METHOD OF PATTERN MAKING FOR SWEATING THERMAL MANIKIN FOR RESEARCH EXPERIMENT PURPOSES

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Abstract: *This paper is showing the technique, which was developed during the research of Redefining Men's Shirt Pattern[1], of making a tightly fitted shirt pattern for the sweating thermal manikin (model-Newton) for the usage of the research experiments. From supplies to the pattern making procedures are clearly reported with details. The finished shirt is closely fitted to the manikin with minimum air gaps and the pattern can also be graded into different sizes for research purposes. The goal of making this pattern set for the manikin is to understand the true effect of air gaps influenced on the thermal insulation (R_{ct}) and the evaporative resistance (R_{et}). With this method, the researcher will know the increase of the air gap that is built into the shirt from minimum to different sizes of the air gap. Hence, it will benefit the study of air gaps related to thermal insulation and the evaporative resistance rather than using the ready-to-wear shirt which will only give the size labels without knowing the air gap distance that is built in the measurements of the shirt.*

Keywords: *shirt pattern, thermal insulation, evaporative resistance, grading, ready-to-wear, sweating thermal manikin.*

1 INTRODUCTION

Using shrink-wrap or duct tape [1, 2] to create a fitting mannequin for clothing is a common method in the fashion industry. However, it is difficult to trace back who is the first one to use this technique nor since when shrink-wrap/duct tape technique has been used. The shrink-wrap or duct tape technique (seems like a molding method in casting sculpture) is mostly used to clone oneself's own body for his/her fitting or to use it as the duplicated self to create clothing for his/herself. Because of this reason, the finished body part can only fit the person who has been duct-taped or shrink-wrapped to create the molding. More, shrink-wrap or duct tape is directly applied onto a lightly clothed person; no detailed or analytical measurements are recorded. The goal of this cloning technique is to obtain "another self" for easy fitting and creating fashion for oneself.

Thermal insulation and evaporative resistance are two major factors influencing wearing comfort. A lot of research had been done by using thermal manikin putting on ready-to-wear garments. For examples: Chen, Fan, Qian & Zhang [3-4] were using thermal manikin to find out the interactions between air gap and thermal resistance, as well as moisture vapor resistance; Jintu Fan & Tsang [5] investigated clothing thermal properties on sweating manikin; Qian & Fan [6] used Walter – the sweating manikin to predict the thermal insulation and moisture vapor resistance. Also, a lot of articles are related to using textiles and ready-to-wear clothing on the thermal manikin to find out the heat and mass transfer related to clothing protection and comfort [7-10]. All of these experiments, even though the results were quite similar that was when the air gap distance increase, the insulation or water vapor resistance increase. However, most of the researchers were using ready-to-use textiles or clothing. For clothing, researchers are relied on the company's size label to determine the dimension (air gap size) of the clothes but each company's standard of sizing system may not be the same and it is difficult to compare the results from one company to another. To solve this problem, the method of preparing a clothing pattern for sweating thermal manikin model of any kind was developed during the research of the Redefining the Man's Shirt Pattern1 (F. T. Fung, A. Havelka, 2017 - 2018). It is the adaptation of combining the shrink wrap and duct tape techniques, with accurate measurements and marking systems to ensure the accuracy of the patterns so that the finished pattern set can be transferred to another laboratory for repetitive research purposes.

The goal of the closely fitted manikin pattern set is to standardize the clothing size (which is the air gap size that is built-in the clothing) just only for the experiment purposes but not for the selling. Hence, results can be compared between different materials and garment sizes from different researchers' experiments.

2 METHODS

2.1 Supplies and tools

Supplies and tools are commonly used stuff that can be found in any supermarket or stationery store. The quantity and their purposes are given in Table 1.

2.2 Techniques and procedures

In order to develop a closely fitted shirt for the sweating thermal manikin model - Newton, the process is divided into 2 parts: Part 1 is the torso, part 2 is the sleeve. The following are the procedures:

Part 1: The torso

Step 1: Using small stickers as reference points and marked on the thermal manikin (Figure 1). Then the distance of each of the position points was recorded by tape measure (Tables 2 and 3).

Step 2: Plastic shrink-wrap was used to wrap around the entire upper body of the thermal manikin for the prevention of accidental damaging the manikin and for easy unmolding. Also, the reference points could be easily seen through the clear plastic film.

Step 3: Silver duct tape was taped along the contour of the manikin's torso on top of the plastic wrap and at the same time the reference points were transferred and marked on the silver tape by a marker.

Step 4: Cut lines were drawn by connecting the reference points along the contour of the manikin. Carefully cut along the drawn lines using a pair of round point scissors.

Step 5: 3D pattern pieces were unmolded.

Step 6: Pressed down the 3D pattern pieces on top of a piece of brown paper and traced the outlines of each piece.

