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EXPERIMENTAL RESEARCHES AND NUMERICAL SIMULATIONS OF COMBINED COLLISION ENERGY ABSORBER

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Abstract *– The subject of this paper is experimental researches and numerical simulations of combined collision energy absorber. The mentioned elements are parts of passive safety measures of railway vehicles. This type of absorbers works on the principle of deformation using shrinking and folding process of the tubes. The idea was to use process of shrinking and folding of the tubes in a parallel mode to absorb as much of the collision kinetic energy as possible by controlled deformation, with limited dimensions of absorber. Energy absorption occurred by elastic-plastic deformations of the tubes and friction between the tube and the cone bush. Using combined method, during the collision, energy absorption starts in the tube which is compressed into cone bush. After pre-defined stroke in the process of energy absorption the simultaneous process of folding of the outer tube starts, so both tubes deform in parallel mode during the rest of the stroke. In this way the force gradually increases without undesirable peaks during the entire stroke, resulting significant bigger amount of absorbed energy. Experimental investigations of combined absorber were realized in laboratory conditions. During experimental investigations the stroke and force were measured. The numerical simulations were used for checking the absorption power of absorption elements before the experimental researches. After the tests were completed, the recorded data were analyzed and force versus stroke diagrams of numerical simulation and quasi-static test were made. Results of calculation using FEM and results obtained experimentaly are in good correlation.*

Keywords - Experimental researches, combined absorber, railway vehicle, passive safety.

1. INTRODUCTION

The subject of this paper is analysis of results of numerical simulations and experimental investigations of combined tube collision kinetic energy absorber. Mentioned elements are a part of passive protection measures of railway vehicle. This type of absorber works on the principle of shrinking and folding the tubes. The idea to combine these two processes of deformations, stemmed from the need to increase the absorption capacity and to reduce the space required for installation, which is in the frontal part of the wagon is very limited. The reason for analysing this type of elements is further increase, of the of the protection of the structures behind the absorbers and unwanted deformations and thus to increase safety of passengers, goods and railway coaches. By using this type of absorber, energy absorption occurs by elasto-plastic deformations of the tube and friction between the tube and the cone bush. The combined method was chosen for two reasons: first, tube shrinking absorber has very good characteristics [1], and second, to exclude very high values of the force (peak) on the deformation start which characterize folding tube absorber [2]. During the collision, absorption of the energy starts in the inner tube wich is compressing into cone bush. After pre-defined stroke, the process of deformation of the outer tube will start and on the rest of the stroke both tubes will absorb collision energy in parallel mode, Fig. 1. Thus the force gradually increases without undesirable peaks during the entire stroke, resulting in a significant bigger amount of absorbed energy. During

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development of absorption elements couple, the results of experimental investigations given in [3] were used. This paper analysed influence of strain-rate on the deformation resistance.

This paper presents experimental investigations based on quasi-static test. During investigations the force and stroke were measured. Prior the experimental investigations, designed characteristics of absorption couple were checked using numerical simulations. After the tests completion, recorded data were analysed and compared with results obtained using numerical analysis.

2. NUMERICAL SIMULATIONS

Numerical simulations was performed using software package ANSYS. Following elements were involved in the model: seamless tube (pos. 1, material S355J2G3) with dimensions ∅75x2x160mm, segments tube (pos. 2, material S355J2G3) with dimensions ∅86x90mm and the cone bush (Pos. 3) from quenched and tempered carbon steel (material C45E) with dimensions ∅105/68x13°, Fig. 1.

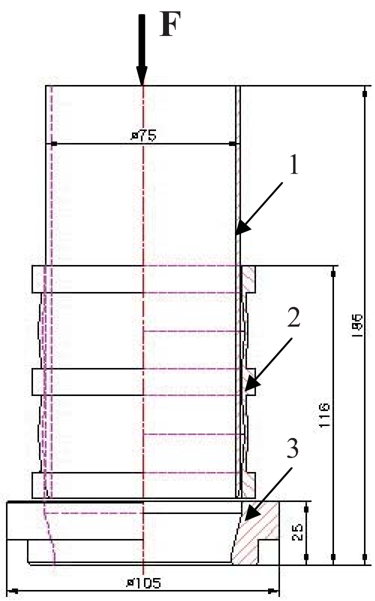

Fig.1. Working principle of combined absorber

Using the finite elements method, the nonlinear numerical simulation on the plane axisymmetric was performed (Fig. 2), using *Perzyna model* with rate dependent option.

