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EFFICIENCY OPTIMIZATION OF FREIGHT WAGON BRAKE RIGGING

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Abstract. *The railway wagons need a brake system in good condition to be used to control of the train speed with safety. This system does not allow failures as it can lead to serious accidents, affecting safety and health of the people surrounding the railroad and the assets of the composition. The study elaborated here deals with the brake system of the freight wagons that cross the Brazilian railroads. The entire operation of the brake system is studied and detailed, as well as the characteristics and functions of each component that contains it. From this study, the causes and effects of brake rigging looseness that cause the loss of braking efficiency and brake reliability was analysed, and then the production of scaled rigging brake was made possible improvements of efficiency as change of forms or levers reductions of the brake rigging. The first proposed solution is to insert a bearing between the brake levers and connecting rods of the brake rigging, reducing the friction between the parts that are in contact. The second solution is the inner coating of the holes of the connecting rods and brake levers by a material with greater resistance to wear, thus reducing the shape change of the orifice and consequently, looseness of the brake rigging.*

Keywords: *Freight train, Freight wagon, Brake Rigging, Rail Brakes.*

1. INTRODUCTION

Rail transport has been one of the oldest means used to move large quantities of cargo by countless corporations from mining, agricultural, industrialized and steel mills. Beginning at the 19th century, the steam train was built to transport raw material, such as coal. In the course of time new improvements were made providing new perspectives for rail transportation (Freitas, 2017).

In spite of some limitations, such as the fact that the train doesn't move over rough surfaces and the need for large curvature radii in a curve, the rail system has always presented low accident rates (ANTT, 2014). When taking into account the transport of large loads for long distances, it is important to require a high level of efficiency of the systems that make up a freight wagon, such as brake rigging. This system is responsible for speed control of the composition in ramps, stops and parking safely in any situation that is requested.

Nowadays due to the transport of large loads in large compositions, the used wagons are placed under great structural stress. When it's moving, all system acquires great energy, that is, a great mass in movement acquires great inertia, so when necessary the stop or reduction of composition speed, the brake system of the wagons is submitted to great efforts. From these points, it is necessary to carry out studies in order to reduce and minimize the damage caused to the brakes by fatigue, providing smaller amounts of maintenance and consequently making the process more economical, feasible and efficient.

For the purpose of maintain the performance and demand already arrived by the wagons, the search for a solution for degrading factors possible is imposed with the attempt to maintain most of the parameters already established in the system, such as the amount of cargo, the system speed, among others. In other words, for greater volume transportation over the same period, it is desirable the maximum availability of the assets and shorter operational cycle, and this is possible by avoiding trains stoppage by maneuvering the withdrawal of damaged wagons, a smaller amount of assets in the responsibility of the mechanics and the shorter maintenance of rolling assets.

Improved efficiency and reliability in brake systems promotes improvements in the aspects mentioned above, consequently, greater volume to be transported. An important information, which the work here elaborated has the objective of increasing the mechanical system efficiency of freight wagon which present an efficiency of 45% to 70%.

2. FREIGHT WAGON BRAKE RIGGING

A train composition on one of the best and most efficient railroads in Brazil, Carajás Railroad, has as a train pattern contain 330 wagons and 4 locomotives, approximately 3.3 km long and 42,000 gross tons, so the braking mechanism of all this composition should promote safety and reliability in its activation (ANTT, 2014).

The need for frequent maintenance on the wagon brake system increases the cost of operation and reduces the time available for the wagon in production, which can lead to lower system viability in the long term. Due to this possibility, it is sought to carry out an analysis of the brake system of fright wagons, prioritizing the main factors responsible for the high wear of this brake system of wagons, this will reduce the cost generated by the excess maintenance.

In order to increase the performance the wagons e efficiency of the railroad system, the search for a solution to minimize degrading factors in the brake system is imposed by trying to maintain of the already established parameters of the brake system, such as the amount of load allowed, maximum permissible speed, among other parameters.

A composition when suffering any type of failure in the brake system, causes the train to stop due to safety reasons, causing the interdiction of the railroad, because in such cases, a mechanical inspection in the composition is necessary to ascertain the problem and then solve it if it is possible in the same place, such as the insulation of some wagon. More complex problems may require the removal of the wagon from the composition, where maneuvering for this type of operation takes considerable time depending on the conditions in place, causing this impact.

The train stoppage unexpectedly in circulation lines causes delays in the circulation of the entire railway network, increasing the system operational cycle. With the greater operational cycle, it means a greater need of wagons and locomotives to promote the attendance of the transport of a same volume in a same period.

