Optimization of Design Parameters, Performance Analysis of Rail-Wheel Assembly

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***Abstract* — In latter-day, the axle load on railways are exceed due to exceeding carry of the goods and faster infrastructural growths. The rail-wheels are subjected to more contacts stresses of alternate magnitude due to roll-actions of the wheels under these types of loads. these types of rails are able to sustain types of varying loads for there future scope or unlimited life. There are some Accidents are occurring due to fractures of the rail-wheels & it effects on the safety of railway facilities. Therefore, large more advertence is giving to the qualities of the rail-wheels. The railways are of wheels failed due to the sum of reasons there are fatigue under the type of loadings where as other mode of failures is damage of rail-bogie, suspension failures and in case of derailment of the vehicles. Therefore, after all advancement in designs, material and non-destructives inspections, the fatigue propagation and failures due to the damages of rail-way components is a one of the issues for those safety engineer peoples in railway. In this research work, a bid is made to inquest the fact of stresses in the rail wheel assembly due to the more contact load at the assemblies' points. The work here shows the culminate of stress von-Mises, strain & safety factor using finite element kitler on ANSYS 16.0. A well-turned sage of these mechanism needs in depth knowledges of physical-interaction between rails and wheels. The rail wheel assembly is assumed to operates under the designed loads. The Goodman-mean-stress-correction theory is used to attain the results. The result on the fatigue-life are shows here, which are assumed to depend on these factors**

Keywords— Wheel-rail; contact stress; Fatigue; Equivalent Stresses; natural frequencies.

I. INTRODUCTION

Solid wheel for railway needs to have several characteristics such as enough strengths, anti-wears and anti-thermal damages and noise-vibrations characteristics. A wheel consists of 3 portions, there are web, hub also rim. Characteristics are different each other [11]. The web portion have an enough mechanical-strength diametrically the load cause by vehicle weight, and at the same time, its configuration is designed from the view-point of thermal stresses distributions. For the rim-portions, steel-grade is to be considered from the view-points of anti-wear and anti-thermal characteristics each of which has different dependence on carbon content of the material. The materials specifications of wheel for chores service was cultivates according to the series of researches on the wear-characteristic of wheel and rail.

This research deals with the design and model of different wheel rims based on weight optimization and also structural analysis has been carried out. It has been compared with standard values by different materials. And also, ANSYS is used to simulate the loading and boundary conditions of the rail and wheel contact for a stress analysis.

II. LITURATURE SURVEY

Optimum Design and Performance Analysis on A Rail Wheel Assembly of Rail Mounted Storage Cum Resting Fixture [3]

A new chassis is designed for storing cylindrical specimens of various sizes and weights in horizontal configurations. This resting fixture is used to carry the propellant stored in the cylindrical specimens. And also, a trolley fixture is designed for a maximum pay load of 90 tons. This design process involves a manual designs calculation, UNIGRAPHICS Software is used to design and analysis to validate the design. Ansys software is used to perform structural analysis.

Design And Analysis Of Indian Wheel-Rail Assembly For Super-Elevation [7]

In this study, The rail-wheel when subject to more stress of their magnitudes. The rail-wheels are found that failure mainly because of fatigue under loads which were applied as in boundary conditions. The 3-Dimensional elastic friction element models of the rail-wheel here used to find out the effect of curve radii and super-elevations on contacts stresses. The work is mainly focused on the interactions of left and right wheels. This paper results shows that curve radiuses and super-elevations have significant effects on almost all the parameters i.e. contact stress, life, damage, safety factor. And also found that natural frequencies are obtained and the values are within the standard frequency range.

Design & Weight Optimization Of A Wheel Rim For Sport Utility Vehicle [9]

weight & design Optimization of a Wheelrims for Sports Vehicle has been carried. The paper shows that the design, model of various wheel-rim based on optimizations of weights and structural-analysis is performed. then these values are compared with the standard values and by varying couple of different types of materials. And this paper shows that by comparing outputs of different materials of simulation and the weight-optimization is performed, by this suggested Aluminum alloys is more suitable for SUV and Models are designed by using solid works 2015,

Optimal Design of Wheel Profile for Railway Vehicles [8] this paper shows that the shapes of a wheel profiles vary during optimizations. Because of this new wheel profiles have to generate given requirement rolling difference function and rail 'r y Δ −'. Measurement of worn and new wheels and rails profiles are used to generate the requirement 'r y Δ −' curves and dynamic simulations of vehicles with obtained wheel profiles had been performed in ADAMS-Rail program package in order to control wear, safety requirements in generating new idea. The one proposed model procedure has been carried here to design of wheel profile for trams and the Numerical results are expressed and discussed. and also, *Integrating Dynamics And Wear Modelling To Predict Railway Wheel Profile Evolution [10]*

the wear modelling approaches it's based on a wear-index basically used in rails wear predictions. This assumes that the wear is propulsions to Tg.

