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Stress Analysis at Contact Region of Rail-Wheel: Review

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Abstract: *The rail track has many components and has to bear dynamic loadings conditions. The sleepers hold the rails in their legitimate (proper) positions with the help of fittings and fastenings. Load transfers from wheel to natural ground through different components of foundation of the track. The sound perpetual track should have capability of absorbing vibration, tough enough to bear load, uniform, straight, free from crimps etc. The designing of rail track play the major role for the carrying load and saving material. Web of the track in India contains long distance and for maintenance the standardization and availability of items easily at each point of requirement. A revive has been done keeping above in to the consideration and found that that the axle load on freight wagon is about 25 tonnes in India. The maximum contact stress is 30% of the ultimate tensile strength i.e. 27 kg/mm^2.*

Keywords: *Rails, dynamic loadings, Ballast, foundation, vibration, material*

1. INTRODUCTION

Satish Chandra & M.M. Aggarwal [1] described that the permanent way or track is the railroad on that trains run. It comprises of two parallel rails secured to sleepers with a predetermined separation between them. The sleepers are implanted in a layer of ballast of indicated thickness spread over level ground known as formation. The ballast gives a uniform level surface and drainage and passes the load to a bigger territory of the arrangement. The rails are joined in arrangement of series by fish plates and screws and these are affixed to the sleepers with different sorts of fittings. The sleepers are separated at a predefined separation and are held in position by the counterweight of ballast. Every segment of the track has a particular function to perform. The rails acts as the member which transmit the wheel load of trains to the sleepers. The sleepers hold the rails in their legitimate (proper) positions give a right gauge with the assistance of fittings and fastenings and transfer the load to the ballast. The arrangement takes the total load of the track and of the trains proceeding onward it. The detailed fig.1. shown below shows the various components of the track.

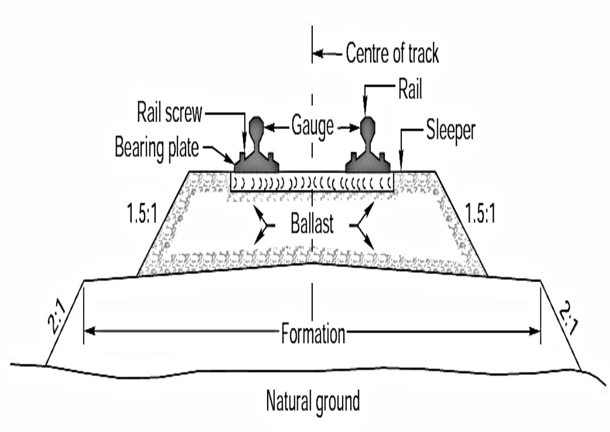

Fig. 1. Components of the track [1]

2. LITERATURE REVIEW

2.1 PREREQUISITES OF A GOOD TRACK

A track ought to give an agreeable and safe ride at the greatest allowable velocity with least support cost. To accomplish these objectives, a sound perpetual way ought to have the accompanying qualities.

(a) The gauge should be right and uniform.

(b) The rails should have impeccable cross levels. In curves, the external rail have a proper super elevation to consider the centrifugal force

(c) The arrangement should be straight and free of crimps. On account of bends, a proper transition should be given between curve and the straight track.

(d) The inclination should be uniform.

(e) The track should be flexible and versatile keeping in mind the absorption of shocks and vibrations of running trains.

(f) The track should have a decent seepage (drainage) framework so that the stability of the track is not influenced by water logging.

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(g) The track should have great sidelong quality with the objective that it can keep up its stability despite of varieties in temperature and other such elements.

(h) There should be procurements for simple substitution and renewal of the different track parts.

(i) The track should have such a structure, to the point that is its beginning cost low, as well as its upkeep expense is least.

2.2 SPECIFICATION OF THE INDIAN RAILWAY TRACK

The majority of the railway lines on Indian Railways are single lines, by and large with its formation 6.10 m (20 feet) wide for Broad Gauge (BG) and 4.8 m (16 feet) wide for meter gauge. The development is for the most part is stable aside except the zones where clayey soil or other sorts of shrinkable soils are found. The majority of the track is straight with the exception of 16% of the track on BG and MG and 20% of the track on NG, which is on curves. The most extreme level of curve allowed is 10° on the Broad gauge, 16° on the meter gage, and 40° on the Narrow gauge. The ballast utilized is broken stone counterbalance, however in a few ranges, sand and coal ash has additionally been utilized. Around a 20 cm to 30 cm (8" to 12") cushion of ballast is typically given underneath the sleepers to transfer the load equitably and to give the essential flexibility to the track. The diverse materials used to build sleepers are wood (31%), cast iron (42%), and steel (27%). Experience has demonstrated that cast iron sleepers are not capable for high-density routes. Solid concrete sleepers have been created by Indian Railways and are proposed to be continuously laid on gathering on group A and B routes which are high speed lines of 160 km/h and 130 km/h on broad gauge routes.

2.3 FUNCTIONS OF RAILS

Rails are like steel supports. These are given to perform the accompanying capacities in a track.

(a) Rails give a persistent and level surface for the displacement of trains.

(b) Rails give a pathway which is smooth and has very small value of friction. The friction between the steel wheel and steel rail is about one-fifth of the friction between the pneumatic tire and metaled road.

(c) Rails serve as a guide for the wheels in a lateral manner.

