MARTIN PEŠEK
Brno University of Technology
e-mail: m.pesek@email.cz

THE INFRARED MEASUREMENT METHOD IN THE AIR IN SMALL CLOSED AREAS

Abstract

The article is focused on the infrared measurement method in the air in small closed areas. This method is based on the visualization of temperature fields on an auxiliary material which is inserted into the non-isothermal air flow in a research area. In small closed spaces where is impossible to put the measuring equipment due to various reasons, it is necessary to visualize the temperature fields through a window. This window must be permeable for infrared radiation of known properties, especially the transmissivity. As an auxiliary material for the visualization of temperature fields in these experiments, the ordinary office paper with high emissivity value was chosen and the viewing window was made of a polyethylene. The presented method for the measurement of temperature fields in the air can be applied mainly in closed spaces where is difficult to situate the infrared camera (due to field of view), in spaces where the infrared camera restricts the flowing air or where is aggressive or too hot environment (a potential damage of infrared camera), etc. In this article the parameter analysis, which is important for a particular application, is performed and an example of temperature fields measurement in closed space is presented. This method can be used in cooling and heating design of means of transport, mostly for cabins of cars and trucks.

Keywords: temperature field, infrared camera, small closed space, transmissivity

1. Introduction

The thermography is a technique for creating images for a noncontact measurement of temperature fields in many scientific disciplines by the very effective device – the infrared camera [1]. The camera detects surface temperatures and converts this information to an image which we can call as a thermogram. In the thermogram, the surface temperatures are indicated by different colours or shades. One huge advantage of an infrared camera usage is the monitoring speed [2]. This measuring technique provides almost immediately a visual image records and we can show the information in actual time for deeper knowledge of thermal states and processes in research areas. The thermography is being used mainly for determining surface temperatures, but this article tries to extend the possibilities of monitoring and the measurement of temperature fields in the air in small closed spaces through the viewing window.

Immediate knowledge of the distribution of temperature field in the airflow can allow to quickly identify a possible problem in the design or adjustment of air conditioning or hot-air heating.

2. The measuring method description

It is impossible to make the air temperature visible directly by the infrared camera because the air is a transparent material in infrared radiation [3]. For visualization the air temperatures in non-isothermal air flows, an auxiliary material, which has to be inserted into airstreams, is necessary to be used. The hot airflow produces the convective heat transfer to the auxiliary material surface that changes the surface temperature which is measured through the surface temperature by the infrared camera [4]. The infrared camera is ordinary used for the non-contact measurement, but this explained method for measuring temperature field in the air is a contact method. For measuring temperature fields where the streamlines are situated parallelly to the auxiliary material, a spacious sheet of this material is suitable to be used.

The device for measuring temperature fields in a closed small space is compounded of the compact sheet of the auxiliary material which is situated at a right angle to the air-conditioning mouth outlet which serves airstreams to be visible into the space. The next part is the infrared camera on the tripod base stand in front of the window, which is made of the transmissive material. This window closes the inside environment (the small closed space) to the outside air in space where the measuring is done.

3. The determination of auxiliary material properties

For a proper usage of this measuring method, it is necessary to determine the temperature in the nonisothermal airstream using the planar office paper which serves the visibility of temperature fields. The next important support material is the polyethylene plastic foil which closes the small space to outside airstream noninfluence.

All measurements were performed by the infrared camera Jenoptik, type VarioCam that has the spectral sensitivity from 8 to 13 μm with the resolution of 320 x 240 pixels. The radiation ambient temperature for all measuring was determined by the radiation thermometer Testo 830-T2 as the arithmetic average of surrounding radiation temperatures where the measuring was done.

