ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XX, NR. 2, 2013, ISSN 1453 - 7397

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Experimental Determination of Chassis Tensions Freight Wagons with High Walls Tensometriei Resistive Method

The paper aims at forwarding an experimental analysis, through the method of resistive tensometry, of the strains occurring in the body of a high-walled freight wagon with handler's platform.

Keywords: wagon body, resistive tensometry, experimental analysis,

1. Introduction

Testing the strength structure of the freight wagons is mandatory for the prototype wagons or when structural alterations are made as a result of a modernisation process. The tests are effected according to the international standards [13], [18]. From the analysis of these standards it clearly results that the primary document which was at the basis of the elaboration of ulterior documents was the ERRI B12/RP17 report. This technical document was elaborated by ERRI (European Railway Research Institute), the technical organism appointed by UIC (The International Union of Railroads). UIC was created on the 22nd of October 1922 with the purpose of realising a technical frame of standardisation of the railroad domain. In this context, UIC reunited since the beginning members from the entire world. As a result of the UIC's activity of almost one century, they elaborated the UIC charts, which relied on the research co-ordinated by ERRI. The UIC charts and the ERRI reports were imposed as official standards only in the UIC member states. The domains that were not covered by these documents were completed with the national rules. The ERRI B12/RP17 report details the tests that should be effected on the strength structure of the freight wagons and also the evaluation criteria of the results obtained.

2. Purpose of the paper

The tests on the strength structure of freight wagons simulate efforts occurring in exploitation. According to [13], [15], [18] the efforts applied during static tensometry tests on the portent structure of the wagons body are:

- of compression, in the axis of the buffers with 1000 kN on a buffer and simulates the case of the occurrence of an effort as a result of braking.
- of compression, in the axis of the automatic couple with 2000 kN, simulating the case of the occurrence of an effort following the train braking, and the wagon is immediately after the locomotive in the case of the automatic couple.
- of compression in diagonals with 400 kN simulating the efforts occurring in the freight wagon's circulation in curves.
- of compression at 50 mm under the axis of buffers with 750 kN on each buffer. This effort of compression simulates the train braking in conditions of circulation of wagons with different loading degrees, as is the case of freight wagons. In the train mass it can happen that one empty wagon be placed between two loaded wagons, and in this case the axis of the buffers of the coupled wagons does not coincide and thus a bending moment is overlapped on the compression effort.
- of axial traction with 1500 kN simulating the wagon circulation in traction regime.
- with vertical load simulating the mass of the load applied on the body.
- of one-end lifting with the loaded wagon, simulating the derailment of the first bogie of the wagon and its re-positioning on the rail;
- of four-point lifting with the loaded wagon simulating the total derailment of the wagon and its re-positioning on the rail;
- combination of horizontal efforts with vertical load.

2.1. Mounting of the tensometric transducers

Figure 1 and 2 shows the placement of tensometric transducers in the front area of the chassis, and the following figures show their photographs.

For a sensible placement of transducers, it is indicated to perform a study through the method of the finite elements of the strength structure's static behaviour. In the absence of such a study, one needs the expertise and knowledge of the person appointed to establish the placement of tensometric marks and rosettes.

The acronyms of the tensometric marks presented in the previous figure have the following significance:

- TF – front traverse;
- LC – central strut;
- LI – intermediary strut;
- LL- lateral strut;
- D – diagonal;

- TC – traverse of the pallet (pivots);
- T – intermediary traverse;
- C – box (side and front walls);
- S – poles.

By marking the marks with the acronym of the structural elements on which they are applied we aim at an easy identification.

