BULETIN ŞTIINŢIFIC, Seria C, Fascicola: Mecanică, Tribologie, Tehnologia Construcţiilor de Maşini
SCIENTIFIC BULLETIN, Serie C, Fascicle: Mechanics, Tribology, Machine Manufacturing Technology, ISSN 1224-3264, Vol. 2023 No.XXXVII

# Considerations on the Current State of Research on Vibration Testing of Rubber-Metal Products

***Alex Marius Cerapon[1], Radu-Iacob Cotetiu[2], Vasile Nasui[3*]***

**Abstract:** *The paper presents some considerations on the current state of research in the field of vibration testing of rubber-metal shock absorbers used in the railway field for high-speed trains. For these, the performance increase due to the accelerated development of transport vehicles with ever higher speed is aimed at. The main problem with rubber plug-type dampers used in the railway sector, which have embedded metal elements in their construction, is the resistance of the rubber-metal contact area.*

**Keywords**: *vibration testing, rubber-metal dampers, high-speed trains, rubber-metal adhesion.*

## 1 INTRODUCTION

The study presents some current achievements regarding the dynamic vibration testing of products made of rubber - metal, such as shock absorbers used in the railway sector, following the increase in performance due to the accelerated development of high-speed road transport vehicles.

Rubber plug shock absorbers have embedded metal elements in their construction and are used in the railway sector, where the main problem is the resistance of the rubber-metal contact area.

The development of a database by consulting the specific specialized literature is necessary for the improvement and development of new concepts of dynamic testing and the interpretation of the obtained results, as well as for the creation of an experimental stand necessary for the development of research [8].

Railway transport represents a strategic sector of national interest and an essential service for society, the purpose of which is to interconnect destinations and contribute to the safe and efficient movement of goods, goods and people, both on the territory of Romania and within the European Union, as well as in that of other areas of economic interest.

High-speed trains are trains that can develop speeds greater than 200 km/h. Normally their speed is between 200 km/h and 300 km/h, the record for a rail train is a TGV: 574.8 km/h, but Japan's experimental magnetic levitation trains JR-Maglev reached 581 km /h.

## 2. THE ROLE OF SHOCK ABSORBERS

Shock absorbers have the role of quickly dissipating the energy of vertical oscillations of the vehicle structure and wheels and represent a basic element in ensuring the comfort and safety of traffic.

The advantage of shock absorbers with regressive characteristics is the lower value of resistance forces at high oscillation speeds and therefore the transmission of small forces to the frame or body.

The range of anti-vibration components includes the family of the following elements: bushings, ball bearings, pads, cabin supports, shock absorbers, engine supports, suspensions, springs, couplings, etc.

Damping or anti-vibration systems are used to isolate vibrations and noise, they are generally made of rubber-metal and create an elastic connection between rigid bodies.

They are used in various fields of activity such as: railway vehicle industry, general engineering applications, construction machinery, special vehicles, wind turbines, marine industry, etc. (Fig.1, Fig.2, Fig.3 )

*Fig. 1. Rubber damper systems* [14]

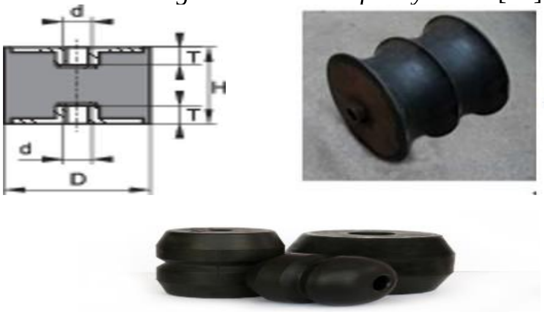


*Fig. 2. Rubber-metal buffer type shock absorber* [3]

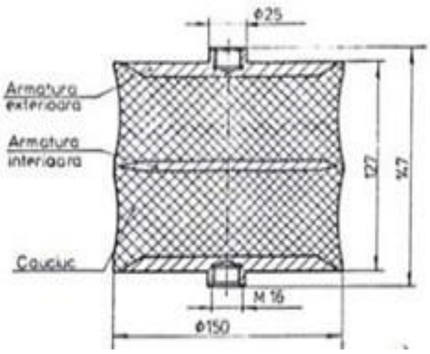


*Fig. 3. Anti-vibration double shock absorber* [3].

## 3. RESEARCH ON VIBRATION BEHAVIOR OF SHOCK ABSORBERS

According to [3], Ciuncan .M. V. in the doctoral thesis entitled Instrumental and computer analysis of the dynamic behavior of elastomeric anti-seismic isolators. Romanian Academy. Institute of Solid Mechanics. Bucharest 2018 presents the design and establishment of quick and precise technical solutions for anti-seismic isolation solutions.