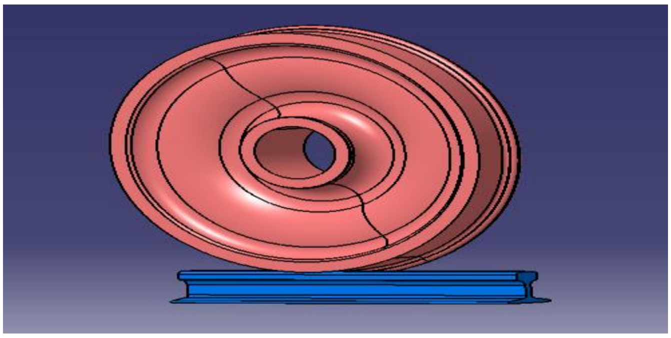
III. METHODOLOGY

A. Geometry of an Assembly

The Rail, Wheel and Axle is modeled with standard Specifications in Catia v5 software by referring the survey in order to study stres in wheel-rail assemblies arrear to high contacts load at the assembly points. The wheel is divided into 5 parts names as Rim, Flange, Hub, Plate, and Thread. The rail-wheel has playing crucial role in nowadays technologies because it is the only content which run on the rails. And both the rails and wheels are made-up of the materials to check optimization and fatigue over the components of rail wheel sets.

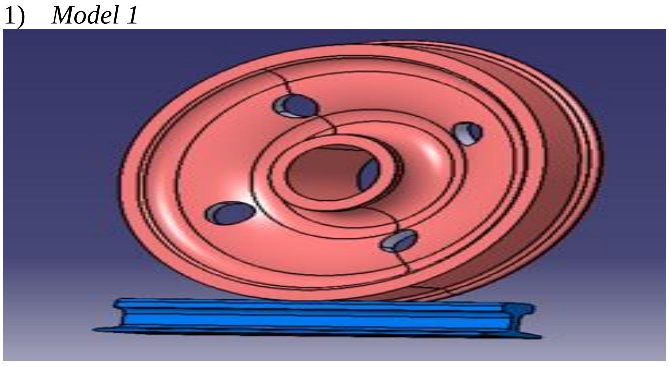
The Wheelset is classified into

- *Rail*
- *Wheel*



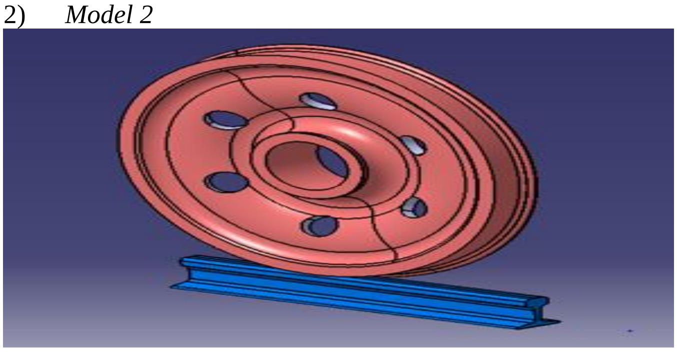
1. Rail-Wheel assembly of basic model.

