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BUFFER TESTING IN ORDER TO EVALUATE THE LONGITUDINAL FORCES THROUGH COLLISION OF TWO RAILWAY VEHICLES

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Abstract: *The paper presents the issue of performing dynamic tests on the absorption capacity of longitudinal shocks that occur during the collision of two railway vehicles and their transmission to the elements that build-up the resistance structure of railway vehicles. The impact between the railway vehicles is normally achieved in triage, at train formation, but especially during braking, due to the pneumatic system, and performing collision tests can help validate the results obtained through simulation programs. The tests were carried out within the Railway Testing Center from Făurei - Romania, monitoring the value of the maximum force transmitted to the resistance structure, the maximum compression of the buffers and the determination of the maximum acceleration at impact.*

Key words: *buffers, railway vehicles, longitudinal forces, shock, vehicles collision.*

1. INTRODUCTION

In order to be part of a train, railway vehicles must be equipped with traction, collision and coupling devices, which have the role of keeping the vehicles in the train body, providing the possibility of relative movements between the vehicles, but especially that of protecting each vehicle against shocks. These devices are found in two constructive categories:

- automatic couplers, which contain the coupling and collision devices,
- manual couplings, consisting of the towing hook and the coupling screw, and the buffers as devices mounted separately on the vehicle chassis.

In addition to the previously mentioned, the purpose of using such devices is to protect its structure and the integrity of the cargo, but especially of the passengers due to the interactions between the vehicles during driving, braking, pushing the train or during its formation [1].

Each vehicle is equipped with a number of four buffers fixed to the front cross-beam of the chassis, two for each end. In addition, on each side there is a buffer with a flat plate and one with a convex plate so that there is always a buffer with a flat plate in contact with one with a convex plate to avoid breaking the rods when driving in a curve or the tendency to lift (in the case of the convex buffers) when there are level differences (the change ramp-slope, ramp-alignment or slope-alignment) [2].

International regulations [3] allow vehicles to be equipped with convex plate buffers if the radius of curvature of the plate is higher than 1500 mm.

As it is known, during the braking of the trains, due to the constructive type of the brake - the indirect brake with compressed air -, the braking force develops for each individual vehicle from the locomotive to the train track and thus, longitudinal forces appear between consecutive vehicles that are taken over by their buffer. Studies and research in this field are carried out by Cole C. [4], Qing W. et al. [5], Pugi L. et al. [6], Zhuan X. [7], Zobory I. et al. [8], Belforte P. [9], Iwnicki S. et al. [10], Cruceanu C. [11].

The forces on the buffers of the vehicles also develop when the trains are composed, having significant values for the freight trains which are formed by pushing the wagons over the shunting hump, the wagons ending up colliding at a speed between 12 and 15 km/h. Starting from the things already presented, it is necessary to determine the maximum value of the longitudinal forces between the buffers of two vehicles subjected to controlled collisions in order to determine the maximum values of the forces, the way of their transmission to the chassis of the vehicles as well as the longitudinal accelerations during the impact. Such a test, which uses real vehicles, represents the purpose of this paper, at the same time outlining the complexity and speed of such collisions that are practiced almost daily in freight transport.

2. TEST CONDITION

The collision tests were carried out during fall of the year 2019 at the Railway Testing Center in Făurei, belonging to the Romanian Railway Authority.

The wagon used for the tests is one of the Zacs type used for the transport of petroleum products (fig. 1) with the following constructive characteristics:

- length over buffers: 14940 mm;
- wagon wheelbase: 9400 mm;
- total tank capacity: 85 m^3;
- *A* category buffers, stroke 105 mm, maximum absorbed energy - 30 kJ;
- height of the axis of the buffers at the level of the rail: 1060 mm;
- gauge: 1435 mm;
- bogie type: Y25 Cs ll-M;
- bogie wheelbase: 1800 mm;
- nominal diameter of the rolling circle of the wheel: 920 mm;
- mass of the empty wagon: 23.4 t;
- mass of the full wagon: 79.6 t.

Fig. 1. The Zacs type tested wagon.

Force transducers (behind the buffers), displacement transducers on the buffers and strain gauges were mounted on the wagon to check the deformations that may occur. Real data recording was performed with an application especially created for this project in the program HBM Catman AP V5.2.2. The measuring equipment, consisting of the HBM MX840B and MX1615B data acquisition system, together with the Panasonic laptop data visualization and recording system is shown in figures 2 and 3. The sampling frequency during the tests was 300 Hz.

Fig. 2. Data acquisition system.

