Design and Validation of Test Rig for Freight and Road Transport Container

A thesis Submitted in partial fulfillment of the requirements for the degree of

Master of Engineering in Automobile Engineering

Submitted by

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that the thesis entitled "**DESIGN AND VALIDATION OF TEST RIG FOR FREIGHT AND ROAD TRANSPORT CONTAINER**" contains literature survey and original research work by the undersigned candidate, as a part of his *MASTER OF ENGINEERING IN AUTOMOBILE ENGINEERING under the DEPARTMENT OF MECHANICAL ENGINNERING,* studies during academic session 2020-2022.

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CERTIFICATE OF APPROVAL

The foregoing thesis, entitled "**DESIGN AND VALIDATION OF TEST RIG FOR FREIGHT AND ROAD TRANSPORT CONTAINER**" is hereby approved as a creditable study in the area of Automobile Engineering carried out and presented by **AJAHAR JAMADAR** in a satisfactory manner to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is notified to be understood that by this approval, the undersigned do not necessarily endorse or approve any statement made, opinion expressed and conclusion drawn therein but approve the thesis only for the purpose for which it has been submitted.

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1. Introduction: -

Freight and road transportation of a wide range of products necessitates the use of numerous different types of freight cars. Both standard cars (such as covered wagons, semi-wagons, and platforms) and customized cars are used for the transportation of cargo (fitting platforms, transporters, dump carts, and others). Specialized automobiles can transport one or more groups of commodities that are comparable in their properties thanks to a specific structure that makes transportation more affordable. All factors that influence the overall cost of cargo delivery must be taken into account due to the competitive nature of the transportation services market. The shift to such economical and progressive constructions that satisfy the current demands of the transport services industry is therefore the most crucial direction in the development of railroad car building.

Inland transportation, or the transfer of commodities by road, rail, and barge, is essential for international commerce and trade on a worldwide scale. Inland transportation is necessary for shipping, especially in the first and last miles, even though the majority of commodities may be moved by sea and some by air globally. For instance, trains and trucks transport merchandise from the port to the end destination of the importer or from the port to the warehouse of the exporter so that it can be loaded onto a ship. As a result, multimodal and intermodal transportation—a combination of two or more modes of transportation for the moving of cargo—includes the use of roads, rails, and barges as significant components.

For a nation like India, which has a sizable landmass and extensive road and rail networks, inland transportation is crucial. With 5.89 million miles of roads and one of the largest rail networks at 123,236 km, India has the second-largest road network in the world. It makes sense that, according to a 2018 government report, 59 percent of the total freight volume in the nation goes on highways and 35 percent by rail. 6 percent of freight volume is transported via waterways, including barge transportation.

The flat 40 feet meter gauge freight wagon is of the open kind. The flat freight wagon has two bogies and a flat body structure, and its flat surface is used to haul wood logs, containers, and other items.

A "flat wagon" is a term used to describe railroad goods wagons with a flat, often full-length deck (sometimes, two decks are used for automobile transports), little to no superstructure. Comparatively speaking, covered goods wagons have a fixed top and sides while open wagons have high side and end walls. Flat wagons are primarily made for the transportation of non-weather-sensitive cargo. Some flat wagons can be completely covered by tarpaulins or hoods, making them ideal for transporting items that are sensitive to the elements. Despite being a "goods wagon with opening roof," a flat's loading space is typically completely open and is only reachable by removing the cover.

The UIC divides flat wagons into two groups: regular goods wagons, denoted by category letters "K," "O," and "R," and special goods wagons, denoted by category letters "L," and "S." The primary distinction between regular and special varieties of flat wagons is that the former must always have a flat deck that can be driven on, whereas the latter typically do not. There are variations with separate axles and bogie wagons within both types of flat wagon. Flat wagons make up a significant fraction of goods wagons; for instance, in 1998 they made up 40% of the German carrier DB's whole fleet of goods wagons, the vast majority of which were flat wagons with bogies. Although they can typically carry the weight in two stacks, the current container/goods carrying flat wagons are only able to stack two 20-foot containers (6.1 m) or one 40-foot standard container (12.2 m) on top of another due to the limited vertical clearance (maximum moving dimension) set by the relevant railway authorities. Other typical goods that can be transported using this flat wagon in addition to the conventional container include: cars, engines, large pipes, metal beams, wire coils, wire mesh, partially finished steel products, rails, sleepers, and entire sections of railway track, as well as gravel, sand, and other bulk goods with the proper add-on attachment (hooks, side panels, etc.) to prevent damage or loss of the goods being transported. When transporting a wide range of items on a flat waggon designed to carry containers, it can be challenging to distribute the load evenly, and there are occasions when eccentric loads or combinations of products necessitate unequal distribution of the load.

1.1. What is haulage?

When talking about inland transportation, the word "haulage" frequently comes up. Transporting goods by road or rail is the business at hand. There are various types of haulage:

1.1.1. Carrier haulage:

In other words, the carrier arranges for the cargo to be transported by road or rail to the carrier for loading and then, when the main voyage is complete, to the destination. Line haulage is another name for it. Unless they are the result of faulty packaging and stowage, the carrier is responsible for any damages, liabilities, and claims that may occur. The preferred mode for door-to-door delivery packages in Europe is carrier haulage.

1.1.2. Merchant haulage:

The merchant/owner of the cargo arranges for the inland transfer of the goods to the carrier and, following the main route, to the final destination. Any damages are the responsibility of the merchant, who may be the exporter, importer, or an agent operating on their behalf.

	Carrier haulage	**Merchant haulage**
Pros	• Responsibility lies with carrier. • Only one invoice needed.	• More control for shipper • Great flexibility
Cons	• Considered less reliable	• Cargo owner is liable for any or all damages

Table 1 : Comparison between carrier haulage and merchant haulage

2. Road transportation:-

The most prevalent method of moving things is by road. It is the most adaptable and has the fewest geographic restrictions when compared to the other modes (sea, air, rail, barge, and pipeline). These are the principal methods for transporting cargo via road.

Figure 1 : Transportation of containers via road

2.1. FTL (full truckload):- An entire truck is occupied by a single shipment. Large shipments typically require FTL shipping. However, if they are valuable or high-risk, shippers may choose FTL for smaller shipments as well. The cost of shipping is determined on the distance. Full container load (FCL) and less than container load (LCL) shipping are related to FTL shipments.

2.2. LTL (less than truckload):- A truck transports multiple smaller-volume shipments than an FTL load. As a result, several shippers use one truck for all of their consignments. They simply have to pay for the individual space they occupy. LTL (less than truckload) shipments are linked to LCL (less than container load) shipping.

2.3. Partial Truckload and Volume LTL:- Partial truckload, also known as volume LTL, is a category used when a shipment doesn't need a full truck but is larger than the typical LTL shipment. Although frequently used synonymously, both phrases have a tiny difference. Eight to eighteen pallets, weighing 3,628 to 12,473 kg, make up a partial truckload shipment (8,000-27,500 pounds). A volume LTL shipment must meet any one of the following requirements: contain at least six pallets, weigh at least 2,268 kg (5,000 pounds), and occupy more than 12 linear feet of space (a linear foot is 12 inches). Due to market-determined pricing, partial truckload does not require a freight class. However, volume LTL requires a freight class because carriers base their quotes on their categorization scheme and their published LTL prices. (Carriers employ a measurement system called "freight class" to set standard charges.)

2.4. Trailer pick-up and drop-off: A trailer is a two-part vehicle that consists of a "tractor or cab unit" that pulls the trailer and an unpowered cargo-carrying unit. It has a generator so that a refrigerated (reefer) unit can be connected. Shipping container transportation is the purpose of trailers. In order to pick up empty containers from a container yard, deliver them to his warehouse for stuffing, then carry the stuffed containers to the port or terminal to be placed on the carrier, a shipper typically hires a trailer service.

2.5. Advantages of Road Transport:

- Door-to-door delivery is only possible with one mode of transportation.
- Fixed delivery days and next-day delivery are made possible by the extensive road network.
- Not constrained by routes and schedules. It is always operable and quickly adaptable to the needs of a particular route or load.
- Transfer of commodities quickly over small distances, particularly for perishables.
- Cheaper than shipping by air and water. There is less need for packaging, which increases savings not requiring much capital. Road construction, operation, and maintenance costs are relatively modest. Compared to ships, planes, and trains, trucks and trailers are less expensive.
- Services the most isolated areas of the globe and promotes trade in landlocked nations.
- A crucial component of cargo transportation by rail, sea, and air.

2.6. Disadvantages of Road Transport :

- Road travel is less safe than other modes of transportation such as the air, sea, and rail due to the high risk of accidents.
- Unsuitable for transporting big, bulky, or long-distance objects.
- Unreliable during the monsoon, when the roads flood and become damaged

- Delivery timings may be impacted by traffic congestion and malfunctions.
- Some nations have significant road taxes and tolls.
- Poor road upkeep is a serious issue.
- Costs of road transportation are quite sensitive to changes in gasoline prices.

3. Rail Transportation :-

When it comes to moving heavy loads over great distances at a reasonable price, train transportation is unmatched. Freight trains are an important part of international trade in nations like India, China, and the US that have huge landmasses and extensive rail networks. Freight trains not only transport goods from point A to point B domestically also aid in the growth of important industries.

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Figure 2: Transportation of containers via rail

3.1. Types of rail cargo

3.1.1. Consumer goods: Fruits, vegetables, textiles, etc.

3.1.2. Bulk cargo : transporting goods that have not been packaged, palletized, or containerized. The freight train in this situation counts as the container because it is the mechanism of transportation itself. Dry bulk and liquid bulk are both examples of bulk freight. Examples of dry bulk include grains, salt, cement, and coal, while liquid bulk examples include fuel and oil.

3.1.3. Break bulk cargo: essentially broken down into tiny pieces and loaded or unloaded one at a time rather than being able to be containerized or loaded in bulk. Examples of break bulk freight include machinery, equipment, and lumber logs.

3.1.4. Special cargo: Special cargo includes automobiles, temperature-sensitive items like perishable foods, large or over-dimensional cargo (ODC), and steel pallets.

3.1.5. Hazardous material: Liquid petroleum gas, crude oil, ethanol, etc. Such products are governed by national and international laws and regulations because they pose threats to people's health and safety.

3.2. Types of freight wagons

A collection of freight waggons drawn by an engine constitutes a freight train, also known as a goods train in India. There are numerous varieties of freight waggons, depending on the cargo:

3.2.1. Hopper: Hoppers can be either closed or open when carrying dry bulk materials like grains and minerals, depending on whether the cargo has to be protected from the elements. Doors on hoppers open from the bottom or sides.

3.2.2. Gondola: It is an open-topped wagon used to move dry goods with a high density, like coils and pipes of steel. To make loading easier, it is lower than a hopper.

3.2.3. Container wagon: It's made to transport shipping containers. Double stack container wagons are available in some nations, notably India, and they provide significant capacity, labour, and energy savings. From inland container depots (ICDs) to ports, such as from an ICD in Gurugram, Haryana, to Nhava Sheva port in Maharashtra, containerized export goods is transported via intermodal freight trains. It would be a travel in the other direction for import cargo.

3.2.4. Refrigerated wagon: It transports temperature-sensitive and perishable goods like milk, meat, and other food items.

3.2.5. Schnabel wagon: This unusually shaped wagon has several wheels and is used to transport big and heavy freight that is suspended from two raising arms. To guarantee that the weight of the cargo is distributed equally, the arms are connected to a system of pivots and frames.

3.2.6. Box car: This enclosed wagon transports items that need to be weather-protected. One or more doors allow access from the sides. Because of the container wagon, it is currently less well-liked.

India has its own way of classifying freight wagons as per Indian Railways standards:

3.2.7. Open wagons: These include boy open wagons with low sides ideal for transporting iron ore and box open wagons with high sides and side-loading for bulk goods such as coal.

3.2.8. Covered wagons: These transport autos and are available as single- and double-decker wagons.

3.2.9. Tank wagons: These transport kerosene, petroleum products, and gasoline.

3.2.10. Special purpose wagons: These include cement and aluminium waggons, as well as milk waggons that can transport 40,000 litres of milk at 4 degrees Celsius.

3.3. Advantages of rail transport

- More economical than road transportation. Compared to moving merchandise by road in India, which costs Rs 2.58 per tonne km, rail transport costs Rs 1.41 per tonne km.

- Compared to trucks, trains are more environmentally friendly and use less energy. According to Indian Railways, road transportation generates 64 mg CO_2e per net tonne km, but rail transportation emits 28 gm CO_2e (CO_2e being a measure of relative global warming potential)
- Trains go great distances quickly.
- Because of the high volume and little packing requirements, cargo loading and unloading is simple.
- Lower chance of cargo damage during travel
- An improved safety record. Road accidents cost eight times as much as train accidents when it comes to moving cargo.
- The effects of weather on train travel are minimal.

3.4. Disadvantages of Rail Transport

- Not an all-purpose means of transporting stuff like trucks. Rail transportation is typically used for long-distance, high-volume freight.
- India's rail network, while extensive, is oversaturated.
- longer transit times rule out time-sensitive products.
- Rail networks typically are not as extensive as road networks. Many container ports in India lack rail connections.
- Particularly in India, trains are less dependable than vehicles.
- Why Rail transportation is less adaptable than vehicle transportation.

4. Barge Transportation

A towboat or tugboat is used to propel a barge, which is a long, flat-bottomed, non-mechanical transport boat. Barges are utilised in sea ports in addition to inland waterways, which are networks of connected rivers and canals. They are a reliable and secure method of moving large quantities of cargo In Europe and the US, barges play a significant role in the transportation of freight, while inland canal cargo services have recently gained popularity in India.

Figure 3: Transportation of containers via barges

4.1. Types of barges:-

4.1.1. Dry bulk cargo barge: It transports things like grains, minerals, steel, coal, sand, and gravel. For weather-sensitive cargo, some dry bulk cargo barges have steel or fibreglass coverings. The covers can be rolled back or raised.

4.1.2. Liquid bulk cargo barge: It transports liquid fertilisers, fuel, and other petroleum-based materials. A barge for liquid bulk cargo may have one or more tanks to hold liquid cargo. As a result, it is also known as a tank barge.

4.1.3. Split hopper: A split hopper is often used in marine construction and is intended to hold dredge material (soil, sand, rocks). To release the material it is carrying, its hull (bottom, sides, and deck) cracks. Locks hold the hull together when sailing.

4.2. Advantages of barge transport:-

- Able to carry more freight than rail carriages, trailers, and trucks
- Energy efficiency and environmental friendlier than trains and trucks
- It is safer than road and rail transportation due to fewer accidents.
- Less chance of damage and theft to cargo.

4.3. Disadvantages of barge transport

- Not advisable for perishable items due to its slower speed than trains and trucks
- For short distances, inefficient in terms of time and money
- Shifting river levels could result in shipping issues.