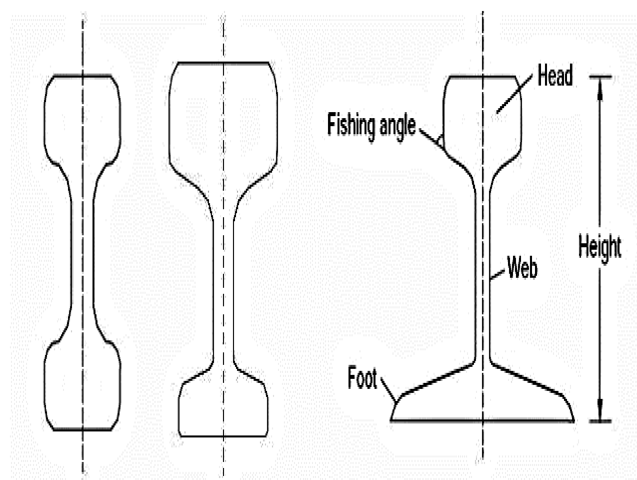
(d) Rails bear stresses grew because of vertical burdens transmitted to them through axles and wheels of moving stock and also because of braking and heating effects of thermal forces.

(e) Rails transmit the load to a vast region of the arrangement through sleepers and the ballast.

2.4 TYPES OF RAILS

The main rails utilized were *Double headed (DH)* and made of an "I" or dumb bell segment (Fig.2). The thought was that once the head gets destroyed during the time of service then the rail could be inverted and can be reused again. Experience, in any case, demonstrated that while the time of service base table of the rail was dented to such a degree due to long and persistent contact with the seats of ballast and sleepers that it was impractical to reuse it. This prompted the advancement of the *Bull-headed (BH) rail*, which had a practically comparative shape yet with additional metal in the head to better withstand wear and tear (Fig. 3.). This rail segment had the significant disadvantage that chairs were needed for fixing it to the sleepers.

A *flat-footed rail* (FF) (Fig. 4.), with a rearranged inverted T-type of cross section was, accordingly, created, which could be settled straightforwardly to the sleepers with the assistance of spikes. Another point of advantage of the flat footed rail is that it is a more conservative and economical design outline, giving more noteworthy quality and sidelong security to the track when contrasted with a BH rail for a given cross-sectional area. The flatfooted (FF) rail has been adopted for selection on Indian Railways.



(a) Double Headed Rail (DH) (b) Bull Headed Rail (BH) (c) Flat-Footed Rail (FF)

Fig.2.Types of Rails [1]

2.5 PREREQUISITES OF RAIL SECTION

The necessities for a perfect rail area are as per the following.

(a) The rail should have strength, stiffness, most economical section and long lasting durability.

(b) The center of gravity of the rail should lie at the mid-stature of the rail so that the compressive stresses may remain equal to the tensile stresses

(c) A rail fundamentally comprises of a head, a web, and a foot, and there should be an appropriation of metal in its different parts so that each of them can satisfy its necessities appropriately.

2.6 RAIL STANDARDS

The rail is assigned by its weight per unit length. In FPS units, it is the weight in lbs per yard and in metric units it is in kg per meter. A 52 kg/m rail means that it has a weight of 52 kg for every meter. The heaviness of a rail and its section is chosen after the following considerations,

(a) Heaviest axle load
(b) Maximum allowable speed
(c) Depth of counterbalance cushion of ballast
(d) Type and distance between sleepers
(e) Other incidental variables

According to IRS–T–12–88, the brand imprints are as per the following:

IRS-52 kg – 710 – TISCO – II 1991 →OB

The definitions for the above mentioned abbreviations are as per the following:

(a) IRS-52-kg : Number of IRS rail segment, i.e., 52 kg

(b) 710 : Grade of rail section, i.e., 710 or 880

(c) TISCO : Manufacturer's name, e.g., Tata Iron and Steel Co.

(d) II 1991 : Month and year of production (February 1991)

(e) →: A bolt demonstrating the direction the highest point of the ingot

(f) OB Process of steel making, e.g., open hearth essential (OB)

The brand stamps on the rails are to be come in letters no less than 20 mm in size and 1.5 mm in tallness at interims of 1.5 to 3.0 m. Indian Railways has basically been utilizing medium manganese rails having an Ultimate tensile Strength (UTS) of 72 kg/mm^2& 90 kg/mm^2 for 52 kg/m rails and 90 kg/mm^2 for 60 kg/m rails, produced by the Bhilai steel plant. The service life of 52 kg (72 UTS) rails is just about 350 GMT (gross million tonnes per km/annum). These rails have the accompanying primary preferences because of the following reasons.

1) The service life of 90 UTS rails is around 50% more than that of customary medium manganese 72 UTS rails.

2) The aggregate GMT that 72 and 90 UTS rails can convey during their essential Service life is as per the following.

3) 90 UTS rails are stronger against wear and have a hardness of about 270 BHN (Brinell hardness number) as against that of 220 BHN of medium manganese rails with 72 UTS.

4) The permissible shear stress of 90 UTS rails is much higher, as can be seen from the table given below.

TABLE 1: GMT limits for Rail Sections along with UTS

Section with UTS	Aggregate GMT
52 kg (72 UTS)	350 GMT
52 kg (90 UTS)	525 GMT
60 kg (90 UTS)	900 GMT

TABLE 2: Allowable Shear Stress

Rails	Allowable shear stress
Medium Manganese Rails (72 UTS)	18.0 kg/mm^2
Wear Resistant Rails (90 UTS)	22.5 kg/mm^2

2.7 STANDARD SECTION OF RAILS

As the 60 kg UIC rails are more common in use on the Indian railway track, that's why here in this chapter 60 kg rail is being used as model geometry. The detailed dimensions of various standard rail sections are shown in Figure 3 & Table 3.

