STUDY ON THE RESISTANCE OF THE CHASSIS-TANK CONNECTION TO THE LOADS THAT APPEAR IN USE

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Abstract: The paper presents a study on the resistance structure of the chassis-tank connection, to the loads that appear in use. The study comprises the theoretical resistance computation to the loads imposed by the international norms of the UIC, as well as the experimental determinations for the same loads, for the purpose of proving the theoretical computation, both for the static regime and for the dynamic regime for the shock caused by collision.

Keywords: von Mises Stress, force transmitted during shock, residual deformation.

1 INTRODUCTION

The conception, execution, promoting to the railway and use of a railway vehicle follow a complex process that submits to rigorous rules and concepts of applied mechanics. Consequently, a well determined scientific course is generally established, attached to a series of imperiously necessary practical norms:

1. Establishing a set of technical norms that comprise the technical characteristics together with the resulting economic and environmental impact.
2. A theoretical study on the constructive and technical solutions adopted and the finalization of the functional technical characteristics for the execution of the vehicle.
3. The actual design phase, preceded by a series of studies that aim at establishing solutions that will be included in the design of the prototype expecting validation by experimental research.
4. The experimental research that follows a program comprising the response of the vehicle in use, in regards to bearing structures' resistance, travel safety and travel dynamics.
5. Modification of the design and implicitly of the prototype as a consequence of the findings from the research and trial program and restarting the experimental research process up to finalization. Completing the vehicle implies fulfilling all the requirements established initially.

In the paper we discuss the phase of the prototype design for a tank wagon, together with the confirmations offered by the experimental study in regards to the resistance of the bearing structures.

2 THEORETICAL COMPUTATION OF THE RESISTANCE STRUCTURE

In the design phase, a 3D model of the car geometry was created and then introduced into the MSC Nastran software and adapted to the requirements for the Finite Element three-dimensional analysis.

The computations were conducted for a tank wagon with the following characteristics:

- Weight of the empty car - $m_c = 27000$ kg;
- Maximum useful load $m_2 = 63000$ kg;
- Axle load $2Q_0 = 22500$ kg;
- Axle base a = 10820 mm;
- External diameter of the tank without insulation D = 2700mm.

The simulated load to which the vehicle was subjected is SV63t+CT2x1MN and the obtained results are shown in figures 1-3.

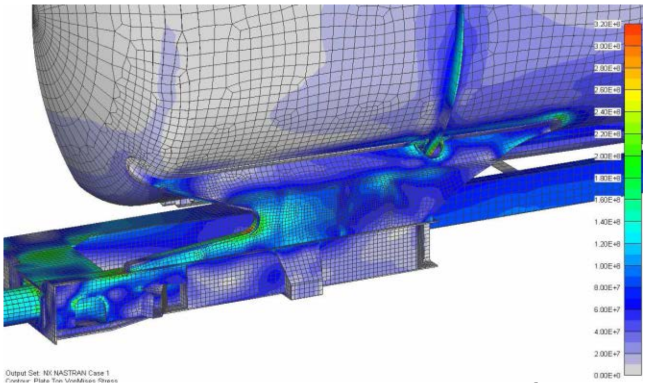

Fig. 1. Equivalent von Mises stress [N/m^2]

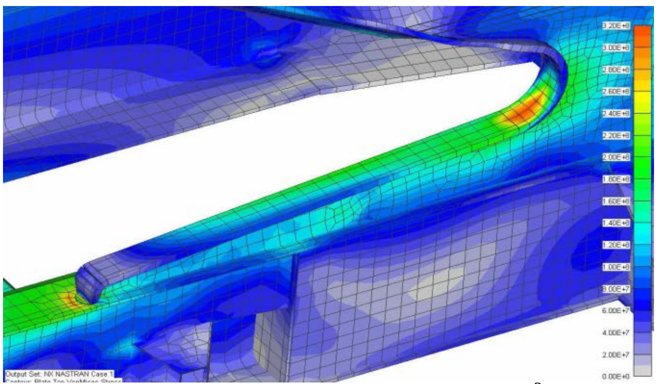

Fig.2. Equivalent von Mises stress [N/m^2]

