Design, fabrication and testing of a heat shield for the thermography of the human feet.

Reporte Técnico

No. 644

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Febrero 2017

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Abstract

A heat shield for thermography of the human plantar skin was designed, fabricated and tested. The main purpose of the heat shield is to provide, during the acquisition of the thermogram, an homogeneous temperature background behind the patient's feet. The heat shield is a water tank made of copper sheet, which is filled up with water of about 4˚C, and it is painted in matte black. By using this heat shield, the thermography of the human feet can be achieved for about 120 minutes, without changing the water in the tank.

Introduction

Several research groups are dealing with the thermograms of patients with diabetes mellitus II, most of them are working with the morphology classification of the temperature distribution on the feet [1 - 3]. The thermogram of the human feet, according to the International Academy of Clinical Thermology, is taken while the patient lay down on an exploration table, without the shoes and the socks. Room temperature should be controlled, and should be between 17 to 20 degrees Celsius. Furthermore, within the room heat leaks and heat promotors must be avoided, allowed persons are limited to two (patient included) [4].

One of the main problems, when working with these thermograms, is to isolate the feet from the whole thermogram [5]. Thus, the thermogram is processed to delete the background. Several digital image processing techniques are available in the literature. A drawback of most of these digital image processing techniques is the human and/or computing time consuming.

In this work, a heat shield (HS), for taking thermograms of the human feet with a homogeneous temperature background, is designed, fabricated and tested. The HS is a tank made of copper sheet (0.030” thick), painted in matte black color by the spray technique. It is filled up with cooled water as refrigerant media (2,150 ml). Thus, the HS was tested in a room with two persons, leaks and heat promoters were avoided. By cooling down the water up to 4˚C, thermography of the human feet can be achieved for about 100 minutes, without changing the water.

HS Design and Fabrication

Figure 1 shows an sketch of the HS and its application to the thermography of the human feet. The main objective of the HS is to have a homogeneous temperature background behind the patient's feet.

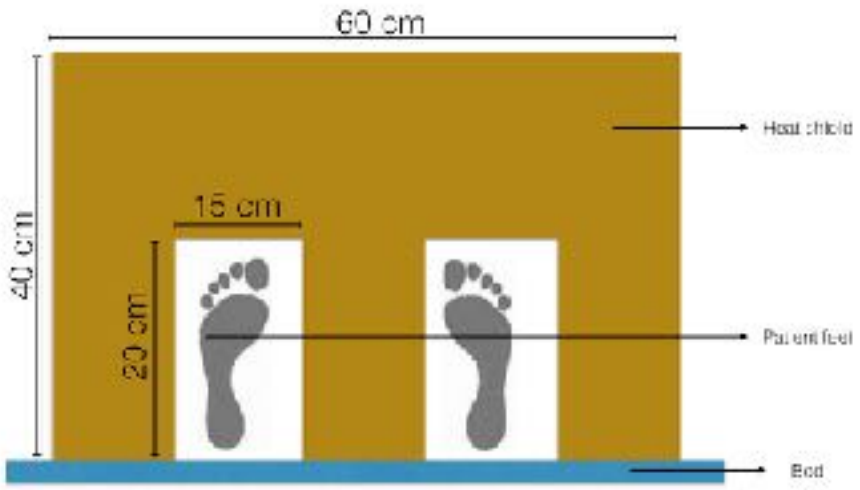

Figure 1. A sketch of the heat shield for the thermography of the human feet. Physical dimensions are shown (depth 1 cm). Fabrication material is copper sheet.

The physical dimensions of the HS are 40 cm hight, 60 cm width, and 2 cm depth (not shown on figure 1). The windows, to show up the feet, are 20 cm height and 15 cm width, respectively. Two fluid connectors, P1 and P2, are shown for water in and out, respectively. Copper was selected as the fabrication material because of its density (light weight), no corrosive, and easily to manipulate (0.030" thick). The HS is painted in matte black color by the spray technique. Water, of about 4˚C, is used as refrigerant fluid, in an amount of 2,150 ml.

HS Test

The HS was tested in a room (5 m width, 6 m large, and 3 m height, respectively), two persons within it, heat leaks, and heat promoters were avoided. Temperatures, within the room, the water within the HS, and on the HS front surface were monitored every 5 minutes. Water within the HS was measured with a Norpro digital thermometer (±0.5˚C), room temperature was measured with a RadioShack thermometer (±0.5˚C), and the HS front surface temperature was measured with FLIR® E60 thermal camera.

The figure 2 shows the front surface of the fabricated HS, that was divided in four subsections A, B, C, and D, so as to have a better knowledge of the temperature distribution on its front surface. Table 1 shows the measured temperatures, in the room, water in the HS, and on the four frontal subsections of the HS.

