DESIGN AND PROTOTYPE DEVELOPMENT OF RAILWAY WAGON FOR VIRTUAL ENVIRONMENT ANALYSIS

Submitted in fulfillment of the requirements
Of the degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

By

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2020

CERTIFICATE

This is to certify that the research work titled **Design and Prototype Development of Railway wagon for virtual environment Analysis** that is being submitted by **SHIVENDRA NANDAN, SATYAJEET KANT, RISHIKESH TRIVEDI & JAVED AHMAD** is in partial fulfillment of the requirements for the completion of Project, is a record of bonafide work done under my guidance. The contents of this project work, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma.

Dr. M. MANIRAJ **(Supervisor)**
Professor
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Internal Examiner **External Examiner**

Approval Sheet

This **Hardware project (MEE 499)** report entitled **Design and Prototype Development of Railway wagon for virtual environment Analysis** by **SHIVENDRA NANDAN, SATYAJEET KANT, RISHIKESH TRIVEDI & JAVED AHMAD** is approved for the degree of Bachelor of Technology in Mechanical Engineering.

Examiners

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Supervisor

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Date: **May ________, 2020**

Place: **Greater Noida**

Declaration

We,

Sl. No.	Name	Enroll No.	Batch	Group	Signature
1.	Shivendra Nandan	1614101198	1	28	
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declare that the work embodied in this hardware project entitled **Design and Prototype Development of Railway wagon for virtual environment Analysis** is our own bonafide work carried out by us under the supervision of **Dr. M. Maniraj** and the co-supervision of **Vishal Pratap Singh (IES Officer)** in the **B. Tech. ME VIII Semester** 2020. The matter embodied in this Industry integrated project has not been submitted for the award of any other degree.

We also declare that we have faithfully acknowledged, given credit to and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further certify that I have not willfully lifted up some other's work, para, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at web-sites and included them in this report and cited as my own work.

Certificate from the Supervisor/Co-supervisor

This is to certify that the statement in the declaration mentioned by the student is correct to the best of my/our knowledge.

Mr. Shrikant Vidya
(Project Co-ordinator)

Dr. M. Maniraj
(Project Guide)

Mr. Vishal Pratap Singh
(Project Co-Guide)

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Best Regards,
All Team Members

ABSTRACT

The Railway is an rapidly growing research field and significant efforts for development are being carried with the aim of up-gradation and focus of enhancing the reliability of railway systems by introducing new features and substantially reducing associated costs with research on materials along with analysis of prototype using software for the prediction of the dynamic nature of railway wagon progressively. The prototype model of railway wagon developed with the aim of availability of railway systems and improving the reliability. Using the virtual environment of software, tedious Designing work can be switched from event-based prototyping to time driven modeling virtual software prototyping. This research work is mainly aimed for effective analysis and criteria fulfilling of modern standards. To development of virtual prototype of wagon model is done by using modeling software applications. To develop an effective and efficient wagon Prototype model, need to linear shaped mode modeling as well as variable mode performance to finalize wagon design on track We are Designing a prototype of Railway wagon for analysis purpose on different loading-unloading conditions of Rolling stock System. To obtain optimum dimensions of railway wagon model is being done by consideration of track balancing and platform positioning. With an objective of design, integration, development, and testing of Wagon Prototype on railway Tracks we need a conformable transportation system. most of the wagon components of wagon has been rolled out for balancing on the track. By applying the ultrasonic vibration intensity testing allowed us to examine and assess the damage indexes corresponded to faults. Actual collected data has been used to assess the overall transport system. it is neither a stationary operation nor the speed of train is constant when moving on the same track.

Key Words: Railway Track, Dynamic operation, Loading-unloading, Prototype Simulation, Research of Materials & vibration Testing etc.

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List of abbreviations

1.	HSR	High-speed rail.
2.	CTV	Caterpillar tracked vehicle.
3.	IMM	Inter-modal modules.
4.	FFT	Fast Fourier Transform.
5.	ACLS	Axle central lateral section.
6.	FOS	Factor of Safety.
7.	DA	Dynamic augment.
8.	FAC	Fatigue allowance Criteria.
9.	IR	Indian Railway
10.	CNG	Compressed Natural Gas.
11.	LNG	Liquefied Natural Gas.
12.	MPa	Mega Pascale.
13.	UST	Ultra-sonic testing
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Introduction

1.1 Background of the Project

Ever since the railways advent, the track rails have been used to guide the trains and operation in a safe manner. Further, Railway development ensured that formation of tracks played a very important and vast role in railways research and development for the economic aspects in prototyping. From the trains type of passage along with the all kind of tracks to needs to be very smooth finish and perfectly aligned for balancing as well as to be leveled; otherwise, in the case of irregularities on the railway tracks may be the main cause of oscillations occurrence and tend to vibrations on the track. So It would have been also found that, the major type of cause for travelers discomfort is occurring due to induced heavy vibrations and on the other hand oscillation. These damages in major amount are also happens as the laden goods on trains acts as source. The traditional approach for dynamic analysis of railway vehicles has been assumption based as the wagon body is modeled by considering as a rigid one. It becomes quite evitable for such type of rigid models, in context to safety of laden goods or ride comfort the critical positions are the vehicle extremities, as at these positions the vertical motion of whole wagon body tends to sum up with the pitching motion. based on above assumptions of rigid wagon body often tends and leads one to believe such that vibration issues occurs at the extremities of vehicle are more significant in nature and need to be addressed with most priority. But the magnitude possibilities for the acceleration levels at the center of wagon floor being comparable with vehicle extremities and cannot be neglected. Increasing demand of railways logistic support improves the order speed in to facilitate time reduction for transport operation. In the past two centuries, it have seen that increase in the speed of travel from 45 km per day using horseback to 640 km per day using car/vehicle or 200-650 km per hour by using High Speed Rails. [1]

Most of the world's railways is facing the growing demands for both passenger and freight wagon transportation. Recent statistics for 2011 shows a worldwide growth of freight wagons in ton kilometers by 3.6% and worldwide rail passenger transportation in kilometers by 3.68% from the previous year. In longer-term outlook, predictions point and strategic goals to continued growth during upcoming decades, it can be exemplified as, In the Europe, the EC (European Commission) in its 2011 transportation facility the white paper sets out the goals to transfer freight type of transportation from the road transport: "32% of road freight cars over 320 km should shifted towards other modes of transport such as rail or waterborne transportation by 2032, and also more than 53% by 2055" [2].

A bogie or coach is a wagon or trolley on wheels. In the mechanics terms, a bogie is a framework or chassis carrying wheels, attached to the wagon vehicle. It can be fixed, as on a cargo type truck vehicle, which is mounted on a swivel, as on when locomotive train carriage, or the suspension of sprung as in a caterpillar tracked vehicle (CTV). A bogie is a structure underneath of a train to the wheels axle (and, also, wheels) are being attached on the bearings. There are mostly two type for each carriage to be used, locomotive and wagon, or alternatively, they are at connections in between the wagons or carriages. The bogies connections with the cars allow to a certain degree of the rotational movement around the vertical axis. Most of the bogies have two types of axles, but the some cars are designed for the extremely heavy types of loads, which have been built-up with up to six axles per bogie. The Heavy-duty type cars may have more than the two bogies and by using the span bolsters to equalize load and to connect the bogies to other car bogies.

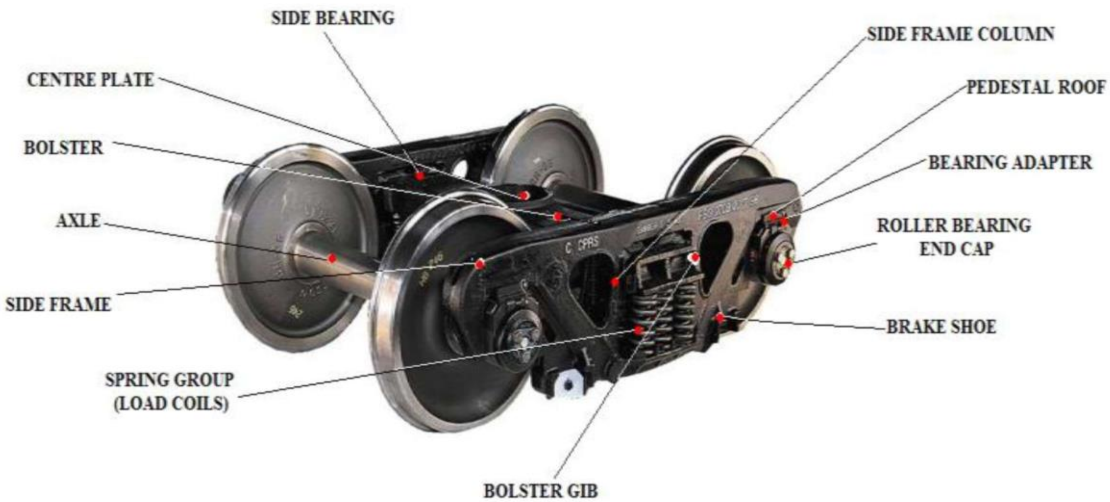


Fig 1.1 Schematic diagram of Railway bogie

Usually the level of train floor is above the bogies; however, for the double decker type of trains the car floor may become lower between the bogies to increase the interior space when staying within the restrictions of the height [3].

1.2 Purpose and meaning of research

The main purpose of designs of new wagon was to increase the versatility concept to allow the containers, Passenger trains, swap bodies and trailers to be freely moved on a common form type of rail vehicle within the most of the standard rail network in the Transport. The Existing wagons are less versatile in the relation of ability to accommodate a mix of IMM. The new design of wagons has greater versatility.

- To Decrease the capital cost of railway to obtain optimum designs.
- More Space availability for the wagons.
- By applying material research for the selection which will give the higher strength with reducing Wagon weight.
- Continuous type vibration testing of railway tracks.
- For the crack checking and track balancing.
- Prepare the suitable Transportation model Design for the Increasing Population.
- Reduction in the wagon as well as Tracks Vibration at the High speeds of train.

- To obtain the Optimum Variables on the matter of Different type in transportation (i.e. Compressed Natural Gas, Oil, Ballast, Coal, Passenger Transport Pesticides.
- To get the optimum load and speed ratios for the various type of weather conditions (Likewise Summer, Rainy Days, Spring Season and Winter etc.)

1.2.1 Railway wagon components

- It consists of the wagon frame.
- The wagon frame has the wheel and Axle arrangements.
- The main system of SUSPENSION.
- The Applied system of BREAKING.

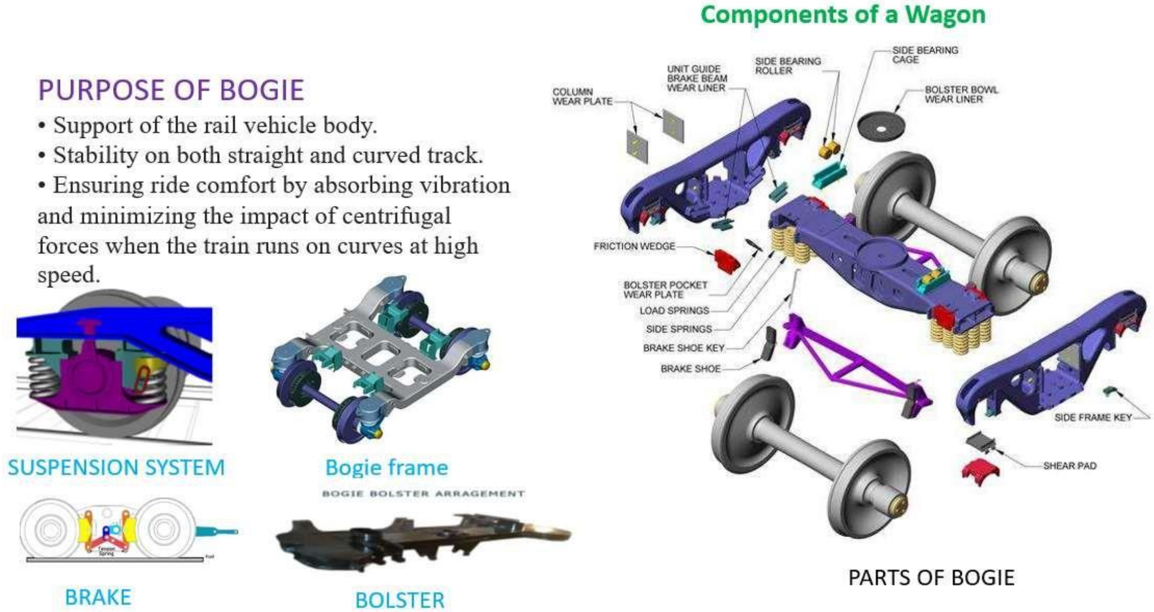


Fig 1.2 Railway Wagon Components

1.2.2 Assembly of wagon Components

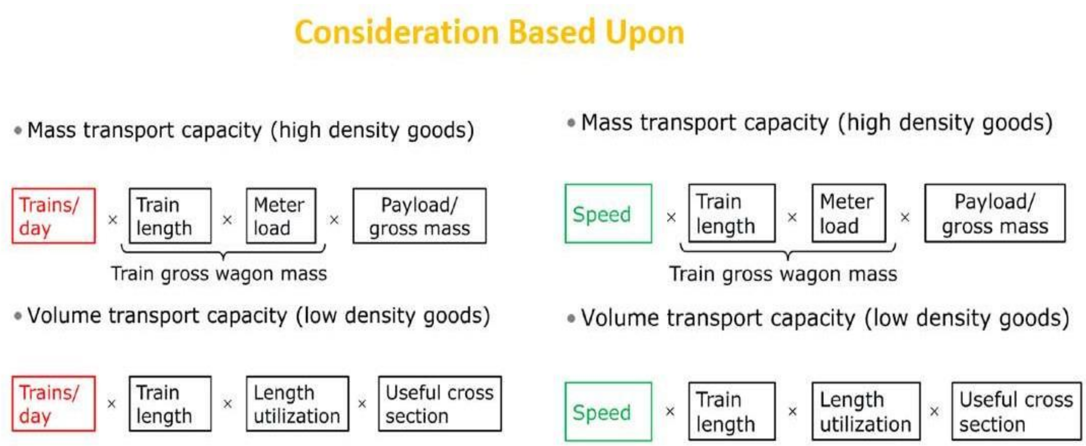
The assembly of wagon includes the combining most of the parts which are mainly modeled or designed from the software and these assembled parts further works to the wagon analysis for the two type's dynamic analysis and static analysis. From the static analysis part of view the maximum stress value comparing von-mises yield stress of the material, factor of safety of material can be calculated. And for the dynamic analysis part of view lateral force values and vertical force values, lateral creep forces and longitudinal creep forces, derailment quotient, coming on tangent to the curve track.

