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Design and analysis of cleaning system for railcar wheels before reprofiling

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Abstract
Railcar wheels get worn out after its life period and it is necessary to reprofile it to the next lower workable dimension to use it again. For this the Indian Railway transfers damaged wheels for reprofiling to different industries. HMT is one among this; where a heavy-duty CNC reprofiling lathe is used for this purpose. Usually these railcar wheels often get accumulated with grime due to its frequent interaction with the outside environment. The present work focuses on designing a fully automatic system for facilitating the cleaning operation. The cleaning process works-out in for different stages like chlorine wash (First stage, degreaser wash, chlorine wash (Second stage) and air drying. The rail car wheel moves under the action of gravity and this motion is controlled by brakes. Separate storage tanks are provided for the storage of chlorine solution and degreaser. The chlorine wash and degreaser washes are done using pressurized Vee-jet Flat nozzles. The wheel then moves to an air-drying chamber to remove moisture. During the cleaning process, waste water flows through the drainage system provided. Railcar wheel after cleaning can be loaded to the CNC machine for the reprofiling process.

Keywords: Hydroblasting, cleaning, reprofiling, railcar wheel

1. Introduction
A train wheel or rail wheel is a type of wheel specially designed for use on rail tracks. A rolling component is typically pressed onto an axle and mounted directly on a rail car or locomotive or indirectly on a bogie. Wheels are cast or forged and are heat-treated to have a specific hardness. New wheels are trued, using a lathe, to a specific profile before being pressed onto an axle. Most train wheels have a conical geometry, which is the primary means of keeping the train's motion aligned with the track. Train wheels have a flange on one side to keep the wheels, and hence the train, running on the rails when the limits of the geometry-based alignment are reached.

The most usual cause of damage is drag braking on severe gradients. Because the brake blocks apply directly on the tire, it is heated up, relaxing the interference fit. It is not feasible to fit the tire with such a heavy interference as to eliminate this risk entirely, and the retaining ring will ensure that the tire can only rotate on the wheel centre, maintaining its alignment. In rare instances the rotation could be so severe as to wear the retaining ring down till it breaks, which could result in derailment.

Severe braking or low adhesion may stop the rotation of the wheels while the vehicle is still moving, which can cause a flat spot on the tire and localized heat damage to the tire material. Tires are reasonably thick, about 3 inches (76 mm), giving plenty of room for wear.

Worn tires or tires with flats are re-profiled on a wheel lathe if there is sufficient thickness of material remaining. An essential ingredient in the successful running of a railway is a well-maintained system. Railways are made up of complex mechanical and electrical systems and there are hundreds of thousands of moving parts.

If a railway service is to be reliable and safe, the equipment must be kept in good working order and regular maintenance is the essential ingredient to achieve this. A railway will not survive for long as a viable operation if it is allowed to deteriorate and become unsafe because of lack of maintenance. Although maintenance is expensive, it will become more expensive to replace the failing equipment early in its life because maintenance has been neglected.

Railcar wheel lathes can also reprofile a wheelset which has been removed from the train. Otherwise a separate wheel turning facility has to be provided in the workshop. Cutting has stocked for a very long time may not be suitable for direct reprofiling, so it is an essential need for having a cleaning process just before the railcar wheel lathe.

2. Concepts-design
Cleaning machinery and other related equipment were some of the basic things man had achieved at the industrial age. Usually all the cleaning mechanisms were rooted on those bedrocks. Some of the present scenario cleaning mechanisms are mentioned below.

- Hydroblasting
- Acid pickling
- Hydro wash using brush
- Hydro wash using detergents
- Enzyme solution

A. Hydroblasting
Hydroblasting is a technique for cleaning internal and external surfaces, which relies entirely on the sheer force of water from a pressurized source to achieve the desired cleaning effect on the intended surface. A highly pressurized and focused stream of water, generally above 10,000 psi, comes from a hydro blasting machine, which includes a pressure pump and the right nozzles.

B. Acid pickling
Pickling is a method of preparing metal surfaces by chemical reaction, electrolysis, or both. In pickling, rust and scales are removed by chemical reactions with mineral acids and with certain alkaline materials. Various acids used in commercial pickling include sulfuric, hydrochloric or muriatic, nitric, hydrofluoric, and phosphoric acid, and mixtures of these can be used as well.
Pickling is considered a desirable method of removing rust and mill scale from structural shapes, beams, and plates in workshops when the cost of such removal is felt to be justified.

