STUDY ON THE SHOCK INSULATORS OF RAILWAY VEHICLES

AURELIA TĂNĂSOIU[1], ION COPACI[2], NICOLAE ILIAŞ[3], SORIN MIHĂILESCU[4]

Abstract: The paper presents and compares two methods for establishing the dynamic characteristics of shock insulators and underlines the authenticity and scientific validity of the method of collision testing in specialized stands.

The paper also contains the experimental results obtained for a shock insulator with elastomer type elastic elements, together with a series of conclusions that regard the equipping of shock insulators with a high capacity for storing and dissipating potential deformation energy, as well as the importance of the 2β energy characteristic for the collision process.

Key-words: shock insulators, railway vehicles

1. INTRODUCTION

The shock caused by collision [2] leads to the transmission of forces and accelerations that can determine unwanted consequences on the resistance structures, equipment, passengers and freight transported by railway vehicles.

In order to reduce the transmitted forces and accelerations and, consequently, the unwanted consequences of the shock, railway vehicles are equipped with shock insulators. The capacity of the shock insulators to store potential deformation energy, described by the 2β energy coefficient [1], directly influences the magnitude of the forces and accelerations transmitted to the vehicles, the level of the potential energy $(1 - 2\beta)E_p$ received by the vehicles, as well as the effects caused by the shock during the collision process. Therefore, during the design and execution of railway vehicles, there is a tendency to increase the storage capacity for potential deformation energy of

[1] *Lect. Eng. PhD. at University „Aurel Vlaicu” of Arad, aurelia.tanasoiu@gmail.com*
[2] *Prof. Eng. PhD. at University „Aurel Vlaicu” of Arad, ioncopaci@gmail.com*
[3] *Prof. Eng. PhD. at University of Petroşani, iliasnic@yahoo.com*
[4] *Assoc. Prof. Eng. PhD., Department for Machines, Installations and Transports, University of Petroşani, mihailescus@gmail.com*

shock insulators in order to reduce the levels of the forces and accelerations transmitted to the vehicles during the collision.

In regard to the use of railway vehicles there is a tendency to increase travel velocities, reduce the formation times of trains as well as increase the axle load. Consequently, the forces and accelerations transmitted to the vehicles as a result of collisions reach relatively high values that need to be considered during the conception, design and execution of railway vehicles.

2. DETERMINING THE DYNAMIC CHARACTERISTICS OF SHOCK INSULATORS EEXPERIMENTALLY

Initially, the characteristic dynamic diagrams were obtained under the action of the shock caused by the free fall of a weight (ram), with a well determined mass, from different launching heights, on the buffer or central coupling dampener affixed to a rigid plane [2]. This adopted system differs significantly from the mechanical system encountered in the use of railway vehicles, specifically the one formed by the masses of the two cars separated by shock insulators, system which has a longitudinal freedom of motion. The excitation function (system entry), specifically the momentum "*mv*" of the ram mass is applied through the buffer or central coupling dampener to a plane with a theoretically infinite mass. Thus, time variations of the force and contraction of the buffer or central coupling dampener are obtained, as response functions to the applied excitation, particular to the used mechanical system and different from those of the real system. Consequently, through the use of this method, characteristic dynamic diagrams are obtained that can not lead to a correct qualitative appreciation of the shock insulator, resulting in erroneous dynamic characteristics.

Through the experimental determination process for the characteristic dynamic diagrams involving the falling ram we have established the diagram in figure 1 for a central coupling dampener type S-2V-90, used by the railway administrations of the former USSR countries. In figure 2 we have represented the characteristic dynamic diagram of the same type of dampener, determined by colliding two railway cars, each with a mass of ≈ 92 t, at a collision velocity of 6,0 km/h. The following observations can be made:

- the variation of the force as a function of contraction differs substantially. In the case of the diagram in figure 1 sudden increases of the force appear, followed by decreases. In the case of the diagram in figure 2, the evolution is approximately linear up to a contraction of ≈ 75 mm;
- the stored potential deformation energy and the dissipation coefficient η for the same maximum contraction D_{max} = 85 mm have higher values for the collision, *We*=30,4 kJ, η=0,88, tan in the situation of the falling ram, when *We*=21,8 kJ, η=0,63.

