International Journal of Technology and Emerging Sciences (IJTES)

www.mapscipub.com

Volume 03 || Issue 01 || January 2023 || pp. 07-13 E-ISSN: 2583-1925

Simulation of stress analysis of rail track

Bateshwar Prasad[1], Vivek Kumar[2]

[1] Assistant Professor, Department of Mechanical Engineering, Cambridge Institute of Technology, Ranchi, India
[2]M. Tech. scholar, Department of Mechanical Engineering, Cambridge Institute of Technology, Ranchi, India

---***---

Abstract - *The Indian Railways have been given a task to meet the demands of growing transportation needs resulting from the fast expansion of the Indian Economy. The IR must see this as an opportunity and come up with different ways to satisfy the need. One method is to increase the allowable axle loads, which will increase the speed of trains and their load-carrying capability. It has become unavoidable for IR to choose dedicated freight lanes with high axle weights of 28 tonnes or perhaps more because of the significant expansion in freight transit that is anticipated. As a result, in order to construct big axle load tracks, Indian Railway track designers need to keep up with varied global norms. controlling rail stresses regarding stress consideration, the rail's design is crucial. Deflection and stress distribution are examined. The static rail deformation and stress development in rail sections subjected to various static wheel axle loads are the subjects of our paper. Our research focuses on the rail's ability to support loads when the train is standing still. The analytical program used is ANSYS R21, and the modeling software utilized is CATIA (V5R14). R60 is the rail model in use (broad gauge). In order to expand on the current, studied work in the future, an attempt has been undertaken to examine the creation and deformation of rail stress.*

Key Words*: *Deformation, Stresses, Quality, Loads, Deflection

1. INTRODUCTION

The Indian economy is on the verge of seeing a high yearly growth rate of between 8 and 10%. This will cause the transport industry to increase by between 10 and 12 percent. This indicates that every seven to eight years, the transit capacity must double. Highways and railroads are anticipated to accommodate the anticipated expansion of the transportation industry. Railways should be prepared to transport the majority of the extra traffic created since they are efficient in both energy consumption and land usage. Since independence, the expansion of both passenger and freight traffic on Indian Railways (IR) has been tremendous. However, the network on IR has not grown significantly, causing congestion on all major lines. To increase the network's carrying capacity, IR has started an aggressive upgrade program. However, these actions will only be of immediate assistance. Separate freight lanes on high-density lines with larger axle weights are necessary for the long run (30 T or even more)

1.1 Indian Railway: An overview

In India, railroads are the main form of transportation. Over a network of 62,495 route kilometers and 6,995 stations, Indian Railways moved more than a million tonnes of freight and approximately 12 million passengers daily in 1997–1998. Indian Railways has a captive research and development organization called the Research, Design, and Standard Organization (RDSO) in Lucknow. It has more than 300 qualified employees on staff whose job it is to help Indian Railways' R&D division with input across practically all disciplines. The current track construction with continuously welded high UTS rails, mechanized maintenance monitoring, and renewal of track, modern signaling, and telecommunication system are only a few examples of the sophisticated rail technology that the Indian railway is continually obtaining.

1.2 Railway track:

The railway music is a shape inclusive of parallel strains of rails with their sleepers to offer a venue for the motion of locomotives and coaches/wagons for the transportation of passengers or freight. The distance among the internal edges of the heads of rails in music, sixteen mm under the top of the floor of the rail is referred to as a gauge of music. The maximum broadly used gauge withinside the international is the usual gauge that's identical to 1435 mm. However, in India, we've got 3 gauges:

1. Broad gauge (BG) 1524 and 1676 mm
2. Standard gauge (SG) 1435, 1451 mm
3. Metre gauge (MG) 915, 1067,1000 mm
4. Narrow gauge (NG) 610 and 762 mm

The benefits of a larger gauge are increased capacity, speed, and safety. However, it necessitates smoother curves and gradients. A railway line's construction cost rises when the gauge is widened.

