Mechanization of Wagon Cleaning process on Vitoria a Minas Railroad

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ABSTRACT: Gondola type wagons are loaded with iron ore in mine to port direction and can carry other products, like coal, in the reverse direction. Due to humidity and vibration the compaction of the iron ore is common. After the wagons pass through the dumper some residual iron ore will still be trapped in the bottom or on the sides of the wagons. These residues were removed by hand where humans entered inside the wagons and removed this material using picks and shovels. This was a slow and unhealthy operation, and at high cost, given that it was performed by a third part contractor. In order to reduce costs, eliminate manual removal and improve working conditions, equipment was developed to perform mechanized cleaning of wagons. In a pioneering project, Vale and the equipment supplier developed a unique machine in the world to run this type of activity. One year after the implementation of equipment, the manual activity was eliminated, the equipment production meets (and even surpasses) the need, all materials (iron ore) which is taken from the wagons is reused, working conditions and health were improved and costs were reduced.

1 INTRODUCTION

The Vitória-Minas Railroad (EFVM – Estrada de Ferro Vitória a Minas) mainly transports the iron ore from the mines of Minas Gerais state to the city of Vitória, where Vale's export port (Tubarão Port) is located in the southeast of Brazil.

This project began in 2011 and at that time consisted of 25 trains dedicated to the transportation of iron ore per day. Eight of these trains were dedicated to transportation of mineral coal from the port to the steel making companies of Minas Gerais state when traveling in the reverse direction.

As the wagons carried iron ore to the port and has to return carrying coal, the cleaning of the wagons was needed, else one product could contaminate the other. Thus a need arose for a process for cleaning these wagons.

The motivation of this project was to mechanize the cleaning of gondola type iron ore wagons. Before mechanization the cleaning was a manual and slow task performed in unsatisfactory ergonomics conditions. Employees were exposed to work at heights, exposed to the sun light, noise and fines (dust) of iron ore and coal. In addition to all these labor concerns there was also the economic factor, given that this task was performed by an outsourced company, which added additional contract costs.

The justification of this project was the development of equipment capable of mechanically performing the task of cleaning wagons in order to mitigate labor and economic conditions presented in the previous paragraph.

The relevance of the project was the fact that the development of equipment capable of performing a task in a mechanized way could generate labor and economic benefits for the company which led to other gains, such as:

- Applicability after the car-dumpers line, using 100% of the material transported and eliminating the dead weight;
- Increased energy efficiency, since the trains are not transporting dead weight in the unloaded wagons.

2. PROCESS OF WAGON CLEANING

At the time of the implementation of this project (2011/2012), the cleaning of wagons was done manually which was a degrading and unhealthy activity. The possibility of implementing the mechanization of the process was realized, aiming to increase the productivity of the activity as well as the working conditions.

2.1 Manual cleaning

Prior to the mechanization of the process, wagon cleaning was a manual activity. The task was carried out by an outsourced company, in an inappropriate place (open-air), with unsatisfactory ergonomic conditions and high generation of iron ore and coal dust. This activity was carried out in the Tubarão Port in Vitória.

Briefly describing the task, the employee of the outsourced company had to climb into the wagon and perform the cleaning using shovels, hoes and picks. Figure 1 and 2 help us to understand the process.

Figure 1. Wagon cleaning process

Figure 1 helps us to visualize the manual wagon cleaning process. The first photo (upper left) shows the GDE type wagon (gondola type). Access to the interior of the wagon is performed using the side ladder at the ends of the wagons. The second photo (upper right) shows the interior of a wagon in rainy seasons with a high volume of material to be removed resulting in slow task completion. The third photo (bottom left) shows the employee performing the cleaning of the wagons using shovels, this image gives us a sense of how slow the task was. The last photo (bottom right) shows us the place of work after the end of the wagon cleaning, where there was high contamination of the ballast and also mineral waste scattered along a long stretch of the cleaning yard.

Figure 2 details the working condition which the employees were subjected to, where the cleaning of the wagons was performed manually by using shovels.

