UDK 621.91

TĂNĂSOIU A., "Aurel Vlaicu" University, Arad, Romania
COPACI I., "Aurel Vlaicu" University, Arad, Romania
ILIAS N., University of Petrosani, Romania

PARTICULARITIES OF THE RESISTANCE OF RAILWAY CAR BEARING STRUCTURES TO THE SHOCK CAUSED BY BUFFING

The paper presents a theoretical and experimental study on the resistance of the tank-chassis connection (seat) to the dynamical strains caused by the shock due to collision. The theoretical resistance computations using the Finite Element Method, for the compression on the buffers constituted fundamental information for the choice of the verified dangerous sections. The paper presents the collision testing conducted for this purpose with the conclusions imposed by the experimental study.
Keywords: shock caused by collision, von Mises stresses, bearing structure.

1.Introduction

The experimental study of the resistance of bearing structures through static trials is mandatorily continued by dynamic repeated shock trials and the determination of the lifetime in relation to the random loads that act upon the vehicle during travel.

In this paper we have aimed to follow the way in which a theoretical and experimental research program proceeds in order to lead to a just appreciation of the technical, technological and constructive solutions adopted for the studied case, meaning the resistance in use of the affixing method of the tank to the wagon chassis [1], [4].

For this purpose, the following working phases were conducted:

1. Computation using the Finite Element Method of the von Mises Stresses for the buffer compression of 2x1MN in the presence of a vertical load SV=63000kg, denoted by SV63+CT2x1MN.
2. Experimental determination of the stresses with linear or three-directional rose type transductors, in the areas or sections determined from the computation to be dangerous.
3. Final verification through the collision shock trial of the vehicle, according to ERRI B12 Rp17 ed.8.

2.Finite Element Method Computation

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.

Due to the fact that the car structure comprises small thickness sheet metal, in the bidimensional anlysis with FEM, plate type elements were used. The thickness of the discretization elements was chosen between 10mm and 70mm, such that in the stress concentrators acceptable values were obtained.

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;

The properties necessary for the static analysis, corresponding to the steel, are – longitudinal elasticity module (Young module), E = 210000 [Mpa]; mass density ρ = 7850 kg/m^3 and the transverse contraction coefficient (Poisson's coefficient) ν = 0.3

The chassis and the tank affixing apparatus are made out of St52 DIN 17100 steel with $R_{p0,2}$=355 N/mm^2 and the flow limit for the tank material, since it is equipped with an exterior heating installation welded on to the tank, with a maximum computation temperature of +190^o, is the flow limit at 190^{o}C obtained by interpolation $R_{p0,2}$=229 N/mm^2.

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

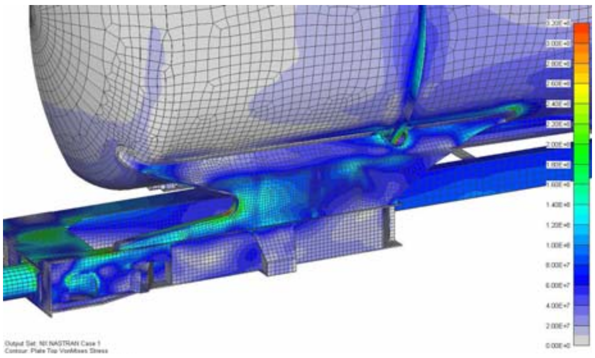

Figure 1 – Equivalent von Mises stress [N/m^2]

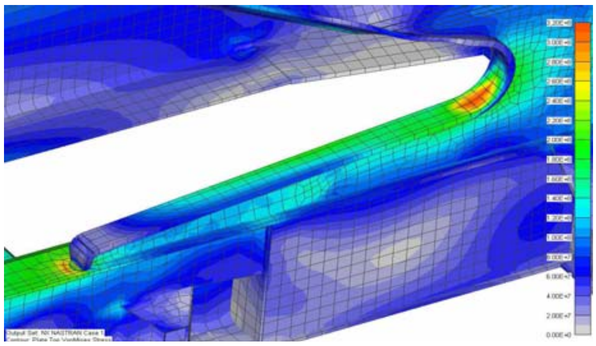

Figure 2 – Equivalent von Mises stress [N/m^2]

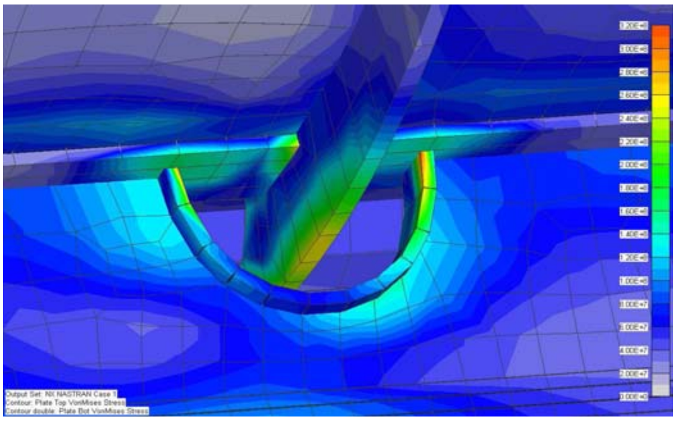

Figure 3 – Equivalent von Mises stress [N/m^2]

