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Improvement of impact protection by KORDCARBON-CPREG-200-T-3K-EP1-4-A composite

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ABSTRACT

This work focuses on the improvement of the impact protection of a motorcyclist protective equipment under the influence of higher temperature. A created composite shell was added to a foam shoulder protector SAS-TEC SCL-2. A drop test was carried out for protector itself and protector including the composite shell. Both, the foam protector and the combined foam/composite protector, were exposed to the three different temperatures, namely 22, 40, and 50 °C, for one hour prior the experiment.

Selection and peer-review under responsibility of the scientific committee of the 36th Danubia Adria Symposium on Advances in Experimental Mechanics.

1. Introduction

Impact protection is an important task in many modes of transport. One of the particularly endangered group are motorcyclists. The absence of a vehicle construction, which serves as the main energy absorber, cause the necessity to supplement the impact protection in other way, namely by using personal protective equipment. This equipment generally consist of a helmet, joint protectors, and a back protector. Many designs of each type of the equipment are nowadays on the market, they differ in their shape, colour, and material. Although it can be the appearance of the protector that attracts customers at first, the material has the key influence on the transmitted force.

A variety of materials is suitable for protective equipment. E.g. composites are good energy absorbers, whether used as a part of a vehicle [1,2] or part of a human body protector [3]. Composites are usually supplemented with foam padding.

Expanded polypropylene and expanded polystyrene are foams often used in motorcycle helmets (such as [4]). Viscoelastic foams are often used to protect motorcyclists' shoulders, elbows, and knees.

The protectors are tested before their marketing. There are two European standards covering motorcyclists' protective clothing against mechanical impact: EN1621-1 and EN1621-2. Since testing at temperature of 40 °C is not obligatory according these standards, the producers usually test their foam protectors only at 23 ± 2 °C. However, it was found out that the foams significantly lower their stiffness in dependency on the rising temperature, which has distinctive influence on its maximum compression and transmitted force during an impact [5].

This work is focused on the improvement of the impact protection of a foam absorber when temperature is higher than 23 °C. The improvement using a composite shell consisting of carbon fibres and epoxy resin was investigated.

2. Materials

As previously mentioned, variety of materials can be used for the protective equipment. For this work, visco-elastic foam protector SAS-TEC SCL-2 having the density of 300 kg/m^3 was selected. This foam protector is commercially available and was recommended for testing by a distributor of motorcyclists' clothing [6]. Since testing according EN1621-1 at higher temperatures than 23 °C is not obligatory, the producer of SAS-TEC SCL-2 claims that the protectors are not destroyed by an impact and can still be used [7]. The characterization of the foam was the subject of previous

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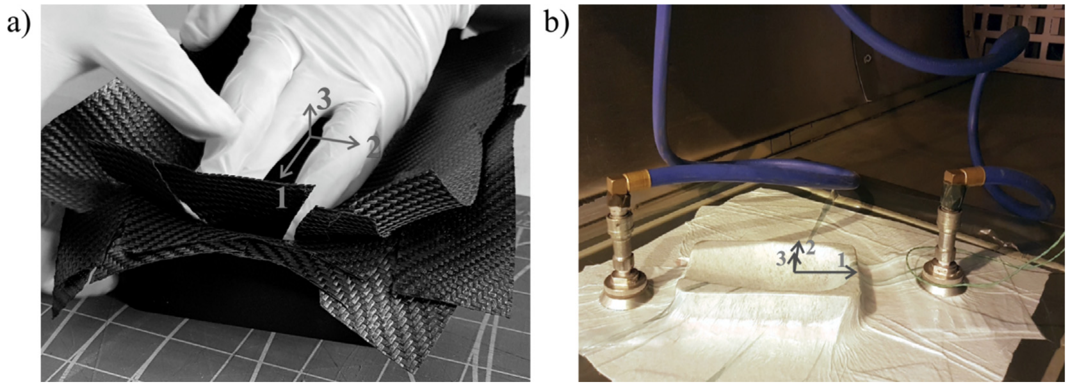

Fig. 1. (a) Shell creation from prepreg, [0/45/0/0] lay-up; (b) composite shell in autoclave.

work [8], where the parameters of the Low-density foam material model were identified.