Figure 2. Manual wagon cleaning – using shovels

2.2 Mechanization reasons

Luz & Kuiawinsk (2006) define mechanization as the use of a machine to replace a work done by man or animals. In the case of mechanization, there is no concern about passing on the "intelligence" of man to the machines. Current industries have gradually thrived in the activity of mechanizing their activities aiming at reducing costs, increasing operational safety and process productivity.

As we saw in Figure 2, the activity was performed slowly, in the open, under unsatisfactory ergonomic conditions. In order to increase the productivity of the process, improve the working conditions of the teams and also reduce the costs of third-party contracts, the need for mechanization of the process arose.

Another goal that could be met with the mechanization of the process was the synchronization of the process of cleaning with the task of loading of coal, in the lines of the coal silos. This would be possible because the equipment should have a production rate that was quicker than the loading task at the silos. In that way the wagons could leave the car-dumpers and go directly to the coal loading line, where they would be mechanically cleaned and thereafter they would be loaded.

After the maturation of the process, with the control of the technology by Vale and also with the guarantee of the reliability of the equipment, they could be allocated after the car-dumpers line. This repositioning could result in the reuse 100% of the iron ore transported throughout the EFVM, eliminating dead weight. This will be the next step of the project, not initialized yet.

2.3 Project idealization

In 2010, Vale had acquired new equipment called a "ballast vacuum cleaner". This equipment consists of two diesel engines, with a vacuum pump connected to each engine. These pumps generates negative air flow (vacuum), and then suck the rail ballast to be cleaned. Figure 3 shows the equipment.

Figure 3. ballast vacuum cleaner

It was realized that the operating principle of the equipment could be replicated in the cleaning of wagons. A test was planned where the ballast vacuum was positioned on a line next to a gondola wagon and it was attempted to clean this wagon. It was seen that the equipment had limitations to clean this due at the fact that it was not designed for the task, however, at the points where the equipment was able to reach the bottom of the wagons it was possible to carry out the cleaning in a satisfactory way.

3. MACHINE DEVELOPMENT

After the tests were carried out with the ballast vacuum cleaner, it was noticed that there was the possibility of adapting of the machine to the cleaning task applied to wagons.

Vale called suppliers to a forum about the topic and presented the need and ideas for the project, the challenges and also the results of the tests carried out. It was noticed that, although the technology was used in railways, there was no supplier that manufactures specific equipment for the cleaning of wagons. The biggest challenge of the project was thus identified, since the equipment technology and also the supplier should be developed at the same time.

3.1 Machine engineering conceptions

Facing the challenge of not having similar equipment in the market, not even a supplier prepared to manufacture the machine, it was necessary to create a partnership agreement, where engineering responsibility should be shared. This means that the design of the equipment would be shared between Vale and the supplier. Figure 4 shows the first machine design idea for the project.

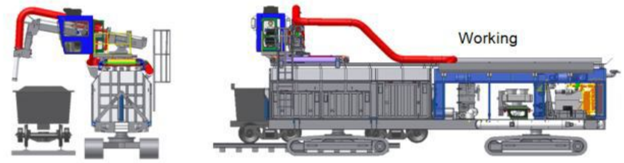

Figure 4. Machine conception

The equipment consisted of a suspended cabin, through which the operator could have line of sight into the whole interior of the wagon. The machine would be manufactured using crawler tracks in order to allow mobility to the equipment alongside the wagons in the train.

Specific suction nozzles would be manufactured for the task the machine would perform. Cameras would be installed in these nozzles in order to provide greater visibility of details to the operator, since the operator would be able to see the surface of the wagon during the cleaning in real time. Specific lighting would also be available on the equipment, since the equipment was designed to work 24 hours per day, so the lighting would provide safety and enable production at night.

Access to the cabin is provided by caged ladders installed opposite the railroad track. It was also imagined that the material removed from the wagons should be unloaded next to the equipment so excavators could be used to remove it and bring it to the wagon car-dumpers. In this way 100% of the material would be used. Figure 5 shows the design of the machine discharging.

