SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA17107
STSM title: Training for the heat transfer measurement devices inclding thermal manikin
STSM start and end date: 14/07/2021 to 18/07/2021
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PURPOSE OF THE STSM:

In recent years, manikins are extensively employed for development of product and testing by the automobile and building industry in order to determine performance of heating and ventilation systems. The clothing industry employs manikins for development of clothing systems with enhanced thermal properties. There are some testing facilities which conduct tests on protective clothing in accordance with specific international standards. The outcome of these activities delivers continuous development which in consequence results in improvement of health, comfort and environment Thermal manikins are very complicated instruments for determination of thermal transmission of clothing in actual wear situations. Shape of thermal manikin represents shape of human body which evaluates the heat losses due to radiation, convection and conduction, convection losses over the entire surface area of the manikin body in all directions. These manikins consist of individually controlled body parts which may be more than 30. After summation of weighted values, total heat loss from the entire body can be evaluated. This is one of the easiest, reliable and standardized methodologies.
Aaims and Objectives:

1- To understand the working principle of the thermal/moisture manikin at Lodz University of Technology
2- To Test samples of real t-shirts and obtain all possible results
3- To compare the results of thermal manikin with the standard method of thermal resistance and water vapour resistance using standard ISO 11092.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

The STSM is used to learn the testing devices available at the laboratories of Lodz University of Technology. Four textile samples were also prepared to understand different testing methods.
In this research 4 knitted shirts with different fiber content are selected. The choice of selection is based on common use of the garment in research papers and general public. Also the important part of the research is to compare the devices and it's not necessary to keep the same material, structure or thickness. The detail of all material is listed below in Table 1.

Table 1: Specification of materials

Sample shirts	
Sr #	**Material composition**
1	94% Lyocell / 6% elastane

2	100% cotton
3	81% silk / 14% nylon / 5% elastane
4	95% viscose bamboo / 5% elastane

Initially all the samples were tested for the thickness using standard ASTM D1777 - 96(2019), and surface density using standard ASTM D3776 and air permeability using FX3300 using standard EN ISO 9237. The values of air permeability, thickness and density of fabrics is mentioned in Table 2.

Table 2: Air permeability, Thickness and Surface Density values of specimens

T-shirts		**Air permeability [mm/s]**	**Thickness [cm]**	**Surface density [g/m^2]**
No.	**Materils composition**			
1	94% Lyocell / 6% elastane	31 (±1.5)	0.069(±0.01)	179(±4.9)
2	100% cotton	30(±1.9)	0.128(±0.04)	210(±5.5)
3	81% silk / 14% nylon / 5% elastane	85(±2.5)	0.121(±0.03)	182(±4.6)
4	95% viscose bamboo / 5% elastane	7(±0.8)	0.075(±0.01)	234(±7.2)

For the water vapour permeability 3 standard methods (as listed below) and one novel technique is used

1. Evaporative dish method or control dish method (BS 7209)
2. Permetest (ISO 11092)
3. Thermal manikin (ASTM F2730-10)

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Moisture vapor is transported through fibrous substrates by following process:

i. Water vapors pass through the air spaces between the fibers by diffusion
ii. Absorption and transmission followed by desorption of the water vapor through the fibers
iii. Water vapors are Adsorbed and transmitted along the surface of fiber
iv. Water Vapors are migrated by forced convection

Study of scientific literature highlighted that researchers are focused to resolve the problems of reliable determination of vapor permeability characteristics of textile substrates. The development of textile substrate with essential moisture transmission properties is the hour of need. The selection of experimental procedure is very important during assessment of moisture transmission parameters of textile substrate or clothing assembly.

Heat and moisture transfer through fabric is evaluated in two states i.e. Steady state and Transient state.

i. Thermal sweating manikins

Thermal manikin was first developed during World War II by America. Afterwards, numbers of manikins were developed. For the last 20 years, Empa has developed heated sweating body parts and a whole body sweating thermal manikin (Sweating Agile thermal Manikin, SAM). These manikins were employed in clothing research to evaluate water vapor resistance and insulation properties under steady state conditions. On the other hand, this investigation of effects of clothing, posture, wind and climate on local heat flux from different parts of the body.