Fig. 3. Data recording system.

The collision tests were done for the loaded wagon (mass being 79.6 t) and exceptional loading leading to a total mass of 90 t. The wagon was loaded with water, and in order to reproduce the conditions as close as possible to reality, when the wagon carries petroleum products (having a lower density than water), and the liquid in the container is at a much higher level, it was used cellular polystyrene anchored at the middle level of the container, by means of plastic nets attached with the help of metal elements welded directly to the container, in order to raise the center of gravity of the load (Fig. 4.).

The wagon was positioned on a rail located in alignment and level landing, a rail that is continued with a sloping rail that simulates the shunting hump in the freight wagon operation area. The collision of the tested wagon was carried out with a high-walled freight wagon without a roof, which is loaded with crushed stone up to a mass of 79.8 t.

Fig. 4. The Zacs type tested wagon filled with cellular polystyrene.

The test consists of launching the bumper wagon on the inclined plane of the shunting hump and colliding with the test wagon, which it was at rest, isolated at the end of the line.

The impact speed between the two vehicles is measured before the collision, only after the bumper wagon has reached the alignment and level landing area with both bogies, so that its movement is no longer accelerated by the descent from the inclined plan.

The collision speeds were between 8 km/h (2.2 m/s) and 15 km/h (4.2 m/s) being consistent with the international requirements [12].

The speeds were determined based on the time elapsed between the time when the first axle of the first bogie of the bumper car triggered the start of the track-mounted timer and the time when the second axle of the first bogie triggered the stopping of the timer.

The collision forces were measured with strain gauges (load cells), placed between the soles of the buffers and the front cross-beam (Fig. 5 and 6). The prestress value was removed by performing an initial tare on each sample. The stroke of the buffers was measured with inductive displacement transducers, located on the bodies of the buffers (Fig. 7 and 8).

During these collisions, it was analyzed the evolution over time, for different collision speeds, of the following measured quantities: the compressions of the buffers, the interaction forces at the level of the buffers, the movement speed of the two-wagon assembly immediately after the collision and the acceleration of the tested wagon.

It should be remembered that the deformation (compression) of the pads, although it was measured only on the tested wagon, is also symmetrical to the pads on the bumper wagon, being of the same type. Acceleration was measured using accelerometers mounted on the front cross-beam of the test wagon.

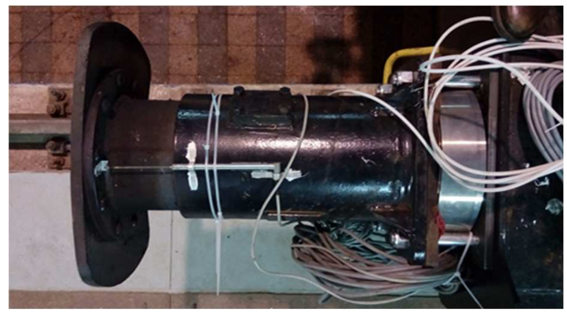

Fig. 5. Mounting the sensors assembly on a buffer.

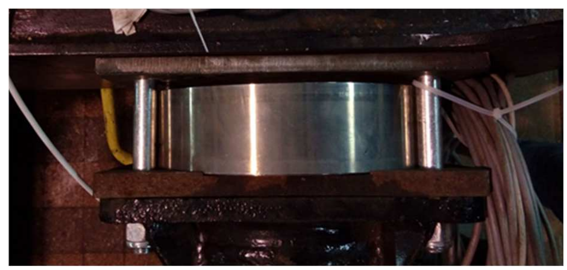

Fig. 6. The load cell mounted behind a buffer.

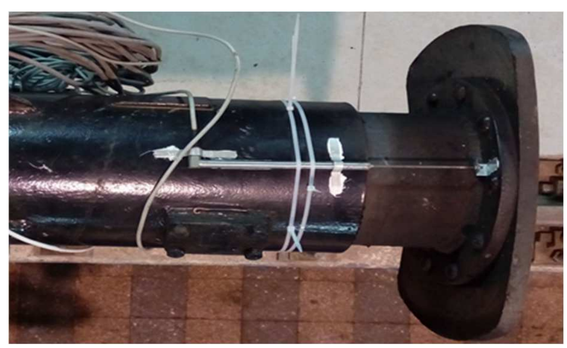

Fig. 7. Mounting the inductive displacement transducer on a buffer.

Fig. 8. Mounting the transducers on a buffer.