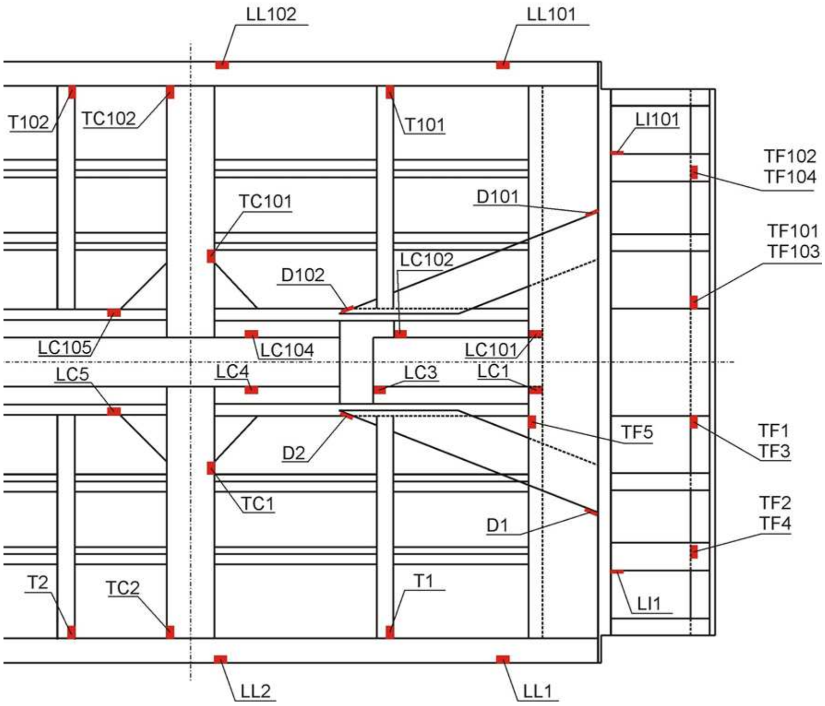

Figure 1. Tensometric marks stuck to the chassis

a) Mark TF101

b) Mark TF1

c) Mark T103 d) Mark LC7

Figure 2. Photographs of tensometric mark

The application of the horizontal forces is not done directly on the connecting and buffering apparatus as the efforts provided by the standards represent overloads and not nominal exploitation loads. For the application of longitudinal efforts, the buffers and the traction apparatus are dismantled and replaced by devices of compression on buffers without elastic elements, and devices of axial compression or axial traction allowing the coupling with the tensometry stand of the Romanian Railroad Authority. For the generation of the horizontal forces one uses a horizontal hydraulic press. The vertical loads are made by the application of ballast on the wagon floor. The distribution of the ballast is made according to the requirements of the tests. The lifting tests suppose the wagon balloting and its lifting form the established points with the help of lifting devices (winches, cranks, etc.).

The manner of positioning the dial comparing meters is presented in the following figures.

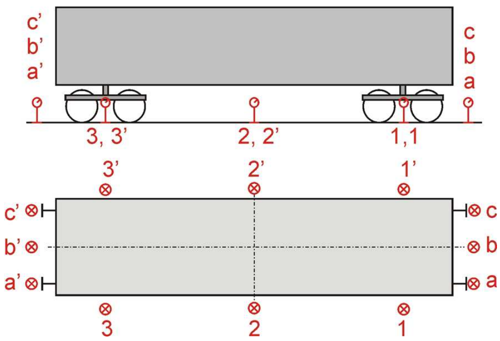

Figure 3. Placement of the roll comparing meters at the strain of wagon with horizontal forces

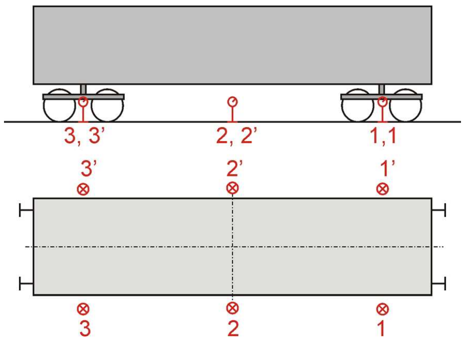

Figure 4. Placement of roll comparing meters at the wagon strain with vertical loads

The compression forces are applied on the buffers or in the axis of the automatic couple. In order to measure the deformation produced by these forces, one places roll comparing meters in the sections a-a′, b-b′ and c-c′ comparing meters b-b′ and the deformation produced by the traction effort applied in the axis of the couple on the wagon traction supports. With the help of comparing meters 1-1′, 2-2′ and 3-3′ one monitors the vertical arrow produced by the compression or traction efforts.

The values of the specific deformations measured with the tensometric marks and / or rosettes are turned into strains. These strains are related to the admissible limits imposed by the standards in vigour. Unlike the marks, for the values of the deformations measured with the dial comparing devices, there were no imposed limits, and consequently the standards do not impose the use of these measuring devices or of equivalent ones. However, the use of comparing meters can supply information on the modality of wagon deformation when efforts are applied.

In Figure 4 we can remark the modality of positioning the comparing meters in the case of the wagon testing with vertical load.

