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EXPERIMENTAL RESEARCH OF CHARACTERISTICS OF IMPROVED TYPE OF COMBINED TUBE ENERGY ABSORBER

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Abstract – *Crash energy absorber represents one of the main and necessary elements of body structure of modern railway vehicles. Intensive research in the field of passive safety produced more different types of collision energy absorbers using different shapes of deformations to absorb as much kinetic collision energy as possible. Different combinations of the shape of deformations lead to compact dimensions of absorber. Subject of this paper is combined energy absorber which works on the principle of shrinking and splitting the seamless tube at the same time, using special tools. Using shrinking-splitting process energy absorption occurs by elastic-plastic deformations of the tube and friction between the tube and the cone bush, respectively friction between the tube and the splitting tool. Energy absorption starts in the tube which is compressed into cone bush. After exactly defined stroke in the process of energy absorption by shrinking the seamless tube, the simultaneous process of splitting of the tube starts, so tube deforms in parallel shrinking-splitting mode during the rest of the stroke. This type of combined process gives gradually increase of the force without undesirable peaks which characterizes second phase of deformation of shrinking-folding combined absorber. Experimental research was realized via quasi-static tests in the laboratory conditions. During tests, reaction force and stroke were measured. Results of the investigations of combined shrinking-splitting absorber and shrinking-folding absorber were compared.*

Keywords – Crash absorber, Passive safety, Shrinking, Splitting, Experimental researches.

1. INTRODUCTION

The subject of this paper is process of improving absorption characteristics of the combined tube absorber using different shapes of deformations. Experimental investigations of combined absorber described in this paper based on the tube absorber that works on the principle of compressing the seamless tube into a cone bush [1, 2]. This type of absorber characterizes gradual increase of the force, without peaks until reaching the maximal value, when the force remains approximately constant with minor deviations to the end of the deformation process. As an idea for combined energy absorption served experimental investigations obtained by axial pressure of the tube of circular and square cross sections with parallel analyzes of inversion and splitting processes were presented in the paper [3]. Folding of the tube characterizes jagged force versus stroke curve. Experimental investigations directed to the shrinking-folding combined process of seamless tube are showing that the folding process not the best solution in combination with shrinking process [4-6]. Results of investigations showed that combination of these two processes may increase absorption power with compact dimension of absorber, but it is not possible to eliminate force peaks at the start of deformation (folding process) of each segments of the tube wall. Using a larger number of folding segments in the tube

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wall, could alleviate jagged effect on the force versus stroke diagram. Reduction of peaks does not mean their elimination, so the further investigations were directed toward research of other possible combinations. Experimental and theoretical analysis of splitting process of the tubes made by aluminum and mild steel were presented in the paper [7-9]. These investigations were realized on the samples with different wall thickness and lengths. Splitting tube, using different top angles of the special cone die, were realized. The angle of the top of cone die has direct influence on the correct flow of splitting tube, so appropriate design of angle is very important. Force vs. stroke diagram characterizes peak at the start of deformation process. After that, force value decreases to approximately half of the initial value and stays on that level with minimal deviations to the end of deformation process. Using above-mentioned facts, quasi-static tests were performed on two different types of combined tube energy absorber. Results obtained by these experimental investigations (shrinking-folding and shrinking-splitting the tubes) were analyzed and main differences between them are presented.

2. EXPERIMENTAL INVESTIGATIONS

Quasi-static tests were realized on servo-hydraulic machine ZWICK ROELL HB250 at the University of Belgrade Faculty of Mechanical Engineering, Fig. 1. Maximum load which can be realized on this machine is 250kN. Acquisition system may record up to 8 measurement channels with sampling frequency up to 10 kHz. During experimental investigations deformation resistance (reaction force) is measured on the defined stroke.

Fig.1. Testing machine Zwick Roell HB250

2.1. Shrinking-folding combined absorber

This type of combined tube absorber uses shrinking and folding processes to absorb kinetic collision energy. Working principle of combined absorber is shown in the Fig. 2. During the collision, process of energy absorption first starts mode of tube shrinking (Item 1) during the stroke of ≈ 63 mm. After the stroke of 63 mm, starts the second mode of energy absorption, using folding of the tube (Item 2). In that moment, energy absorption continues in parallel working mode, compressing and folding the tubes on the stroke of 40 mm (Item 1 and 2).