3. RESULTS AND DISCUSSION

The collision test with the loaded wagon had the following main objectives:
- determining the maximum force behind both buffers on the test wagon;
- determining the compression of both buffers on the test wagon;
- determining the maximum acceleration upon impact of the test wagon.

The speed immediately before the collision was determined in two ways:
- by the ratio between the wheelbase of the bogie, which has a value of 1.8 m, and the time recorded by the timer;
- by analyzing the video images with a special program, following the markings on the wheels and the angle made by them with a rectangular grid superposed on the image.

In figure 9, the mark on the wheel in a vertical bottom position is circled in red, and lengths ***a*** and ***b*** denote the length of a buffer of 750 mm, respectively the distance of 750 mm between two successive concrete crossbars (it turns out that between two adjacent points in the grid there are 250 mm at the level of the nearest rail).

Figures 10, 11 and 12 show the diagrams drawn up based on the numerical data obtained for the collision speed of 12.2 km/h and the mass of the wagon of 79.6 t.

It is about the evolution over time of the force measured for each buffer separately, the force depending on the displacement of the buffer plate and the acceleration recorded during the collision. The evolution over time of the forces on the two buffers of the vehicle under test indicates an unequal absorption of the impact, explained by the fact that since the production

Fig. 9. Calculation of collision speed based on video images.

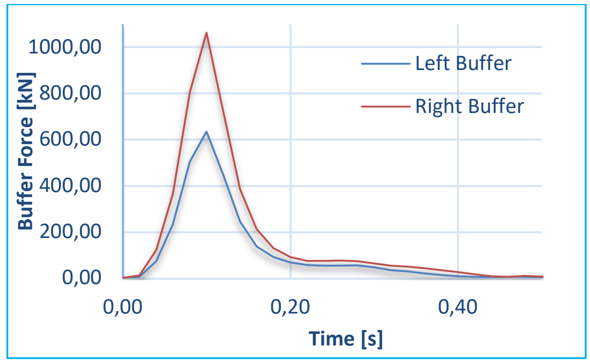

Fig. 10. Variation of the force over time at the level of the buffers for a collision speed of 12.2 km/h, vehicle mass of 79.6 t.

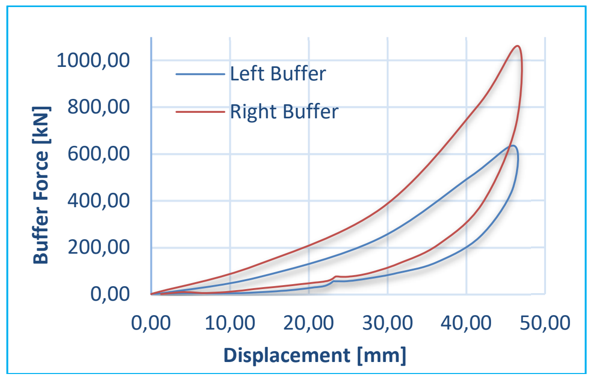

Fig. 11. Force-Displacement diagram for a collision speed of 12.2 km/h, vehicle mass of 79.6 t.

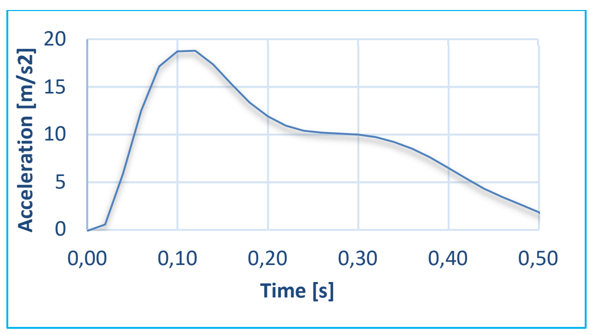

Fig. 12. The variation of the longitudinal acceleration over time for a collision speed of 12,2 km/h, vehicle mass of 79,6 t.

stage, the force resulting from the impact is transmitted on the diagonal to the frame.

Another explanation is related to the positioning of the flat and convex buffers and how they work. From the data recorded by the displacement transducers, it can be seen that the buffer on the right side makes the first contact and therefore it takes most of the impact energy. The maximum recorded displacement, or the maximum compression, is 47 mm.

From the point of view of the longitudinal acceleration obtained and presented in figure 12, we can draw the conclusion that the maximum peak is of 1.8 g, corresponding to the received shock, and the resulting average acceleration is 0.8 g (where g = 9.81 m/s^2).

Next, the wagon is loaded according to the maximum vertical load accepted by the mounted axle with which it is equipped; it was loaded with water up to the total mass of the vehicle of 90 t. The results are shown in the figures 13, 14 and 15.

