Experimental Research of the Tube Absorbers of Kinetic Energy During Collision

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Development of collision energy absorbing elements is a constituent part of passive protection of passenger coaches. The target of passive protection is to minimize the collision consequences. The absorber, described in this paper, is constructed from a standard seamless tube of the quality P235T1 and conical ring of the quality C45E. The solution presented is based on the application of special elements that absorb a certain amount of collision kinetic energy by means of controlled plastic deformation, significantly decreasing the part of the energy which is transferred to the vehicle bearing structure. The tube is compressed - pushed through the conical ring in collision. The paper focuses on the quasi-statics and dynamics experimental research. Based on the analysis of the results obtained in the research, a final design of the absorber is suggested as a part of the future front part of vehicle bearing structure.

Keywords: *Passenger coach, passive safety, energy absorber, experimental research, plastic deformation*

1. INTRODUCTION

This paper analyzes a new type of absorber of passenger coaches collision kinetic energy based on the principle of compressing the tube into a special ring by reducing its diameter. Mentioned elements are a part of passive protection measures in collision of passenger coaches. The purpose of passive protection is to minimize the collision consequences. It is based on controlled deformation of specially designed elements during which some part of collision kinetic energy will be absorbed and some significantly smaller part of it will be transferred to bearing structure. The subject of this paper is the research of the characteristics of shock absorbing elements of passenger trains collision energy.

Energy absorption occurs by: elastic-plastic deformation of the tube and friction between the ring and the tube.

The total absorbed energy depends on the quality of the material, production quality and construction solution of the ring and the tube. A limiting factor in the design of an absorption couple is primarily the space available for installing a shock absorber in a row with a buffer, and dimensioning of absorption couples is performed according to the installation point (dimensions of the buffer and frontal part of the bearing structure), required amount of absorbed energy [1] and experience [2], [4], [5] and [6].

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2. EXPERIMENTAL

Having in mind all the limitations and all stated above a standard seamless tube from low carbon steel (JUS C.B5.221, material P235T1) with dimensions $\varnothing 219.1 \times 5.9$ mm and height 220 mm was used for the absorption couple.

The ring was made from quench and tempered carbon steel (material C45E) with dimensions $\varnothing 220/\varnothing 100/13°$ and height of 60 mm.

The following methods were used to investigate the collision absorption:

- quasi -static pressure load, and
- dynamic (impact) load.

2.1 Quasi-static investigations

Hydraulic press LITOSTROJ with maximal force of 2500 kN was used for quasi-static investigation (Fig. 1).

Figure 1. Hydraulic press

During experimental research the compression distance and force were measured. Measurement of the compression distance was realized using two potentiometer movement transducers of the PM2S 150 type. Transducers were installed in parallel.

To eliminate possible slanting of supporting surfaces, the average value of movement of two transducers was taken. Measurement of the compression force was performed using special transducers on the basis of strain gauges connected into a full bridge where temperature self-compensation was accomplished. Strain gauges positioning enables insensitivity to the ex-centric force action. Acquisition and analysis of data was performed using "Spider 8" measurement acquisition system. All measurements were monitored and recorded using the "Catman 32 Express" software package.

Quasi-static investigations were performed in two phases. In the first experimental phase the tubes of all absorption couples were compressed approximately 70mm into the ring (Figure 2).

Figure 2. Phase I - coupling

In the second experimental phase (phase of impact energy absorption) the absorption couples were loaded on a hydraulic press, i.e. hammer where the tube was compressed by additional 105 mm into the ring (Figure 3).

Figure 3. Phase II – absorption

2.2 Dynamic investigations

For dynamic investigations was used pneumatic hammer HUTA ZYGMUNT TYPE 6300B on which maximal work of 70kJ can be reached (Figure 4).

Measurement of the compression distance and force, data acquisition and their recording was performed using the same potentiometer and force transducers, as used in quasi-static tests.