TABLE 3: Details of standard sections of Rails

Rail Section	Wt/metre (kg)	Area of section (mm$^{2)}$	Dimensions (mm)					
			A	B	C	D	E	F
50 RBS	24.80	3168	104.8	100.0	52.4	909	32.9	15.1
60 RBS	29.76	3800	114.3	109.5	57.2	11.1	35.7	16.7
75 RBS	37.13	4737	128.6	122.2	61.9	13.1	39.7	18.7
90 RBS	44.61	5895	142.9	136.5	66.7	13.9	43.7	20.6
52 IRS	51.89	6615	156.0	136.0	67.0	15.5	51.0	29.0
60 UIC	60.34	7686	172.0	150.0	74.3	16.5	51.0	31.5

Rails are largely manufactured by Bhilai steel plant, Sail, Tata steel and Jindal steel & power. UIC 60 kg rail is most common manufactured by all of the industries; apart from this fact this particular section of rail is heavily dependent section of Indian railway. The following geometry of 60 kg rail has been adopted from UIC and is as per the strict dimensions.

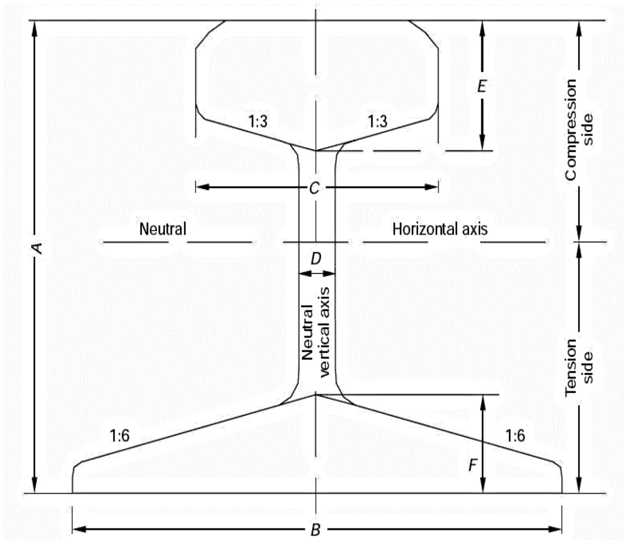


Fig. 3. Standard flat foot Rail Section [1]

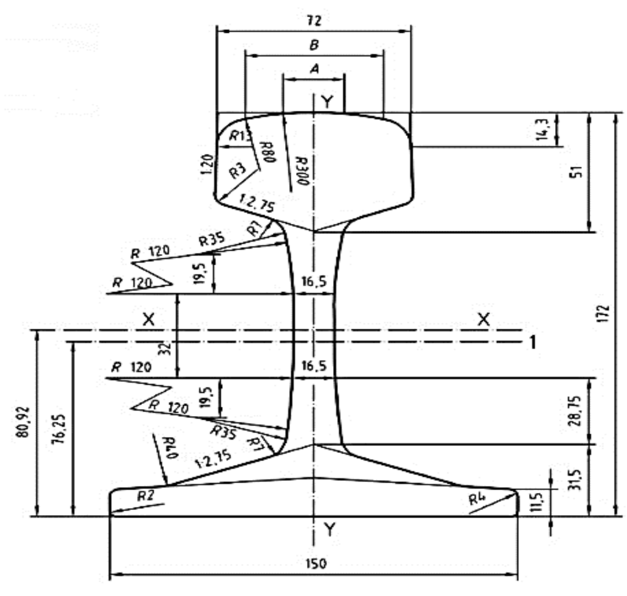


Fig. 4. UIC 60 kg Rail {A=20.456 mm, B=52.053 mm}; [2]

1 is the Centre line of branding in Figure 4 and all the dimensions are in mm. Following are the details of above shown Figure 4.

Cross-sectional area : 76.70 cm^2

Mass per meter : 60.21 kg/m

Moment of inertia x-x axis : 3038.3 cm^4

Sectional modulus - Head : 333.6 cm^3

Sectional modulus - Base : 375.5 cm^3

Moment of inertia y-y axis : 512.3 cm^4

Sectional modulus y-y axis : 68.3 cm^3

2.8 STANDARD SECTION OF RAILWAY WHEEL

Below Standards for the wheel of train has been adopted from Rail Wheel factory, located at yelahanka, Bangalore (one of the production unit of Indian Railways). The wheel is of BOXN type, used primarily for transporting iron ore. These are open top wagons and are being used for the wagon having tare weight of 25 tonnes and axle load of 22 tonnes [3, 10, 11].

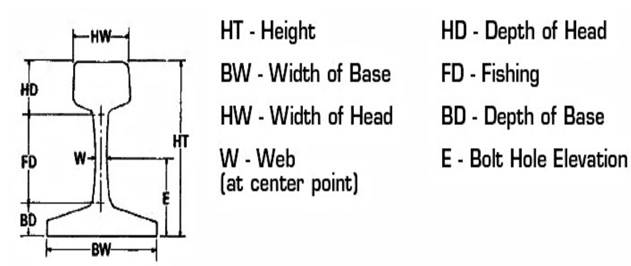


Fig. 5. Nomenclature of UIC 60 kg Rail [11]

TABLE 4: Dimensions of UIC 60 kg Rail

Part names	Designations	Dimensions (mm)
Height	HT	172
Depth of head	HD	51
Width of base	BW	150
Fishing	FD	89.5
Width of head	HW	72
Depth of base	BD	31.5
Web	W	16.5
Bolt hole elevation	E	80.92

Tread diameter is the second outermost diameter of the wheel which is about 1000 mm with positive tolerance of 7 mm. Maximum diameter of the rim at inside is about 848 mm. Front hub & Back hub diameters are of 280 mm with the positive tolerance of 12 mm. Bore diameter is of 203 mm with positive tolerance of 1.5 mm and negative tolerance of 3 mm. Flange height is of 28.5 mm with the positive tolerance of 1.5 mm. Rim width is 127 mm with positive tolerance of 4.5 mm. Hub length in which axle shaft has to be inserted is of 190 mm with ± 6 mm tolerance. Plate thickness at the mid of the wheel has to be maintained at least 22.2 mm. Overall diameter of the wheel is about 1057 mm. The below shown wheel in Figure 6 has been captured at Sahibabad Railway Station, Uttar Pradesh. The wheel is of open top wagon and is having the appropriate dimensions [8, 9].