1.3 Objective of Project

This project is mainly aimed to develop a optimum as well cost-effective ways for design generation and testing methods for vibrations and prevention of accidents by oscillation intensity testing and which will further used for un-manned railways gate in the mode of automatic controlling and also loading-unloading by platform based systems.

Dynamically in railways behavior prediction of bogie model by use of the produced parts is highly cost spending, very lengthy and tough type of work. Therefore, in today's scenario the many design companies & railways researchers are preparing virtual prototypes of bogie model and simulating through environment prepared by software's virtually for dynamic behavior prediction of prototype Bogie frame.

There are many global used software's of designing, which are used & available for design, drawing & modelling like solid works and universal mechanism, for evaluation of dynamic behavior of prototype Bogie frame software's used such as Ansys, PTC Mathcad etc. In the material which is applied presently is steel or iron based alloys used for the prototype freight wagon, we can find the alternative by using alloys of aluminum in future manufacturing units. In this project work, we worked for modelling and components assembly of a bogie type frame model of fright wagon by application of PTC Mathcad, Ansys and universal mechanism software etc.



General model of railway system transport capacity – infrastructure (fixed asset) perspective

General model of railway system transport capacity – train operating (moving asset) perspective

Fig 1.3 Transport Capacity of Wagon

In this we are also performing the mode of linear shape designing freight wagon on virtual railway track. As from evaluation results the aluminum alloys has more strength to weight ratio that justifies fuel reduction in transportation.

1.4 Methodology used for Design:

Here are the various Steps which are mainly focused in Design purpose of wagon.

1.4.1 Problem into modules deviation

The stages, which are involved in modified bogie design are as follows under:

a) Step I – The Concept Design of wagon

b) Step II – Blue print of Detailed Design

c) Step III – For the Manufacturing of Prototype required Design Validation for the best suited Speed testing

d) Step IV - Oscillations Trials

e) Step V - Introduction of the upgraded prototypes in the Line

1.4.2 BASIC DESIGN PARAMETERS OF PROPOSED WAGON DESIGN

Parameters
A. General
1. T.L.D.
2. weight ratio of tare to payload
3. Axle Load
4. Wagon length
5. Complete wagon Tare weight
6. Wagon payload
7. Payload of rake /. Commodities To be transported through wagon
8. Design for other commodities in fully and empty mode
9. Centre of gravity height in loading conditions
10. Rake payload

Parameters
B. Overall Dimensions (mm)
1. Bogie Centre length
2. Over head Length
3. Coupler faces length
4. Inside chamber Length
5. Coupler height over level Track from rail level
6. Width inside chamber
7. Width overall
8. Height inside chamber
9. Rail level floor height
10. Capacity of bogie
11. heap Loading Capacity
12. Total Volumetric wagon capacity

1.4.3 TECHNICAL DATA OF THE PROPOSED WAGON DESIGN

1. wheel load adjusting method on axle
2. Clearance details of coupler movements on head of wagon
3. Mass Calculation
4. C.G. of each component for balancing analysis of wagon frame.
5. calculation of total wagon weight
6. Force calculation of flange at curvature
7. lateral or longitudinal unbalance elimination by load distribution
8. Curve layout for turnout in bogie.
9. Vibration testing of the bogie frame.
10. calculation in stable mode
11. Stress calculation under dynamic and static conditions
12. dynamic projection of masses based on railway Tracks
13. Energy absorption measurements

2

Literature review

2.1 Introduction

Transport model of railway is mainly used for passengers and commodities (likewise laden goods) in terms of wheel base bogie transport which is designed and modelled specifically to move along tracks. It is a method of transport chain, which facilitates and avail the service to growing of country economy and comfort in travel experience with cost-effective as well time saving method. [1, 2].

The track of railroad having two parallel rails, secured by sleepers of cross type beams. These sleepers always maintain fix distance for wheels between two cross beam rails; a measurement to specify this constant gap known as gauge length. To maintain track alignment, it secured on ballast bed or foundation of the concrete, that's why it is always preferred as Permanent type way[3-5].

The travel of long distance or transport of heavy and more amount of laden goods. It is found that rail mode always better than road mode transport. Because the impact of environment, efficiency of energy and safety reasons. It is always preferable nationwide.

In our project work, we are focusing to design a bogie frame prototype under the track or railroad balancing for the various type of loading-unloading conditions. For the Optimum parameters i.e. dimensions, weight etc. Need to be accomodate to the bogie frame and vibrations testing of prototype bogie frame need to rolling out on railroads. If problems due to corresponding index of damage, data collection is required for assistance and examination the operation of system. [1]

PTC Mathcad and Universal Mechanism is a method of Parameters evaluation of bogie frame. & in this current Project work, alloy studies is analyzed and summarized for alloys of aluminum which contains greater self weight to material strength and less self-weight as compared to existing systems. And it can replace the current iron-alloy material in future. Also due to reduction in vertical forces tends to less material wear and corrosion. The purpose of prototype design is to maximizing the versatility of containers, swap body wagons, trailers and Passenger bogies to be freely movement within rail transport network of most standard gauge in relation to accommodate a mix model of inter-modulus.

The broad gauge of Indian standard (1675 mm) are modifying in meter gauges (1000 mm) & further standard gauges will be used.

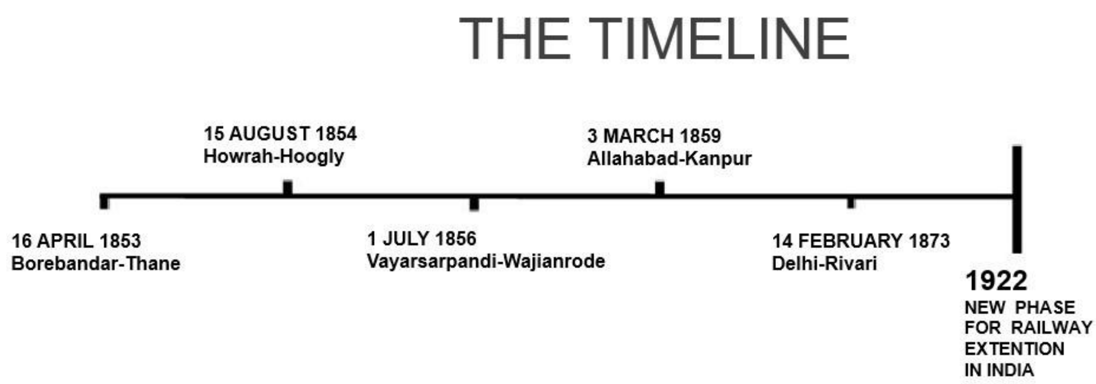


Fig. 2.1: Timeline of Indian Railway

2.2 Reviews

Vinod Kumar B. et al. Studied in their research paper work as during the movement of bogie frame prediction of dynamic nature using manufactured model is very lengthy, time-consuming and tedious work. So for virtual modelling of railway Prototype and running through the software environmental tools for virtual behavior during motion analyzing of bogie frame models. At current steel alloy material is replaced with wagons of freight model.

Krasson Wieslaw et al. studied in their research paper that Bogie frame with a rotatable loading-unloading based platform for transportation structure. Which is easier and can allow loading-unloading without terminal of structure. Process of loading-unloading in the bogie frame can be performed easily on every bogie from anywhere (no other modes required). Becomes cost & time effective comparing to road transport. Which implies environmental feasible situation with safety in transport.

Vladimir Milovanovic et al. studied in their research paper that the methods which are intensively used in the identification of failure causes of crack nearest to the body joins. Bogie frame of train also bodies of swap containers. The objective to conduct this type of evaluation is mainly for identification of stresses which occurs after assembly process of bogie frame on the downside. The research was carried out to find loading type due to that cracks on bogie joins induced.

Mehdi Koohmishi et al. studied in their research paper that layers under the railroads are follows by sleeper support in the previous system of Tracks structure. In the transition the loads for bases and removal of water from to the railroads. Ballast of layers mostly influenced by responding of different materials to reduce the weakening strength of the particular layer and find the stability of railroads.

Lukas Lestinsky et al. studied in their research paper that vibrations reduction in wheeled bogies are maintained by many ways of rail road balancing. In simple terms, it is very problematic in identification of noise by the conventional parameters and simple drafting system. Simulation is a way to find out the role of actual circumstances, which can be viewed in environmental scenario. In most of the cases methods of simulating are done by using software's of mathematics features.

3

Problem description

In current scenario, the IR transport facilities are mostly dominated by Iron-ores, coal-stones, Cement bags, Products of metals, hydrocarbon products etc. These type of transport services are nation wide used in vast range. Now some new kind of commodity are under consideration for transport. These are opportunities to gain some new emerging and developing market. So far new wagon of optimum capacity will be manufactured with help of new designs of wagons in virtual type environment.

3.1 Area : Modelling of prototype and Analysis for bogie frame Development

3.2 Title: Design and Prototype Development of Railway wagon for virtual environment Analysis.

3.3 Aim: Component Design and assembly of Bogie frame of wagon for Development of a model Prototype in emerging software methods.

3.4 Motivation:

- Design Improvement
- Sustainability
- Factors of economics.
- Research on materials.
- Reduction in time
- Frequency Vibration Testing
- Guide lines up-gradation
- Application of newly modified Standards and Specifications
- Optimum space availability

3.5 Problem description

Each and every country, weather under development or developed needs the upgraded Transport in almost most of the sectors by means of wheeled bogies Transport (widely known as rail transport). But due to usage increase, convention systems are not efficient and effective for railroad transport. Innovations is lacking in railways and previous guide lines of Specifications are not suitable now.

In the present status of IR -

- Lack of railroad Maintenance
- Poor stage of railway tracks.
- Accidents because of unbalancing force in railroad designs.
- Lack of Blue-Prints
- Weakening of Single tracks
- Speed reduction due to less railroad strength.

In the design work, we are modelling a virtual wheelset bogie frame of railway and simulating in universal mechanism for calculating the motion behavior of prototype frame Wagon model.

The drawback related to existing systems of bogies can be eliminated through

- use of automatic rotatable loading-unloading platform
- Platform based ramps, lifts & model based ramps in logistics type of services.
- Increasing average speeds
- reducing overall transit time
- Finding Optimum weight-Speed
- intensive utilization of assets
- Constraints management efficiently
- integrated wheelset model of FEM
- Weight consideration
- stress intensity factors
- Estimation of residual life and strength
- identify cracking causes
- Conducting Noise and vibration testing
- Life Cycle increment by enhanced features of safety
-

3.6 Research Methodology

In this research, we are developing a railway wagon prototype in consideration of balancing of tracks for the different loading conditions. By which Optimum dimensions can be integrated to the wagon and testing of railway prototype wagon has been rolled out on track. If actual faults correspond to damage indexes, collection of data is available for assess and examine the overall system operation. [1] Universal Mechanism Software and Ansys Software is used to analyzing of wagon Parameters.

And In present research work, Aluminum alloy study is focused which has greater strength and less self-weight as compared to existing systems. And it can replace the current iron-alloy material in future. Also due to reduction in vertical forces tends to less material wear and corrosion. The purpose of prototype design is to maximizing the versatility of containers, swap body wagons, trailers and Passenger bogies to be freely movement within rail transport network of most standard gauge in relation to accommodate a mix model of inter-modulus.

In methodology, various stages of wagon design is to be involved.

1. Concept and detailed design
2. Prototype testing and design validation
3. Optimum speed and oscillation trial
4. Open track line introduction of wagons

Wagon dimensions for drawings and diagrams arrangement is necessary input in the software for study of load distribution with consideration upon FOS, DA, FAC along with specific component fatigue life. IR system suitability for loading and unloading methods become enhanced by opting material research.

4

Design Aspects of Wagon Components & Assembly

Structure plan of prototype is drawn by standard dimensions of IR gauge and components are prepared. A wheeled bogie is a wagon. According to engineering Mechanics, chassis of a vehicle attached to wheel carrying framework on a locomotive or carriage train is termed as bogie. And structure of bogie underneath a train to connect each wagon with a certain degree of rotation around axis. The Axles designed for heavy loading conditions varies up to five but most of them built up with two axles. And also, bogies are used with span bolsters to make connection and load equalization**.**

Wagon Type: Freight Wagons

BOX variant: open wagon of High-sided bogie with using the pneumatic type of brakes, CASUB casting wagons, high tensile type of the CBC coupler and cartridge with the tapered shape roller bearings.