Figure 5. Machine discharge conception

3.2 – Operational premises

Specifying the project, Vale highlighted the operational requirements, among others, that should be mentioned:

- Manufacture two sets of equipment: as it would be an unprecedented device, this should mitigate the risks of premature failure ("bathtub curve"). In this way, if one set failed, there would be another to handle the demand;

- Time taken to clean each wagon car should be a maximum of 1 minute;
- The sliding movement of the cab should be 1 meter longer than the length of the wagon. In this way, there would be a tolerance for positioning the wagons;
- The cleaning would be carried out simultaneously with the loading of coal, in the silos line;
- The machine should have a working life of 720 hours without need major maintenance shutdowns. It would be subject to preventive maintenance in parallel to the maintenance of the silos, that is, once every 30 days;
- The machine should have a fuel tank designed for at least 24 uninterrupted operating hours.

3.3 Manufacturing

In November, 2012, the purchase order for the machines was signed, which included six months of engineering, and thereafter the beginning of the equipment manufacturing.

Manufacturing was monitored through monthly meetings between Vale and the supplier in addition to technical visits to the manufacturer's headquarters in the United States for the physical follow-up on the equipment manufacturing. In addition to the design assumptions already presented, specific attention was given to critical points of the machine.

There was a need for mobility of the equipment because it would work on the lines of the coal silos, but could also be reallocated in the wagon car-dumpers. There was also the need for moving in for major maintenance, where the machine should be relocated to maintenance workshops. With this in mind, the equipment was manufactured on crawler tracks, enabling the required mobility.

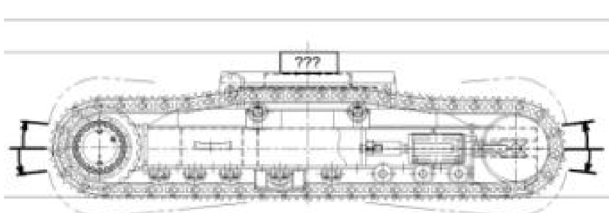

Figure 6. Crawler track

Dedicated attention was given to the operating cab. This cabin is located on the top of the machine and the floor had to be glass so the operator could see the wagons as they were cleaned. In order for the operator work in a more comfortable position and not to spend all the time looking down, cameras were installed on the suction nozzles with a monitor in the cabin, so the operator can see the activity that is being performed in real time.

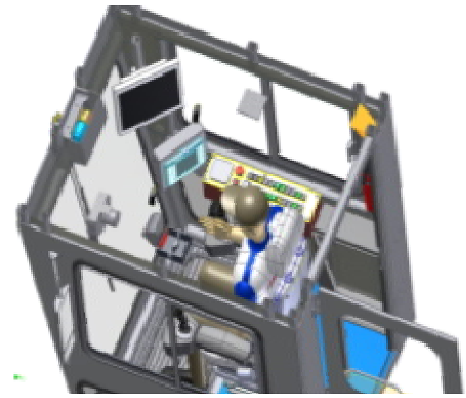

Figure 7. Machine cabin

The iron ore suction system (vacuum system) was designed to be reliable and simple. The same was done for maintenance such as filter changes, that, operator should be able to execute it without interruption of the cleaning tasks. It would also be necessary to have real-time equipment monitoring in the cabin, in order to show the operator the main system pressures and identify the needs of maintenance interventions.

There were some concerns about the suction hoses, since they were heavy and long in length. There were also several points of tension concentration on the suction hose, and at these points structural reinforcements would be introduced to extend the service life of the asset.

The operating cab frame, on the top of the equipment has several moving parts as well as in the suction nozzles arms. The machine was designed to work 24 hours a day, so it was necessary to fit an automatic lubrication system for the moving parts, so there would be no need to stop the machine activity to perform the lubrication.