Fig. 6. BOXN standard wheel (Image captured at SBB Railway station)

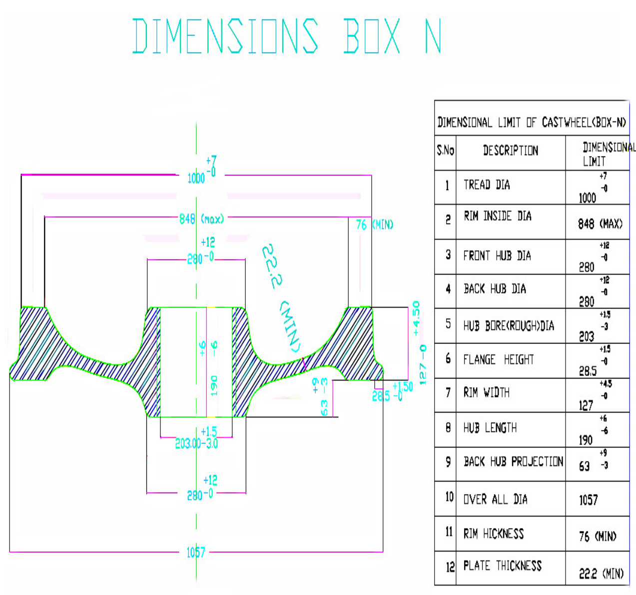


Fig. 7. Sketch of BOXN standard wheel [3]

3. MATERIAL SELECTION

In ansys workbench, the static structural project has been used in order to carry the analysis. The file has been renamed as Rail-wheel. Cast steel of grade 880 is used as the material for the rail and wheel. Under the engineering data the values of material properties has been entered, before that units has been checked carefully and the metric activated units are done in millimeter and second, which are the desired units. The material used for the rail & wheel is structural steel which has been given the properties of cast steel by manipulating the default properties of the structural steel. Density is to be in tonne/mm^3, young's modulus to be in Mpa and the value of poisson ratio is 0.265, which is for cast steel grade 880.

4. RESULTS

4.1 CONTACT STRESSES BETWEEN RAIL AND WHEEL

Hertz [4] defined a hypothesis to calculate the area of contact and the pressure distribution at the contact region between the rail and the wheel. According to this hypothesis, the rail and wheel contact is like that of two cylinders (the round wheel and the curved head of the rail) with their axes at right angle to one another. The territory of contact between the two surfaces is bound by an elliptical shape as demonstrated in Figure 8.

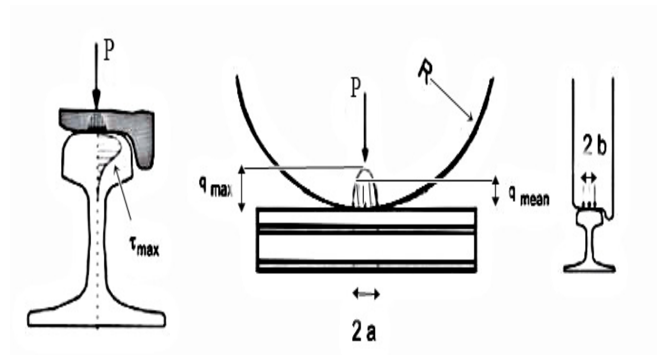


Fig.8. Shear Stress Distribution at Railhead [5]

Eisenmann [6] did the experiment and given expression for the maximum contact shear stress value at the point of contact between the rail and the wheel as

τ_{max}= 4.13(P/R)$^{1/2}$

Where, τ_{max} is the maximum shear stress in kg/mm^2, R is the radius of the wheel in mm, and P is the (static wheel load in kg + 1000 kg due to curve loading). Maximum Contact shear stress presents at a depth of 5-7 mm below the rail surface.

4.2 BENDING STRESSES IN RAILS

Satish Chandra & M.M. Aggarwal [1] explained the general hypothesis (theory) of bending of rails is taking into account the suspicion that the rail is a long bar constantly bolstered by a flexible establishment of elastic foundation. The rail is subjected to flexural or bending stresses due to the vertical load on it. The bending stresses that a rail is subjected to as an aftereffect of vertical burdens is outlined in figure 9. The hypothesis of stresses in rails considers the elastic nature of supports. Based on this theory the outcome for the bending stresses is as follows.

$$M = 0.25pe^{-(x/l)} [\sin x/l - \cos x/l]$$

where, M is the bending moment, p is the segregated vertical load, $l=(EI/\mu)^{1/4}$ is the characteristic length, EI is the flexural stiffness of rail, μ is track modulus, and x is the distance of the point from the load.

As indicated by the bending moment equation the bending moment is zero at the points where

x= πl/4, 3πl/4 and maximum where x = 0, πl/2, 3πl/2, and so on.

For ascertaining the stresses following up on the rail, first the maximum bending moment needs to be calculated due to the series of loads. Then bending stress can be easily calculated by dividing the bending moment by the section modulus (z =I/y) of the rail [12, 13, 14].

Limiting Values of Stresses on Broad Gauge for 90 UTS Rail

TABLE 5: Limiting value of stresses on BG for 90 UTS

Parameter	Permissible value (kg/mm^2)
Bending stresses on the Rail	36.0
Contact stress between Rail and wheel	21.6
Fish Bolt Stresses	30
Bolt hole Stresses	27

4.3 BILINEAR ISOTROPIC HARDENING

Bilinear isotropic hardening has been included. In isotropic hardening the yield surface expands uniformly in all the directions during the plastic flow. The term 'isotropic' in isotropic hardening refers to the uniform dilatation of the yield surface which is different from a general 'isotropic' yield criterion (i.e., material orientation).The slope of stress-strain curve is shown in figure 10& the general representation of Isotropic hardening is shown in figure 11.