Movement of material commodities: coal, metals, iron ore, luggage and stone etc.

Table 4.1 Wagon Development data-1

Material of wagon Construction	IRS M46, CRFI sections
Type of Commodity to be transported	Coal, Food grain, Fertilizer & Bag Quantities
Loading	Top loading
Unloading	Side doors & Grabber
Length over head stock(mm)	12800
Length over couplers(mm)	13729
Length inside(mm)	12790
Width inside/Width Overall (mm)	2852/3156
Height inside/Height (max.) from RL.	3072/3161
Height of C.B.C. from R.L. (mm)	1106
Floor area (Sq.M)	30.32
Cubic Capacity (Cu.M)	61.05

Table 4.2 Wagon Development data-2

Maximum axle load(tonne)	22.95
Tare Weight (tonne)	21.6
Pay load (tonne)	71.30
Gross load (Pay+Tare) (tonne)	92.63
No. of wagons per train	58.265
Throughput per rake (tonne)	4128.32
Brake System	Modified Air Brake
Coupler	C.B.C.R
Bearing	R.B.M.
Bogie	C24 HS Bogie
Brake rigging (Under frame mounted/Bogie mounted)	Bogie Mounted
Maximum Speed	100 kmph

Table 4.3 Wagon Development data-3

Axle load (for maximum)	20.312 tons
Grouping of Spring per bogie (for outer)	12.0
Grouping of Spring per bogie (for inner)	8.0
Tare weight	23.297 tons
Payload weight (spec. by RDSO)	59.81 tons
Revised Payload weight (with incl. tolerance)	66+2.1=68.1 tons
Gross load (excl. tolerance, spec. by RDSO)	81.280 tons
Revised Gross load (, incl. tolerance)	87.27+2.5=89.77 tons
Capacity	61.05m^3
Width	3.156m
Height	3.161m
Length (over the headstock)	12.800m
Length (over the coupler faces)	13.729m
Distance between the centers of bogies	8.800m
Standard size of rake	60
Total train load (spec. by RDSO, excl. tolerance, incl. BVZC)	4809.3 t
Total train load (CC+10+22, incl. BVZC)	5229.366 t
Revised Total train load (incl. tolerance, incl. BVZC)	5223.225 t
design speed : RDSO (loaded)	65(CC+10+22), 70 (CC)
design speed : RDSO (empty)	85(CC+10+202), 75 (CC)
sanctioned speed : CRS (loaded, SER)	65km/h
sanctioned speed : CRS (empty, SER)	85km/h

4.1 Blue Print data for prototype development Modified dimensions are introduced in newly developed blue print.

Most of data are as similar as Indian Railways standard.

Data is processed in further design, assembly, and analysis and testing for prototype.

Modifications are made according to constraints used for new prototype development.

4.1.1 Design Work for Prototype development.

The gauge length between wheels is changed from 1670 mm

The dimensions of buffer front is modified.

New design of joint is proposed.

Some wagon components are extracted from design library and most of design and assembly are done by using wagon blue print data.

Major components are modified and introduced some new features (like alloy material, dimension change) to enhance lifecycle of wagon.

The design become comfortable for analyzing in virtual environment.

Assembly of components specifies some new guidelines in project work (based on our constraints and assumptions).

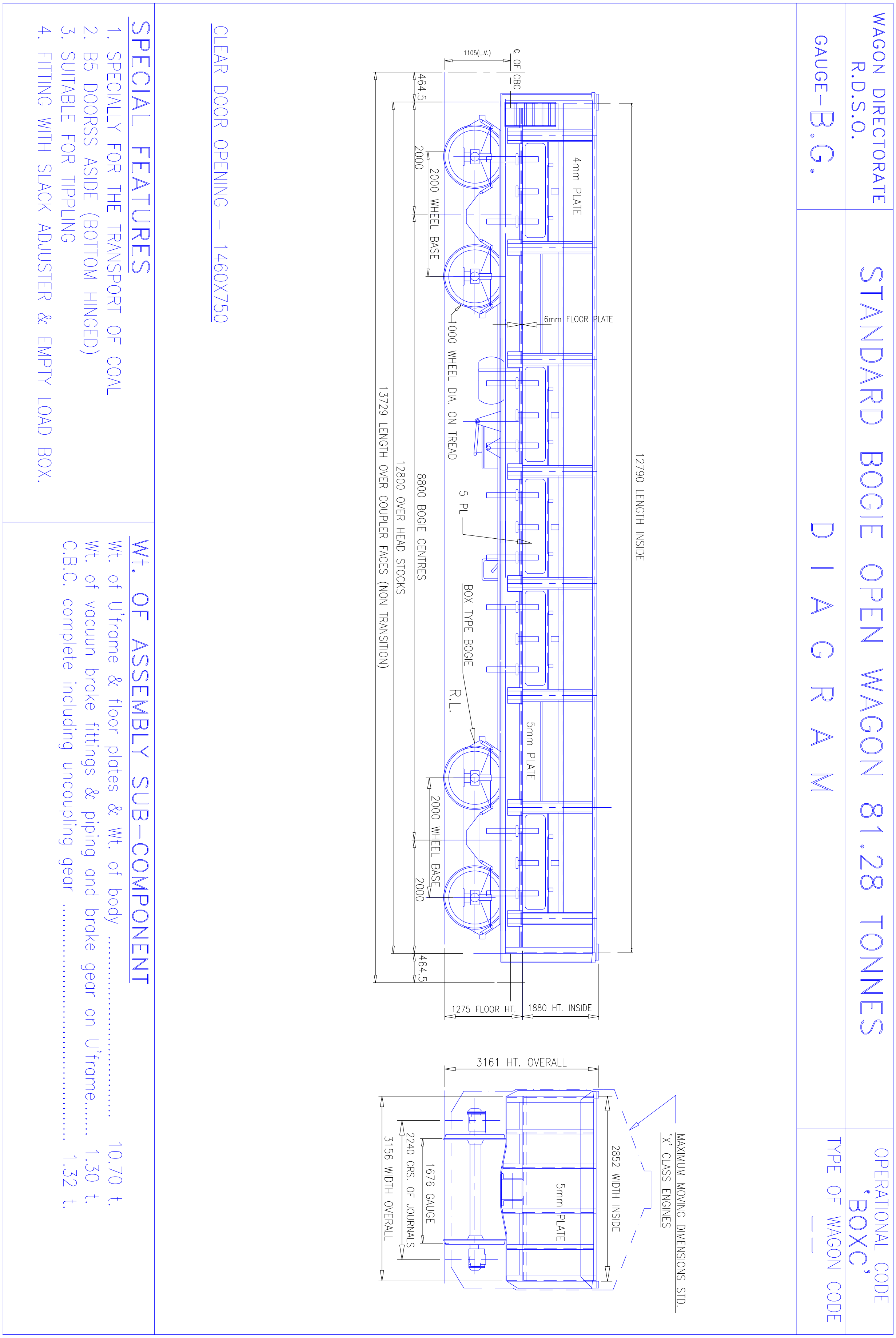


Fig 4.1 Standard bogie open wagon.

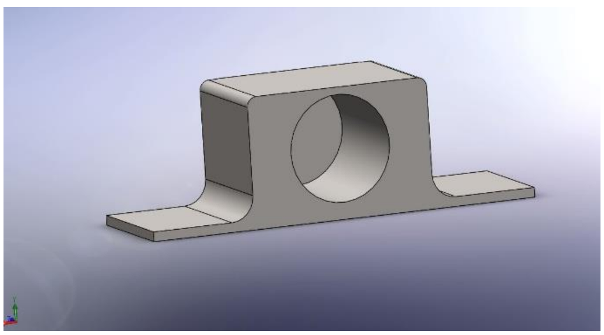
4.2 Proposed Tools:

These are the tools which are used for the Project.

Solid-works	: Design of parts and assembly
Ansys	: Analysis and stress-strain calculation
PTC Mathcad	: Calculation of loads on the components
Universal Mechanism	: Dynamic Testing of Freight wagon

4.3 Designing of Components

To simplify the assembly process for creation of freight wagon and preparation of frame models, it is required to design the components in solid works virtual software. due to this Design assembly enables and making accessibility the simulation of wagon frame system.



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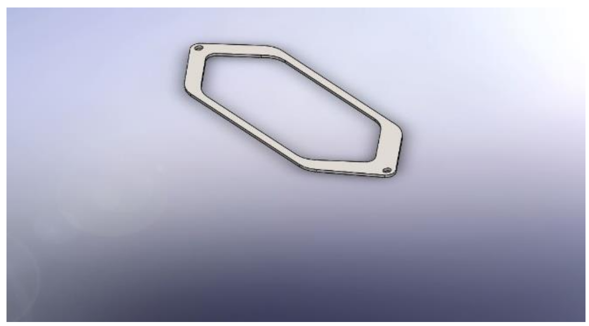

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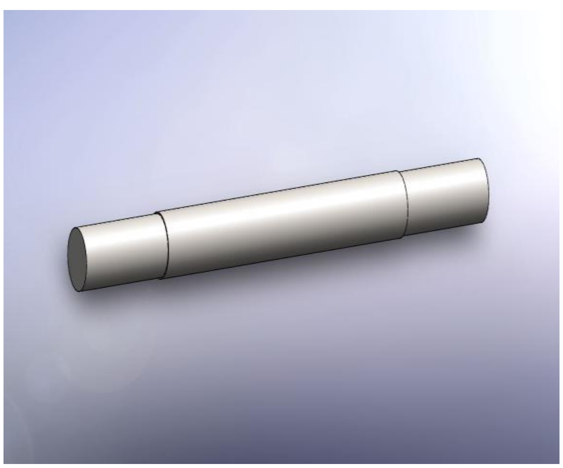

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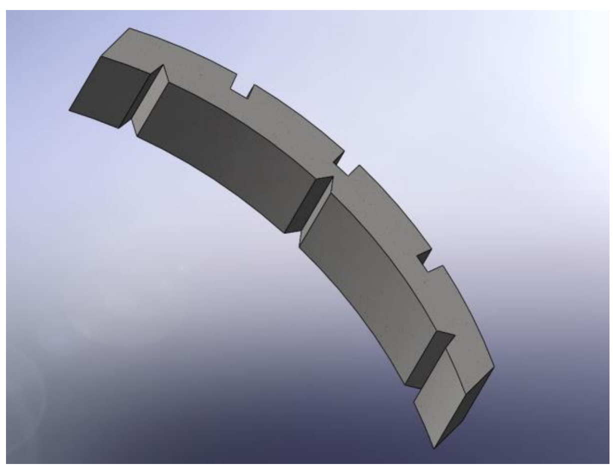

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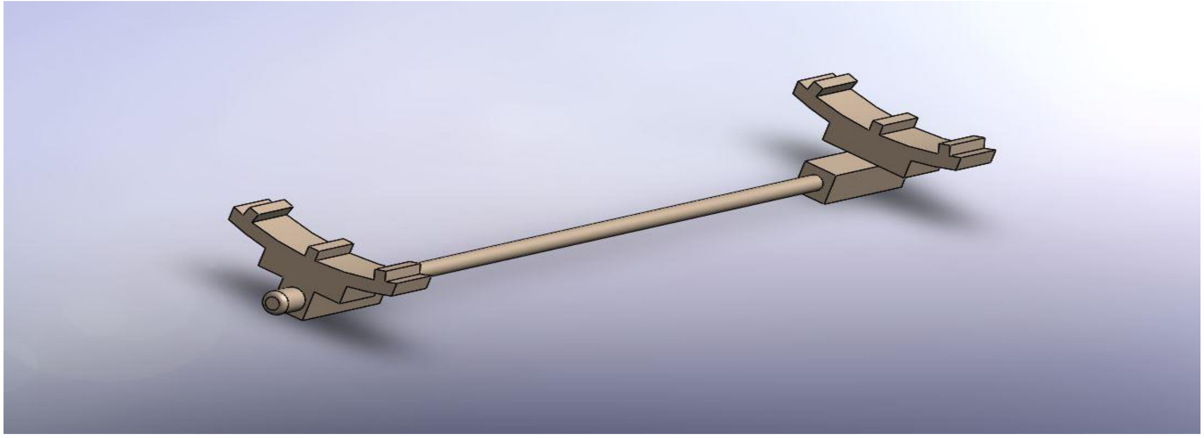

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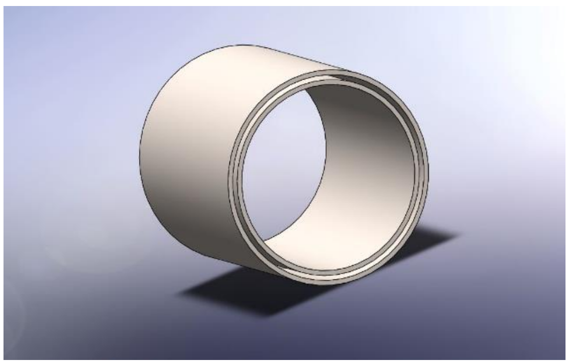

