Experimental Study of the Characteristics of Shock Insulators Used on Railway Vehicles

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*Abstract:*The paper presents theoretical notions regarding the shock due to collisions of railway vehicles as well as a study on the applied methodology used to experimentally determine the static and dynamic characteristics of the bumpers that equip railway vehicles. The experimental stand, the transductors, the measurement, recording and data processing apparatus are also presented. The experimental force as a function of displacement (contraction) diagrams are presented for the shock insulators as well as the characteristics obtained during the static testing, both for normal temperature and extreme temperatures (+50°C and -40°C). Furthermore, the paper contains a study on the dynamic characteristics obtained for collision velocities between 6,15 km/h and 14,7 km/h with the appropriate conclusions regarding the category of classification of the elastic element that equips the studied bumpers (shock insulators) in order to categorize them in one of the A, B or C categories according to the international norms of the European railways, UIC 526-1.
Keywords: shock insulators, static characteristics, dynamic characteristics.

1 General Information

Due to current tendencies to increase travel velocities and car masses by allowing increasingly larger axle loads, railway equipment shows a series of special problems regarding shock loads that appear during collisions [6] . Collision of railway vehicles occurs during use, during car coupling operations, triage maneuvres and during travel, as a consequence of sudden breaking or of a change in coupling systems [1].

The shock caused by railway vehicle collisions results in the transmission of forces and accelerations of considerable magnitudes, which determine:

- strains on the resistance structure of the cars (chassis, carbody) and bogies;
- strains of the internal equipment and facilities of passenger cars or of different devices, mechanisms, functional equipment of freight cars;
- accelerations transmitted to the transported freight, which can endanger their integrity and that of the anchoring or packaging systems;
- accelerations transmitted to passenger cars with considerable consequences on the comfort of the passengers.

In order to insulate and protect against longitudinal shocks, railway vehicles are equipped with shock insulators:

- Buffers used to equip locomotives, freight and passenger cars that travel on the European railways and other administrations that have adopted this protection system.
- Central coupling dampener, system adopted by many administrations in South America (Brazil), North America (USA, Canada), Asia (countries in the former USSR, Vietnam), Australia and Africa [11];
- Long displacement dampeners, which equip platform cars, used supplementary to protect the platform on which the freight is loaded [4].

2 Experimental determinations

The testing for shock insulators [6], [8], [9], [10], [11] was conducted according to the prescription of the UIC 526-1 document. From the testing program presented in UIC 526 - 1 file the following tests were conducted:

1. Testing in order to determine the static characteristics;
2. Testing in order to determine the static characteristics at extreme temperatures -40ºC and +50ºC;
3. Testing in order to determine the dynamic characteristics.

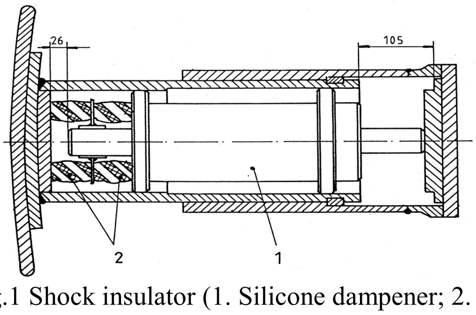

Fig.1 Shock insulator (1. Silicone dampener; 2. Rubber elastic elements)

2.1 Static characteristics

Test at +15ºC. For the static test, a number of 2 shock insulators were studied (fig. 1) [4], [7]. The characteristic parameters of the category C shock insulators are imposed by the UIC 526-1 file and are the following:

- Precompression force 10 ÷ 50 KN;
- Force after 25mm compression 30 ÷ 130 KN;
- Force after 60mm compression 100 ÷ 400 KN;
- Force after 100mm compression 400 ÷ 1000 KN;
- stored energy (W_e) ≥ 12.500 J;
- absorbed energy (W_a) ≥ 0,5 W_e.

The experimentally determined characteristic diagrams of the shock insulators are shown in figures 2 and 3.

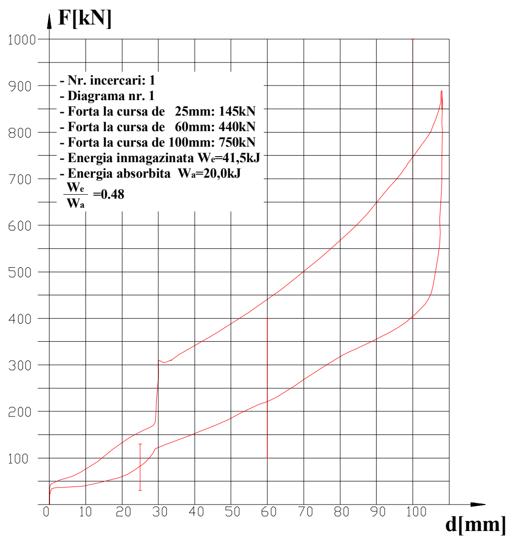

Figure 2.