Thus, significant differences are observed in regards to the obtained dynamic characteristics, which categorically impose the option for determining the characteristic dynamic diagram for the shock insulators through the collision method.

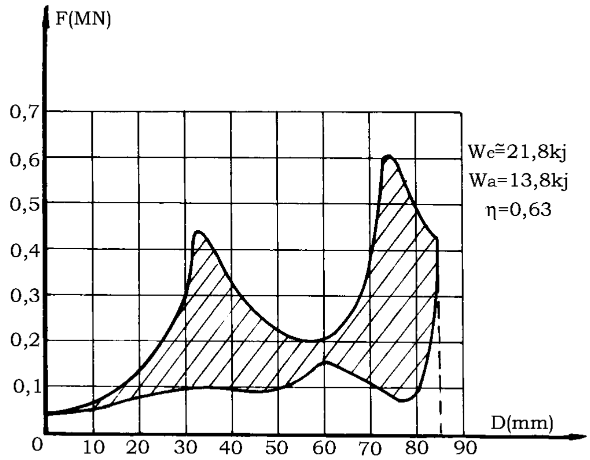

Fig.1. The characteristic dynamic for a central coupling dampener type S-2V-90, used by the railway administrations of the former USSR countries

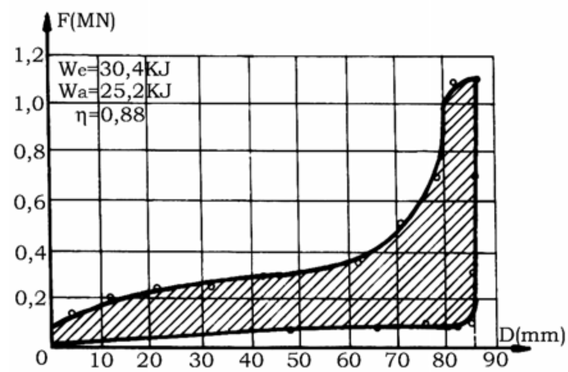

Fig. 2. The characteristic dynamic for a central coupling dampener type S-2V-90, determined by colliding two railway cars, each with a mass of ≈ 92 t, at a collision velocity of 6,0 km/h

3. FORCES TRANSMITTED TO THE VEHICLES DURING THE COLLISION

A series of authors have tried to theoretically establish mathematical expressions for the forces and accelerations transmitted to the vehicles during the collision process. The general case of the collision of two railway cars is considered. The colliding car, with mass m_1 and velocity v_1, interacts with a collided car, with mass m_2 and velocity v_2, where $v_1 > v_2$. The cars are equipped with shock insulators (buffers or central coupling insulators).

During the collision process, part of the kinetic energy of the vehicles is transformed into potential deformation energy that is maximal at time t_{12} when the vehicles travel at the same velocity v_{12}. The expression for the potential deformation energy E_p is:

$$E_p = \frac{m_1 m_2}{m_1 + m_2} \cdot \frac{(v_1 - v_2)^2}{2} = \frac{m_1 m_2}{m_1 + m_2} \frac{v^2}{2} \tag{1}$$

where: m_1 – mass of the colliding car; m_2 – mass of the collided car; v– relative velocity between vehicles (collision velocity).

The energy factor that characterizes the efficiency of shock insulators is 2β, which represents the ratio between potential deformation energy stored by the shock insulators, W_e, and the total potential energy, which includes the potential energy stored by the elastic elements that represent the bearing structures, the elastic elements that form the suspension of the vehicle, the equipment and the existing load (freight, passengers):

$$2\,\beta = W_e / E_p \tag{2}$$

The theoretical expressions of the transmitted force established previously can be used only under the condition that the vehicles are equipped with shock insulators that show a linear variation between force and contraction, consequently we propose the following relations.