5. Road versus Rail versus Barge

	Road Transport	Rail Transport	Barge Transport
Pros	➢ Flexible and versatile ➢ Only mode with door-to-door delivery ➢ Wide network that connects remote regions ➢ Very fast over short distances	➢ Low energy consumtion ➢ Less polluting than trucks ➢ Covers long distances ➢ Carry large volume ➢ Cost effective ➢ Better cargo security than trucks	➢ Huge cargo capacity ➢ Less polluting of the three ➢ Safest, has the fewest accidents ➢ Low risk of cargo theft and damage

Cons	➢ Most expensive of the three ➢ Unsafe ➢ Unreliable in bad weather ➢ Most polluting of the three	➢ Less reliable than trucks ➢ Not flexible ➢ Only good for high volume corridors and long distances	➢ Slowest of the the three ➢ Not meant for short distances ➢ Not meant for perishable cargo

Table 2: Comparison between road, rail and barge transport

6. What Are Shipping Containers Made Of?

Figure 4: Shipping container internal structure

Corrugated wall panels, cargo doors, cross members, and frames make up a shipping container. Corten steel was used to make each of these components.

The main component of shipping containers is corten steel, sometimes referred to as weathering steel.

6.1. Why, though, Corten steel?

Corten steel is distinct from other kinds of steel that need to be painted to stop rusting. It distinguishes out as the only class of rust-resistant steel alloys. Corten steel is preferred by container producers since it doesn't need to be painted for this reason. It can also be welded.

A shipping container is made up of other parts in addition to the main body, and not all of these parts are constructed from Corten steel. One thing is certain, though. The containers are made with carefully chosen components to ensure they are sturdy, secure, and weatherproof.

7. Components of a Shipping Container

Most shipping containers will come with the following distinctive qualities, according to container manufacturers.

7.1. Corner Castings

The corner posts at each intersection where two corrugated wall panels meet are known as corner castings.

To make sure they can support the container firmly, the posts have been strengthened. Corner castings generally incorporate apertures for connecting the shipping containers to anchor points or other containers. Twist-lock connectivity is made possible by these apertures.

Additionally, corner castings are made to be sturdy enough to support successful crane rigging, regardless of the container's load level, whether it is empty or fully loaded.

7.2. Twist Locks

Twist locks are parts that secure connections between shipping containers and anchor points or other containers. You can hoist the container and lock it to a moving vehicle or any other desired location by inserting its end piece into the corner casting.

To pivot the containers, we frequently use a lever.

7.3. Cross Members

Manufacturers use joists or beams known as cross members to support the floor of the shipping containers.

The cross members make ensuring that there is a space between the flooring and the ground in addition to providing support. In this manner, the floor of the container is not immediately on the ground. This is crucial to do in order to prevent moisture from the ground below from entering the container.

Have you ever wondered why so many container buildings lack a foundation? They usually won't have it because of the cross members of the shipping container bottom, regardless of whether the container is a ground-level house or office. By elevating the structure above the ground, the cross members reduce the chance of damage from natural forces.

7.4. Forklift Pockets

The gaps located close to the bottom edge of shipping containers are known as forklift pockets. Two forklift pockets are present on standard containers, which are typically 20 feet long. These reinforced apertures are designed to accommodate forklift tines.

You must use the forklifts to insert the tines into the pockets before you may move or raise the containers.

It is important to keep in mind that some structures have modifications that make forklift lifting hazardous and inappropriate. Additionally, some shipping containers, such modified 40-foot containers, weigh more as a result of the alterations. Such weight might not be supported by forklifts.

7.5. Cargo Doors

Figure 5: Shipping container steel doors

At one end of each shipping container are two steel doors. But in certain containers, the cargo doors are either on the side walls or both ends.

The doors were first created with security and weather protection in mind. They guard against weather-related damage and theft of goods kept inside the containers.

The doors also have a locking system that is usually used by container users. It can be advisable for first-time users to learn how to open the cargo doors by becoming familiar with them.

7.6. CSC Plate

A set of guidelines that control shipping container design is known as the International Convention for Safe Containers (CFC). By ensuring that the containers are secure against structural breakdown, the convention safeguards human life.

For instance, the loaders must stack high cargo units in order for a shipping container to hold enormous cargo that weighs several thousand pounds. This entails dangers because it's possible for the stacks to collapse and injure port workers.

Before the ship sets sail, a certified inspector must inspect the container to ensure that it is secure enough to transport the cargo in order to prevent such tragic occurrences. The container will subsequently receive a CSC Plate from the inspector as proof that it is secure.

7.7. Falcon Plate

CSC plates and falcon plates are comparable, however the latter is exclusive to Falcon Structures. The company Falcon Structures makes shipping containers.

Modified containers must adhere to their standards, which include safety and cargo-worthiness inspections.

7.8. Marine-Grade Plywood Flooring

Figure 6: Plywood flooring

The most typical type of flooring included with shipping containers is marine-grade plywood.

Manufacturers of containers inject tiny amounts of insecticides into the flooring to keep pests and insects from entering the container.

And since the pesticides only kill the six-legged, hungry stowaways seeking to board your container for the journey, you don't have to worry about their aerosolizing and harming you.

7.9. Bamboo Flooring

Figure 7: Bamboo flooring

Bamboo flooring is increasingly being produced by producers in place of marine plywood flooring. This is due to the accessibility and low cost of bamboo flooring.

Additionally, bamboo has a number of advantages. It resists mildew and lasts a long time, for instance. Bamboo is also a renewable resource, thus it is widely available.

Keep in mind that bamboo is more aesthetically pleasing than plywood. This characteristic can be crucial, particularly in applications for shipping containers that integrate business and residential rooms.

8. How Shipping Containers Are Made – Manufacturing Process

The following steps are involved in the production of shipping containers:

- First, cut a number of steel sheets from a single, big roll. To cut these sheets, factories use highly sophisticated mechanical systems.
- As a method of surface preparation, the sheets are sandblasted and primed to get rid of dirt, dust, debris, and impurities.
- To increase the overall strength of sheets, corrugation is used.
- Floor braces and roof panels are produced individually. Wall panel sheets are also welded together.
- On the tops of the walls, fuse square tubing.
- A floor frame is created by assembling floor panels.
- Following completion of this, the corner post assembly and door assembly are prepared separately.
- Wall panels and door assembly installation come next.
- Corner pillars, door assemblies, and wall panels are all welded together.
- The roof panel's construction and welding come next.
- Painting and priming are finished at this point.
- The flooring is then prepared with varnished wood framing.
- After the floor panels have been fixed to the container floor, holes are drilled in them.
- The door hardware is up and running. To make sure the doors are watertight, rubber seals are incorporated.
- The container bottom is then waterproofed and put through a water tightness test.

The container is now finished. The container still needs to be inspected to make sure it is watertight and to fix any mistakes.

9. Objective

The objective of this computation is to ensure that the permissible parameters on the 40' container wagons for 1000mm metric tracks are not exceeded in certain load circumstances (the most stringent) set by standard NF EN 12663-2.

10. REFERENCE DOCUMENTS

The documents considered in this analysis are as follows:

- The TWA diagram of the 40' container wagon for 1000mm metric gauge as well as its loading plan (3-630180);
- Standards NF EN 12663-2, NF EN 10025-2, NF EN 10025-5;
- The ANSYS V11 user manual, including modelling limitations and results reliability.

11. DESCRIPTION AND PRESENTATION OF THE STUDY

11.1. Presentation of the wagon:

- The wheelbase of the 40' container wagon is 6940mm;
- The pulling height is 780mm ARL and the bumping height is 790mm ;The
- total length of the wagon including buffers is 13140mm;
- The mass of the modeled structure (1/4 frame) is 1363kg.

11.2. Description of the finite element model:

The ANSYS V11 software is used for the finite element modelling (for the pre and post processing of the data, as well as for the calculations).

- Appendix A contains the quarter mesh of the optimised superstructure. It consists of:
- 23017 elements mainly in SHELL43 type shells.

The used unit system is:

- The mm for the dimensions and displacements,
- N for efforts,
- N/mm² (MPa) for pressures and stresses.

The coordinate axes are:

- X: longitudinal,
- Y: transverse,
- Z: vertical.

The average mesh size is 30mm justified by the sheet thicknesses varying from 4 to 16mm and the reliability limitations of the results in relation to the thick shell formulation
"MINDLIN" of the SHELL43 element of ANSYS.

For reasons of simplification of the model, and for the load cases which allow it, the calculations will be carried out on a quarter of the superstructure of the wagon.

11.3.Loadings and Boundary Conditions

Appendix B will include visuals of the loadings and boundary conditions.

11.3.1. Static and longitudinal loads

Descriptions	Intensity	Application areas
Buffer compression	2MN	Knots near to the pad's anchoring screws (pad pockets)
Diagonal compression	0.4MN	Knots near to the pad's anchoring screws (pad pockets)
Axial compression	3MN*	Compression clamp
Axial tension	1.5MN**	Tension clamp

Table 3 : Static and longitudinal loads

* : This load case is being studied in anticipation for the wagon being equipped with an automatic coupler and/or being installed in a lengthy and heavy train.
** : This load case is being studied for the screw coupling configuration, which will be used on the wagons delivered.

11.3.2. Vertical static loads

Several container loading configurations are proposed for vertical loading, namely:

- CV1: 1 40' container loaded at 36t;
- CV2: 2 containers of 20' loaded at 29t each;
- CV3: 1 20' container loaded with 22t at the end of the wagon;
- CV4: 1 20' container loaded at 36t centered on the wagon.

Descriptions	Intensity	Application areas
Maximum load of working	1.3gz	Wagon pins
Laden lifting	1gz + mass of two bogies	Wagon pins + center plate pivots

Table 4 : Vertical static loads

11.3.3. Fatigue load case

Descriptions	Intensity	Application areas
transverse fatigue	±0.2gy	Wagon pins

Table 5 : Fatigue load case

11.3.4. Conditions to the limits

Load cases	Degrees of freedom	Application areas

	blocked*	
Buffer compression	UY-UZ-ROTX/ UX-ROTY-ROTZ/ UY-ROTX-ROTZ	Center plate pivot/Symmetry with respect to the YZ plane/Symmetry with respect to the XZ plane
Diagonal compression	UY-UZ-ROTX/UX	Center plate pivots/Nodes close to the buffer fixing screws and diagonally opposite those where the forces will be applied
Axial compression	UY-UZ-ROTX/ UX-ROTY-ROTZ/ UY-ROTX-ROTZ	Center plate pivot/Symmetry with respect to the YZ plane/Symmetry with respect to the XZ plane
Axial tension	UY-UZ-ROTX-ROTZ/UX-ROTY-ROTZ/UY-ROTX-ROTZ	Center plate pivot/Symmetry with respect to the YZ plane/Symmetry with respect to the XZ plane
Maximum working load	UX-UY-UZ-ROTX/ UX-ROTY-ROTZ/UY-ROTX-ROTZ	Center plate pivot/Symmetry with respect to the YZ plane/Symmetry with respect to the XZ plane
Lifting	UX-UY/ UX-ROTY-ROTZ/UY-ROTX-ROTZ/UZ	Center plate pivot/Symmetry with respect to the YZ plane/Symmetry with respect to the plane XZ/Lifting-lifting bases
transverse fatigue	UY-UZ /UZ/ UX-ROTY-ROTZ	Toe plate pivots/Screed soles

* With: U = displacements and ROT = rotations

Table 6 : Loads applied at different areas and its limits

12. Acceptance criteria

The construction is built of sheet steel and steel products of various thicknesses and grades. For the proof load scenarios, the permissible values extracted from the standards NF EN 12663-2, NF EN 10025-2, and NF EN 10025-5 are as follows:

Thicknesses (mm)	shades	Elastic limits in tension (MPa)	
		Full Sheet (PT)	Welded Zone (ZS)
Ep ≤ 16	S355 J0	**355**	**323**
16 < Ep ≤ 40	S355 J0	**345**	**310.5**

Table 7 : Acceptance criteria of different loads

The wheelbase of the wagon being 6940mm, the maximum apparent deflection under load must not exceed 3% of this wheelbase, i.e. 21mm, measured along the side rails, thus the transverse deflection (for example that of the pivot crossmembers) must not be taken into account.

13. RESULTS

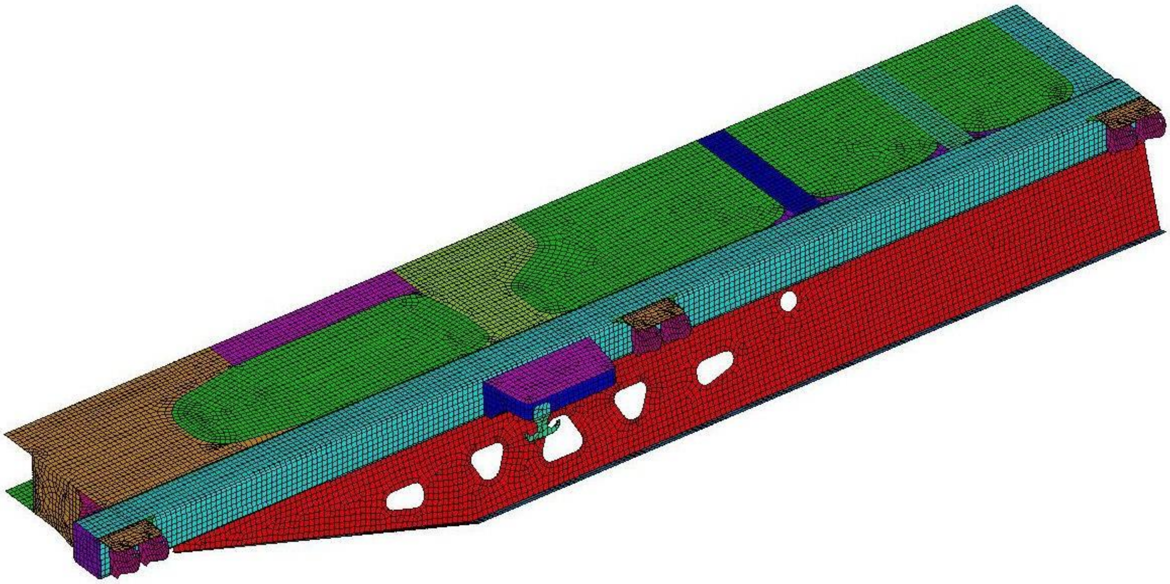
Screenshots of the results will be given in **appendix C**.