1) *Model 1*



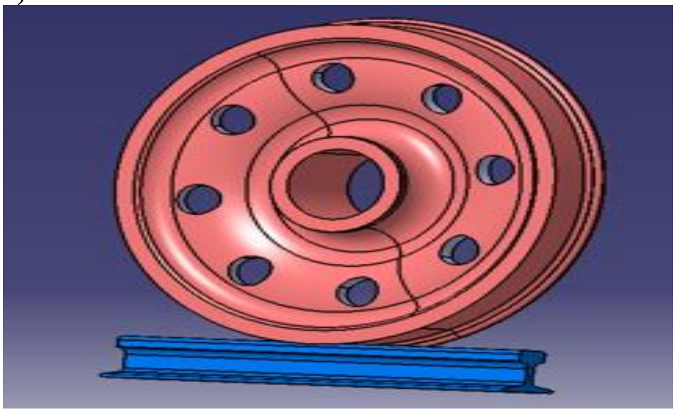
2. Designed model wheel 4 hole

2) *Model 2*



3. Designed model wheel 6 hole

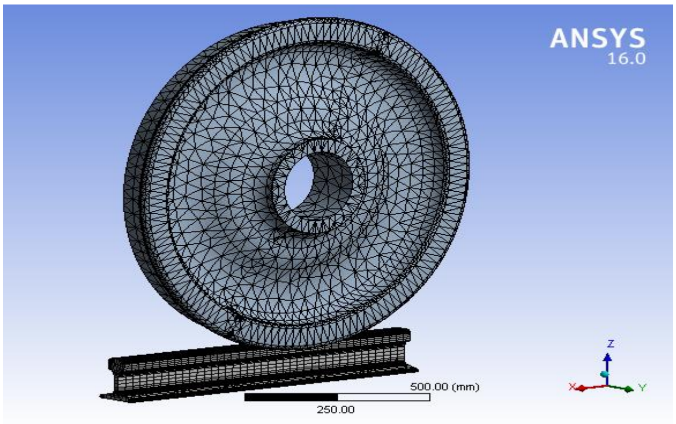
3) *Model 3*



4. Designed model wheel with 8 hole

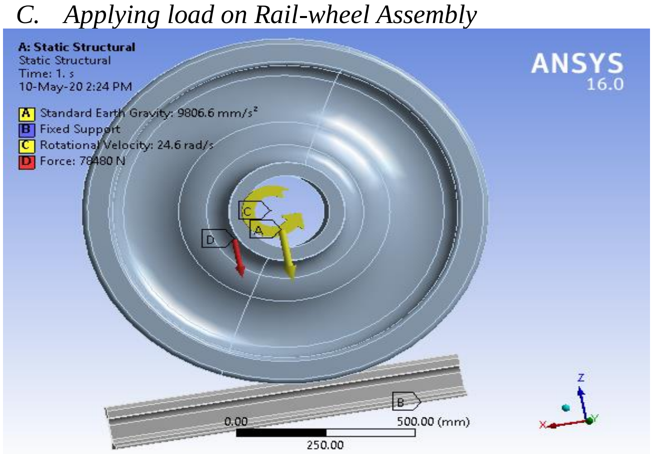
B. Meshing of a Rail-wheel Assembly

The interaction between rail and wheel is happened at only two places those are left side and right side at the assembly conditions. To snap high stress-strain gradients near rail-wheel contacts area, higher meshing density that is fine is used here. In CATIA V5, Rail-wheel are created separately then these components are assembled w.r.t survey, and created the model of R/W assembly. For that calculate the stress, strain at the rail joint, load and stresses are applied. The total assembly is discretized into 37028 elements and 93833 nodes.



5. Meshing of a Rail-Wheel assembly

C. Applying load on Rail-wheel Assembly



6. Loads on Rail-Wheel assembly.

IV. THEORITICAL ANALYSIS

A. *Fatigue Analysis*

Under the designed loads the operation of rail wheel assembly is carried out. and The Goodman-mean-stress-correction theory is used to attain result as per design requirements. The result on the fatigue-life are represented which are assume & depends on factor of boundary conditions.

B. *Material Selection*

The railway paths are mostly a steel material. High Strengths Steels are commonly used and widely used metallic materials in modern industries. And steel have almost all the properties which are required to withstand the deformations.

