FREIGHT RAIL VEHICLE BUFFING IMPACT TESTING

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Railway vehicles must be subjected to a series of tests in order to verify aspects related to safety traffic. These tests are similar for all rail vehicles (locomotives, passenger cars and freight vehicles), in accordance with European standards. In particular, freight vehicles are subjected to a different set of dynamic structural tests (buffing impact tests). Buffing impact tests are carried out in order to test the inertia effects of the vehicle parts and also to test the effect of a load on the superstructures. This paper presents the study of a freight rail vehicle structure and the results for a series of buffing impact tests performed in Romania at the Făurei railway test center.

Keywords: Railway vehicle, testing, structure, buffing.

1.Introduction

Railway transport, one of the most important and complex system of transportation, offers many advantages, such as: fast transportation, large volume of transport, safety, efficiency and in many cases, zero CO_2 emissions.

Railway vehicles must satisfy a series of technical and safety requirements for the purpose of being declared able to run in good conditions.

European standards require performing a series of tests for railway vehicles, such as: static and dynamic structural tests, static and dynamic brake tests, dynamic behavior etc.

Some of the wagons are operated in special conditions on railway lines equipped with humps (Fig. 1) used to compose or decompose trains. During this time, impact forces transmitted from a structure to another appear between vehicles, as is explained in [1] and [2].

The actual trend of freight rail transport is greater loads and increasing speeds, that's why, in time, freight railway system suffered many changes in order to satisfy our demanding needs.

Based on a series of preliminary vitual analyses and experimental results [3], the vehicle structure was declared able to carry a extra 10 tones load. In order to confirm the virtual analyses results, the vehicle was subjected to a series of dynamic tests.

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This paper presents a series of dynamic structural tests (buffing impact tests) performed on a freight railway vehicle loaded with a greater charge (from 80 tones to 90 tones). The tested rail vehicle was equipped with 22,5 tones axle in order to resist to the new increased load.

This type of test reproduces a real situation when the vehicles are handled in special conditions and a series of shocks appear between vehicles.

The main purpose of these tests was to verify the new increased load influence to the vehicle structure during impacts.

Fig. 1. Railway line equipped with hump

Buffing impact tests are carried out with wagons for two cases: for the empty wagon and for the fully charged wagon.

Buffing impact tests with empty wagons are carried out in order to test the inertia effects, in particular the connection between the wagon frame and the bogies, and the response of the superstructures.

Buffing impact tests on loaded wagons are carried out to test the effects of a load on the superstructures.

The tested wagon should be stationary and the impact test is carried out using a second rail vehicle as a partner wagon, loaded to a total weight of 90 t which is released from the railway hump towards the tested vehicle [4].

2. The properties of the vehicle and the preparation for testing

The tested rail vehicle (Fig. 2) is an Eaos type open wagon used for transport of goods like: ore, coal, woods, scrap metal, boxed materials etc.

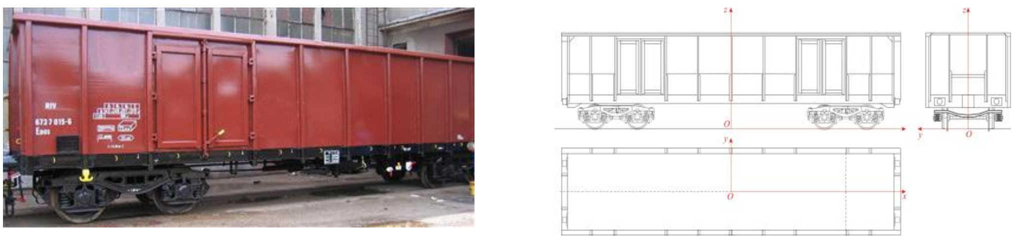

Fig. 2. Tested wagon

The main characteristics of the tested wagon are:

- Length of the vehicle body: 12792 mm;
- Width of the vehicle body: 2772 mm;
- Height of the vehicle body: 1890 mm;
- Body vehicle surface: 36 m^2;
- Vehicle mass: 22 t;
- Maximum axle load: 22,5 t [5].

