Experimental Investigation of Foams Suitable for Motorcycle Protectors

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Abstract

Protectors of motorcycle riders should be light and safe. This work deals with the impact test of the shoulder protectors, which differ with the use of foams of different densities. The acceleration and displacement of an impactor having the mass of five kilograms were measured. The impactor dropped from a height of one meter. For each sample, two impacts were used. The results show how the use of the different foams affects the deceleration of the impactor and the distance between the impactor and the base block (compression of the protector). Moreover, the results show how the deceleration and the distance change when the impact is repeated. The ideal protector would have low density, low maximum impact deceleration, low maximum protector compression, and its properties would not change when impact is repeated. The foam with good compromise properties was evaluated.

Keywords *:* Impact, Foam, Protector, Motorcycle, Personal protective equipment

I. Introduction

Road traffic accidents cause one of the highest numbers of severe injuries. Due to the high share of motorcycles in transport (e.g. more than 40% of the total number of vehicles in Malaysia, Saber et al., 2014) and other aspects, motorcycle riders are among the most vulnerable road users. Primarily, helmets protect the riders from injuries, however, other protectors, such as the shoulder protector, also contribute to increased safety (Hynčík et al., 2018; de Rome et al., 2011).

Fig. 1. Shoulder protector

EN 1621-1 (2012) is a standard for the production of limb protectors. This standard has two levels. Level 2 means safer protector. A shoulder protector that meet level 1 of the standard (Fig. 1) is the subject of this study. The protector consists of four layers (see Fig. 2). The fourth layer is a plastic shell with a honeycomb (Fig. 3). Its purpose is to absorb part of the impact energy and distribute the remaining part of the impact energy to a wider area of the foam with the density of 170 kg·m^3 (second layer). Between the fourth and second layers is the layer of leather that reduces penetration of the honeycomb into the foam.

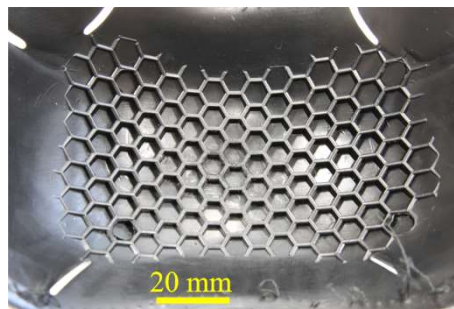**Fig. 2.** Cross-section of shoulder protector

Fig. 3. Plastic shell with honeycomb

The aim of this work was to investigate the effect of the foam type on the acceleration and displacement of the impactor during the impact test. Six types of the foam of different densities were investigated. Moreover, some samples having the third layer made from paper instead of the leather or samples without the third layer were tested.

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Experimental samples

Ten types of samples were tested. The samples varied:

- In type of the foam (second layer in Fig. 2). Six types of the foam were investigated. The thickness of the foam layer was approximately 10 mm;

- In layer between the foam and the plastic shell (third layer in Fig. 2). Leather or paper having the thickness of 1 mm was used. Some samples were tested without this layer.

Designation of the samples and foams is obvious from Table 1. Sample 300_0 differs from sample 300_X by including holes (with axis in the direction of loading) of diameter 7 mm. The shortest distance between the holes was 7 mm. Outer surface of the foams is obvious from Fig. 4 - Fig. 9.