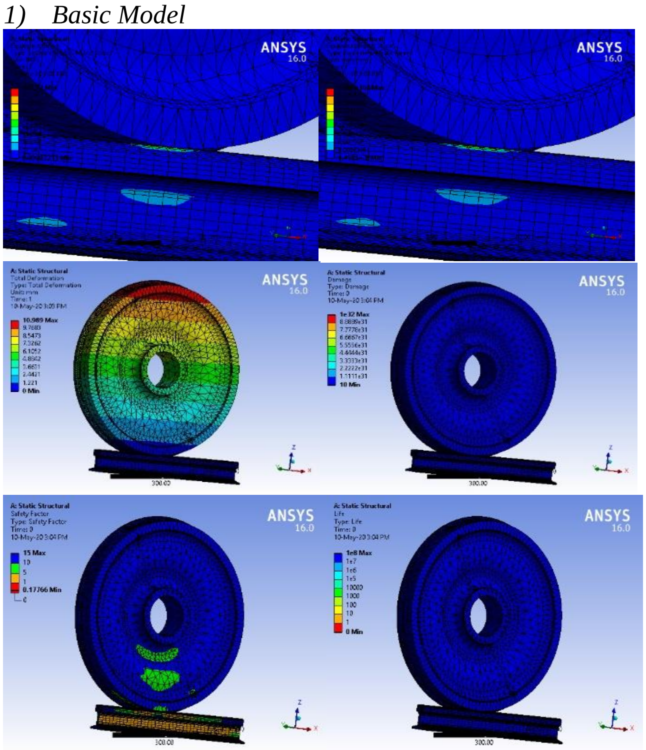
TABLE I. MATERIAL PROPERTIES

Material	Properties			
	Density g/cm3	Yield Strength MPa	young's modulus KN/mm^2	Poisson's Ratio
Structural Steel	7.85	250	210	0.3
Aluminum Alloy	2.7	276	68.9	0.33

V. RESULTS AND DISCUSSIONS

A. *Aluminum Alloy Material*

1) *Basic Model*

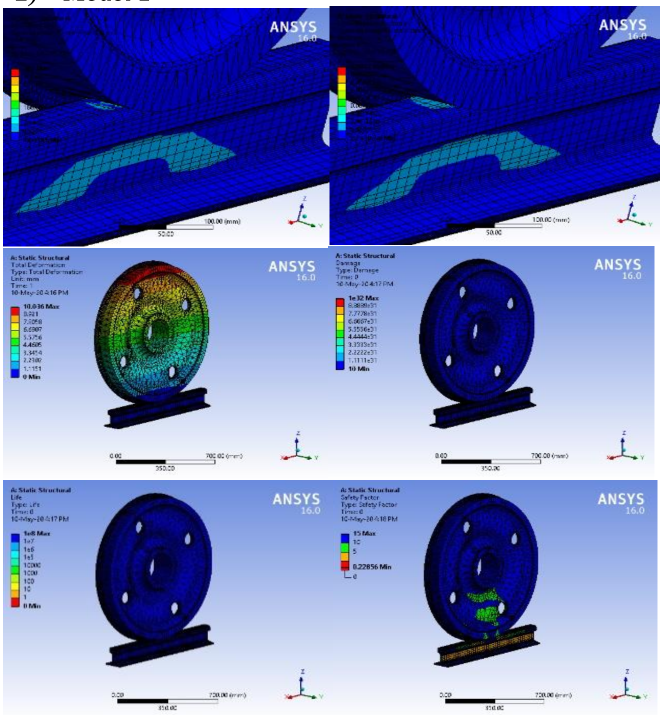


7. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on Basic model

The equivalent-stress obtained on basic-model is 465.72MPa, which was max at the wheels showed in fig. 7, the Equivalent Elastic Strain obtained on the basic-model aluminum-alloy material is 6.6104^{e-003}mm/mm shown in above fig. 7, the Deformation obtained on the basic-model of aluminum alloy material is 10.989mm the Damage obtained on the basic-model aluminum alloy material is 1e^{32}Max shown in the above Fig. 7, the life of assembly for aluminum alloy 1e^{8} cycles is shown in fig. 7. Now, and also the fatigue Safety factor of assembly for aluminum alloy 0.17766 Min and the total mass of the Basic-model of aluminum alloy material assembly is 39.78kg, it is calculated by using ANSYS16.0 Software. By Theoretically,

Stress Tool Safety factor for Basic Model =276/465.72=0.59263.