With the aim of verifying all aspects required by EN 12663-2:2010, the vehicle was equipped with force cells for measuring the longitudinal impact forces, displacement transducers for measuring the buffers impact displacement and strain gauges for measuring the strains in different points of the vehicle structure.

All measurements were performed using HBM MX840B (for displacements and forces) and MX1615B (for strains) data acquisition systems and HBM Catman software [5].

Fig. 3. Measuring devices

For this application, the following equipment and materials were used (Figs. 3 and 4):

- HBM 1-LY11-10/120 strain gauge;
- HBM RMS 1 spray for surface cleaning;
- HBM BCY01 accelerator for the Z70 glue;
- HBM Z70 strain gauge special glue;
- HBM SG 250 silicone protection for strain gauges;
- HBM connection cables with 4 wires [6].

Fig. 4. HBM materials used for tests

For these tests, the vehicle structure was equipped with 16 strain gauges [7], in points chosen based on the static tests results obtained on the vehicle structural strength test rig of Romanian Railway Authority in Bucharest.

The structural static tests were performed with the intention of verifying the vehicle strength for different cases of longitudinal and vertical loads, in accordance with the European standards requirements [2],[8].

Figs. 5 and 6 show the structure of the vehicle equipped with strain gauges:

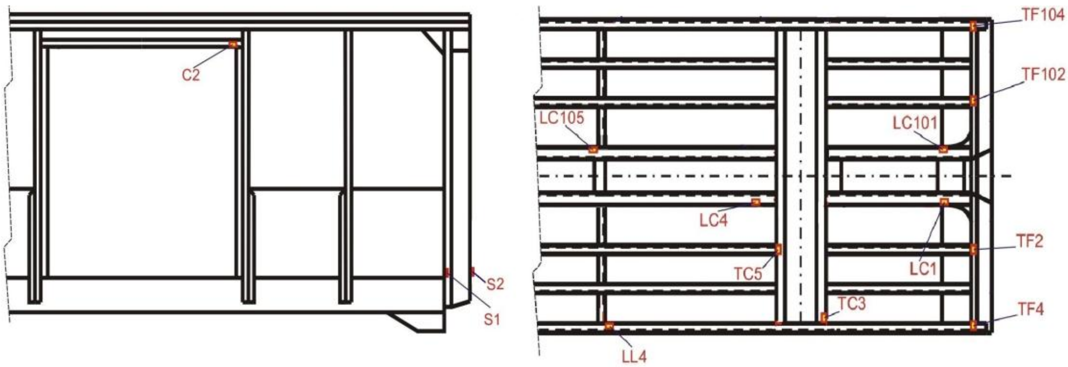

Fig. 5. Strain gauges positions on the vehicle structure

Fig. 6. Strain gauges mounted on the vehicle structure

3.Test description

The buffing impact tests were done using a locomotive, a buffing wagon, the tested vehicle and a second stationary buffing wagon, as shown in Fig. 7.

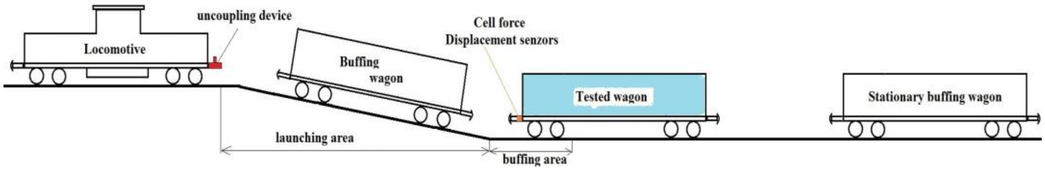

Fig. 7. Buffing impact test scheme

The next steps were followed:

