Design and Analysis of Railway Power Pack

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Abstract. This paper includes the designing of the Railway Power Pack used by the Container Corporation of India. The power packs when in motion are subjected to several forces and their failures have resulted in many casualties. The work starts with the designing of the Power Pack container, with all its major components so that weight of all the components can be applied during the analysis. The Analysis of the Power Pack is done using ANSYS Software. The two major analyses for the Power Pack are Frequency and Dynamic Analysis. Through the analysis result, the re-arranged mass distribution of the Power Pack components can be suggested and vibrations can be reduced to a certain level.

Keywords: Vibration · Power Pack · Frequency · Mode Shape · Natural Vibrations

1 Introduction

The Railway Power Pack [1] are used by the Container Corporation of India Ltd. in India at a large scale in the application of Refrigerated Containers. A good amount of extra electricity is required for the refrigerated container in comparison to the normal railway containers and this extra energy is produced by the power packs. The most common configuration of the power pack contains 2 Diesel Engines connected with DG sets individually. The Power of DG sets and change in their configuration, depends upon the power that is required for the refrigerated container trains.

Container Corporation of India Ltd. (hereinafter referred to as CONCOR) is operating many Container Terminals at different locations. The main activities of these terminals are to receive inward cargo in containers from other Terminals as well as to dispatch outward cargo in Containers to various destinations in India by Rail/Road. These cargos are stuffed/de-stuffed in containers either at the terminal itself or at the consignee's/consignor's premises. All the major Shipping Lines/Transporters/Freight Forwarders are operating from these Terminals.

It has been observed over a period of time that the Power Pack used by the CONCOR fails due to the vibration [2] that arise in the Power Packs during their operational periods and in the case when railway rides at higher speeds [3, 4]. For a conventional container fitted over the wagons [5] of the railway these vibrations are less as compared to configuration of diesel engines which are installed inside the Power Packs as containers.

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A lot of research has already been made to reduce the vibrations in the railway wagons [6–8]. But the vibration that arise due to the Diesel engine and its components placed inside the Power Pack are not taken into much consideration. The need of improvement to increase the level of comfort of the operator of Power Pack, operating in its cabin should be looked upon. Also, analyzing the vibrations that arise from within the Power Pack would help to improve the safety and life of Power Packs.

2 Materials and Methods

2.1 Material Selection

The Shipping containers are exposed to very tough weather conditions during their life cycle. These tough weather conditions include when they are in Ships and they even face storms in the oceans. They also face very extreme mechanical loads during the process of loading and unloading. So for this reason the shipping containers are made from a special material called CORTENA [9] Steel which is made from two words COR-which means corrosion and TENA- which means Tensile. This especially grade material for the making of shipping containers has very high resistance towards corrosion and also they have a very high tensile strength. The most commonly used material in the making of Shipping Containers is the grades of CR steel or CORTEN Steel. The Indian Railways uses a special grade of CORTEN steel which is named as IRSM 41–97 grade steel (Tables 1 and 2).

Table 1. Mechanical Properties of Weather Resistant Steel.

Weather Resistant Steel	Standard	Tensile Strength MPa	Yield Strength MPa	Elongation in 2 Inches (min.) %
CORTENA	US Steel	470-630	355	20
IRSM 41-97	Indian Railways	480 min	340 min	21
ASTM A 588	ASTM	485 min	345 min	21

Table 2. Chemical Properties of Weather Resistant Steel.

Weather resistant steel	C	Mn	P	S	Si	Cr	Ni	Mo	Cu
CORTENA	0.12	0.20-0.50	0.070-0.150	0.030	0.25-0.75	0.50-1.25	0.65	-	0.25–0.55
IRSM 41–97	0.10	0.25-0.45	0.075-0.112	0.030	0.28-0.72	0.35-0.49	0.20–0.49	-	0.30–0.39
ASTM A 588	0.20	0.75-1.30	0.04 MAX	0.050	0.15-0.50	0.30–0.50	0.50 MAX	-	0.20–0.40

2.2 Design of the Power Pack

The layout of the Power Pack with all its components is placed inside a 40 feet conventional Container. The Layout of the power pack contains 3 main sections and these sections have sub individual parts. The 2 main sections are DG Set Area with the Diesel Tank, and Operator's Cabin.