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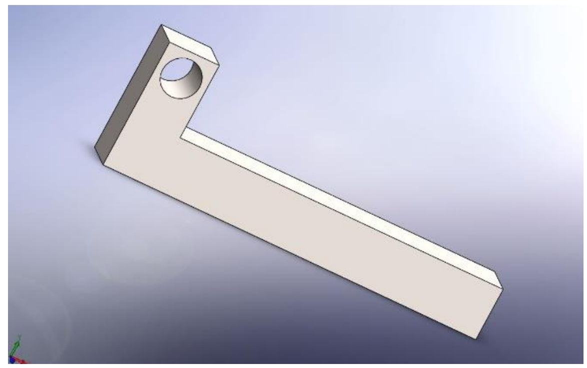

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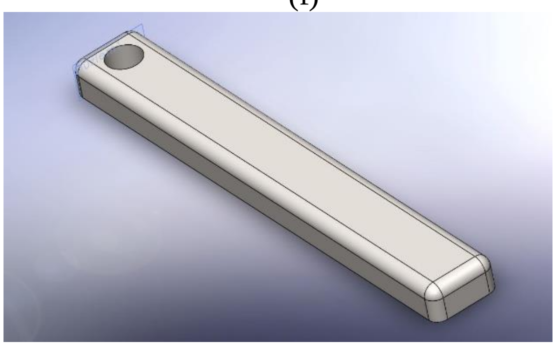

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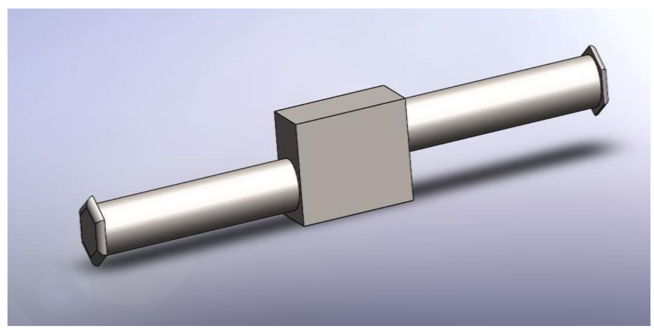

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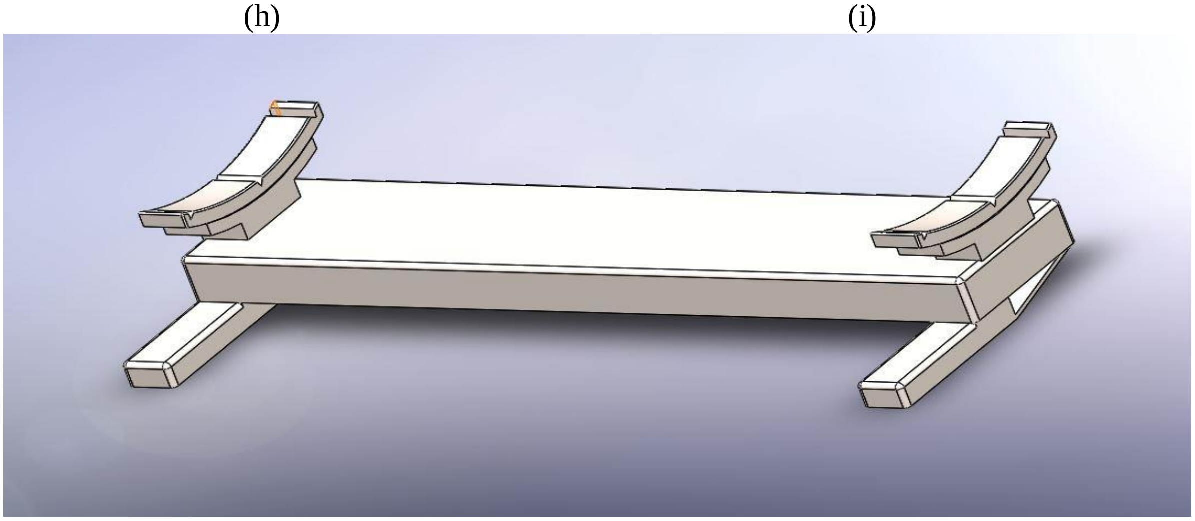

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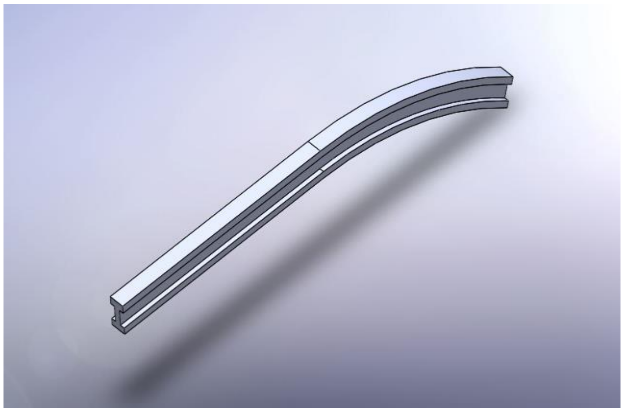
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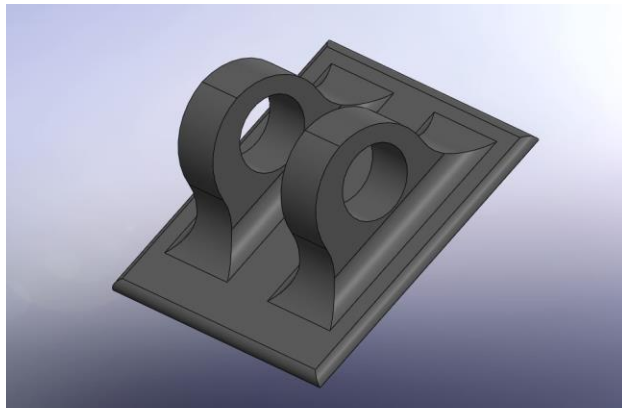
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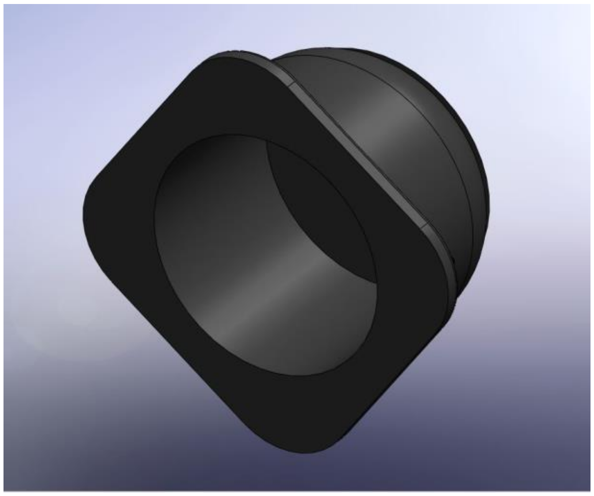
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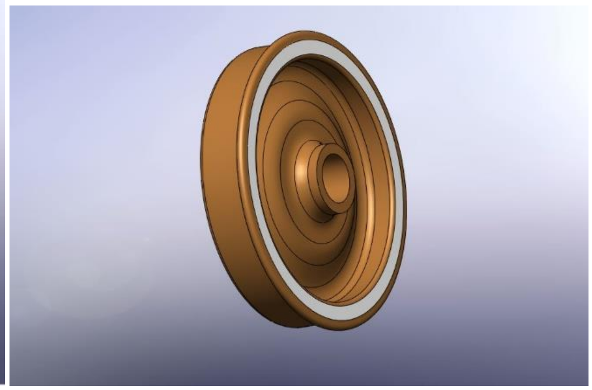
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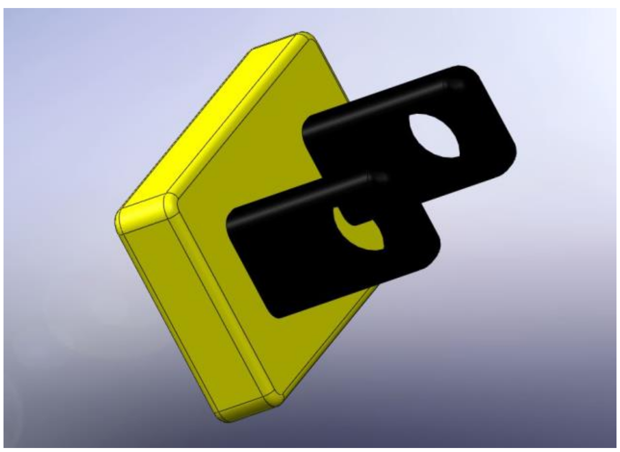
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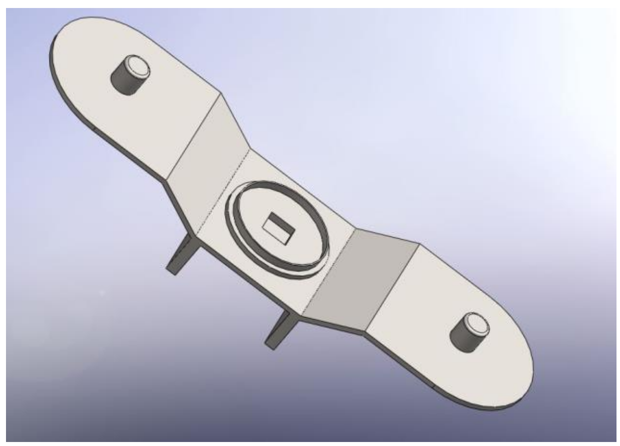
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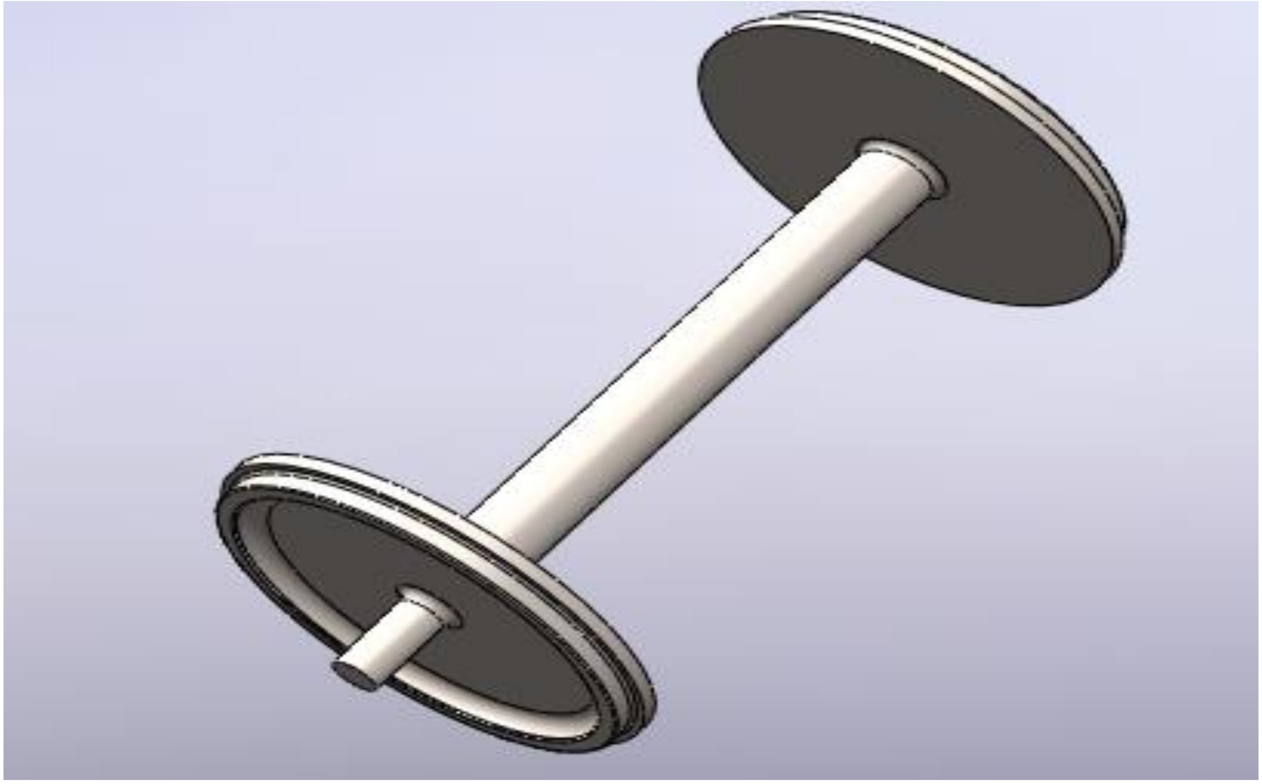

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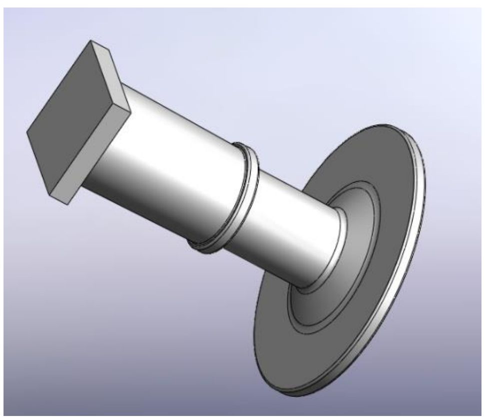

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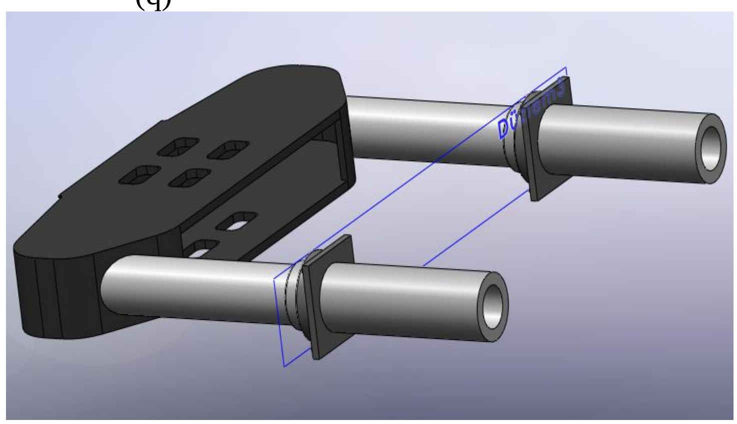

