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Influence of temperature on foam used in motorcycle protective equipment

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Abstract. This paper researches influence of the temperature on a foam, which is used in motorcycle protective equipment. The impact test was carried out on samples, which were cut from the center part of the protector that is suitable to protect shoulder, elbow and knee areas. Its main goal was to demonstrate an effect of three different temperatures, 22, 40, and 50 °C, on the foam. Six impacts, with impact velocities 1, 2, 3, 4, 5, and 6 $m \cdot s^{-1}$, were realized for each temperature. Surfaces of the impactor and the anvil were flat. The weight of the impactor was 5.25 kg. Obtained data were evaluated and subsequently can be used for a material model identification.

Introduction

Nowadays is a common matter to create simulations of the test of a protective equipment as shown in [1]. This trend is beneficial for both financial and time aspect of a protector designing process. However, it requires many experiments to acquire truly eligible material model, which can be used for these simulations. This is due to a lot of aspects affecting the real material behavior such as type of loading, loading velocity and temperature. It is the temperature that has potential to significantly affect mechanical behavior of an energy absorbing foam. Unfortunately, temperature changes are common matter during motorcycle sport.

This work follows previous research [2] and demonstrate the behavior of the energy absorbing foam in the course of both different impact velocity and different temperature. The tested foam SAS-TEC SCL-2 is commonly used in motorcyclist' protective equipment, for instance to protect shoulder, elbow and knee areas [3]. Used samples were cut from the central part of the protectors.

The aim was to determine temperature dependency of the force and the deformation responses during the impact test of the foam.

Obtained data can serve for comparison with different type of dumping material or for the material model identification. Thus obtained model will be coupled with the model of the leather [4] and together will complete model of the motorcyclist garment. Finally, this garment will be added to the model of a human body and used for motorcycle accident simulations, such as [5].

Experiment

The impact test was chosen as the best experiment to capture influence of the temperature on the foam. This experiment was selected mainly because its accuracy to the real accident situation.

The impact test was carried out in a drop tower designed and constructed by the authors. The weight of the impactor with a flat steel head was 5.25 kg. The reaction force was measured by the force cell KISTLER 9351B under a flat anvil (see Fig. 1). The impactor displacement was measured using two Micro-Epsilon optoNCDT 2300-50 lasers on the both sides of the impactor cross beam. The impactor deceleration was measured by the accelerometer KISTLER 8742A5. The sampling frequency was 26 kHz.

The experiment was carried out for six impact velocities: 1, 2, 3, 4, 5, and 6 m·s^{-1}. The impactor releasing height was determined as

$$h_v = \frac{v^2}{2 \cdot g} + l_v \, , \qquad (1)$$

where v is the impact velocity, g is the gravitational acceleration equal to 9. 81 m·s^{-2} and l_v is the sample height.

The test was conducted under three different temperatures. Namely 22, 40, and 50 °C. The samples were subjected to the particular temperature for one hour prior to the experiment. Each sample was used repeatedly at identical impact velocity (6 samples were used). Samples relaxed at least 24 hours between tests of different temperature (firstly, samples were tested at 22 °C, followed by 40 and 50 °C).

The rectangular samples were cut from the center part of the shoulder protector. The sample blocks had 80 mm per 80 mm base and their thickness was 11 mm. Their weight was 18 g.

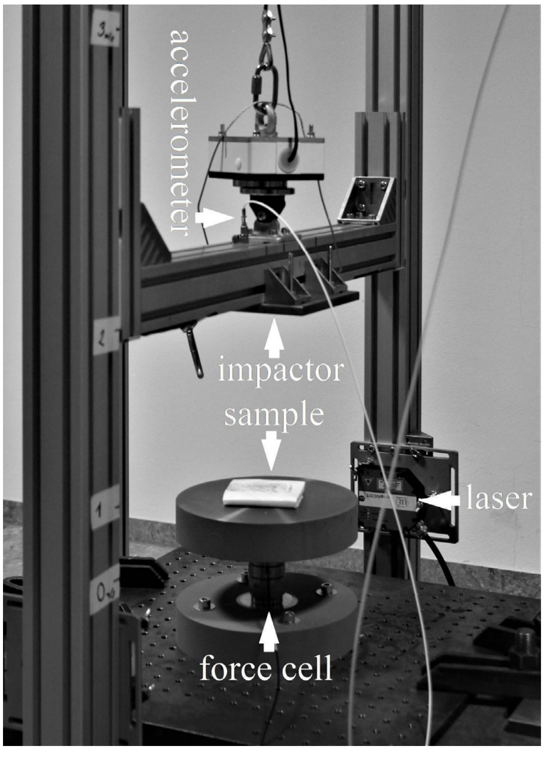

Fig. 1: Drop tower with the foam sample

Results

Obtained data are displayed in three graphs on Fig. 2 – 7. The first graph shows impactor displacement *u* (*u* = 0 represents contact of the impactor head and the anvil). Used lasers were able to register maximum 50 mm displacement. Moment, when the impactor is registered by the lasers, is *t* = 0. The second graph displays the reaction force *F*. The third graph displays impactor deceleration.