Table 1. Types of samples

Designation of sample	Designation of foam	Density of foam ($kg \cdot m^{-3}$)	Material of 3. layer
025_L	025	25	leather
030_L	030	30	leather
030_P	030	30	paper
170_L	170	170	leather
170_P	170	170	paper
200_L	200	200	leather
200_P	200	200	paper
300_X	300	300	no 3. layer
300_O	300	300	no 3. layer
400_X	400	400	no 3. layer
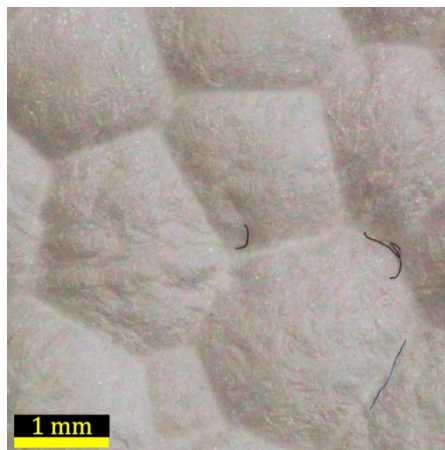
Fig. 4. Foam 025
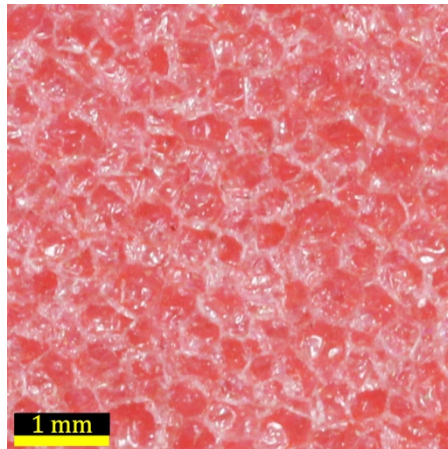
Fig. 5. Foam 030
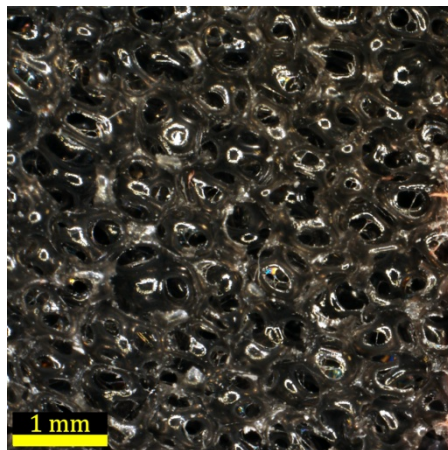
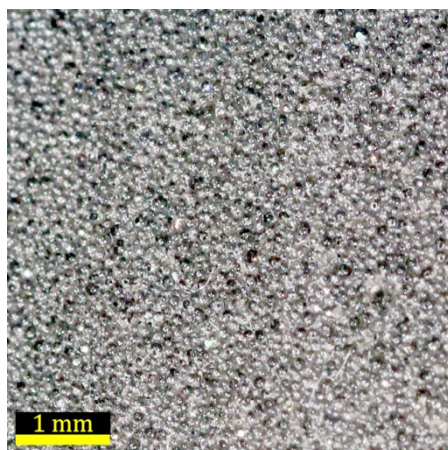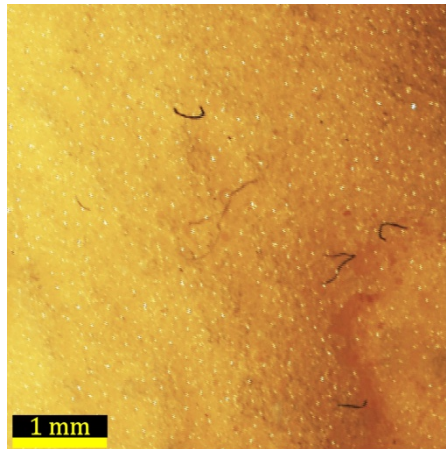**Fig. 6.** Foam 170

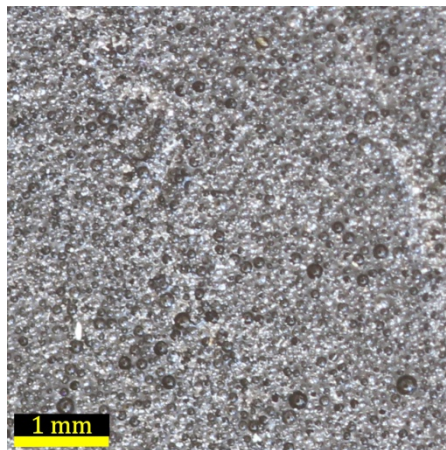**Fig. 7.** Foam 200

Fig. 8. Foam 300

Fig. 9. Foam 400

Experiment

The impact test was performed in a drop tower designed by the authors (Fig. 10). The impactor with shape of the head according to EN 1621-1 (2012) weighted 5 kg. The impactor dropped from a height of one meter on the sample placed on a spherical base block having the diameter of 100 mm. For each sample, two impacts were used. The impactor displacement u, which represents a position of the bottom side of the impactor head above the spherical base block, and the impactor deceleration a were measured. The deceleration was measured by the accelerometers KISTLER 8742A20 and 8715A5000M5. The displacement was measured using the Micro-Epsilon optoNCDT 2300-50 lasers (these lasers can measure the displacement of up to 50 mm). The experiment was realized in the temperature equal to 23 ± 1 °C and the humidity equal to 5 ± 6 %.
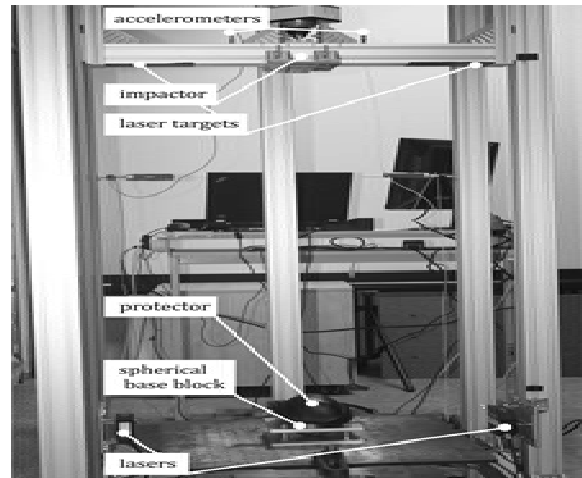
Fig. 10. Drop tower