C. Hydrowash using brush
This method is primarily used in order to wash automobiles and other equipment like that. The basic procedure for hydro wash using brush is as follows. The equipment is passed on through a passage of any sort and usually the equipment is fixed and if in case of a car wash the vehicle is geared to neutral and made to pass through the conveyor.
The detergents or cleansing agents are pre-applied and the equipment is set in the track to pass through them and we get our cleansed system at the end of the path. Usually there is a pre-set guide way through which the equipment moves and along this path the brushes help in the cleaning of the outer parts and nowadays even inner sections are cleaned through this procedure.

D. Hydrowash using detergents
Usually called "touchless" washes, were developed as an alternative wash using brushes. During the friction zone of a conveyorized wash, a touchless car wash forgoes brushes and uses high water pressure plus chemicals to clean the vehicle which minimizes the chance of surface damage to the vehicle. There are five primary factors to cleaning a vehicle successfully using a touchless system. These five factors are water quality, water temperature, chemistry, time, and water pressure generated by the equipment. If these factors are all set properly, machinery will come out clean and shiny without the chance of damage caused by brushes.

E. Enzyme solution
Enzyme solutions are live solutions formulated using strains of safe, natural bacteria along with specifically selected enzymes. Both bacteria and enzymes work together to clean, relying on each other to get the job done. When applied to surfaces, soils, stains and malodours are broken down by the enzymes, then consumed by the bacteria. As long as soil is present and surfaces are sufficiently damp, these microscopic “cleaners” multiply, continuing to remove traces of grime and odour from surfaces hours or even days after the initial application.

3. Conveyance of wheel
Rather than a conventional equipment usually undergoing cleaning process a railcar wheel is its entirety a complex equipment to be transported along its process the few possible ways it could be transported along the entire process are through:

- Rails
- Hydraulic cylinder lift
- Conveyor belt

A. Rails
The best suited mechanism for motion of the railcar wheel during cleaning mechanism is through rails. This is because if the rails are given a small degree of slope, the wheel can roll down by itself under the action of gravity. This would reduce complexity of motion and only an additional stopping or braking mechanism is needed. The breaking mechanism is given by lifting the end of the rail at the lower side of the slope using a pneumatic system. Since the pneumatic system alone can’t lift the rail, a compression spring is also given along the piston which is in contact with the rail and they raise the rail together to stop the wheel. Since the wheel rolls down at very low velocity, this mechanism is sufficient to raise the lower end of the rails and to stop the wheel.

B. Hydraulic cylinder lift
Hydraulic Cylinder Lift method focuses on using separate hydraulic cylinder lifts inside each tank and dipping the railcar wheel into it at every stage of the process. This is most suitable for acid pickling process as splashing needs to be reduced to minimum. But getting this idea into practice requires a huge amount of cost and leak proofing as the hydraulic lift comes inside the tank and chances for getting a leak or corrosion of the cylinder are very high. Above all, this requires a separate hydraulic system for the operation of the lift itself. Hence, this method comes as a part of acid pickling and will only be adopted if such intensive cleaning is necessary.

C. Conveyor belt
Conveyor belt method does the transportation by locking the wheel onto a conveyor and moving it along the desired path of the cleaning process. The method is suitable for lighter components, but when it comes to the railcar wheel, which weighs three tonnes, designing a conveyor that can work effectively under such heavy loads is difficult. Hence, conveyor system is more practical than the hydraulic cylinder lift mechanism but less plausible than using rails

which are placed at a slope. Hence, we selected rails placed at a small degree of slope (Which moves under the action of gravity), as our method of moving the railcar wheel for cleaning.

4. Design comparison

The comparison between different cleaning processes is shown in the table below:

Table 1: Comparison of cleaning methods

Processes	Degree of Cleaning	Cost	Feasibility	Maintenance	Automation
Hydroblasting	High	Average	High	Low	Possible
Acid Pickling	High	Average	Low	High	Difficult
Hydro Wash with Brushes	Average	Average	High	Average	Possible
Hydro Wash with Detergents	Average	Low	High	Low	Possible
Enzyme Solution	Low	High	Low	Average	Difficult

The comparison between different methods of motion of the railcar wheel is given in the table below:

Table 2: Comparison of methods to move wheel

Methods	Ease of Operation	Cost	Feasibility	Maintenance	Automation
Rails	Easy	Low	High	Low	Possible
Hydraulic Cylinder Lift	Difficult	High	Low	High	Possible
Conveyor Belt	Difficult	Average	Low	Low	Possible

From the table 1 it is clear that hydroblasting could be the best process to clean the railcar wheels. Considering the design considerations, we have mentioned at the introduction hydroblasting process could easily cover the requirement within the provided constraints like economics, practicality and the ease of operation.