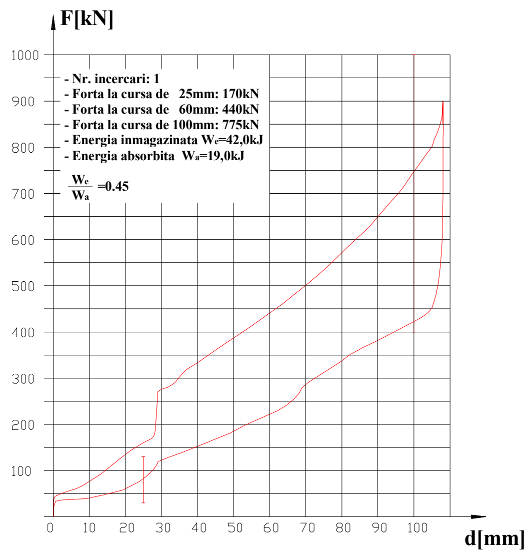

Figure 3.

From the analysis of the experimental results it is observed that for the two shock insulators tested, the force characteristics for the 25mm and 60mm compressions and the $\eta = \frac{W_a}{W_e}$ factor do not fall within the limits imposed by the UIC 526-1 file, while the other characteristics fit within the prescribed limits.

Test at +50ºC. The test was conducted in a sealed climate controlled chamber where the shock insulators were introduced for a period of 8 hours. The heating was done with an air heater and the temperature control was done with a thermometer..

The results of the tests with the obtained parameter values are shown in figures 4 and 5.

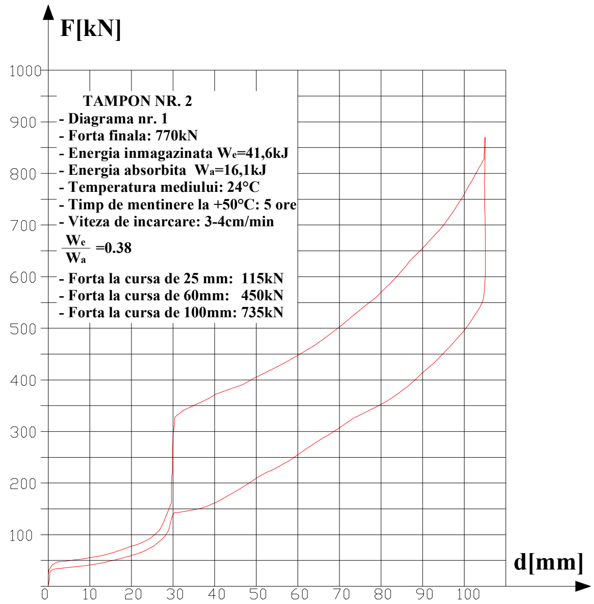

Figure 4.

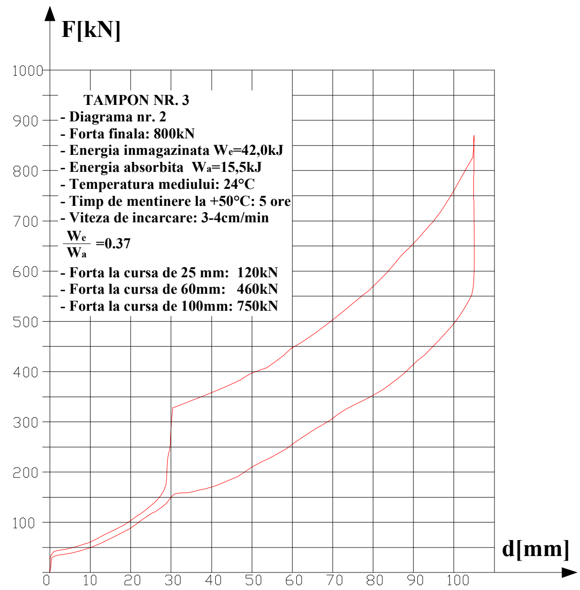

Figure 5.

Comparing the results from figures 2 and 4 for the first shock insulator, and from figures 3 and 5 for the second one, the following procentual differences are observed:

Shock Insulator 1:

- $\Delta F_{25} = 21\ \%$
- $\Delta F_{60} = 2{,}2\ \%$
- $\Delta F_{100} = 2\ \%$
- $\Delta W_e = 0{,}2\ \%$
- $\Delta W_a = 20\ \%$

Shock Insulator 2:

- $\Delta F_{25} = 29{,}4\ \%$
- $\Delta F_{60} = 4{,}5\ \%$
- $\Delta F_{100} = 3{,}3\ \%$
- $\Delta W_e = 0\ \%$
- $\Delta W_a = 19{,}4\ \%$

From the analysis of the above results it is observed that the shock insulators fit (with the exception of ΔF_{25} and the η factor) within the 20 % tolerance admissible by the UIC 526-1.