The volume transported (V) behaves as Eq. (1) below, is directly proportional to the period determined (T), average weight of wagons capacity (P), the number of wagons available (N) and inversely proportional to the operating cycle (C). That is, for greater volume transportation over the same period, the maximum availability of the available assets, locomotives and wagons, and shorter operating cycle is desirable, and this is possible by avoiding trains' downtime for whatever reason and shorter asset maintenance time, in other words, more assets in production.

$$V = \frac{T.P.N}{C} \tag{1}$$

2.1 Function of the Brake System

Understanding the operation of the brake rigging provides the ability to understand function as designed and how the forces transmission works.

Body mounted or conventional brake rigging on freight cars uses a body mounted brake cylinder located approximately in the center of the car. The majority of coal cars (open top hoppers or gondolas) are equipped with body-mounted brake assemblies mounted on the end of the car. This design has the brake cylinder in close proximity to the control valve and other brake devices.

Early conventional rigging arrangements used rods and levers attached to the underside body of the car with a manual type slack adjuster. Conventional rigging today uses automatic or self-adjusting slack adjusters to do the same job of manually adjusting the brake rigging.

Other car designs use truck mounted brake arrangements. This design eliminates a lot of the rigging necessary for conventional rigging by having the brake cylinder attached directly to the truck rigging assembly.

The freight wagon brake rigging is the metal components assembled together to transmit a brake application directed by either the handbrake or the air activation of the brake cylinder, this brake system is shown in Fig. 1 below. Brake rigging can be in the form of a body mounted brake assembly with foundation brake rigging or truck mounted brake assemblies, in this study is analyzed the first one.

Brake levers are mounted as part of the brake rigging under the car body and as part of the truck brake assembly. The levers are used to transmit the pulling or pushing forces exerted by the connecting rods. Each brake lever is a specific size designed to amplify or reduce the brake force. This is determined by the distance between the pin connections. When the holes in the lever become elongated or show excessive wear they do not provide correct braking force.

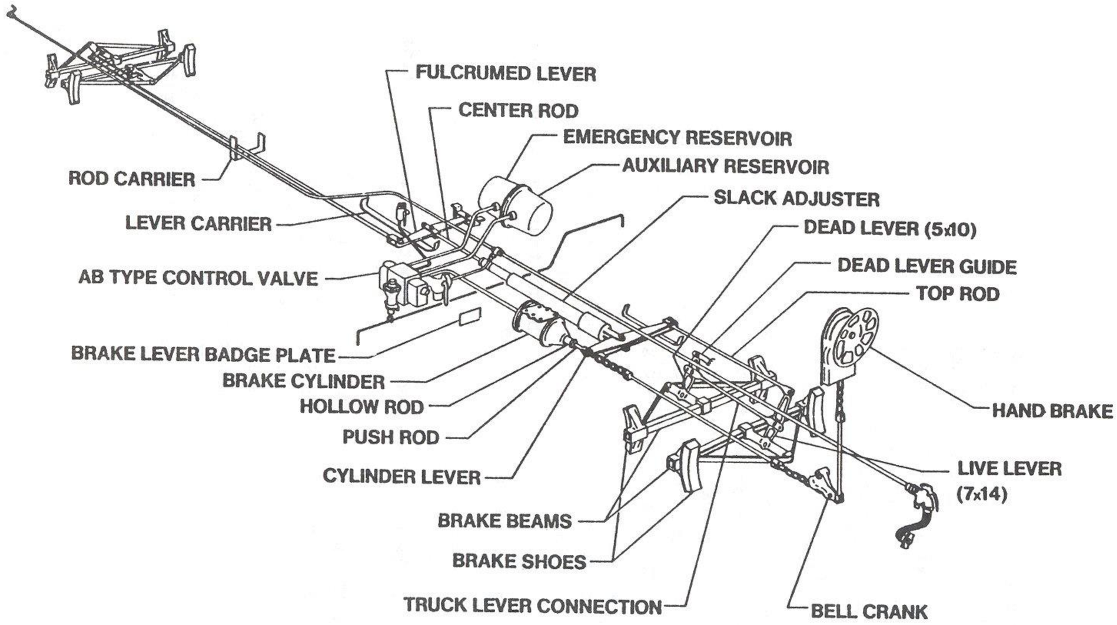

Figure 1. Foundation brake rigging

The brake cylinder push rod is a solid rod with a jaw formed on one end. A brake pin is inserted into the jaw end to make the connection to the brake rigging. The push rod transmits the force caused by the "push" of air entering the brake cylinder or by the "pull" of the hand brake, through levers and rods to the brake shoes. The push rod is not connected to the piston. The push rod end fits loosely in the tube of the piston hollow rod. At one time, push rods were of different lengths. The push rod is designed to provide adequate movement of the jaw end without binding in the piston-hollow rod (Li et al., 2015).