From the table 2 it is clear that out of the various conveyance listed the rails are the best as far as the constraints like cost, feasibility and maintenance is considered.

5. Cleaning system

As we have discussed in the above section, we have chosen the hydroblasting system in association with rail guided conveyance method for the rail car wheels. As the railcar wheel with the help of an overhead crane is placed on the rails which is bolted on the rail bed. The rail beds are usually concrete structures which transfers the entire load of the machinery to the ground. The rail beds are designed such that the velocity acquired by the wheel is as slow as possible. The calculation of the railcar wheel is mentioned below along the next section. We are assuming a no slip case for the motion of wheels on the rail.

As we place the railcar wheel on the rail the wheel starts rolling with a very small velocity such that it acquires a momentum as it reaches the break point, almost negligible to ignore. Since the momentum is negligible the situation can be assumed to be a static situation where a mass is being obstructed by the rail section. We are using a rail section for the braking in order to control the motion of the railcar wheels. The rail is cut at the end for a distance of 50 cm. This rail section is directed up and down using a pneumatic system which will be elaborately discussed on the next section. The wheel goes straight to the blower after the pneumatic cylinder releases its effort.

A compression spring is being used which acts as a medium to transfer the load from the wheels to the rail bed which will in turn be transferred to the ground. The spring also drastically reduce the load being transferred to the cylinder.

A hydroblasting system is used for the cleaning of the wheels. There are three sections for the effective cleaning of the rail car wheels. Namely the hydroblasting system consists of three different sections.

- Chlorine wash at the beginning
- Rinsing using Degreaser
- Final Chlorine wash

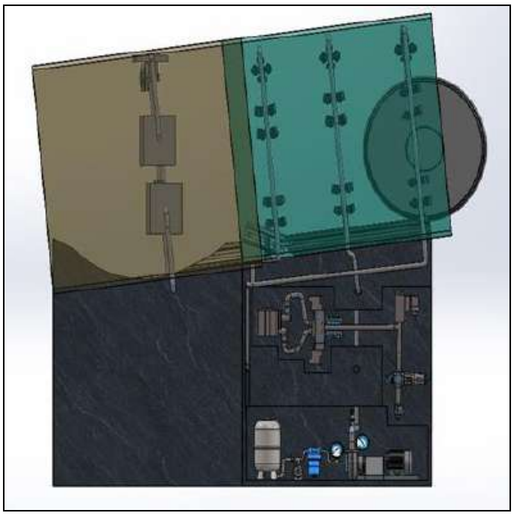

Fig 1: Cleaning system (Side View)

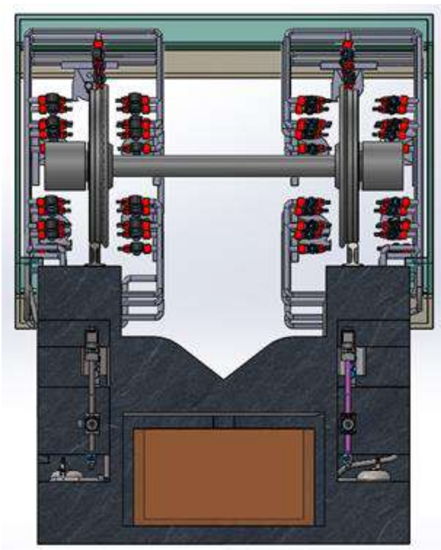

Fig 2: Cleaning system (End View)