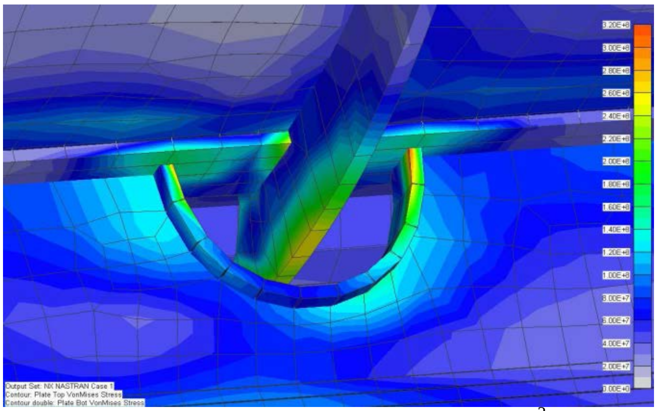
Fig. 3. Equivalent von Mises stress [N/m^2]

3 STATIC EXPERIMENTAL DETERMINATIONS

From the analysis of the theretical results obtained from computations, the most dangerous sections and areas in regards to the resistance to static loads that simulate the loads that appear in use, were determined, according to ERRI B12 Rp17 [1], [3], [4]. Consequently, a number of 20 linear transducers and 15 rose type three directional transducers (denoted with R further on) [2] were placed on the structure of the tank and its affixing apparatus to the chassis. The transducers are electric resistive transducers with the purpose of determining the relative deformations and the stresses (in the elastic domain). The placement plan for the transducers is shown in figure 4.

In a specialized stand with adequate measurement, recording and data analysis equipment, the following trials were conducted:

- Axial compression with an applied force of 2MN (CA 2MN);
- Axial traction with an applied force of 1,5MN (TA T1,5MN);
- Pressure of 3bar in the presence of a vertical load SV=63000 kg (SV63P3bar);
- Compression on the buffers with an applied force of F=2x1MN (1 MN on each buffer) in the presence of a vertical load SV=63000kg (SV63+CT2x1MN).

The method of electric resistive tensometry is a high precision one.

The results of the experimental determinations are found in the tables:

- Table 1 – value of stresses for the linear transducers in N/mm^2;
- Table 2 – value of the von Mises stresses computed following the determination of the main stresses σ_1 and σ_2 on the basis of the experimental determination of the relative deformations on 3 directions.

$$\sigma_e = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2} \quad (1)$$

Table 1

Trial	CA 2MN	TA T1,5MN	SV63P3bar	[SV63+CT2x1 MN]
Transducer	N/mm^2	N/mm^2	N/mm^2	N/mm^2
101	-65	-6	-16	-334
102	-42	-20	-21	-298
0102	-51	-9	-18	-282
103	129	-109	12	12
104	100	-81	20	29
105	20	-7	23	44
106	12	-26	9	-55
107	1	-2	8	-4
108	-103	105	19	-92
109	-127	130	30	-216
110	-3	2	2	-5
111	-78	63	33	-121
112	-38	40	28	-59
113	3	-1	-71	7
114	9	-6	89	14
115	-269	288	30	-203
116	-296	283	-29	-236
117	6	-41	0	-347
0117	7	-38	2	-301

Table 2

Trial/Transducer	CA 2MN	TA T1,5MN	SV63P3bar	[SV63+CT2x1 MN]
R1	28,5	28,2	12,1	64,6
0R1	27,1	23,5	15,7	51,7
R2	54,9	68,6	21,5	87,3
R3	108,9	90,3	70,0	175,0
0R3	119,0	92,7	58,9	174,8
R4	155,3	164,7	47,3	206,0
R5	277,2	295,4	48,4	291,1
R6	201,2	171,7	42,1	68,3
R7	147,0	134,8	19,0	39,0
R8	24,7	19,9	98,3	15,5
R9	6,8	4,7	70,6	3,3
R10	6,2	3,7	28,4	13,1
R11	42,3	28,8	33,8	72,4
R12	33,7	23,7	152,0	123,0
R13	54,0	39,2	16,1	117,4