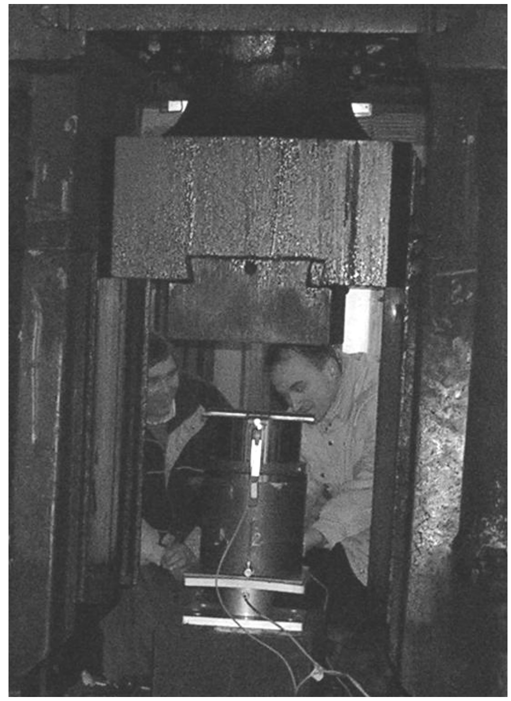

Figure 4. Pneumatic hammer

3. RESULTS

After the investigations were completed, recorded data were analyzed and diagrams describing the dependence of the force on the press as a function of the piston stroke were formed.

3.1 Results: Quasi-static investigations

Figure 5 shows a typical dependence of the compression force on the distance function obtained in the pre-strain phase of the quasi-static investigations.

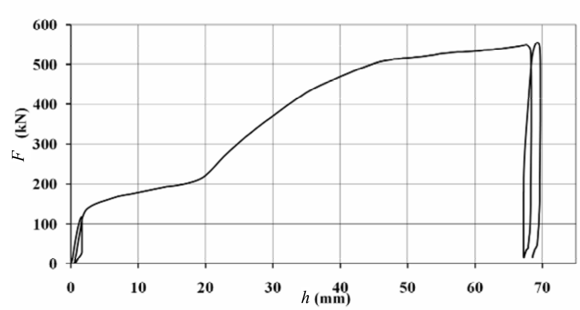

Figure 5. *F(h)* diagram – Phase I

Table 1. Characteristic parameters of phase II of the experiment

No.	Investigation type	Average value	F_{max} [kN]	F_{sr} [kN]	F_{max} / F_{sr} [kN]	h [mm]	W [kJ]
1	Quasi-static	$x_{1\text{-}3}$	603.08	585.86	1.03	105	61.52
2	Dynamic	x_4	719.96	562.12	1.28	20	11.24

The dependence is characterized by an increase in force in the whole investigated range and also presence of hysteresis at the beginning and at the end of the test. The occurrence of hysteresis is a consequence of manual control of the press. The force first increases linearly to the values ≈ 100 kN, when it leaves the elastic region and moves into the region of plastic deformations. Then it has a very gentle and approximately linear increase to the distance of about 17 mm and when the value of about 200 kN is reached. Above these values the force increases rapidly following an approximately parabolic dependence.

A typical dependence of compression force vs. distance function obtained in the second phase, energy absorption phase of the quasi-static investigations is shown in Figure 6.

The dependence is characterized by an approximately constant force value in the whole investigated range (for the distance of ≈ 105 mm) and the presence of hysteresis at the start of the test.

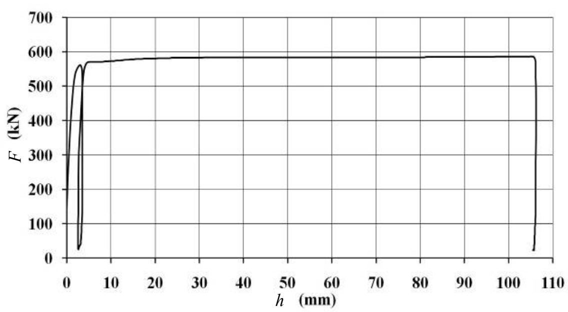

Figure 6. ***F(h)*** **diagram – Phase II**

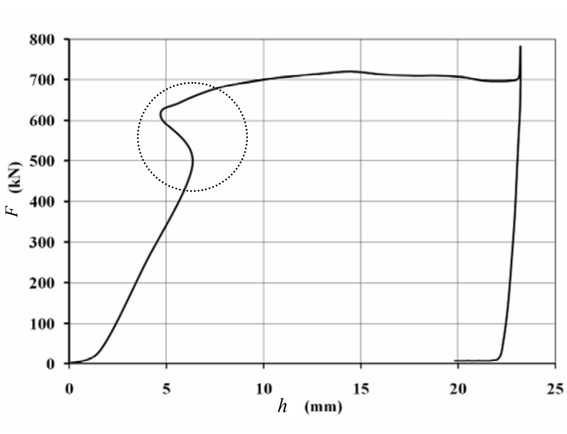

Figure 7. ***F(h)*** **diagram – Dynamic investigations - Phase II**

The rapid increase of force for the distance of ≈ 5 mm, i.e. reaching the value at the end of phase I of the experiment occurred likewise at the end of phase I, the tube is narrowed (from $\varnothing 220$ to $\varnothing 199$), thus reaching the highest deformation resistance, i.e. the highest compression force value. In this phase the tube continues to go through the ring for the 105 mm distance, where the force retains an approximately constant value.