Railway vehicles can be equipped with shock insulators whose elastic elements show a nonlinear variation between force and contraction [2], [3].

In the case of a collision between two vehicles of the same type, with $m_1 = m_2 = m$, $K_{T1} = K_{T2} = K_T$, $p_1 = p_2 = p$, and $\beta_1 = \beta_2 = \beta$, the expression of the transmitted force becomes:

$$F_{max} = (v_1 - v_2)\sqrt{\frac{m}{4} \cdot 2\beta \cdot \frac{K_T}{p}} \tag{3}$$

where: $p = f(v)$ is the plenitude coefficient and represents the ratio between the stored potential deformation energy and the product between the maximum transmitted force and the maximum contraction of the shock insulator; $K_T = f(v)$ is the conventional rigidity of the shock insulator (buffer) and represents the ratio between the maximum transmitted force and the maximum contraction of the shock insulator.

4. EXPERIMENTAL DETERMINATIONS

During the testing, the colliding car, launched from the inclined plane of the testing stand, collided at various velocities the standing, unbraked, collided car sitting on the level part of the stand. The used cars, colliding and collided, were 4 axle freight cars, loaded with uniform materials (sand, gravel, broken rock, etc.) up to a total mass of 80 t/car. The colliding car was equipped with category A buffers and the collided car with category C buffers (studied with elastomer elastic element).

For each shock caused by the collision of the vehicles, during the collision process the following parameters were determined experimentally:

- collision velocity v;
- forces transmitted through the buffers $F_1(t)$, $F_2(t)$;
- contraction of the dampener of the collided car $D_1(t)$, $D_2(t)$.

Tables 1 and 2 show the experimental results obtained during the testing conducted.

The annotations made in the tables represent:

- F_{total} - force transmitted during collision;
- $F_{\text{med}} = \dfrac{F_1 + F_2}{2}$ - average force transmitted through the buffer;
- $D_{\text{med}} = \dfrac{D_1 + D_2}{2}$ - average buffer contraction;
- W_{e1}, W_{e2} - potential deformation energy stored by the buffers of the collided vehicle (category C);
- W_{a1}, W_{a2} - potential deformation energy dissipated by the buffers of the collided vehicle (category C);
- η_1, η_2 - energy coefficients for the dissipation of potential deformation energy of the shock insulators: $\eta_1 = \dfrac{W_{a1}}{W_{e1}}$ and $\eta_2 = \dfrac{W_{a2}}{W_{e2}}$;
- $W_{\text{emed}} = \dfrac{W_{e1} + W_{e2}}{2}$ - average potential deformation energy stored by the category C buffers.

Table 1. **The experimental results obtained during the testing conducted**

v [km/h]	F_1 [MN]	F_2 [MN]	F_{total} [MN]	F_{med} [MN]	D_1 [mm]	D_2 [mm]	D_{med} [mm]
8,4	0,564	0,551	1,115	0,557	48,1		48,85
9,6	0,627	0,628	1,255	0,627	60	65,9	62,95
10,7	0,652	0,718	1,37	0,685	65,9	70,4	68,15
12,7	0,852	0,872	1,724	0,862	74,1	77,8	75,95
13,9	0,952	1,026	1,978	0,989	75,6	80,7	78,15
14,7	1,09	1,038	2,128	1,064	77	78,5	77,75
16	1,215	1,217	2,432	1,216	89	90,1	89,55

Table 2. **The experimental results obtained during the testing conducted**

v [km/h]	W_{e1} [KJ]	W_{a1} [KJ]	η_1	W_{e2} [KJ]	W_{a2} [KJ]	η_2	W_{emed} [kJ]
8,4	15,1	13,4	0,887	15,3	14,3	0,934	15,2
9,6	23,4	20,5	0,876	25,5	22,5	0,882	24,45
10,7	28,6	24,7	0,863	31,6	28,1	0,889	30,1
12,7	38,8	34,6	0,892	41,8	37,8	0,904	40,3
13,9	46,5	41,6	0,995	48,7	45,4	0,932	47,6
14,7	48,5	43,6	0,9	51,8	48,8	0,94	50,15
16	70,5	65,5	0,93	74,5	69,7	0,93	72,5

Figures 3, 4, 5 and 6 show the diagrams of the force transmitted through the buffers as a function of the buffer contraction, together with the energy characteristics for the collisions at the marked velocities.

