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Investigation of Mechanical Behaviour of Commercially Available Polymeric Materials and their Suitability as Impact Absorber

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Abstract. A drop test was carried out to investigate mechanical behaviour of commercially available polymeric materials, namely expanded foams, polyurethane elastomers and urethane plastic. The Shore A hardness of presented material was verified. Moreover, the influence of the impact from higher position was investigated. Selected materials were further exposed to the higher temperatures 40 and 50 °C and subsequently tested. The obtained data were evaluated, promising damping material for use in personal protective equipment was selected.

Introduction

The variety of materials used in the industry nowadays is immense. Metals are gradually substituted by other types of plastic-like materials e.g. polyurethanes, polypropylenes, and silicones [1]. Unfortunately, the mechanical behaviour of many of these plastics is not sufficiently described. Therefore, their potential is not fully utilized.

One particularly problematic aspect of such materials is the influence of the temperature. A change of few degrees Celsius can significantly change mechanical behavior. This creates essential problem for personal protective equipment as shown in [2]. In the cited paper, the presented issue is overcomed by an additional composite layer.

This works deals with the comparison of different types of polymeric materials as a material suitable for impact-damping components. Obtained data will serve for the identification of selected material model parameters. Furthermore, the selected material will be used for the improvement of personal protective equipment as shown in [3].

Experiment

A drop test was carried out to evaluate the ability of the material to dampen the force during an impact. Three different types of materials were used, expanding foams (FF-it 8, FF-it 10, FF-it 14, and FF-it 25), polyurethane elastomers (CF 50, VF 60, PMC 770) and solid urethane plastic (T 13a14). Samples were approximately 10 mm high and had 55 mm in diameter. All presented materials were commercially available in form of two-component suspensions and the creation process of the final samples followed the distributor instruction.

According to the distributor, the last two digits in the label of the foams and elastomers refer to their hardness on the Shore A scale. This fact was verified using Wolpert Wilson Durometer (see Fig. 1a). Obtained data are shown in table 1. The Shore A value for the plastic T 13a14 was also measured. Values were obtained from five points on the sample, one centre point and four points around the diameter. The scheme of these points is displayed in Fig. 1b. Measured values correspond to the material labels. The biggest difference was in the case of PMC 770, all measured points gave lesser value than 70. The average Shore A values equal or slightly exceeded material label values. The difference could be caused by the material production process, when the presented materials are developed by a chemical reaction between two different types of components. The samples were produced by the distributor.

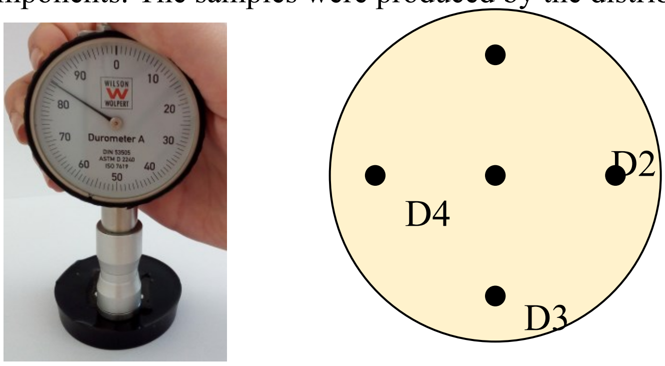

Fig. 1: a) Verification of Shore A value, b) measured positions

Table 1: Shore A values

Sample	Shore A values					
	C	D1	D2	D3	D4	Average
FF-it 8	8	9	11	9	9	9
FF-it 10	12	13	14	13	12	13
FF-it 14	15	14	15	14	14	14
FF-it 25	24	26	27	26	26	26
CF 50	51	52	52	52	53	52
VF 60	60	61	62	61	62	61
PMC 770	67	67	66	66	66	66
T 13a14	85	84	85	85	85	85

The experiment was divided into two parts. In the first part, cylindrical samples were placed on an anvil with a spherical head. The samples were approximately 1 cm high and their diameter was 5.5 cm. A flat head impactor was released from 25 cm height above the anvil. The impactor weight was 5 kg. The temperature during the experiment was 23 ± 2 °C. The transmitted force was measured using the KISTLER 9351B load cell and the impactor displacement was measured by the two Micro-Epsilon optoNCDT 2300-50 lasers on each side of the impactor crossbeam railing. The aim of this experimental part was to determine the damping ability of the material.

