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IMPROVING OF ABSORPTION POWER OF TUBE COLLISION ENERGY ABSORBER BY USING POLYURETHANE FOAM

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Abstract – *Tendencies to increase the speed in the railway transport lead to intensive work on active and passive safety improvement of railway vehicles with the aim to reduce possibilities of collision to a minimum. Frequently, we have collisions in the main railway stations during shunting and forming trains at speed higher than allowed. Consequences of these collisions are damages of the vehicles structure and sometimes parts of infrastructure that require time for repairs. These reduce the availability of the vehicles and causes loss of profit and increase of maintenance costs. Subject of this paper is experimental investigation of absorption characteristics of foam filled tube collision energy absorber which works on the principle of shrinking the seamless tube through special cone bushing. This type of absorber is intended for mounting in a line with standard buffer. Tube is filled with high density polyurethane foam with the aim to increase deformation resistance during collision. Using shrinking process energy absorption occurs by elastic-plastic deformations of the tube, friction between the tube and the cone bushing and compression resistance of high density polyurethane foam. This type of absorber gives gradually increase of the deformation resistance and higher absorption power in comparison with empty seamless tube. Experimental researches were realized on the hydraulic testing machine in the laboratory conditions. During tests, reaction force on defined stroke was measured. Results of the experimental investigations of foam filled tube collision energy absorber and empty tube collision energy absorbers were compared.*

Keywords – Passive Safety, Foam Filled Tube, Experimental Investigations, Collision Energy Absorber.

1. INTRODUCTION

This paper presents experimental investigations of characteristics of improved type of tube collision energy absorber filled by high-density polyurethane foam. Base for improving of absorption characteristics is seamless tube shrinking absorber that works on the principle of shrinking the seamless tube passing through a special cone bushing [1-5]. Shrinking the tube, as a shape of deformation, is possible to combine with more other shapes of deformation with the aim of getting better absorption characteristics with compact-unchanged dimensions of absorber. Shrinking tube absorber characterizes gradual increase of the deformation resistance (force), without any peaks at the beginning of deformation process. Force increases to its maximal value and remains at this value to the end of the deformation process. There is many ways to absorb collision kinetic energy on railway vehicles. Very limited space in the front part of the vehicle structure requires compact dimensions of absorber. On the other side, absorber must have required absorption power. Serious challenge for designers and researchers presents connection of these two conditions. Axial crushing analysis of empty and foam-filled concentric cylinder tubes is one of more ideas for collision energy absorption is [6, 7]. These types of energy absorbers use folding of the tube as primary deformation process. This shape of deformation characterizes jagged flow of the force during energy absorption. Jagged effect may cause start of deformation of vehicle structure before the fully utilization of absorption power of energy

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absorber. Impact of high-density polyurethane foam on increasing of absorption power presented in papers. Low velocity impact of empty and foam filled circumferentially grooved thick-walled circular tubes are presented in the paper [8]. Experimental results show that foam filling in dynamic loading, though effective from the energy absorption perspective, is not as effective as in the case of quasi-static loading. In addition, experimental investigations of crushing response of square aluminum tubes filled with polyurethane foam and aluminum honeycomb were presented in the paper [9]. Influence of the shape of deformation and polyurethane foam on absorption characteristics was analyzed. Experimental and numerical results of crushing of foam-filled aluminum tubes were presented in the papers [10, 11]. Results of these investigations clearly indicated that the energy absorption of a foam-filled tube is significantly higher than that of the empty tube. Next to these results also indicated that the friction coefficient between the foam and the tube has negligible influence on the energy absorption. Folding process as a way of deformation process in the mentioned research papers also characterizes jagged effect. Consequences of this type of deformation were explained above. This undesirable effect leads to choose shrinking process of deformation as a most acceptable for tube deformation for purpose of collision energy absorption on the railway vehicles.

Experimental investigations of absorption characteristics of empty and foam-filled circular steel seamless tubes under axial loading were realized in this paper. Polyurethane foam of high density was made by mixed of two chemical components (isocyanate and polyol) in precisely determined concentrations and with exactly defined technology. The foam was formed directly in the seamless tube and in this way connection with the tube wall is obtained. Quasi-static tests were performed on empty and foam filled tubes. Results obtained by these experimental investigations were analyzed and main differences are presented.

2. EXPERIMENTAL INVESTIGATIONS

Working principle of this type of absorber is shown in the Fig. 1. The same deformation process was used for empty (Fig. 1 left) and foam filled tube (Fig. 1 right). Shrinking absorber works on the principle of shrinking the seamless tube passing through special cone bushing. During deformation, tube diameter reduces from 75 mm to 68 mm, at the stroke of ≈ 90 mm. Using shrinking process energy absorption occurs by: *elastic-plastic deformations of the tube, friction between the tube and the cone bushing and compression resistance of high density polyurethane foam*.