The composite shell was made of 4 layers of KORDCARBON-CPREG-200-T-3K-EP1-42-A prepreg [9]. This prepreg consists of carbon fibres with a diameter of 7 μm and solvent free epoxy based resin. Specific weight of dry fabric is 205 g/m^2 and the fabric weave of the prepreg is twill 2/2. The mechanical properties of the composite were identified in [10] based on tests in tension, compression and bending.

The first, third and fourth layer (counted from the interface between the foam and the shell) had an orientation of 0° with respect to direction 1 in Fig. 1, the second layer had the fibres rotated by 45°. The proper shape was ensured by the 3D printed negative mould. The ASC autoclave was used in the curing process (Fig. 1b). The thickness of the cured shell was 1.2 mm. The composite shell was attached to the outside of the foam protector SAS-TEC SCL-2.

3. Methodology

The foam protector SAS-TEC SCL-2, which meets protection level 2 of EN1621-1 [7], was investigated. Protection level 2 means that the maximum transmitted force F in the drop test must be less than 20 kN when the central area of the protector is tested. The thickness of the central area was 11 mm.

Both the foam protector without the composite shell and the foam protector including the composite shell were subjected to a drop test (Fig. 2) to demonstrate the benefit of the composite shell. The impactor and the anvil corresponded to EN1621-1. The weight of the impactor with a flat steel head was 5 kg and was dropped from the height of 1 m. The diameter of the spherical anvil was 100 mm, also corresponding to EN1621-1 standard. The transmitted force F was measured by the force cell KISTLER 9351B. The impactor displacement u was measured using Micro-Epsilon optoNCDT 2300-50 lasers. The impactor deceleration a was measured by the accelerometer KISTLER 8742A5. The sampling frequency was set to 26 kHz to capture peak values of the force and the deceleration.

4. Results

Obtained data are displayed on Figs. 3–5.

Fig. 3 shows the data measured by the accelerometer. Higher peaks are notable in the part b), data for the protector with the composites shell, in case of the secondary impactor landings for temperature 22 °C and 40 °C. This was caused by protector falling from the anvil after the first impactor landing (the impactor collided directly with the anvil). This part of the data was excluded

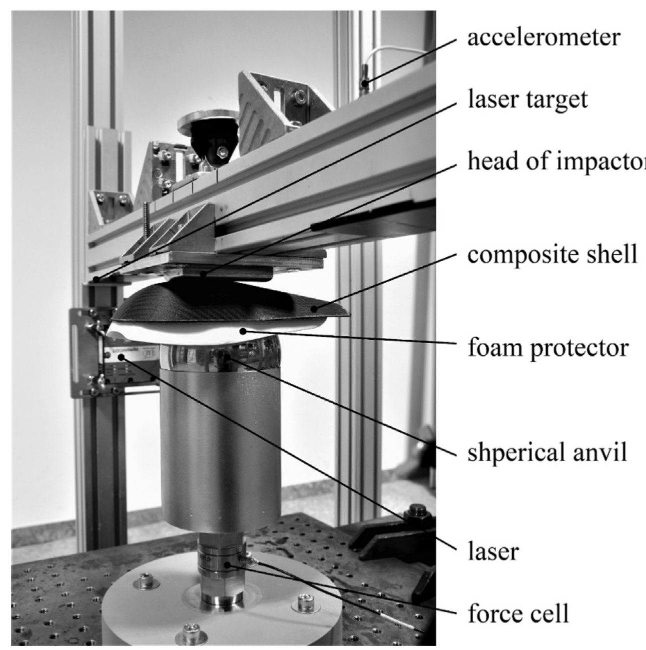

Fig. 2. Foam protector with composite shell in drop tower.

from further work. Generally, the maximum deceleration values increased with temperature of the protector. Maximum values were comparable for both protectors in case of 22 °C and 40 °C, however, the maximum deceleration for 50 °C was higher for the protector with composite shell. This was caused by the larger swing of the impactor during the first landing, which affected the off-axially placed accelerometer.