Perzyna model requires defining key parameters which characterize rate dependent option. The key parameters are: m - strain rate hardening parameter and γ – material viscosity parameter. Results of experimental investigations, described in [3], defined next values of key parameters for quasi-static tests: m=0,23 and γ=305.

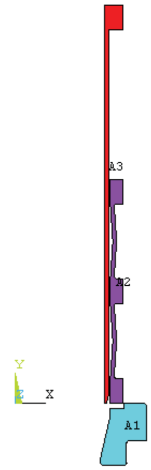

Fig.2. Plane axisymmetric model

3. EXPERIMENTAL INVESTIGATIONS

Experimental investigations were realised on the servo-hydraulic testing machine Zwick Roell HB250 at the Faculty of Mechanical Engineering, University of Belgrade (Fig.3). This machine is property of Laboratory of machine elements and systems testing.

Fig.3. Testing machine Zwick Roell HB250

The following elements were used for this investigation: seamless tubes (pos. 1, 2, 3 and 4) from structural steel (material S355J2G3) and the cone bush (Pos. 5) from quenched and tempered carbon steel (material C45E), Fig. 4.

Fig.4. Samples

Samples on the Fig. 4 are separated in five groups: a) seamless tubes with two folding segments with cone walls (pos. 1), b) seamless tubes with two folding segments with plane walls (pos. 2), c) plane seamless tubes of length L = 160 mm (pos. 3), d) plane seamless tubes of length L = 71 mm (pos. 4) and e) cone bush (pos. 5). Different geometries of the folding tubes are created to shows influence of the wall geometry on the start values of the deformation resistance.

Working principle of combined absorber is shown in the Fig. 1. Combined absorber works on the principle of compressing and folding tubes at the same time. During the collision, process of energy absorption first starts mode of tube shrinking (pos. 1) during the stroke of ≈ 63 mm. After the stroke of 63 mm, starts the second mode of energy absorption, using the folding of the tube (pos. 2). In that moment, energy absorption continues in parallel working mode, compressing and folding the tubes on the stroke of 40 mm (pos. 1 and 2). Combined principle was chosen to decrease undesirable peaks of the force at the start, which characterize the folding process. The combined process of energy absorption gives significant lower values of the force peaks at the start of the folding process and at the same time, for the same amount of absorbed energy requires lower thickness, comparing to absorber using only folding tube process. Experimental investigations were realized in two phases using quasi-static loading. First phase served for selection of the most appropriate design of the folding tube.

As expected, tube consisting of segments with coned wall (Fig. 4, pos. 1) showed better characteristics, more appropriate for the combined process of energy absorption. Geometry of the tube with cone wall allows predicting the deformation starting position (peak of the cone). This geometry shows lower values of the force at the start of the folding process what was the one of the aims of this paper. Second phase of experimental investigations, quasi-static test, was realized with speed of piston stroke of 25 mm/s.

4. RESULTS

4.1. Numerical simulations

After the numerical simulations were completed, the recorded data were analyzed and force versus stroke diagram are shown in the Fig. 5.

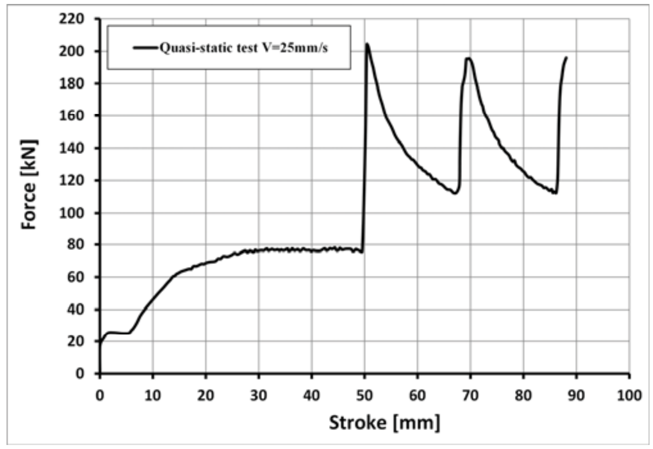

Fig.5. Force vs. stroke diagram – Numerical simulation

Fig. 6 shows shape of the combined absorber after deformation process. .

