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EXPERIMENTAL AND NUMERICAL DETERMINATION OF THE FREIGHT WAGON BUFFERS CHARACTERISTICS

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Abstract *– Draw-buff gear plays a significant role in the transmission and damping of longitudinal forces generated during accelerating and braking of trains. The role of the buffers is to protect the railway vehicles bearing structure, cargo and passengers from excessive longitudinal impacts. Especially when shunting freight wagons. For that reason, they have built-in elastic-damping elements that absorb shocks and partially convert kinetic energy into heat. This paper analyzes buffers with rubber-metal springs, which are the most often used in the freight cars nowadays. The static and dynamic force-stroke characteristics obtained by measurements on hydraulic press and during buffing impact tests are presented. These results are then compared with calculations using FEM analyses. The analyses included checking of the buffers ability to absorb a sufficient amount of energy that can be generated during wagon normal operation and in the case of exceptional shunting impacts.*

Keywords – buffers, force-stroke characteristics, measurements, absorbed energy.

1. INTRODUCTION

The requirements that must be met by buffers for installation on railway vehicles are very extensive. They concern both the geometric characteristics of the buffers, the materials used, as well as the corresponding characteristics of the force-stroke they achieve during loading cycle. For different types of buffers, these requirements are specified in the European standard EN 15551:2016 [1]. This paper presents the determination of the characteristics of a 105 mm stroke freight wagon buffer with an elastomer-based elastic-damping element, i.e. rubber-metal springs [2]. Specific for elastomers, which are the most often type of material nowadays used in buffers of freight wagons, is that they combine elastic and damping properties.

Experimental measurements were performed statically on the press. While dynamic measurements were performed during buffing impacts of one freight wagon type Eanos on a tank wagon type Zacns at increasing speeds up to 12 km/h [3]. Considering that for exact numerical analysis were not available real material properties, obtained results of measurements served for determination of possible hypothetic constants of non-linear Mooney-Rivlin 2-parameter model, which give the best agreement with the experimentally obtained results [4, 5, 6].

The tested elastomeric elements TecsPak®, used in tested buffers, have been successfully produced by company Miner for many years [2].

2. BUFFER CHARACTERISTICS

The main role of the buffers is to reduce longitudinal shocks caused during accelerating, braking and shunting of the wagons. The characteristics of the buffer, depending on the rate of deformation, can be divided into static and dynamic. The static characteristics of the buffers, at low speeds of the buffer stroke, are significant when the vehicle passes through a curve, and during their initial preloading when forming the train composition. While the dynamic characteristics are valid for shunting impacts, as well as for longitudinal oscillations in the trains.

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Determining the static characteristics of the buffer is performed by loading the buffer on the press at a maximum speed of 0.05 m/s [1]. The characteristic is obtained by measuring the stroke and the force that is set on the hydraulic press. The displacement transducers and force transducer located under the buffer are presented in Fig. 1.

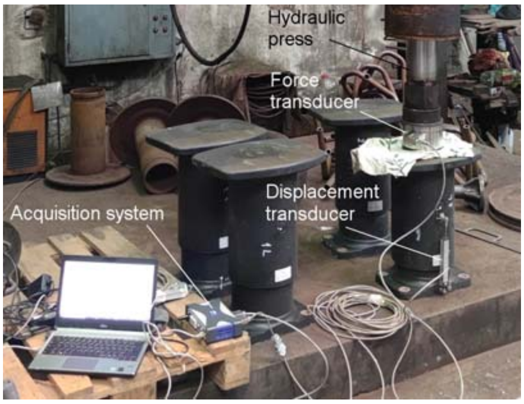

Fig.1. Measurements of buffers static characteristics [3]

Static energy capacity or stored energy during compression stroke must be greater or equal to 12.5 kJ. At least half of this energy during the first load cycle must be absorbed. During the second third etc. full loading cycle, this energy has to be greater or equal to 42% of stored energy. Depending on a vehicle type, i.e. buffer category, buffers have different demands for energy capacity [1].

As for the dynamic characteristics of the buffer, it is necessary that during the compression stroke of 105 mm, dynamic store energy is at least 30 kJ and absorbed energy 60% of the stored energy [1].

The main goal is that the characteristics of the buffer should be such that at normal shunting speeds of up to 12 km/h, during buffing impact, forces and accelerations do not reach values higher than prescribed. In order to check whether the buffers in the assembly with the wagon meet these requirements, a buffing impact test is performed. This test, in addition to checking the forces and acceleration, checks the strength of the supporting structure of the wagon, as well as the bearing capacity of the connections of equipment, which is attached to the vehicle body.

Determination of the dynamic characteristic of the buffers is performed by simulating the shunting of wagons. For testing, it is necessary that both wagons are equipped with buffers of the same category. In this case, it is necessary that the buffers are of category A. One of the wagons is standing unbraked on a straight and level track. The second wagon, loaded with bulk material, up to a total mass of 80 t impacts a standing wagon. Impact is done at gradually increasing speeds up to 12 km/h 1, 3]. During the impact, the force between each buffer and end beam, as well as the stroke of buffers were measured (Fig. 2).