2. MODERN RAIL MANUFACTURING PROCEDURE

For their role in guiding trains to go ahead and transporting loads before transferring them to the lower structure, railroad tracks, also known as railroad rails or railway tracks, are crucial to railway systems. Modern standards for rail quality are rising steadily as railroads evolve in the direction of high-speed and large loads. Rail life gets shorter and shorter as a rail vehicle's speed rises. Asymmetry in size scratches on the surface, decarburization, and other issues greatly impede the development of the quality of the railroad tracks due to the inherent flaws in the conventional method, including the appearance of straightness and the blind zone of the internal quality inspection.

Now, high manganese steel is used to make the train rails. It may be made tough and robust by adding 13% manganese. In addition, the manufacturing process for the train track has additional specifications. The internal quality and mechanical qualities of steel rails made using the conventional die-casting technique no longer fulfill the standards of high-speed trains for rail dimensional precision. The casting process has increasingly been replaced by forging or rolling in the modern steel rail production method in order to match the specifications. The rail portion is shaped like an "I." It is separated into the rail web, the rail base, and the railhead in contact with the wheels. On the rolling mill, rolling and forging are done. There are various needs for different lines.

2.1 Blast furnace

In reality, steel is simply iron that has been refined and has had additional elements added to it in precisely calculated quantities. Rocks sometimes referred to as iron ore, contain iron as iron oxide. Only a few isolated regions of the world—most notably Scandinavia, the Americas, Australia, North Africa, and Russia—have significant quantities of this and acceptable access to it. A portion of the finer ore is sent to the sinter plant after being crushed and graded, where it is combined with coke and limestone and burnt to create a sinter, an iron-rich clinker. This sinter is added to the top of the blast furnace together with additional iron ore, coke, and limestone in measured amounts, and the combined material is then burnt. Blasts of superheated air create a lot of heat and fan it to a white-hot intensity. The placement of the lances, estimation of the amount of oxygen to injecting, additions to be made, and any corrective actions are all completely automated and computer-controlled processes. The converter is turned upside down once all the steel has been tapped out into a ladle.

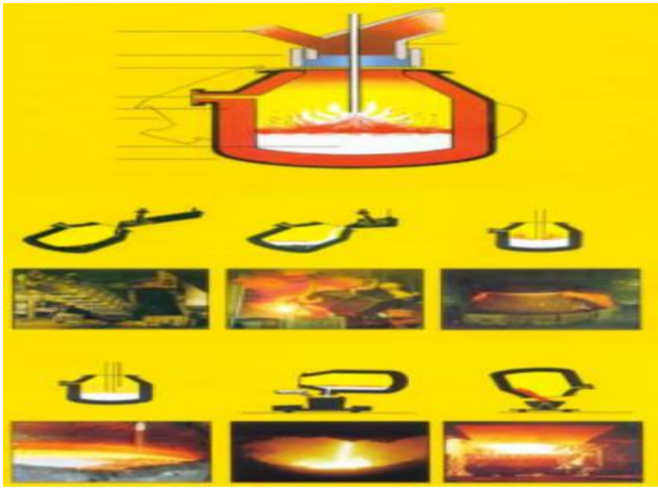

Figure-1: Basic Oxygen Furnace

Figure-2: Filling process

2.2 Continuous casting

Figure 3 provides annotations for the continuous casting concept, which is now employed by the majority of steelworks. The liquid steel is delivered in a turret-mounted ladle weighing 150–350 tonnes. The next ladle might be ready when the molten steel is poured from the ladle into the tundish. Teeming may continue in this manner continuously.

Figure-3: Continuous Casting

Using submerged pouring methods, the liquid steel is cast from the ladle into the tundish. The correct amount of steel is carefully delivered to the 6 to 8 molds using metering nozzles.

Figure-4: Hot strands passing through cooling chambers in a circular arc

Between the ladle and the tundish as well as between the tundish and the mold, refractory tubes shield the whole steel from air oxidation. The water-cooled double-walled molds have two walls. They can have various cross-sections and shape the strands. To avoid corner cracking, the mold corners are chamfered. The internal metallurgical quality of the cast bloom is significantly influenced by the quantity of super-heat present in the liquid steel. As a result, the tundish's liquid steel is kept at a temperature between liquidus + 15 C. Depending on the casting speed and oscillation stroke, the molds oscillate between 60 and 200 times per minute during the casting process to prevent the steel from sticking to the copper mold. The approximate throwing speed is 0.8 meters per minute. The strands have electromagnetic stirring coils to help with the solidification structure.