Fig. 4 shows the impactor displacement. The measuring range of the lasers is limited to 50 mm above the anvil. Therefore, the displacement obtained after the impactor overcome this height during a jump did not display the real impactor trajectory and was excluded from further work.

Fig. 5 shows the comparison of the transmitted forces in the impact test and Fig. 6 shows maximum transmitted forces. It is obvious that the values are smaller when the combined foam/composite protector was tested. Moreover, when the protector was tested without the shell, the increase in temperature-induced force was more significant. The positive effect of the composite shell (reducing the maximum transmitted force) was caused by more uniform distribution of the impact force into the foam protector. When the protector was tested without the shell at a higher tem-

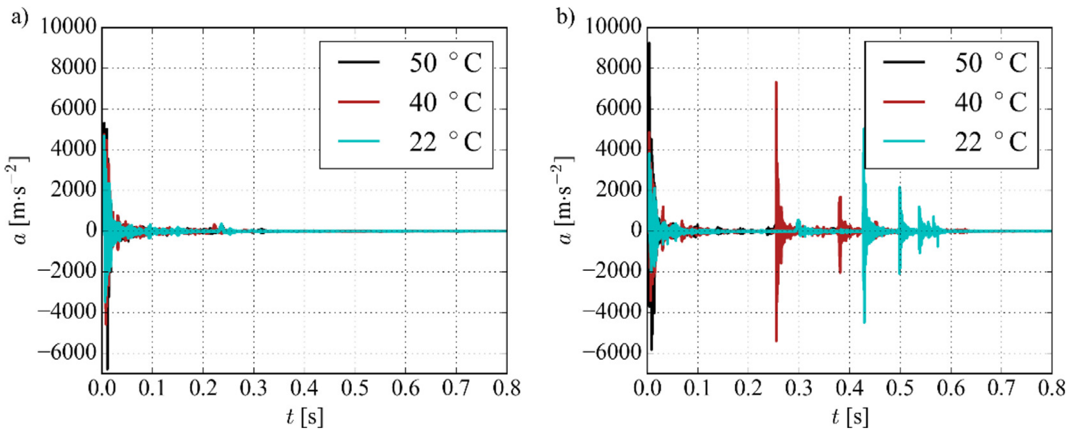

Fig. 3. Acceleration: (a) without shell; (b) with shell.

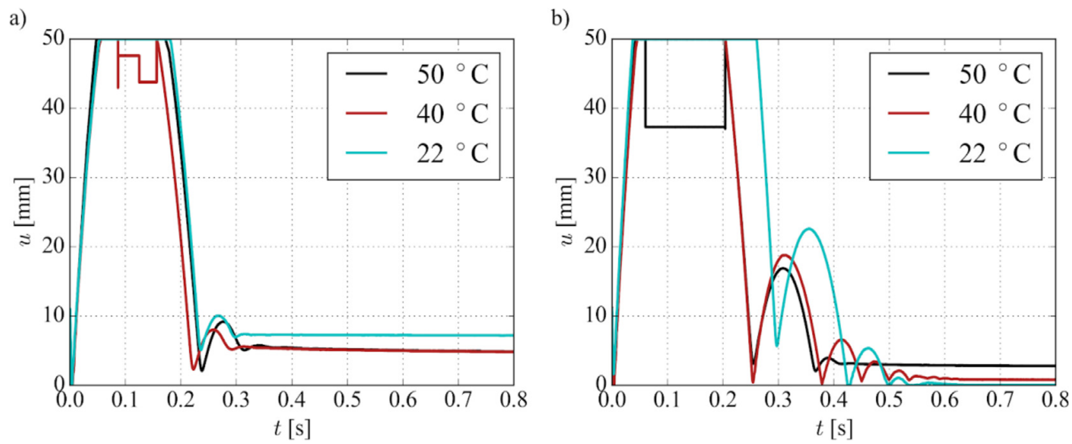

Fig. 4. Displacement: (a) without shell; (b) with shell.