- **DG Set Area**

The DG Set area contains Engine Chassis, mounted using damping pads with the container. On the top of the Chassis the Engine and GENSET are mounted. In the 200 KVa Power Pack an engine of Cummins/Caterpillar/Volvo/Kirloskar [10] make, suitable for 200KVA GENSET, Turbocharged After cooled, Water cooled, electric starting, 1500 RPM, four strokes, multi-cylinder diesel engine conforming to BIS standards with 10% overloading for 01 h in any 12 h of continuous operation in standard operating conditions is used. The engine should be able to take 100% load without de-ration up to 50° Centigrade. The DG Set should comply with the latest CPCB norms.

- **Diesel Tank Area**

The diesel tank area have only two major components that are namely 2 diesel tanks and its mounting frame that attaches it to the container. The size of diesel tank is 3.5 x 1.1 x 0.7 m with a diesel storage capacity of 2290 L.

- **Distribution Panel**

The Distribution Panel is placed inside the operator cabin. Through distribution panel the operator can monitor and control the power supplies that are connected to the other containers. The distribution Panel has controls like MCB, MCCB, Volt meter, Amp Meter, and 42 output supplies.

- **Operator Cabin**

The operator Cabin area is allocated to the operator of the Power Pack who runs and operates power pack during its working cycle. The operator area needs to have a Toilet, Kitchen and a sleeping area also known as Bunk Bed for the operator. The operator Cabin also has very important element known as Distribution Panel through which the operator can turn on/off power supplies and Control most of the power distribution operations through it.

Layout of the Power Pack

The Power Pack is made out of a Standard 40 feet container used in shipping world globally. The Power Pack as compared to a standard container has been modified, so that it can easily adapt the changes such as sliding doors for engine compartment, door to access operator cabins, Windows for air ventilations, Cut outs for exhaust ventilations ducts and some other minor changes to use a standard container for Power Pack application. The container is divided in two major sub compartments, one for DG Sets and the other one for Operator cabin (Fig. 1).

The Compartment used for the Engine and its auxiliaries have a ratio of about 63% of the total space of the container. This compartments includes Chassis for engine which is made from Structural steel and mounted to the base of the container through rigid

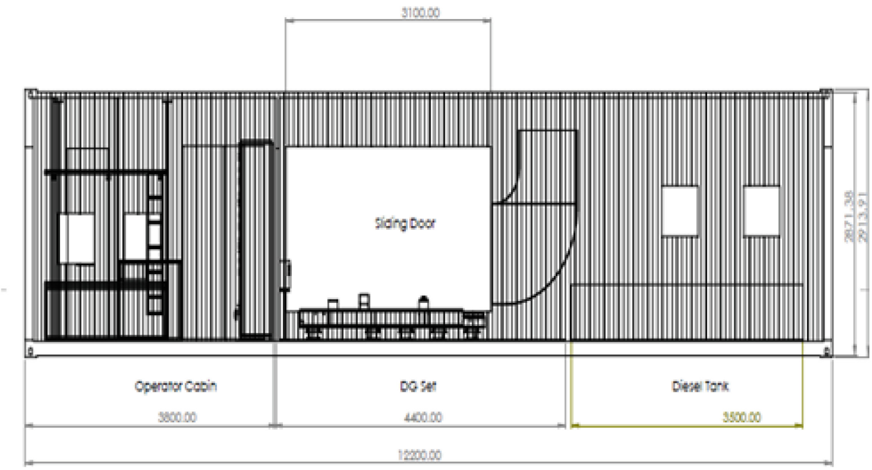

Fig. 1. Wire Frame Side View of Power Pack.

bolt connections. On this engine chassis the engine from Kirloskar and an alternator is mounted using AVM pads and bolted connections. Two such sets of DG sets are used in parallel configuration with a 200 KVA capacity of each. To take out the exhaust gases produced from the diesel engines, in the container, ducts are used. For easy access of maintaince and repair work required for diesel engine, on both sides of the container the sliding doors are provided and these sliding doors are enough in size so that the whole engine can be taken out of the container in case of complete engine replacement. Just next to the DG Sets, 2 Diesel tanks are placed with a dimension of 1.1 * 3.5 * 0.7 m. The Diesel tanks are mounted to the base of container using a frame which is welded to the container base.

