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Effect of Side-wall Reinforcement on Energy Absorption of Thin-wall Cylindrical Damper

M. Chau[1], J. Hoffmann[2], M.V. Blundell[3], A. Ordys[1], H. Hadavinia[1]

[1]Faculty of Engineering, Kingston University, SW15 3DW, UK
[2]Toyoda Gosei Europe NV, Ernst-Abbe-Str. 3, D-66115 Saarbrücken
[3]Faculty of Engineering and Computing, Coventry University, Coventry CV1 5FB, UK

m.chau@kingston.ac.uk, joerg.hoffmann@tg-europe.com, m.blundell@coventry.ac.uk, a.ordys@kingston.ac.uk, h.hadavinia@kingston.ac.uk

Abstract
This study is focused on modification of a conventional bumper damper to increase its energy absorbability. This bumper damper device is currently used on passenger vehicles for reducing structural damage, as well as part of the pedestrian protection system. A hollow aluminium cylinder with 2mm in thickness was subjected to a range of experiments. The energy absorption takes place as a ram displaces along the cylinder's bore, where the outer diameter of the ram is slightly wider than the inner diameter of this cylinder.

Results from laboratory experiments and ANSYS finite element software showed that the hollow cylinder absorbs 3.2 kJ energy, after the ram was displaced 80mm inside the cylinder. The damper is modified by attaching two metallic rings with 1mm thickness outside the cylinder surface to increase its crashworthiness, the addition of these rings resulted in increase of 16% in energy absorption.

Keywords: Damper, Energy absorption, Impact

Introduction
Using damper on vehicles becomes one of favourable options for absorbing crash energy on modern vehicles. These dampers are normally hydraulic based, where the fluid inside the tube would take the impact energy, and prevent the vehicle structure from severe damage [1-7]. In order to increase the energy absorption, several ideas have been developed over past years; one of these ideas is modification of the damper body, by deforming part of the damper body to increase the energy absorption and to reduce the structural damage to the vehicle. However, these dampers are effective approximately up to a speed of 16 km/h and at higher crash speed, severe structural damage is still inevitable.

The work describes here is based on finite element simulation and experimental studies to improve the crashworthiness of the damper. Experimental and numerical results showed that by placing two rings on the outside of the damper body, the energy absorption capability will increase.

Description of the damper
The damper studied in this paper is used in conventional vehicles, and it is made by Boge GmbH in Germany. The damper is composed of two parts, cylinder tube and outer tube, respectively. The outer tube contains a hydraulic chamber that stores hydraulic fluid. The inside cylinder tube is an air chamber that filled with nitrogen. A piston is located at the end of the cylinder tube for preventing the fluid and nitrogen

mixed together, until the cylinder is pushed in, which will cause a chemical reaction that allows the nitrogen and fluid mixture absorb all the energy, and the structure remains undamaged.

The rear part of the damper is a hollow circular tube, which would be deformed by the cylinder as soon as the hydraulic force no longer withstands the impact force. The bore of the tube would be enlarged as the cylinder tube pushed in, these results in preventing the main frontal structure from severe damage up to the speed of approximately 16 km/h. In order to produce multi-stage kinetic energy absorption, the outer tube is modified by addition of two external rings. Hoffmann et al. [8] and Vetter et al. [9] have developed this device further for pedestrian safety protection.

Experimental and numerical studies

Experimental works and ANSYS finite element software have been used to study the crashworthiness of the original and modified damper. The components that were subjected to testing were two metallic tubes, one being the bottleneck part of the outer tube (a cylinder) and the other being the ram piston (Figure 1). The cylinder was made of aluminium alloy 6060 with wall thickness of 2 mm [10].

The experimental tests were as follow; the tests were performed on a 100 kN universal testing machine at a speed of 1 mm/min with a maximum stroke of 80 mm. During the loading, the flange of the cylinder was widened while the force remains constant until the end of the 80 mm stroke. The constant load during energy absorption is a positive aspect of the original damper while the amount of energy absorption is not at a desirable level. The experimental and FEA results of original damper are presented in Figure 2.

In the next stage two reinforcement rings were added to the cylinder surface, in order to increase the energy absorption capability of the cylinder. These two rings are 2 mm thick each, and installed 15mm apart from each other.

