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DEVELOPMENT OF A COLLISION ENERGY ABSORBER OF A PASSENGER TRAIN

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ABSTRACT

Development of shock absorbers is one of the necessary measures for passive protection of passenger coaches. The purpose of passive protection is to minimize the collision consequences for passengers. Present solutions are based on the use of elements with a special structure that absorb a large amount of collision kinetic energy through controlled plastic deformation, allowing transfer of a significantly smaller part to the supporting vehicle structure. The shock absorber developed in this work consisted of a low carbon seamless steel tube and ring fabricated from quench and tempered carbon steel. During collision, the seamless tube is compressed into a ring with a reduced diameter. Therefore, the aim of this work was to determine the actual properties of the absorber, by testing it in both low and high strain rate tests. Based on the measured and calculated compressing parameters and calculation, some modifications of the absorber are suggested.

Keywords: Energy absorbers, passenger coaches, plastic deformation, passive safety

INTRODUCTION

The subject of this paper is research of the characteristics of elements of shock absorbers of collision energy of passenger trains operating on the principle of tube compression into a ring with a reduced diameter. The shock absorber role is to use up most of the collision energy in a controlled deformation in order to protect the structure behind the elements as much as possible from permanent deformations and thus protect the passengers and passenger coach.

A shock absorber consists of a seamless tube and ring. In the moment of impact the kinetic energy is transferred to the ring that starts to compress the seamless tube. Thus energy absorption occurs by: *elastic-plastic deformation of the tube and friction between the ring and tube.* The total absorbed energy depends on the quality of the material (it should have a high plasticity), production quality and construction solution of the ring and tube. As the limiting factor of designing an absorption couple is primarily the space available for installing a shock absorber in a row with a bumper, dimensioning of absorption couples is performed according to: the installation point (dimensions of the bumper and frontal part of the supporting vehicle structure), required amount of absorbed energy [1] and experience [2, 4].

The purpose of this paper is to investigate the suitability and justifiability of the proposed construction of an absorber of collision energy of a passenger coach and determine solutions that are more efficient and suitable for applications in actual passenger coach constructions.

EXPERIMENTAL

Having in mind all limitations and all stated above a seamless tube from low carbon steel (JUS C.B5.221, material P235T1) Ø219,1x5.9mm, height 220mm was used for the absorption couple. The ring was made from quench and tempered carbon steel (material C45E) with dimensions Ø220/Ø199/13° and height of 60 mm.

The following methods were used to investigate collision absorption: (i) quasi-static load on pressure and (ii) dynamic (impact) load.

Quasi-static investigation. Quasi-static investigations were performed on a LITOSTROJ hydraulic press where a maximal force of 2500 KN can be realized. During experimental research the compression distance and force were measured. Measurement of the compression distance was realized using two potentiometer movement indicators of the PM2S 150 type installed in parallel. With the purpose of eliminating possible slanting of supporting surfaces (panels) the average value of movement of two indicators is taken. Measurement of the compression force was performed using a special indicator constructed on the base of measuring tapes connected into a full bridge where temperature self-compensation was accomplished. Tape positioning enables no sensitivity to the ex-centric force action. Acquisition and analysis of data was performed using a "Spider 8" measurement acquisition system. All measurements were followed and recorded using the "Catman 32 Express" software package.

Quasi-static investigations were performed in two phases. In the first experimental phase tubes of all absorption couples were compressed approximately 70mm into the ring (this way absorption couples were formed, figure 1a), while in the second experimental phase (phase of impact energy absorption) absorption couples were loaded on a press, i.e. hammer where the tube was compressed an additional 105 mm into the ring (figure 1b).

a) Phase I – coupling *b) Phase II - absorption*

Fig. 1: Absorption couple

Dynamic investigations. A HUTA ZYGMUNT TYPE 6300B pneumatic hammer where maximal work of 70 kJ can be realized was used for dynamic investigations. Measurement of the compression distance and force, data acquisition and their recording was performed using the same potentiometer indicators and force indicators used in quasi-static tests.

RESULTS AND DISCUSSION

After the investigations were complete the recorded data was analyzed and diagrams describing the dependence of the force on the press as a function of the piston operation were formed.

Pre-strain phase - Quasi-static investigations. A typical dependence of the compression force on the distance function obtained from investigations in the pre-strain phase is presented in figure 2.

