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Journal of Textile Engineering & Fashion Technology

Research Article

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Development of a test method for investigating moisture transfer rate of textiles

Abstract

Moisture management textiles have proved to be one of the fastest growing sector in textiles. New research and development of these textiles have pushed the boundaries of textile testing equipment as new test methods are required.

This paper will focus on the development of test method with potential application in testing and analyzing of textile fabrics which can be used in moisture management industry. A new system has been developed which allows fabrics moisture transmission to be tested whilst situated between two variable conditions mini chambers. The system allows moisture level to be monitored by precision weight scale and all the real-time data can be controlled and analyzed by computer.

The system was tested by using a knitted spacer fabric and proved to be useful and reliable kit for analysis of moisture transmission at various testing conditions.

Keywords: moisture transmission, spacer fabrics, textile testing

Volume 4 Issue 3 - 2018

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Received: May 29, 2018 | **Published:** June 11, 2018

Introduction

Moisture management fabrics are one of the leading textile research areas.[1–3] They are types of textile materials, which provide needful protection for the wearer in outdoors environments. Majority of outdoor activities especially in the northern hemisphere regions require the wearer to be protected from cooler outside environment. As a the wearer level of activities increases, the body heats up and the human body regulates its body temperature automatically; it will try to remove excess heat by perspiration.[4–6] This occurs by sweating on the skin. At this situation, an outer environment is much cooler than what the body requires and inside the clothing is warmer than required. So technically, the body requires cooling and warming simultaneously. This is very tricky to perform because; in cold environment clothes must keep us warm and vise versa.[7] So a special moisture management system to prevent sweat from clogging inside the garment by trying to remove it to the outer environment for evaporation is developed.

Studying performance of textile material in these extreme situations at the same time maintain conformability to the wearer, special testing equipment have to be developed. Research into creating equipment's to study this phenomenon has been done before.[6,8–10] One of the earliest one includes the creation of controlled chamber with the ability of monitoring and controlling temperature, air levels and humidity.[11] This allows most textile developments and athletes to use this to test performance in the selected conditions of choice. Another improvement into this study was the development of manikins. These are special built models with sweating and sensing mechanism to simulate human body perspiration system at different levels. These manikins are then placed inside the controlled chamber which simulates outside environmental conditions. The aim of whole system is to monitor the textile covering the manikin set at predefined activity levels at known outside conditions. Examples of this kind can be found at Hohenstein institute into which they created a manikin called 'Charlene' situated in the condition controlled chamber.[11] The system proved to be a success as different vital properties could be monitored on the garment whilst situated at pre-defined environmental conditions. However they are expensive to make and operate due to scale of the whole system. Also it's difficult to investigate smaller fabric samples as the manikin requires full garment which makes it difficult to study textiles at a smaller scale. A smaller cost effective way to study textile performance at various conditions is important.

Concept

The main concept regarding this type of textile testing is basically placing a textile sample in between two environmental chambers of controlled and monitored conditions and weight change of the sample. This system is similar to the one used here.[12] This means a weighing mechanism will be incorporated into the system to provide weight reading of the fabric sample. The fabric sample prior to any experiment has to be wetted with distilled water to allow the monitoring process to start. The idea is to wet the sample before starting the experiment so that the fabric will have certain weight added and then monitor how effectively will transmit this moisture when located between these conditions. In real situation, the process is dynamic in the sense that, as human body sweats, moisture is produced continuously. In the setup it was assumed a static process in which the sample is wetted once and then monitored its performance. The static process is easy to study and understand the performance of the fabric than a dynamic process which is much unpredictable. The schematic arrangement of the system is presented on Figure 1.

The schematic diagram above describes two environmental chambers in which knitted spacer fabric is placed between and its weight monitored at the same time. A test rig was designed, built and commissioned so that experiments applying the same principle can be conducted. These are explained on the following section.

Design and construction

The test rig design consists of two chambers one for heating and one for cooling purposes as explained earlier. The design also used here[12] can be clearly illustrated on Figure 2.

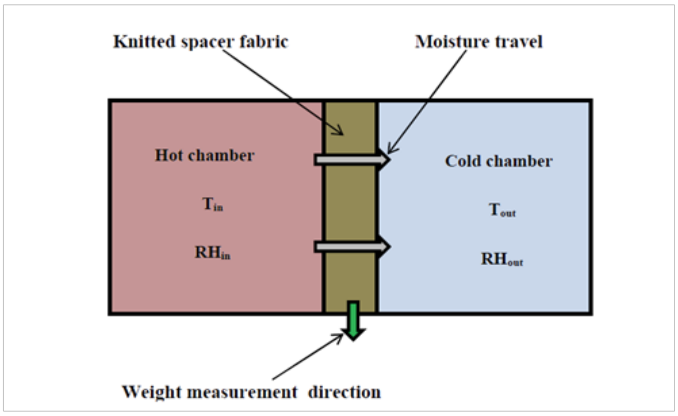

Figure 1 Experiment concept.