The second part of the experiment focused only on the outstanding materials from the first part. These materials were further investigated, using the described drop test with the higher 50 cm release position of the impactor.

The influence of the higher temperature was also investigated in the second part of the experiment. The best samples were conditioned in the temperatures 40 ± 2 °C and 50 ± 2 °C for one hour prior the drop test. The impactor release height was 25 cm.

Results

Fig. 2 shows maximal transmitted forces F in the first part of the experiment, the drop test from 25 cm and in temperature of 23 ± 2 °C. FF-it 25 transmitted the lowest force from not only the investigated expanding foams but also elastomers and solid urethane. The best polyurethane elastomer was CF 50, transmitting lower force than the two other elastomers with higher hardness. The maximal transmitted forces increase their values with the increasing hardness of the material. The only solid urethane T 13a14 has the worst ability to dampen the force during the impact.

The foam FF-it 25 and polyurethane elastomer CF 50 displayed the best force damping ability, therefore, were selected for further investigation in the second part of the experiment.

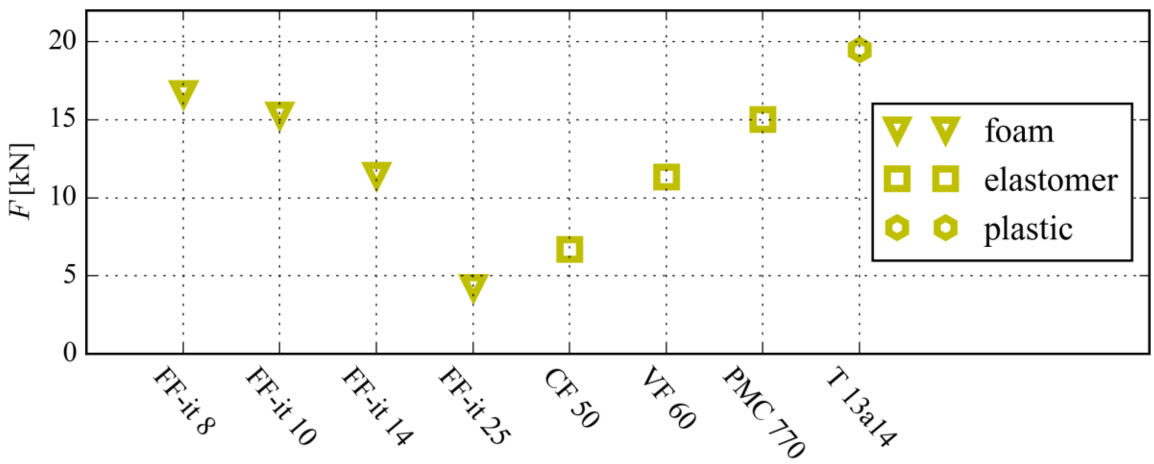

Fig. 2: Maximal transmitted forces

Fig. 3a shows the minimal height u of the sample during the drop test (maximal compression occurred). The 10 mm value equals uncompressed sample, 0 mm equals collision of the impactor head and the anvil. Fig. 3b shows the maximal transmitted forces F. The change of the minimal height and the maximal transmitted force in dependency on the impactor releasing height are similar for both FF-it 25 and CF 50. The maximal force transmitted by FF-it 25 is lower than the maximal transmitted force by CF 50. The increase of the height may cause ultimate compression of the sample and direct contact between anvil and impactor.