With the comparing devices a, a′, b, b′, c, and c′ one determined the longitudinal deformation along the application directions of forces, with the relations:

$$\Delta_a = \delta_a - \delta_{a'} [mm]$$
$$\Delta_b = \delta_b - \delta_{b'} [mm]$$
$$\Delta_c = \delta_c - \delta_{c'} [mm]$$

With the help of the comparing meters 1, 1′, 2, 2′, 3 and 3′ one determined the mid wagon arrows, with the relation:

$$f = \delta_{2m} - \frac{\delta_{1m} + \delta_{3m}}{2} [mm]$$

Where: δ_{1m}, δ_{2m} and δ_{3m} are the average shifts on each of the three considered sections and are calculated with the relation:

$$\delta_{2m} = \frac{\delta_i + \delta_{i'}}{2} [mm]$$

At the tests with horizontal forces and vertical loads, the wagon deformations in the horizontal plane were called "deformations", whereas the deformations in vertical plane were called "arrows". They were given different names in order to differentiate the vertical plane deformations from the horizontal ones and because the reference documents use the same denominations.

Although the lifting tests are strains with vertical forces and loads, and thus the wagon deformations are measured only on the vertical, as the reference documents refer to the wagon deformation, the vertical deformations will be called "deformations" hereinafter for the lifting tests.

The permanent deformation was calculated with the relation:

$$\delta_{pi\div i'} = \frac{\delta_i + \delta_{i'}}{2}[mm] \quad \text{for } i=i'=1\div 6$$

where: $\delta_{pi\div i'}$ is the permanent deformation in the measuring section i÷i', δ_i, δ'_i represent the shifts of the roll comparing meters i and i', for i=i'=1÷6.

The relative permanent deformation was calculated with the relation:

$$\delta_{ri\div i',i+1\div i'+1} = \left(\frac{\delta_{pi\div i'} + \delta_{pi+1\div i'+1}}{2}\right)\cdot 1000\left[{}^{0}\!/_{00}\right] \quad \text{for } i=I'=1\div 6$$

where: $\delta_{ri\div i',i+1\div i'+1}$ is the relative permanent deformation between the sections i÷i' and i+1÷i'+1, d is the distance between the sections i÷i', i+1÷i'+1.

2.2. The modality of tests performing

The sequence of test operations in view of determining the strains in the measuring points and the measuring of the arrow and longitudinal deformations in the wagon structure is the following:

- the wagon is positioned in the stand;
- for measuring the strains in the wagon structure one uses the tensometric marks connected to the devices;
- one places roll comparing meters in order to measure the longitudinal deformations and the vertical arrows;
- one removes the wagon traction and connection devices and replaces them with compression devices;
- the stand is configured for the tests performance;
- the devices are poised (brought to the "0" position);
- one applies horizontal forces or vertical loads according to the test requirements;
- one reads the value of the deformation specific for each measuring point as a result of the application of exterior forces;
- one determines the strains in the wagon structure by introducing the values of the measured specific deformations in a Microsoft Excel application as well as the deformations suffered by it during tests.

Appreciation criteria:

The strains determined in N/mm2 must fall within the ranges of the following table:

Table 1. Admissible values of the strains

	Material characteristic	Admissible strain
Weld-free area	$R_p > 0{,}8 \cdot R_m$ and $A > 10\%$	$\sigma = R_p$
Welded area		$\sigma = R_p / 1{,}1$

σ_{aH} is the admissible strain for the tests with horizontal forces and loads with combined efforts:

- For the weld-free areas :

$$\sigma_{aH} = R_{p0,2} = 355 \ \mathrm{N/mm^2}$$

- For the welded areas:

$$\sigma_{aH} = \frac{R_{p0,2}}{1{,}1} = 322 \ \mathrm{N/mm^2}$$

For the vertical loads, the static tests applied to the strength structure try to determine the behaviour of the strength structure of the freight wagon, at fatigue.
For the tests with vertical loads, the admissible limits imposed by the reference documents are:

Table 2. Admissible limits for steel widely used in the freight wagons construction

	Admissible strains for the steel [N/mm^2]		
Steel	S235	S275	S355
Weld-free area	235	275	355
Welded area	214	250	323

3. Results

The following table presents the results obtained at the test of the high-walled freight wagon subjected to the test of buffer compression with 50% of the force maximum value.