This takes into account both the actual existing situations and the regulated requirements regarding the protection of the built fund against seismic actions. It shows that the technical capability level of rubber damping devices is conditioned by the multitude of factors, parameters and physical-mechanical properties in correlation with the insulation performance of the system.

In this context, the decisive stages for attesting the conformity of a shock absorber in accordance with the requirements of the reference document (norm, technical specification, technical sheet, etc.), must ensure a sequence: from design, execution, manufacture, control and the stage of the attestation of conformity which follows its methodology from the reference standards.

Also, the performance of dynamic tests on specialized stands are intended to establish the constancy of the device's production based on the dynamic shear and compression stiffness parameters as well as the damping factor equivalent to the linear viscous behavior of the elastomer.

Prestigious companies on an international level produce a very diverse constructive and functional variety specific to their field of use, for example SELECO.

The new generation that seeks to introduce damping systems that ensure the storage of the potential deformation energy of the shock insulator

There is a tendency to use modern vibration-free damper systems that facilitate the configuration of machines capable of taking on various applications.

The studies carried out until now by increasing the requirements, as well as their expansion, highlight, through their efficiency, the attempt to satisfy the interests of the industry.

## 4. THE STUDY OF THE CHARACTERISTICS OF SHOCK ABSORBERS

According to [3], the scheme of the measurement chain for determining the characteristics of the damping elements in the cushion is presented in figure 4 [3], having the following component: 1 - tensometric doses; 2 - metal base plate of the rubber pad; 3 - rubber damper; 4 - inductive transducer for movements; 5 - amplifier with the carrier frequency; 6 -oscillograph.

In the study of the vibrations of a railway vehicle, the first problem that arises is its representation through an equivalent mechanical model, made up of rigid masses, linked together by elastic and damping elements.

Establishing a mechanical model, with a certain degree of complexity, is closely related to the precision required of the results.

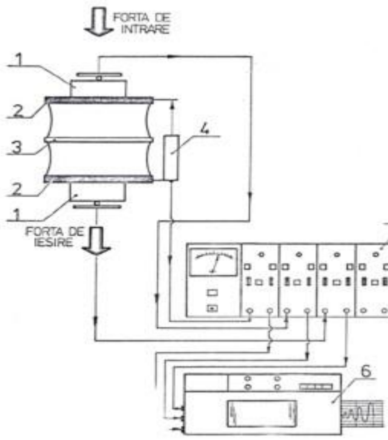


*Fig. 4. Scheme of the measurement flow for determining the characteristics of shock absorbers* [3]

But a large number of degrees of freedom of the model makes it difficult to draw general conclusions about the behavior of the vehicle. In order to achieve high speeds, in safe traffic conditions and with high comfort, both the vehicle and the track must meet special constructive conditions.

At high speeds, the influence of disturbances caused by wheel defects, especially centering defects, increases [3]. In order to measure the vibrations of an elastic element (or assembly of elastic elements) from the suspension of a railway vehicle, a stand is required to simulate operating conditions.

The vibration measuring device works on the principle of seismic devices that have an oscillating system. Vibrators (vibration exciters) are used in reliability tests, fatigue tests or device calibrations, either to determine the dynamic characteristics of structures, machines, foundation land, or in the present case to determine the characteristics of the primary suspension from a railway vehicle [3].

In the paper [6], "Experimental determination of the stiffness characteristic and the elastic modulus of rubber using the time-frequency representation" authors Gilbert-Rainer Gallich s.a. indicates methods for determining stiffness characteristics.

The first consists in compressing the rubber elements and allowing free vibration and the second and the second by exciting the rubber element, to obtain resonance.

The authors reach some conclusions, namely that for small deformations, Hook's law is taken into account, and for large deformations, the stiffness characteristic, statistical methods are used.

By introducing the notion of corrected static stiffness k, proposed by the authors, the behavior of rubber elements at large deformations can be exactly modeled.

Determining the stiffness characteristics by using the Wigner-Ville Distribution leads to accurate results because short-term transient phenomena are not taken into account.

The possibility of rapid adaptation to the stress conditions allows obtaining a series of results with the use of dynamic stiffness characteristic curves when lifting [6].

For a system in the resonance zone, the dynamic stiffness characteristic k is determined with the relation:

$$k_D = m \cdot \left[ \frac{4\pi^2}{T^*} - \left( \frac{c}{2m} \right)^2 \right] \quad (1)$$

where m is the mass of the system, c- the damping coefficient, and T is the pseudo period of the signal.