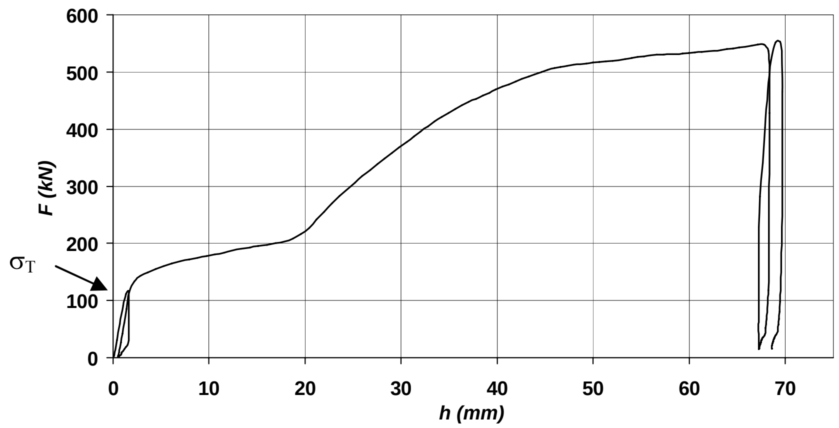

Fig. 2: F(h) diagram – Experimental phase I

The dependence is characterized by an increase in force in the whole investigated range and also presence of hysteresis at the beginning and end of the test. The appearance of hysteresis is the consequence of manual control of the press. Hysteresis is also repeated at the end of the test and will not be commented on further. During load introduction (by manual press control) as the sample has not retained its starting dimensions it is clear that plastic deformation of the element has occurred. The force increase is continual. The force first increases linearly until values ≈100kN when it leaves the elastic region and moves into the region of plastic deformations. Then it has a very gentle and approximately linear increase until 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.

Impact energy absorption phase - Quasi-static investigations. Figure 3 shows a typical dependence of the compression force on the distance function obtained from investigations in the second phase of the experiment, the impact energy absorption phase.

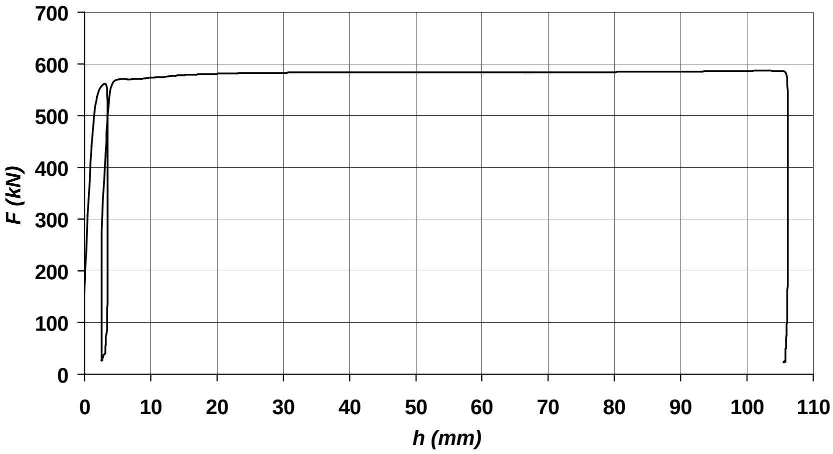

Fig. 3: F(h) diagram – Experimental phase II

The dependence is characterized by an approximately constant force value in the whole investigated region (for the distance of ≈105mm) and the presence of hysteresis at the start of the test. The rapid increase of force for the distance of ≈ 5mm, i.e. reaching the value at the end of phase I of the experiment occurred as at the end of phase I the tube is completely deformed (from Ø220 to Ø199) thus attaining 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.

Such behavior was registered in all investigated samples, with small deviations caused by the same events as in the first experimental phase.

Dynamic investigations. Figure 4 shows the dependence of the compression force on the distance obtained by dynamic investigations in the second phase of the experiment, impact energy absorption phase for a distance of ≈ 20mm.