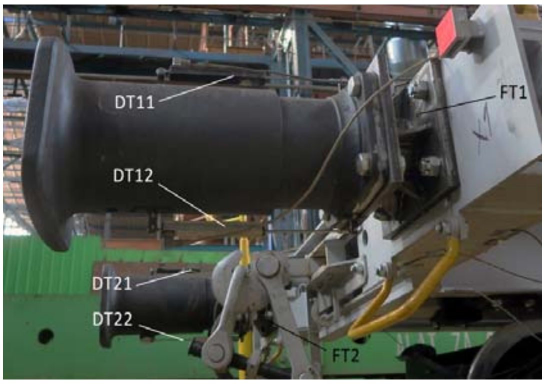

Fig.2. Measurements during buffing impact [3]

Diagrams in Fig. 3 represent measured buffers static characteristics for stroke 105 mm i.e. up to 1000 kN force. From the presented diagram can be seen that stored and absorbed energy during one load cycle meet requirements of the referent standard i.e. stored energy is about 40 kJ and damping coefficient is higher than 0.5.

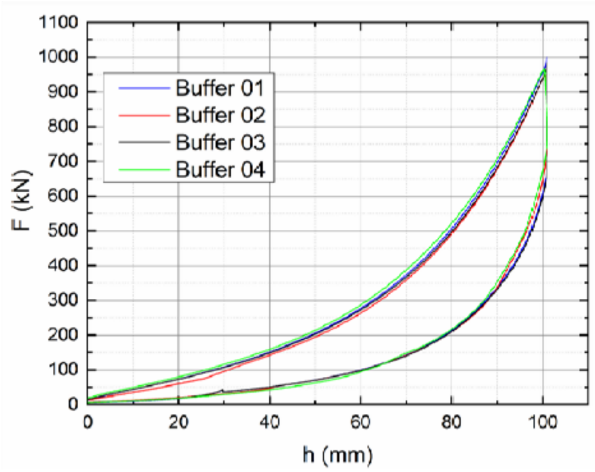

Fig.3. Buffers static force-stroke characteristics [3]

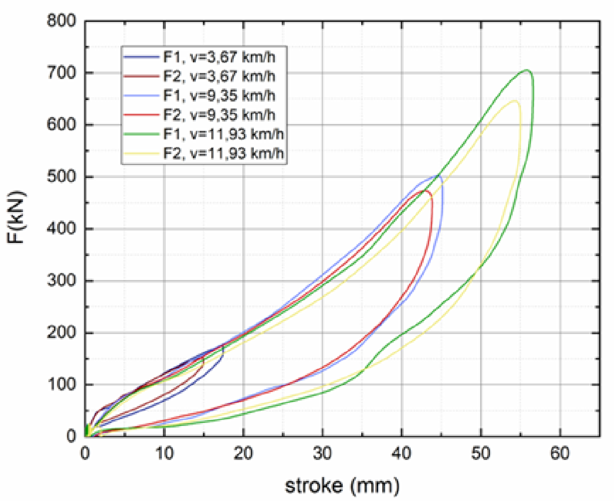

Fig.4. Buffers dynamic force-stroke characteristics [3]

Dynamic force-stroke characteristics for different impact speeds are presented in Fig. 4. Damping coefficient calculated for the recorded function is higher than 0.6.

3. NUMERICAL ANALYSES AND THEIR COMPARISON WITH TEST RESULTS

The rubber-metal element of the buffer is modeled according to the sample and the manufacturer's available drawings. Fig. 5 shows the complete buffer with spring. The numerical calculation was carried out in the Ansys software package.

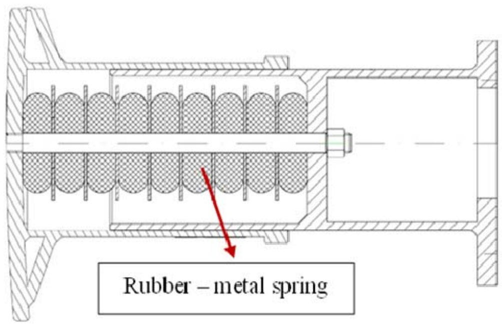

Fig.5. Category A buffer for stroke 105 mm [2]

Due to the reduction of computer resources required for simulation of the entire spring, the calculation was carried out with one segment pressed between two steel plates (Fig.6).

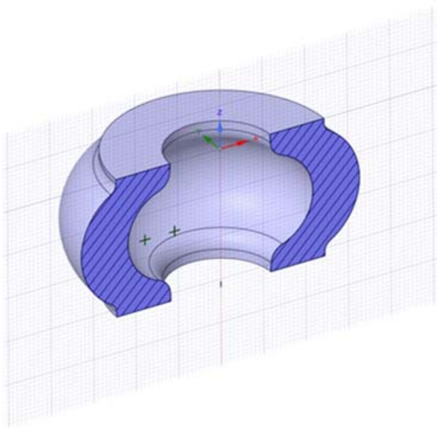

Fig.6. One elastomeric element of the spring

The 2-parameter Mooney-Rivlin hyperelastic material model was used.