6. Calculation

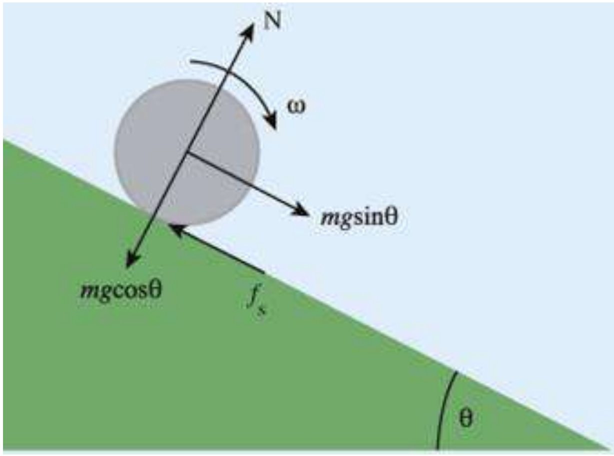

Fig 3: Free body diagram of wheel

Linear acceleration, $a = \alpha R$

Torque on the wheel will be

$$\tau = I\alpha = f_s R$$

So,

$$f_s = \frac{I\alpha}{R} = \frac{Ia}{R^2}$$

Also, we can see that

$$mgSin\theta - f_s = ma$$

Fig 4: Equations used

Radius (R)	= 570mm
Mass (m)	= 2735.84 Kg
Density	= 7700 kg/m^3 (steel)
Time of Process	= 90 sec
Distance of travel	= 181 cm
Velocity (v)	= 0.0211 m/s
Acceleration (a)	= 2.3x 10---------$^{-4}$ m/s^2
$I=I_{zz}$	= 4186.85 Kg m^2
θ	= 0.733^0

7. Hydro blasting

Hydro blasting or water blasting can effectively remove a wide variety of tough dirt in difficult-to-reach points or locations in a safe and efficient manner. In fact, the results are comparable to those of cleaning techniques that use abrasives and cleaning agents, but without the dust and other health hazards, which allows the workers to focus on their daily tasks in a health-friendly workplace environment. This cleaning method uses a variety of pressures, ranging between 10,000 to 40,000 psi, at a rate of 10 to 50 gpm. Ultra-high-pressure (36,000 to 40,000 psi) equipment is also used where needed. Automated and semi-robotic systems improve efficiency in certain applications and can be used to clean limited- or difficult-access areas. These automated systems also help to minimize operator exposure to high pressure water. Specialized systems are available to clean heat exchanger bundles (both shell-side and tube-side), boilers, suction rolls, air heaters and other process equipment

Fig 5: Hydro blasting

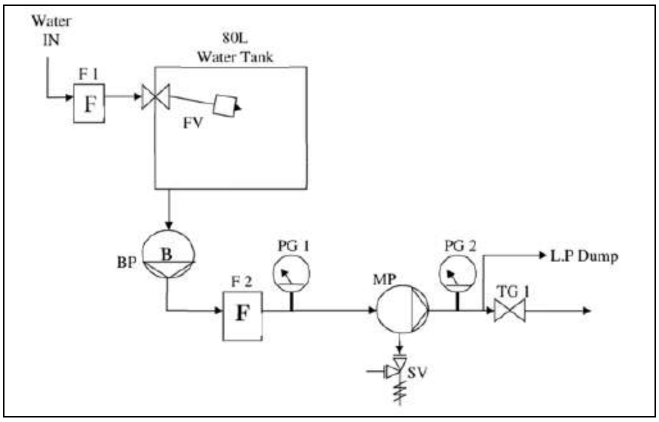

Fig 5: Hydro blast Circuit

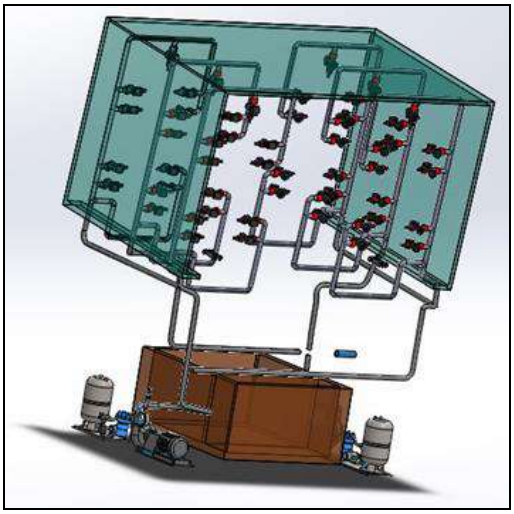

Fig 6: Hydro blast System

A 25 HP, 30kW, 1000 rpm motor is used in the circuit. The safety valve is set 20 – 30 bar pressure above PG 2. Working pressures come close to 250 bar and hoses used to support the flow of water has a capacity of 500 bar or above. Flow capacity is 5.3gpm or 20 liter/min. Power required to operate the hydraulic system is 415V 50Hz.

7.1 Nozzle

Veejet Flat spray nozzle is used in all the three stages as they have wider length of cleaning and as the wheel rolls, complete cleaning can be done with minimum rotation of the wheel. Flat sprays also make sure that the wheel surface doesn't get damaged due to the high-pressure water.