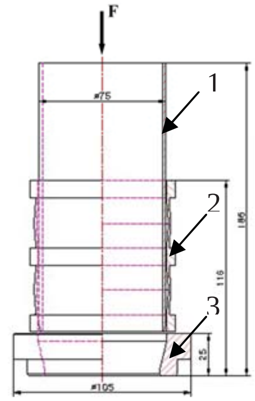

Fig.2. Working principle of shrinking-folding absorber

The following elements were used for this investigation: seamless tube (Item 1, material S355J2G3) with dimensions Ø75x2x160mm, segments tube (Item 2, material S355J2G3) with dimensions Ø86x90mm and the cone bush (Item 3) from quenched and tempered carbon steel (material C45E) with dimensions Ø105/68x13°, Fig. 2. Samples are separated in five groups: a) seamless tubes with two folding segments with cone walls (Item 1), b) seamless tubes with two folding segments with plane walls (Item 2), c) plane seamless tubes of length L = 160 mm (Item 3), d) plane seamless tubes of length L = 71 mm (Item 4) and e) cone bush (Item 5), Fig. 3. Different geometries of the folding tubes are created to show influence of the wall geometry on the starting values of the deformation resistance.

Fig.3. Samples

2.2. Shrinking-splitting combined absorber

This type of tube absorber uses shrinking and splitting processes for energy absorption. Working principle of combined absorber can be described using

Fig. 4. During collision, process of energy absorption first starts with the tube (Item 1) shrinking using cone bush (Item 2) at the stroke of ≈ 50 mm. After stroke of 50mm, second mode of energy absorption, i.e. splitting of the tube, starts with contact between predeformed tube and the die (Item 3). In that moment, energy absorption continues in parallel working mode, compressing and splitting tube at the stroke of 40mm. The absorber was installed in the special tool (Item 4) which was used as a support during the testing.

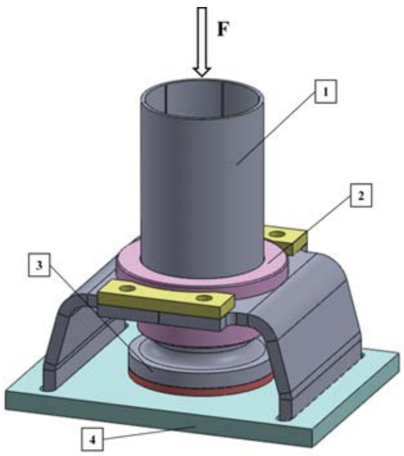

Fig.4. Working principle of shrinking-folding absorber

The following elements were used for this investigation: seamless tubes (Item 1 and 2) from low carbon steel (material P235T1), cone bush (Item 3) with dimensions ø75/68x13° and die (Item 4) with dimensions ø61/r8 from quenched and tempered carbon steel (material C45E), Fig. 5.

Fig.5. Samples shrinking-splitting absorber

Seamless tubes are separated in two groups according to the lengths: a) seamless tubes with dimensions ø75/70 of the length L = 100 mm (Item 1) and b) seamless tubes with dimensions ø75/70 of the length L = 70 mm (Item 2), Fig. 5. Shorter tubes were used for the control tests and for the check in shrinking process that was used as a base for evaluation of the combined process. Six grooves on the inner wall were made on all tube samples in the inner wall. These grooves were used as initial places for tube wall cracking during splitting process of deformation.

3. RESULTS

3.1. Shrinking-folding absorber

Deformed shrinking-folding absorber shown in the Fig. 6.

Fig.6. Deformed shrinking-folding absorber

Charateristic diagram obtained by experimental investigations is shown in Fig. 7. This diagram characterizes two clear separated phases. The first phase is compressing the 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.

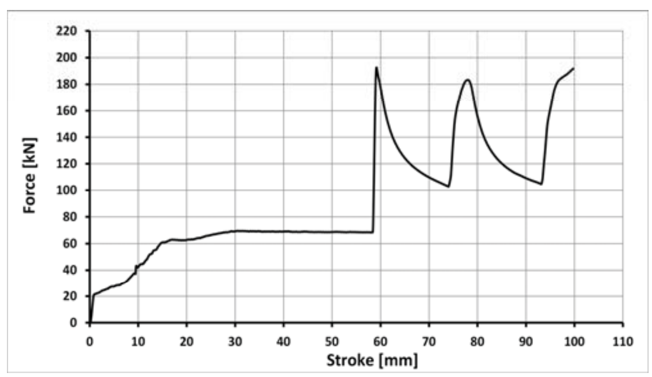

Fig.7. Force vs. stroke diagram: shrinking-folding absorber

3.2. Shrinking-splitting absorber

Fig. 8 shows the sample after deformation. Three samples were tested with the combined shrinking-splitting process and force-versus stroke diagrams obtained by these investigations are shown in Fig. 9. The diagram clearly shows two separate phases of deformation. The first phase of deformation process, until the stroke of ≈50 mm, has the characteristics of shrinking. After this phase, the splitting process starts on part of the tube that was plastically deformed during the first phase. Until the end of the test at a stroke of ≈90 mm, energy absorption occurs in parallel shrinking and splitting processes.