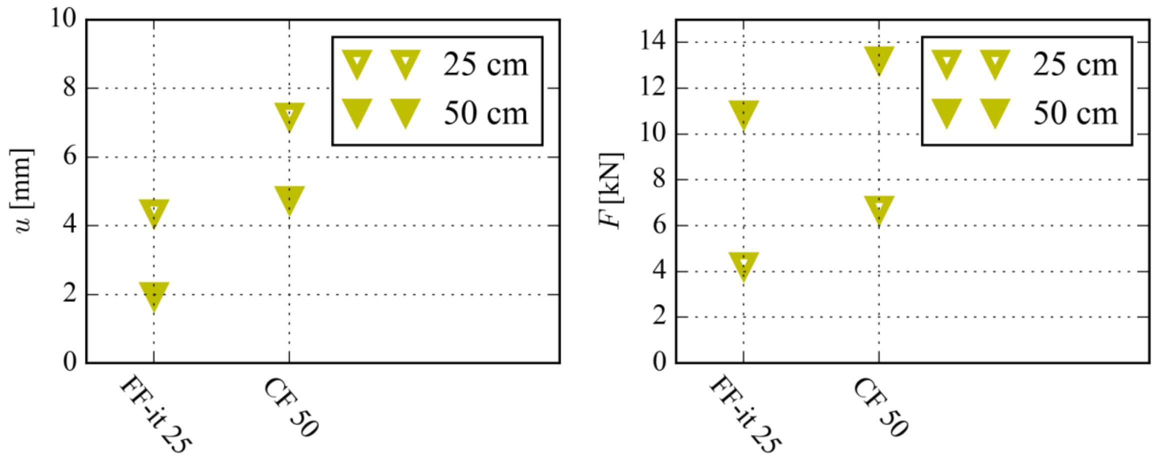

Fig. 3: a) Minimal height of the sample during the drop test, b) maximal transmitted force

Fig. 4a shows the influence of the temperature on the minimal sample height u and Fig. 4b shows the influence of the temperature on the maximal transmitted force F. Fig. 5 and 6 show the comparison of the impactor displacement and the transmitted force in time for all tested temperatures.

The sample fell of the spherical anvil after the first landing in case of the FF-it 25 - 40 °C and the CF 50 - 50 °C drop test, therefore, the impactor collided directly with the anvil, thus obtained data after the first anvil landing were excluded from further work.

The increase of the temperature had negative influence on the mechanical behaviour of the investigated materials. The samples exposed to higher temperature were more compressed during the drop test and transmitted higher forces. This trend is more evident in the case of expanding foam FF-it 25. The impact damping ability of both the expanding foam FF-it 25 and the polyurethane elastomer CF 50 was reduced in dependency on the increasing temperature. Therefore, the impactor jumps reached higher positions.

