Vol. 10, No 2/2021, 15-22

DOI: 10.17512/bozpe.2021.2.02

Construction of optimized energy potential
Budownictwo o zoptymalizowanym potencjale energetycznym

ISSN 2299-8535 e-ISSN 2544-963X

Thermal emissivity of tent fabric and its influence on the thermal insulation of tent walls

Adam Ujma[1] (*orcid id: 0000-0003-2538-0014*)
Jakub Jura[1] (*orcid id: 0000-0001-5331-6808*)
[1] Czestochowa University of Technology

Abstract: The article presents research aimed at determining the thermal properties of tent fabric and, as the final result, the value of the heat transfer coefficient of the thermal protection of a pneumatic tent. It was assumed that the thermal insulation capacity of the tent cover, consisting of two fabric layers separated by an air gap, was determined for two seasons, summer and winter. The tested material had two sides that differed in color, which resulted in obtaining a different value of the thermal emissivity coefficient. The thermal conductivity coefficient of the tent fabric was also measured with the use of a lammeter. The obtained data from the measurements were then used to determine the resistance to heat transfer on the tent surfaces, the thermal resistance of the partition, and finally the value of the heat transfer coefficient.

Keywords: tent fabric, heat resistance, heat transfer coefficient

Please, quote this article as follows:

Ujma A., Jura J., Thermal emissivity of a tent fabric and its influence on the thermal insulation of tent walls, Construction of Optimized Energy Potential (CoOEP), Vol. 10, No 2/2021, 15-22, DOI: 10.17512/bozpe.2021.2.02

Introduction

Tents of various sizes have a simple structure and are quick to set up. They are used in many situations requiring the creation of an effective roof for, usually, short periods of use. They are used all over the world as temporary shelters for the poor, refugees or people affected by natural disasters (Poschl, 2019). They are also used as field hospitals, laboratories, etc. Due to the low thermal insulation of thin tent coatings, the temperature in these specific rooms often does not provide comfortable thermal conditions for their users. The problem is the rapid increase in internal temperature during intense sunlight and a rapid decrease when the external temperature decreases. (Zhang et al., 2017b). This is due to the practically zero thermal capacity of the structure. Conducted research on the modification of the structure of materials (Stegmaier et al., 2018), applying additional layers (Liu et al., 2016), the technology of layers and the construction of external partitions from which tents are made are aimed at improving the conditions of the internal microclimate (Cena et al., 2003). The conducted experiments show that, for example, by applying a reflective layer to the outer layer, the air temperature in the tent is reduced (Lee et al., 2016; Zhang et al., 2017a). The use of reflective insulation in building partitions also significantly improves the thermal insulation of these partitions (Ujma & Umnyakova, 2019). Modification of tent partitions and the use of various thermal insulation layers (Jura, 2015), reduces the cost of heating or cooling rooms, while providing appropriate conditions of thermal comfort for people staying in them (Kysiak & Ujma, 2018). The article presents tests on the thermal properties of tent materials and the external partitions made of them.

1. Research materials

Tests conducted on the tent fabric were carried out in order to determine the value of the heat transfer coefficient of the thermal cover of the pneumatic tent. Such data may be used in the case of planning to use heating or cooling inside the tent, when determining the demand for heating power or cooling power for devices heating or cooling the air in the tent.

The tested tent (Fig. 1) has a pneumatic structure. The load-bearing system is a skeleton structure with a frame made of connected, longitudinal and transverse, inflated sleeves. The lengths of the elements forming the structure arch, starting from the base to the top, are as follows: 1,950 mm – 1,800 mm – 500 mm. The frame is filled with one or two layers of tent fabric. Material weight of approx. 310 g/m^2 and a thickness of 0.30-0.35 mm.

The inside of the tent consists of two zones, one from the entrance to the tent – the vestibule (unheated and not requiring cooling) and the other, depending on external conditions, heated or cooled (Fig. 2). In these two zones, the external partitions are structurally different and therefore have different thermal insulation properties.

In the vestibule zone, only one layer of tent fabric is used, attached to the outside of the pneumatic skeleton. In the heated-cooled zone of the tent, a fabric is attached to the frame on both sides, both from the outer and inner sides of the tent. As a result, the main thermal protection of the tent in the heated and cooled zone is a partition made of one outer fabric layer, 0.30-0.35 mm thick, an air gap of 220 mm and another fabric layer, 0.30-0.35 mm, forming a lining. In the gable wall of the tent, the air layer between the fabrics is 110 mm thick.