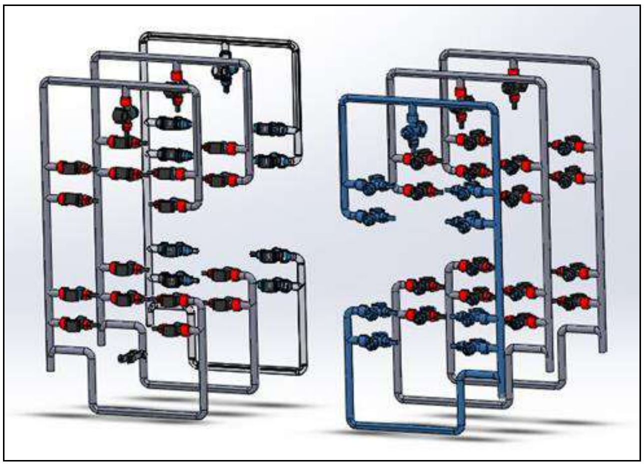

Fig 7: Nozzle system

Calculations

θ = 120°

Considering the cone of the spray produced

Time travel for the process	= 90sec
Angle of spray	= 120 deg
Distance for nozzle to wheel	= 25cm
Slant height	= 50cm
Distance covered by spray = 2 x 50 sin 60	= 88cm
So total no of nozzle to be used for one face	= 3 Nos
No of nozzle at the top	= 1 No
Total no of nozzle for one side of the wheel	= 7

(For both sides a wheel has 14 number of nozzles for chlorine wash)

7.2 Tank

Capacity of chlorine wash tank	= 1000 L
Capacity of degreaser solution tank	= 500 L

As per the nozzle selected

Amount of water per minute	= 0.88 L

For a single process to take place time required is one minute for chlorine wash and 30 seconds for the degreasing process to take place.

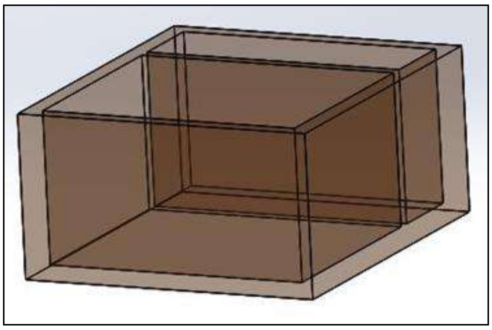

Fig 8: Tank

No of nozzle for chlorine wash	= 28
No of nozzle for degreasing process	= 14

Amount of water for chlorine wash = 28 x 0.88 = 24.64 L

Amount of degreasing solution = 14 x 0.88 x 0.5 = 6.14 L

No of wheels can be washed from one full fill of chlorine tank = 1000 / 24.64 = 40.58 ~ 40 wheels

No of wheels can be washed from one full fill of degreasing tank = 500 / 6.14 = 81.43 ~ 81 wheels

For a single fill of chlorine tank, we can wash 40 wheels at the same time a single fill of degreasing solution can fill up to 81 wheels

7.3 Drainage system

The high-pressure washing process of the railcar wheels takes place inside a closed cabin. Hence no water or dirt is splashed out to the surroundings. The waste water left out after the cleaning process is carefully drained out through the wedge-shaped portion on the basement to a wastewater collection tank in the shop floor and finally taken out and released to waste outlet. Since the drainage system is designed along with the slope of the basement, the wastewater can automatically flow down under the action of gravity.

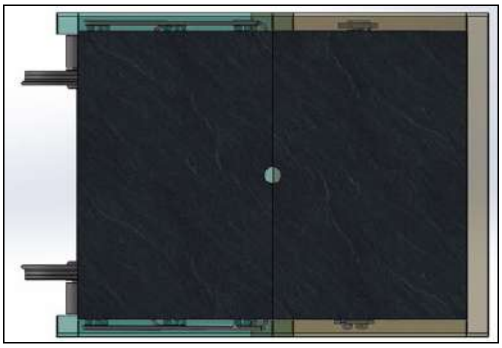

Fig 9: Drainage system

7.4 Pneumatic system

Pneumatic systems used in industry are commonly powered by compressed air or compressed inert gases. A centrally located and electrically powered compressor powers cylinders, air motors, and other pneumatic devices. A pneumatic system controlled through manual or automatic solenoid valves is selected when it provides a lower cost, more flexible, or safer alternative to electric motors and actuators.