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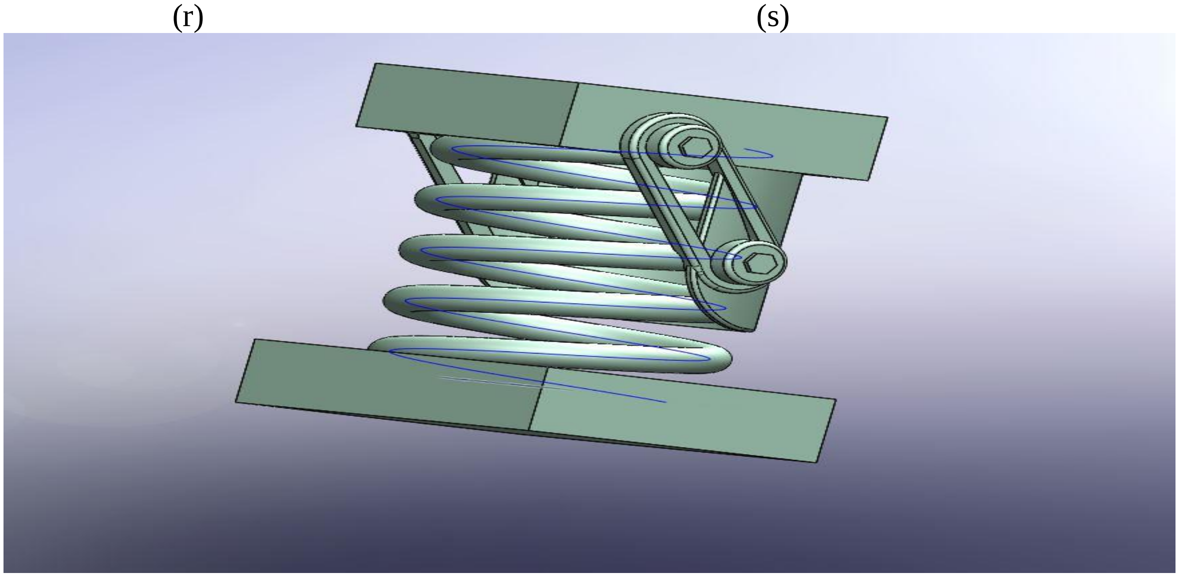

(t)

Fig.4.2 (a, b, c…..t) Components of Designed Prototype freight wagon.

4.3.1 Assembly of Frame components

After the designing of the freight bogie components, frame is to be modeled to support the compartment of wagon and balance the force static as well as dynamic forces in motion. By using the assembly feature the e-software the frame of model is designed.

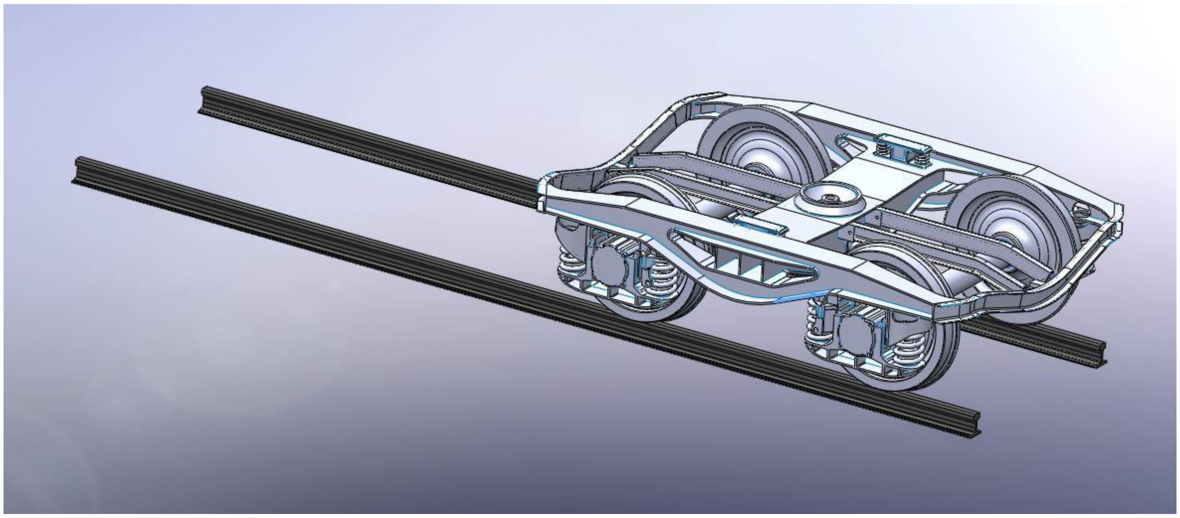

Fig. 4.3 Assembled view of frame for freight wagon.

4.3.2 Assembly of Freight wagon prototype

When designing of frame as well as compartment of wagon prototype has been done. the next step is to full development of freight wagon and for doing so, the similar process need to be carried out and the freight wagon assembled using the SolidWorks software the virtual view of wagon is shown below.

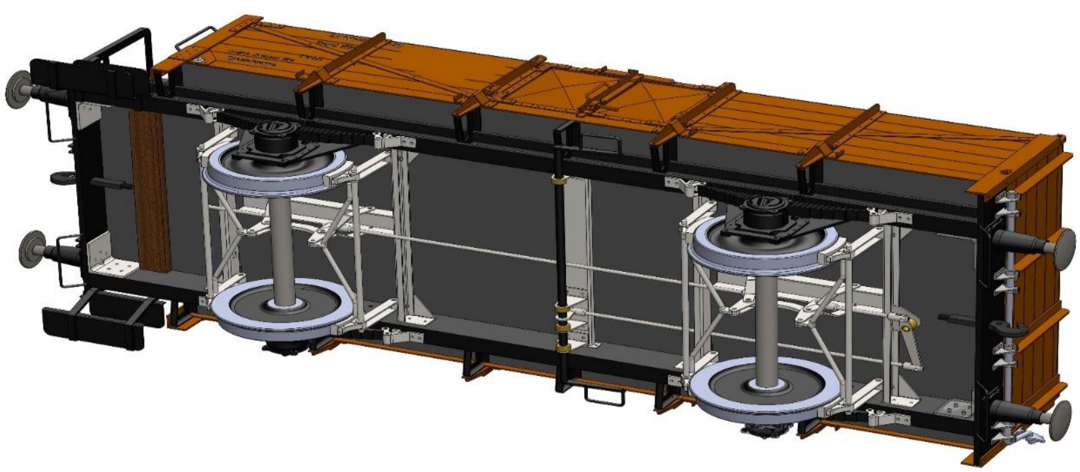

Fig. 4.4 Bottom view of virtual Freight wagon.

Fig.4.5 rear view of virtual Freight wagon.

Fig. 4.6 side view of virtual Freight wagon.

4.4 Assembling of railway wagon for analysis

The wagon assembly is created by using the solid works, universal mechanism and pro/e type of software. These are some of the most appropriate design ways for the preparation of blue-prints by assembly. As some wagons are unloaded by means of gravity and have no external assistance. It is necessary to fill rail road level for self-discharging bogies. Freight wagons can also unloaded by means of gravity without any other external assistance and also classified as self-discharging (SDB) type of wagons. The majority type of wagon may be filled by similar principle, when these are at the road or rail level, by high- level discharge chutes (whose ends are more than 70 cm above the top of the rails) or conveyor belts. Because a controlled amount of the load can be discharged at any place the wagons may be sent anywhere and are even used individually. Railway companies also use freights as departmental wagons in maintenance of way trains for ballasting the track.

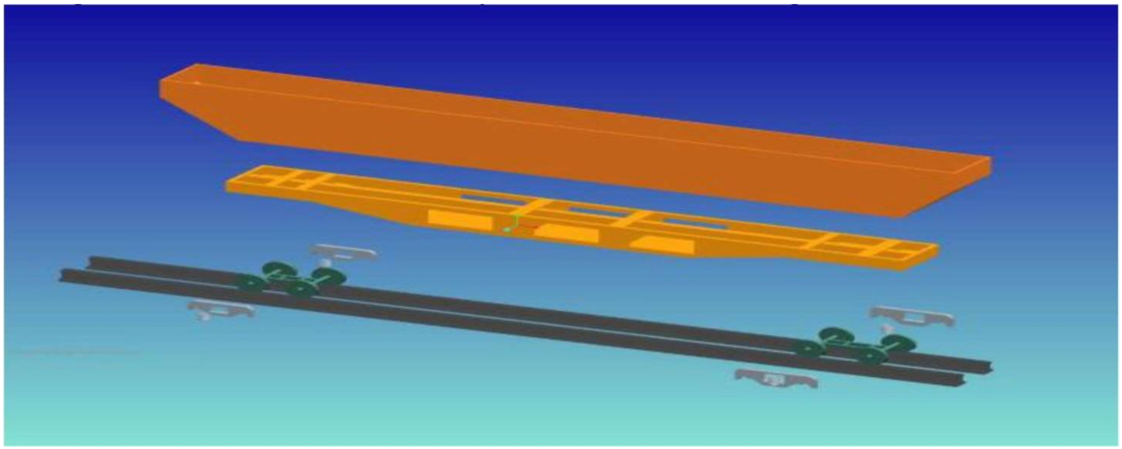

Fig 4.7 wagon components assembly

4.5 Mechanism of Suspension

Locomotive and freight wagons are fitted with double acting suspension system which are primary suspension mechanism and secondary suspension systems. The primary provides suspension between bogie chassis and axles. Also, the secondary suspension mechanism provides suspension between the coach and bogie chassis.

4.6 The Supporting Elements on Bogie

The axle is a bogie element which holds the two wheels on each end and carries the weight to transfers the torque to the wagon wheels. Its bearings carry the weight of freight wagon and transfer it to journals.

General functions of the wheel system are:

taking the power from the traction motor and transfer,
taking the brake power on itself and making the train stop,
making another shaft to turn the alternator,
transferring the weight of the locomotive to the railroads equally,
reducing the friction and rolling resistances via bearings,
preventing the locomotive to derail via wheel flanges,
damping and transferring the vertical, horizontal,
complex vibrations from railroad to the chassis of the bogie,
damping and transferring the dynamic vertical,
horizontal and complex forces from railroad to the chassis of the bogie while transferring the weight of the bogie to the railroad.

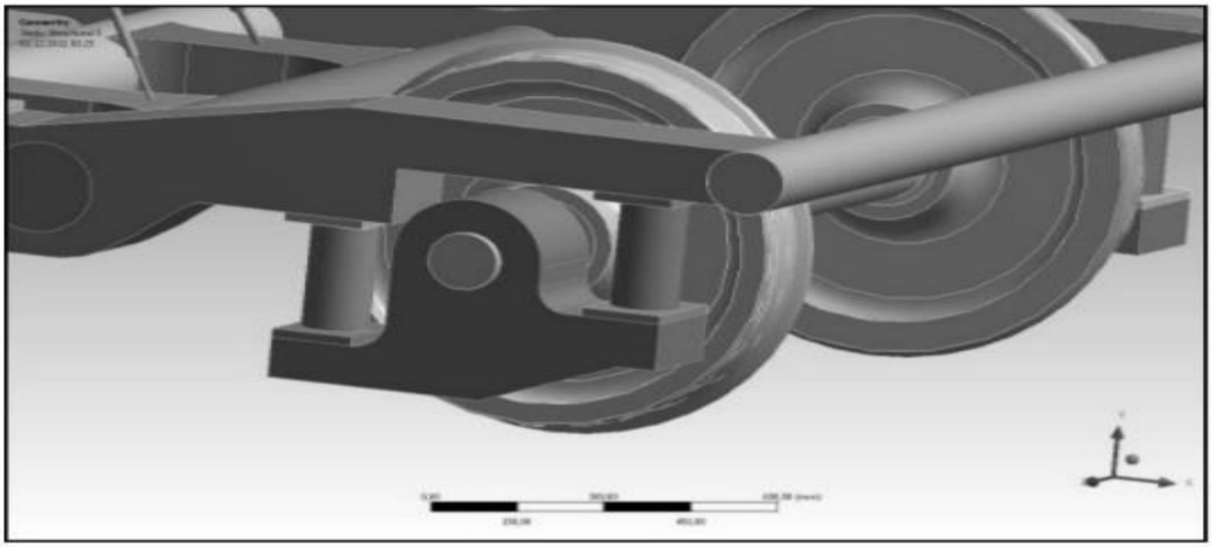

Fig. 4.8 suspension system of wagon

4.7 Bogie Model for Analysis

In the present Prototype development system, the vertical damper are also same as the chevrons. These elements are designed to act as a damper of layers. This structure acts as a vertical damper as well and shows high rigidity horizontally. The characteristic of this type of element's rigidity is non-linear. These elements are used in the primary and the secondary suspension mechanisms. There are dampers are used against pitch and roll movements. These dampers are viscous in nature. In the primary suspension mechanism helical springs are used on the other side in secondary suspension mechanism air springs are preferred.