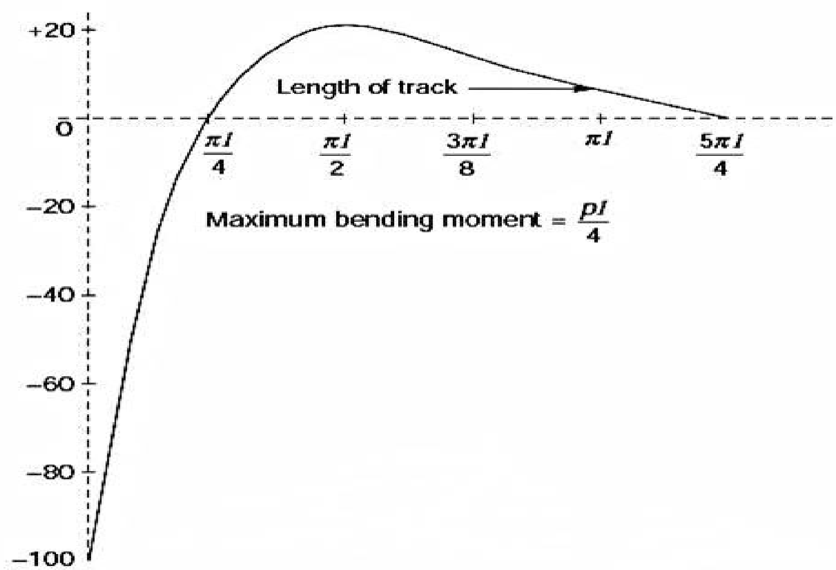


Fig. 9. Variation of bending stress with the distance from the contact [1]

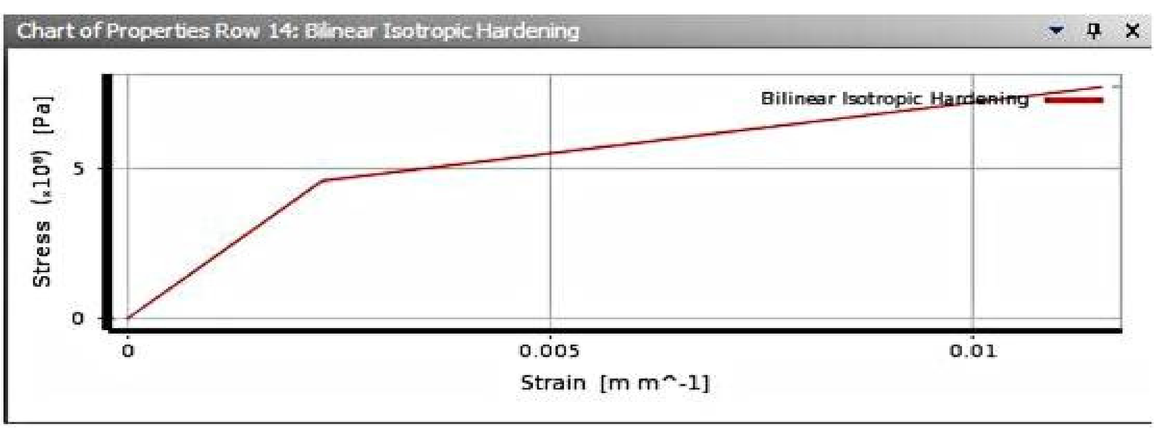


Fig. 10. Bilinear isotropic hardening in Ansys 15.0 for cast steel grade 880

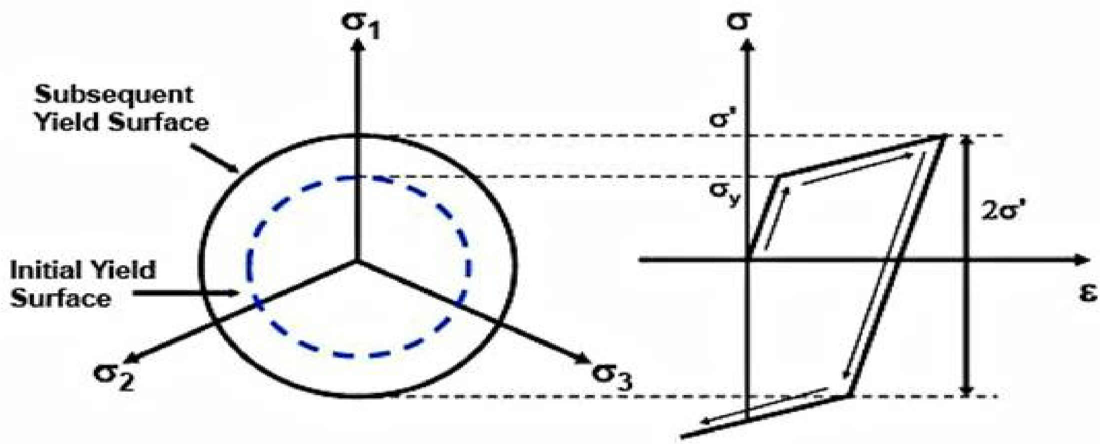


Fig. 11. Isotropic hardening (Ansys Inc. proprietary) [7]

4.4 TANGENT MODULUS

It is the slope of the stress strain curve at particular value of stress or strain. The units of yield strength and tangent modulus to be in Mpa. Yield strength to be 460 Mpa and tangent modulus to be 34000 Mpa. It is 20000 Mpa for the structural steel. Tangent modulus is another interesting property of this structural steel, when the material shows the non linear elastic stress-strain behavior tangent modulus need to be included to know the value of change in strain for a specified range of stress. There is no particular value of tangent modulus and it varies with the strain and describes the type of hardening. The value of tangent modulus is given by the Ramberg-Osgood equation. It is the inverse of first derivative with respect to strain

$$E_t = \frac{E\sigma_{ys}}{\sigma_{ys} + 0.002\, n\, E\, (\sigma/\sigma_{ys})^{n-1}}$$

Where, E_t = Tangent modulus

E = Young's modulus

σ = stress

σ_{ys}= yield strength

n = Ramberg-Osgood parameter (strain hardening exponent), measure of non-linearity of the curve. Normally its value is 5 or more than 5.

