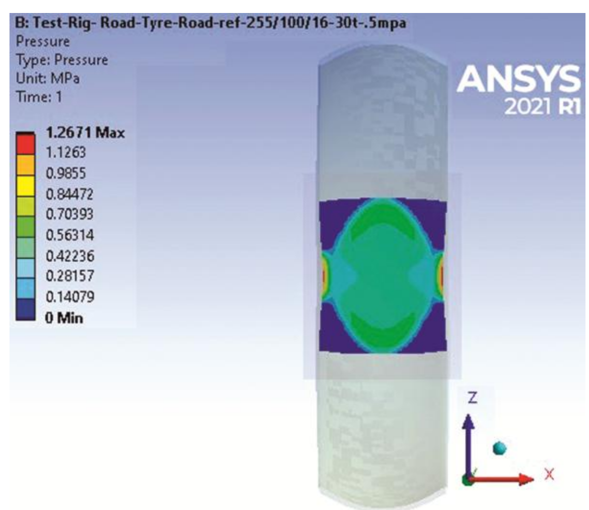

Fig. 6 — Contact pressure between rubber tire and road.

Simulated results in the above two cases are compared, Table 8. The results obtained from numerical simulation of road and rubber tire at 3 Ton shows good agreement with existing published research work.[2] It means parameter used in modeling of test rig and tire are correct. On the basis of these results the same simulated model can be used to perform Case 3.

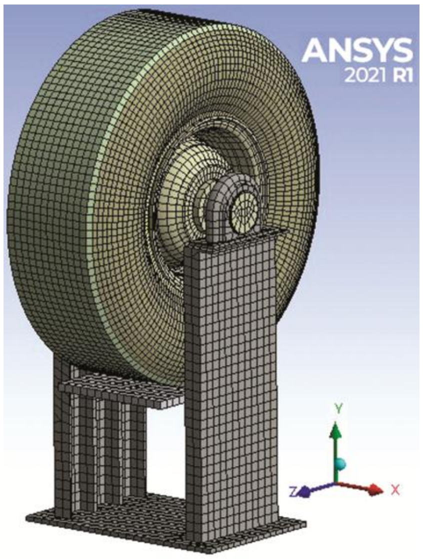

Fig. 7 — Meshed model of the assembly.

Fig. 8 — Contact pressure between rubber tire and road in test rig.

3.1.3 Case-3: New Rubber tire and Rail (fitted in Test Rig)

The above validated test rig assembly is now used to simulate contact behavior of a new rubber tire with rails. A finite element model of the new rubber tire with rail fitted in the same test rig is also developed, Fig. 9. The assembly is again analyzed at 30000 N load and 0.5 inflation pressure and the results i.e. total deformation (Fig. 10), von-mises stresses, and frictional stresses (Fig. 11) are obtained. The max. stress and deformation recorded in the tire with 30000 N load and 0.5 MPa inflation

pressure is of the order of 182.43 MPa and 57.772 mm respectively while the length and width of the rectangular contact patch are 250.031mm and 62.41mm respectively.

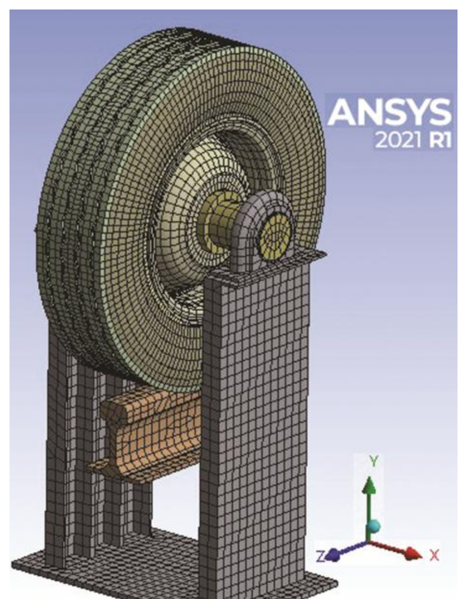

Fig. 9 — Meshing of rail-new rubber tire with test rig.

TABLE 8 — RESULT OBTAINED FROM NUMARICAL SIMULATION OF RUBBER TIRE-ROAD WITH OR WITHOUT TEST RIG

Case No	0	1	2
Tire Size/Type	Road-Reference tire [40] (Experimental) Reference-255/100/r16	Road-Reference tire without test rig (Simulated) Reference-255/100/r16	Road-Reference tire with test rig (Simulated) Reference-255/100/r16
Load (N)	30000	30000	30000
Deformation (mm)	59	54.467	46.376
Von-mises stress (Mpa)		267.59	192.31
Von-mises stress (Mpa)		267.59	192.31
Frictional Stress (Mpa)		0.9356	0.6724
Nodes		55062	72916
Element		14801	18994

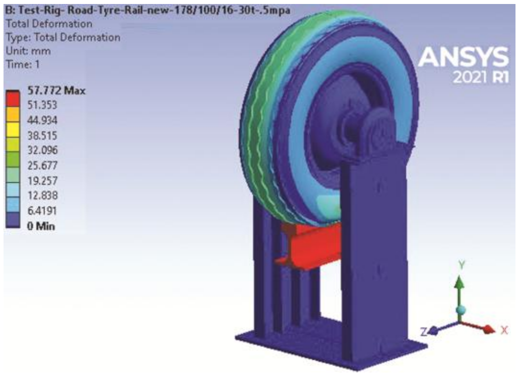

Fig. 10 — Deformation of rail-new rubber tire with test rig.