2.3 Post-processing

A few more processes after flash butt welding might be used to provide better geometry and higher fatigue strength values. The hot weld is provided a stress-free overlight of 2 mm on a 1.2 m base right after welding and stripping. A specialized press 36 m in front of the welding machine performs this task. In order to regain adequate strength to prevent plastic deformation during transport to the new place, the weld is precooled with air during over lifting. To ensure a safe transition for rails, the water-cooling process does not begin there until 4 minutes after welding. A strait system automatically decreases the 2 mm vertical over the lift to an over lift within the 0.1–0.3 mm range at the following station. Favorable residual compression stresses provide an increase in the weld's fatigue strength of roughly 8%. The final part of the process, grinding, is likewise managed through this dashboard. 36 m in front of the strait machine is where you'll find the grinder. Depending on the weld geometry detected, the grinder automatically grinds the weld both vertically and horizontally for a duration of 1.5 to 4 minutes.

Figure-5: Press and operate the console

2.4 Significance of rolling process in rail making

The characteristics of rail steel benefit greatly from the rolling process used to create rails. Rolling refines the steel's grain structure while destroying the detrimental oriented cast structure. Unwanted brittle layers are broken up, diffusion of separated alloys is encouraged, and the metal becomes more homogenous. If the metal surrounding them does not have oxide, the fractures, blowholes, and porosity are welded. Steel gains increased ductility and hardness. Steel's characteristics change direction when rolling because it has superior qualities in the rolling direction. The chemical makeup of rail steel that is considered standard is as follows:

Table -1: About the materials

Element	**Percentage**
Carbon	0.45 - 0.60
Silicon	0.05 - 0.35
Manganese	0.95 - 1.25
Phosphorous	0.04 max
Sulphur	0.04 max

2.5 Heat treatment

Quenching and tempering, often known as slack quenching, is a common heat treatment. By adjusting the temperature during rolling or online heat treatment, certain nations have attempted to increase the yield strength and tensile strength of railroad tracks. The microstructure of the rail is stabilized by complete heat treatment.

Figure-6: cooling chambers

2.6 Straightening

After cooling, a straightening machine operates in both horizontal and vertical orientations on the train rails.

Figure-7: Straightening of rail

2.7 Inspection

Inspection of railroad tracks is another critical stage. Through eddy current and ultrasonic examination, train tracks' surface and internal defects may be checked.

2.8 Sawing and drilling

To achieve great precision while processing and drilling the railhead, use a carbide machine with a strong alloy.

3. TYPES OF RAILS

Earlier An "I" with double heads (DH) was utilized. The concept was that the rail could be reversed and used again if the head were to break off while it was in use. Experience, however, had shown that it was difficult to reuse a rail whose service base table had been damaged to such a degree through repeated, prolonged contact with the seats of ballast and sleepers. This led to the development of the, which had nearly the same design but more metal in the head to better withstand deterioration. The primary drawback of this rail section was that chairs were required to attach it to the sleepers. As a result, a flat-footed rail (FF) (Figure-7) with a T-type of cross section was made, which could be directly fixed to the sleepers with the use of spikes. Another benefit of the flat-footed rail is that, when compared to a BH rail for a given cross-sectional area, it has a more conservative and economical design outline, providing the track with more remarkable quality and sidelong security. The Indian Railways have used the flatfooted (FF) rail for selection.