II. Results and Discussion

The ideal protector would have these properties:

- Low density, as personal protective equipment should be as light as possible (de Rome L, 2006).
- Providing low maximum deceleration during an impact. Maximum forces according to level 1 resp. level 2 of EN 1621-1 (2012) are 35 kN resp. 20 kN. These forces approximately correspond to the measured decelerations of 400 g resp. 700 g.
- Providing distance between human body and an impactor. This means that the distance between the impactor and the base block (minimum displacement u) should be high because it is the opposite of the protector compression.
- Above properties should not be changed when the impact is repeated.

Fig. 11 shows the maximum decelerations a during the impact tests. Circles and squares represent values from the first and second impacts (from both accelerometers), respectively. It is obvious that the deceleration in the case of sample 025_L had higher value than 700 g. Therefore, this foam is not suitable for use in the protector. Interestingly, the maximum deceleration from the first impact on the sample 025_L was higher than from the second impact, after the first drop rebound (see Fig. 12 and Fig. 13, where records from one laser and one accelerometer are shown).
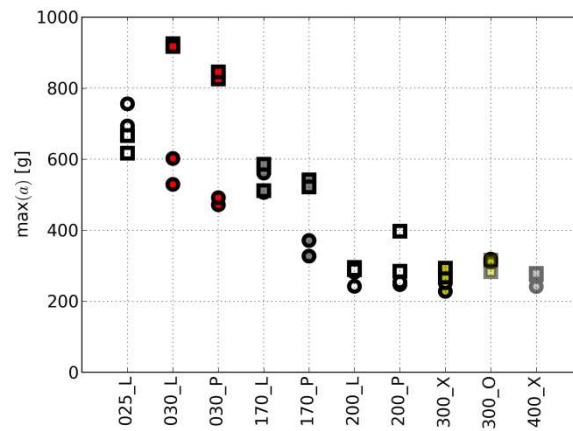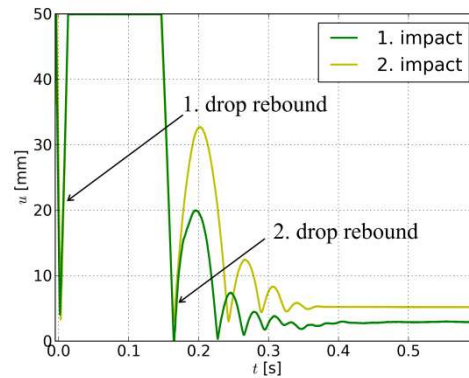
Fig. 11. Maximum decelerations

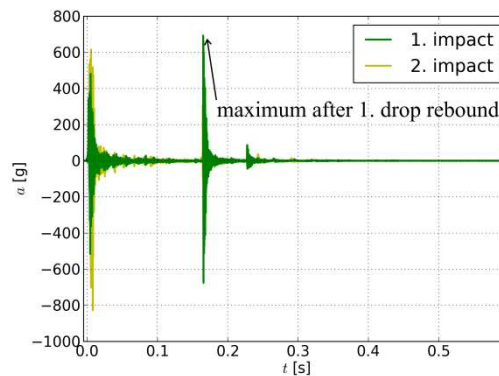**Fig. 12.** Impactor displacement vs. time in case of 025_L

Fig. 13. Impactor deceleration vs. time in case of 025_L

The decelerations of lower than 400 g in both impacts provided the protectors consisting of foams with the density higher than 170 kg·m^3 (Fig. 11).