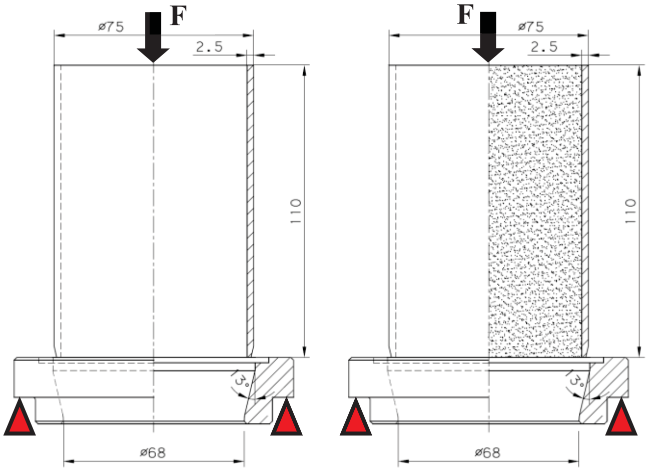

Fig.1. The working priciple

Experimental, quasi-static, investigations of the empty and foam filled seamless tubes were realized on the servo-hydraulic testing machine Zwick Roell HB250 that can be realized maximal force of 250 kN, Fig. 2.

Fig.2. Testing machine Zwick Roell HB250

Tests were realized at speed of the head of the machine of 1 mm/s. During tests, the values of the force were measured on defined stroke.

The following samples were used for tests, Fig. 3:

a) Seamless tubes (Item 1) from quench and tempered carbon steel in grade C45E with dimensions ∅75/2.5x110 mm,

b) Cone bushing (Item 2) from quench and tempered carbon steel in grade C45 with dimensions ∅75/68/13°x25 mm,

c) Steel tubes (Item 3) and

d) Steel covers of the tubes (Item 4).

Items 3 and 4 were used as auxiliary tools for filling the tubes with polyurethane foam. During expansion of polyurethane foam, chemical process produces high-pressure on the tubes wall as well as on the covers of the tubes, so it is necessary to perform this process in strongly controlled environment. In this way is possible to get foam of defined density with adequate structure, Fig. 4.

Fig.3. Samples

Fig.4. Filling the tube with foam

Fig. 5 shows seamless tube filled by polyurethane foam (ρ ≈ 115 kg/m^3).

Fig.5. Filled tube

3. RESULTS AND DISCUSSION

During experimental investigations three samples of empty and three of foam-filled tubes were deformed. Characteristics force vs. stroke diagrams obtained by experimental investigations of empty tubes is shown in Fig. 6. This diagram characterizes gradual increase of the force until the maximal value is reached. The force remains approximately constant to the end of the deformation process at the stroke of ≈ 90 mm.

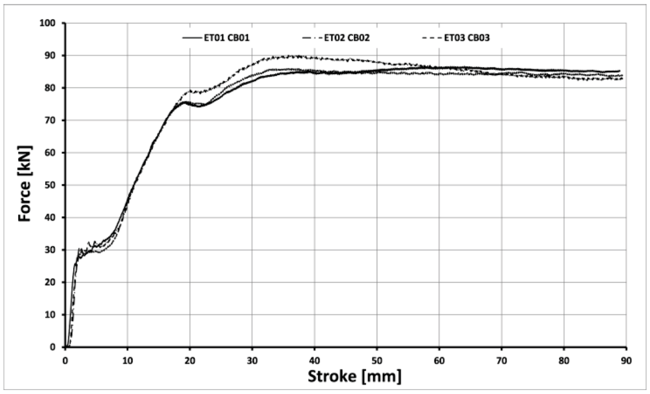

Fig.6. Force vs. stroke diagram – empty tubes

Fig. 7 shows force vs. stroke diagram obtained by experimental investigations of foam-filled seamless tubes.

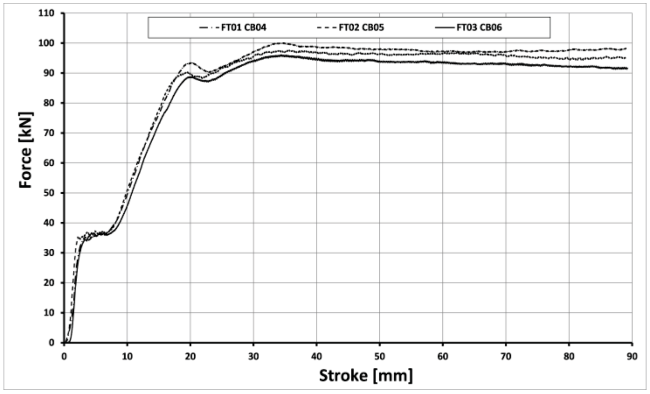

Fig.7. Force vs. stroke diagram – foam filled tubes

This diagram shows the same flow of the force as previous one, but with larger force values at the whole stroke. With the aim to present clearer relation between force vs. stroke curves of the empty and the foam-filled tubes, Fig. 8 shows average values of empty and foam filled tubes.