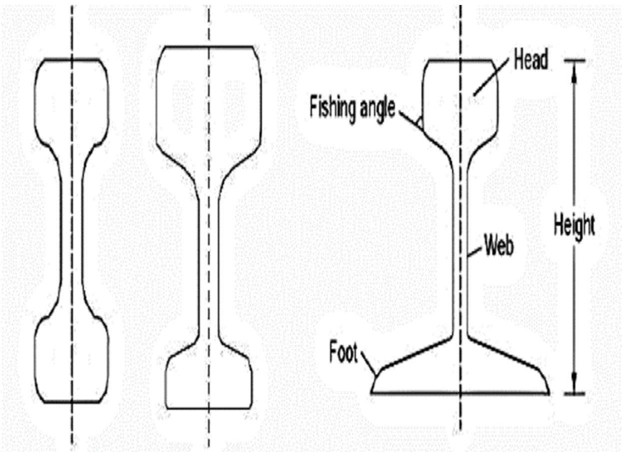

Figure-7: Double-headed Rail, Bull Headed Rail, Flat Footed Rail

4. PREREQUISITES OF RAIL SECTION

The following requirements must be met for a great rail area.
- The rail should be sturdy, and strong, have the most cost-effective portion and be long-lasting.
- For the compressive and tensile stresses to stay equal, the rail's centre of gravity should be located in the middle of the rail.
- A rail consists primarily of a head, a web, and a foot; each of these components has to have the right amount of metal allocated to it so that it may fulfill its functional requirements.

4.1 MATERIAL DATA OF STRUCTURAL STEEL GRADE 880

TABLE 2: Steel structural constants

Density	7.85e-009 tonne mm^3

TABLE 3: Isotropic Elasticity

Young's modulus (MPa)	Bulk Modulus (MPa)	Poisson's Ratio
2.e+005	1.6666e+005	0.3

TABLE 4: Isotropic bilinear hardening

Tangent Modulus (MPa)	**Yield Strength (MPa)**
34000	460

5. EXPERIMENTAL APPROACH

5.1 Steps involved in the creation of the model

The following steps are involved in the creation of the model.

1. Start with mechanical design and then move on to part design.
2. Choose the plane in which the product will be modeled in the new window.
3. Use the profile sketcher to create a drawing.
4. Use the profile option or other entities with the necessary dimensions to sketch the profile.
5. Before leaving the workstation, the sketch has to be limited. A drawing that is completely confined is green, but one that is excessively constrained is pink.
6. The profile is then padded with the necessary measurements.
7. The constructed component body is then stored.

Different rail and wheel models for this project were created using CATIA.

5.2 Modelling of Rail in CATIA R5

Modeling of the rail in Figure 8. These bodies have been modeled in CATIA V5R14 and then imported for further study using ANSYS 2021R1.

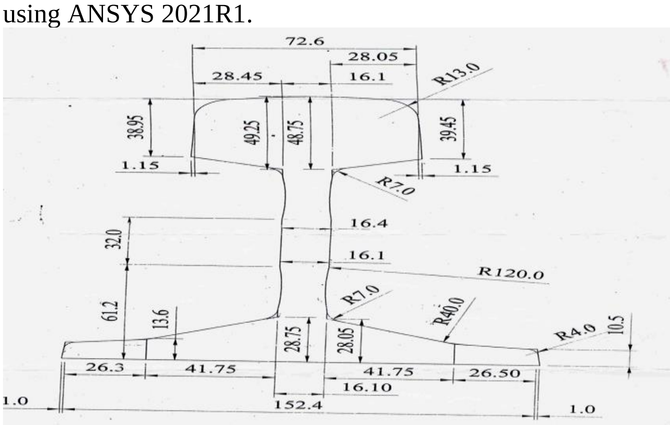

Figure-8. a: Actual rail profile (R60)

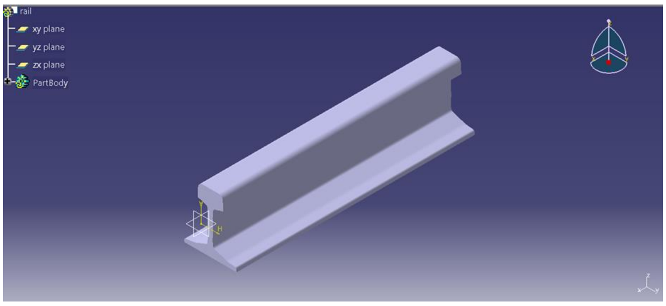

Figure-8. b: Actual rail model in CATIA V5 (isometric view)