The operator cabin consist of around 30% of the total area of the container. The main components in this compartment of the container are for the use of operator like Toilet, Kitchen, and Bunk Bed. And through this area the operator can control and monitor the power supply that is send to the other containers using Distribution Panel. The distribution panel gets the input supply from DG Sets using the Control Panel in the Engine compartment. The Distribution panel has 42 output lines which can used to provide power supply to the other containers (Fig. 2).

The components weight plays a very important role for simulation purpose and for this reason the weight of the components that contributes to a major part of the power pack were measured. The table shows the main components of the power pack, their quantity used and their weight.

2.3 Frequency Analysis of Power Pack in ANSYS

To address the main problem of vibration which occurs on the power pack it was decided to go with the model analysis simulation of the ANSYS software. Initially the CAD of the container which was designed in the SOLIDWORKS was transferred to the ANSYS using a Parasolid file format. To decrease the time required for simulation some additional

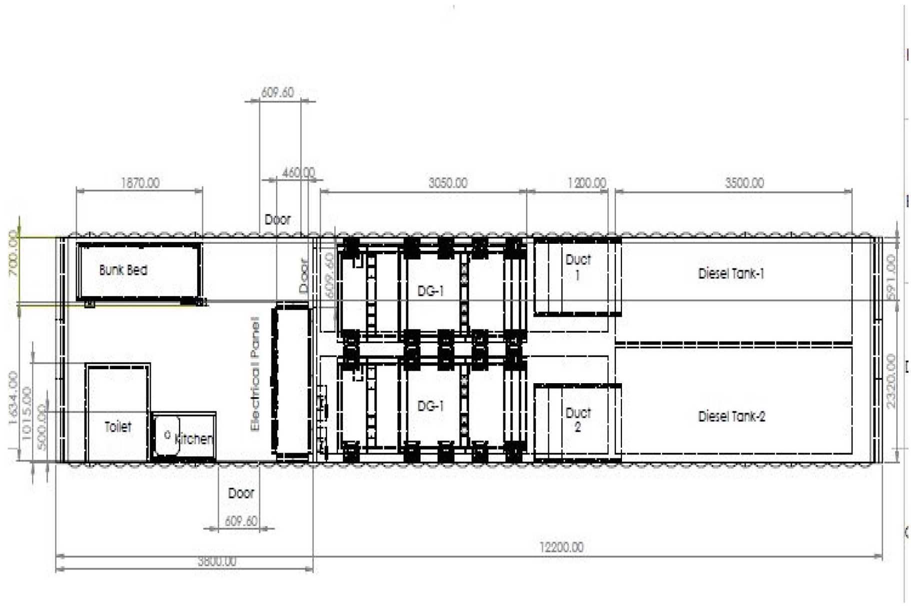

Fig. 2. Layout Plan of Power Pack with its Components.

Table 3. Weight of major components and Quantity used in Power Pack.

Component	Weight (KG)	Quantity
Material Engine Chassis	200	
Diesel Tank	1500 * 2 = 3000	2
DG SET	3400 * 2 = 6800	2
Distribution Panel	200	1
Kitchen	180	1
Bunk Bed	200	1
Toilet	200	1
Control Panel	80	2
Battery	45 * 4 = 180	4
Total Weight	10840	

features like wave patterns of the outside wall of the container were simplified to simple wall. Also an additional 1 mm extrude of the component layout was also included in the design just for the analysis purpose. This was done just to apply the distributed mass of the components at their exact location where they are placed inside in the Power Pack.