2) *Model 1*



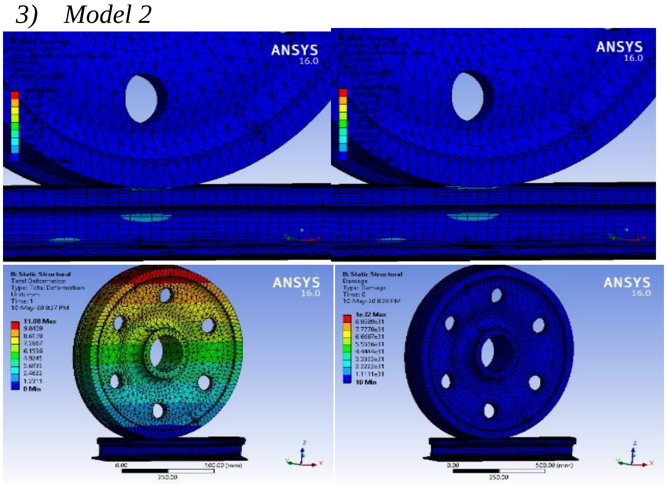
8. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 1.

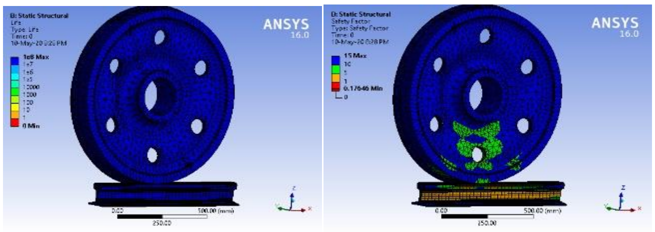
The mass of the model 1 of aluminum alloy material assembly is 39.54 kg, the Percentage of reduction is 1.38 % as compare to the Basic Model it is calculated by using ANSYS16.0 Software.

By Theoretically,

Stress Tool Safety factor for Model 1 =276/362=0.76243.

3) *Model 2*

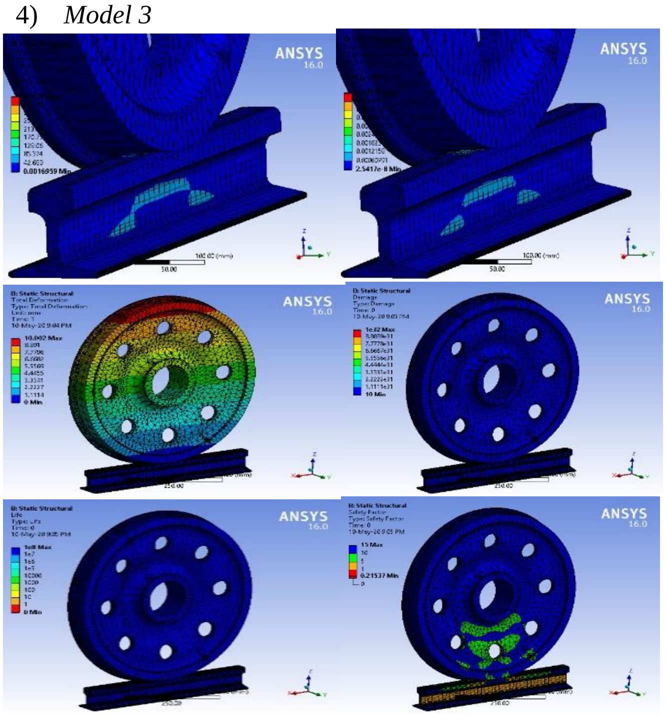




9. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 2

The mass of the model 2 of aluminum alloy material assembly is 39.41 kg, the percentage of reduction is 2.22% as compare to the Basic Model it is calculated by using ANSYS16.0 Software.
By Theoretically,
Stress Tool Safety factor for Model 2 =276/468.88=0.58863.