- the tested vehicle was positioned in straight line, between the two buffing wagons and it was secured with brake hand shoes;
- the stationary buffing wagon was placed after the tested vehicle in order to reduce it’s movement after the impact;
- using the locomotive, the active buffing wagon was placed on the hump and it was released (towards the tested wagon), using a special uncoupling device mounted between the locomotive and the buffing wagon;
- a series of tests were performed to establish the speed of the buffing wagon and the forces on the tested wagon buffers. During the tests, two main criteria should be followed: the maximum speed of the buffing wagon should not exceed 12 km/h and the maximum force at the level of the tested vehicle buffers should not exceed 3000 kN (1500 kN/buffer). If the force is lower than 1500 kN/buffer, all tests should be performed at the maximum speed of 12 km/h, which is the case of the presented tests;
- the values of force, displacement and strains were measured and registered using the measuring devices mentioned before, in order to determine the final values required by the reference documents;
- after the first test impacts, the fully loaded vehicle was subjected to a series of 40 buffing impacts, in order to verify the cumulated strains registered in all 16 measuring points.

During tests with the empty vehicle, the behavior of the vehicle in general and the behavior of all components mounted on the structure were verified.

In the case of fully loaded vehicle, the behavior of the vehicle, the evolution of the force, displacement and strains in the measuring points were tracked. The speed of the buffing vehicle was measured using a special device (Fig. 8), mounted at the rail level, before the tested wagon [2].

For the empty vehicle tests, in accordance with EN 12663-2:2010, during buffing impact tests, the following parameters should be determined:

-acceleration-speed evolution diagram;

-inertia effects, in particular the connection between the wagon frame and the bogies, and the response of the superstructures. All parts of the vehicle must remain in place.

Fig. 8. Speed measuring device

Using an HBM accelerometer mounted at the chassis level, in the middle area of the tested vehicle, accelerations of the tested vehicle during buffing impacts were measured.

A second buffing vehicle was placed after the tested vehicle in order to reduce its movement.

The buffing wagon should be a four-axle vehicle, fully loaded, with a total weight of 80t , as shown in Fig. 7. This one needs to be released from the hump and let run free towards the tested vehicle.

The first set of tests were carried out at lower speeds in order to verify the inertia effects on the vehicle structure and components and also, for the purpose of verifying the forces acting at the buffers level.

For the fully loaded vehicle tests, in accordance with EN 12663-2:2010, during buffing impact tests the next following parameters should be tracked/determined:

-force-speed evolution diagram, presented in table 1 and Fig. 10;

-displacement-force (at the buffers level) evolution diagram;

-acceleration-speed evolution diagram;

-strain values using strain gauges, mounted in the most important points of the vehicle structure.

4.Test results

4.1. The empty vehicle tests

The vehicle was then tested at a speed between 8 km/h and 12 km/h. All components of the vehicle reacted well during tests and the forces generated by the buffing impacts registered a maximum value of 600-700 kN/buffer.

Fig. 9 illustrates the variation of acceleration for the empty tested vehicle for speeds between 8 km/h and 12 km/h, in accordance with EN 12663-2:2010. As it can be seen in figure 9, the vehicle acceleration increases directly with the buffing impact speed.

Speed [km/h]	Acceleration [m/s^2]
8.2	2.8
9.0	3.1
9.4	3.5
10.1	4.0
10.5	4.4
11.0	4.7
11.6	5.2
12.0	5.7
12.2	6.1
12.4	6.4