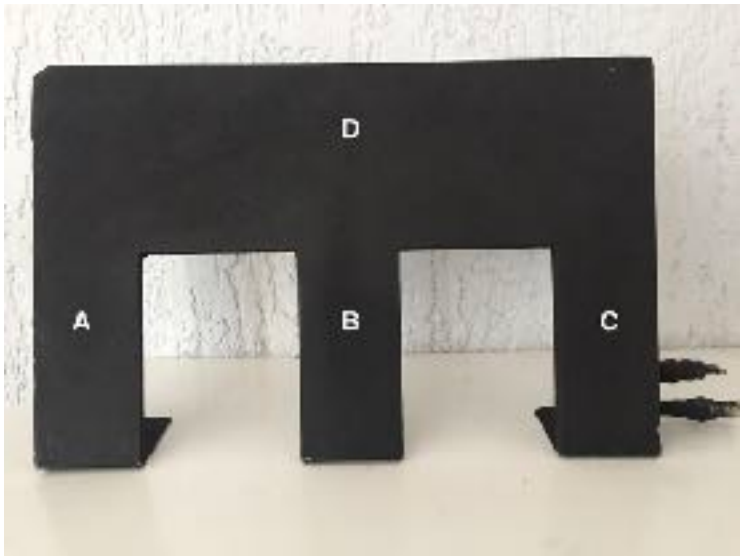

Figure 2. A photograph of the fabricated HS. The front surface of the HS is divided in subsections. P1 and P2 are the water connectors.

Table 1.Temperature measurements at the room, water (in the HS), and at the front surface of the HS (the average temperature by subsections is shown in the corresponding column).

Time (minutes)	Room Temperature (˚C)	Temperature of the water within the HS (˚C)	Average temperature of the HS subsection A (˚C)	Average temperature of the HS subsection B (˚C)	Average temperature of the HS subsection C (˚C)	Average temperature of the HS subsection D (˚C)
0	20	4	N.R.	N.R.	N.R.	N.R.
5	20	6.5	10.2	11.8	12.2	10.2
10	20	7.2	10.7	11.6	12.1	10.7
15	20	8.5	11.8	12.4	12.8	11.9
20	19.9	9.5	12.6	12.9	13.2	12.5
25	20	10.3	13.2	13.3	13.6	13
30	20	11.2	13.7	13.8	14.1	13.6
35	19.9	11.7	14.4	14.5	14.7	14.3
40	20	12.3	14.8	14.9	15.2	14.7
45	20	12.8	15.4	15.3	15.5	15.2
50	20	13.2	16.1	15.8	16.2	15.7
55	20.1	13.7	16.1	15.9	16.2	15.8
60	20.1	14	16.6	16.3	16.7	16.2
65	20.1	14.3	16.8	16.6	16.9	16.5
70	20.2	14.6	17.4	17.2	17.5	17
75	20.2	14.8	17.7	17.6	17.9	17.5
80	20.2	15	17.9	17.8	18.1	17.7
85	20.3	15.2	18.2	18.1	18.4	18
90	20.3	15.3	18.5	18.4	18.7	18.2
95	20.4	15.5	18.8	18.6	19	18.4
100	20.4	15.6	19	18.9	19.3	18.7

N.R. not recorded.

The figure 3 shows a thermogram of the human feet using the HS. The background temperature, behind the human feet, is homogeneous, as required by the image processing.

Copper strips (0.03” thick, 6 cm wide, and 38 height), in contact and attached to the HS, are used to cover the clearance between the ankles and the HS’s windows.

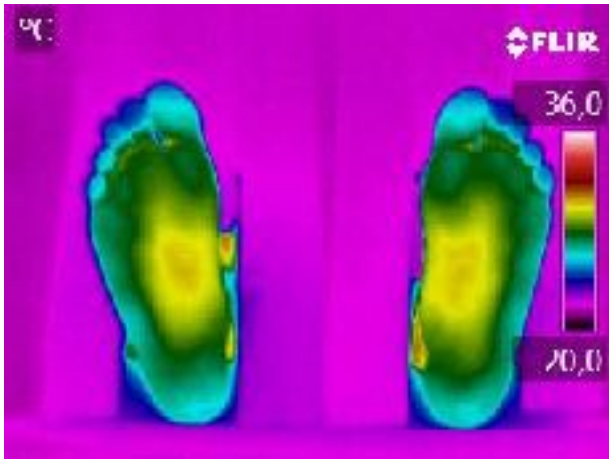

Figure 3. A thermogram of the human feet using the HS. The well contrasted thermogram of the human feet is obtained due to the homogeneous temperature behind the human feet.

Conclusions

A design, the fabrication, and the testing of the HS for the thermography of the human feet have been presented. The HS front surface temperature, 10˚C below the human body temperature, is appropriate for contrasting the temperatures of the human feet. Also, the front surface of the HS shows a homogeneous temperature, which is good enough for the image processing. By using the HS with initial water temperature of 4˚C, the thermography of the human feet can be achieved for about 100 minutes, which means 7 - 8 thermogram.

References

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