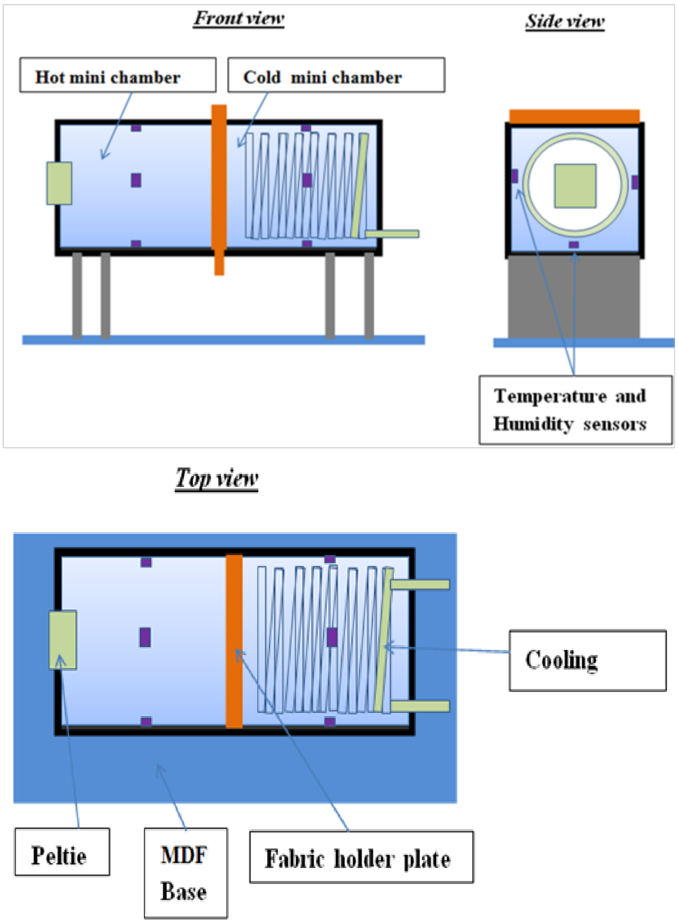

Figure 2 Test rig design layout.

Construction of these chambers was created by using acrylic material which is readily and cheaply available. The acrylic is provided in 210×297×4mm size dimensions, so to obtain a required size 210×210×4mm for the system, a 5W laser cutter was used to provide precise cutting. After cutting, the pieces of acrylic were glued together with a special industrial grade adhesive from RS. This glue insured reliable joint between the pieces. To ensure no heat loses, a 4mm cardboard rapped with aluminium foil was used to cover the walls of the chambers.

The same acrylic material was used again to create a fabric holder plate. Dimension of 164×250×4mm, were laser cut and the two pieces of 4mm acrylic glued together. This plate is placed in between the chambers and lays on top of the weigh scale for weight measurements. At the centre of the plate, a 100×100mm hole was laser cut to create space for fabric samples. The fabric sample is secured in place by thin frame of acrylic and three spring holders.

Heating on the hot chamber was done by using a 200W Peltier. The Peltier is placed on the wall of the chamber so that hot side faced inside the chamber and cold side outside the chamber. Cooling fins with 12v fans are placed on both sides of the Peltier. They ensure efficient heat transfer from the Peltier. Power supply to the Peltier is produced from a TTi variable voltage supply.

Similarly, on the cold chamber, cooling was done by using the system of heat exchange. Two systems of 8mm diameter copper coils are used. One coil is placed inside the cold chamber and the other on ice bath. The principle is that, heat is removed from the cold chamber and cooled in the ice bath. A Watson Marlow variable speed peristaltic pump was used to accurately circulate cooling liquid between these two coils. The cooling liquid used was a mixture of water and ethanol. Ethanol prevents freezing of water in the copper pipes. The ice box consisted of 210×210×210mm dimensions and ice was obtained from the ice bath.

Furthermore, to monitor the temperature and humidity from the chambers, six DHT22 high accuracy temperature and humidity sensors were installed. It consisted of three in each chamber, one on the bottom and two on the wall side (Figure 2). Signals from the sensors were collected by using an Arduino Mega2560 microcontroller board. Weight measurement from the fabric holder plate was done by using Adam PGW753i precision weigh scale with 1mg sensitivity. LabView 2011 computer package was used to acquire, display and export data from the sensors via Arduino mega 2560microcontroller board and from the Adam weigh scale. A LabView program (Figure 3) was created to perform this function.