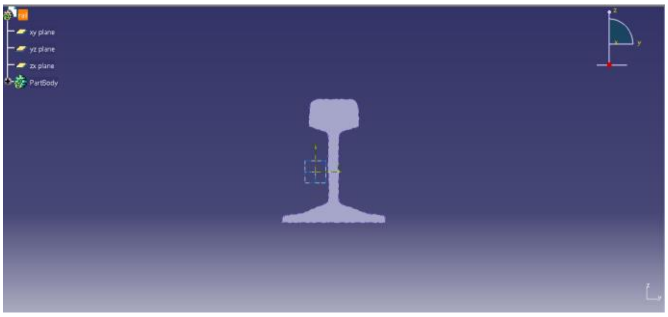

Figure-8. c: Actual rail model in CATIA V5 (front profile)

5.3 Analysis in ANSYS 2020 R1

Various steps involved in Analysis in ANSYS are:

1. We first access the "Analysis System" Toolbox in the Workbench. This technique enables us to pick the files for our study in a more general way. Basically, this is the domain or region in which we are willing to have our analysis performed. Our area of interest is "Statis Structure" in this case.
2. Engineering Information: - The "Statis Structure" section allows us to define the components of the model that will be analyzed. Here, we choose certain restrictions that must be applied to a body in order for it to be defined as a representation of true material.
3. Geometry: This area of ANSYS Workbench allows users to model the body in the ANSYS environment without having to search for additional modeling tools for sketching and modeling. ANSYS allows models from practically any drawing and modeling program to be imported into the ANSYS environment, making it simple to use such models for analysis.
4. Model: The central component of ANSYS, here is where all load definition and analysis work is done. The domains in which we look for analysis findings are listed below together with all the relevant constraints.
5. Results: This part gives us a very condensed summary of the results of our analytical work, which we may examine in several graph and tabular formats.

Meshed Body: -Meshing, also known as mesh generation, is the process of producing a two-dimensional or three-dimensional grid; it discretizes a domain by breaking complicated geometries into manageable pieces. The Ansys Mesh capabilities are frequently cited as the industry benchmark for modeling and workflow simulation for meshing complicated components. Under the guise of fine meshing, an element size of 8 mm is used here. When it comes to the engineering simulation process, meshing is important. One of the most important aspects that should be taken into account to ensure simulation accuracy is creating a high-quality model. Engineering simulations must start with the best possible mesh since it affects the simulation's precision, convergence, and speed. Mesh elements enable the solution of governing equations on mathematically specified volumes with predictable shapes. The analysis is shown in various figure 9.

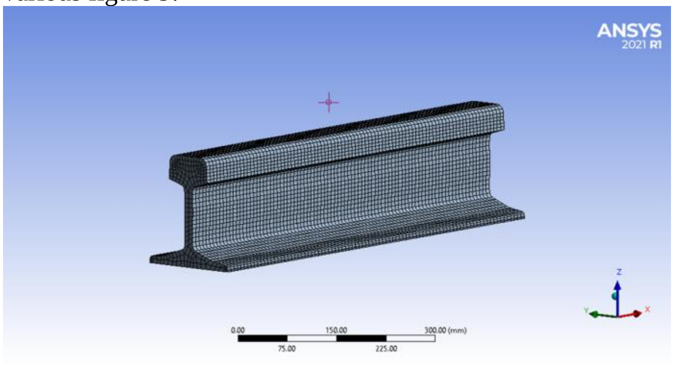

Figure-9. a: Model after meshing

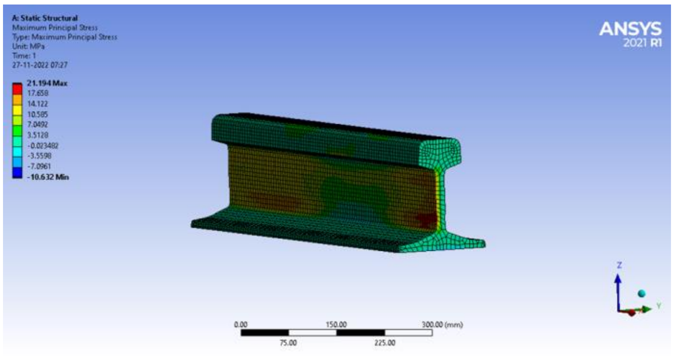

Figure-9. b: Stress distribution (Principal Stress)