The table 3 one may remark exceeding of the admissible limits for several tensometric marks, although one has not applied the maximum compression forces on buffers.

These results confirm the results of the study through numerical methods. Both the simulation conducted with the wagon model with finite elements and the results obtained through resistive electric tensometry confirm the design and execution flaw in the front area of the wagon, where the false traverse is situated. In this area it is necessary to apply a reinforcement solution meant to eliminate the risk of the occurrence of strains higher than the admissible strains. The proposed reinforcement solution will be verified on the finite elements model after the validation of the numerical model by the comparison of the numeric / experimental results.

Table 3. Strains determined

No.	Mark	Admissible strain	Measured strain	No.	Mark	Admissible strain	Measured strain
1	TF1	323	-77	32	LL1	323	-119
2	TF101	323	-282	33	LL101	323	-197
3	TF2	323	148	34	LL2	323	-38
4	TF102	323	931	35	LL102	323	-32
5	TF3	323	-553	36	LL3	323	-66
6	TF103	323	-653	37	LL103	323	-67
7	TF4	323	134	38	LL4	323	-70
8	TF104	323	443	39	LL104	323	-65
9	TF5	323	83	40	LL5	323	-44
10	TF6	323	36	41	LL105	323	-36
11	TF106	323	38	42	D1	323	-464
12	TF7	323	470	43	D101	323	-77
13	TF107	323	630	44	D2	323	-74
14	TC1	323	-10	45	D102	323	-46
15	TC101	323	-29	46	T1	323	-5
16	TC2	323	-2	47	T101	323	8
17	TC102	323	-4	48	T2	323	-2
18	LC1	323	-28	49	T102	323	-6
19	LC10	323	-124	50	T3	323	-1
20	LC102	323	-68	51	T103	323	-1
21	LC3	323	-31	52	T4	323	-2
22	LC4	323	6	53	T104	323	4
23	LC104	323	12	54	T5	323	1
24	LC5	323	-95	55	T105	323	5
25	LC105	323	-83	56	S1	323	-1
26	LC6	323	-97	57	S2	323	6
27	LC106	323	-78	58	S102	323	1
28	LC107	323	-98	59	C1	323	-11
29	LC8	323	-80	60	C2	323	-14
30	LI1	323	342	61	C3	323	43
31	LI101	323	44	62	C4	323	11

As the positioning of the resistive tensometric transducers is known with precision, one may verify the values of the measured strains in the knots of the model. Moreover, the values of the deformations measured with the help of comparing meters will be used for verifying the deformations calculated numerically.

The reinforcement of the area where higher strains than the admissible ones were recorded can be made by adding ribs and gussets, by caissonning certain constituting elements of the chassis in that area, by extending the diagonals etc. One will choose the solution that is optimum both from the technical and the economical viewpoint.

The following tables show the measured values of the longitudinal deformations and of the arrow:

In Table 5 we can remark the smaller value of the deformation in the central section, as the forces are applied on buffers.

The positive values of the arrows are pointing downwards.

Table 4. Longitudinal deformations

Longitudinal deformations [mm]	$\Delta_{a\text{-}a'}$ =-6.7 $\Delta_{b\text{-}b'}$=-2.6 $\Delta_{c\text{-}c'}$=-7.8
Remanent deformations [mm]	$\Delta_{rem\ a\text{-}a'}$ = -0,2 $\Delta_{rem\ b\text{-}b'}$ = -0,1 $\Delta_{rem\ c\text{-}c'}$ = -0,8

Table 5. Arrow

Absolute arrow [mm]	-1.8
Remanent arrow [mm]	0.1

4. Conclusion

The tensometric tests are by their nature non-destructive tests, which is a big advantage, especially for the complex structures such as freight wagons. The transducers applied on the wagon structure can be used both in static tests and in dynamic tests, depending on the testing requirements. Furthermore, if we want to monitor the behavior of a structure in time, tensometry allows this, as the transducers resist to the fatigue cycles the model is subjected to.

The establishment of the strains and deformations state in the wagon structure can be effected with the help of resistive electric tensometry; and the same method can be used for measuring forces, arrows and deformations, couple etc. Depending on the physical dimension one intends to measure, one chooses the type of transducer (make, force cell, shift transducer) as well as the connection type (quarter bridge, semi-bridge, or whole bridge).

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