Test at -40ºC. In order to conduct this test, shock insulator 2 was dismantled, the elastomer capsule together with the rubber elements were inserted into feutron where they were kept at -40ºC for 16 hours. After the cooling time was done, the shock insulator was reconstructed and then the experimental determinations were carried out.

The results of the tests together with the obtained parameter values are shown in fig. 6.

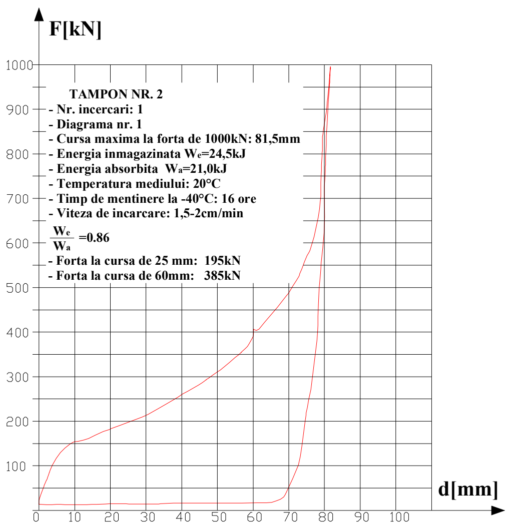

Figure 6

Comparing the results from figures 3 and 6, the following procentual differences are observed:

- $\Delta F_{25} = 34{,}4\ \%$;
- $\Delta F_{60} = 22{,}5\ \%$;
- $\Delta W_e = 41\ \%$;
- $\Delta W_a = 5\ \%$.

From the analysis of the results it is observed that during the -40ºC testing the buffer no longer complies with the requirements of UIC 526-1. Furthermore, the buffer only underwent a compression of 81mm.

2.2 Collision testing in order to determine the dynamic characteristics of the shock insulators

Collision testing was conducted according to the prescriptions of UIC 526-1. The testing was done with two cars with masses of 80t (figure 7), the collided car being equipped with category C shock insulators [1], [5]. The colliding car was equipped with category A shock insulators with rubber elastic elements.

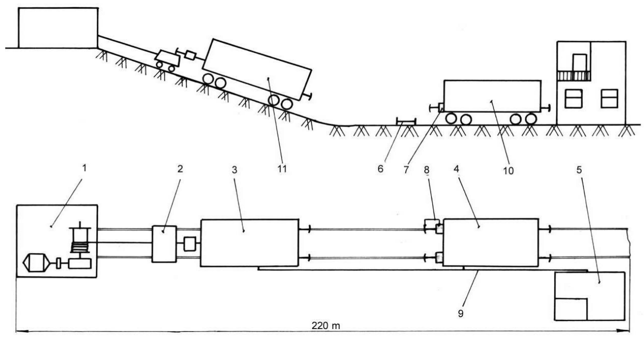

Fig. 7 Collision testing stand
(1.whinch ; 2. Releasing cart ; 3. Colliding car ; 4. Collided car ; 5. Stand building ; 6. Velocity transductor ; 7. Force transductor ; 8. Displacement transductor ; 9. Connection cables ; 10. Acceleration transductors)

The colliding car was launched at increasing velocities, up to 15 km/h towards the collided car. During the impact, the time evolutions of the following parameters were measured (table 1):

- force transmitted throufh the buffers F_1 and F_2;
- buffer compression D_1 and D_2;
- acceleration of the collided car „a".

Table 1

No.	Velocity [km/h]	W_{e1} [kJ]	W_{e2} [kJ]	$W_{e\ MEDIU}$ [kJ]	F_1 [MN]	F_2 [MN]	F_{MEDIU} [MN]	a (0-20Hz) [g]
1.	6,15	7,5	9,0	8,25	0,381	0,297	0,340	1,41
2.	8,20	18,0	13,9	15,95	0,559	0,348	0,454	1,79
3.	10,14	30,5	22,1	26,30	0,725	0,478	0,601	2,27
4.	11,84	47,7	35,4	41,55	1,031	0,620	0,825	3,14
5.	13,84	57,3	38,2	47,75	1,297	0,930	1,113	4,48
6.	14,70	61,3	42,8	52,05	1,514	1,059	1,286	5,31

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By eliminating time from the variations of force F = f(t) and compression D = f(t) the diagrams F=f(D) were obtained. From these diagrams, the following parameters were determined: W_e - stored energy; W_a - absorbed energy and $\eta = \frac{W_a}{W_e}$ [3].

the F = f (D) diagrams are shown in figures 8 and 9.