14. Proof loads

Load Case	Maximum Stress(MPa)	Location	Allowable Limit
Axial compression at the pads (2MN)	328	Buffer pocket(ZS)	323
Diagonal Compression (0.4MN)	301	Buffer pocket(ZS)	323
Axial compression at the compression stop (3MN)	364	Lower sill flange (PT)	355
Axial traction at the level of the traction stop (1.5MN)	182	Lower sill flange (PT)	355
Lifting CV1 (under 1gz)	216	Tow bracket (ZS)	323
Lifting CV2(under 1gz)	315	Tow bracket (ZS)	323
Lifting CV3 (under 1gz)	242	Tow bracket (ZS)	323
Lifting CV4 (under 1gz)	254	Tow bracket (ZS)	323

Table 8 : Proof loads

Appendix A: Optimised Structure Quarter Mess



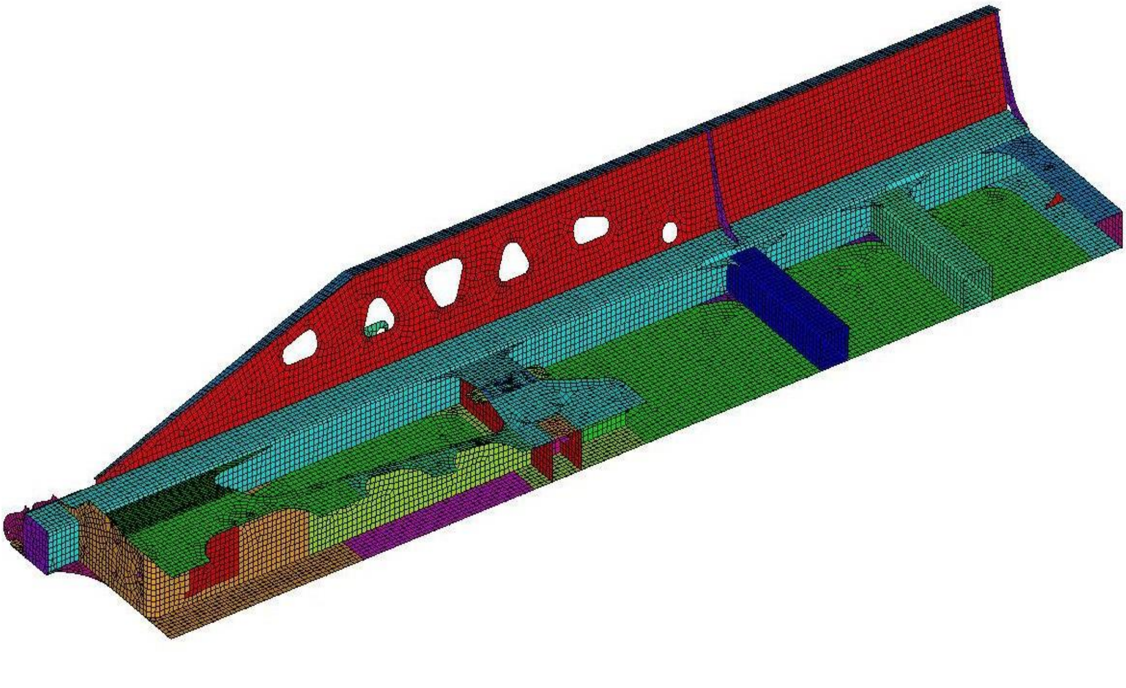


Figure 8: Optimised structure quarter mess

Appendix B : Loading and Boundary Conditions

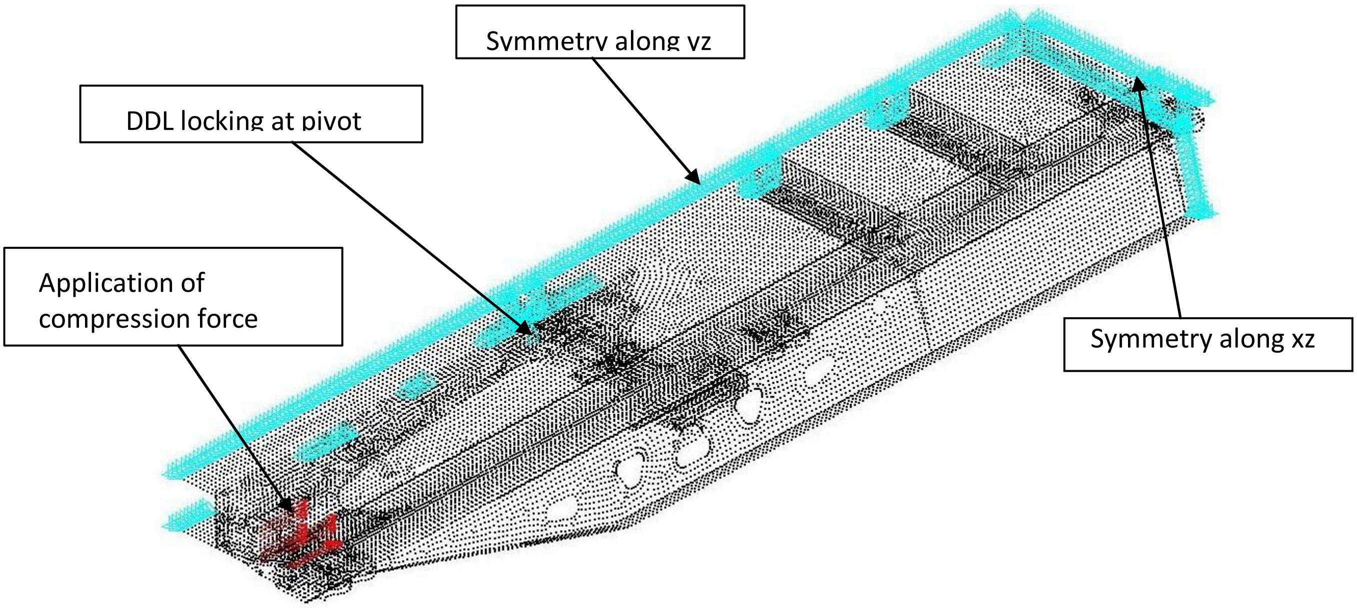


Figure 9 : 40´flat wagon, axial compression 200t at buffers

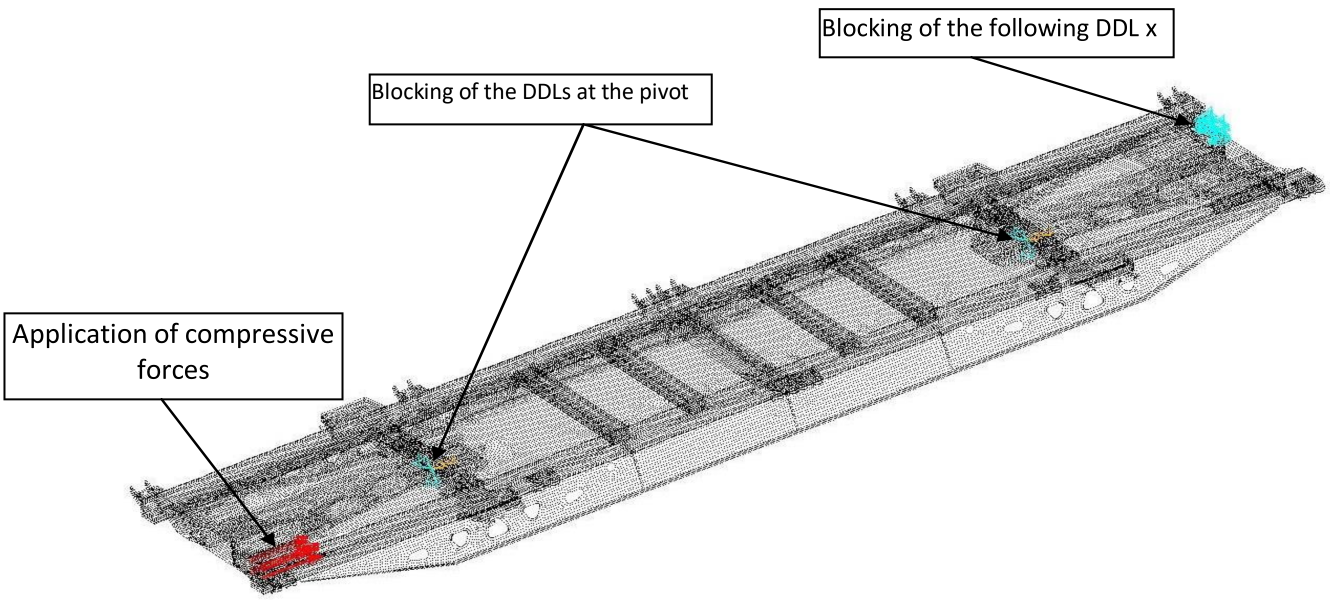