5

Analysis and Simulation of Wagon

This work is mainly focused on steel and aluminum material, which is analyzed dynamically and statically. Most of this part is done by using PTC Mathcad and Ansys analysis. [2]
The followed steps are:

1. Extraction of design assembly
2. Assigning boundary conditions
3. Define Material properties
4. Load and stress analysis
5. Fatigue life cycle study
6. Simulation of component

5.1 Analysis Procedure

In present work, freight wagon can be made of different Materials like steel and aluminum analyzed by

a. **Dynamic Analysis**
b. **Static Analysis**

The step followed is as under:

1. Modeling
2. Assigning Material properties
3. Boundary Conditions

The material properties assigned for freight wagon are considered by density values.

Modeling: according to dimensions the model of freight wagon made up of steel and aluminum, The mass momentum of the car body, wheel axle set are been designed by using pro/e software and cad software . From the comparison of steel and aluminum material freight wagon alloy of these two gives the best result of having the liter weight, less stress acting are acting due to this the train is going to move in the safe way.

Table 5.1 Load analysis table.

Parameters	Aluminum (unit)	Steel (unit)
Modulus of Elasticity	$7.01e^{-10}(N/m^2)$	$2.741e^{-11}(N/m^2)$
Density	$2693.5(kg/m^3)$	$8012.2(kg/m^3)$
Stress on Yield	$4.92e^{8}(N/m^2)$	$4.21e^{8}(N/m^2)$
Modulus of shear	$2.32\ e^{10}(N/m^2)$	$8.329e^{10}(N/m^2)$
Endurance limit	0.51	0.39
Poisson’s Ratio	0.34(unit less)	2.33(unit less)
Strength	290(MPa)	290(MPa)

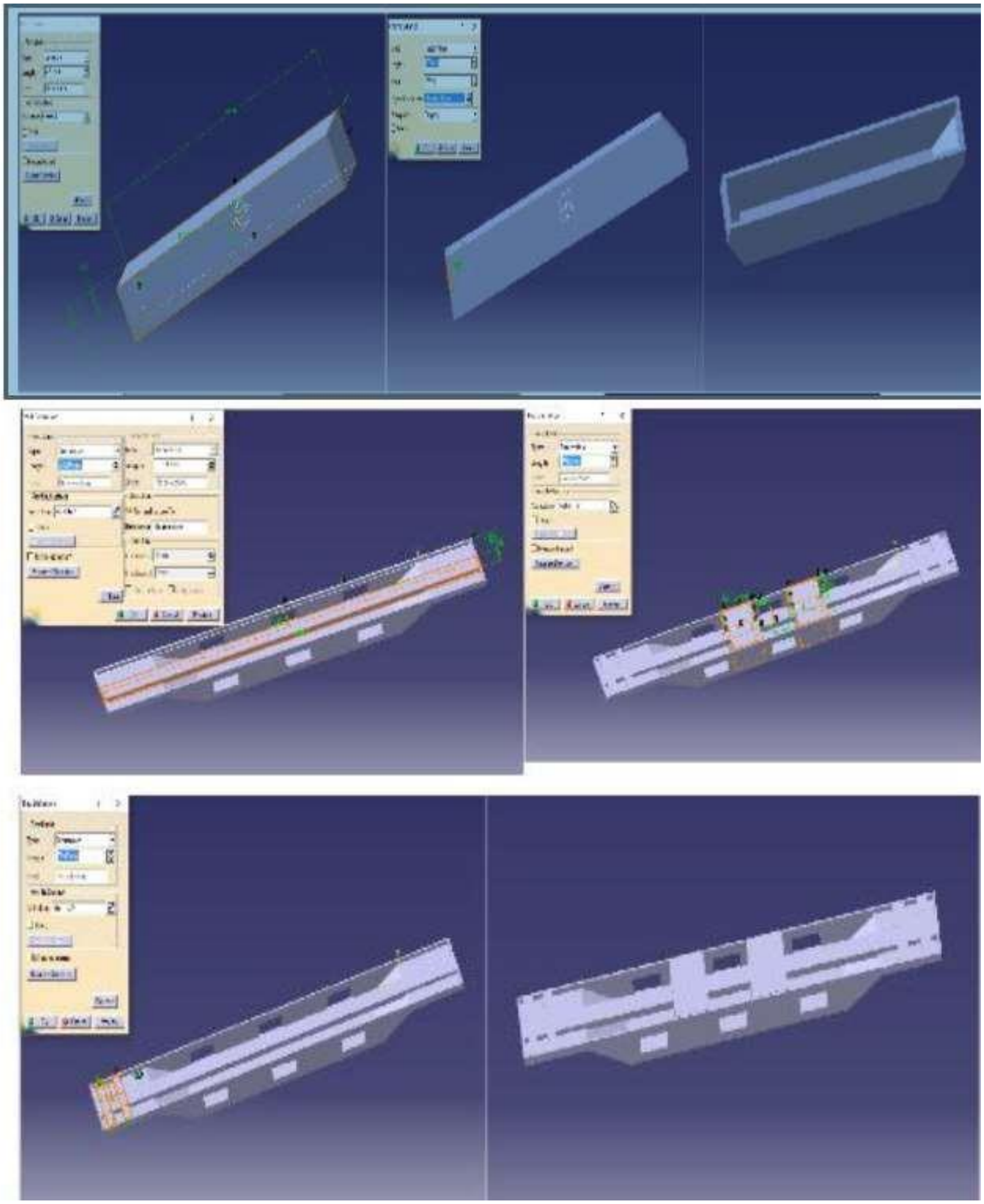

Fig 5.1 Software modeling of wagon

5.2 Force Calculation on each Surface

The forces acting on the wagon body depends upon the type of material, which is under consideration for transportation. Likewise,

a) Solid matter: Coal, Ferrous Material, Industrial Products etc.
b) Liquid matter: Milk, Petroleum, water etc.
c) Gases: CNG, LNG and other gases

Apart from these human beings are also under consideration for the analysis of the force. So, we refer Table 2. For the different material values which are to be analyzed for the pressure or force calculation on the wagon prototype. Here are given some values of respective matters for the 110 m3 volume of space.

Table 5.2. Loading Material Values

Product	Density	Mass=Density x Volume
Anthracite Coal	1490(kg/m^3)	163,900 kg
Water	1000(kg/m^3)	110,000 kg
Bituminous Coal	1354(kg/m^3)	148,940 kg
Ballast	1206(kg/m^3)	132,660 kg
CNG	0.87(kg/m^3)	95.7 kg
Lignite Coal	1287(kg/m^3)	141,570 kg

Force Calculation equation on each surface

$$F = ma \tag{1}$$

Based on the acceleration, the applicable forces on the prototype can be calculated and further simulation of the prototype proceeded for the optimum dimension of coaches. But simulation on prototype produces.

5.3 Analysis result on Materials

After performing the Ansys material simulation the following data is obtained.

Table 5.3. Material Loading Conditions

Material	Total Deformation	Stress	Strain
Aluminum	0.092691	0.52364	6.25e^{-6}
Aluminum Alloy	0.072325	0.49635	5.98e^{-6}
Alloy Steel	0.025964	0.54308	2.02e^{-6}
Steel	0.034602	0.56812	2.92e^{-6}

These are the materials which are used as body material of wagon. So, as we obtained that aluminum or its alloy can replace the steels in future and become an integral part material of wagons.

5.4 Load and Boundary Condition for wagon Prototype:

Heat treated wheels are used to improve the resistances of wear, and enables the compressive residual stress in upper rim of wheel for the mean to reduce the tendency of fatigue cracks and also includes tensile stress in axial direction, causes less impact of fracture with the thermal load.

Case 1: Structural Analysis of wagon

Static position of the hub is fixed to axle and total acting load on the wheel rim is to constrained so that there is no deflection occurs in the hub and restrains to the rigid body motion of wagon. And the total acting load on rim is to be applied as vertical and horizontal load applied on the wheel under the consideration.

Case 2: Thermal Analysis of wagon

The boundary conditions which are applied on the hub of the wheel set is considered at ambient temperature, the plate edges are subjected to the heat transfer as air is also in contact with outer body surface and edges of rim in contact with the rails of track undergoes the generation of due to friction. This flux of heat is calculated as,

The diameter of the wheel from the hub is 480.5mm.

The width of the rim that is in contact with the rail is approximately 98.04mm for the selected wheel.

Load acting on for wheels = 220/235KN = 22426.0958/23955.1478Kg.

Load acting on one wheel (m) = 5988.78695Kg

Velocity of the bogie (v) = 120KM/h = 33.33m/s.

Time the bogie brought to rest = 30s.
Kinetic energy generated at wheel = 0.5*m*v2 = 332643847 J.
Power generated = kinetic energy / time taken = 110881.282 W.
Area = π*diameter of wheel*width = 147994.838mm^2.
Heat flux generated = power generated / area = 0.203696454 W/mm^2

Case 3: Combined Loading Analysis of wagon

In this combined loading analysis both thermal as well as structural load are applied on wheel. To solve the static loading problem of loading and then thermal loads are applied as wagon load of body. Then combined loading condition problem is formed and to be solved.

Case 4: Analysis for wagon wheel

The wheel of wagon is re-profiled by considering a fillet on interface. The static, thermal and combined loading analyses were done on wheel obtained results are plotted on a graph between the displacements and fillet radius, as well as different stresses, by changing the fillet radius at the interface of wheel. The analysis has been done also for the changed wheel profile from the original profile, to an interface of fillet two analyses results are compared

5.5 Discussion on the results by Simulation

The analysis method of finite element model represents the prototyped freight wagon which is further coupled to a virtual environment. The wagon body is to be deformed in elastically influenced mode under sidewall along with frame. The modes for local deflections are being considered to influence the comfort zone level and stability of transportation material under the frequency of 28.95 Hz. hence with consideration of an upper frequency limit which is of of 28.95 Hz, for the Different modes of structure are identified and described in Table.

The excitation frequencies applied to the first model to the Eighth model frequency for the objects located within the maximum displacement zone of the side walls and may be caused for excitation in continuous manner. This type of swaying motion can be converted in the rolling action, that’s why affecting stability in the lateral direction. With a range of a frequency of 20 Hz the model is indicating five different types of mode shapes with dominant form in elastic deformations for Prototype wagon structure. The lowest frequency in this range is 4.63 Hz which is representing the first mode shape of the structure. This type of motion can be described as lateral in swaying of side walls or the lateral swaying can also be referred sometimes as distortion by diagonal since it mainly causes change in wagon body the diagonal length in cross-section.

Table 5.4. Frequency for mode shape

Mode Numbers	Frequency (in Hz)	Description of mode shape
8th	28.95	Lateral swaying and Rolling to longitudinal and central end.
7th	26.38	Breathing of Shell in longitudinal and lateral direction.
6th	22.61	Longitudinal and Torsion of diagonal distortion.
5th	16.87	Lateral swaying and Rolling at central length.
4th	15.42	Shell breathing with rear and front wall swaying.
3rd	11.25	Lateral swaying and Torsion of side wall.

2nd	8.19	Breathing of Shell in lateral directions.
1st	4.63	Lateral swaying of side wall.

By changing the frequency of next modal becomes fractionally greater than the previous one, but the dynamic behavior of prototype is changed very drastically by side wall swaying in the lateral direction. For the mode shape we may say that the side walls would be out of the phase to vibrate and the objects which are in maximum displacement region of side wall, which will also be sway under frequencies influence, which is equivalent to the value of shape mode.

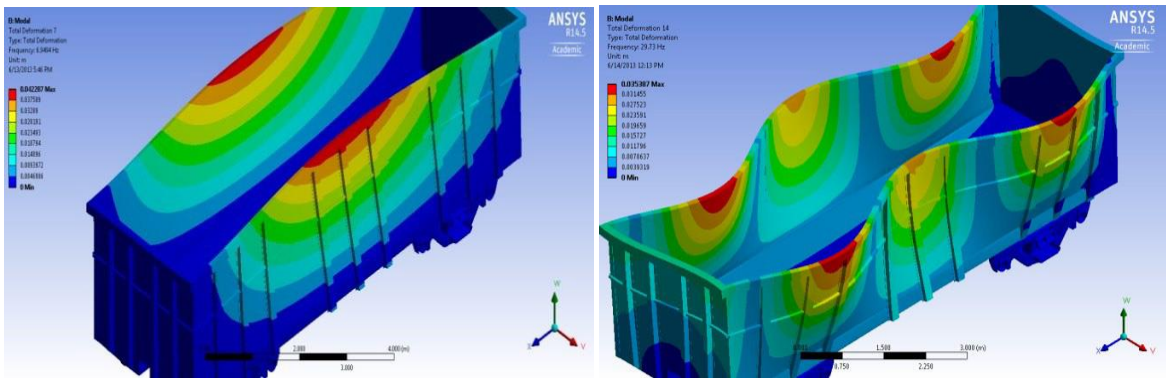

Fig. 5.2. Flexural mode effect of vibration.

5.6 The Strength analysis

It is the next step of the body of the considered freight wagon the assumed load of the model was applied on the wagon. The structural design depend on loads and characteristics of the materials used in manufacturing to provide a uniform basis for structural design within the Standard. In addition, the elastic deformation seen during the test loading of the freight wagon.