Hyperelastic materials are characterized by nonlinear elastic behavior. They can withstand a large elastic deformation that is fully reversible after removal of the deformation strain. To describe a hyperelastic material, it is necessary to choose a specific model of material behavior, based on the deformation energy density W, whose exact representation is obtained experimentally obtained by simple strain tests, which include the following tests with specially prepared test specimens for: uniaxial, biaxial, pure shear and volume tests. Although these tests are performed separately and the stress states are different, the data from all the individual tests are used as one set to define the material model [4]. They cover different possible deformation cases and ensure a better agreement between the calculation results and the experiment. It should be emphasized that the test specimens must be made of the same material from which the elements whose characteristics we want to determine will be made [4, 5].

Since in this case we did not have the experimental results necessary to determine the constants of the Mooney-Rivlin model. With a combination of constants selected based on possible shear modulus and correlation with measured elastomer hardness, a numerical analysis was performed. Analysis results are presented in Fig.7 and Fig.8.

Fig.7 presents deformed element preloaded during assembling the buffer, plus deformed for buffers stroke of 105 mm. This deformation is reduced to represent of one of nine elements that form one spring.

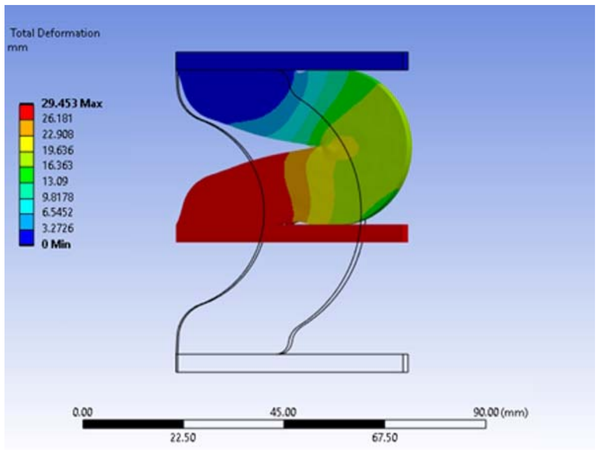

Fig.7. Deformation of one element corresponding to buffer stroke 105 mm

Fig. 8 presents static force-stroke diagram of one spring element obtained by numerical analysis.

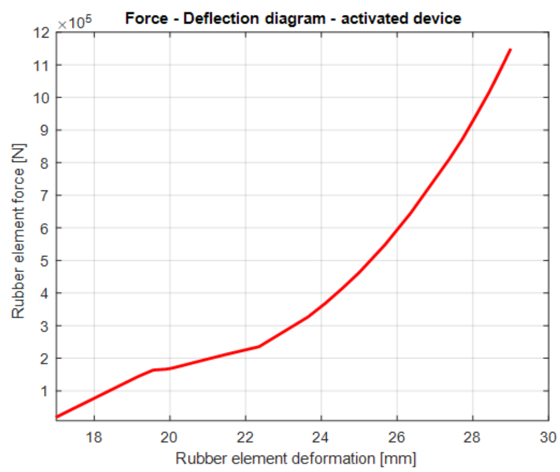

Fig.8. Buffers static force-stroke characteristics obtained by numerical analysis

Both diagrams, obtained experimentally and by finite element non-linear analysis are presented in Fig.9. Although there is fair well agreement between these two functions, it does not mean that material model will provide good results for other type of elements and parts subjected to different strain state and strain rate. This model and the analysis serve for better understanding of elastomeric material features and properties.

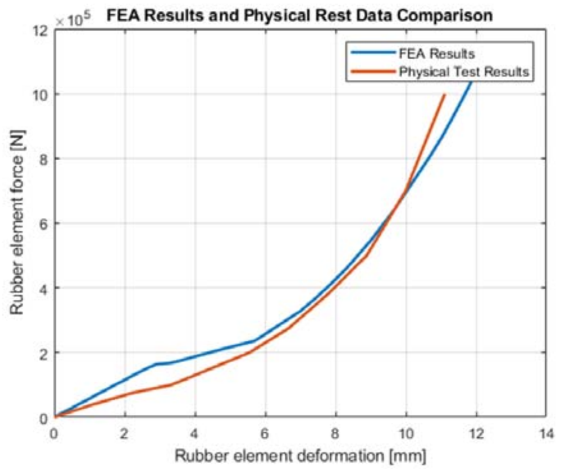

Fig.9. Comparison of the static force-stroke characteristics for one spring element obtained experimentally and by numerical analysis

4. CONCLUSION

Rubber-rubber springs are often used as an elastic-damping element of the buffers. Their force-stroke characteristics important for longitudinal dynamics of train and protection of vehicles bearing structure, cargo and passengers from excessive longitudinal impacts can be obtained by measurements but also by numerical simulations. By choosing the appropriate parameters and creating a numerical model based just on the knowledge of material hardness, it is possible to do it approximately. More detailed and precise analysis requires performance of material tests under simple strains, with special test specimens. Recorded sets of curves serve as input parameters of the material model. Nonlinear calculations in the large deformation's domain, with such material models, enable easier optimization of parts made from elastomers and selection of desired elasticity characteristics.

ACKNOWLEDGEMENT

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