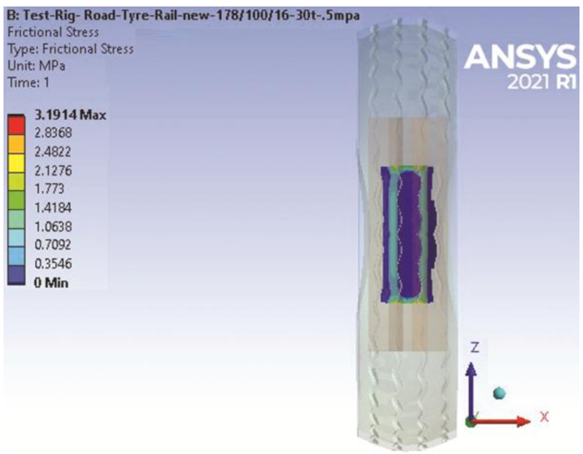

Fig. 11 — Contact pressure of rail-new rubber tire with test rig.

3.2 Development of test rig for experimental study:

Fabrication of validated test rig is done and experimentation is carried out on the developed test rig. The developed test rig has ability to accommodate different size rubber tires and rail wheels for the study of contact behavior of these wheels/tires with rail or regular road. For the development of test rig firstly CAD model is created and analyzed using CATIA and ANSYS software respectively as detailed out in section 5. Based on the analysis iterations and results obtained the dimensions of each part are finalized and the test rig is fabricated, Fig. 12. The test rig comprises of following main parts:

- Base plate with fixing provision for rail.
- Supporting Pillar
- Plummer block
- Shaft and attachments for fixing rail wheel and rubber tire
- Loading unit.

The main purpose of this test rig is to the study the contact behavior of different sizes rubber tires and rail wheels with road and rail at different loads. For controlled loading a conventional hydraulic jack is modified and calibrated. A dial pressure indicator calibrated in terms of load is fitted in the hydraulic jack to make it capable of applying metered load up to 5 ton. The pressure gauge used is capable to measures pressure up to 10,000 psi or 700kg/cm^2 with least count of 100 psi. The cross sectional area of the piston inside the hydraulic jack is 2290 mm^2 hence the conversion of pressure measured by the gauge into load is given by:

Fig. 12 — Fabricated Test rig.

Force (N) = Pressure (N/mm^2) x 2290 (mm^2)

The experimentation is carried out on the developed test rig for contact analysis between 'rubber tire and rail/road'.

1) Experimentation related to contact of new Rubber tire with Road in static situation.
2) Experimentation related to contact of new Rubber tire with Rails in static situation.

As a sample, experimentation procedure and results obtained in case of contact behavior of new rubber tire with rail are presented here.

3.2.1 Experimental Case of Contact behavior of new Rubber tire with Rail

In this test, contact patch of rubber tire was imprinted on plain A4 sized white papers with help of carbon paper. At first, the rubber tire was cleaned and inflation pressure of wheel was set at 0.5 MPa (70 psi) and the rail piece is placed on the base plate of the test rig. White paper was kept on the rail just under the rubber tire and above this paper, carbon paper was placed. The base plate is moved up with the help of hydraulic jack till the pressure gauge indicates 3 Ton load. Due to contact between Rubber tire and rail the contact patch of the tire was imprinted on the white paper. To unload the tire, the jack pressure is released. The contact area is calculated approximately by assuming the contact patches as rectangle and the

Table 9 — Comparison of contact patch obtained experimentally and numerically for new rubber tire in contact with rail at 3 Ton and 0.5 MPa inflation pressure (Carbon paper test)

Contact Patch Area (Experimental) Size:
62mm x 227 mm
Area: 14074 mm^2
Contact Patch Area (Numerical):15603.83 mm^2

Fig. 13 — Experimentation for new rubber tire with rail using pressure paper for determining stress distribution.

corresponding numerical values are compared for validation in, Table 9.