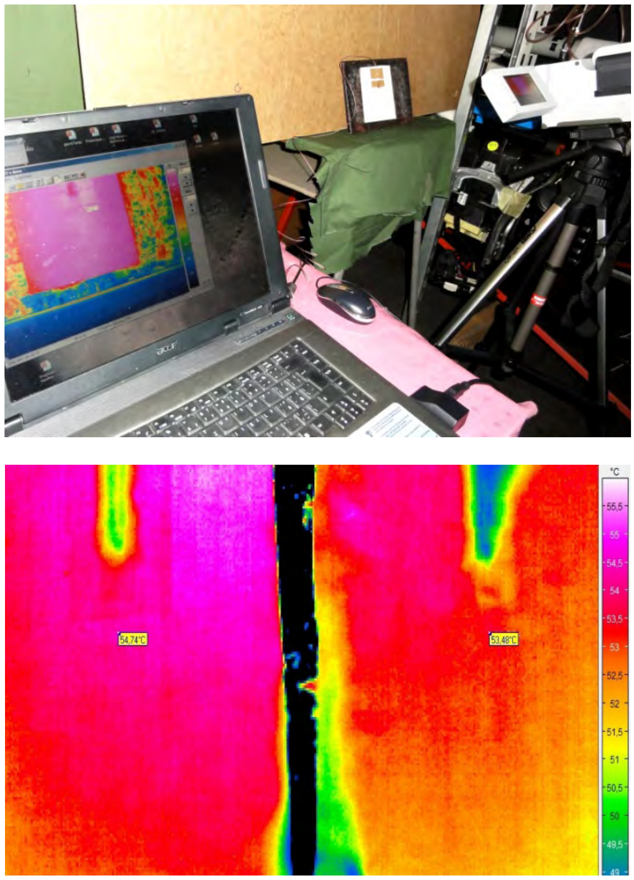

Fig. 1. The stand and the thermogram from the office paper emissivity measuring. The area 1 is a temperature measuring by thermocouple sensor and the area 2 is area of temperature measuring by thermovision

3.1. The emissivity determination of auxiliary material

The auxiliary material, on which the temperature field is visualized, must have suitable static properties, mainly high emissivity ε [-] in order to maximize the accuracy and for noninfluence of ambient radiation temperature.

The emissivity of the auxiliary material for the suitable wavelength range of infrared camera VarioCam (8 to 13 μm) and for the investigated temperature range [5] by the infrared camera was measured. For this measuring it was necessary to determine the temperature from thermogram (with setting of emissivity of infrared camera to value 1), the sample surface temperature measured by the thermocouple and the radiation ambient temperature determined by the radiation thermometer. The emissivity of planar office paper was measured on heated samples in a cooler environment. The paper sheet was fixed to a steel plate. On the plate the calibrated thermocouple was placed, which measured the actual temperature (Fig. 1).

The resulting emissivity of the planar office paper 80 g/m^2 was calculated to the 0.96 value [6].

3.2. The transmissivity determination of auxiliary material

For correct measuring of temperature fields in small closes spaces through a transparent material, the viewing window material properties is necessary to know. The main important property of transparent material is its transmissivity, the ability to transmit an infrared radiation that the infrared camera detects. The polyethylene foil, in a thickness 0.05 mm as the viewing material, was chosen. The polyethylene foil transmissivity for the suitable wavelength range was determined likewise by the same infrared camera. The resulting transmissivity of this polyethylene foil was calculated to the 0.90 value.

The transmissivity of polyethylene viewing window together with the emissivity of an auxiliary material, mean radiation temperature inside the small closed space and the mean radiation temperature in the outside space where the device is placed are crucial values that they have a major influence on the measurement. These values can be entered directly

environment

into the infrared camera before the measurement of temperature fields, or subsequently after the measurement to Irbis Professional program.

4. The measuring of temperature field in the car cabin

One of possible examples, where is possible to use the method of measurement of temperature fields in the air in small closed spaces through the transmissive material using an infrared camera, is the measuring in the car cabin. Measurements were carried out in a car of brand name Škoda. Specifically, it was the Octavia Combi II, 2.0 TDi with dual air conditioning. For the experiment the ventilation outlet of the center console for air conditioning of rear seat was chosen.

The size of auxiliary material was modified according to the geometry of the rear row of seats (Fig. 2). The geometric shape of the paper sheet has the shape of a rectangular trapezium with the bases of lengths of 60 and 80 cm and the height of 80 cm. The paper sheet was attached to the car cabin roof and the bottom was equipped by weights to its perfect plane balancing. The measuring of temperature fields was carried out by the left rear car door. The car glass window was rolled down into the door and the free visor was equipped by the polyethylene sheet for the closing the inside space from the space where the car was placed. The plastic foil on the door was attached by an adhesive tape.

The measurements were performed in the space with a homogeneous radiation temperature. The room was closed and the exhaust outlet was drained away from the room through a flexible air duct. The infrared camera was set up in front of the side door to the best view inside the car. Only the outlet for rear row of seats in a car was opened and from possible air conditioning modes only this outlet was selected (leg conditioning or windshield was not used). The value of the temperature to which the cabin should be air-conditioned was always set to the same value for the right and the left half of the car (duality of air conditioning was not used).