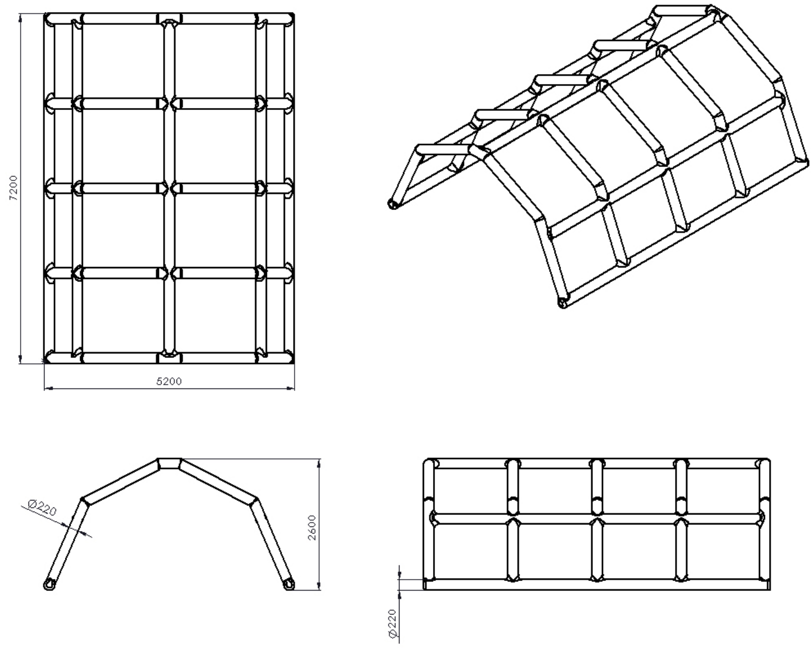

Fig. 1. Structural arrangement with the basic dimensions of the tent (source Lubawa S.A.)

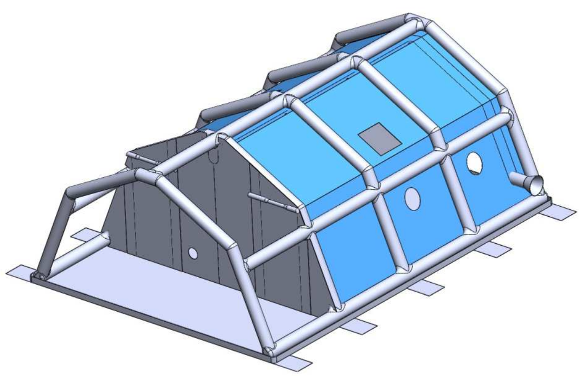

Fig. 2. Tent structure with a fabric layer forming a lining on the inside, with a distinguished vestibule zone and a heated or cooled zone (source Lubawa S.A.)

2. Testing the properties of the tent fabric

Due to the lack of data necessary to calculate the values of the heat transfer coefficients of the tent's external partitions, it was necessary to plan and perform appropriate laboratory tests. The scope of the research included the determination of the emissivity coefficients of the tent fabric coatings and the thermal resistance of the fabric.

2.1. Tests of thermal emissivity of the tent fabric surface

The tent fabric has a surface that differs in color (Fig. 3). Therefore, tests were performed separately for each surface. The dark green side of the fabric is used in the tent from the outside and inside, while the gray side is used from the air layer side.

The emissivity test was performed indirectly using the VarioCAM thermal imaging camera. On the other hand, the processing of measurement data from the thermal imaging camera was performed using the IRBIS remote 3.0 computer program.

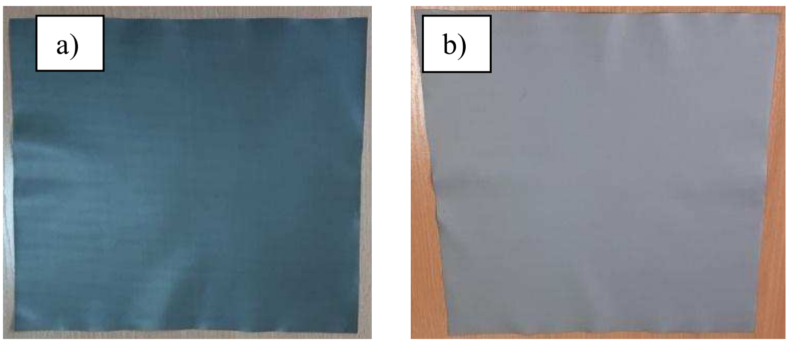

Fig. 3. Two different sides of the MP-144 fabric, with the colors: a) dark green, b) gray (size 30x30 cm) (*own photography*)