Impactor jumps are notable on Fig. 2 – 7. When the displacement *u* during the impactor jumps exceed 50 mm (the displacement graphs have staircase character), obtained data are evidently incorrect. In Fig. 7, the second landing in case of the temperature of 50 °C, the sample jump out of the center of the anvil and caused the impactor to collide directly with the anvil. Therefore, the measured data related to the second impactor landing were excluded from further evaluation.

Results summaries are displayed in Fig. 8 and Fig. 9. Fig. 8 shows maximum compressive deformations of the sample for six impact velocities in dependency on its temperature. It is obvious that the maximum deformation values increase with temperature increasing. The impactor and the anvil contact is notable in case of the impact velocity 6 $m \cdot s^{-1}$, were deformation equals 1. This collapse is given by the low stiffness of the foam caused by the temperature of 50 °C.

Fig. 9 shows maximum forces for six impact velocities in dependency on the sample temperature. The displayed values are determined in two ways, directly by the force cell (F in legend), indirectly as a multiple of impactor weight and maximum deceleration (A in legend). The forces show similar progressive character for increasing velocity for both ways of determination, however, there is also an increasing deviation between values of both forms of the determination. Forces from the force cell were used as the key results for future work.

As for result itself, it was already mentioned, higher temperature results in lower stiffness of the foam. Therefore, the maximum force decreased with increasing temperature in case the impact velocity was lower than 4 $m \cdot s^{-1}$. In the case of higher impact velocities than 4 $m \cdot s^{-1}$, the samples at 50 °C were compressed so much that maximum forces were higher than those tested at 22 °C.