Figure 8. Automatic lubricating system

Another attention point during manufacturing was the suction nozzles for iron ore. Its design should allow productivity, reliability and speed of replacement. Productivity could not be worse than the design specification, where a maximum time of 1 minute was specified for cleaning each wagon. The reliability of the nozzle is related to operational losses and gains, because the reliable nozzles will last longer. Another factor would be the speed of exchange and replacement of these nozzles. For this task to be performed quickly and safely, a quick connection system was designed through pneumatic cylinders, where the replacement time of the nozzles was achieved within the desired standards.

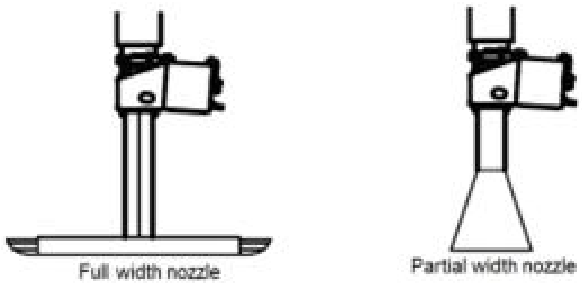

Figure 9. Nozzle conceptions

The manufacturing of the equipment was completed in March 2014 and the test phase was performed at the manufacturer's headquarters.

Figure 10. Frontal view of the equipment

3.4 Validation tests

As it was an unprecedented project, the contract stated the validation tests of the project would occur at the manufacturer's headquarters. The objective of this was to evaluate the performance of the machine and if any anomalies were identified the repair would be immediate. These tests were carried out in March 2014, in the city of Hamel (USA).

Figure 11. During validation tests

3.5 – Implementation

After successful validation tests, the equipment was shipped, arriving in Vitória Port in June 2014. Once the non-inspection letter was obtained from the Federal Revenue Service, the equipment was unloaded and moved on the same day, to the Vale facilities. This benefit allows the importer a saving in the costs of stocking the equipment inside the yard of Customs Department. This does not include the customs clearance of the cargo, but allows the equipment to be moved to Vale's facilities. The equipment can only be released for use after the visit of the inspector of the Revenue and final release of the cargo.

After the customs clearance of the equipment, the machine was reassembled by the manufacturer and with the support of Vale team. Reassembly was necessary due the large size of the equipment and for shipping, partial dismantling was the viable solution.

3.5.1 Startup (commissioning)

The startup of the equipment consisted of operational field tests, where the performance of the equipment during the execution of the tasks for which the machines were designed was evaluated.

During this stage it was possible to identify fragile points of the equipment, which were evident with use in the production line. These points were raised and treated by Vale and the equipment manufacturer.

Some identified improvements that would require re-engineering of parts were addressed to provide reliability to the equipment and listed for future improvement. When a new machine is needed these points would be included in the new technical specification. Also during this step, the theoretical and practical training of Vale employees were carried out with the crews responsible for operating and maintenance of the equipment.

Figure 12. Qualified crew of operators and maintainers

3.5.2 – Assisted operation

After the tests and validations of the commissioning phase, the equipment entered into the operating rhythm at "full capacity". At the same time the machines started to be operated and maintained exclusively by Vale's crew.

The tests were witnessed by manufacturer, where the responsibility for the equipment was to help only in situations where the Vale team (due to the maturing of the knowledge) still had difficulties to intervene, or in operational failures due to machine design failures.

Figure 13. Equipment being operated by Vale's employee

4. RESULTS

In December, 2014, the technology evaluation phase was considered complete and the equipment was transferred to routine management, under the responsibility of the operational areas. The implementation of the technology proved efficient and fulfilled project specifications. As expected, as it is an unprecedented equipment, improvement points have been identified and documented to serve as reference the acquisition of new equipment becomes necessary.

Throughout 2015, the equipment proved to be reliable and production was able to meet the need for the EFVM coal silo line, as well as all the project specifications. The unhealthy activity where manual wagon cleaning was necessary had been eliminated and the main purpose of mechanization of the activity was successfully achieved.

5. ACKNOWLEDGMENTS

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