Figure 10: 40´flat wagon, 40t diagonal compression at buffers

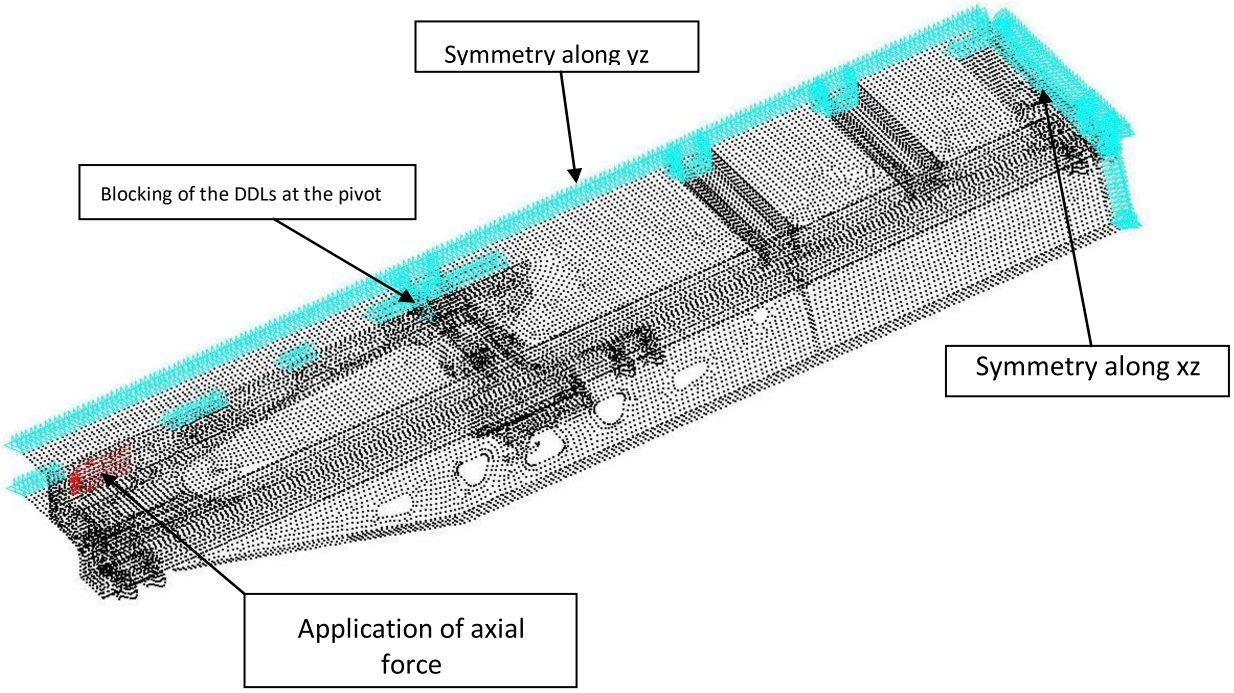


Figure 11: 40′ flat wagon, 150t axial tension at central coupler stops

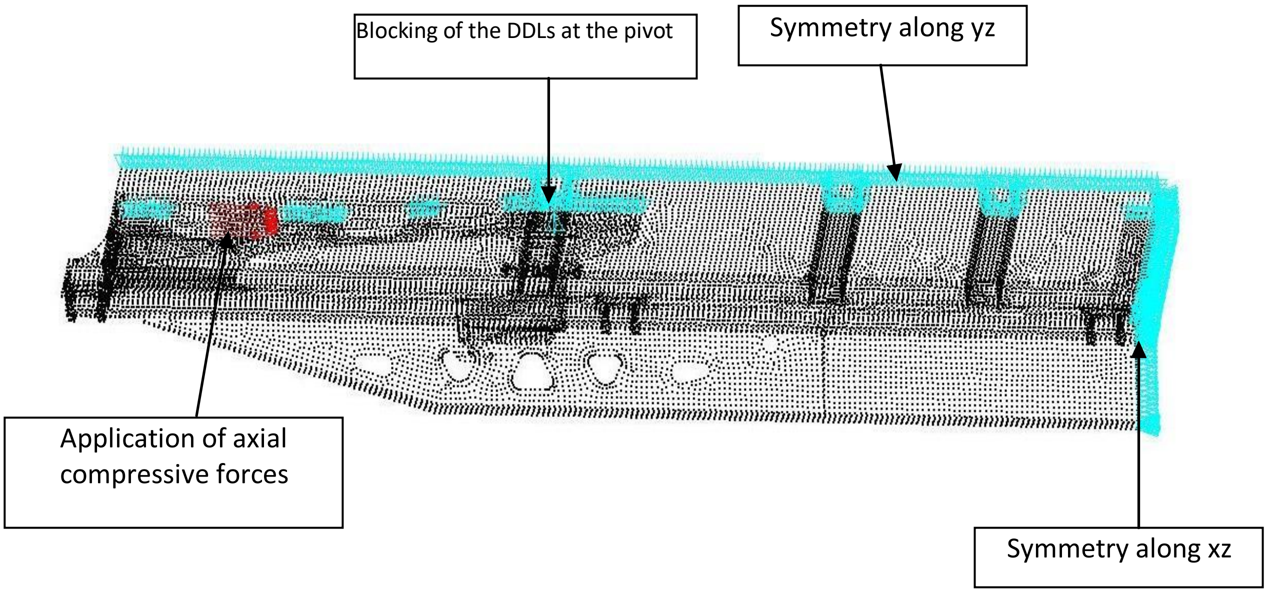


Figure 12: 40′ flat wagon, 300t axial compression at central coupler stops

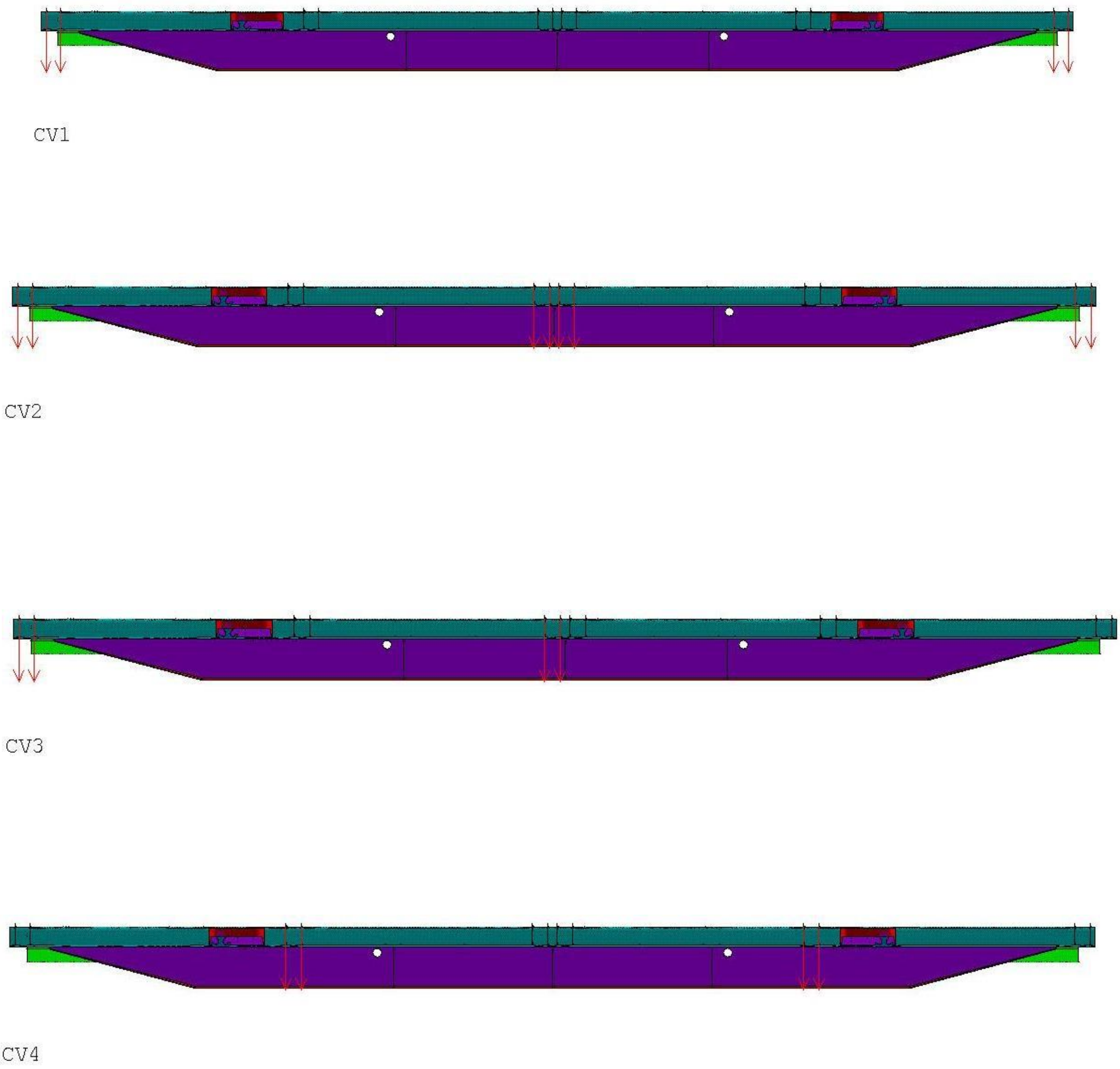


Figure 13: CV1, CV2, CV3, CV4 vertical static loads

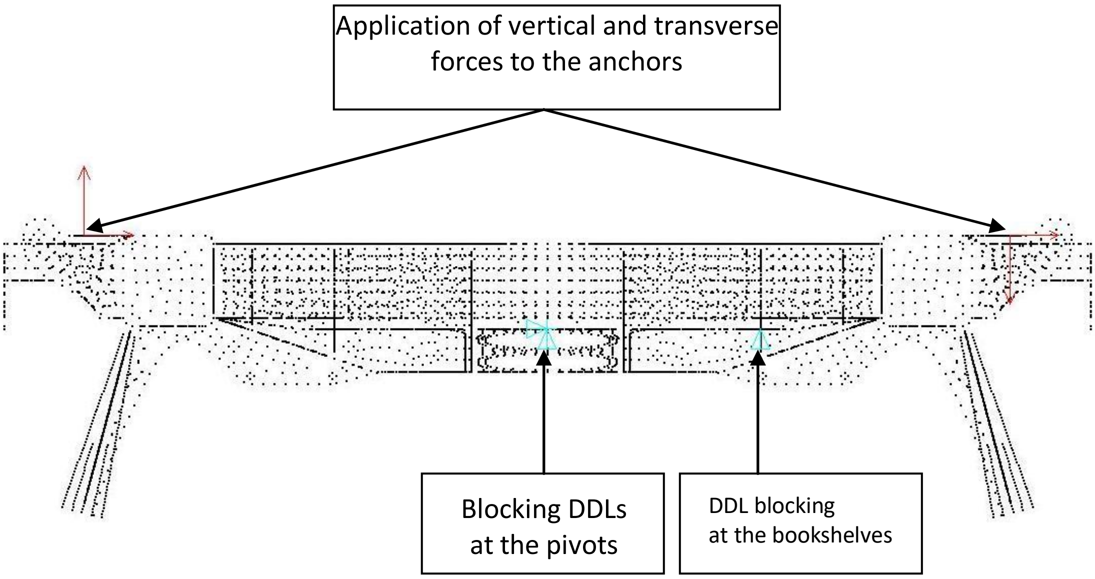


Figure 14: 40΄feet flat wagon, 0.4 gy, 36T

Appendix C : Test and Fatigue Load Results

- ***Proof Loading***

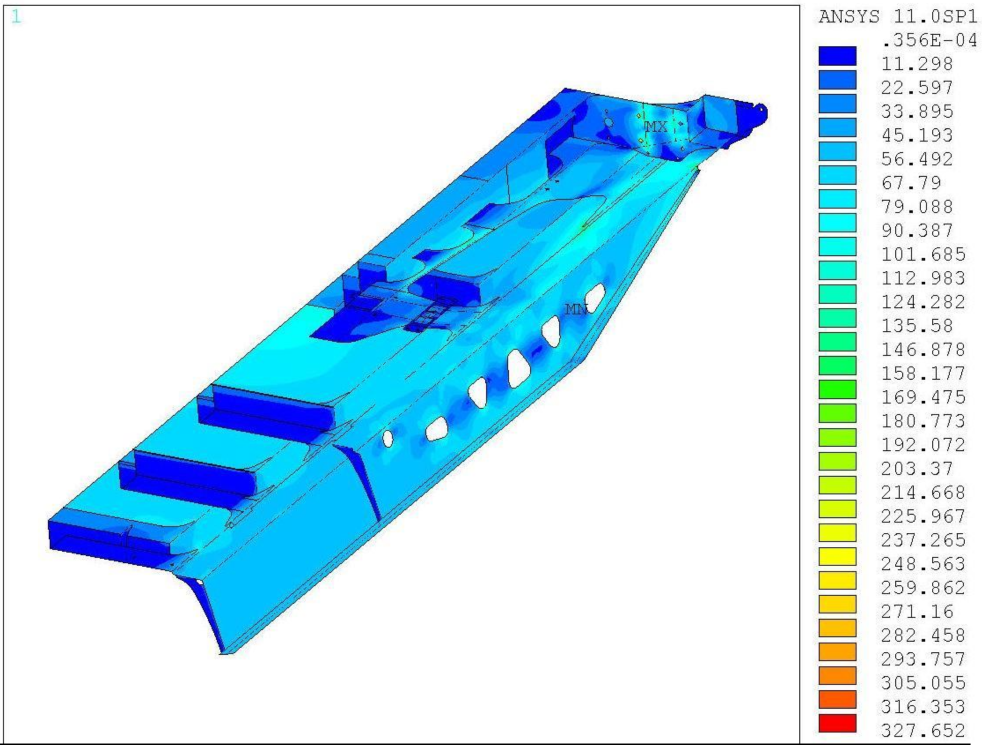


Figure 15: 40' flat wagon, axial compression 200t at buffers

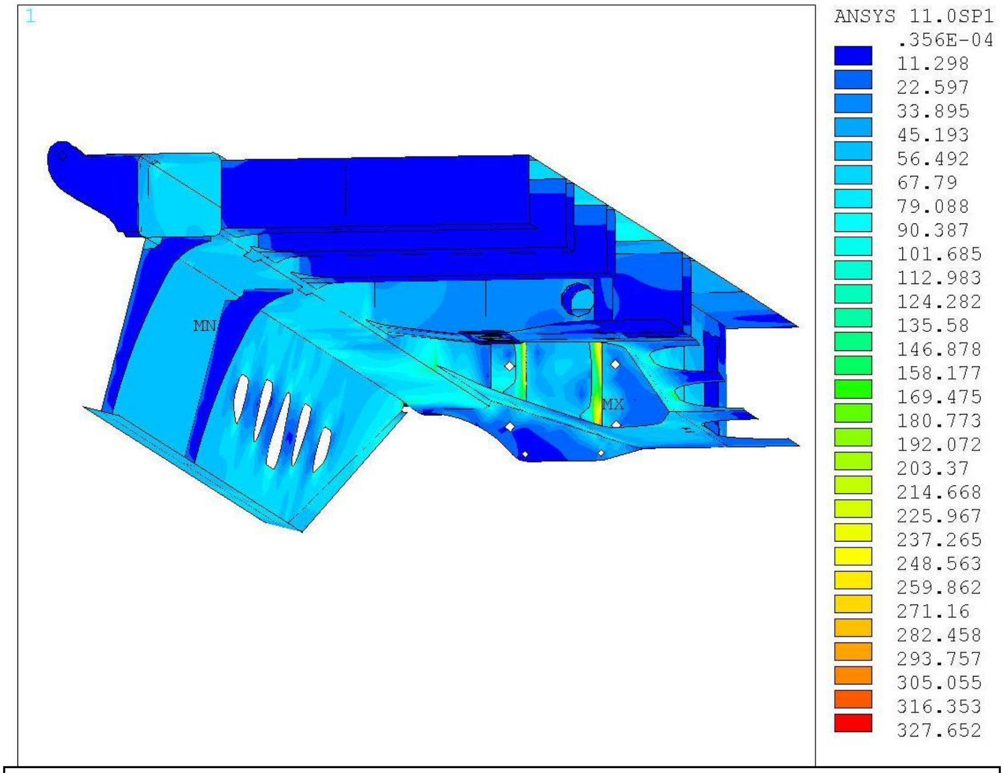


Figure 16: 40' flat wagon, axial compression 200t at buffers

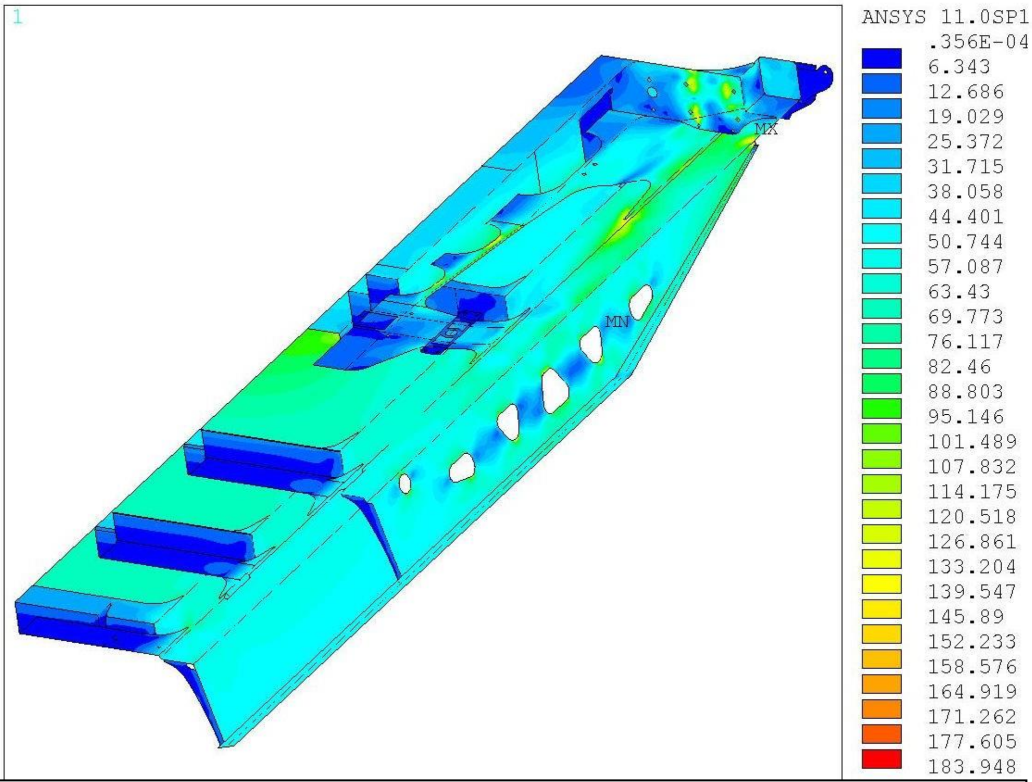


Figure 17: 40' flat wagon, axial compression 200t at buffers

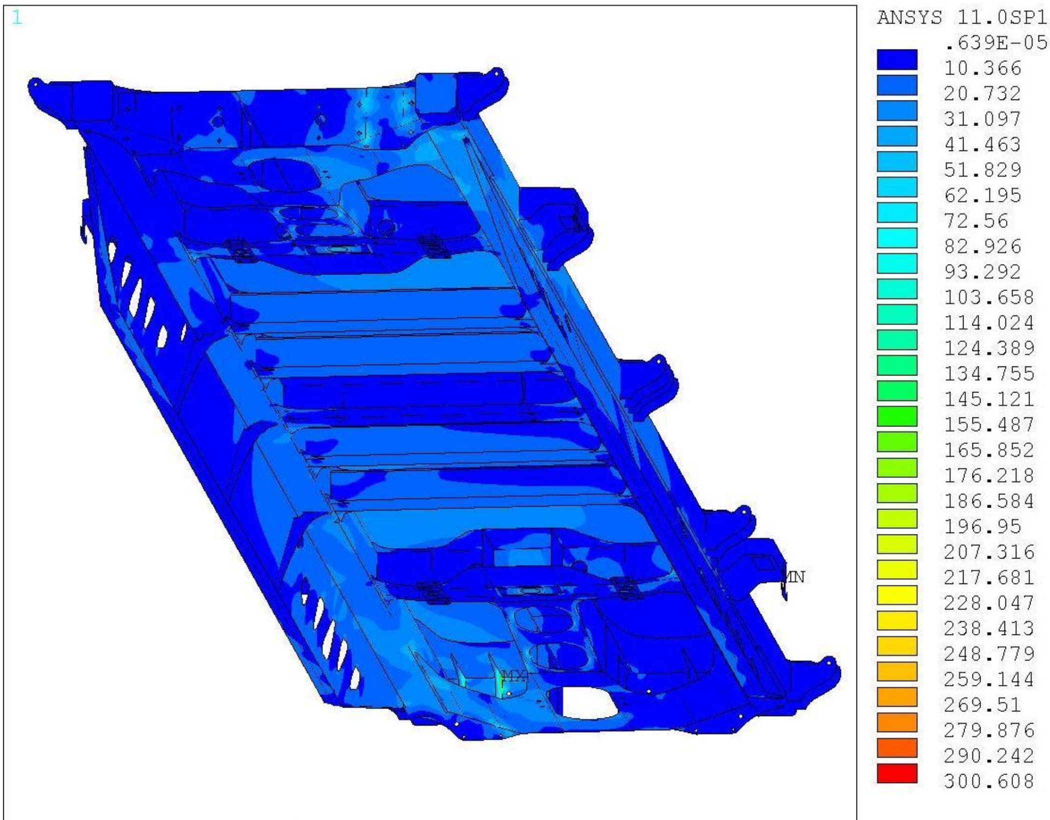