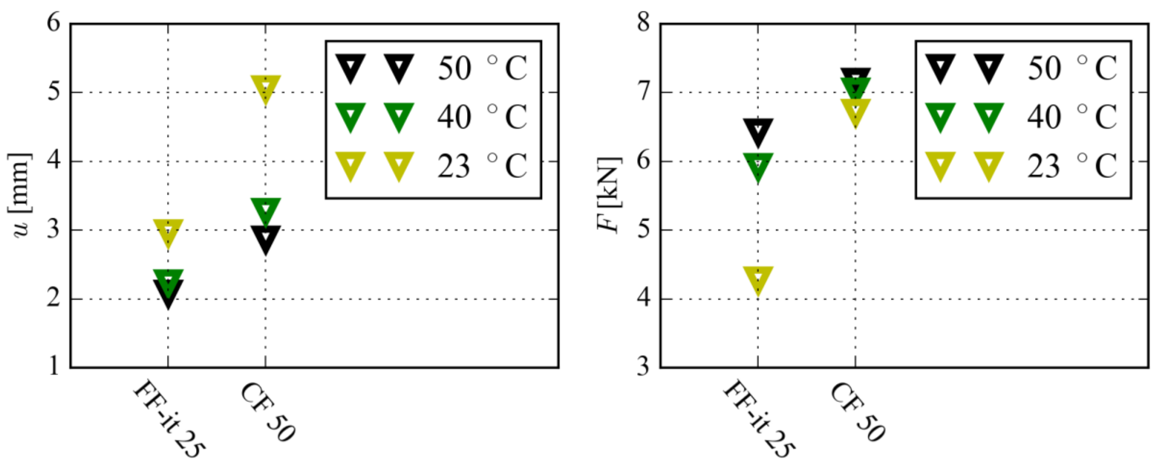

Fig. 4: The temperature influence: a) Minimal height of the sample during the drop test,
b) maximal transmitted force