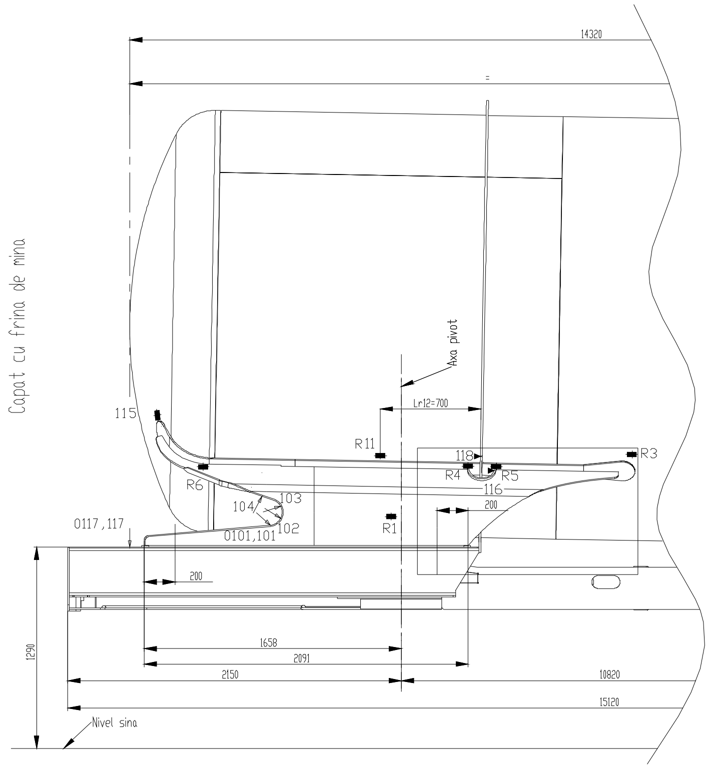

Figure 4 – Placement plan for the transducers on the tank wagon

3.Experimental results

The vehicle was equipped with electric resistive transductors for the experimental study in direct accordance with the dangerous areas determined through the computation. Consequently, 9 linear and 5 tensometric rose-type transductors [2] were affixed to the car, according to the placement plan shown in figure 4.

In an adequate testing stand, the static compression trial in the presence of a vertical load was conducted, with the results being presented in table 1.

Table 1.

Transducer	[SVm1m2+CB2x1 MN] [N/mm^2]
101	-334
102	-298
103	12
104	29
115	44
116	-236
117	-347
0117	-301
R1	64,6
R3	175,0
R4	206,0
R5	291,1
R11	72,4

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 collision trials had two phases:

1. Preliminary trials conducted at increasing collision velocities, from 6,71÷12,01 km/h, in order to determine the areas with the highest strains. The results of these trials are shown in tables 2 and 3.
2. Endurance testing at a velocity of approximately 12 km/h, in a series of 40 collisions. The results of these trials are shown in tables 4 and 5.

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.

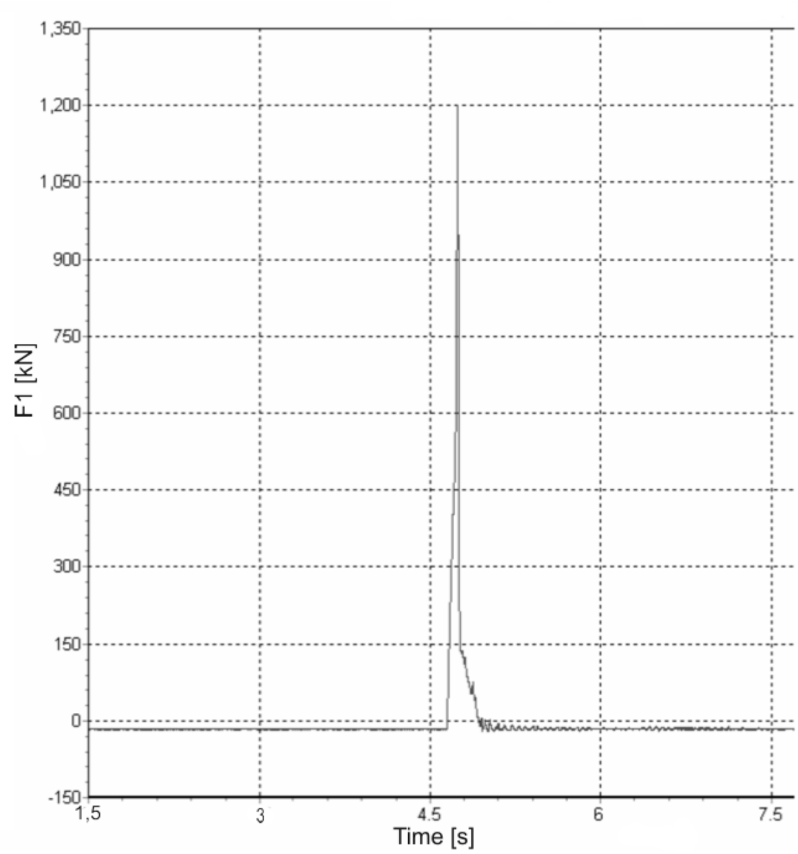

Figure 5 – Variation of force F1 as a function of time during the collision process – loaded car