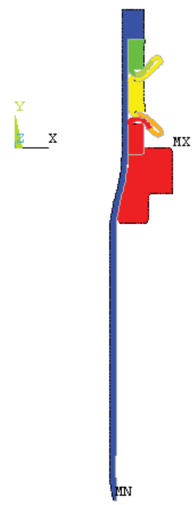

Fig.6. Combined absorber after deformation process

4.2. Experimental investigations

In this phase of the reasearches were formed assemblies, as shown in the Fig. 7. Charateristic diagram obtained by experimental investigations shown on Fig. 8.

Fig.7. Combined absorber after experimental investigations – V = 25 mm/s

This diagram characterizes two clear separated phases. The first phase is compressing of the shrinking tube into a cone bush at stroke of approximately 60 mm. The second phase characterizes parallel work of the shrinking tube and the folding tube at the stroke of approximately 35 mm.

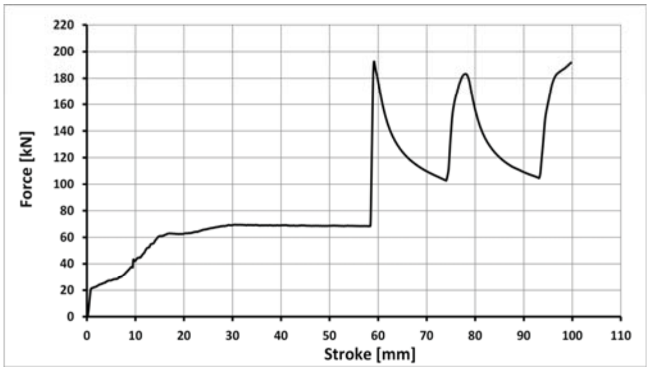

Fig.8. Force vs. stroke diagram – experimental investigations

With the aim of better review of results and their relations, in Fig. 9 are shown two curves obtained by numerical simulations and experimental investigations. The same key parameters were used for both investigations as mentioned above.

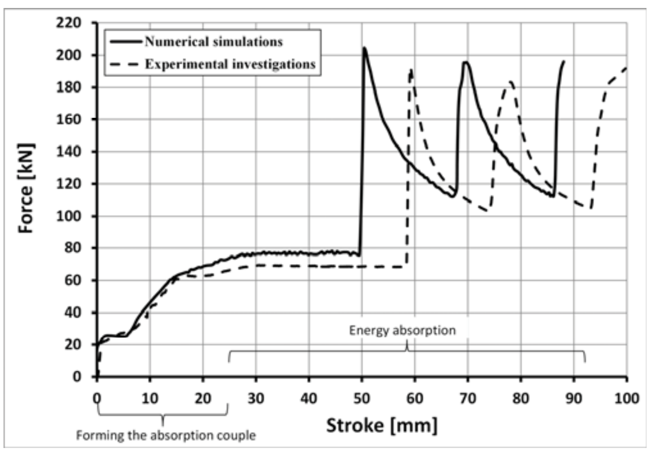

Fig.9. Force vs. stroke diagram – numerical and experimental curves

In this diagram can be clearly seen that numerical and experimental results are in a good correlations. Differences in stroke values between the curves are caused by difference in defined stroke of the first phase characterized by shrinking of the tube. Characteristic parameters which can be used for evaluation of this type of absorber are shown in the Table 1.

The aim of this analysis was to compare two types of energy absorption elements and since it was performed using scaled model, as expected, scaled values of force and absorbed energy were obtained. Bold numbers in table 1 are the values of absorbed energy in case of using only shrinking method. Using the combined absorber, amount of absorbed energy is approximately twice as higher compared to tube shrinking absorbers, at the same stroke.

Table 1. Characteristics parameter

	F_{Imax} [kN]	**F_{IImax} [kN]**	**h [mm]**	**W [kJ]**
Numerical	76	204	62	7,3 **[4,6]**
Experimental	69	191	68	8 **[4,6]**

5. CONCLUSIONS

Using combined principle of energy absorption, absorption element with compact dimensions can be designed. This type of absorber may absorb significant higher amount of collision energy in comparison with using only shrinking or folding process. Good corellation between results of numerical and experimental investigations indicate the possibility of using the developed numerical model for future research in this field. The next step of this researche will be experimental investigations on the full size combined absorber during collision of two passenger coaches.

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