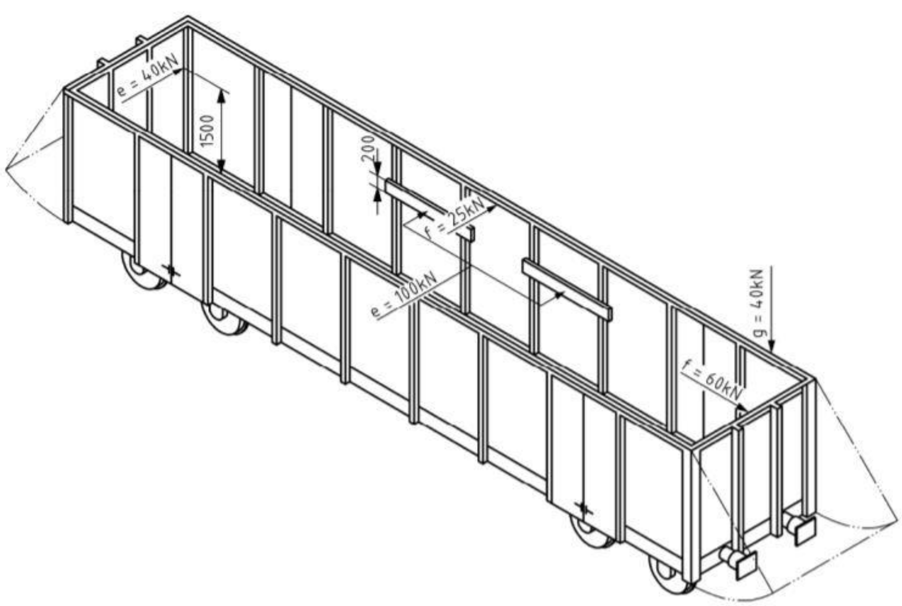

Fig. 5.3 freight wagon under application of forces.

Maximum displacement value was occurred on the upper beam side. Average stress in strength analysis is obtained 55-75 MPa and yield strength is 245 MPa. The analysis support frame was carried out two times.

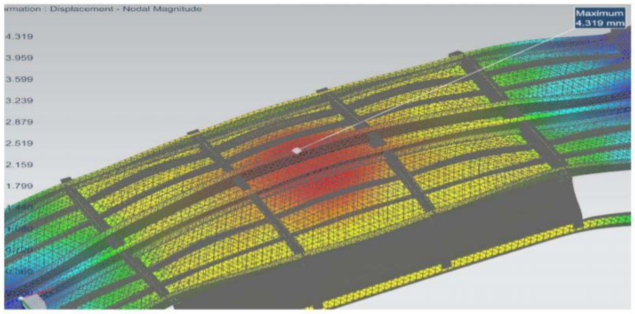

Figure 5.4 freight wagon's Displacement

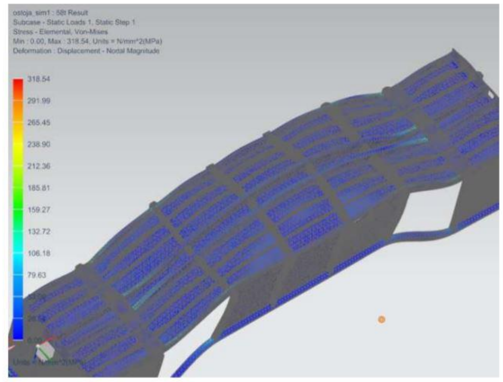

Figure 5.5 freight wagon's support frame Stress

In the first case only the UDL (uniformly distributed load) was taken into consideration, while in the second case also compressive force on axis of bumpers was applied. and the results for strength analysis is to be find out for the works, while tests on the Prototype object carried out to get the values of displacement as well as stresses.

6

Material Research and Balancing of Track

Balancing of track and ultrasonic Testing Track geometry is 3D in construction and layout of track may be straight or curvature in nature. A variety of gauge systems are available based on the track geometry and expressed in terms of separate layouts as Horizontal layout and vertical layout. A reference rail line is the base point for measurement. Balancing of track achieved when train speed and track support amount are in balance. Which justifies the equilibrium of Centrifugal forces with centripetal force. And rail wheel force normal to track plane have same for inside and outside rail. Our study focuses on rail inspection by automated ultrasonic testing method, where Track failures can be easily identified and detect the surface as well as internal defects by ultrasonic defectoscopy, on different angles several transducers are provided to enable detection of defects at different orientations. And graphical record of inspection displayed on monitor. [3]

6.1 Load Calculations for balancing of track

During design stage, possible loads are regularized by a design code. For the present axle, the loads are applied. As shown as in Fig., the loads set is constructed from the vehicle dynamic behavior of the mass m_1 above each wheelset with a vertical dynamic factor α_v and a lateral dynamic factor α_H, which are respectively defined as

$$\begin{cases} V = (1+\alpha_v)m_1 g \\ H = \alpha_H m_1 g \end{cases}$$

where g is gravity acceleration, and the mass m_1 can be deduced as

$$m_1 = (2P - m_2 g)/g$$

Using the sample wagon parameters, the loads set for the present check of axle reliability is given:

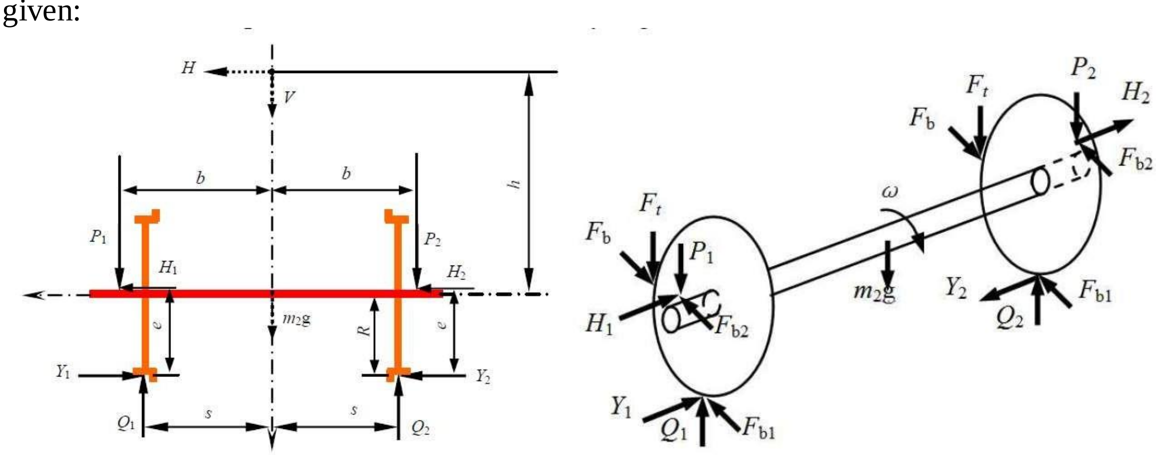

Fig 6.1 Force Effect on wheels

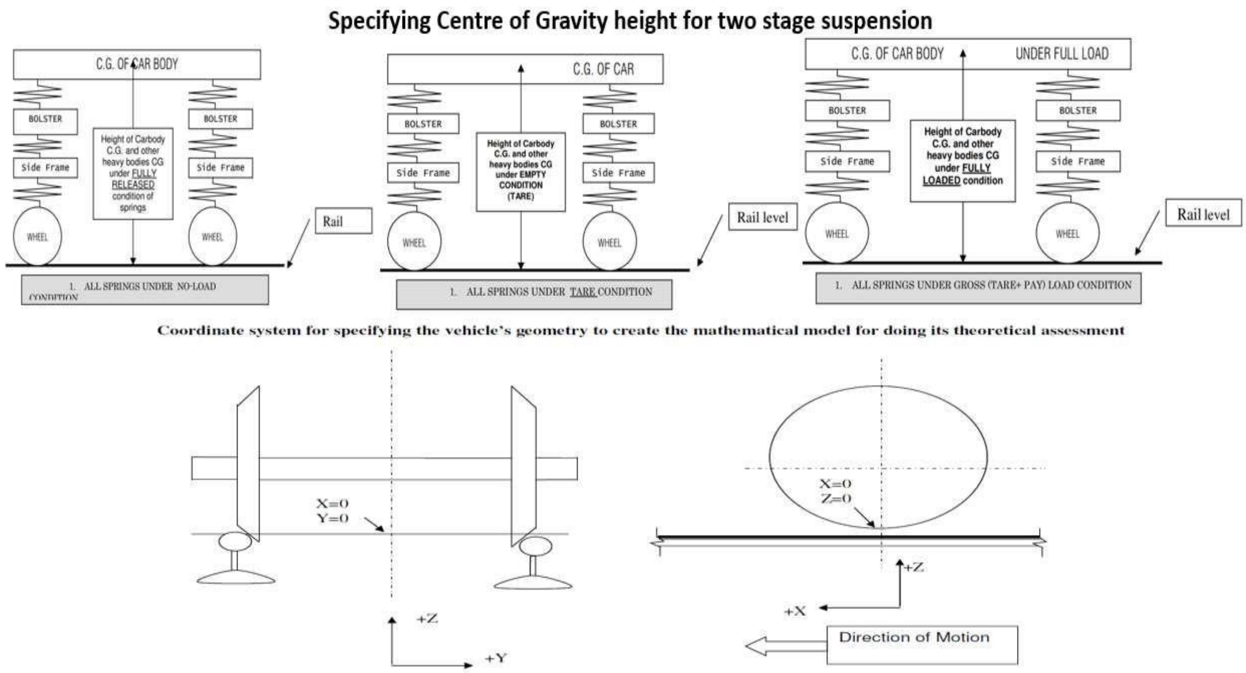

Fig 6.2 Arrangement of wheels on track

6.2 Calculations of loads for track balancing

Finite element Ansys software is used for strength analyses which allows to create virtual models of structures, system components of whole machine, by applying load and other design criteria to study physical responses such as pressure, stress levels, deformations, etc.

A process step of the model frame computer analysis needed to perform for successful calculation. We can it describe as follows:

- Creation of a CAD model of the considered body, appropriate model files generation.
- Setting up a FEM model in Ansys.
- Model - generation to define these parameters of material model:
- Material was considered homogenous, isotropic, linear and elastic.
- Mechanical properties - Young's modulus of elasticity and other material properties.

Table 6.1. Model frame load calculation

Load	Calculated Value [kN]
F_Y	393.14
F_{YPmax}	774.98
F_{Y1max}	171.52
F_{YP}	402.67
F_{Z1max}	96.55
F_{X1max}	42.13

As mentioned above, it was focused on four most load combination cases. These load combinations are in the standard described values which practically represent combinations of loads on points of application and directions of the individual load.

Table 6.2. Load combination calculation

Load case	F_{YPmax} [kN]	F_{YP} [kN]	F_{Y1max} [kN]	F_{Z1max} [kN]	F_{X1max} [kN]
1st	774.98	0	0	0	0
2nd	0	402.67	171.52	0	0
3rd	0	402.67	171.52	96.55	0
4th	0	402.67	171.52	0	42.13

From strength numerical analyses of modified freight wagon frame under four loading cases, We have calculated stresses according to forces. The frame structure is stable, if in all load cases evaluated stresses are less than the yield stress of the used material.
This would indicate, that the frame structure in this region is at the limit of acceptability. But we have to consider important facts.

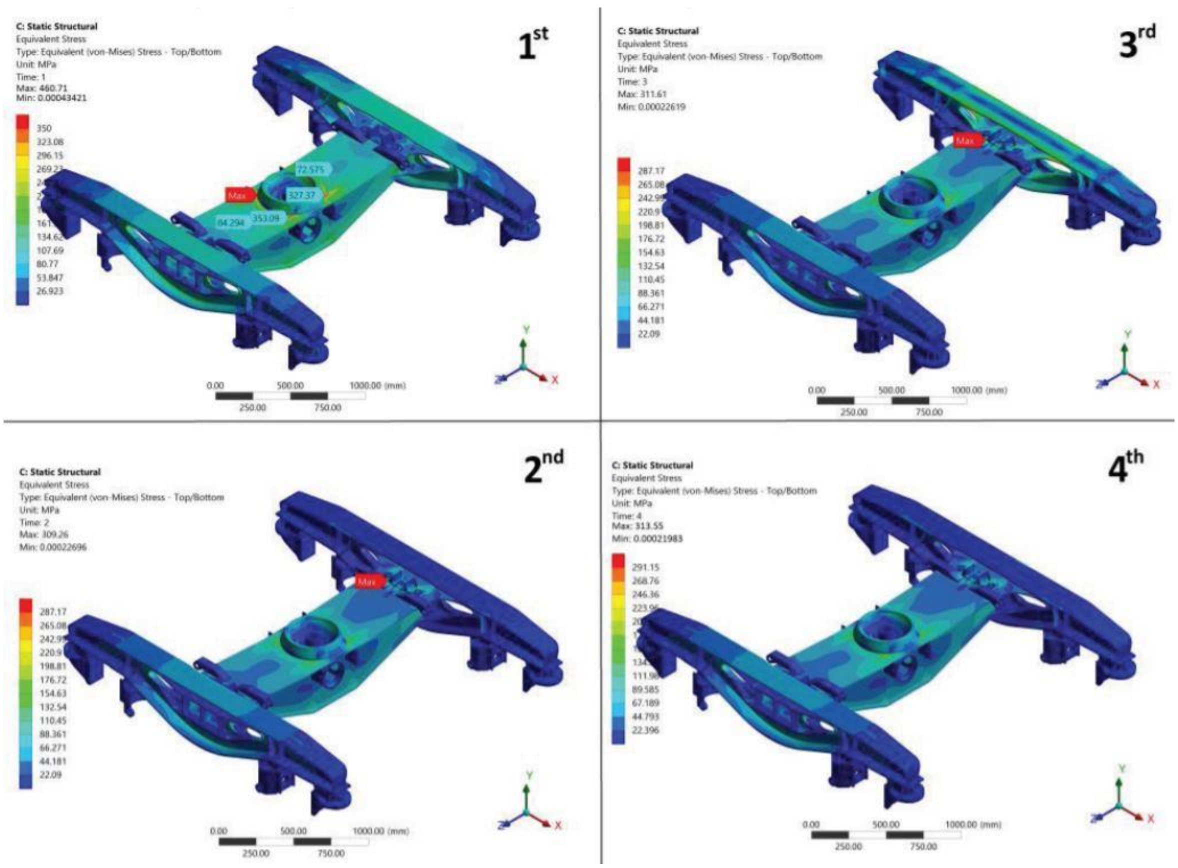

Fig. 6.3 strength analyses of wagon frame

The pivot in the center is made up of steel with higher of the yield stresses, therefore in this particular part the minimal of the yield stress is validated. Moreover during the evaluations variants of Finite Element meshing size are used for comparison. And based on the obtained results we have found out that extreme values is caused by calculation errors. Other values are in lower range and under given limits. In the other exceptional loading cases the wagon frame was loaded by forces in central pivot and acting on one side. It is below the yield stresses.
In the modification, we will research the mechanical properties of materials and the virtual dynamic behavior of entirely modified prototype. We will also create a mechanical virtual system of a wagon frame in a multibody analysis software to analyze the finite element software model, which will serve as input for setting up a combined multibody system with

a flexible wagon body in order to study its dynamic and static properties to compare with the original model for the detection of problems in long-term operation.