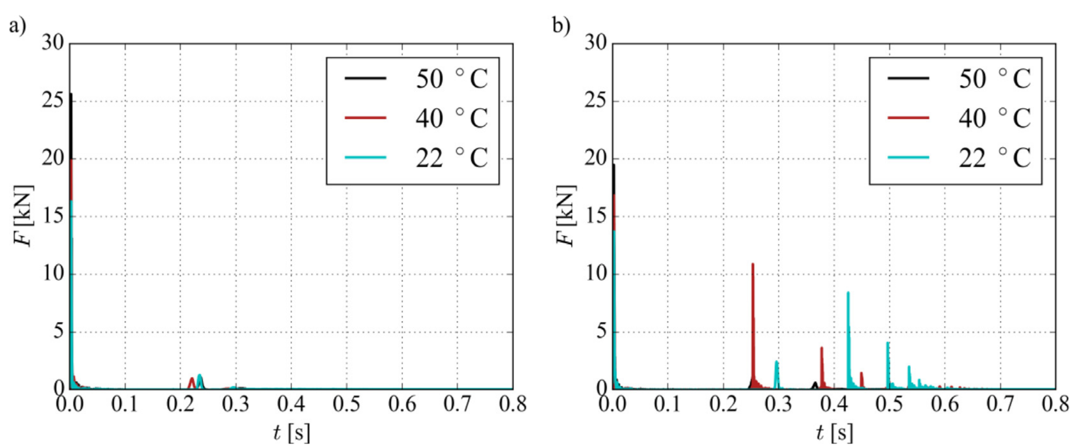

Fig. 5. Force: (a) without shell; (b) with shell.

perature, a foam failure occurred (a visible hole at the point of contact with the top of the spherical anvil, see Fig. 7).

5. Conclusions

The addition of the KORDCARBON-CPREG-200-T-3K-EP1-42-A composite shell has a positive effect on the mechanical response of the protector SAS-TEC SCL-2. The maximum transmitted forces are significantly reduced, especially in case of higher temperatures, 40 and 50 °C. Moreover, the maximum forces transmitted by the SAS-TEC SCL-2 protector with the composite shell are under 20 kN for all tested temperatures, which is the threshold value of the level 2 requirements of the EN1621-1 standard. The shell distributes the force during the impact, which prevents the failure of the foam protector. Experimental data will be further used for

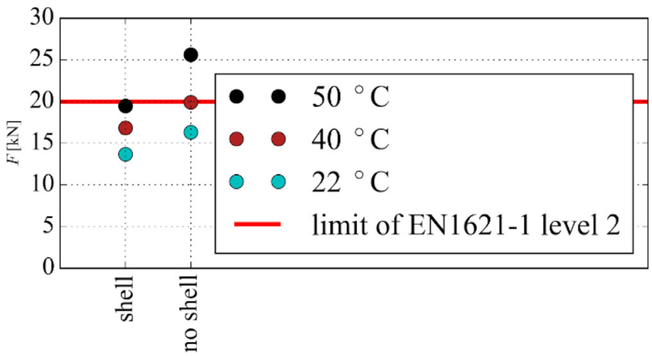

Fig. 6. Maximum transmitted forces.

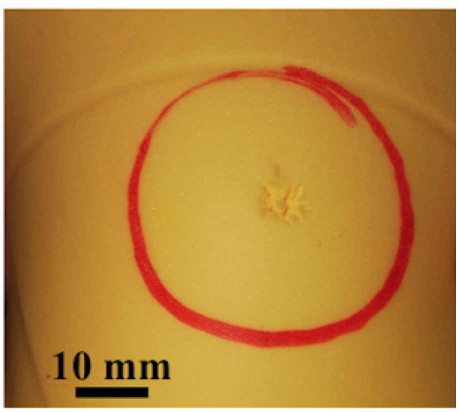

Fig. 7. Foam failure.

the validation of the numerical models of investigated foam and composite.

CRediT authorship contribution statement

Radek Kottner: Conceptualization, Methodology, Validation, Writing - review & editing. **Sandra Kaňáková:** Software, Investigation, Data curation, Writing - original draft. **Tomasz Bońkowski:** Investigation, Methodology. **Ronaldo Yeung:** Resources, Methodology. **André Pukaro:** Resources, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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