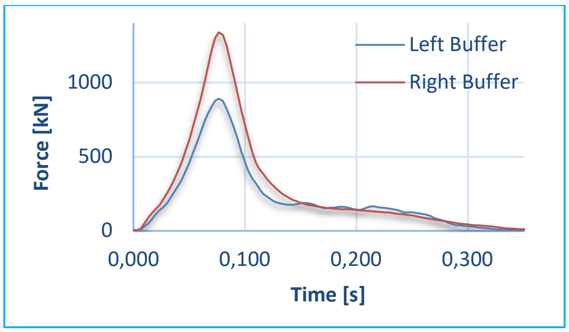

Fig. 13. Variation of the force over time at the level of the buffers for a collision speed of 12.2 km/h, vehicle mass of 90 t.

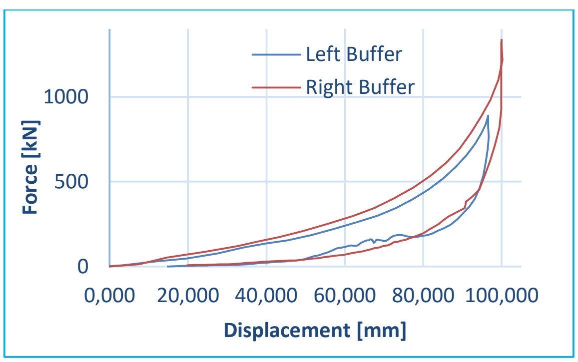

Fig. 14. Force-Displacement diagram for a collision speed of 12.2 km/h, vehicle mass of 90 t.

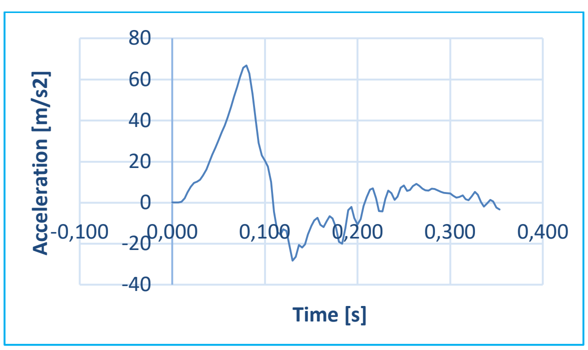

Fig. 15. The variation of the longitudinal acceleration over time for a collision speed of 12.2 km/h, vehicle mass of 90 t.

Comparing the results with the previously presented case, a significant increase in the forces on the two buffers can be seen, as expected due to the additional loading.

A gap is still maintained between the two buffers, but this time it is much smaller than in the previous case. An explanation may be that the vehicle was centered in the path following the numerous tests carried out and the collision of the two vehicles happened almost on the longitudinal axis. This time we can see an increase in the maximum value of the acceleration and practically the balance of the water which has reached a very high level in the tank.

5. CONCLUSIONS

Starting from the aspects presented and the results obtained during the tests, the following conclusions can be drawn:

- testing of freight vehicles by colliding at different speeds is mandatory for every new vehicle designed, according to international standards;
- performing such tests first of all highlights how the crash devices work and how the shock is transmitted to the vehicle chassis;
- manufacturing errors can be highlighted as well as possible deformations that may appear;
- it is possible to check the dynamic behavior of the goods during the collision of the wagons;
- the absorption of the force by the buffers is unequal on the buffers positioned on the same front cross-beam;
- the acceleration acting on the vehicle is quite high, in the presented case reaching values of up to 1.8 g.

6. ACKNOWLEDGMENT

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EVALUAREA FORȚELOR LONGITUDINALE OBȚINUTE LA COLIZIUNEA DINTRE DOUA VEHICULE FEROVIARE, LA TESTAREA TAMPOANELOR

Lucrarea prezintă problema efectuării testelor dinamice asupra capacității de absorbție a șocurilor longitudinale care apar în timpul coliziunii a două vehicule feroviare și transmiterea acestora la elementele care formează structura de rezistență a vehiculelor feroviare. Impactul între vehiculele feroviare se realizează în mod normal în triaj, la formarea trenului, dar mai ales în timpul frânării, datorită sistemului pneumatic, iar efectuarea testelor de coliziune poate ajuta la validarea rezultatelor obținute prin programe de simulare. Încercările au fost efectuate în cadrul Centrului de Încercări Feroviare din Făurei - România, urmărindu-se valoarea forței maxime transmise structurii de rezistență, compresia maximă a tampoanelor și determinarea accelerației maxime la impact.

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