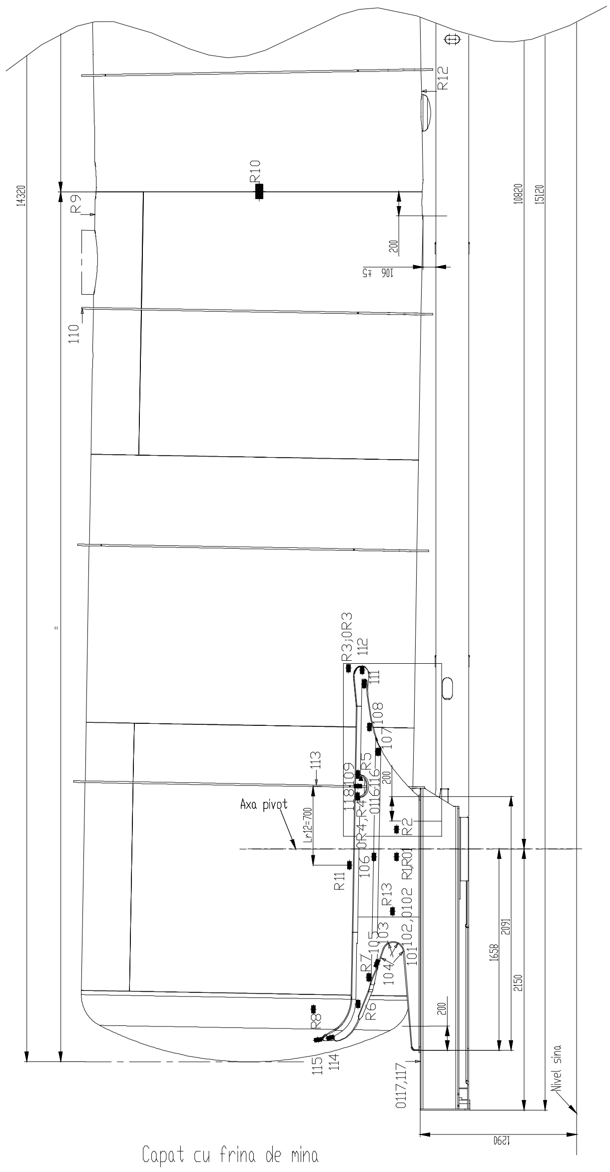

Figure 4.

4. EXPERIMENTAL DETERMINATIONS REGARDING THE SHOCK CAUSED BY COLLISION

The collision trials were conducted in a specialized stand by launching the colliding car, with a mass of 80t, that impacted the collided car (tank wagon), with a mass of 90t. Both vehicles were equipped with category A buffers, according to the norms of the European railways, UIC 526-1 [3].

During the trials, the following parameters were determined:

- v [km/h] – velocity of the colliding car;
- F_1 [kN] and F_2 [kN] – forces transmitted during impact;
- D_1 [mm] and D_2 [mm] – contractions of the buffers of the collided car;
- Acc1 [g] – acceleration of the collided car;
- Stresses σ [N/mm^2] for linear transductors and von Mises stresses [N/mm^2] for rose type transductors, denoted by R in the following.

In the tables showing the experimental results, for linear transductors 116 and 118, the values written in italic and bold represent relative deformations determined experimentally in [μm/m].

The results of the endurance testing at a velocity of approximately 12 12km/h, series of 40 collisions, are shown in tables 3 and 4.

Figures 5, 6 and 7 show the parameters F_1, F_2, and the acceleration Acc1 for one of the collisions. Figure 8 shows an area of a studied stress concentrator.

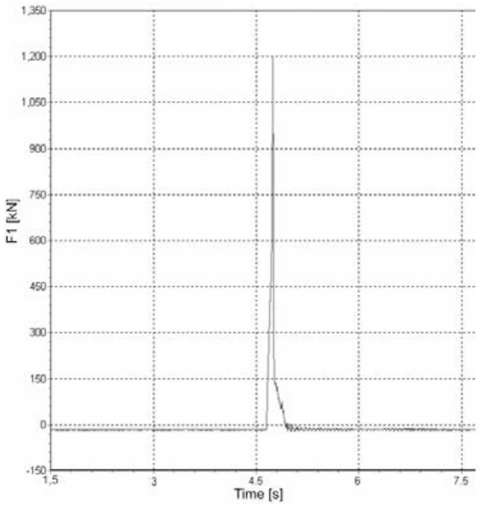

Figure 5. Variation of force F1 as a function of time during the collision process – loaded car