The system was placed on top of a 360×480×18mm MDF material and chambers placed on top of side pates to hold it so that a balance can be placed on the bottom of the chambers. The system is highly sensitive due to the fabric holder plate, so it is placed on top of the anti-vibration inflatable tubes. A level meter was used to ensure the system is operating in an appropriate level position. The complete system can be seen by Figure 4.

Testing and experimentation

In this section a series of experimentations where conducted to test the system performance. The type of experiments conducted aimed to investigate the effect, reliability and importance of the two mini chambers to the moisture transmission on knitted spacer structure. The knitted spacer structures where designed and manufactured using a computerised flat-bed knitting machine. It consisted of two single jersey courses made from 2 ends of 167/48 polyester yarns and the spacer yarn made from 2 ends of 167/48. The weight of dry fabric was 379.027g with an area of 100cm^2. The moisture transfer process was studied and modelled here.[13,14]

In conducting the experiment to evaluate moisture transmission rates of knitted spacer fabrics by using the test rig, the following procedures were followed:

a. Ice preparation: the ice bath required to be filled with fresh ice which was found in the ice bath. The ice bath must be covered on top to prevent heat losses. The peristaltic pump on switched on to start the circulation process.

b. The peltiers and fans are switched on according to required settings.

c. Weigh scale calibration: the weigh scale is switched on and calibrated.

d. Sample preparation: 115×115mm samples were cut from a large knitted fabric and weighed.

e. Sample Fixing: the sample is fixed at the holder plate and secured by using the spring loaded clips.

f. Water spraying: after cutting, the sample were sprayed with determined amount of distilled water on side (which should be placed on the hotter side of the chambers) of the fabric.

g. Fixing: the fabric holder plate containing the sample is placed in between the two chambers and on top of the weigh scale.

h. Data acquisition software: connecting leads from the weigh scale and sensors are connected to the computer and the data acquisition software is started.