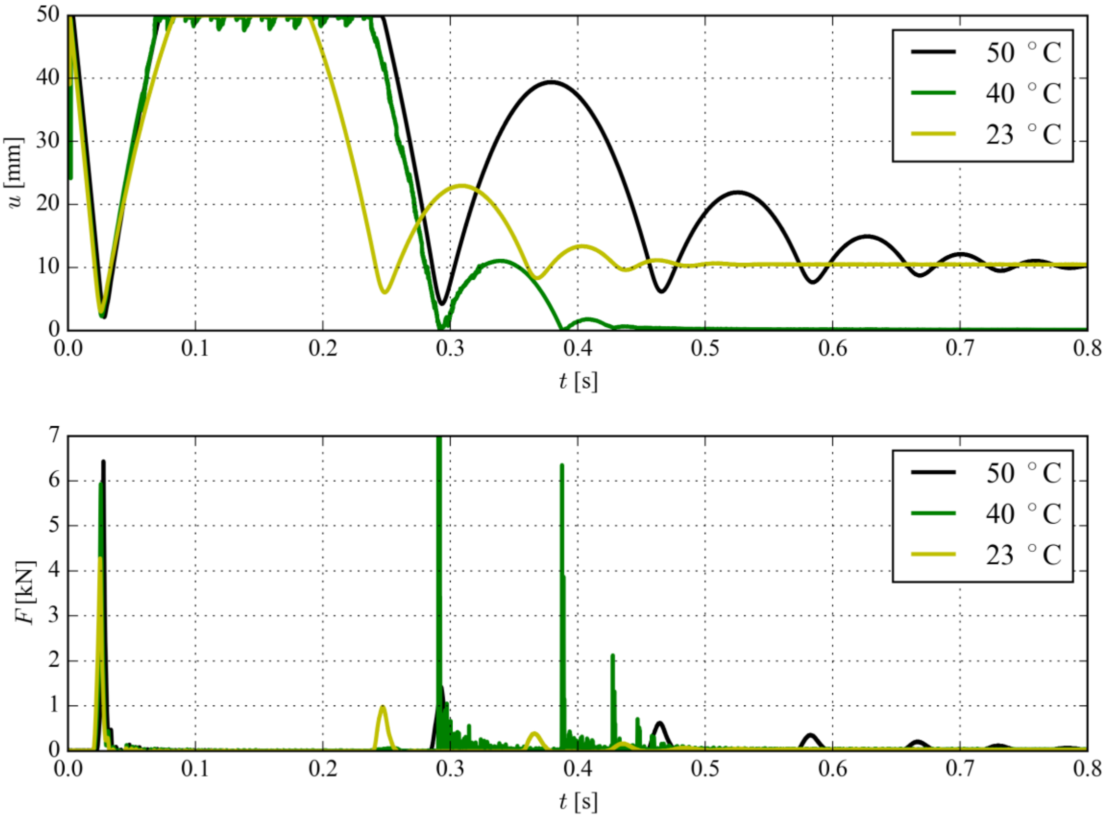

Fig. 5: Temperature influence on FF-it 25

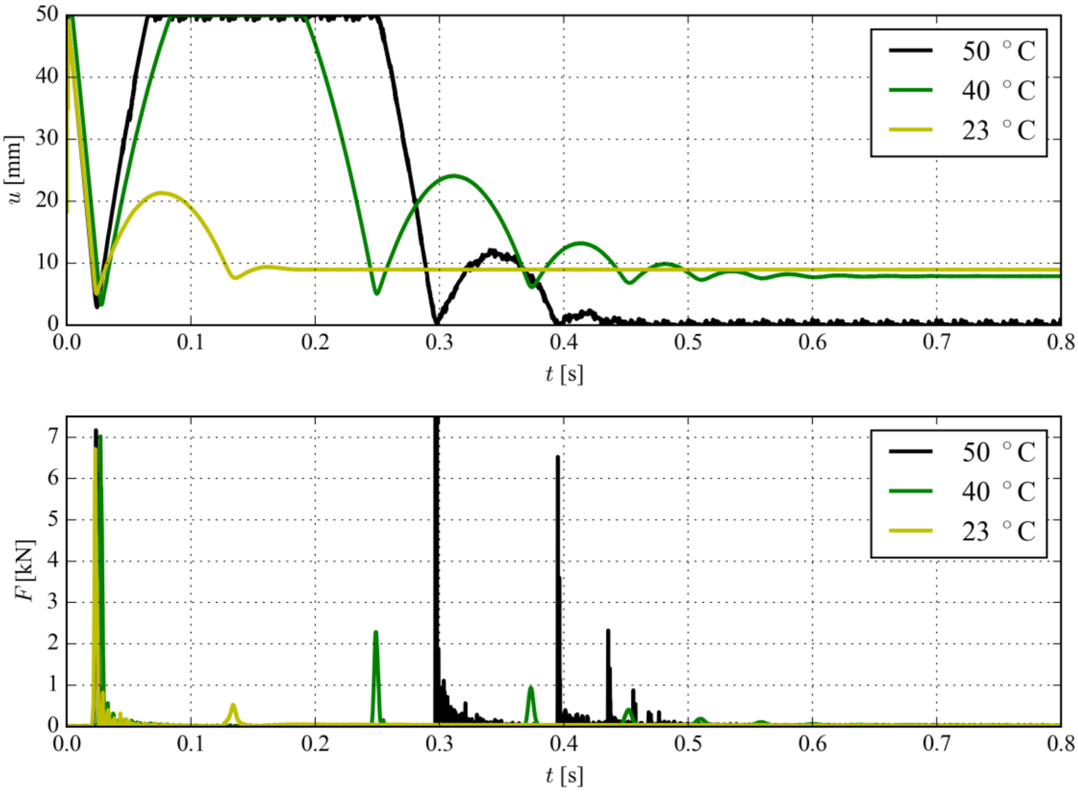

Fig. 6: Temperature influence on CF 50

Conclusions

The hardness specified by the distributor (the label of the materials) corresponded to the Shore A measurements.

The best impact damping ability for 23 °C had the expanded foam FF-it 25. This foam transmitted lower forces for drop test from 25 cm and 50 cm. The CF 50 polyurethane elastomer was better damper than other two elastomers with higher hardness from the Shore A scale. The worst damper was the only solid urethane T 13a14.

The influence of the elevated temperature was negative for FF-it 25. The differences between individual temperatures in case of CF 50 were not significant. Therefore, this material is suitable for an impact damping components, such as motorcycle protectors, where are higher temperatures common matter.

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References

[1] B. Kratochvíl, V. Švorčík, D. Vojtěch. Introduction to study of materials. 1st ed. ISBN 80-7080-568-4. 2005.

[2] R. Kottner, S. Kaňáková, T. Bońkowski, R. Yeung, A. Pukaro Improvement of impact protection by KORDCARBON-CPREG-200-T-3K-EP1- 4-A composite. Materials Today: Proceedings. 10.1016/j.matpr.2020.02.084.

[3] B. J. Ramirez, V. Gupta. Evaluation of novel temperature-stable viscoelastic polyurea foams as helmet liner materials. Materials & Design, Vol. 137, 5 January 2018, pp. 298-304.