The infrared measuring was done in the infrared camera stable state and after the auto calibration of the camera. At the same time the radiating temperature in the car cabin and in the room were measured by the infrared thermometer Testo. The temperature fields were shown directly on the display of the infrared camera or on the display of connected laptop in Irbis Online program.

Fig. 2. The photo of air-conditioning mouth outlet for back row of seats in Škoda Octavia II and the photo of auxiliary material position before this mouth outlet

5. Results

Temperature fields in the car cabin was scanned from several viewing angles and different distances of the infrared camera in front of the polyethylene window including the case the camera lens was pressed directly to the window of polyethylene (during the handheld measuring) to prevent the non-uniform picture of the outside environment which could be shown on the polyethylene window. In the handheld measuring also the polyethylene foil in viewing window at maximum stretch is ensured (Fig. 3). The measuring in several different settings of mouth outlet air flowing was done. The visualization of hot airflow (heating) and cool airflow (cooling) was recorded.

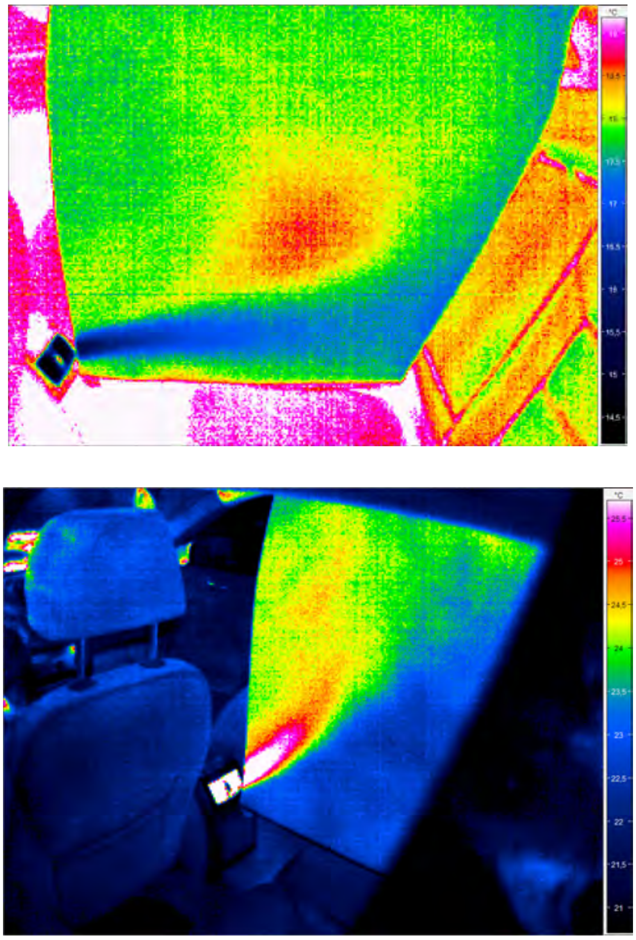

Fig. 3. Thermograms of measured temperature field in 2D airstream (left-cold and right-hot) in a car cabin using the method of measuring temperature field on the sheet of planar office paper through the polyethylene window

6. Conclusion

The experiment results show that the measurement of temperature fields in the air on the auxiliary material through a partially transmissive viewing window is possible and results are very illustrative. The temperature fields of isolated air outlet for rear seats of Škoda Octavia II Combi was visualized on the planar office paper through the polyethylene foil using the infrared camera. This measuring method of visualization was used because air streamlines from mouth outlet was practically situated parallelly to the planar sheet of an auxiliary material (the temperature fields measuring method in 2D airstream).

For measuring temperature fields in front seats in the car cabin or during the measuring with more outlets together is necessary to use the measuring net with measuring targets. Moreover, measuring targets are necessary use in measuring temperature fields in 3D airstreams.

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Acknowledgement

The support of this research from Czech Science Foundation project no. GA 101/09/H050 "Research into energy-saving devices to achieve comfort of the internal environment" and the standard project FSI-S-11-6 "Human Centered Design" is gratefully acknowledged".

This paper has already been presented at the Conference: ICCCS 2012 – International Symposium on Contamination Control 2012, ETH Zurich.