Brake levers are used throughout the brake system to transmit, increase, or decrease braking force. They are also used to transfer or change direction of force. Levers are named for the various conditions and positions that they serve in the system. There are body levers, such as the cylinder lever and fulcrum lever. There are truck levers, such as the live lever, dead lever, and horizontal truck lever, where these items are disposed in their respective places in Fig 1.

Body mounted brake equipment has the bottom connecting rod running through the opening in the bolster or the bottom rod under the truck bolster. The Fig. 2 below shows a rod-through design.

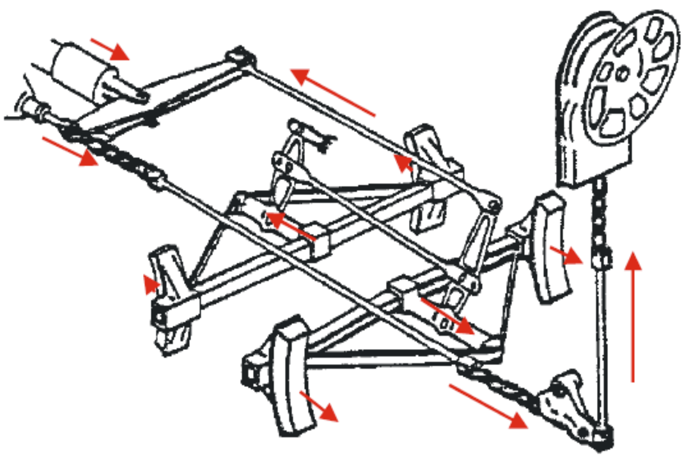

Figure 2. Kinematics of brake rigging

Notice the truck lever connection passing through the truck bolster is pinned to the center hole of each truck levers. The bottom holes of the truck levers are pinned to the brake beams. The top rod, which is pinned to the top of the live lever, must pass over the truck bolster to connect to a body lever. The top end of the dead lever is usually supported to the truck bolster by the dead lever guide. The truck levers usually have a 2 to 1 ratio so the forces exerted at the brake shoes are twice that of the top rod force. Conversely, the top rod movement is 4 times the movement of the brake beam. When the handbrake is applied, the levers and rods move in direct relationship to the movement of the body lever. The body lever is connected to the piston push rod. In this way the brake shoes are force against the wheel on an application of the brakes whether the application is directed by the handbrake or the force of the brake cylinder piston as shown in the diagram and brake. Note the dead lever bracket and guide are used as an anchor to maintain the correct force applied at the shoes (Zenert, 2004).

Truck assemblies with the bottom connecting rod under the truck bolster function in a similar manner with a couple of exceptions. The bottom rod or connecting rod being under the bolster is pinned to the bottom hole of each truck lever. The center holes of the truck levers are connected to the brake beams and the top lever holes are for the top connecting rod and dead lever guide.

3. METHODOLOGY

To develop this work, the construction of freight wagon brake rigging prototype was carried out. Considering that the failures generated in this system can be caused by the appearance of clearances between the pins and their respective holes, due to the fatigue process generated by the relative movement between them during the brake activation in the reduction of the train speed, the construction of prototype was responsible for allowing the performance of tests and analyzes on the behavior of the levers, rods and pins of the system.

The construction of the prototype started from the mensuration of all pieces of the freight wagon brake rigging in real scale, from a PNR, wagon platform. With the use of a CAD drawing software (Solid Works) was designed a structure in 3D format with its real dimensions how can see in the Fig 3 below. Adopting a 1:3.4 scale, was defined the new dimensions for each structure piece, defining the prototype dimensions.