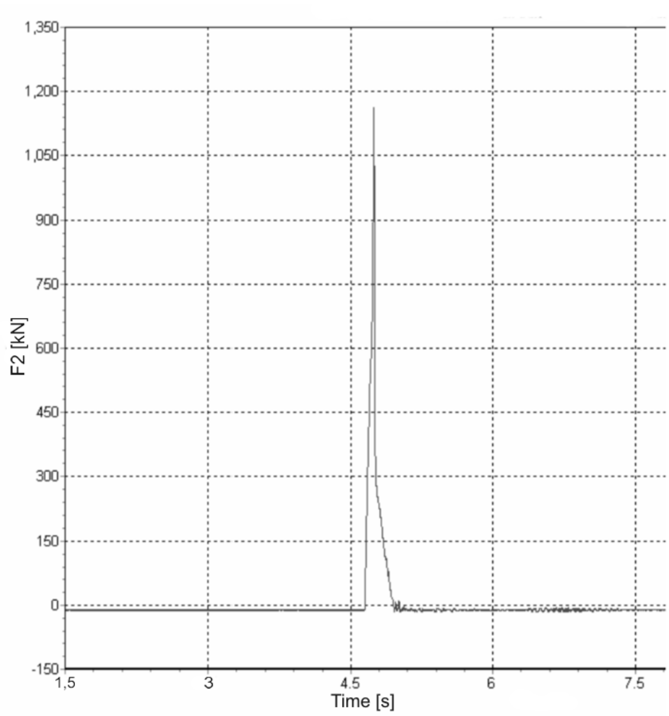

Figure 6 – Variation of force F2 as a function of time during the collision process – loaded car

Table 2.

TER	**SV**	**Velocity [km/h]**									
		6,71	**7,39**	**8,5**	**9,02**	**9,02**	**9,16**	**10,3**	**11,04**	**11,2**	**12,01**
101	-6	-106	-112	-122	-118	-110	-116	-120	-148	-172	-258
0101	-7	-114	-124	-124	-120	-134	-142	-146	-176	-194	-286
102	-9	-108	-114	-122	-126	-122	-116	-126	-144	-148	-228
103	-9	20	27	31	32	35	35	39	50	52	94
104	-4	26	32	36	40	39	40	44	52	57	92
105	4	18	21	24	25	25	27	28	29	30	44
116	-97	-224	-226	-274	-286	-295	-319	-323	-339	***-1664***	***-2028***
118	69	182	193	220	245	252	278	280	297	301	***1734***
117	-4	-62	-77	-74	-77	-75	-79	-80	-93	-100	-170
0117	-2	-60	-68	-74	-75	-78	-79	-81	-90	-94	-167
F1 [kN]		339	370	435	457	463	465	532	596	602	1224
F2 [kN]		421	458	522	544	542	551	620	681	687	1158
D1 [mm]		58	64	74	78,5	79	80	90	97	98	105
D2 [mm]		57	63	73	77,5	78	79	89	96	97	104
Acc1 [g]		1,87	2,16	2,35	2,61	2,61	2,66	3,19	3,46	3,46	6,32

Table 3.

Velocity [km/h]	6,41	7,43	8,59	9,5	10,4	11,04	12,02
Transducer							
R1	48	50	53	54	57	60	73
R3	72	77	94	112	114	116	174
R4	191	209	234	241	256	281	372
R5	157	166	178	185	192	206	265
R11	97	103	109	121	124	122	140

Table 4.

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 5.

Coll. 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 8 – Studied stress concentrator area

4.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.

References: [1] Copaci I., Olaru S., Tănăsoiu A. – ”Fatigue Resistance and Lifespan of Railway Vehicle Bearing Structures Under Random Strains”, The Knowledge Based Organization, Applied Mechanics, Military Technical Systems and Technologies Conference, pag. 218-225, ”Nicolae Bălcescu” Land Forces Academy, Sibiu, Noiembrie 2007, ISSN 1843-6722. [2] Mănescu T., Copaci I. Et.al. – ”Tensometria electrică în cercetarea experimentală”, Editura Mirton, Timi□oara, 2006.[3] Sebe□an I., Copaci I. – ”Teoria sistemelor elastice la vehiculele feroviare”, Editura Matrix, Bucure□ti, 2008 [4] Tănăsoiu A., Copaci I. – ”Study on the Shock Caused by Collision of Railway Vehicles”, International Journal of Mechanics, ISSN 1998-4448, pag. 67-76, www.naun.org/journals/mechanics.[5] Copaci I., Mănescu T., Olaru S., Creangă F. – “Rezisten□a la solicitări variabile carea par în exploatarea vehiculelor feroviare”, Editura Mirton, Timioara, 2005.