Figure 18: 40' flat wagon, 40t diagonal compression at buffers

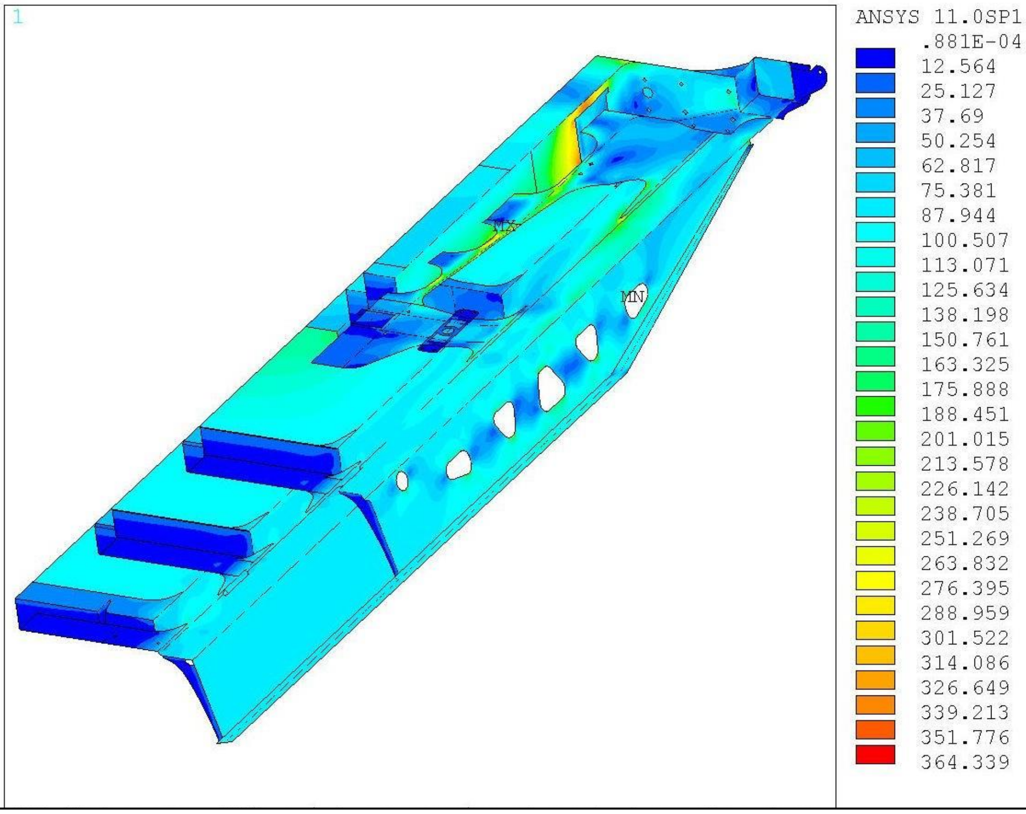


Figure 19*: *40' flat wagon, 300t axial compression at central coupler stops

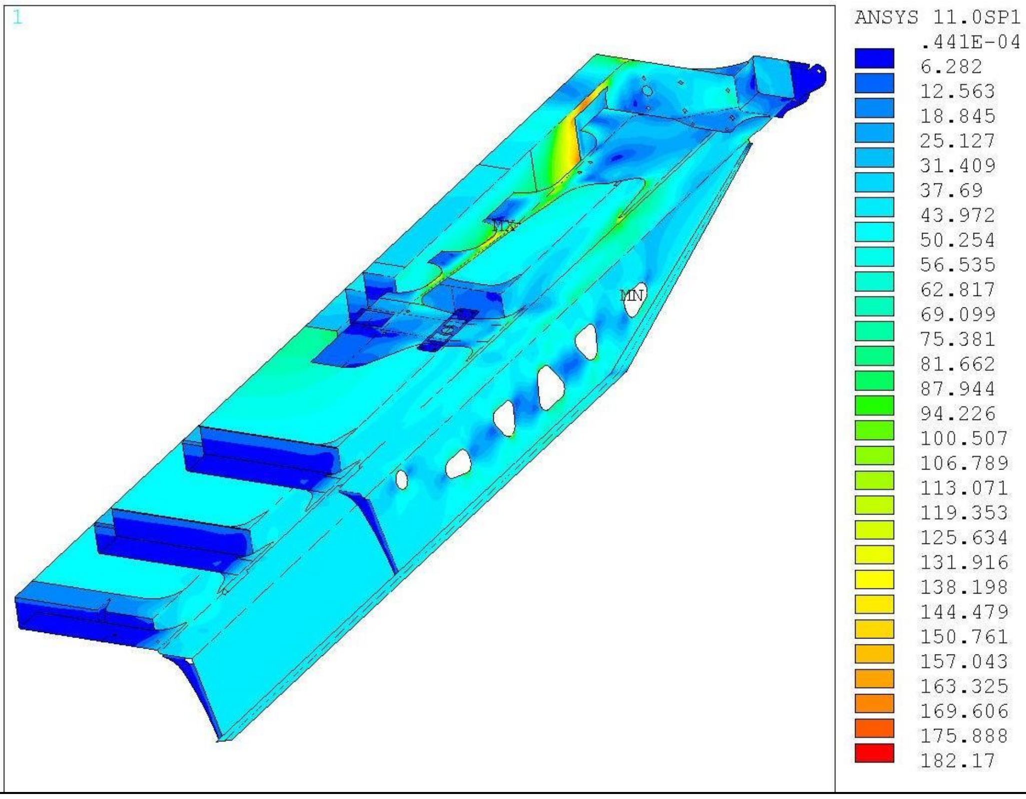


Figure 20*: *40' flat wagon, 150t axial tension at central coupler stops

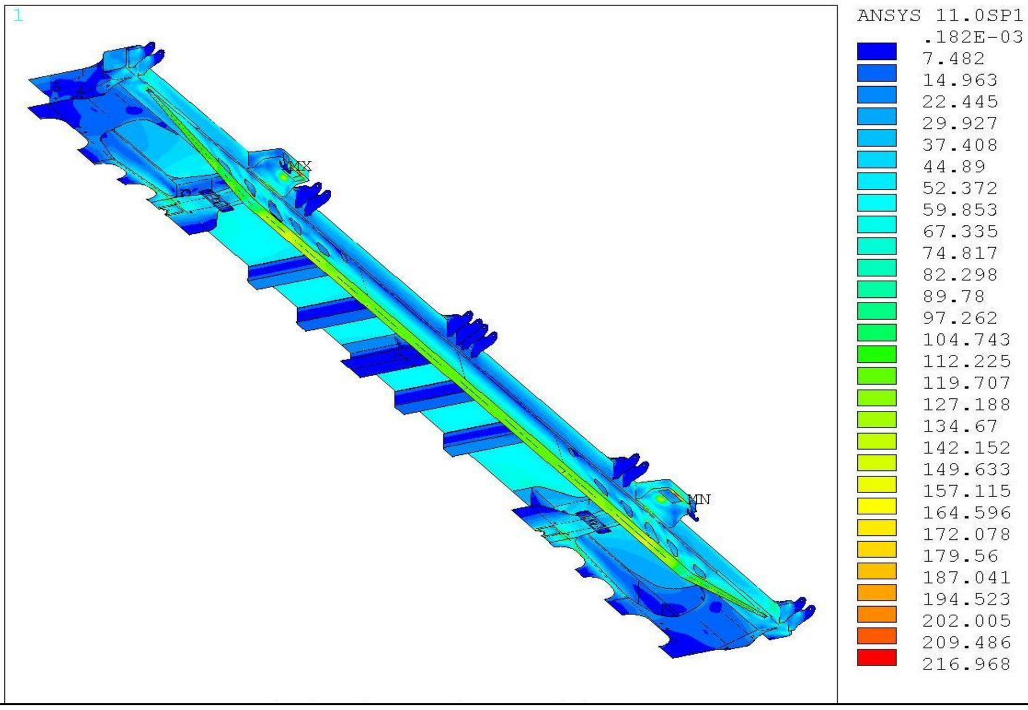


***Figure 21**: 40' flat wagon lifting in loading condition, 40',36T*

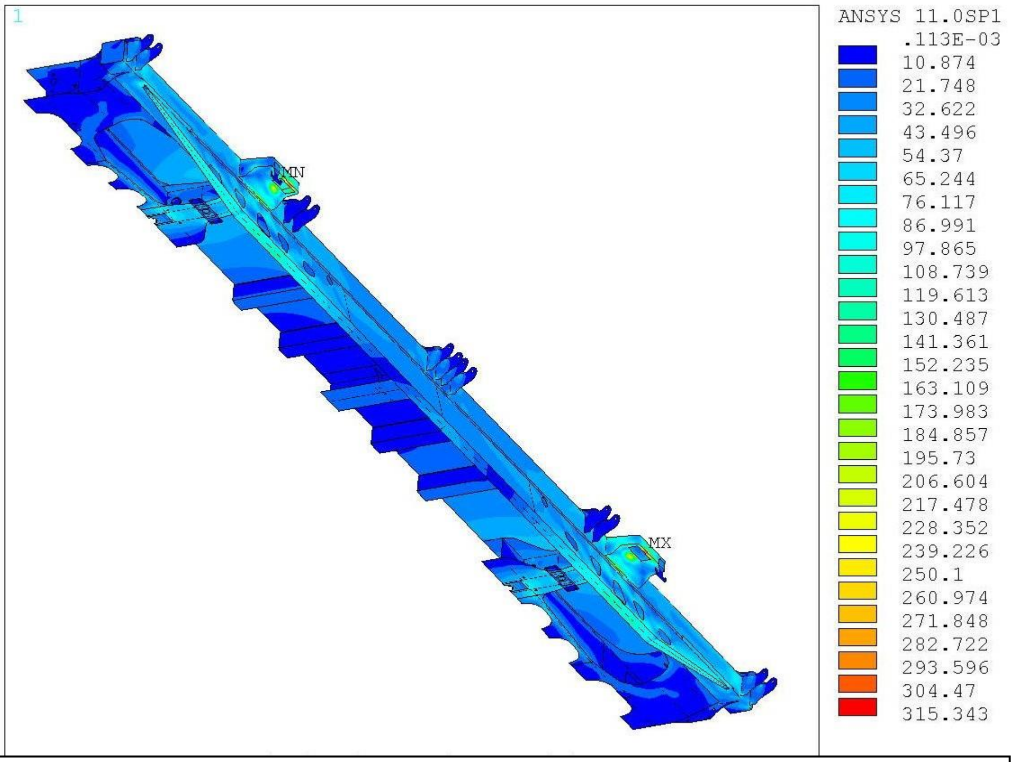


***Figure 22**: 40' flat wagon lifting in loading condition, 2*20', 29T*

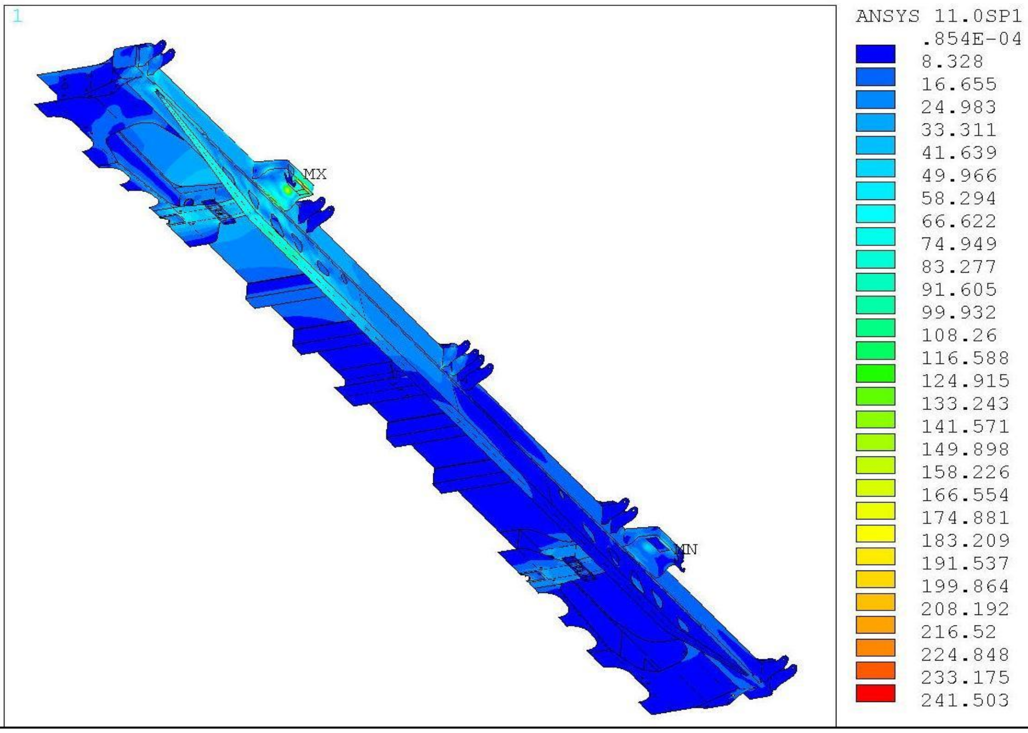


***Figure 23**: 40' flat wagon lifting in loading condition,1*20' asymmetric 22T*

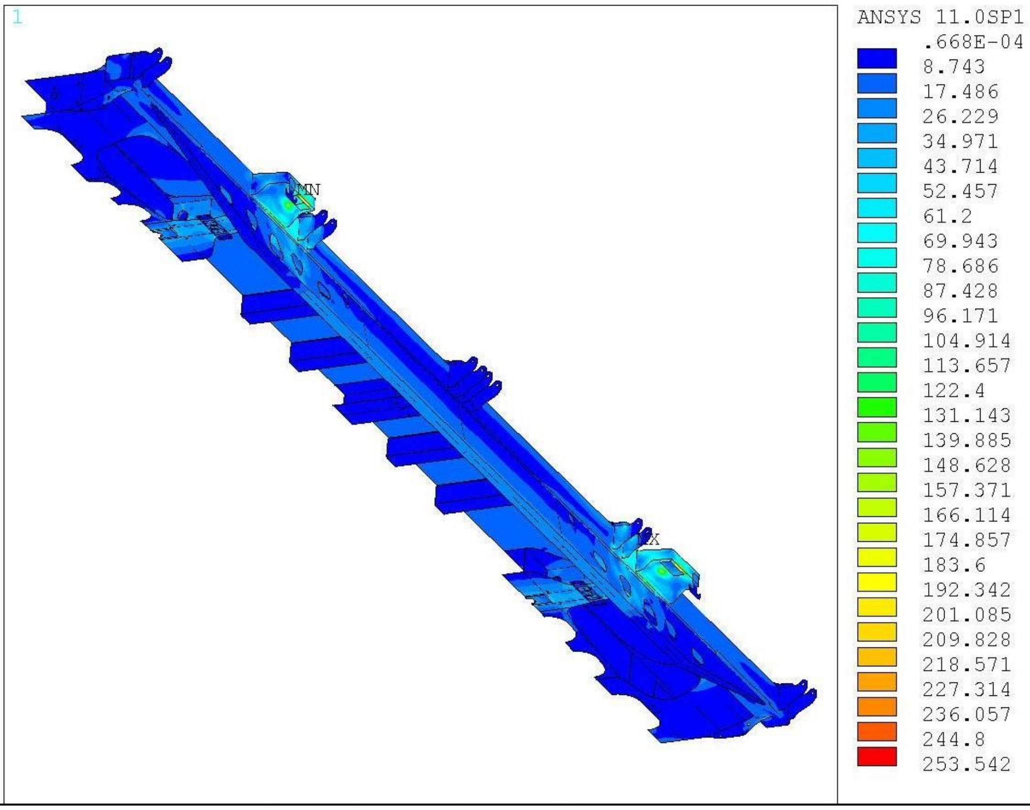


***Figure 24**: 40' flat wagon lifting in loading condition, 1*20' centered 36T*

- ***Vertical Loads***

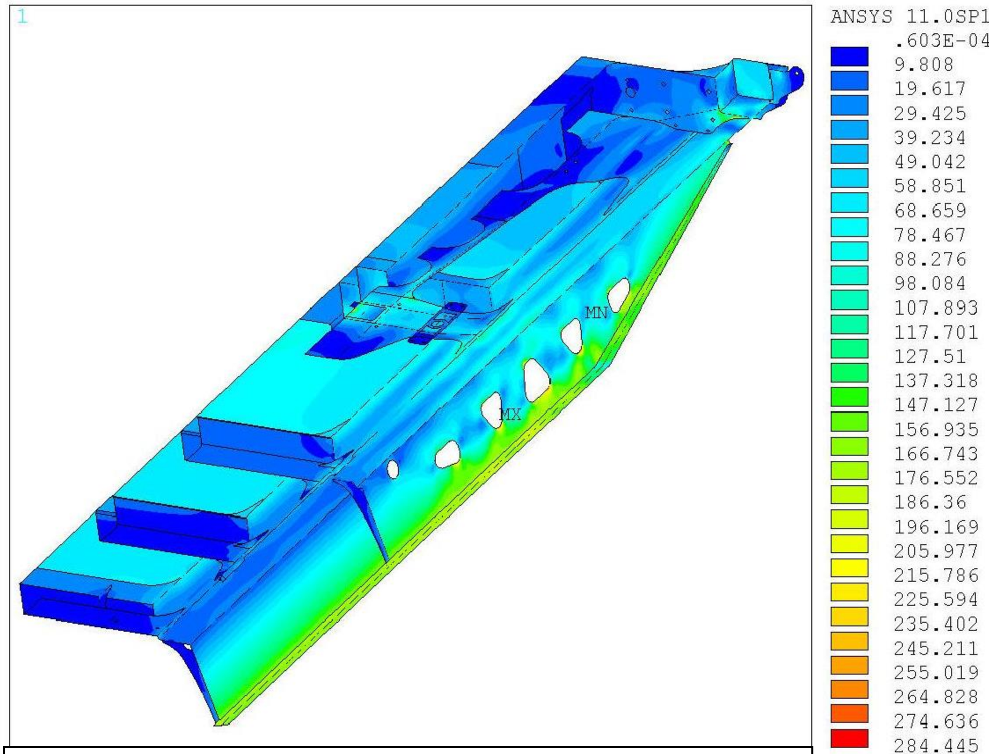


Figure 25: 40´flat wagon 1.3gz, 40´36T