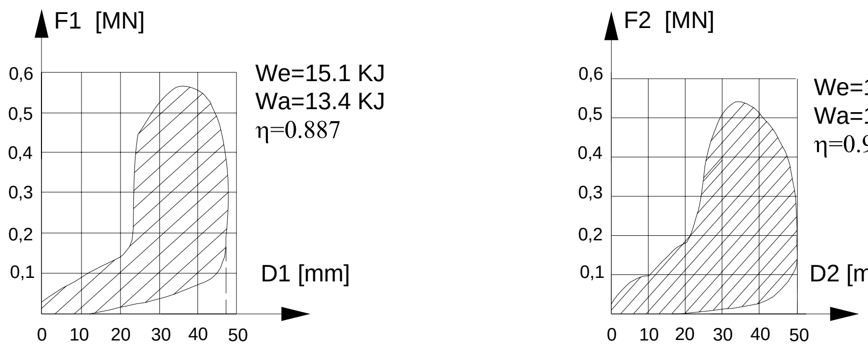

Fig. 3. Diagrams of the force transmitted through the buffers, v = 8,4 km/h

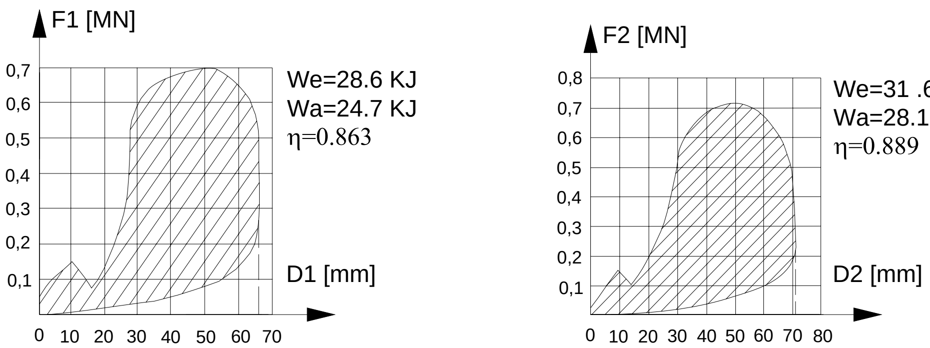

Fig. 4. Diagrams of the force transmitted through the buffers, v = 10,7 km/h

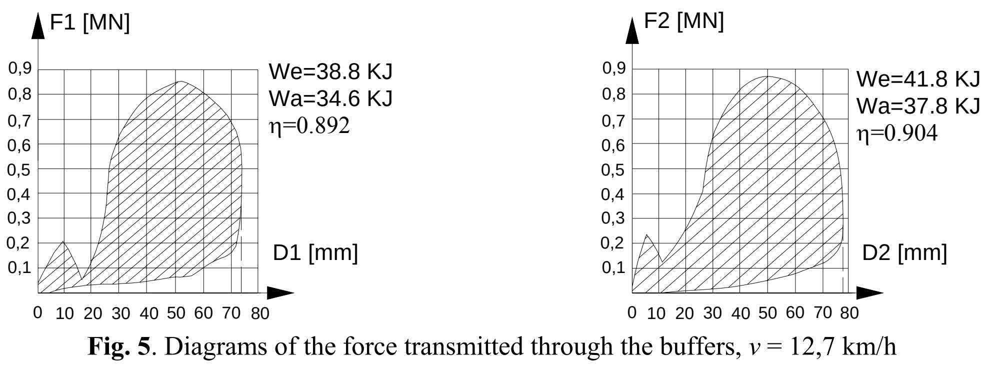

Fig. 5. Diagrams of the force transmitted through the buffers, v = 12,7 km/h

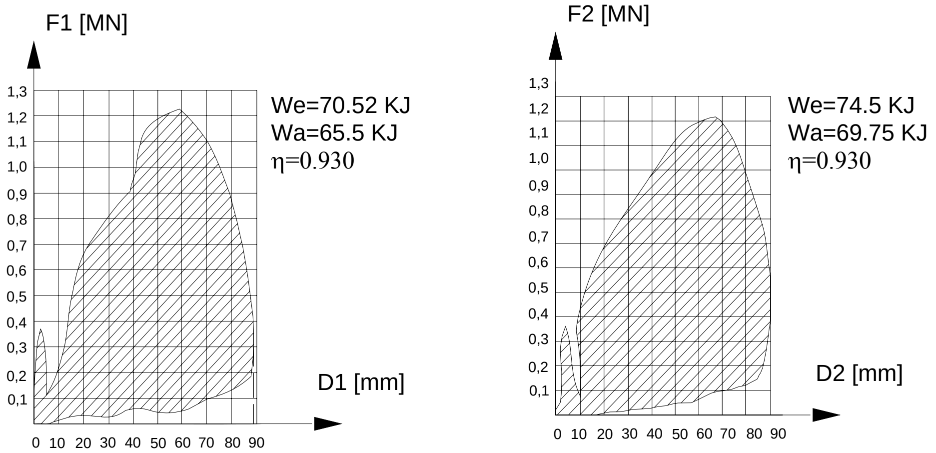

Fig. 6. Diagrams of the force transmitted through the buffers, v = 16 km/h

Figures 7 and 8 show the variations of the average stored potential deformation energy of the category C buffers, as a function of the average force transmitted through the buffers and the collision velocity (curves 1). In the diagrams the same variations are shown for a category C buffer with a RINGFEDER type elastic element connected in parallel with a hydraulic dampener of own design (curves 2).