4) *Model 3*

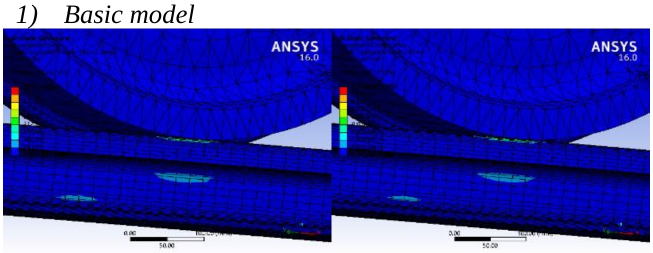


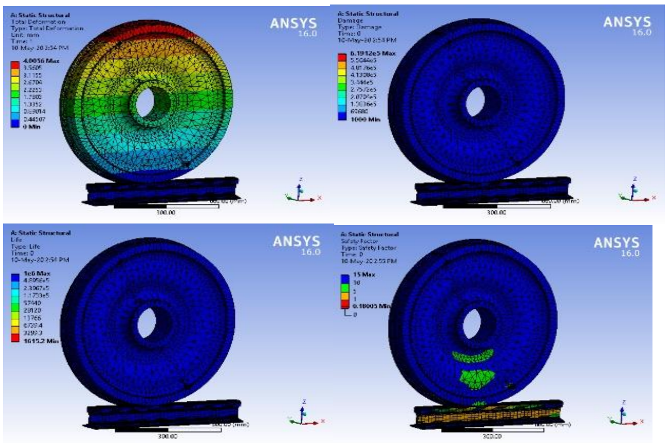
10. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 3

The mass of the model 3 of aluminum alloy material assembly is 39.29kg, % of reduction is 3.0% as compare to the Basic Model it is calculated by using ANSYS16.0 Software.
By Theoretically,
Stress Tool Safety factor for Model 3 =276/384.18=0.71841.

B. Structural Steel Material

1) *Basic model*

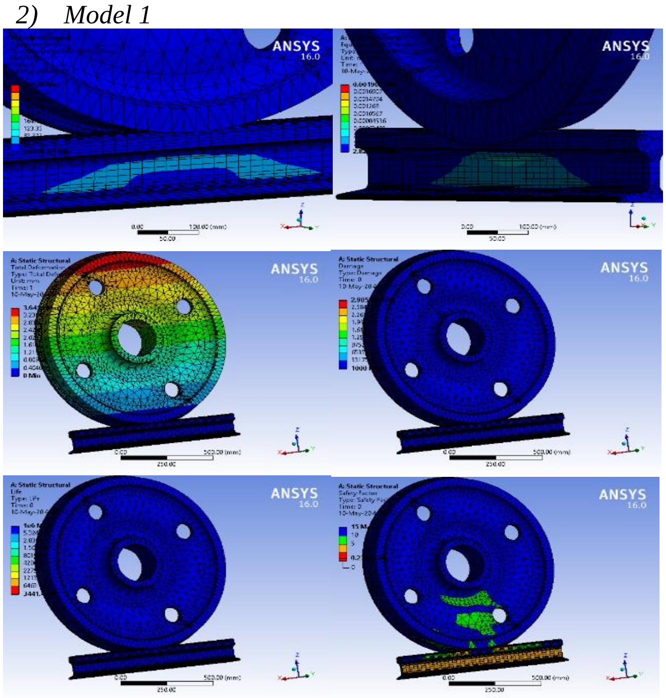




11. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on Basic model

The equivalents stress obtained on basic model is 478.77MPa, it is maximum at the wheel as shown in fig. 11, the Equivalent Elastic Strain obtained on basic-model Structural Steel material is $2.4143e^{-003}$ mm/mm is shown in above fig. 11, the Deformation obtained on the basic-model Structural-Steel material is 4.0056mm the Damage obtained on the basic-model Structural Steel material is $6.1912e^{5}$Max Is shown in fig. 11, the life of assembly for Structural steel $1e^{6}$ cycles shown in the above fig. 11. Now, and also the fatigue Safety factor of assembly for Structural Steel 0.18005 Min and the total weight of the Basic-model Structural Steel material assembly is 112.72kg, which is carried out by using ANSYS 16.0 Software.
By Theoretically,
Stress Tool Safety factor for Basic Model =250/478.77=0.52217.

2) *Model 1*



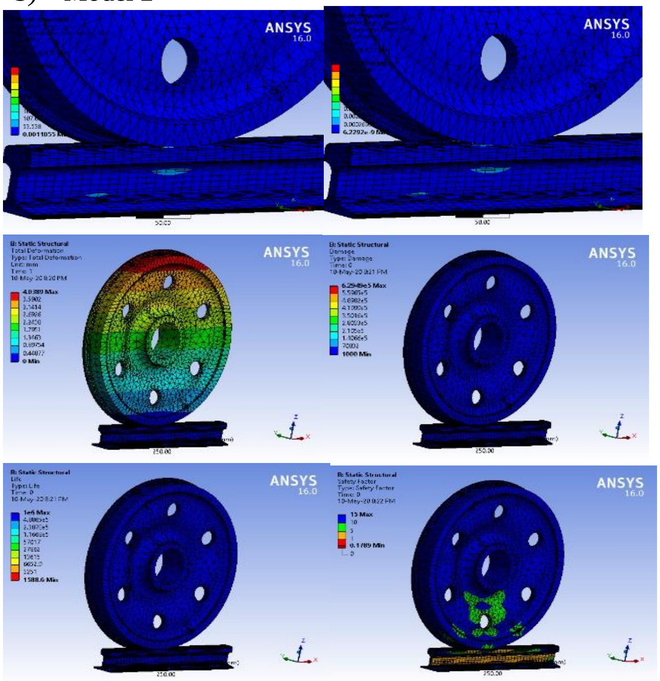
12. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 1