The minimum displacement of the impactor u is shown in Fig. 14. Similar to Fig. 11, circles and squares represent values from the first and second impacts (from both

lasers), respectively. Also with respect to the displacement u, sample 025_L is not suitable for use in the protector because the distance between the impactor head and the base block was almost zero (after the first drop rebound during the first impact, see Fig. 12). This inappropriate behaviour is also apparent in the sample 030_P (during the second impact). The highest values of the minimum displacement u for both impacts were measured in the case of sample 200_L.
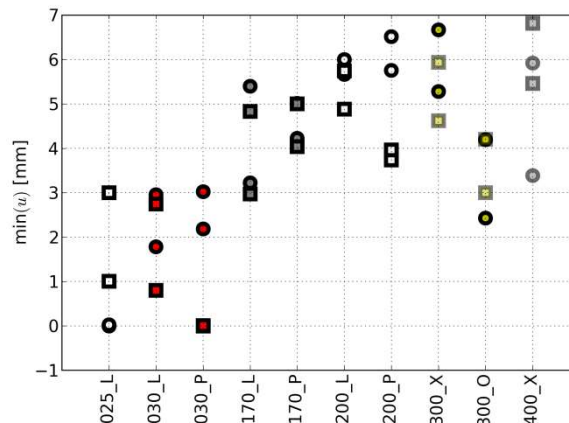

Fig. 14. Minimum displacement of impactor

The present design of the protector consists of the foam 170 with the layer of the leather (sample 170_L). As is obvious from Fig. 11, the foam 170 with the layer of the paper (sample 170_P) resulted in decrease of the maximal deceleration. In the first impact, the maximum deceleration was even less than 400 g, which is important to meet the level 2 of the standard EN 1621-1 (2012).

Since the foams with the density higher than 200 kg·m^3 did not provide another significant reduction of the maximum deceleration a and the highest minimum displacement u was measured in the case of sample 200_L, the foam 200 together with the leather as the third layer can be recommended to use in the protectors. The displacement and deceleration of the impactor in time in the case of sample 200_L are shown in Fig. 15 and Fig. 16. The displacement and deceleration curves of other selected samples are listed in Appendix (Fig. 17 - Fig. 24). Records from only one laser and one accelerometer were used in these curves.

III.   Conclusion

The foam with the density of 200 kg·m^3 is recommended as the second layer of the shoulder protector. The leather is recommended to be used as the third layer between the foam 200 and the plastic shell of the protector. Such protector should meet the safer level of the standard for the production of limb protectors and should not significantly change its properties when impacts with a similar energy as in this work are repeated.

If the present foam 170 had to be preserved, it would be better to use paper as the third layer.
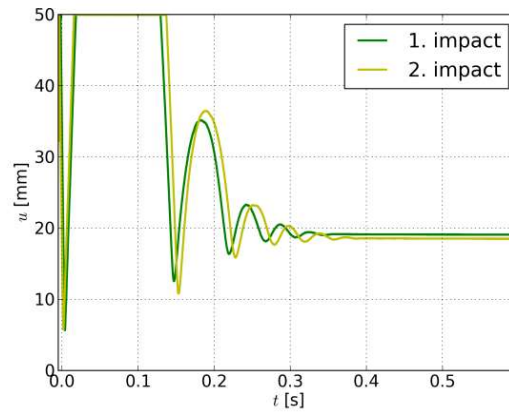
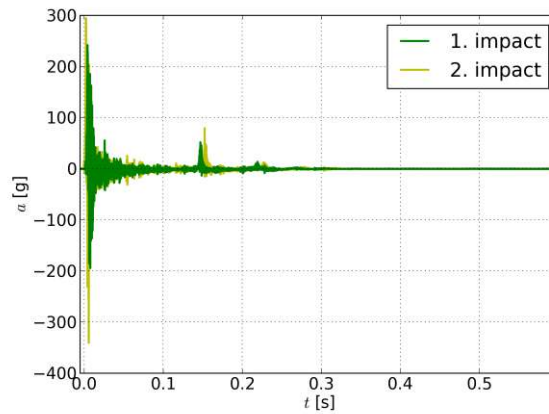**Fig. 15.** Impactor displacement vs. time in case of 200_L

Fig. 16. Impactor deceleration vs. time in case of 200_L
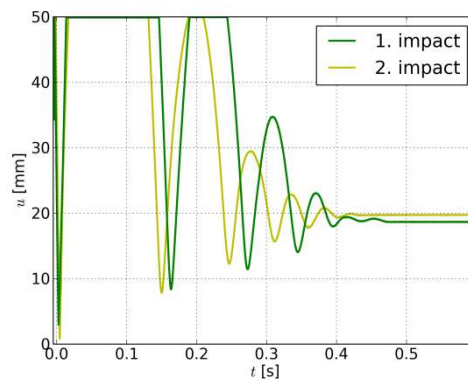
Appendix