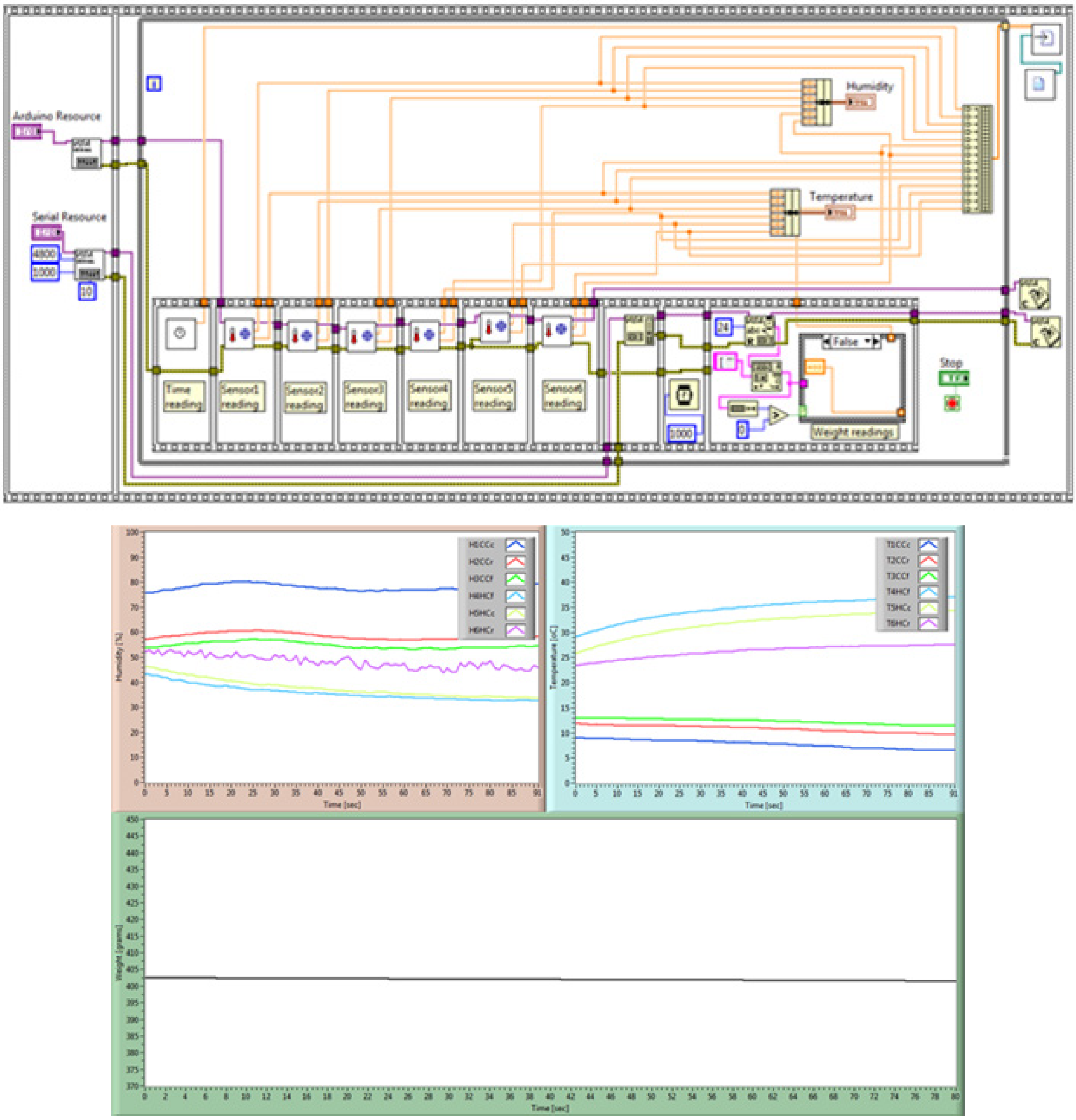

Figure 3 LabView program.

Citation: Mbise E, Dias T, Hurley W, et al. Development of a test method for investigating moisture transfer rate of textiles. *J Textile Eng Fashion Technol.* 2018;4(3):254‒261. DOI: 10.15406/jteft.2018.04.00149

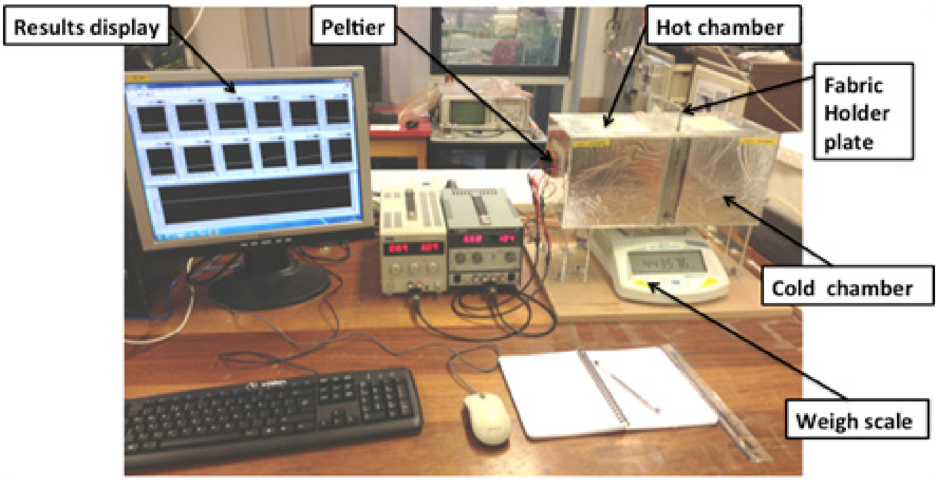

Figure 4 Moisture transmission test system.

Results and discussion

The experimental results of the knitted spacer fabric to investigate the performance of the test rig are displayed on Figure 5. Summary of temperature and humidity variation on cold mini chamber were recorded and are displayed on Figure 6. For the hot mini chamber; results of temperature and humidity variation are displayed on Figure 7 and Figure 8.

Temperature distribution spectrum of the testing equipment was taken by using an infrared camera to understand the temperature distribution during experimentation when all the chambers are functioning. Results are displayed on in Table 1.

The moisture transmission of the fabric was also monitored during experimentations while placed between the two mini chambers. Results are shown in Figure 9.

Another result from conducted experiment was the sample dry weight reliability during fully functioning mini chambers and can be displayed on Figure 10 and Figure 11.