The total weight of model 1 of Structural Steel material assembly is 112.04kg, % of reduction is 4.08% as compare to the Basic Model which is carried out by using ANSYS 16.0 Software.

By Theoretically,

Stress Tool Safety factor for Model 1 =250/369.98=0.67572

3) Model 2



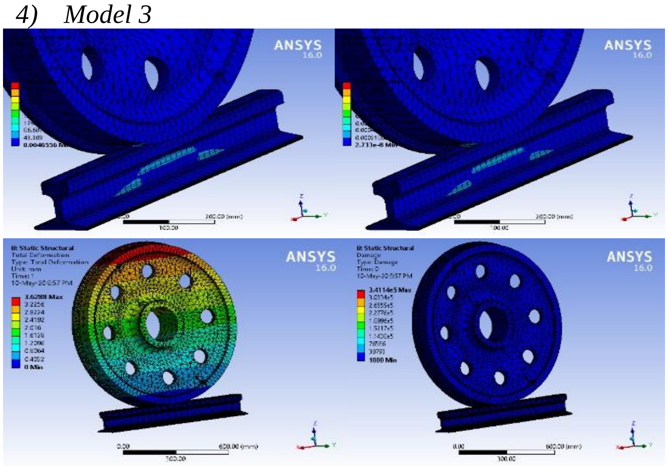
13. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 2.

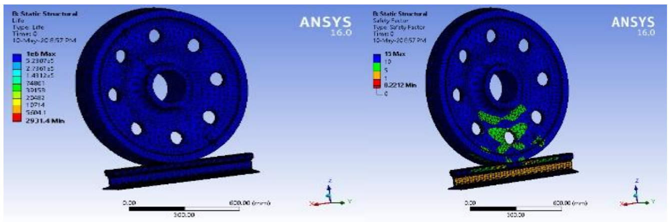
The total weight of the model 2 of Structural Steel material assembly is 111.69kg, % of reduction is 10.3% as compare to the Basic Model which is carried out by using ANSYS 16.0 Software.

By Theoretically,

Stress Tool Safety factor for Model 2 =250/481.84=0.51884.

4) Model 3





14. Equivalent von-misses Stress, Equivalent Elastic strain, Total deformation, Damage, Life, Safety factor on model 3.

The total weight of the model 3 of Structural Steel material assembly is 111.35kg, % of reduction is 13.7% as compare to the Basic Model which is carried out by using ANSYS16.0 Software.

By Theoretically,

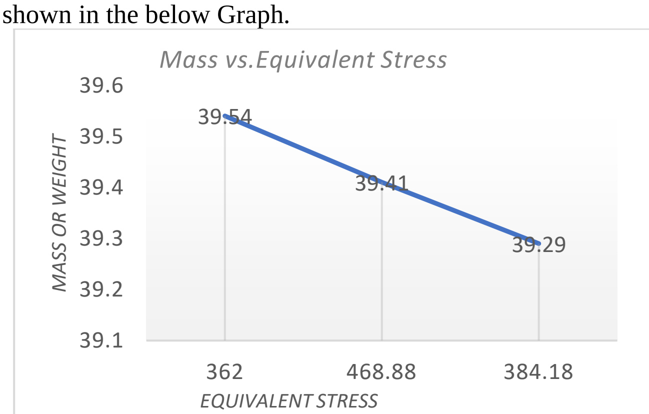
Stress Tool Safety factor for Model 1 =250/389.69=0.34154.