For deformations of small values, where the dependence on force F and on Δh compression deformations is linear, Hook's law being valid, the value of the static stiffness characteristic ks is determined with the relation [6]:

$$k_s = \frac{F}{\Delta h} \quad (2)$$

In the work [8], "Considerations on the vibrations from the suspension of railway vehicles and their measurement" Vidican, I and Bejan, M. specify that in the study of the vibrations of a railway vehicle the first problem that arises is its representation by an equivalent mechanical model, made up of rigid masses, linked together by elastic and damping elements.

It also classifies the vibrations of railway vehicles and states that the constructive solution that is adopted to create a suspension depends on the type of vehicle it is used on, its speed, the quality of the lines on which the vehicle travels, the level of comfort required .

For railway vehicles, a specific frequency is required for each type of movement (vertical, twisting and swaying). In the case of the vertical motion of a vehicle on rails, it can be modeled by a complex oscillating system consisting of continuously distributed masses and concentrated, linked together by elastic and damping elements.

In order to measure the vibrations of an elastic element (or set of elastic elements) from the suspension of a railway vehicle, they created a stand to simulate operating conditions

The vibration measuring stand works on the principle of seismic devices that have an oscillating system (Fig. 5). The component parts of the seismic apparatus are: the support S, rigidly connected to the body whose vibration is measured, the mass m, connected to the support and a transducer - T [8].

It mentions that when adopting the suspension parameters, other conditions arising from the study of vehicle dynamics must also be taken into account: ensuring the suppleness coefficient, the torsional capacity of the vehicle on the rails, the stability of the winding movement, the ride quality.

In the technical literature, the natural frequencies are indicated in the case of high-speed vehicles.

At high speeds, the influence of disturbances caused by wheel defects, especially centering defects, increases.

Shock absorbers mounted in parallel with the suspension of the axles produce a high resistance to these disturbances, which causes them to be transmitted to the suspended masses of the vehicle.

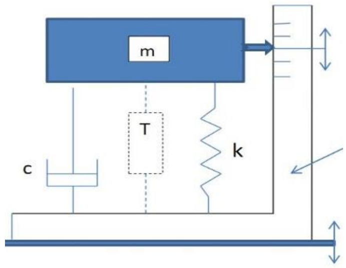


*Fig. 5. Vibration measuring stand* [8]

Suspension design involves the initial establishment of elastic and damping constants from conditions related to ensuring the dynamic performance of the vehicle.

Achieving minimum values of vibration amplitudes is the most frequently used criterion for determining the optimal level of damping.

The vibrations in the stand are produced by a pulsating system with an eccentric, which is driven by an electric motor with variable speed to produce vibrations of different values.

It is also provided with a mechanism for adjusting the amplitude when producing vibrations. With the help of a displacement transducer, the magnitude of the ensemble amplitude can be determined.

It is also provided with a mechanism for adjusting the amplitude when producing vibrations. With the help of a displacement transducer, the magnitude of the ensemble amplitude can be determined. For railway vehicles, a specific frequency is required for each type of movement (vertical, twisting and swaying).

In the case of the vertical movement of a vehicle on rails, it can be modeled by a complex oscillating system consisting of continuously distributed masses and concentrated masses, linked together by elastic and damping elements.

Taking into account the particularities of the vibrations of vehicles on rails, the complex system of the suspension can be decomposed into individual systems with one or two degrees of freedom (Fig. 6), which reflect to an acceptable extent, for practical calculations, the behavior of the studied system [8].

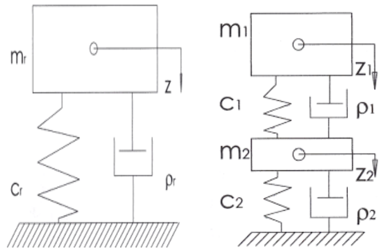


*Fig. 6 Equivalent system with one degree of freedom and two degrees of freedom* [8]

Rail vehicles are equipped with shock absorbers (buffers, central coupler shock absorbers) against the shocks that require longitudinal operation. The higher the storage capacity of the potential deformation energy of the shock absorber, the lower the stored potential energy returning to the vehicles.

After the tests, it is established whether the shock insulators have the capacity to store the potential energy of deformation at the required level or it is necessary to replace them with shock insulators of increased capacity [8].

Both excitations and responses in the random domain are vibrations of the vehicle masses that cause fatigue in the materials from which they are constructed. The amplitude of the excitations determines, depending on the protective elastic elements, the real stress on the vehicle components.