Fig. 8. Deformed shrinking-splitting absorber

At the moment the splitting process starts (there is a transition in the region 50-55 mm stroke) the force increases sharply from ≈100 kN to ≈194 kN. With the appearance of the first cracks at the end of the tube, along the inner grooves, the force drops to ≈150 kN at the stroke of 60 mm. After this, the splitting of the tube along the inner grooves is more controlled and the force again increases gradually to ≈210 kN at the stroke of 80 mm, remaining thereafter at this value until the test ends at 90 mm stroke.

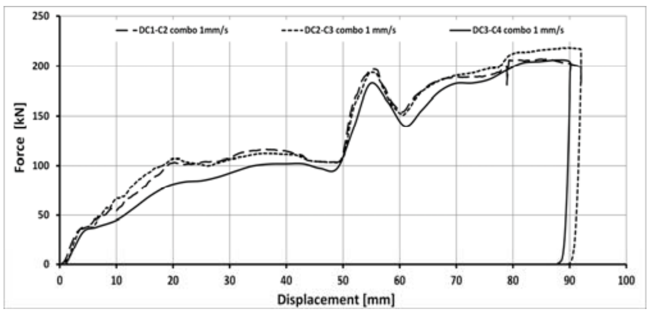

Fig. 9. Force vs. stroke diagram: shrinking-splitting absorber

These two diagrams (Fig. 8 and 9) show similar curves during analysing two clearly separately phases. Second phase serves as a base for the evaluation of characteristics of combined absorbers. The jagged part of diagram, which characterises folding process, was eliminated using splitting process of deformations. On the other side, absorbed energy given by shrinking-splitting process is higher than shrinking-folding absorber. This was the main improvement of the combined absorber.

Absorbed energy in the first and the second phase was calculated as the work of force at defined stroke (amount of absorbed energy is equal to area under curve):

$$W=F_{sr}\ x\ h$$

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

The average calculated value of the total absorbed energy was 11,52 kJ for the shrinking-splitting process and 8 kJ for the shrinking-folding process. The energy absorption of the improved absorber is increased by ≈ 40 %.

4. CONCLUSION

Using combined principle of energy absorption leads to better absorption characteristics. Improved type of absorber may absorb significantly higher amount of collision energy in comparison with using combined shrinking-folding process. Using shrinking-splitting process it is possible to eliminate jagged characteristic which is very important in terms of gradual introduction of the force in the vehicle structure.

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REFERENCES

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

[2] Tanaskovic J., Lučanin V., Milkovic D., Simic G., Milos 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.

[3] Alghamdi A.A.A., Collapsible impact energy absorbers: an overview, Thin-Walled Structures, Volume 39, Issue 2, Pages 189-213, February 2001.

[4] Reid S.R., Plastic deformation mechanisms in axially compressed metal tubes used as impact energy absorbers, International Journal of Mechanical Sciences, Volume 35, Issue 12, 1993.

[5] Tanaskovic J., Milkovic D., Lucanin V., Miloradovic N., Experimental and numerical analysis of the characteristics of combined collision energy absorbers, Journal FACTA UNIVERSITATIS - Series Mechanical Engineering, Vol.10, No 2, 2012.

[6] Salehghaffari S., Rais-Rohani M., Najafi A., Analysis and optimization of externally stiffened crush tubes, Thin-Walled Structures, Volume 49, Issue 3, 2011.

[7] Huang X., Lu G., Yu T. X., On the axial splitting and curling of circular metal tubes, International Journal of Mechanical Sciences, Volume 44, Issue 11, 2002.

[8] Reddy T. Y., Reid S. R., Axial splitting of circular metal tubes, International Journal of Mechanical Sciences, Volume 28, Issue 2, Pages 111-131, 1986.

[9] Atkins A. G., On the number of crack in the axial splitting of ductile metal tubes, International Journal of Mechanical Sciences, Volume 29, Issue 2, 1987.