Observation of above results, useful information can be obtained and are explained below:

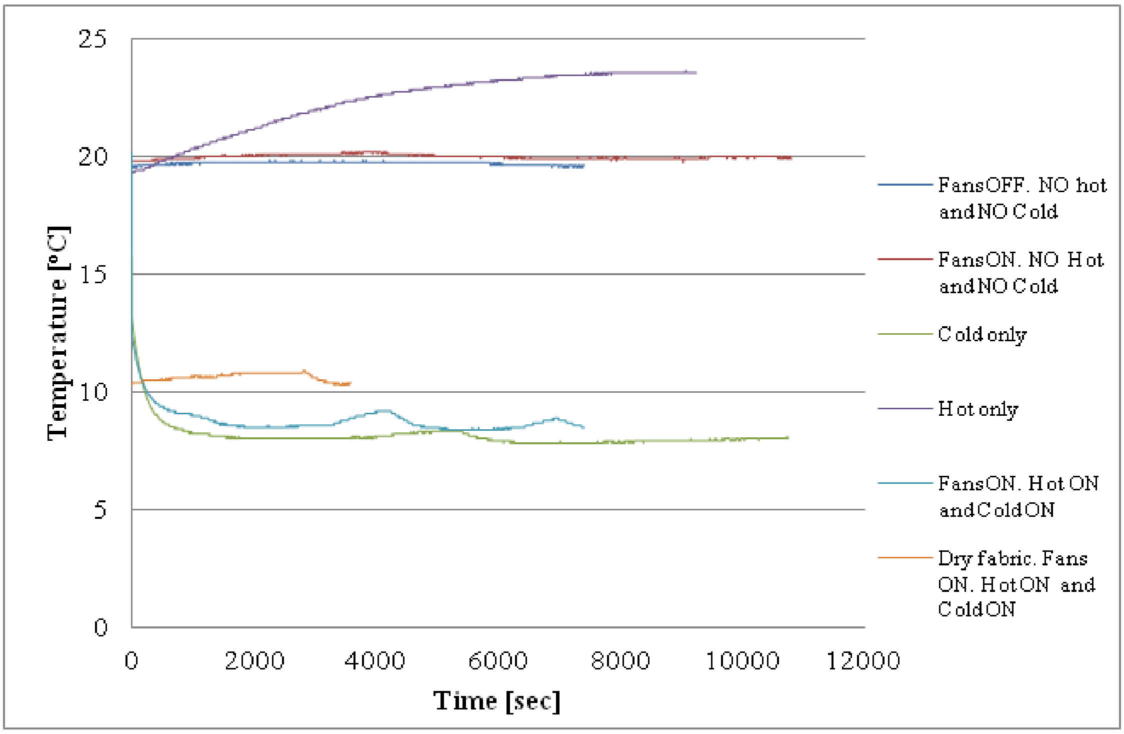

Figure 5 Temperature variation of cold mini chamber.

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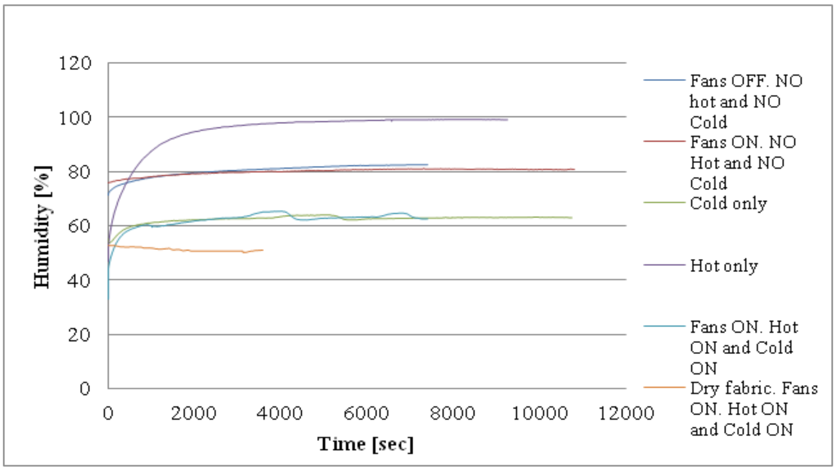

Figure 6 Humidity variation of Cold mini chamber.

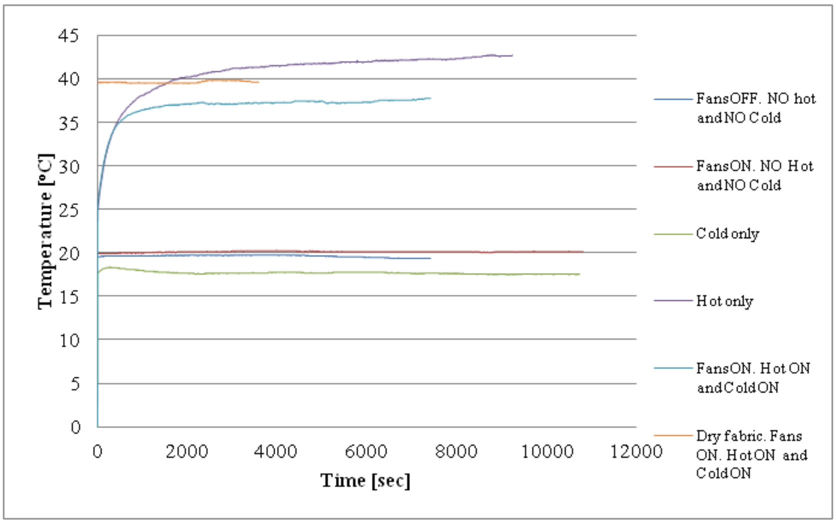

Figure 7 Temperature variation of hot mini chamber.