For structural steel - the values are

E_t = 20000 Mpa,

E = 2 x 10^5Mpa

σ_{ys}= 250 Mpa

Inserting these values in the formula of tangent modulus, we get the following results

$$20000 = \frac{2 \times 10^5 \times 250}{250 + 0.002\, n \times 2 \times 10^5\, (\sigma/\sigma_{ys})^{n-1}}$$

$n(\sigma/\sigma_{ys})^{n-1} = 5.625$

if , $((\sigma/\sigma_{ys})^{n-1})_{\text{structural steel}} = ((\sigma/\sigma_{ys})^{n-1})_{\text{cast steel Grade 880}}$ then,

For Cast steel Grade 880 - we have the following values

E_t = ?

E = 2.1 x 10^5Mpa

σ_{ys}= 460 Mpa

$n(\sigma/\sigma_{ys})^{n-1} = 5.625$

Inserting these values in the formula of tangent modulus, we get the following results

$$E_t = \frac{2.1 \times 10^5 \times 460}{460 + (0.002 \times 2.1 \times 10^5 \times n\, (\sigma/\sigma_{ys})^{n-1})}$$

$$E_t = \frac{2.1 \times 10^5 \times 460}{460 + (0.002 \times 2.1 \times 10^5 \times 5.625)}$$

E_t = 34224.977 Mpa
For the design purpose the value of tangent modulus for rail & wheel has been taken 34000 Mpa.

4.5 MATERIAL DATAOF STRUCTURAL STEEL GRADE 880

TABLE 6: Constants for structural steel

Density	7.85e-009 tonne mm^{-3}
Coefficient of thermal expansion	1.2e-005 C^{-1}
Specific heat	4.34e+008 mJ $tonne^{-1}$ C^{-1}
Thermal conductivity	6.05e-002 W mm^{-1} C^{-1}
Resistivity	1.7e-004 ohm mm

TABLE 7: Parameters of Strain life

Strength coefficient, Mpa	Strength exponent	Ductility coefficient	Cyclic hardening component	Cyclic strength coefficient, Mpa	Ductility Exponent
920	-0.106	0.213	0.2	1000	-0.47

TABLE 8: Isotropic Elasticity

Young's modulus, Mpa	Bulk Modulus MPa	Poisson's Ratio	Shear Modulus MPa
2.e+005	1.4184e+005	0.265	79051

TABLE 9: Bilinear isotropic Hardening

Tangent Modulus MPa	Yield Strength MPa
34000	460

4.6 ANALYSIS SETTINGS FOR SIMULATIONS

As the load will be applied gradually, hence the *time stepping* has been defined. Initial substeps have been setup to 20, minimum substeps as 10 and the maximum substeps as 50. So that load will be divided into 20 equal number of parts and minimum steps will be 10 and maximum limit is 50. Newton Raphson method of non-linearity remains default selected.

4.7 SOLUTIONS FOR STATIC ANALYSIS

The solutions has been achieved by evaluating all the results for different parameters i.e. Equivalent stresses, principal stresses, shear stresses, strains, factor of safety, contact pressure, contact penetrations etc. and strains. The solutions for different parameters are discussed along with its graphical, tabular and pictorial representation in this chapter. The analysis results for the different parameter are in the following order.

4.8 EQUIVALENT STRESSES (VON-MISES)

The contact region of rail and wheel is under the encumbrance of the load applied to the wheel. Maximum stress is at the contact region of rail and wheel is 53.274 Mpa highlighted in the red colour. Minimum stress is at the most part of the model and is equal to 8.87 x 10^{-6} Mpa which is highlighted in blue colour and is quite usual. The region below the contact region is under the critical load and showing most of the stressed zone of the whole assembled body. The region of the rail which is far away from the contact region is also having the least the stress zone. The variation of the stress value on the assembled model is shown in the Figure 13 below and the graphical & tabular representation of the stress with respect to the time steping is further shown in Figure 15& Table 4-5 respectively.

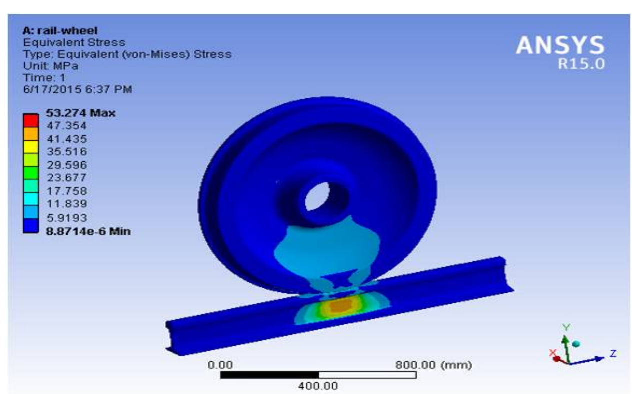


Fig. 12. Model analysis of Equivalent stress (von-mises)