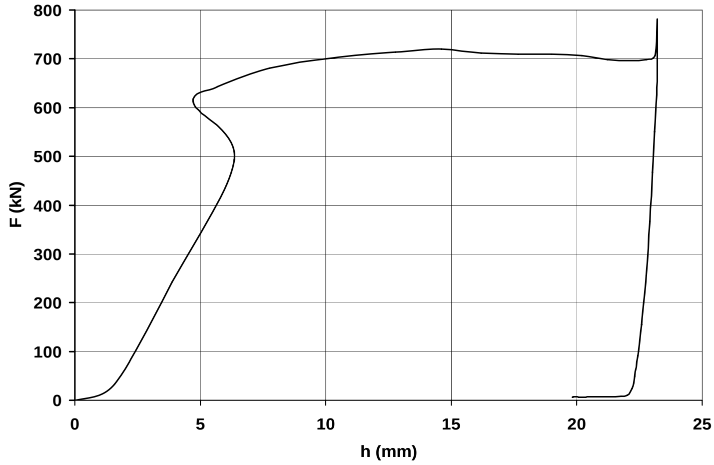

Fig. 4: F(h) diagram– Experimental phase II – dynamic investigations –

The enclosed diagram shows that the force increases linearly until the value of ≈ 500kN and distance ≈ 7mm after which with certain deviations the force increases significantly less sharply for the ≈ 20mm distance. The distance decrease with force increase (marked part of the diagram) occurs as potentiometer indicators were used instead of induction indicators that are not designed for measuring distances for fast deformation rates. Having in mind that there were no technical possibilities during this research to realize a distance higher than 20 mm with one hammer hit, in accordance with force changes for quasi-static investigations one can assume that the force would have approximately constant values for higher distances.

Review of the realization of absorber parameters. Analysis of the diagrams given above gave parameters according to which an evaluation of the suitability of this type of element for energy absorption was given: average force – F_{av}, maximal force – F_{max} and compression work – W.

Table 1 contains parameters of significance for evaluating elements for energy absorption of the collision of passenger coaches obtained in the second phase of quasi-static and dynamic investigations. The total compression work was analyzed for the distance of 105 mm, i.e. 20 mm.

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_{1-3}	603.08	585.86	1.03	105	61.52
2	Dynamic	x_4	719.96	562.12	1.28	20	11.24

The experimentally obtained values of the force and work function are somewhat lower than the defined ones [1] so a correction of dimensions of elements of the absorption couple or joining of phase I and II of the experiment are necessary (figure 5). Joining of phases I and II would utilize the pre-strain energy (structure formation) for absorption of collision energy and that way come closer to the set requirements.

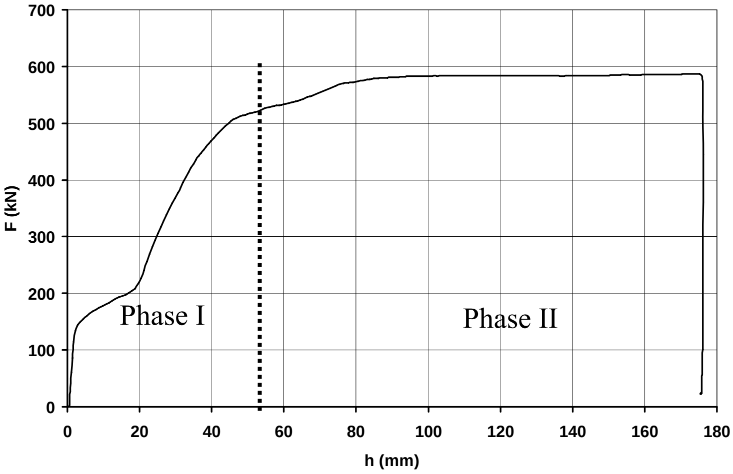

Fig. 5: F(h) diagram – Experimental phases I + II

CONCLUSION

According to the parameters obtained from experimental investigations one can conclude that absorption elements working on the principle of tube radius changes (narrowing) are suitable for the planned application. A characteristic noted for all investigated samples is a gradual force increase, passive characteristic, good utilization of the tube material and also small ratio between maximal and average force.

Having in mind that a somewhat lower force and thus energy values from the set ones [1] were obtained it is necessary to perform certain modifications of the absorption elements. As the space for absorber installation is very limited possible increases in dimensions (absorber distance) are not possible but correction of some dimensions of absorption elements of the material are possible that would enable accomplishment of the desired results. After these modifications are made, experiments are planned using a CRASH TEST enabling a final evaluation of this type of absorption elements.

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