3.2 Results: Dynamic investigations

Figure 7 shows dependence compression force vs. distance function obtained by dynamic investigations in the second phase of the experiment.

The enclosed diagram shows that the force increases linearly to the value of ≈ 500 kN and distance ≈ 7 mm after which, with certain deviations, the force increases significantly less sharply by the ≈ 20 mm distance. The deviation in the force (encircled part of the diagram) is due to the limitations of the transducers. Inductive transducers are better for fast deformation rates.

3.3 Review of the absorber parameters

Analysis of the diagrams shown above gives the following parameters suitable for evaluation of the acceptability of this type of elements for energy absorption: average force $-F_{sr}$, maximal force $-F_{max}$ and compression work – W.

In Table 1 are presented parameters significant for evaluation of elements for energy absorption during collision of passenger coaches, obtained in the second phase of quasi-static and dynamic investigations.

The experimentally obtained [1] values of the force and work function are somewhat lower than the defined ones, so some changes in dimensions for the absorption couple or joining of phase I and II of the experiment are necessary (Table 2).

Table 2. Comparison of the parameters

No	Investigation type	W [kJ] (II)	W [kJ] (I+II)	W [kJ] (Defined)
1	Quasi-static	61.52	≈ 81	101.2-118.1

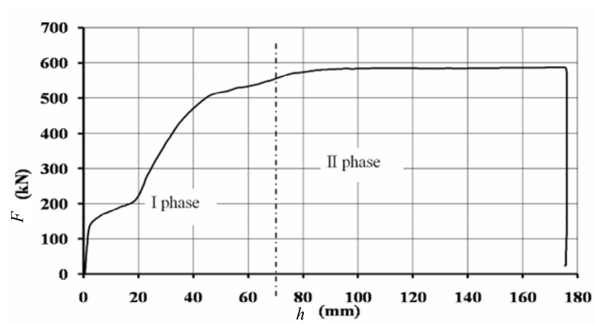

Figure 8. ***F(h)*** **diagram – Experimental phases I + II**

Joining of phases I and II would utilize the pre-strain energy for absorption of collision energy and in that way the set requirements will be approached closer (Figure 8). Also, joining of phases I and II causes the increase in overall dimensions of the absorbers, which is not acceptable because of the limited available area for installation of the absorbers.

4. CONCLUSION

According to the parameters obtained from experimental investigations, it can be concluded that absorption elements working on the principle of tube narrowing are suitable for the planned application. Characteristics noted for all investigated samples are: gradual force increase, good absorption characteristics, good utilization of the tube material and also a small ratio between maximal and average force.

Having in mind that a somewhat lower force and thus energy values from those set [1] were obtained, it is necessary to perform certain modifications of the absorption elements. As the available space for absorber mounting is very limited, elements enlargement are not possible, but corrections of some dimensions or changes in material are possible to accomplish the prescribed aims.

After performing these modifications, CRASH TEST is planned to verify this type of elements for crash energy absorption.

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ЕКСПЕРИМЕНТАЛНА ИСТРАЖИВАЊА КИНЕТИЧКЕ ЕНЕРГИЈЕ ЦЕВНИХ АПСОРБЕРА ПУТНИЧКИХ ВАГОНА ПРИ СУДАРУ

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Развој елемената за апсорбцију енергије судара је саставни део пасивне заштите путничких вагона. Пасивна заштита има задатак да последице судара сведе на минимум. Апсорбер приказан у раду неправљен је од стандардне бешавне цеви у квалитету P235T1 и конусног прстена квалитета C45E. Представљено решење се заснива на коришћењу специјалних елемената који апсорбују одређену количину кинетичке енергије судара путем контролисане пластичне деформације, чиме се значајно смањује део енергије који се преноси на носећу структуру возила. При судару долази до сабијања-провлачења цеви кроз конусни прстен. Тежиште рада је на експерименатлним истраживањима ради одређивања стварних карактеристика апсорбера овог типа. На основу анализе добијених резултата испитивања, предложено је коначно конструктивно решење апсорбера, као елемента будуће конструкције чеоног дела постоља вагона.