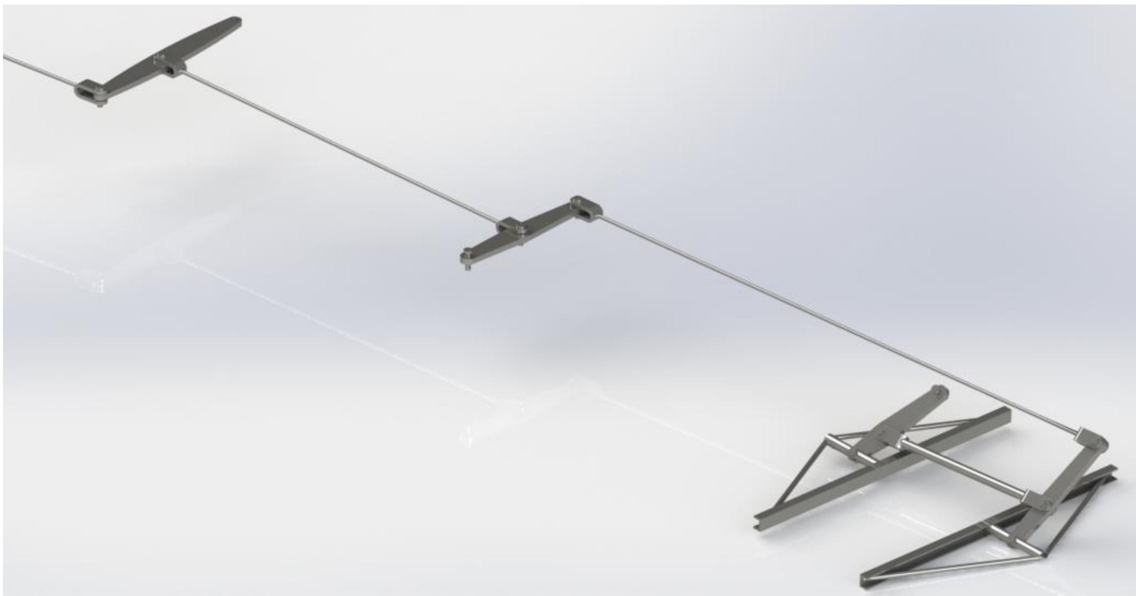

Figure 3. Freight wagon brake rigging prototype

A new CAD drawing was generated for the prototype and from it the technical drawings for the construction of this one were elaborated with the new dimensions of the prototype. Once the technical mechanical design was finished, the manufacture of all brake rigging structure began.

Using manufacturing processes such as machining, welding, forming, among others, each piece was built and prepared for mounting. Regarding the existing connections in the structure, pins were machined to allow such connections, plates and rods were joined by the MIG welding process.

For the manufacture to the parts of the system brake, was utilized a machining and welding laboratory to mark, cut, sanding, grinding and welding and other mechanical process.

Figure 4. Freight wagon brake rigging prototype

After the prototype assembly, the assembly shown in Fig. 4 was obtained, it was possible to visualize the necessary adjustments in the project for the pieces perfect fit in their respective places, and these adjustments were necessary due to possible propagations of errors that occur during the process of pieces manufacturing for example unevenness, loss of concentricity among others.

From the assembly, it was made kinetic tests of the mechanism to visualize which points are most requested of the structure. Afterwards, we performed fatigue tests in the mechanism to obtain the sites with the greatest mechanical discharging in the brake system and implemented an improvement option for the system proposed at the beginning of the study, the insertion of a material of greater mechanical resistance in the joints of the system. This promotes a smaller geometric change in the joints by pins.

The study is still under development, where new techniques for improving the mechanical efficiency of the brake system will be implemented.

4. RESULTS

It is observed that a better performance of the brake system was obtained in its activation. That is, the brake system still being tested with the same material of its levers, rods and pins, caused some geometric changes of approximately 0.5mm, small variation of the shape of the system, but since low forces were used compared to the forces smeared at the real brake system. Where also, the study was performed on a scale brake system.

When a more resistant material was used in the bores of the rods and levers, we obtained a smaller variation of the circular geometry of the connections, a mean of 0.15 mm, using the same forces applied in the first test.

With this lower variation, it was also concluded, a greater efficiency of the mechanical brake system, or even, a lower variation of energy loss along the chain of levers and tie rods of the brake rod compared to the first test without the most resistant material. Then, the greater the gap in the connections, the greater the loss of energy, which impairs the braking of the composition.

5. CONCLUSION

A reduction of 70% in the geometry variation in the connections was observed. A considerable reduction to ensure a greater efficiency of the brake rigging system, where gaps at the joints cause the reduction of system reliability, requiring more application of brake at the entrance of the mechanical system to promote effective braking of the composition.

Any improvement in efficiency in one type of safety mechanism can make a difference in emergency situations, avoid catastrophes and ensure the safety of people around the railroad, environment and the goods to be transported.

Another important point, such changes in the brake rigging system, can promote a longer period of rail assets in the production of the company, which is summarized in a longer time in the transportation of products and less time retained by breakdowns in yards and workshops for such types of problems coming from the brakes.

It is evident the importance of appropriate equipment for the manufacture of parts and mechanical systems to achieve the final objective, which are items of dimensions and mechanical characteristics pre-established in projects, which must be respected for the success of the final project.

6. ACKNOWLEDGEMENTS

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