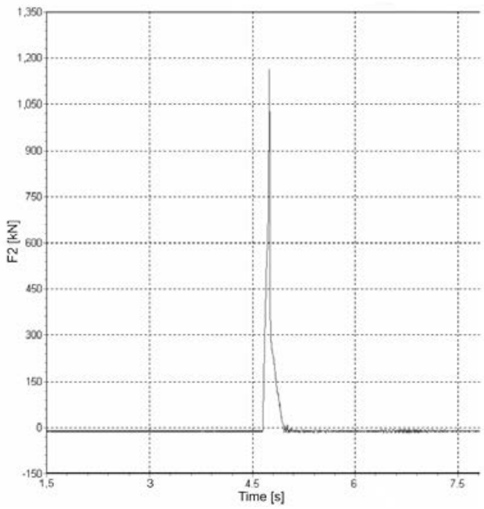

Figure 6. Variation of force F2 as a function of time during the collision process – loaded car

Table 3

Velocity [km/h]		11,92	11,92	12,04	12,03	Rezidual deformation	11,92	Rezidual deformation
TER	S.V.	Coll. 1	Coll. 10	Coll. 20	Coll. 30	[$^{o}/_{oo}$]	Coll. 40	[$^{o}/_{oo}$]
101	-6	-258	-266	-280	-278	0,07	-274	0,07
102	-9	-193	-194	-243	-240	0,19	-221	0,19
103	-9	66	40	52	60	0,02	53	0,02
104	-4	124	111	95	93	0,06	88	0,06
116	-97	***-1501***	***-1883***	***-2021***	***-1996***	***0,3***	***-1891***	***0,3***
118	69	***1707***	***1859***	***2058***	***1961***	***0,27***	***1961***	***0,27***
117	-4	-203	-217	-266	-252	0,02	-231	0,02
F1 [kN]		1266	1214	1273	1208		1234	
F2 [kN]		1234	1159	1231	1110		1156	
Acc [g]		6,5	6,3	6,6	6,3		6,3	

Table 4

Collision No.	1	10	20	30	Rezidual deformation	40	Rezidual deformation
Velocity [km/h]	11,92	11,92	12,04	12,03	[$^{o}/_{oo}$]	11,92	[$^{o}/_{oo}$]
R3	222	217	221	210	0,07	215	0,07
R4	393	394	379	395	0,3	386	0,3
R5	240	215	181	183	0,13	172	0,13

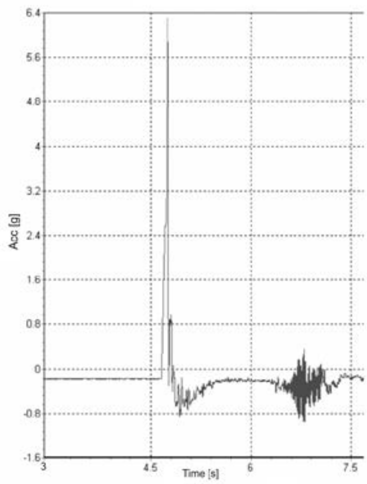

Figure 7. Variation of acceleration Acc1 as a function of time, during the collision process – loaded car

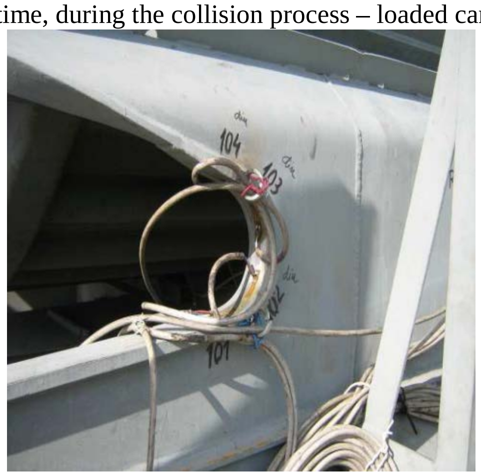

Figure 8. Studied stress concentrator are

5 CONCLUSIONS

Following the study conducted, the following conclusions can be drawn:

1. The theoretical Finite Element computation is a support and offers important information in regards to the dangerous (most strained) areas that need to be investigated experimentally.

2. The collision shock trial confirms the positive response of the studied structure to the loads that appear in use, since at all measurement points for the relative deformations and stresses, there were no recorded permanent deformations that exceeded the value of $2^{o}/_{oo}$ according to ERRI B12 Rp17 ed. 8.

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