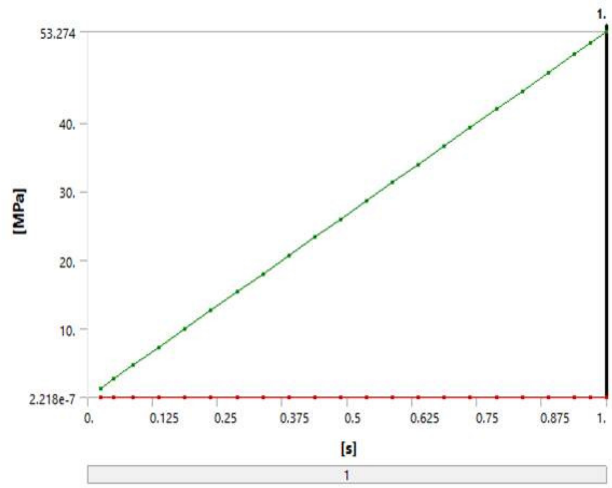


Fig. 13. Graphical Representation of Equivalent stress (von-mises)

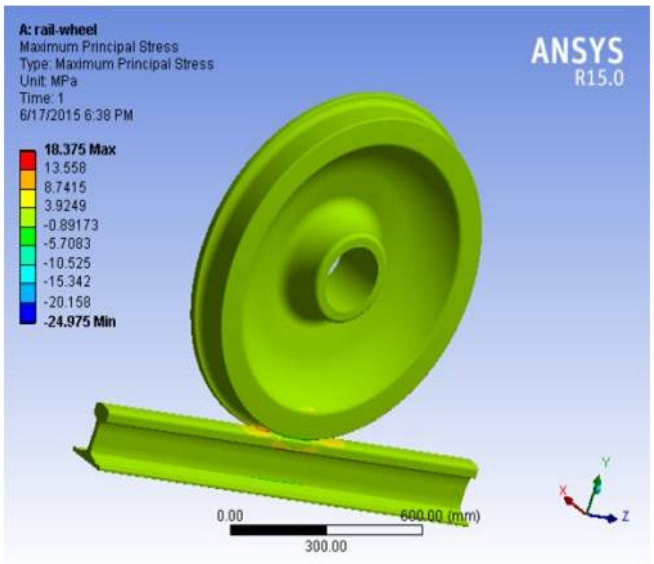


Fig. 14. Model analysis of Maximum principal stress

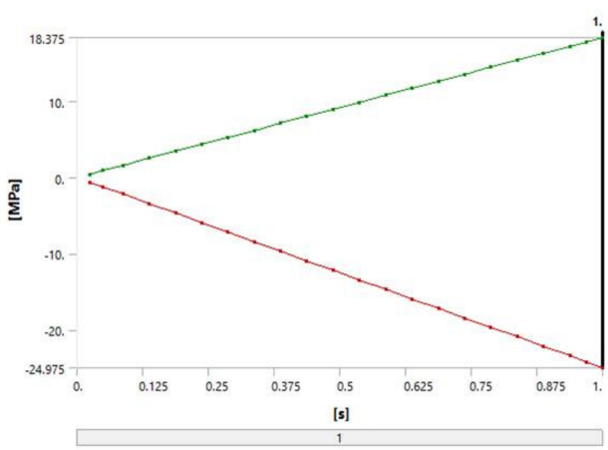


Fig. 15: Graphical Representation of Maximum principal Stress

TABLE 10: Tabular Data of Equivalent stress (von-mises)

Steps	Time [s]	Minimum [MPa]	Maximum [MPa]
1	2.5e-002	2.218e-007	1.3318
2	5.e-002	4.4356e-007	2.6637
3	8.75e-002	7.7623e-007	4.6614
4	0.1375	1.2198e-006	7.3251
5	0.1875	1.6633e-006	9.9888
6	0.2375	2.1069e-006	12.652
7	0.2875	2.5505e-006	15.316
8	0.3375	2.994e-006	17.98
9	0.3875	3.4376e-006	20.643
10	0.4375	3.8812e-006	23.307
11	0.4875	4.3247e-006	25.971
12	0.5375	4.7683e-006	28.635
13	0.5875	5.2119e-006	31.298
14	0.6375	5.6554e-006	33.962
15	0.6875	6.099e-006	36.626
16	0.7375	6.5426e-006	39.289
17	0.7875	6.9862e-006	41.953
18	0.8375	7.4297e-006	44.617
19	0.8875	7.8733e-006	47.28
20	0.9375	8.3169e-006	49.944
21	0.96875	8.5941e-006	51.609
22	1.0000	8.8714e-006	53.274

TABLE 11: Tabular Data of Maximum principal Stress

Steps	Time [s]	Minimum [MPa]	Maximum [MPa]
1	2.5e-002	-0.62439	0.45938
2	5.e-002	-1.2488	0.91876
3	8.75e-002	-2.1853	1.6078
4	0.1375	-3.4341	2.5266
5	0.1875	-4.6828	3.4453
6	0.2375	-5.9316	4.3641
7	0.2875	-7.1803	5.2828
8	0.3375	-8.429	6.2016
9	0.3875	-9.6778	7.1203
10	0.4375	-10.927	8.039
11	0.4875	-12.175	8.9578

Steps	Time [s]	Minimum [MPa]	Maximum [MPa]
12	0.5375	-13.424	9.8765
13	0.5875	-14.673	10.795
14	0.6375	-15.921	11.714
15	0.6875	-17.17	12.633
16	0.7375	-18.419	13.551
17	0.7875	-19.668	14.47
18	0.8375	-20.916	15.389
19	0.8875	-22.165	16.308
20	0.9375	-23.414	17.226
21	0.96875	-24.194	17.8
22	1.00000	-24.975	18.375

5. RESULTS

Contact shear stress Results

The Results has been verified by comparing the Ansys 15.0 result with the Hertzian analytical approach as well as with Hertzian Contact stress Calculator.