The first thermal manikin “walter” was made of water and high strength breathable textile substrate to keep thermal regulation system of human body. Walter is not expensive and acquires high accuracy.

The key systems of “Walter” are:

i. Water circulation system

ii. Control and measurement system
iii. System for imitation of "Walking" motion

The sweating heated TORSO consists of cylinder with external diameter of 30 cm, segregated into two guard section at the end and determination section in the center. Each segment is operated with either constant power or temperature. Water was utilized for stimulating heat at controlled rate through 54 sweat outlets spread over the surface of evaluation section.

Fan and Chen mentioned a new perspiring fabric for thermal manikin replicating gaseous perspiration by moisture transportation through "skin" made of a breathable fabric. The manikin has been utilized to measure moisture vapor resistances and thermal insulation of clothing assemblies and established high reproducibility and accuracy.

ii. The PERMETEST apparatus

This instrument is patent of Prof. Hes employed for determination of water vapor permeability of textile substrates, soft polymer foils, non-woven webs and garments. The principle of this equipment is based on sensing of heat flux by calculation of evaporative heat resistance. In case of isothermal conditions, the temperature of measuring head is maintained at room temperature. Heat provided to keep constant temperature with and without fabric mounted on plate is evaluated.

$$\text{Relative watervapor permeability } (\%) = \frac{\text{Loss of heat by placing fabric on measuring head}}{\text{Loss of Heat from bare measuring head}} \times 100 \quad (1)$$

This method can be utilized according to both BS 7209 and ISO 11092 standards [4].

iii. Evaporative dish method

It is also called Gravimetric method, which is employed to measure water vapor transmission rate through textile substrate. The tested specimen is secured over the open mouth of a dish containing water and placed in the standard atmosphere. After certain period of time, total system maintained its equilibrium state. Then weight of the dish is performed sequentially and rate of water vapor transfer through the sample is determined. Water vapor permeability is measured in steady state condition. The relative permeability of the specimen is measured by comparing experimental test results with a reference fabric.

$$\text{Water vapor permeability(WVP)} = 24\ \text{M/A.T}(\text{gm}^2/\text{day}) \quad (2)$$

$$\text{Relative water vapor permeability index}(\%) = (\text{WVP})\text{f} \times 100/\ (\text{WVP})\text{r} \quad (3)$$

Where M is the loss in mass (g) of water vapor through the fabric specimen, T is the time between weighing (h), A is the internal area of the dish (m^2), (WVP)f and (WVP)r are the water vapor permeability of the test fabric and reference fabric, respectively.

Following results are obtained:

Water vapor permeability through gravimetric method, thermal manikin, and Permetest is mentioned in Table 3

Table 3: Water vapor permeability values of different specimens

T-shirts		***Water vapour permeability-gravimetric method [g/m²/d]***	***Ret-Thermal Manikin [m².pa/W]***	***Ret-Permetest [m².pa/W]***
No.				
1		*4333 (±28)*	*62.03(±2.4)*	*3.1(±0.2)*
2		*3996(±31)*	*31.26(±3.1)*	*4.4(±0.09)*
3		*4214(±17)*	*67.09(±4.2)*	*1.9(±0.08)*
4		*4090(±35)*	*62.55(±5.7)*	*3.6(±0.14)*

The difference of the unit is not a matter of concern as different devices work on completely different working principal and it only important if the trend of each sample is comparable to the other device measurement.

It can be concluded from our research that water vapor permeability from different devices/standards are comparable especially in terms of the trend behavior, but the absolute values are very much different.

FUTURE COLLABORATIONS (if applicable)

The STSM was very useful to know the research capacbilities of both institutes and find opurtunities to apply for mutual projects.
The research work performed can alse be used for a conference proceedings.