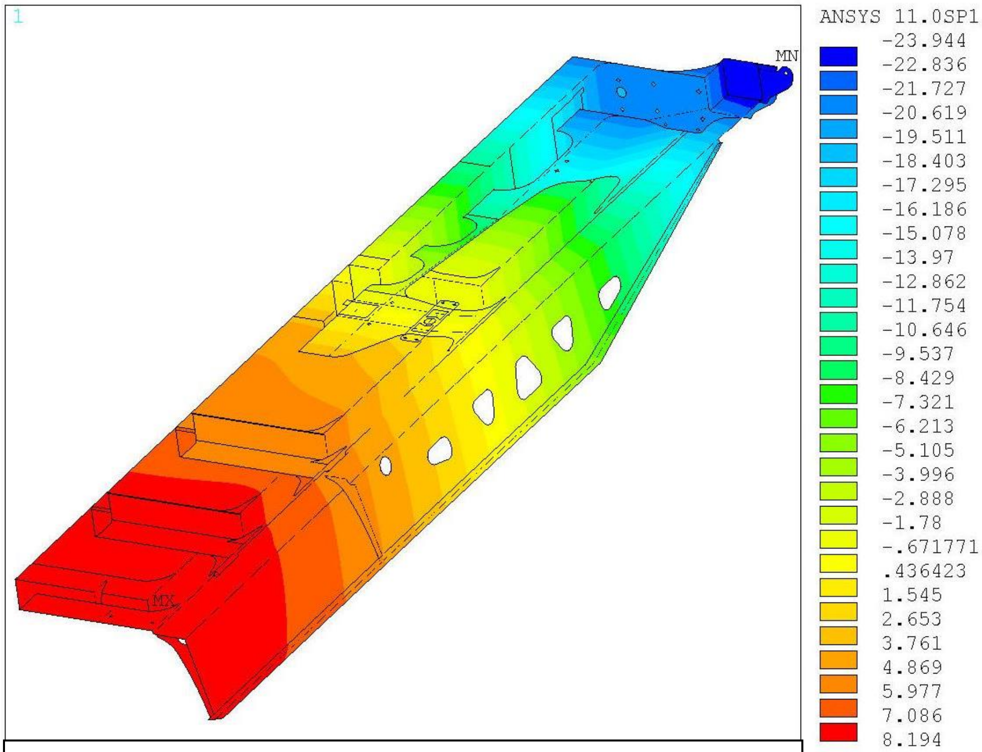


Figure 26: 40´flat wagon 1.3gz, 40´36T

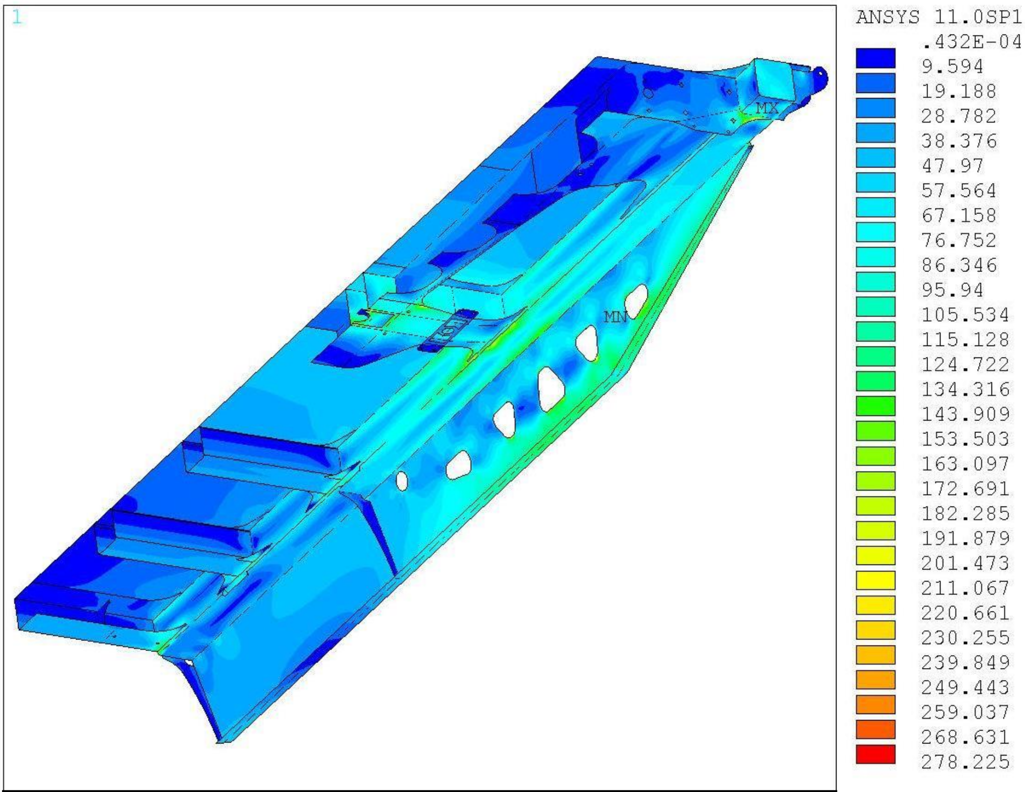


*Figure 27: 40' flat wagon 1.3gz, 2*20' 29T*

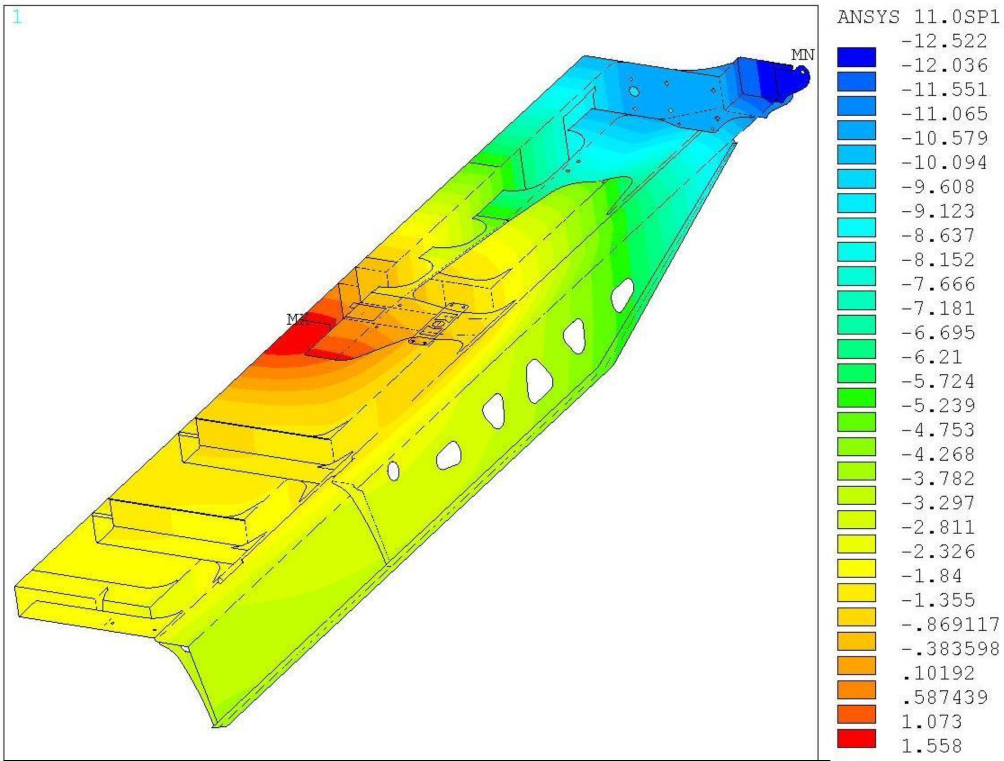


*Figure 28 : 40' flat wagon 1.3gz, 2*20' 29T*

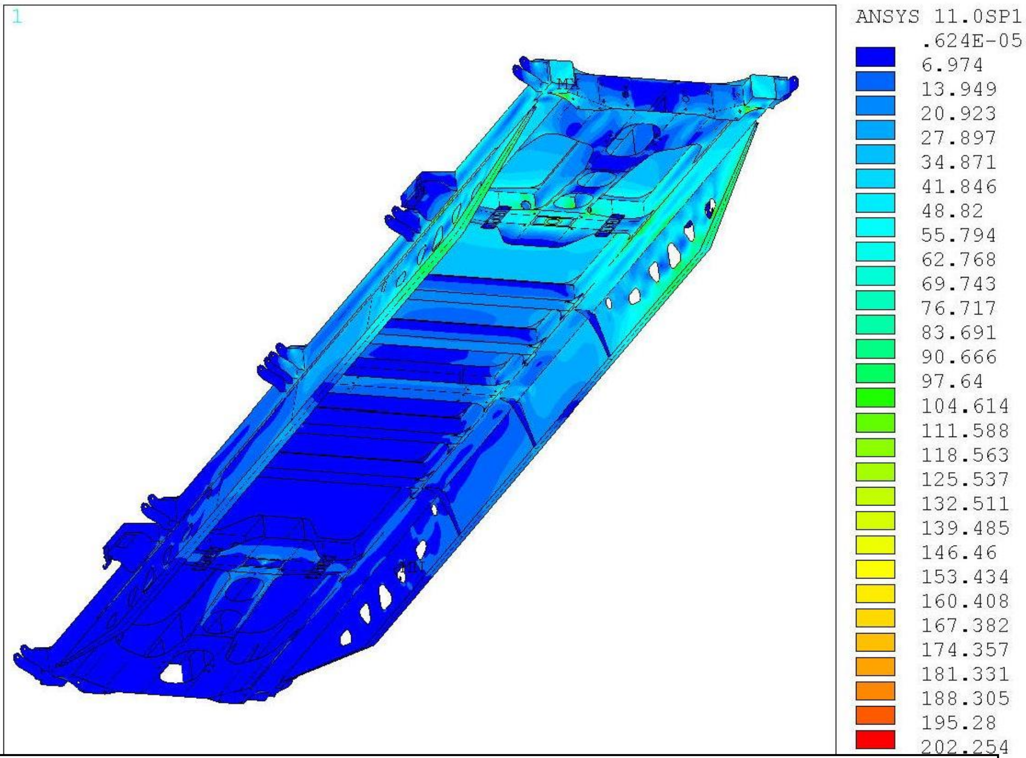


*Figure 29 : 40΄ flat wagon 1.3gz, 1*20΄ asymmetric 22T*

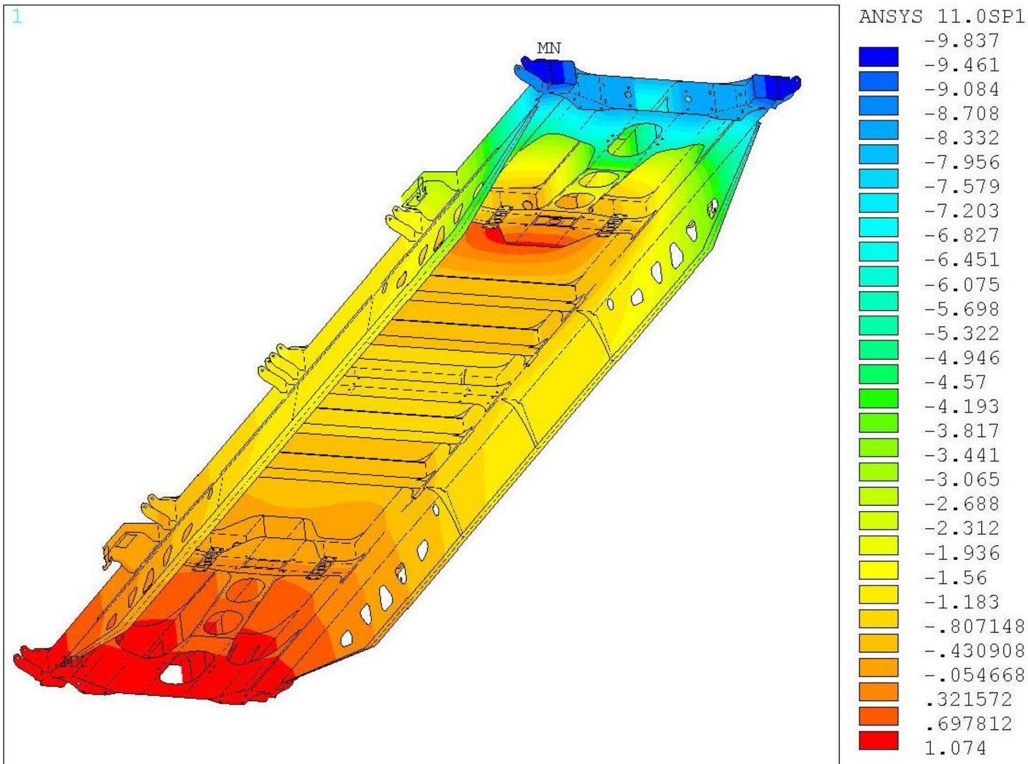


*Figure 30: 40΄ flat wagon 1.3gz, 1*20΄ asymmetric 22T*

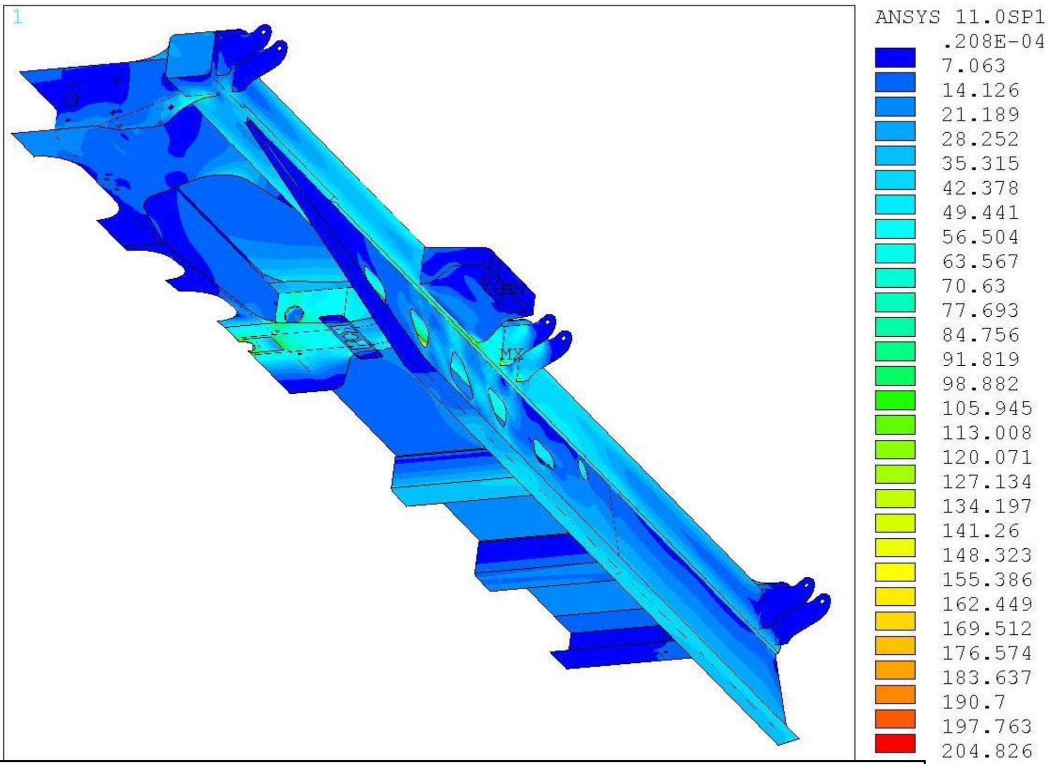


*Figure 31: 40΄flat wagon 1.3gz, 1*20΄centered 36T*

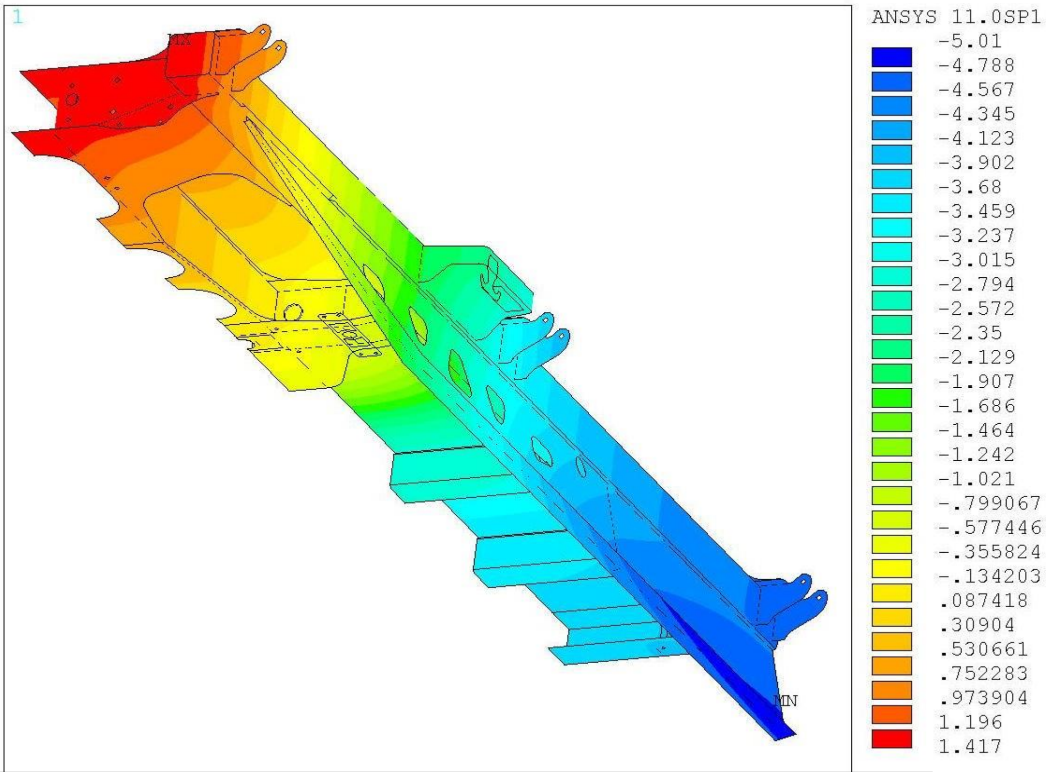


*Figure 32: 40΄flat wagon 1.3gz, 1*20΄centered 36T*

- ***Fatigue Load***

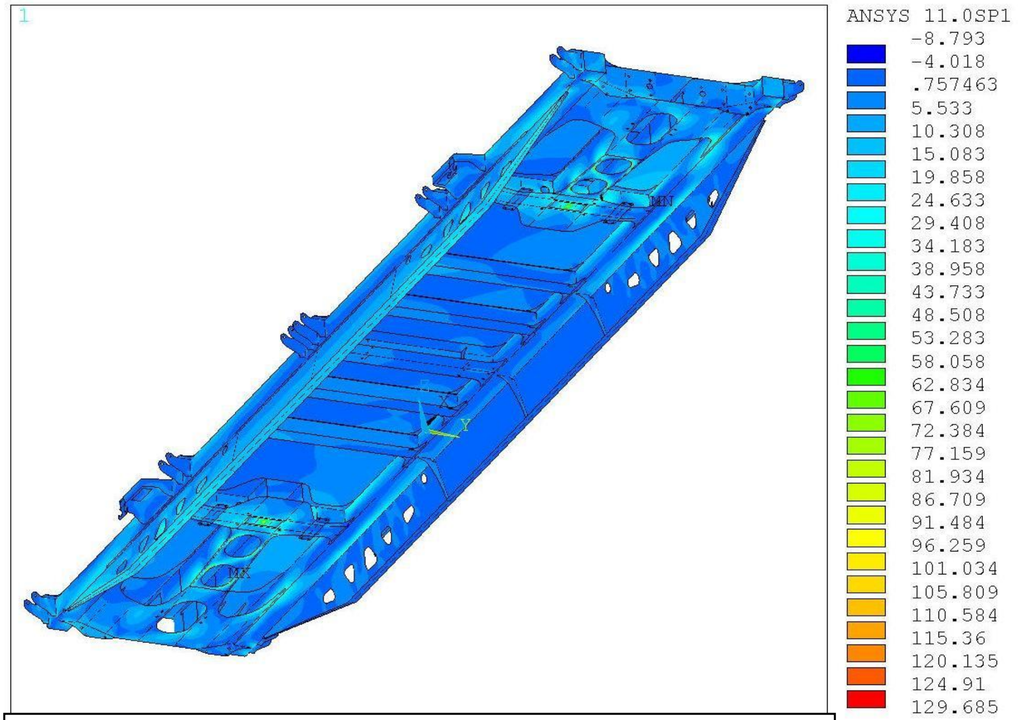


Figure 33: 40' flat wagon 0.4gy, 40' 36T

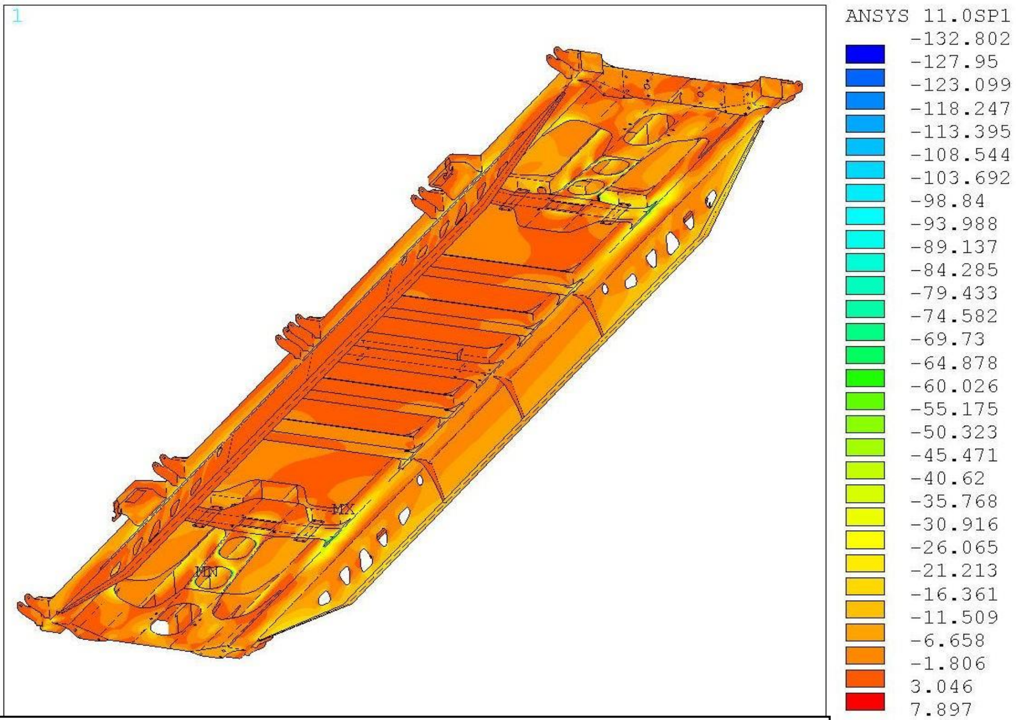


Figure 34: 40' flat wagon 0.4gy, 40' 36T

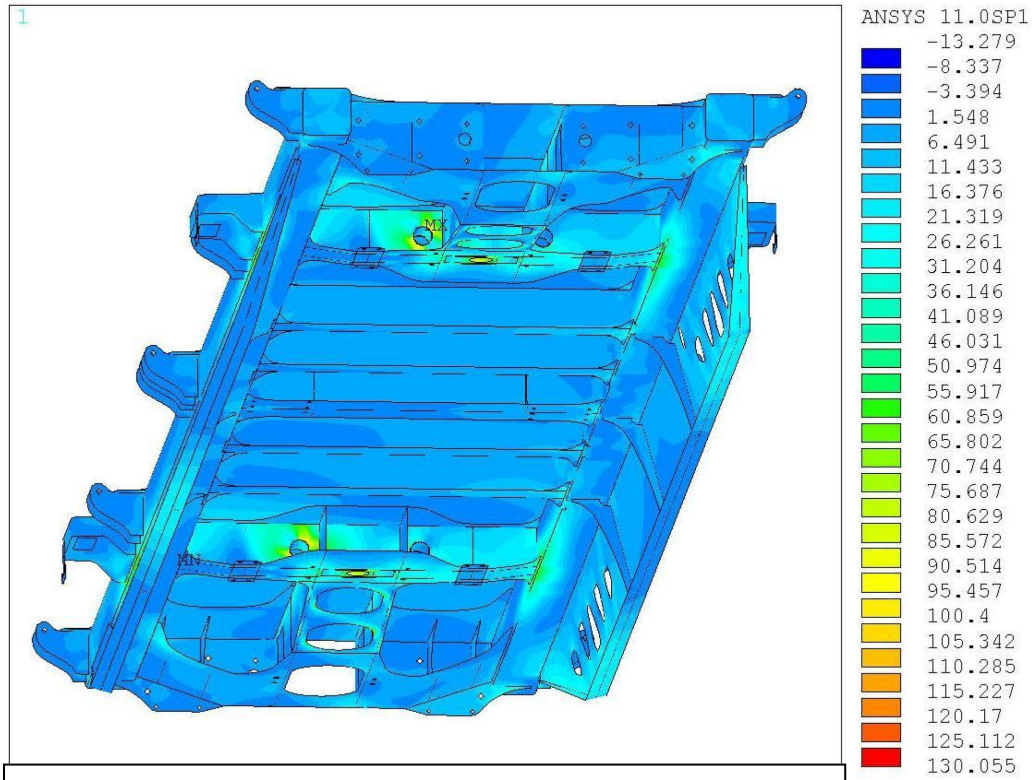