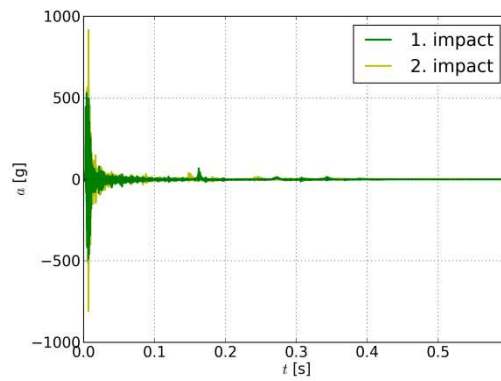**Fig. 17.** Impactor displacement vs. time in case of 30_L

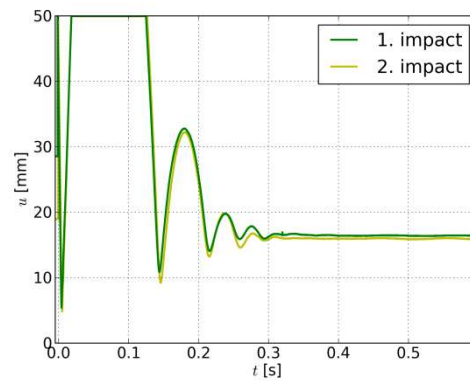**Fig. 18.** Impactor deceleration vs. time in case of 30_L

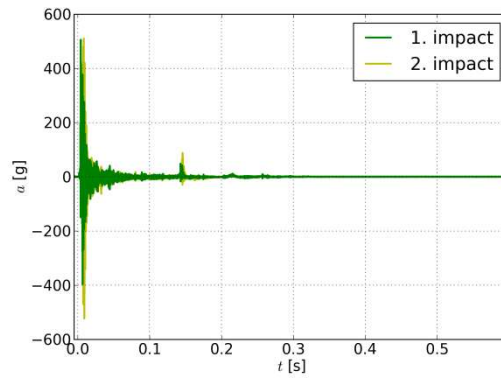**Fig. 19.** Impactor displacement vs. time in case of 170_L

Fig. 20. Impactor deceleration vs. time in case of 170_L
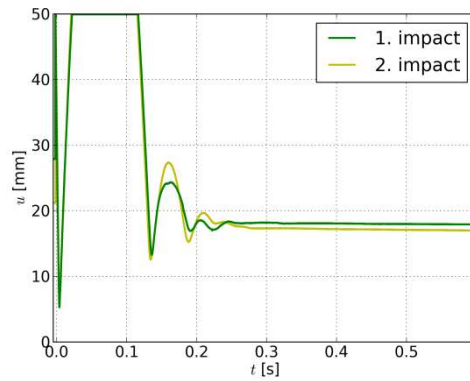
Fig. 21. Impactor displacement vs. time in case of 300_X
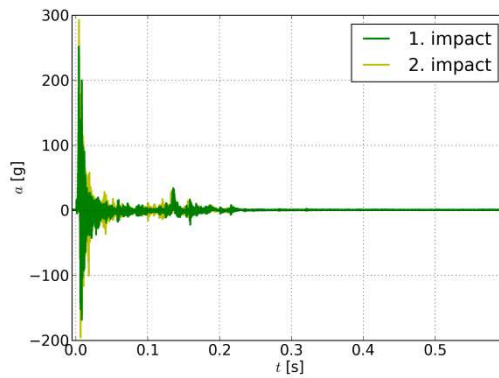

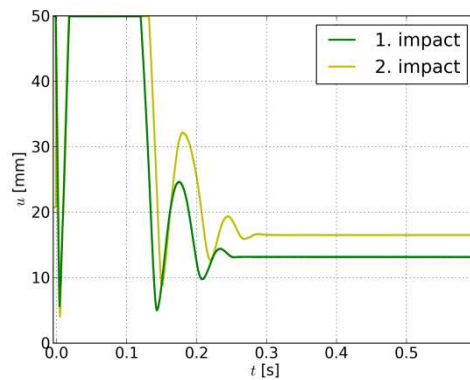**Fig. 22.** Impactor deceleration vs. time in case of 300_X

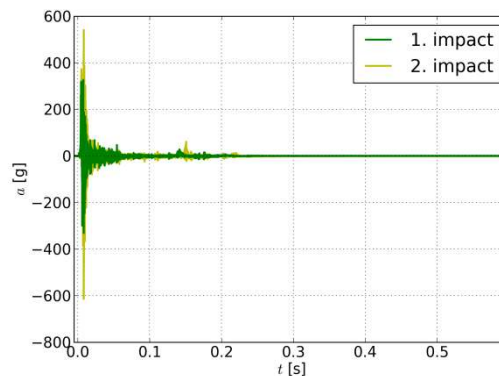**Fig. 23.** Impactor displacement vs. time in case of 170_P

Fig. 24. Impactor deceleration vs. time in case of 170_P

IV. Acknowledgment

References

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