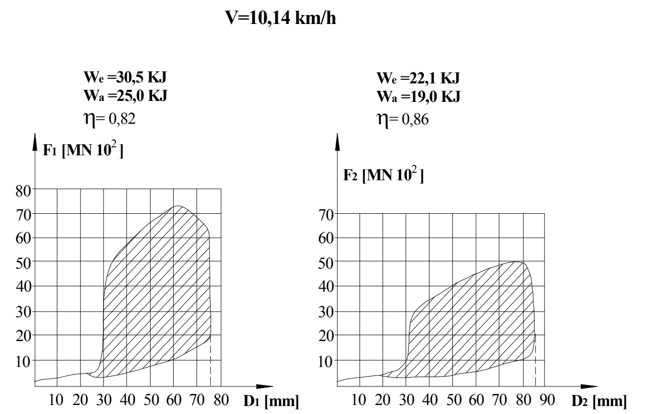


Figure 8.

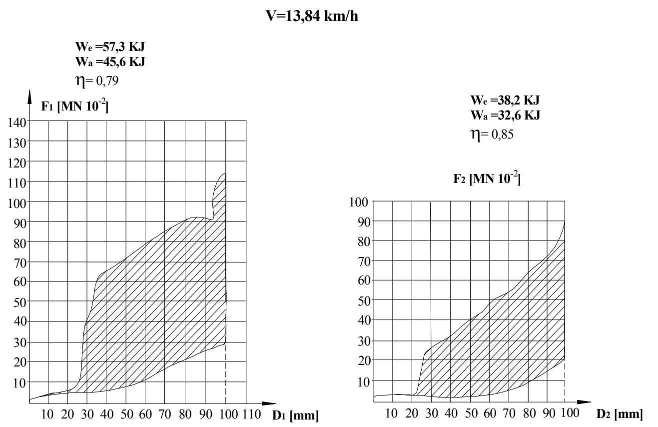
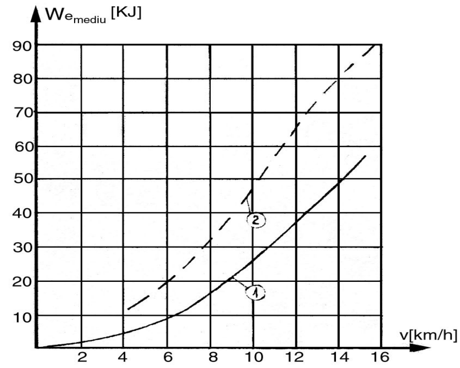


Figure 9.

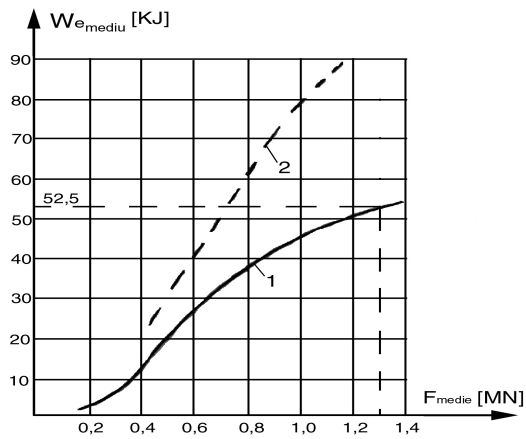
The variations of the average stored energy of the two shock insulators were represented as a function of the velocity of the collided car (figure 10), and of the average transmitted force through the two shock insulators (figure 11).

According to the diagram in figure 11, the average stored energy on the two studied shock insulators, $W_{e\,MEDIU}$, at the average force transmitted through the buffers of 1,3 MN is $W_{e\,MEDIU} = 52{,}5\ kJ$. According to the requirements of the UIC 526-1, for category C buffers it is necessary for a value in excess of 70 kJ to be reached.



1. Cat. C buffer with elastomers
2. Cat. C buffer ICPVA

Figure 10.



1. Cat. C buffer with elastomers
2. Cat. C buffer ICPVA

Figure 11.

3 Conclusions

After the analysis of the experimental results, the following conclusions can be drawn:

1. In regard to the static characteristics, the buffers do not correspond to the requirements of the UIC 526-1, the values of the absorbtion coefficient η corresponding to the force at 25 mm and 60 mm does not fit within the admissible limits.

2. For the extreme temperature tests, the studied buffers do not correspond to the UIC 526-1 norms. We point out that at -40ºC the buffer only underwent a compression of 81 mm and it did not return to the initial displacement, by 31mm, which, in use, determines the altering of the clearance between car buffers.

3. In regard to the dynamic characteristics, the tested buffers do not correspond to the requirements imposed by the UIC 526-1 for category C buffers. The buffers fit within the limits imposed by category B buffers.

In conclusion, the tested buffers correspond to the norms of cateory B buffers in regards to the dynamic characteristics without fulfilling the requirements for the static characteristics at extreme temperatures..

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