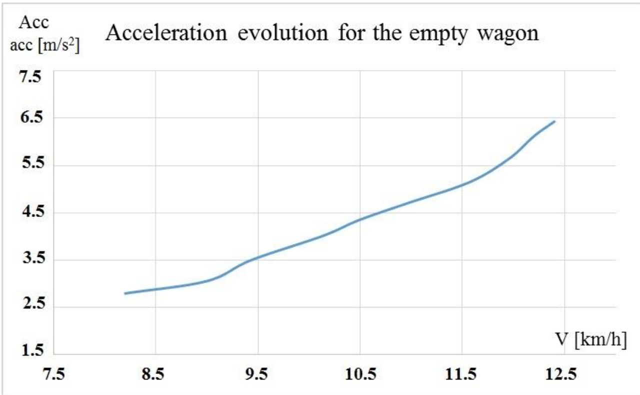

Fig. 9. Acceleration evolution for the empty wagon tests

4.2.Fully loaded vehicle tests

In the case of the fully loaded vehicle tests, the forces behind buffers, acceleration of the vehicle, buffer displacements and strains in the measuring points are followed.

Table 1 presents the force results measured using the HBM force cells for all buffing impact speeds.

Table 1

Force-speed evolution for the fully loaded vehicle tests

Speed [km/h]	Left buffer force cell [kN]	Right buffer force cell [kN]	Left cell + Right cell [kN]
6.1	652.5	627.5	1280.0
6.3	686.4	656.2	1342.6
7.0	751.9	729.4	1481.3
8.1	886.8	863.2	1750.0
9.0	921.7	912.6	1834.3
9.5	976.3	961.4	1937.7
10.3	1016.2	998.7	2014.9
10.6	1043.5	1021.3	2064.9
11.3	1123.3	1099.7	2223.1
11.7	1251.6	1209.1	2460.7

The force evolution according to buffing impact speed is illustrated in figure 10: with blue color is illustrated the right buffer force curve, with red color is illustrated the left buffer force curve and with green color is illustrated the two vehicle buffers cumulated force.

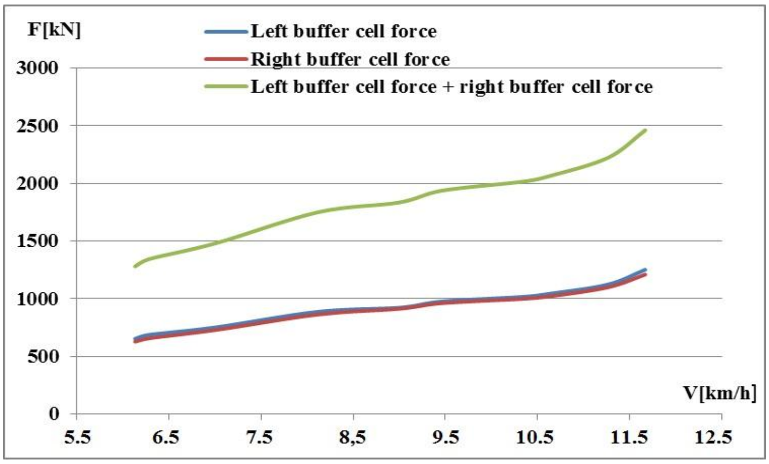

Fig. 10. Force-speed curve for the fully loaded vehicle tests

In Table 2 and Fig. 11 is presented the force-displacement evolution for the fully loaded vehicle, tested at the speed of 9 km/h, as the reference document requires.

Table 2

Force-displacement evolution for the fully loaded vehicle tests (9 km/h speed)

Force cell	Force cell	Displacement sensor	Displacement sensor	Displacement sensor	Displacement sensor
left buffer	right buffer	left top	left down	right top	right down
kN	kN	mm	mm	mm	mm
0	0	0	0	0	0
54	45.7	2.24	1.67	3.17	3.15
118.8	145.5	12.34	11.87	14.57	15.15
313.8	311.5	23.84	23.77	27.07	27.95
572.8	536.2	33.04	33.27	36.37	37.15
741.8	684.9	38.04	38.47	41.37	42.25
626.6	582.2	39.04	39.37	42.17	42.95
403.8	376.2	36.84	36.87	40.07	41.25
240	230.2	32.84	32.67	36.07	36.85
85.8	111.1	23.54	23.47	27.07	28.15
50.2	81.8	17.44	17.37	20.77	22.25
24.4	51.8	11.84	11.87	15.37	16.25
16,4	41.6	10.04	9.77	13.57	14.55
12,8	34.5	8.04	7.47	11.57	12.65
12,2	24.8	3.34	2.17	6.87	7.95