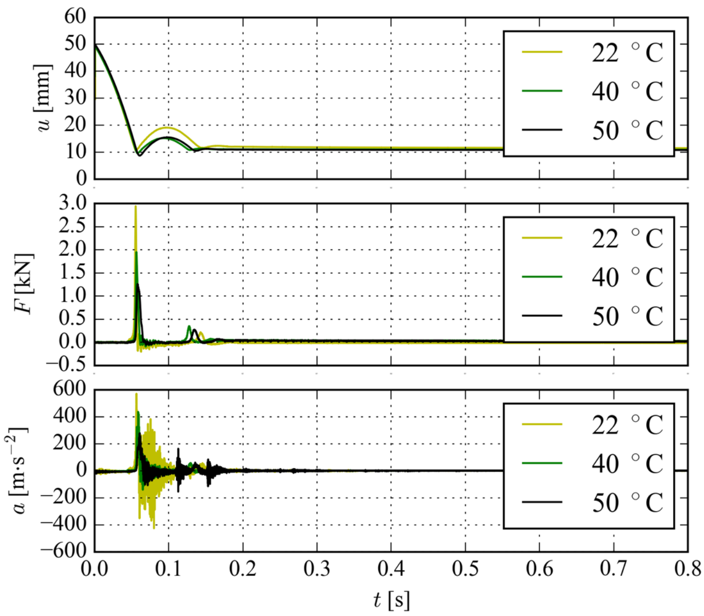

Fig. 2: Data from impact - 1 $m \cdot s^{-1}$

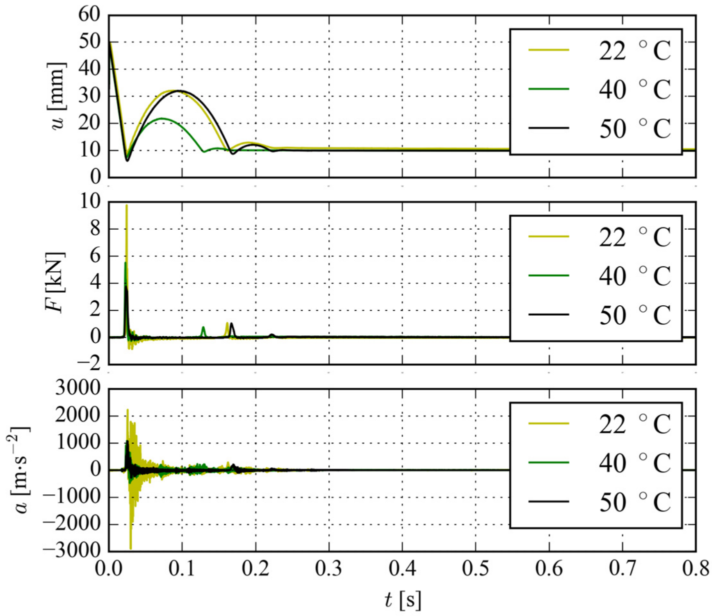

Fig. 3: Data from impact - 2 m·s^{-1}

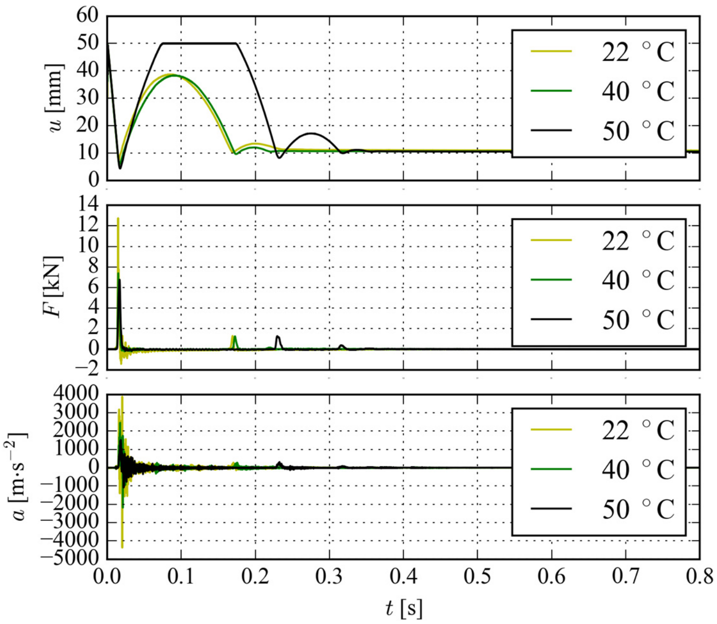

Fig. 4: Data from impact - 3 m·s^{-1}

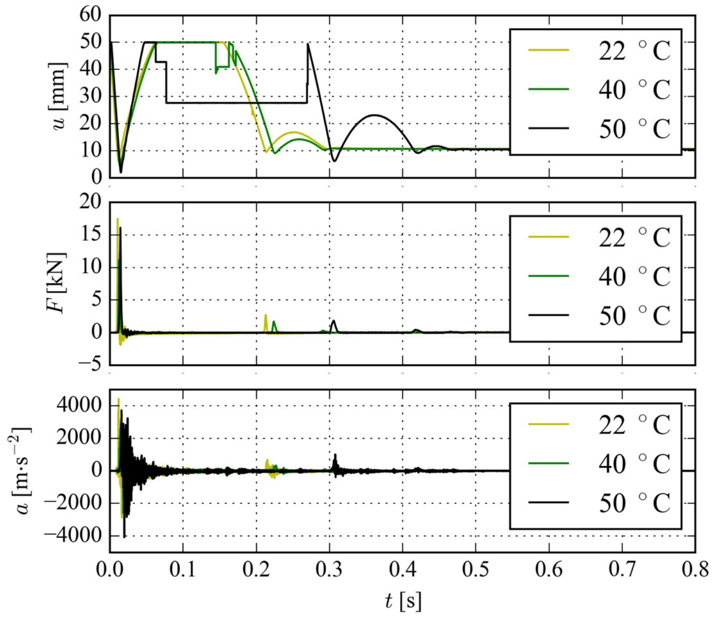

Fig. 5: Data from impact - 4 m·s^{-1}

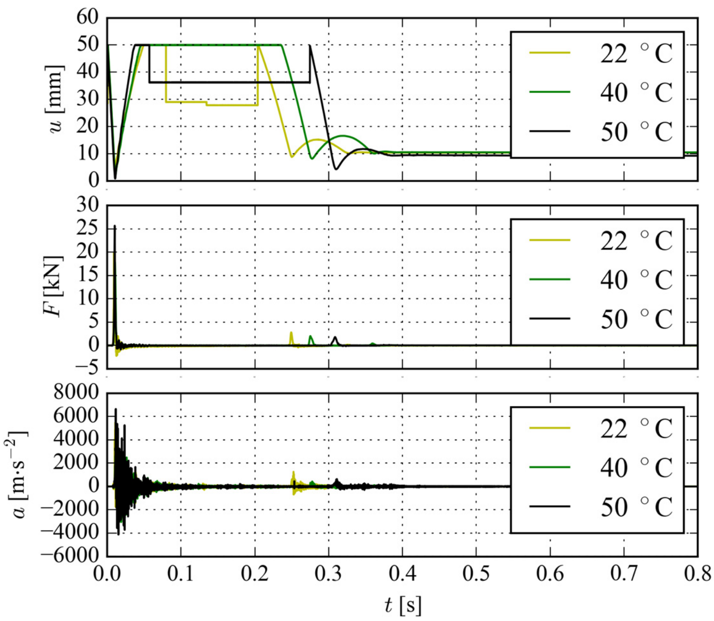

Fig. 6: Data from impact - 5 m·s^{-1}

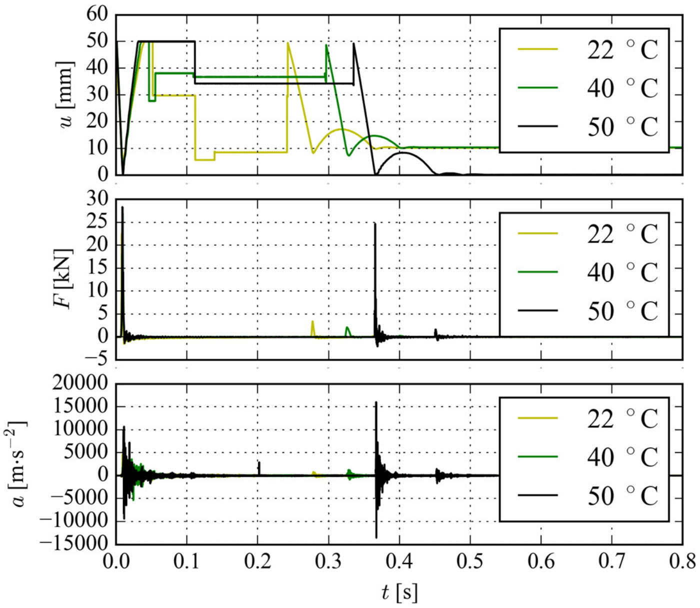

Fig. 7: Data from impact - 6 m·s^{-1}

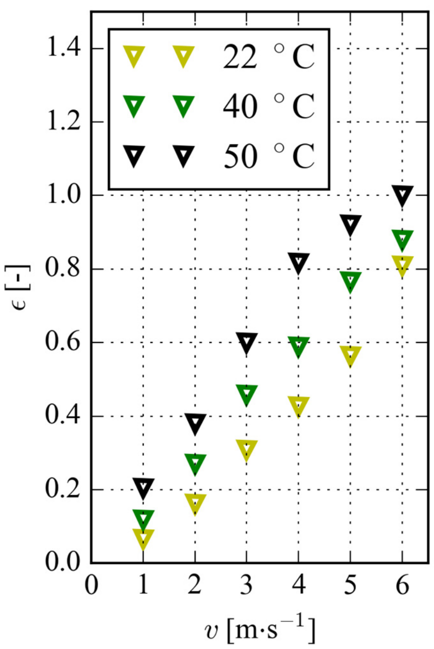

Fig. 8: Maximum compressive deformations

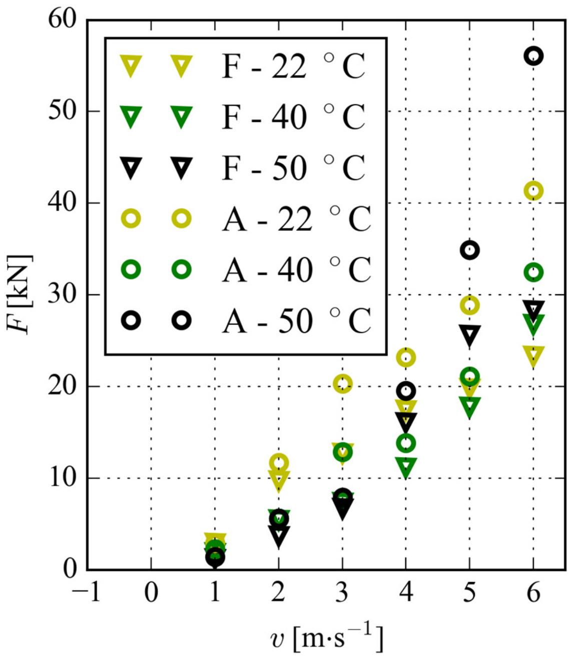

Fig. 9: Maximum forces

Conclusions

The foam significantly lowers its stiffness in dependency on the rising temperature, which has distinctive influence on its maximum compression and transmitted force. It is the maximum transmitted force that is the key value in the standard tests, and places the protective equipment in respective category, grading its quality.

The investigated experimental data serves as a target for the material model identification of the foam. In the future, a similar experiment will be carry out also with a spherical anvil. The concentration of the impact force and the significantly lower stiffness of the foam, caused by the temperature, could present serious problems in the protection of motorcyclists because both aspects are common matter in real accidents.

Acknowledgement

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