TABLE II. RESULT COMPARISION

Designed model	Equivalent Von Misses Stress	Aluminum Alloy Mass or weight of assembly	Equivalent Von Misses Stress	Structural Steel Mass or weight of assembly
basic model	465.72	39.78	478.77	112.72
model 1	362	39.54	369.98	112.04
model 2	468.88	39.41	481.84	111.69
model 3	384.18	39.29	389.69	111.35

C. For Aluminum Alloys

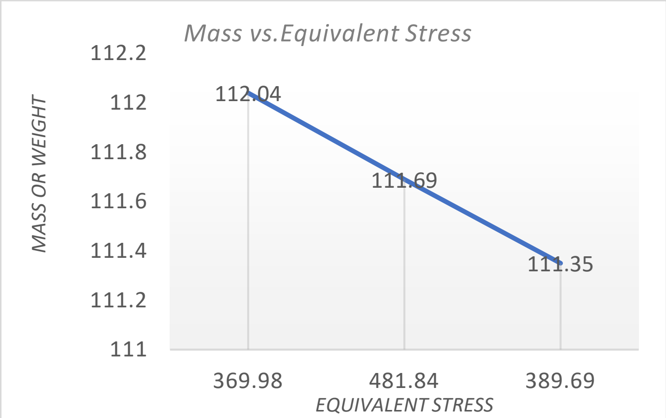
The figure. 15. show the relations between the weight vs equivalent-stress developed on the rail-wheel (R/W) Assembly here the Fig. 15. the 1st point shows 39.54 kg on the graph represents the weight for the model 1 of the R/W Assembly, where the weight of R/W is max and equivalent stress is Min as compared to the 2nd point and a 3rd point. The 2nd point is 39.41 kg shows the weight of the model 2 of rail-wheel(R/W) Assembly, whose Weight is less than the Weight of model 1 as shown in above table The 3rd point is shows that the weight of the model 3 of rail-wheel (R/W) Assembly, whose Weight is very less than that of the other models. Hence, the weight of the model 3 for Aluminum alloys of R/W Assembly Designed models is 39.29kg and Equivalents Stress 384.18MPa as shown in the below Graph.



15. Mass or weight vs. Equivalent Von Misses Stress for aluminum alloy

D. For Structural Steel

Figure. 16. showing that the relation between the weight of the Designed Models and the equivalent stress obtained on the R/W Assembly. Graph shows from the model 1 to model 3 the weight is decreasing because of increasing in reduction of material by adding of holes on the wheel and the points shows i.e., first point is showing that the weight of the model 1 of the rail-wheel assembly, also weight of model is maximum at this point and also equivalent stress is low as compare to the model 2 and 3. The second point shows that the weight of the model 2 Rail wheel Assembly, whose weight is more than the weight of model 3 as showing in below graphs. The finished point is represented the weight for the model 3 Rail-wheel Assembly, and lower point compared to all points Hence, the weight of the last model that is model 3 for Structural steel material R/W is 111.35kg and equivalent stress is 389.69MPa.



16. Mass or weight vs. Equivalent Von Misses Stress

VI. CONCLUSION

In this practice, a numerical analysis of Equivalent von-mises stresses, equivalent elastic strain and fatigue, static analysis of 3Dimensional Rail– Wheel (R/W) contacts is successfully carry-out by using Finite-Element-Analysis with ANSYS Applications of realistic-FE-loading and boundary conditions has played an important role in getting accurate results. And It is observed that fatigue life depends on the Equivalent stress.

1. here an effort is made to inquest the stresses on the roadwheel assembly by this it was observed that stresses are more at the contact points. and also, the rail will get the maximum stresses while running condition

2.here optimized the models with respect to design and materials by this analysis it was clear that both design and materials where taken the optimization technique can be easily obtained without any much more requirements

3.In this work, we optimized the rail wheel assembly design to achieve weight reduction and Design Modification with Respect to material. The goal of weight optimization is achieved by comparing the two materials likes Aluminum alloys and structural steel for the Railways under the same boundary condition.

4. The weight of the rail wheel assembly for Aluminum alloys is reduced from 39.78 to 37.29. i.e., 3%, The strength of the final part or model 3 is 384.18MPa, the aluminum alloy shows that which is less than ultimate bearing strength 607MPa as per the safety is considered and the structural steel is reduced from 112.72 to 111.35 i.e., 8.22%. Then the strength of the model 3 is 389.69 by this the structural steel is showing that maximum reduction as compared to the aluminum alloy.

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