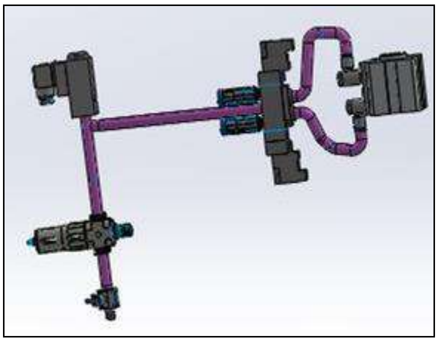

Fig 10: Pneumatic system diagram

Pneumatic system works for raising up the rails using pneumatic power at a high speed intermittently as programmed to stop the wheels. The raised rail blocks the wheel motion after second chlorine wash. As the next wheel starts the rail moves downward and allows the wheel to continue further motion. The overall weight component of the wheel transfers to the basement and the rest partially dampened by a high stiffness spring. Thus, save the cylinder from subjecting to high impact load and corresponding failures.

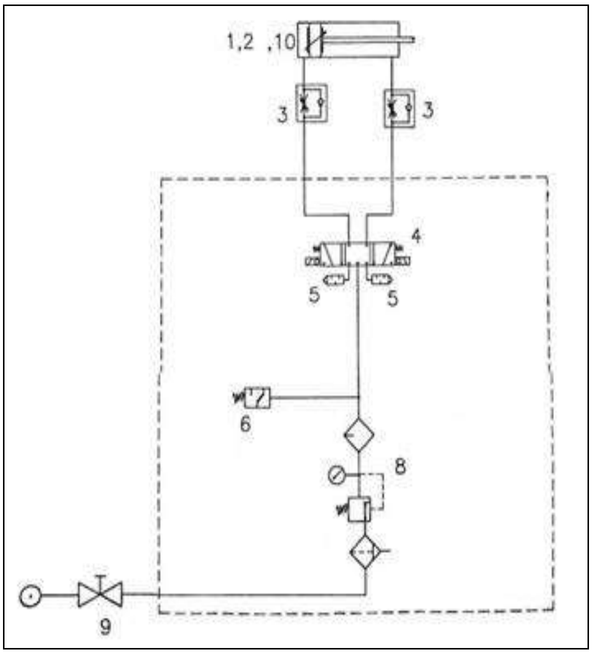

Fig 11: Pneumatic system circuit

Spring Constant
F= kg.
k = spring constant
x = maximum displacement due to the load = 50cm
Force = F = 2793.56 N
k = 5587.12 N/m
Hence, a compressive spring must be chosen
The outer diameter of the spring must be 50 mm and the inner diameter 25mm as from the figure in order or cover the cylinder piston rod.

7.5 Air dryer or blower

An air dryer is a machine used for generating flow of air at substantial pressure. The air flow generated is used for different purposes such as small car cleaning blowers, vacuum cleaners, air conditions etc. A group of arranged air dryer chamber placed at specific locations wipe out the existing water content from the railcar wheel surface. All surfaces are targeted dried so that later corrosion due to water presence can be avoided. As the wheel reprofiling may delay up to certain days so the wheels are more likely to get corroded. An air dryer is an apt solution for corrosion resistance of the wheels which can be a temporary solution.

Fig 12: Dryer sample for cars

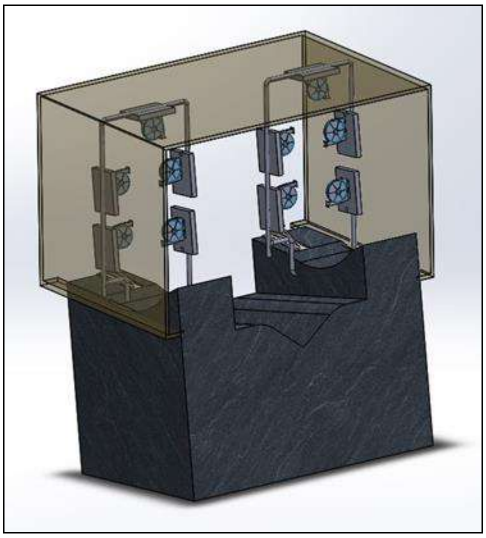

Fig 13: Dryer system

8. Conclusion and future scope

The present design was made by keeping two major factors in mind, like the ultimate effectiveness of the system in removing the dirt from the wheel in an efficient manner and the easiness of implementing the design to fabricate the actual system. Two factors were majorly considered while analyzing the effectiveness like reduction in energy consumption and processing time.

It is believed that designing is an iterative process and it requires modification. We have gone with this design for various ride of iteration and could possibly able to design a well refined system.

Future scopes of the system include in providing a mobilised nozzle system which could perform the hydro blasting process. And it is possible that the railcar wheel could be made stationery and the nozzle movement helps in cleaning.

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