Figure 35: 40΄flat wagon 0.4gy, 2*20΄29T

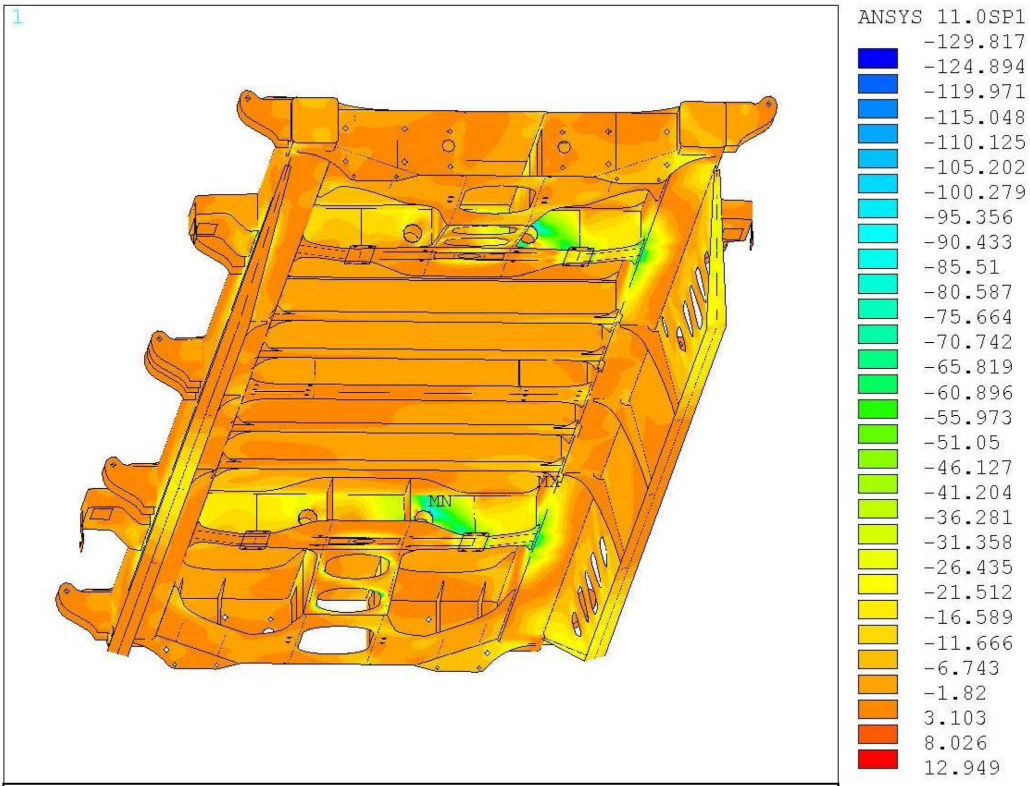


Figure 36: 40΄flat wagon 0.4gy, 2*20΄29T

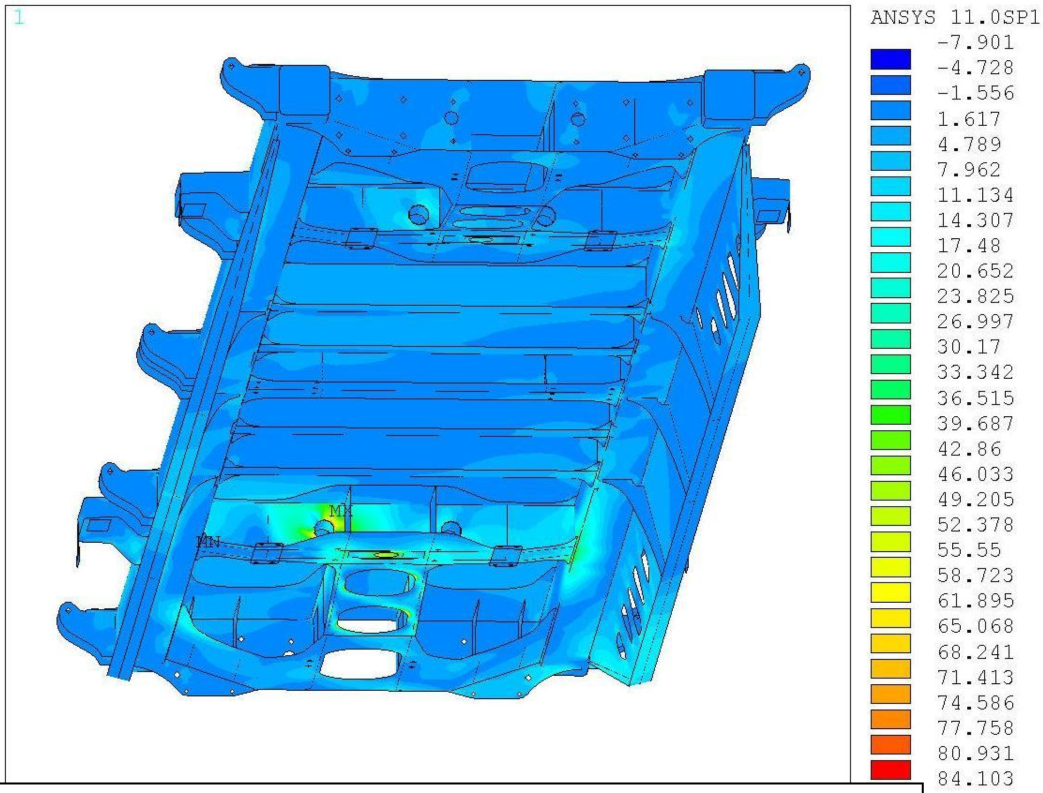


*Figure 37: 40΄ flat wagon 0.4gy, 1*20΄ asymmetric 22T*

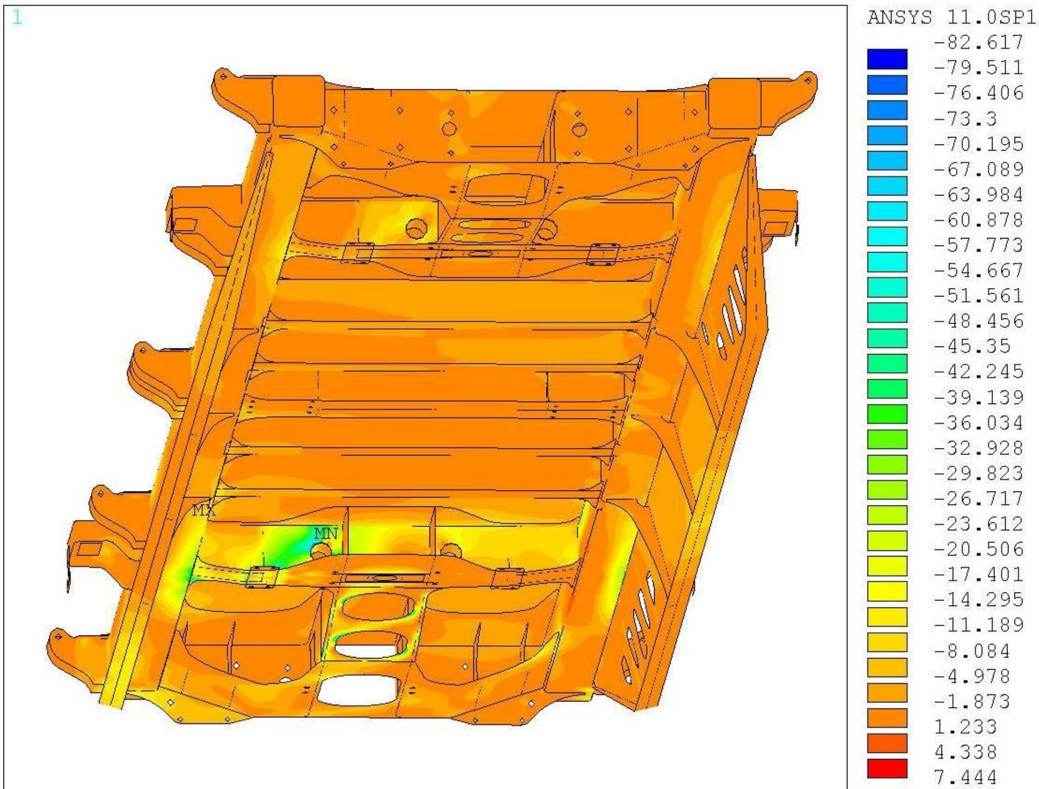


*Figure 38: 40΄ flat wagon 0.4gy, 1*20΄ asymmetric 22T*

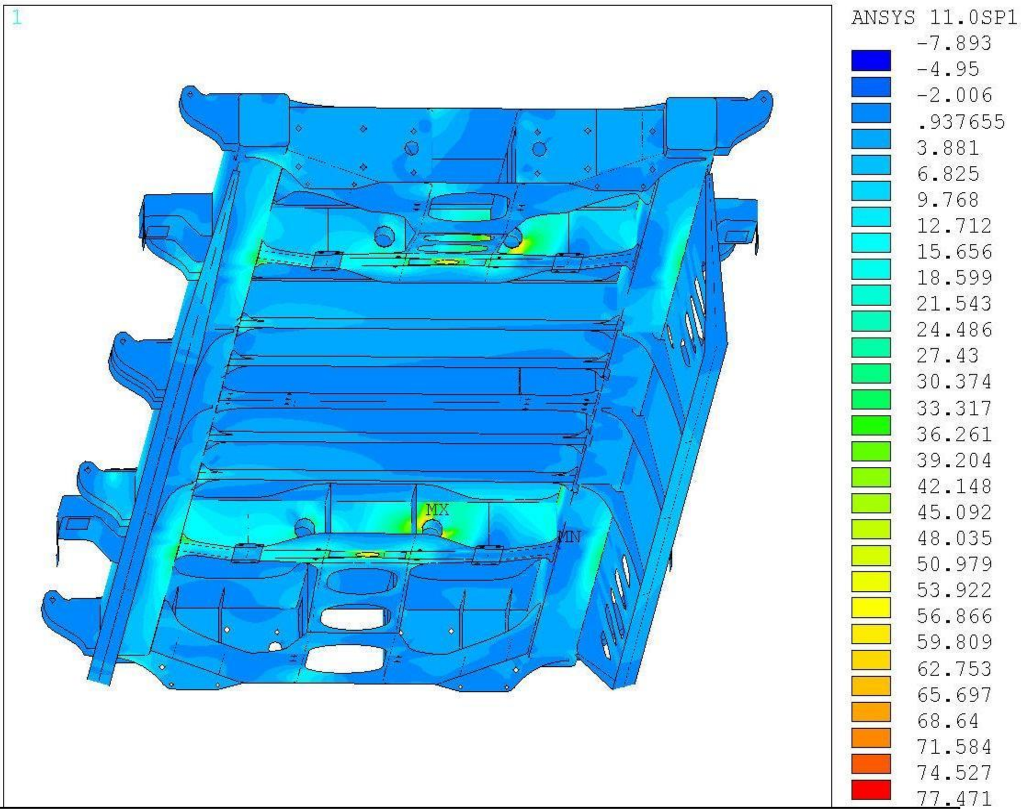


Figure 39: 40′ flat wagon 0.4gy. 1*40′ centered 36T

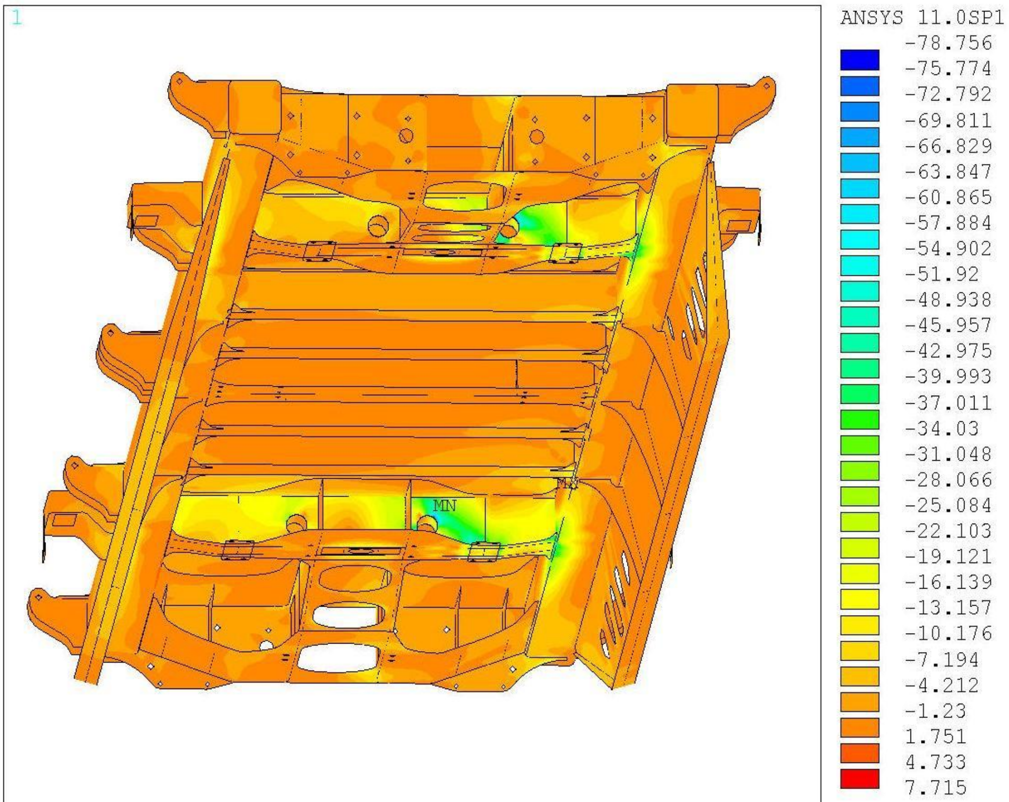


Figure 40: 40′ flat wagon 0.4gy, 1*40′ centered 36T

15. **Results and Discussion :**

In the first load case, we see a stress overrun of around 1.6 percent, which is insignificant, and the concentration zone is positioned near the application of the load, which has little physical significance. Furthermore, the rest of the structure's stresses are well within the permissible limits.

In the third load case, we see a stress overrun of around 2.5 percent which is likewise minimal; additionally, the stress concentration is at the free edge, which means there is no chance of cracking. It should also be noted that the force delivered to the structure is significantly greater than is typical for this type of vehicle.

16. **Future Scope :**

Apart from these tension and compression fatigue tests in future we should test bending and torsion tests as well for better understanding.

17. **Conclusion :**

The prototype of the 40' container wagon is ready to be constructed and pass the structural validation tests as is after completing the various calculations under test and fatigue loads.

To test the wagon bogies under static and dynamic loads, a standard testing setup and procedure are established. Any new prototype wagon bogie must pass this testing in order to be approved.

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