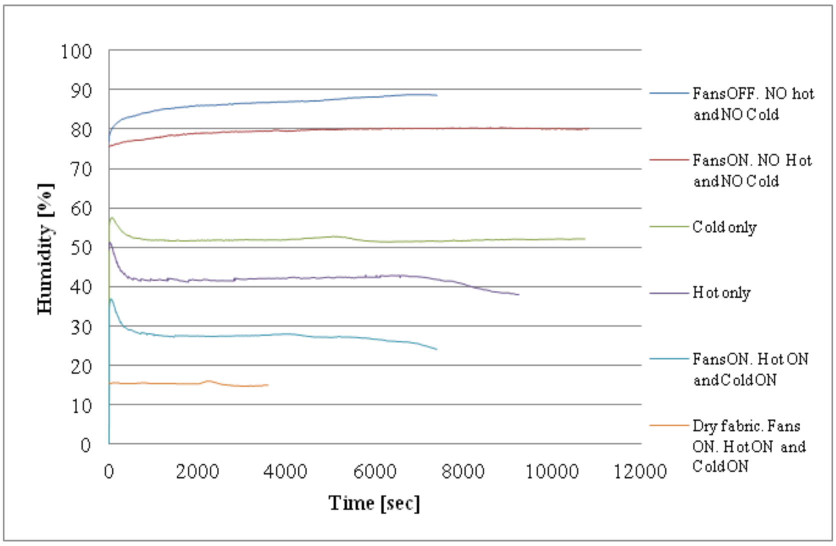

Figure 8 Humidity variation of hot mini chamber.

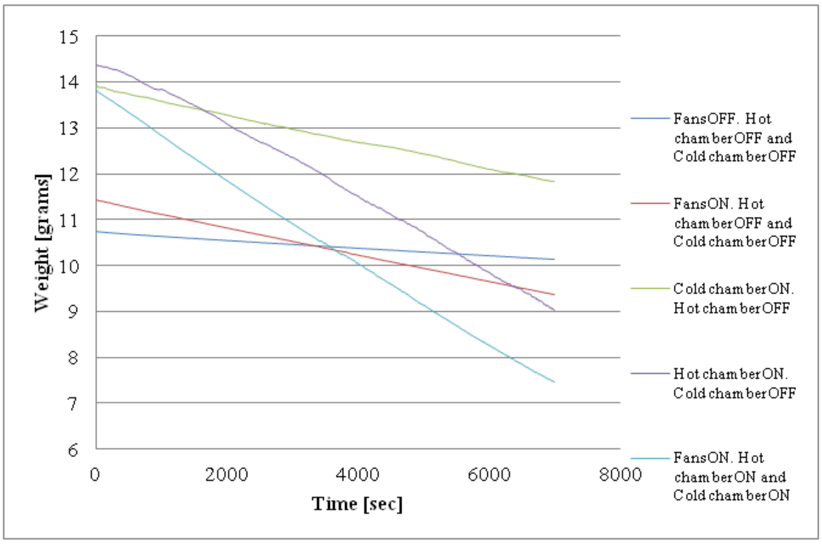

Figure 9 Moisture transmission of spacer sample.

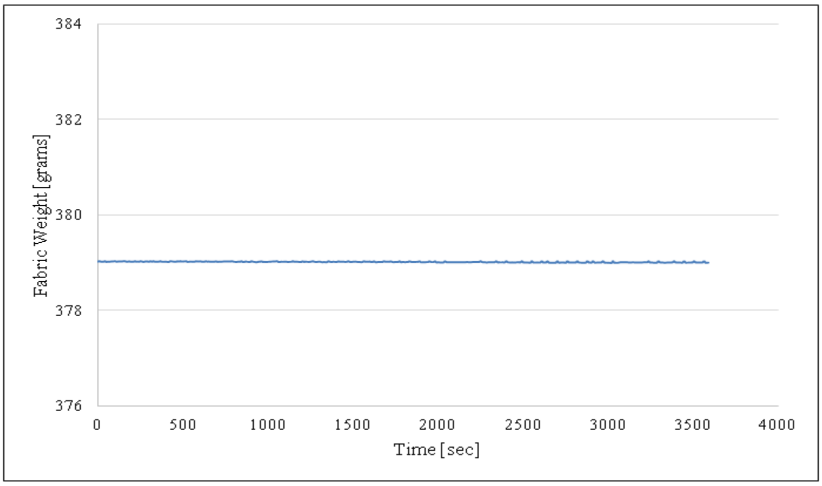

Figure 10 Weight change of dry fabric.