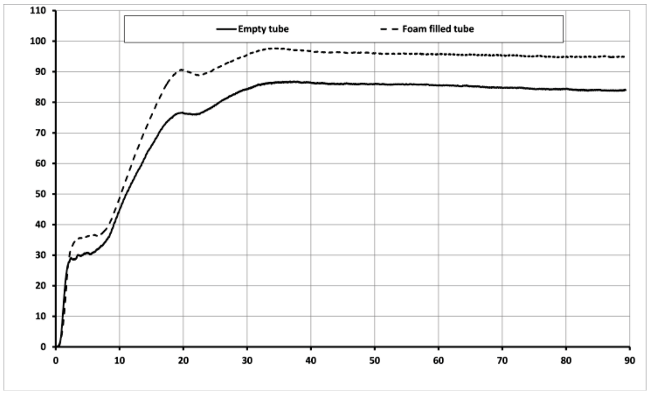

Fig.8. Comparison vs. stroke diagram – empty and foam filled tubes

Characteristic parameters that can be used for evaluation of this type of absorber are shown in the Table 1. Absorbed energy "W" is calculated as a work of force at defined stroke (amount of absorbed energy is equal to area under curve):

$$W=F_{av} \times h$$

where: F_{av} – average value of the force at defined stroke, h – stroke of deformation.

Tab.1. Characteristics parameters

	F_{max} [kN]	**F_{av} [kN]**	**h [mm]**	**W [kJ]**
Empty tube	86.86	73.87	≈ 90	**6.65**
Foam filled	97.79	83.38	≈ 90	**7.50**

The aim of this analysis was to compare two types of energy absorption elements. Since it was performed using scaled model, as expected, scaled values of force and absorbed energy were obtained. Using foam-filled tube, amount of absorbed energy is approximately 13 % higher compared to empty tube shrinking absorbers, at the defined stroke.

4. CONCLUSION

The use of foam-filled tube for collision energy absorption gives opportunity for increase of absorption power with the compact dimensions of absorber. Shrinking tube absorber filled by high-density polyurethane foam leads to better absorption characteristics. Improved type of shrinking absorber may absorb higher amount of collision energy compared to empty tube shrinking absorber. Most important is to keep gradual increase of the force at the beginning of the deformation process, without any peaks, and to get constant value of the force after reaching the maximal value. This is significant for gradual introduction force in the vehicle structure and to proper energy absorption, which begins at the buffer and goes through crash energy absorber in the front part of the vehicle structure.

The next step of this research will be experimental investigations of the polyurethane foam-filled tube with different values of densities with the aim to show influence of the foam density on increase of deformation resistance.

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REFERENCES

[1] Simić G., Lučanin V., Tanasković J., Radović N., 2009, *Experimental research of characteristics of shock absorbers of impact energy of passenger coaches*, Journal of Experimental Techniques, Vol. 33, Issue 4, pp. 29-35, 2009.

[2] Tanasković, J., Milković D., Lučanin V., Miloradović N., *Experimental and numerical analysis of the characteristics of combined collision energy absorbers*, FACTA UNIVERSITATIS, Series: Mechanical Engineering, Vol. 10, No 2, pp. 125 – 136, 2012

[3] Tanaskovic J., Lučanin V., Milković D., Simić G., Miloš M., *Experimental Research of Characteristics of Modified Tube Absorbers of Kinetic Collision Energy of Passenger Coaches*, Journal of Experimental Techniques, Volume 38, Issue 3, page 37-44, 2014.

[4] Tanaskovic D. J., Milkovic D. D., Lucanin J. V., Franklin Vasic G., *Experimental investigations of the shrinking-splitting tube collision energy absorber*, Journal of Thin-Walled Structures, Volume 86, page 142-147, 2015.

[5] Tanaskovic J., Franklin F., Dišić A., Mišković Ž., *Numerical validation of the combined extrusion-splitting process of energy absorption through experimental study*, Journal of Experimental Techniques, Vol. 41, No. 4, page 421-431, 2017.

[6] Zarei H.R., Ghamarian A., *Experimental and Numerical Crashworthiness Investigation of Empty and Foam-Filled Thin-Walled Tubes with Shallow Spherical Caps*, Experimental Mechanics, Vol. 54, page 115–126, 2014.

[7] Azarakhsh S., Rahi A., Ghamarian A., Motamedi H., *Axial crushing analysis of empty and foam-filled brass bitubular cylinder tubes*, Journal of Thin-Walled Structures, Volume 95, page 60-72, 2015.

[8] Darvizeha A., Meshkinzarb A., Alitavolic M., Rajabiehfardc R., *Low velocity impact of empty and foam filled circumferentially grooved thick-walled circular tubes*, Journal of Thin-Walled Structures, Volume 110, page 97-105, 2017.

[9] Husseina R.D., Ruana D., Lua G., Guillowa S., Yoonc J.W., *Crushing response of square aluminium tubes filled with polyurethane foam and aluminium honeycomb*, Journal of Thin-Walled Structures, Volume 110, page 140-154, 2017.

[10] Yan W., Durif E., Yamada Y., Wen C., *Crushing Simulation of Foam-Filled Aluminium Tubes*, Materials Transactions, Vol. 48, No. 7, page 1901 to 1906, 2007.

[11] Onsalung N., Thinvongpituk C., Pianthong K., *Impact Response of Circular Aluminum Tube Filled with Polyurethane Foam*, Materials Transactions, Vol. 55, No. 1, page 207-2015, 2014.