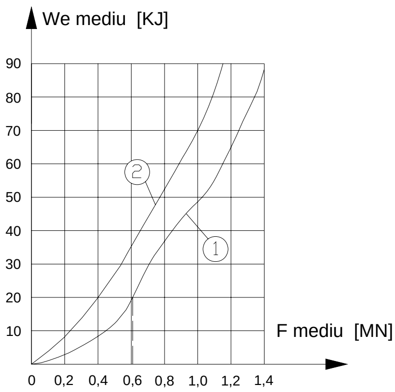

Fig. 7. The variations of the average stored potential deformation by F_{med}

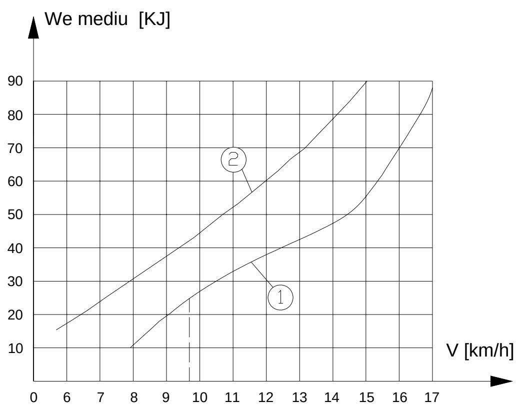

Fig. 8. The variations of the average stored potential deformation by v

5. CONCLUSIONS

In order to establish the dynamic characteristics of the shock insulators (buffers, central coupling dampeners, long displacement dampeners), the method of the collision is imposed, which offers the real characteristics. Following the analysis of the experimental results for a force of under 1,3 MN and a collision velocity above the velocity of 15 km/h, the studied buffers store potential deformation energy above 70 kJ and consequently they can be classified as being category C according to UIC 526 -1 in accordance to the type of testing conducted.

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