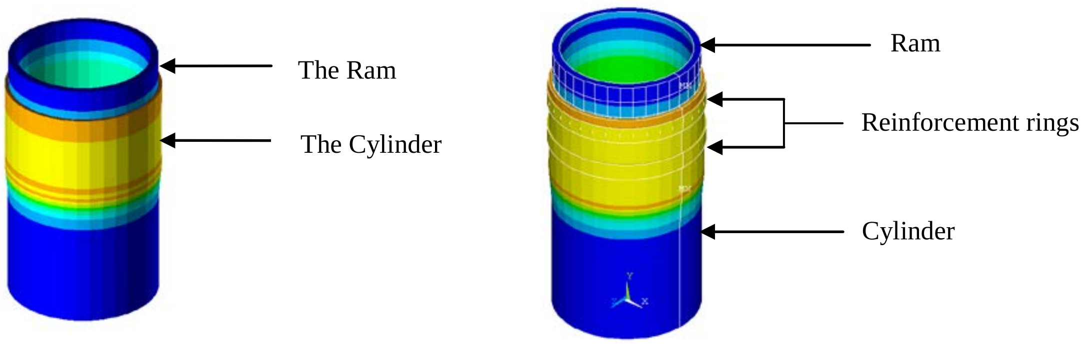

Figure 1: ANSYS model of original (Left) and modified (right) cylinder

Similar to the original cylinder, the modified cylinder is deformed during the ram stroke of 80 mm along the cylinder axis. The two rings caused an increase in energy absorption by the cylinder as the area under the load-displacement has been increased. The experimental and FEA results for both original and modified outer tubes are compared in Figure 2. In the modified cylinder, the opening process of the first and the second rings are matched the experimental results.

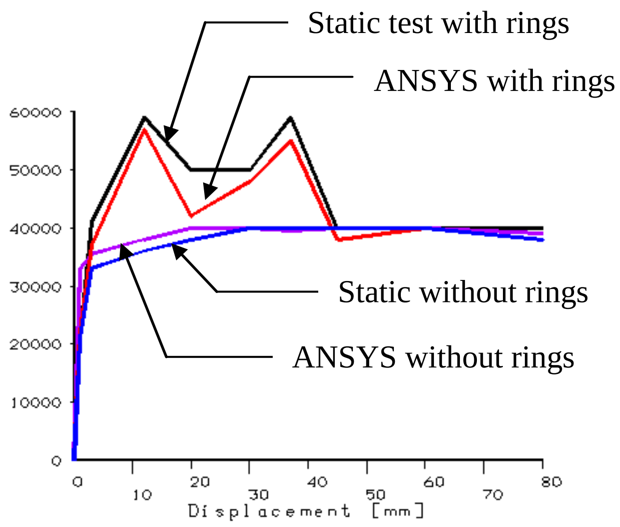

Figure 2: Comparison of experimental and FEA of original and modified cylinder

In Table 1 the mean force and specific energy absorption (SEA) of FEA results for the cylinder without the rings are compared with the experiments. The SEA results of FEA and tests are very close. Table 2 shows that the difference between SEA results from FEA has 4% error relative to experiments which is acceptable. The SEA of the modified cylinder is 16% higher than original cylinder.

Table 1: Comparison of FEA and experiment of original damper

Original outer cylinder of the damper			
	Experiment	**FEA**	**Error (%)**
Mean force (kN)	39.5	39.57	1.8
SEA (kJ/kg)	3.2	3.2	0

Table 2: Comparison of FEA and experiment of modified damper

Modified outer cylinder of the damper with two rings			
	Experiment	**FEA**	**Error (%)**
First peak (kN)	59	58	1
Second peak (kN)	59	55	7.3
Mean force (kN)	50	49	2
SEA (kJ/kg)	3.8	3.65	4

Conclusion and future work

In this work it has been shown that the crashworthiness of the metallic tube as part of the damper can be improved by incorporating reinforcement rings to the cylinder wall. As the damper is fixed to the front of both longitudinal beams of a vehicle, in order to avoid severe structure damage in low speed crashes, the modification investigated here resulted in a 16% increase of damper energy absorption as soon as the tube has reached to its maximum stroke. Thus, this modification enables a more compact and lighter design of the damper system.

Other design modifications under investigation are:

- Modification of outer tube to multi-wall tubes.
- Optimisation of the number of reinforcement rings for multi-stage energy absorption.
- Using magnetorehological (MR) fluid inside the outer tube section to control the energy absorption capability of the damper.

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