The characteristic of the limit state - the fatigue resistance can take an infinity of values, depending on a series of factors, which influence the fatigue resistance and implicitly the lifetime, work factors determined by the operating conditions, constructive factors, technological factors..

The use of modern calculation methods, such as that of the finite element in the evaluation of stress results to detect critical areas in the conditions of the existence of stress values: equivalent stress, main stress, etc., and comparing these theoretical results with possible experimental results.

Conducting experimental studies in static mode where the forces applied to achieve the demands were assessed through simulation and in dynamic mode.

## 5. CONCLUSIONS

The paper briefly presented the current state of the art regarding the dynamic testing of buffer-type rubber damping systems and some conclusions regarding their advantages and disadvantages.

It can be seen that the damping technique used in road transport with high-speed trains has reached exceptional performances, but there is still significant potential for innovations and approaches to new research fields.

REFERENCES

[1]. Bratu, P., 2000. Vibrațiile sistemelor elastice, Editura Tehnică, București.

[2]. Bratu, P., 2011. Analiza structurilor elastice. Comportarea la acțiuni statice și dinamice, Editura Impuls, București.

[3] Ciuncanu, M. Valentin „Analiza instrumentală si informatică a comportării dinamice a izolatoarelor antiseismice elastomerice. Teză de doctorat. Academia Română. Institutul de Mecanica Solidelor, București 2018,

[4]. Gafițanu, M.,s.a. 1989. Diagnosticarea vibroacustică a mașinilor si utilajelor, EdituraTehnică, București.

[5] Marin, C., 2000. Vibrațiile structurilor mecanice. Editura Impuls București.

[6]. Gilbert-R. Gallich, s.a., Determinarea experimentală a caracteristicii de rigiditate şi a modulului de elasticitate a cauciucului utilizãnd reprezentarea timp - frecvenţă. *Materiale plastice 44, nr. 1/2007*

[7]. Năsui, V., Cotetiu, A., Cotetiu, R., Lobontiu, M., Ungureanu, N., 2007, Bazele cercetarii experimentale actuatorilor electromecanici Editura Universităţii de Nord din Baia Mare.

[8]. Vidican, I., Bejan, M.,2013, Considerații asupra vibrațiilor din suspensia vehiculelor feroviare și măsurarea lor. *A XIII-a Conferinţă Naţională multidisciplinară, Sebeş 2013*

*[9]*. Stănescu, D.N., Munteanu, L., Chiroiu, V., Pandrea, N., 2007, Sisteme dinamice. Ed. Academiei, București.

[10]. Tănăsoiu B.F., 2014, Cercetări privind creşterea duratei de viaţă a structurilor portante şi elementelor elastice ale vehiculelor feroviare pentru transport produse petroliere, Teză de doctorat. 2014, Universitatea din Petroşani

[11].Tătaru M.B., 2014, Contribuţii privind studiul si ameliorarea suporţilor elastici amortizori utilizaţi la utilaje cu şocuri si vibraţii, Teză de doctorat. Universitatea din Oradea, 2014.

[12]. Zeveleanu, C., Bratu, P., 2001, Vibrații neliniare, Editura Impuls, București.

[1**3**].*** Procedură de încercare a aparatelor de reazem din elastomeri. Institutul de Cercetări ptr. Echipamente şi Tehnologii în Construcţii ICECON SA, 2009

[14].***https://www.infinitraderomania.ro/categorie/marcicomercializate/soleco-amortizoare-vibratii/

**Authors addresses**

[1]*Cerapon Alex Marius. Technical University of Cluj-Napoca, North University Center of Baia Mare, 62A V. Babes St., RO-430083, Baia Mare ROMANIA, Tel. 0264-202975. E-mail:* alexcerapon7@gmail.com

[2]*Cotetiu Radu-Iacob Professor Ph. D. Eng., Technical University of Cluj-Napoca, North University Center of Baia Mare, Faculty of Engineering, 62A Victor Babes St., RO-430083, Baia Mare, ROMANIA, E-mail: Radu.Cotetiu@imtech.utcluj.ro*

[3]*Năsui Vasile, Professor Ph. D. Eng., Technical University of Cluj-Napoca, North University Center of Baia Mare, Faculty of Engineering, 62A Victor Babes St., RO-430083, Baia Mare, ROMANIA, E-mail:* Vasile.Nasui@imtech.utcluj.ro

**Contact person**

**Năsui Vasile. Professor Ph. D. Eng., Technical University of Cluj-Napoca, North University Center of Baia Mare, Faculty of Engineering, 62A Victor Babes St., RO-430083, Baia Mare, ROMANIA*

*E-mail: Vasile.Nasui@imtech.utcluj.ro*