6.3 Software analysis of the wagon frame

The prototype properties have significantly influence on the vehicles of mechanical systems for the dynamic behavior Prediction. We can also theoretically predict the prototype movement of the wheelset on an improved railway track geometry by means of the track and wheelset geometric characteristics analysis.

The Geometric characteristics defines the rail profiles for wheel contact to couple geometrical relationship. The contact couple shape crucial influences the contact patch size and the contact stresses between rail value and wheelset. This creates the loading forces and excitation forces acting inside the vehicle body and systems of track. The analysis for dynamics of the mechanical systems can be analysed by using the various methods.

The analysed wagon frame is component of prototype freight wagon. According to standard values this bogie may belongs the category of Freight bogies with a pivot and the two side bearers. This bogie wagon frame is analysed in such a way that it must be proceeded in accordance to valid standards. From the boundary conditions and definition of the bogie frame load.

6.3.1 Bogie frame load definition

Total weight of proposed wagon m = 8.56 t,

Wheelbase of wheel set dia. b = 1.8 m.

The model of freight wagon is determined with a total weight of MW = 81.28 t.

If the wagon bogie frame is loaded in the vertical direction of force.

So for in the vertical direction the exceptional load value is given by the formulas: -

If vertical forces act only in the center pivot:

$$F_{YPmax} = 2X(F_Y)$$

If vertical forces will act in the central pivot on one side bearer:

$$F_{Y1max}\,(\text{or } F_{Y2max}) = 1.5\,.\,F_{Y}\,.\,\alpha$$

$$F_{YP} = 1.5\,.\,F_Y\,(1-\alpha)$$

where F_Y is equal to the total vertical load applied by the bogie frame, FYP is the overall vertical force, which will acts in the central pivot, F_{Y1} and F_{Y2} are the two vertical forces acted on the side bearers, where α is coefficient for wagon body in swinging. In this case we already have considered with a value of $\alpha = 0.341$. For this a lateral force by the exceptional load acting on every wheelset, wherever it is applied by following:

$$F_{Z1max} = F_{Z2max} = \frac{FZmax}{2} = 10^4 = \frac{FY+m.g}{6} \qquad (6)$$

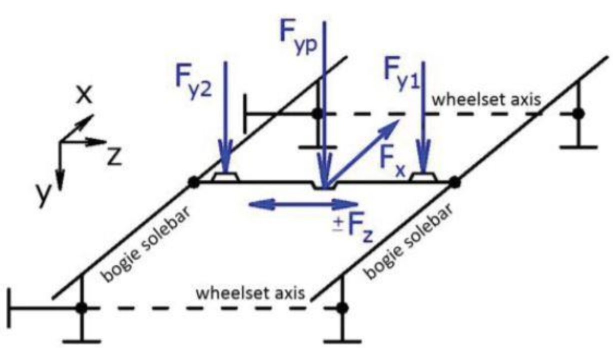

Fig. 6.4 Wheelset forces in Point load applications.

The involved load in this case of wagon creates impact to enables the possibility of substitute for the longitudinal force of static mode acting on system, where the equipment is to be connected to the bogie. The value can be determined from the mass of each and every individual elements and the maximum acceleration is to be acting on them during the wagon impact.

6.4 Vehicle vibration modes for model analysis

The Frequency analysis of freight wagon is consists of two major type of analyses in this domain; that is the spectral density and eigenvalue analysis. in the consideration for characteristics of wagon bodies and frame elements which are used in the track formation and vehicle parameters, Likewise stiffness, mass, density and damping factor, For this the analysis of eigenvalue is more appropriate. So, natural frequencies can be analyzed from the analysis and stability investigation of the vehicle by natural frequencies. Also, it helps in detection of the Eigen modes. Therefore, user find that the sensitive resonance frequencies of model wagon vehicle elements. Since linearized system is used for eigenvalue analysis non-linear relations in virtual dynamic system behavior for simplification by using the linearization method.

Following assumptions required during mode shapes evaluation for freight wagon:

Linearly elastic behavior of material in nature.
There is no non-linearity.
The theory of Small deflection can be used, damping need not to be included, it is assumed that there is no possibility of the structure excitation.
The wagon structure type can be either constrained in type or unconstrained in type.
The mode of shapes are not being the absolute but have therelative values.
Time variation in unknown nodal displacements.

6.5 Material Research

Aluminum and steel are compared for wagon material for the analysis of static-dynamic analysis and stress values corresponds to load. As seen that equivalent longitudinal creep and lateral creep on track curve are tangent. [1] Further normal force and vertical force effect for both steel and aluminum for different components of bogie is analyzed. Other properties are also under consideration i.e. corrosive strength, wear resistance etc. which affects the dynamic strength of material.

After performing the Ansys material simulation the following data is obtained.

Table 6.3 Material Loading Conditions

Material	Total Deformation	Stress	Strain
Aluminum	0.092691	0.52364	$6.25e^{-6}$
Aluminum Alloy	0.072325	0.49635	$5.98e^{-6}$
Alloy Steel	0.25964	0.54308	$2.02e^{-6}$
Steel	0.034602	056212	$2.92e^{-6}$

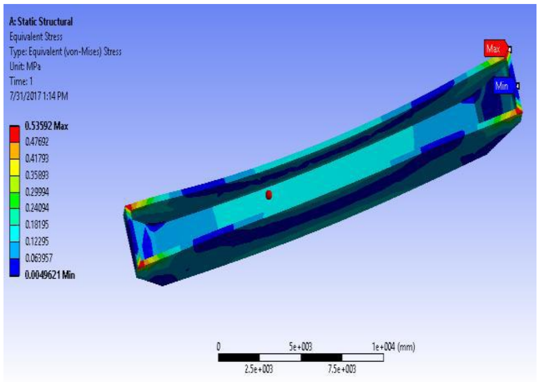

Fig. 6.5 Aluminum

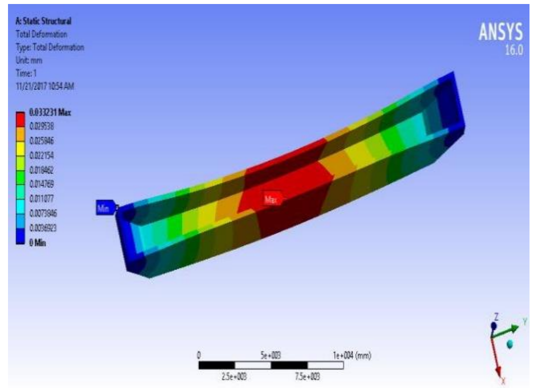

Fig.6.6 Steel

Table 6.4 Analysis of material properties

	Total Deformation	Strain	Stress
Steel	0.033231	2.8441E-6	0.55239
Aluminium	0.093499	7.8114E-6	0.53592

6.5.1 Calculation of Pressure on each surface:

Let's considering lignite coal,

Coal Density = 1290 Kg/m^3

Volume = 110 m^3

$$\text{Mass} = \frac{141900}{110}\ \text{Kg}$$

F= ma= 14190 x 9.81 = 139203.9 N

So, Total force = 139203.9 N

6.6. Future Works criteria

Whenever we need to increase the load carrying capacity of the freight wagons and also need to reduce the self-weight of freight wagon because of reducing fuel requirement, therefore increasing speed of the train in curve type of passing a tangent like track and, to increase safety along with comfort zone of passenger inside the coach.

1) Application of Change in material of freight wagon from steel alloys to aluminium alloys
2) Current type of two axle type of bogie can be replaced with the three axle type of bogie to carry more amount of load,
3) Comparison can be made based on the virtual dynamic software prototyping and its accuracy etc.

CONCLUSION

Based on the Design, simulation, testing and material research the following conclusions can be drawn based on the study of wagon.

Modeling Purpose: according to model dimensions the freight wagon produced with the steel alloys and aluminum alloys, the wagon momentum for the bogie weight, set of wheel axle have been designed by by application of solid works software and is to the cad designing software. From the comparison based data of steel alloys and aluminum alloy materials for freight wagon, alloy of these two type of materials gives the optimum result of having the reduction in weight, stresses are acting less because of this the train of wagon is moving in the safe way of transportation.

Assembly Purpose: the assembly of wagon includes the meshing of most of the parts which are already modeled or designed from the used software of pro/e for this type of assembling the part further work onto the analysis. Here the wagon analysis for the two types dynamic analysis and static analysis. From the static analysis part of view the maximum stress value comparing von-mises yield stress of the material, factor of safety of material can be calculated. And for the dynamic analysis part of view lateral force values and vertical force values, lateral creep forces and longitudinal creep forces, derailment quotient, coming on tangent to the curve track. from comparison based data of steel alloys along with aluminum alloys material for development in prototyping of freight wagon, the reduction in percentage for normal and vertical forces, lateral creep and longitudinal creep forces by applying the aluminum alloys material for the calculation of results, which are being achieved when aluminum alloy is used as wagon material, these % reduction of force values is reflected:

a) Vertical forces of wheel set are reduced by 8.32% whereas normal forces are reduced by 6.01%.

b) Longitudinal creep is reduced by 6.23 - 7.85% and lateral creep is reduced by 5.5 – 8.32%.

d) Reduction in longitudinal creep force is 5.99 to 7.65%

e) Reduction in wheel set normal force is 4.7 to 8.5%f) Fatigue strength less variability tends a longer component life and due to less fluctuation more reliable components are introduced.

So above results concluded that Aluminum alloy is more reliable and economical as wagon material as compared to steel.

ECONOMICAL FEASIBILITY

This method is completely in the favor of Prototyping economy; its components are designed by software and can be easily assembled. By using this method we can save time and part of money in field of wagon prototyping.

Present Conflicts:

By using this process, a real time analysis of prototype is to be find which reflects the optimized environment for analysis and according to that the Prototype can be developed at the minimum of cost and time.

Future Scope:

It is a wide field of work and finding solution for lot of challenges of transport model. Many types of commodities are transported by wagons, trailers and containers, which are need to be optimized and implemented by new design prototype analysis. Because analysis by virtual software is provide more accurate data and requirement of real environment feasibility of prototype can be fulfilled.

By the aim to increase the load carrying and transporting capacity of the freight types of wagons, as well also self-weight reduction of the developed wagon will help in reduction of fuel requirements,

If increase the trains speed on the tangent track or in the curve type of passing with consideration of increasing the comfort level and safety of the travelling passenger inside the coach.

So by Application of this type of method for the various types of wagons can be analyzed in virtual software with optimum type of prototype development conditions.

IR CODES & SPECIFICATIOS

Gauge code

- N: (prefix) NG
- M: (prefix) MG

Wagon type code

- V: Brake/parcel van (see above for brake van codes)
- B: (prefix) Bogie wagon (sometimes omitted)
- O: Open wagon (gondola)
- BV: Brake Van
- C: Covered wagon (boxcar)
- F: Flat car
- FK: Flat car for container transport
- LB: Low flat car with low buffer height
- LA: Low flat car with standard buffer height
- FU: Well wagon
- R: Rail-carrying wagon
- LAB: Low flat car, one end with low buffers, the other with high buffers
- K: Open wagon: ballast / material / refuse transport (older wagons)
- T: Tanker (additional letters indicate material carried)
- C: Centre discharge
- U: Well wagon
- R: Rapid(forced) discharge, bottom discharge
- S: Side discharge
- H: Heavy load
- X: Both centre and side discharge
- Y: Low sided
- X: (also?) High sided

Coupler, brake, and other suffixes:

- C = Centre buffer coupler (CBC)
- N = Air-braked
- R = Screw coupling only
- M = (suffix) Military
- T = Transition coupler (CBC with additional side buffers and screw coupling)

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Conferences and Publication details

Conference: International Conference of Advance Research and Innovation

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Paper-1

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No. of pages: 8

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Paper Link: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3566682

Title: Design, Analysis and Prototype Development of Railway Coaches for Different Loading Conditions and Optimum Dimensions in Consideration with Balancing of Track

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