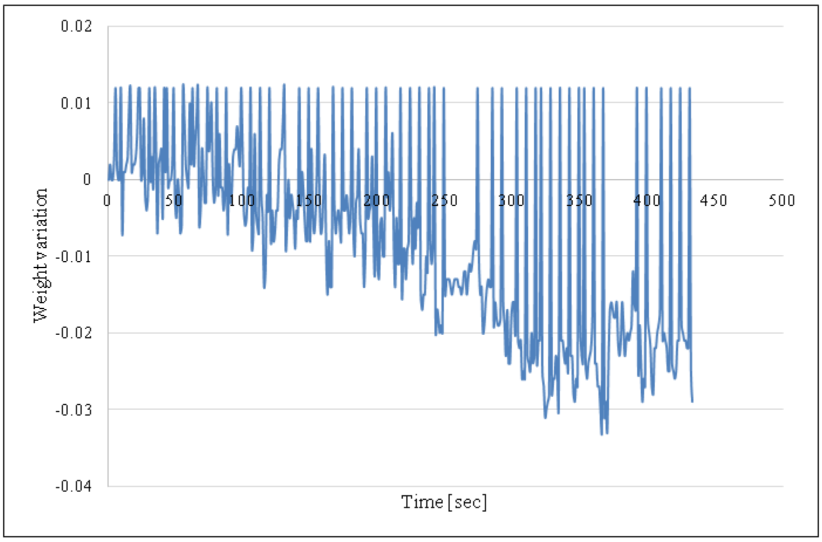

Figure 11 Weight change sensitivity of dry fabric.

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Table 1 Test rig temperature spectrum

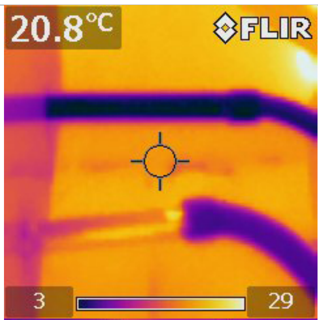
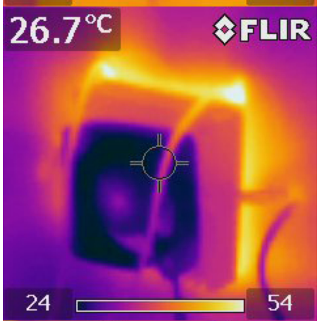
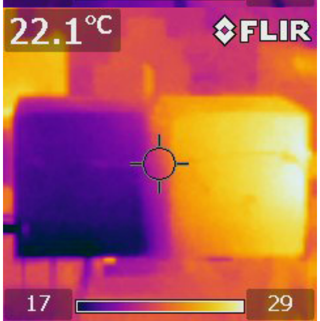
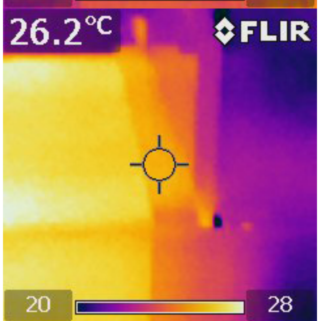
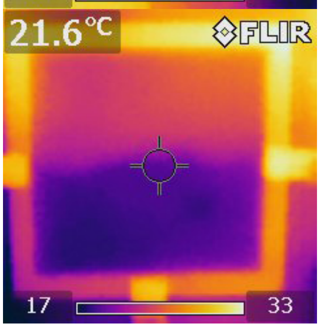
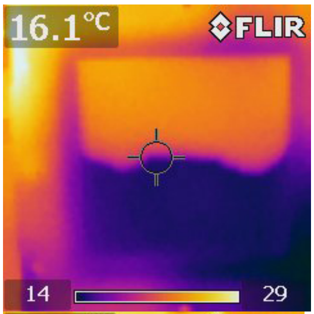
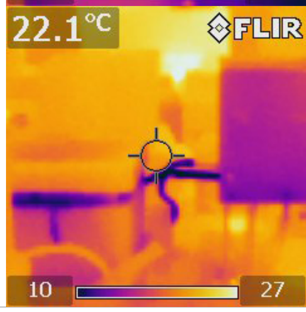
Cooling pipes	
Peltier	
Chambers (Back view)	
Holder plate	
Fabric (hot side)	
Fabric (Cold side)	
Ice bath	