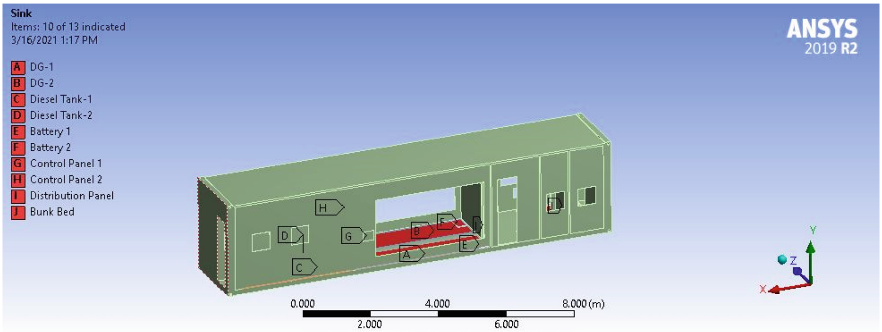

Fig. 3. Imported CAD model of the Power Pack in ANSYS Workbench.

The figure below shows all the components that are included in the imported design for adding the distributed mass and the simplified CAD model of the container (Fig. 3).

After Importing the CAD model of the Power Pack, the material data was defined in the Engineering section of ANSYS and the ASTM A 588 material mechanical properties were used to define the material properties. The distributed mass of individual components on the extruded layout was individually defined in the Geometry section of the ANSYS mechanical as per the Table 3. A very optimistic mesh was created with 18229 nodes and 7576 elements.

3 Results and Discussing

3.1 Model Analysis of Power Pack

As per knowledge obtained by doing research on the vibration analysis of railway wagons it was found that most of the failures occur at lower frequency and with this in mind the exciting frequency till 50 Hz were taken into consideration. Six modes shapes were obtained for Power Pack which were starting from 18.473 Hz and going up to 50.159 Hz. By closely understanding the different mode shapes of the power pack it was analyzed how these excitation vibration can occur in actual world (Table 4).

Table 4. Modes shapes at different frequencies.

Mode Shape	Frequency [Hz]
1.	18.473
2.	21.532
3.	37.664
4.	41.586
5.	46.52
6.	50.159

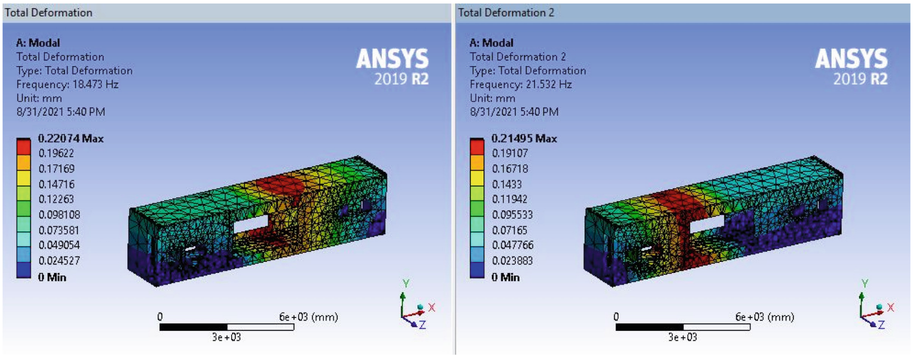

Fig. 4. Mode Shape 1 and 2.

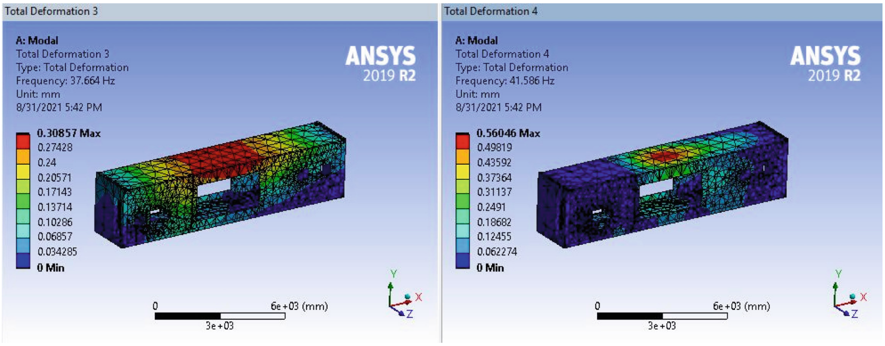

Fig. 5. Mode Shape3 and 4.