The tests were performed on a test stand created for the purpose (Fig 4). The measurements consisted of determining the apparent temperature with the use of aluminum foil and setting the emissivity $\varepsilon = 1.0$ on the thermal imaging camera. The apparent temperature during the measurements was 25.5°C, this was necessary for the proper measurement of thermal emissivity. For this purpose, strips of black cardboard with an emissivity close to 1.0 were placed on the fabric samples. The fabric samples prepared in this way were glued to glass to create a smooth surface, without bulges, and then placed on a tripod with a lamp below. The lamp bulb was aimed at heating the samples of the tested material to a temperature higher by about 20 K compared to the ambient temperature. The camera set the emissivity equal to 1.0 in order to record the temperature on the black strip and on the appropriate material, and then the camera was adjusted in the emissivity range for the tested material, at which the temperature would be close to that recorded on the material with the emissivity 1.0. This value was defined as the emissivity of a given material sample. The process of determining the emissivity of the material was repeated, then the thermal images were processed in the IRBIS remote 3.0 program.

As a result of processing the measurement data, the average value of the emissivity of the tent fabric was determined. The emissivity for the green side was 98%, and for the gray side 84%.

This data was used to calculate the coefficients and resistance to heat transfer on the surface of the walls and roof of the tent, as well as the equivalent emittance needed to determine the thermal resistance of the air layer.

Fig. 4. Measuring station for testing the thermal emissivity of a fabric (*own photography*)

The test was carried out on a test stand with the HFM 446 Lambda M lambdameter, made by NETZSCH (Fig. 5). Due to the fact that the lammeter is used to test the thermal conductivity of material samples with a thickness of 2 cm, the measurements had to be made indirectly. The approach was used to measure the thermal conductivity of the material, which should have a thermal conductivity similar to that of the fabric. Registering the thermal resistance given by a sample of this material, and then measuring the thermal resistance with the layers of tent fabric added to the original sample.

Fig. 5. Samples with the starting material and tent fabric samples placed between them, placed in the lammeter chamber (*own photography*)

The obtained values showing the difference in thermal resistances of the individual tests, divided by the number of fabric layers, made it possible to calculate the average thermal resistance and thermal conductivity of the fabric. The most advantageous in terms of comparative measurements were the MDF board samples for which the tested thermal conductivity was 0.10 W/(m · K).

The lammeter also measured the thickness of the tested samples. The measurements show that the average thickness of the samples of the material made available for testing was 0.31 mm. Measurements made with the use of a lammeter indicate that the average thermal resistance of a single layer of fabric is 0.00351 m² · K/W. This value was also used for further calculations of the thermal insulation of the walls and the roof of the tent. Assuming the average thickness of the fabric samples at the level of 0.31 mm and the average value of the thermal resistance of a single fabric layer of 0.00351 m² · K/W, the average value of the thermal conductivity coefficient of the tent fabric was 0.088 W/(m · K).

3. Determination of the thermal insulation properties of the tent shell

The calculations of the parameters of the tent partitions were made for two cases, the cold period, assuming a temperature outside the tent of –30°C and the temperature difference between the heated zone and the external environment of 40 K, and for the hot period, at the external temperature of 50°C and the temperature difference of 30 K. The determined values of heat transfer resistances on the surfaces of the tent partitions, taking into account the emission properties of the fabric surface, are presented in Table 1.

Table 1. Calculation results of the heat transfer resistance on the surfaces of the tent partition (*own study*)

The surface of the outer baffle and the color of the tent fabric	Resistance to heat transfer	
	Cold period	Hot period
	m² · K/W	
	R_{si}	
wall – green	0.134	0.125
wall – gray	0.147	0.137
roof – green	0.101	0.162
	0,107	0.182
	R_{se}	
wall, roof – green	0.0035	0.032

Due to the fact that the temperature conditions of the partition operation and their emission properties were taken into account in their calculation, they were used for further calculations.

The determined values of the thermal resistance R_u and R_T as well as the heat transfer coefficient of the vestibule space and the entire system, also taking into account the internal partition, between the vestibule and the main operating zone of the tent for the cold and hot period are shown in Table 2. Table 3 presents the values of the thermal resistance of the air layers R_{wp} in the individual partitions of the tent for the cold and hot period.