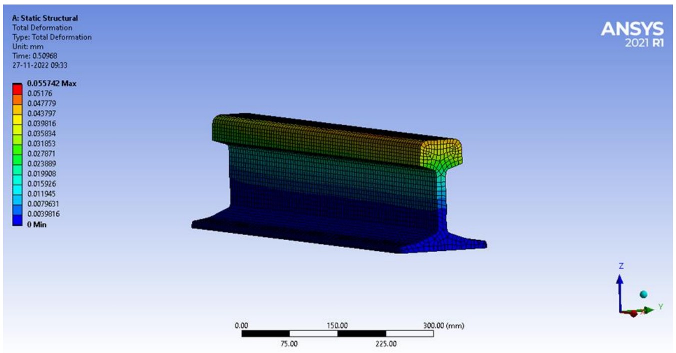

Figure-9. b: Model showing deformation (z-axis)

TABLE 5: Tabular Data of Maximum principal Stress:

Time [s]	**Minimum [MPa]**	**Maximum [MPa]**
0.2	-2.1265	4.2389
0.4	-4.253	8.4778
0.7	-7.4427	14.836

1	-10.424	21.194

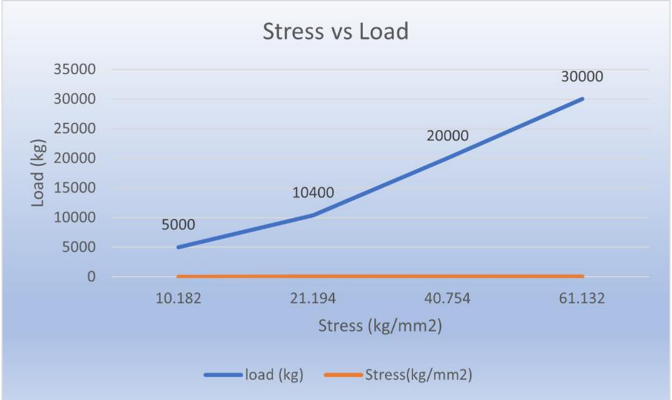

Figure-10: Stress vs. load (ANSYS analysis)

The calculated stress and deformation are 20.779 kg/mm^2 and 0.07095 mm, respectively.

TABLE 6: Tabular Data of Stress vs Load

Stress(kg/mm2)	load (kg)
10.182	5000
21.194	10400
40.754	20000
61.132	30000

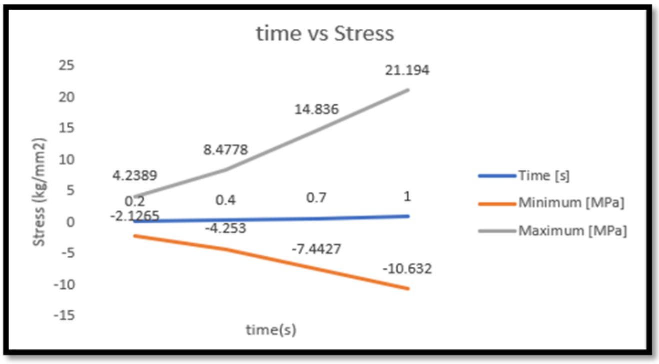

Figure-11: Graphical Representation of Maximum principal Stress

6. Rail-wheel contact stresses (Analytic Approach)

$\tau_{max} = 4.13(Q/R)^{1/2}$
τ_{max}= Maximum shear stress in kg/mm^2
Q= static wheel load in kg increased for on-load on curves. This on-loading is taken as 1000 kg.
R=wheel radius in mm (fully worn condition)
Now, Q=9.4 tonne (9400 kg) + 1 tonne (1000kg)
Total = 10,400 kg

R = 1000/2 = 500 mm
$\tau_{max}=4.13(10{,}400/500)^{1/2}$
$\tau_{max}=18.8356$ kg/mm^2

6.1 Equivalent Stresses

The load applied to the wheel is weighing down the area of the rail and wheel that make contact. The area of greatest stress between the rail and the wheel's point of contact is marked in red and measures 21.194 MPa. The model's minimum stress, which is marked in blue and is relatively common, is located at the model's most extreme point and equals -10.632 MPa. The majority of the stressed zone of the entire constructed body is seen in the area below the contact region, which is under the critical load. The rail's farthest section from the contact area likewise has the least amount of tension.