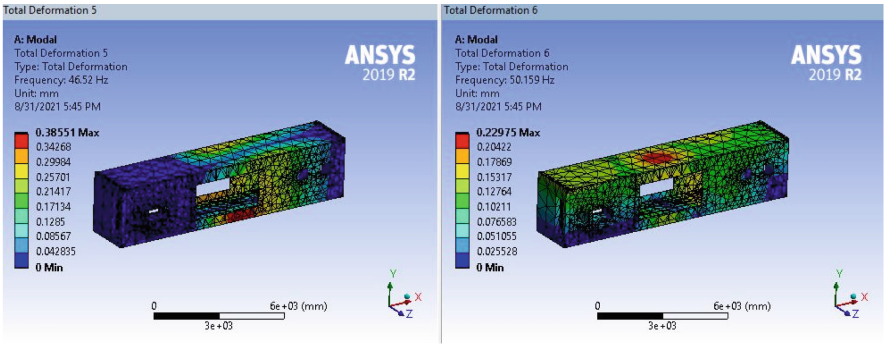

Fig. 6. Mode Shape 5 and 6.

From analyzing all the mode shapes of the power pack some major common points of excitation vibration were taken into account and found to have some common regions among different mode shapes. The common possible regions of failure are upper wall of container at the top of DG SETs, Bottom of Engine Chassis, Corner points around

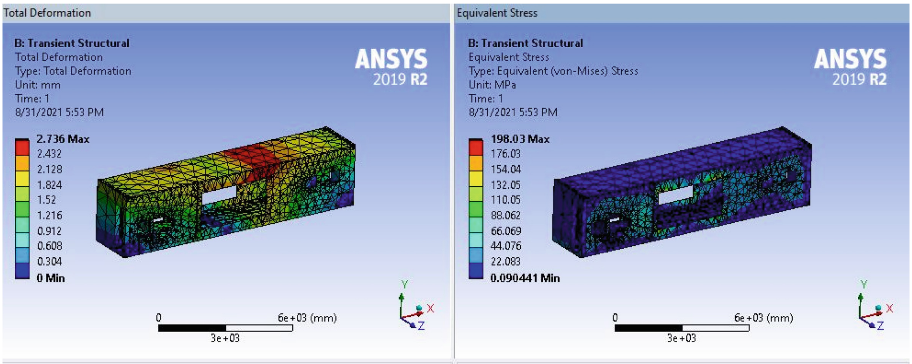

Fig. 7. Total Deformation and Von-Mises Stress obtained during Transient Structural Analysis.

the walls of sliding doors, also region of distribution panel in the operator cabin (Fig. 4, 5 and 6).

3.2 Transient Structural Analysis of Power Pack

In reality, the failures inside the Power Packs also occur due to high accelerations and decelerations of the container when the rail is accelerating condition. The acceleration some time also shifts the mass, and due to high masses of the components like Diesel Engine, Gen Sets, Diesel Tank etc. the mass transfer results in breaking of the smaller mounting components. The Modal analysis of the Power Pack were linked with Transient Structural Analysis and inside the ANSYS and an acceleration of 2 m/s^2 was provided. The acceleration of the 2 m/s^2 was taken as an extreme acceleration compared to normal train acceleration. The results showed that a deformation of 2.73 mm was obtained in the region above the sliding doors of the Power Pack. Also, a Maximum of 198.03 MPa Von Mises stresses were generated in the region around the Sliding door's, Window and doors of the operator cabin (Fig. 7).

4 Conclusion

1. The upper wall of container at the top of DG SETs are found to generate natural vibration and this region was common in many mode shapes. The vibration in this region can be reduced by providing support Structural Members with the help of side walls. By providing the extra cross member on the top of container in the region above DG sets, the total deformation seen in the Transient Structural analysis will fall under the safer limits.
2. The Diesel Tank and Engine Chassis regions were also found to generate natural vibration and this can reduced by not connecting these components rigidly to the base of the container and should rather be connected those using AVM Pads or any other flexible type of connection that could take up the vibrations. The AVM Pads or Kush Pads should also be provided on the sides of the Diesel tank so that it can also take up the vibrations that arise from the side wards of the diesel tank.

3. The region around the sliding door was also found to have natural frequency peeks in many mode shapes. And this can reduced by adding extra sheet of metal around the corners of the sliding door and connecting with U structural member that connects the top, bottom and sliding door of the container.

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