Figure 5 and Figure 7 illustrate the conditions recorded inside the mini chambers. One of the things to be picked up is the effect of turbulent air inside the chambers. Fans are used inside the chamber to circulate air. They are also used in the hot chamber to draw hot air from the peltier. In this case it did make no significant difference in temperature inside the chambers. As we know air velocity have influence on temperature like we experience in our surrounding environments;[5,15,16] during high winds we experience lower temperature feelings compared to low winds situations. This is important as it alleviates the effect of air velocity in the investigation of moisture transfer of fabrics; however this can be used as one of the factors by varying the air velocity in the cambers.

Also in Figure 5 and Figure 7 it shows that, when all the chambers are operating, there is a clear temperature difference between the two sides. This is important as it creates pressure difference and this would affect the moisture transfer dynamics of fabric placed between them.[14.16] The hot mini chamber is operated at temperature just above skin conditions while cold mini chamber at predefined temperature. This temperature distribution can be seen on Table 1 in which infrared images recorded from the mini chambers during operation and also can be observed in Figure 9 which shows higher moisture transfer rate when all chambers were active.

Another important observation is when only one of the chambers was working. When hot chamber was working and cold chamber switched off; Figure 5 show increase in temperature in cold mini chamber. This shows that temperature from hot chamber was causing air temperature in the cold chamber to be increased and at much higher rate than when hot chamber was switched off; this time there was less decrease in air temperature in hot mini chamber as shown Fgure 5. This shows that both temperature conditions are important to ensure that appropriate pressure difference is created between the two chambers as shown on Figure 5 and Figure 7 when a dry fabric was placed between the mini chambers.

Looking at Figure 6 and Figure 8 which showed humidity variations inside the mini chambers; proved that humidity decreases as temperature was increased and vice versa.[16] This together with temperature has significant difference in pressure between the two chambers and might also affect moisture transfer as it prevents the amount of moisture the surrounding holds. This is important in the cold chambers as high humidity might influence moisture transfer coming from the hot side. This can be varied as well to explore more about humidity effect in moisture transfer.

Figure 10 and Figure 11 shows the reliability of fabric weight change recorded by the weigh scale. Since the amount of moisture used in the test is small; maximum 10grams;[10] it is important for the weight measurements to be reliable and repeatable. This proves that, there is no interference of weight measurements as the fabric is placed between the two mini chambers. This allows all the three important variables temperature, humidity and fabric weight to be studied simultaneously.

Table 1 shows thermal images of the test system during fully operation. This was to identify and observe temperature distribution patterns. Results show clearly how temperature profile is distributed between the two mini chambers. The major significance is the boundary of these two temperature profiles situated right at the middle where the fabric sample is placed. This would create the necessary pressure difference on both sides of the fabric which would be responsible for improving moisture transfer across the fabric. Looking at the fabric sample test plate thermal images; we can see distribution of temperature profile with the top half been hotter than bottom half. This might be due to properties of air. When air is heated it decreases in density and rises leaving colder air below.[16,17] This might be the reason why we see this variation. However this could be improved by increasing air flow within the chambers to further distribute and mix warmer and colder air within the chambers.

Conclusions and recommendations

An affordable moisture transfer testing equipment has been successfully developed and commissioned. Its small scaled size can be used to test moisture transmission of fabrics situated between two mini chambers of controlled and measured conditions. Dedicated software was development by using LabVIEW software to provide measured data from the system for analysis. The system was tested using spacer fabric with varying chamber conditions and proved to be essential in testing fabrics as they had significant effect into which moisture is transferred across the fabric.

Thermal images of the unit were taken as well providing evidence information of the two mini chambers and distribution of air temperature between them. Moisture transmission was monitored by precision weigh scale and results showed reliable results from the unit as the fabric was placed in between the two mini chambers.

The test rig requires further developments at various scale sizes to determine the effectiveness of the system; the author would kindly recommend this study.

Acknowledgements

Firstly; I would like to pass my sincere thanks to the almighty God for his guidance through the while process during this project.

Secondly; I would like to thank my co-authors; Prof. Tilak Dias, Dr. Rob Morris and Dr. Will Hurley for their timeless support and guidance on this project.

Thirdly; I would like to thank my friends and family for advice and help; and finally would like to thank the University of Dar es salaam and Nottingham Trent University for providing excellent facilities and space to conduct this exiting project.

Conflict of interest

I would like to emphasise this article does not affect any conflict of interest whatsoever.

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