To determine the contact pressure between Rubber tire and rail, Fuzifilm Pressure sensitive papers are used in place of carbon paper. The Rail is placed on the base plate and same technique is applied to obtain the Contact pressure between Rubber tire and Rail with same inflation pressure (0.5 MPa) and load (3 ton) by replacing the carbon paper with pressure sensitive films, Fig. 13. The distribution of contact pressure normal to the Rail surface was measured by slowly applying load on Tire (adjusted to 3 ton) onto a sheet of pressure sensitive film placed between the tire and the rail. The load was maintained for 5 seconds before being removed by activating the hydraulic jack. Again the contact area is calculated approximately by assuming the contact patch as rectangle and contact pressure is measured by comparing the color of obtained contact patch with

Table 10 — Contact pressure patch of new rubber tire with rail and at 3000N load and 50MPA using pressure film

Max Pressure (Experimentally using Pressure sensitive film): 1.6 MPa
Size: 150mm x 235 mm
Area: 35250 mm^2
Max Pressure (Numerical study): 1.9681 Mpa

Table 11 — Comparison of experimental & numerical radial deformation of rubber tire in contact with rail (Load 3 ton and inflation pressure 0.5 MPa)

Case	Rubber Tire with Rail	Rubber Tire with Road
Radial Deformation Experimental	390-372=18mm	390-364=26mm
Radial Deformation Numerical	21.355mm	27.011
% Error	18.639% more	10.504% more

Fuzifilm Pressure shade card. The magnitude of contact pressure is also compared with the corresponding Numerical values for validation, Table 10. It is observed that due to conicity in Rail the pressure on one side of the rail is more as compared to other which is endorsed by the dark magenta/blue colour on side as compared to other.

3.2.2Radial deformation for rubber tire in contact with rail:

The radial deformation was calculated by measuring the deformed height of the tire under 3 Ton and 0.5 MPa inflation pressure from center axis of tire to road surface and then subtracting it from radius of the unreformed tire (390 mm). The radial deformations obtained in this way for Rubber Tire-Road and Rubber Tire-Rail are compared with corresponding numerical values obtained from ANSYS, Table 11.

4 Conclusion

The main objective of this research is to design and fabricate a test rig for experimental study of contact behavior of ‘Rubber Tire-Road’, ‘Rubber Tire-Rail’ and ‘Rail wheel-Rail’ combinations. To establish the dimensions of the Test Rig, two stage FEM is performed. In stage-I, different contact combinations viz. ‘Rubber Tire-Road’, and ‘Rubber Tire-Rail’ are studied using ANSYS software without any test rig while in stage-II the same pairs are analyzed using same simulation environment with the proposed test rig. The negligible stresses and deformation in the test rig are indicators of the rigidness of the designed test Rig. On the basis of study conducted it can be concluded that:

- Both experimental and numerical studies are performed to establish the dimensions of the developed test rig and to develop the simulation environments for ‘Rubber Tire-Road’, and ‘Rubber Tire-Rail’ combinations, which can further be used for similar studies.
- The developed Test rig is capable of testing combination of Rubber tire and Rail wheel in contact with Rail and road together of different sizes and at different load values upto 5 ton.
- Good agreements were achieved between the numerical and measured contact patch areas, contact pressure values and deflections under various contact situations. The analysis showed that tire deflection is primarily affected by radial ply, sidewall stiffness and the steel belt crown angles. The results of static tire Finite Element analysis and experimental studies shown in this research attempt indicate that it can successfully be used to predict the performance of the developed test in order to improve tire characteristics on rails.

Analysis and testing of Contact behavior of Rubber Tire with Rails under dynamic condition is a complex research problem that can be taken up in future.

References

1 Anghelache G&Moisescu R, *Vehicle Syst Dyn*, 50 (2012)1747.
2 Baranowski P Bogusz P Gotowicki P & Małachowski J, *Acta Mech Autom*, 6 (2012) 17.
3 Bruni S Meijaard J P Rill G & Schwab A L, *Multibody Sys Dyn*, 49 (2020) 1.
4 *https://www.montanstahl.com/products/stainless-steel-structurals-bright-bars/stainless-steel-channels/c-channel-standard-asian-sizes/*
5 De Beer M Maina J W Van Rensburg Y& Greben J M, *Tire Sci & Technol*, 40 (2012) 246.
6 Douglas R A Alabaster D & Charters N, *Annu Conf Transp Assoc Can*, (2008).
7 Guo M Li X Ran M Zhou X & Yan Y, *Sustainability*, 12 (2020) 10603.
8 Ilse M, *Int J Transp Sci & Technol*, 4 (2015) 107.
9 Li B & Li S, *Int J Simul Syst Sci Technol*, 36 (2017) 1473.
10 *https://www.india.gov.in/spotlight/pm-gati-shakti-national-master-plan-multi-modal-connectivity.*
11 *https://openresearch.surrey.ac.uk/esploro/outputs/book/Proceedings-of-the-4th-International-Tyre/99515814602346.*
12 *https://www.nsk.com/.*
13 Zhang Y Yi J & Liu T, *IEEE Sens J*, 13 (2013) 1756.