Table 2. The results of calculations of the thermal resistance R_u and the heat transfer coefficient of the vestibule (*own study*)

Vestibule thermal parameters	Cold period	Hot period
Thermal resistance R_u, m² · K/W	0.061	0.064
Thermal resistance R_T, m² · K/W	0.212	0.205
Heat transfer coefficient U, W/(m² · K)	4.717	4.878

Table 3. Calculation results of the thermal resistance of air layers in the tent's partitions (*own study*)

Air layer in the outer partition	Resistance to heat transfer	
	Cold period	Hot period
	m² · K/W	
in the wall	0.182	0.141
in the roof	0.145	0.123

The determined values of the thermal resistance R_T and the heat transfer coefficient U of the external partitions of the heated or cooled tent zone are illustrated by the results presented in Table 4, relevant for the cold and hot period.

Table 4. Results of calculations of thermal resistance R_T and heat transfer coefficient U, external partitions of the tent (*own study*)

External partitions	Thermal resistance R_T		Heat transfer coefficient U	
	Cold period	Hot period	Cold period	Hot period
	m² · K/W		W/(m² · K)	
wall	0.353	0.298	2.833	3.356
roof	0.283	0.317	3.533	3.155

Conclusions

The tests presented in the article determined the value of the thermal emissivity factor ε of the tent fabric on both sides. This factor has a significant impact on the value of the heat transfer coefficient on the surface of the fabric. For the dark green surface $\varepsilon = 0.98$, and for the gray side $\varepsilon = 0.84$. As a result of the thermal conductivity test in a lammeter, the average value of the thermal conductivity coefficient λ of the tent fabric was 0.088 W/(m · K). The determined value of the thermal resistance of the air layers in the partitions of the tent (wall, roof), separately for the hot and cold period, ranges from 0.123 to 0.182 m² · K/W. In turn, the specific value of the heat transfer coefficient of the tent's partitions for the cold period is 2.833 W/(m² · K) for the wall and 3.533 W/(m² · K) for the tent roof. However, for the hot period, 3.356 and 3.155 W/(m² · K) were obtained respectively. The test results indicate a significant importance of the thermal emissivity parameters of the tent fabric on the thermal insulation value of the tent partitions and significant differences in the insulation performance for the cold and hot period of operation of such facilities. In further tests, it is possible to check other structural variants of the tent partition. Such solutions could be: choosing a different thickness oftent fabric, changing the thickness of the air gap, as well as choosing a different layer arrangement in the building partition.

Bibliography

Cena, K., Davey, N. & Erlandson, T. (2003) *Thermal comfort and clothing insulation of resting tent occupants at high altitude.* Applied Ergonomics, 34, 543-550.

Jura, J. (2015) *Budowlane materiały izolacyjne*. Construction of Optimized Energy Potential, 2, 39-44.

Kysiak, A. & Ujma, A. (2018) *Ocena prawidłowości rozliczania kosztów ogrzewania w budynkach wielorodzinnych na podstawie wskazań podzielników ciepła*. Construction of Optimized Energy Potential, 7, 103-110.

Lee, S.W., Lim, C.H. & Salleh, E.I. (2016) *Reflective thermal insulation systems in building: A review on radiant barrier and reflective insulation*. Renewable and Sustainable Energy Reviews, 65, 643-661.

Liu, J., Jiang, Y., Gong, Z. & Yang, H. (2016) *Experiment Research on Shading to Improve the Thermal Environment of Tents*. MATEC Web of Conferences 61, DOI: 10.1051/mate-conf/20166101009.

Pöschl, R. (2016) *Modelling the thermal comfort performance of tents used in humanitarian relief.* Loughborough's Research Repository.

Stegmaier, T., Sarsour, J., Gresser, G.T., Wagner, R., Kröplin, B., Kungl, P., Kneer, A., Arnold, W. & Bögner-Balz, H. (2018) *Energy-efficient textile building with transparent thermal insulation for the solar thermal use according to the model of the polar bear's fur*. Innovative Energy & Research, DOI: 10.4172/2576-1463.1000218.

Ujma, A. & Umnyakova, N. (2019) *Thermal efficiency of the building envelope with the air layer and reflective coatings*. E3S Web of Conferences 100, 000 EKO-DOK 2019, DOI: 10.1051/e3sconf /2019100000201982.

Zhang, L., Menga, X., Liua, F., Xub, L. & Long, E. (2017a) *Effect of retro-reflective materials on temperature environment in tents*. Case Studies in Thermal Engineering, 9, 122-127.

Zhang, L., Yu, Y., Xu, L., Zhang, W. & Shen, Q. (2017b) *Experimental study on indoor air thermal equilibrium model of the tent.* International Journal of Low-Carbon Technologies, 12, 36-42.