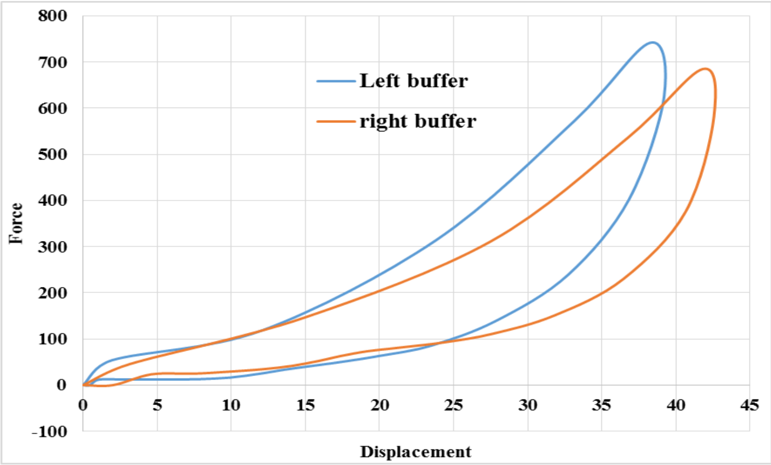

Fig. 11. Force-displacement curve for the fully loaded vehicle tested at the speed of 9 km/h speed

During buffing impact the force and displacement at the buffers level increase to a maximum value and after the impact these two parameters return to zero value, as it can be seen in figure 11.

The preliminary strain results were calculated using the following relation:

$$\varepsilon_{rcp}=\varepsilon_{rcp1}+\ldots\varepsilon_{rcpn} \tag{1}$$

in which ε_{rcp1}, … ε_{rcpn} are strains registered in case of the 40th buffing tests.

The final reported strain was calculated using the following relation:

$$\varepsilon_{rcc}=\varepsilon_{rcp}+\varepsilon_{rc1}+\ldots+\varepsilon_{rc40} \tag{2}$$

in which ε_{rpc} - strains registered in case of preliminary buffing test;

ε_{rcc} - cumulate strains for all buffing tests (preliminary tests + the set of 40 buffing tests).

In figure 12 are presented the acceleration curve in speed range of 8 km/h to 12 km/h and the registered values for the fully loaded vehicle.

As was expected, the acceleration of the vehicle during buffing impact tests with the fully loaded structure increased almost linear with speed.

Speed [km/h]	Acceleration [m/s²]
7.9	1.2
8.2	1.8
8.9	2.2
9.3	2.6
10.1	3.2
10.9	3.6
11.4	4.4
11.9	4.8
12.1	5.2
12.3	5.4

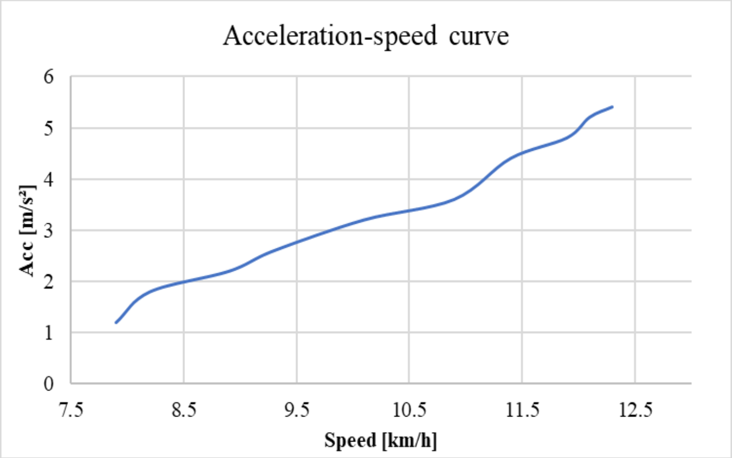

Fig. 12. Acceleration curve in the speed range of 8 km/h to 12 km/h for the fully loaded vehicle

At the end of the 40 buffing impact tests, all strain results should be added together and the final value should be less than 2000 µm/m in order to be declared able to run;

The strains obtained for the fully loaded vehicle tests are presented in Table 3.