Contact shear stress - Ansys 15.0 Approach

From the article 4-5-5 of last chapter it has been found that the *Maximum Contact shear stress is 250.155 Mpa or 250.155 N/mm^2 i.e. equal to 25.5 kg/mm^2.*

Contact shear stress – Hertzian Approach

From the article 2-13 of Chapter 2 we know that

$$\tau_{max} = 4.13(P/R)^{1/2}$$

Where, τ_{max} is the maximum shear stress in kg/mm^2, R is the radius of the wheel in mm, and P is the (static wheel load in kg + 1000 kg due to curve loading). Maximum Contact shear stress presents at a depth of 5-7 mm below the rail surface.

NOTE: The maximum value of contact stresses for BG is limited to 30% of the UTS value i.e.

For 72 UTS Rail the maximum contact stresses value will be 30 % of 72 i.e. 21.6 kg/mm^2.

For 90 UTS Rail the maximum contact stresses value will be 30 % of 90 i.e. 27.0 kg/mm^2.

6. CONCLUSIONS

In this thesis report, the Rail-wheel model of Indian railways has been analyzed computationally after modelling and analyzing on the software Creo-parametric 2.0 &Ansys 15.0. The design of the model of rail was according to International Union of Railways (UIC) and also according to weight per unit length used in India. The rail cross section is UIC 60 kg and the wheel standards was according to the Indians standards of BOXN Wagon manufactured by Rail wheel factory (production unit of Indian railways).

The results for the contact stress on the rail was found safe and in the permissible range as the values were lying below the permissible stresses. The maximum contact shear stress found to be less than 27.0 kg/mm^2 which is 30% of for the 90 UTS rails (90 kg/mm^2). Maximum contact shear stress between Rail -wheel is found to be 25.5 kg/mm^2, 23.33 kg/mm^2, 26.83 kg/mm^2 for Ansys 15.0, Hertzian theory and for Hertzian stress calculator respectively for 90 UTS rail of UIC 60 kg section and all are less than the limiting value of contact stress which is 27.0 kg/mm^2 for 90 UTS rails and it was the prime objective of thesis.

1) The model was given the proper dimensions along with the desirable tolerances. Conditions for axle load wereactual, which a UIC 60 kg rail can take over it. The maximum axle load for the UIC 60 kg rail is about 33.6 tonnes, which it can take according to the standards. But on the tracks of Indian railways about 25 tonnes of axle load of freight train including the tare weight of BOXN wagon are in operations. The analysis was static in nature so the contact between rail and wheel was not frictional but a bonded contact. As in general a BOXN wagon of freight train consists 4 axles having two wheels on each axle, so converting axle load to wheel load it becomes half of the axle load i.e. 16.8 tonnes. In fact it is equal to 164640 N i.e. (16.8 x 1000 x 9.81 N).
2) The rail was being fixed from the bottom surface as it remains on the track of P-way (permanent way) with the assistance of sleepers and ballasts by fish plate.
3) The analysis was static and the wheel load was acting in vertical downward direction so it was necessary to constraint the wheel in such a way so that it could move in vertical downward direction but not in other two directions.

Material used for the analysis is Cast steel of Grade 880 which has the desired properties and is being used by the leading industries (Tata Steels, Jindal steels, SAIL and Bhilai steel plant of India) for manufacturing of rails.

REFERENCES

[1] Chandra, S.; Agarwal, M.M. Railway Engineering. Oxford University Press, Third Impression 2009.

[2] Jindal Steel and power limited. *JSPL Rails*; Product_ Brochure / Rail _Brochure; 2015.

[3] Yelhanka Bangalore. http://www.rwf.indianrailways.gov.in/; *Rail wheel factory*. IST; December, 2014.

[4] *Hertzian Contact stress*. http://www.amesweb.info/HertzianContact/HertzianContact.aspx. IST, January-Jun, 2015.

[5] Sharma, S.K.; Effect of Increased loading on track structure. National Technical Seminar on Impact and Experience of Heavier Axle Loads on Indian Railways and Resultant Maintenance Strategies & Innovation in Design & Construction of Road Over Bridges and Road under Bridges on the Indian Railways. Pune Technical papers, 2010 (Volume- I), 1.1-1.13; Institution of P-way (India).

[6] Doyle, N.F.; Railway Track Design, A review of current practice. Bureau of Transport Economics; BHP Melbourne Research Laboratories, Australian Government Publishing Service Canberra, Australian Government Publishing Service; 1980.

[7] ANSYS Inc. proprietary; ANSYS Customer training material, lecture-5, Rate independent Plasticity. Release 13.0, December 2010.

[8] Indian Railways Fan Club. http://www.irfca.org/faq/; IST, September, 2014- January 2015.

[9] Uzzal, R.; Ahmed, W.; Rakheja, S. Dynamic Analysis of Railway Vehicle-Track Interactions. Journal of Mechanical Engineering, 2008, Vol. ME39, No. 2.

[10] Krishna, G., Rajpal, M.K., Yadav, G.; Track Design Parameters for 30 tonnes axle load. SESSION NO. 621, 1994, Senior Professional /P.Way.

[11] *A.R.E.A*. Manual for railway Engineering, 2015.

[12] Garcia, A.; Numerical and Experimental Analysis of the vertical dynamic behavior of a railway track. Master of Science Thesis, Delft University of Technology, 2014.

[13] RDSO, Rail stress calculation methodology. No. CT/DG/Research, 2006.

[14] Reddy, M.; Srinadh, K.V.S.; Teja, T.V.; Shaik, R. Stress Analysis on Behaviour of Rails. International Journal of Engineering Research, 2015, Volume No.4, Issue No.1, pp : 4 – 8.

[15] Indian Standard, Determination of Young's Modulus, Tangent Modulus and Chord Modulus - Test Method. Bureau of Indian Standard, First Revision, December 1990.