For BG, the maximum contact stress value is restricted to 30% of the UTS value, or

The maximum contact stress value for 72 UTS Rail will be 21.6 kg/mm2, or 30% of 72.

The maximum contact stress value for 90 UTS Rail will be 27.0 kg/mm2, or 30% of 90.

7. CONCLUSIONS

The Indian Railways' Rail-Wheel Model has been computationally analyzed in this report after being modeled in CATIA V5 and examined in Ansys 2020 R1. The International Union of Railways (UIC) and the weight per unit length practiced in India were both taken into consideration in the construction of the rail model. The wheels were made to Indian standards for the BOXN Wagon by the Rail Wheel Factory, and the rail cross-section is UIC 60 kg (production unit of Indian railways). Given that the readings fell within the allowable stresses, the findings for the contact stress on the rail were deemed safe and within the acceptable range. The highest contact shear stress measured was less than 27.0 kg/mm^2, or 30% of the 90 UTS rails' (90 kg/mm^2) maximum value.

The primary goal of this thesis was to determine the maximum contact shear stress between a 90 UTS rail and a wheel, which was found to be 21.194 kg/mm for Ansys 2020 R1, Hertzian theory, and a Hertzian stress calculator, respectively. All of these values are less than the limiting value of contact stress, which is 27.0 kg/mm^2 for 90 UTS rails.

The correct dimensions and desired tolerances were supplied to the model. Actual axle load conditions existed, and a UIC 60 kg rail can support them. According to the specifications, the UIC 60 kg rail can support an axle load of up to 36 tonnes. However, a freight train with an axle load of around 25 tonnes, including the tare weight of the BOXN wagon, is now operating on Indian railway rails. Because the analysis was static, the contact between the rail and the wheel was bonded rather than frictional. Since a BOXN wagon of a freight train typically has four axles with two wheels on each axle, the axle load is converted to wheel load, which equals half of the axle load, or 10.4 tonnes. In actuality, it is 102000 N. (10.4 x 1000 x 9.81 N).

With the aid of sleepers and ballasts by fish plate, the rail was attached from the bottom surface as it remained on the track of the P-way (permanent way).

The analysis was static, and the wheel load was acting downwardly and vertically, therefore it could only apply weight downwardly and neither upwards nor upwardly or in the other two directions. In future works, an attempt has been undertaken to examine the creation and deformation of rail stress.

REFERENCES

[1] Mundrey J.S, "Railway track engineering", Tata McGraw Hill, pp 5-50, 140- 150, 2001

[2] C. E, "Modern railway track" (Second Edition), Professor of Railway Engineering, Delft University of Technology 2001.

[3] Kalker J.J, "A fast algorithm for the simplified theory of rolling contact", Vehicle Syst. Dyn., 11, pp.1-13, 1982

[4] Singh R, Prasad B, and Rai R.N, "Effect of parameters in arc welded mild steel plates" IOP Conf. Materials Science and Engineering 377, pp 1-5, 2018

[5] Prasad B, Kumar R., and Mahato S. K, "Study of Mechanical properties of AA7075 with nano silicon carbide" IJTES, Vol-02, pp10-14, 2022

[6] Nakasone Y. and Yoshimoto S, "Engineering Analysis with ANSYS Software", a book from the Department of Mechanical Engineering Tokyo University of Science, Tokyo, Japan.

[7] Telliskivi T, Ulf Olofsson, Ulf Sellgren and Patrik Kru, a thesis submitted on "a tool and a method for fe analysis of wheel and rail interaction" Machine Elements, Department of Machine Design Royal Institute of Technology (KTH), Stockholm, Sweden.

[8] S.A.I.L, Ranchi, Jharkhand, India (R&D Division).

BIOGRAPHIES

Bateshwar Prasad
Assistant Professor, Department of Mechanical Engineering, Cambridge Institute of Technology, Ranchi, India, 13 years of teaching experience, published more than 10 papers in various international journals. **Email id-** bateshwarprasad90@gmail.com
Mob.-+919631249249

Vivek Kumar
M. Tech. Mechanical Engg., CAD/CAM scholar, Department of Mechanical Engineering, Cambridge Institute of Technology, Ranchi, India