Table3

Strains results for the fully loaded vehicle tests

Buffing nr.	preliminary	10	15	20	25	30	35	40	
Speed [km/h]		12.5	12.37	12	12.2	11.36	12	11.43	
	Average speed [km/h] 12.05								
Measuring point	ε_{rcp} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rc} [µm/m]	ε_{rcc} [µm/m]
TF2	79	5	27	22	15	38	10	28	282
TF102	-113	-276	-86	-212	-202	-230	-151	-235	-1609
TF4	70	35	28	26	24	23	21	20	297
TF104	-183	-100	-72	-68	-46	-58	-65	-75	-825
LC1	-153	-59	-45	-43	-39	-47	-41	-39	-606
LC101	-40	-16	1	-24	-9	-18	1	-20	-185
LC4	164	90	59	71	66	27	67	64	741
LC105	-278	-163	-125	-133	-87	-76	-124	-147	-1280
TC3	-195	-68	-53	-75	-43	-38	-58	-85	-746
TC5	25	23	41	-2	-21	35	18	27	148
LL4	-309	-179	-132	-137	-93	-91	-134	-150	-1484
LL105	107	300	100	223	183	96	228	193	1552
S1	-29	-22	-19	-2	0	-21	-9	-22	-137

Buffing nr.	preliminary	10	15	20	25	30	35	40	
Speed [km/h]		12.5	12.37	12	12.2	11.36	12	11.43	
S2	-182	-188	-105	-95	-90	-16	-121	-88	-1064
R1	-243	-136	-97	-102	-70	-76	-99	-114	-1141
C2	-34	-25	-1	-7	-5	-27	-1	-17	-136

The maximum value of the cumulated strains was -1609 μm/m and it was registered by TF 102 measuring point, in the front cross beam of the vehicle.

5. Conclusions

This paper presents the buffing impact test results of an Eaos type open wagon. The tests were carried out using the special railway (equipped with hump) from Făurei Railway Testing Center, with the aim of verifying aspects related to freight rail vehicles structure behavior in special cases of handling.

During tests, forces, displacements, accelerations and strains were measured, using special devices: force cells, displacement sensors, strain gauges, data acquisition systems, HBM Catman software. Also, two special buffing wagons (one active and one stationary) and a locomotive were used.

The tests for two cases of loading for the empty vehicle and for the fully loaded vehicle were carried out.

The purpose of the first case of loading (the empty case of loading) tests was to verify the integrity of the vehicle structure and all equipment mounted on it. During these tests, the vehicle was subjected to buffing impacts in speed range of 5km/h to 12 km/h, forces and accelerations being measured. The vehicle acted conformable, without any deteriorations or abnormal values.

For the second case, the vehicle was loaded at maximum capacity and the tests were carried out in two steps: a preliminary set of tests and a series of 40 buffing impacts. The preliminary tests were performed with the aim of determining the necessary speed for the 40 buffing impacts.

During the 40 impacts, the forces behind buffers, the buffers displacements, the accelerations and the strains were measured, as European standards require. For measuring the strains, 16 measuring points were used, in the main areas of the vehicle structure, based on vehicle structure static tests results. Higher strain values were measured in the buffer cross beam area but none of them were above the prescribed limit of 2000μm/m.

The final conclusion of the presented research is that the vehicle can be declared able to run in traffic and, most important, to be maneuvered on rail lines equipped with humps.

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