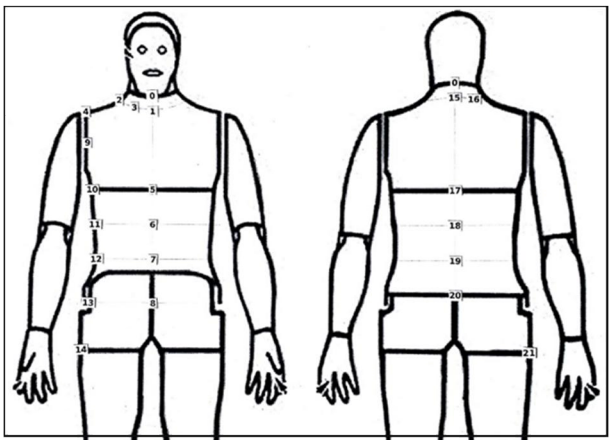


Figure 1 Thermal manikin was marked with reference points from 1 to 21

Table 1 Details of materials, quantity and the purpose of the shirt making procedures

Supplies and tools	Quantity	Purpose
Shrink-wrap	1 roll – any dimension	to protect the manikin from scratches
Duct tape	1 roll – wider the better	to create the 3D pattern from the manikin
Small sticker	1 package – smaller the better	for marking on the manikin
Marker	1 Black, 1 Red, 1Blue	for transfer marks and marking on the manikin
Tape measure	1 roll	to take measurements for confirmation
Scissor	1 pair	for cutting materials to fit the manikin and cutting pattern pieces
Pen and writing pad	1 each	for taking records
Camera	1 piece	for taking photo records
Brown paper	1 roll – wider on the width	for converted 3D patterns to 2D pattern pieces
Pencil and eraser	1 each	for pattern pieces transferring
Curve rulers	1 set	for truing the pattern pieces

Table 2 Reference points and their position chart

Number	(X, Y) [cm]	Description	Number	(X, Y) [cm]	Description
0	(0, 0)	center front neck	11	(0, 10)	from point 10
1	(0, 5)	5 mm down from center front neck 0, 0	12	(0, 10)	from point 11
2	(12, 5)	from center front neck 0, 0	13	(0, 14)	from point 12
3	(-7.5, 5)	from point 2 to point 1	14	(0, 14)	from point 13
4	(0, 10)	from point 2	15	(0, 5)	5 mm down from center back neck 0, 0
5	(0, 22)	from center front neck 0, 0	16	(-6, 5)	from point 15 to point 2
6	(0, 33.5)	from center front neck 0, 0	17	(0, 24.5)	from center back neck 0, 0
7	(0, 42)	from center front neck 0, 0	18	(0, 35.5)	from center back neck 0, 0
8	(0, 56.5)	from center front neck 0, 0	19	(0, 44.5)	from center back neck 0, 0
9	(0, 14)	from point 4	20	(0, 59)	from center back neck 0, 0
10	(25, 5)	from point 5	21	(-48, 0)	from point 14

Table 3 Confirmation of the measurements between reference points

Description	Connected numbers	Total measurement [cm]	Description	Connected numbers	Total measurement [cm]
half front neck	1-3-2	8+7.5=15.5	side-mid-waist to waist	11-12	10
shoulder	2-4	10	side-waist to hips	12-13	13.5
half front chest	5-10	24.5	half back neck	15-16-2	6+6=12
half front mid-waist	6-11	22.5	half back chest	17-10	21
half front waist	7-12	20	half back mid-waist	18-11	18
half front hips	8-13	24	half back waist	19-12	17
mid armhole	4-9	14	half back hips	20-13	24
under armpit	9-10	14.5	center front length	1-5-6-7-8	17+12+9+14=52
side-chest to mid-waist	10-11	10.5	center back length	15-17-18-19-20	20+9.5+10.5+14.5=54.5

a) The torso of the manikin was wrapped around by shrink-wrap

b) Silver duct tape applied on the manikin to obtain the tightly fitted 3D body shape measurements

c) The unmolded half of the right front side of the 3D molding which was cut open along the center front and the center backline

d) Half of the right side back 3D body molding

e) After transforming from 3D pattern pieces to 2D pieces by using confirmation of measurement table to correct the dimension of each piece of the 2D pattern and 1 cm of seam allowance is added around each pattern piece for sewing purpose

f) The first test shirt was made from the 2D pattern pieces with minimum air gaps between the manikin and the shirt

Figure 2 The procedures of the molding method for the torso pattern development

Step 7: Using reference points and the recorded position tables to confirm the dimension of the 2D pattern pieces were accurately drawn when they were compared to the 3D molding pieces. Using a curved ruler set to perfect the outline of each piece of the pattern. Figures 2a - 2f are showing the procedures of the process.

Step 8: To finish the pattern set, one centimeter of seam allowance (for joining pattern pieces together) is added around each pattern piece.

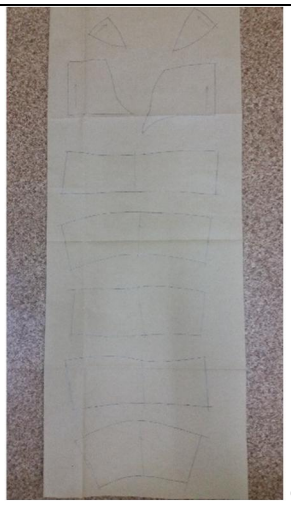
Part 2: The sleeve

The steps were similar to the torso. Figures 3a - 3f are the procedures for arm pattern development:

a) Sticker marked the center point of the upper arm which was wrapped by shrink-wrap

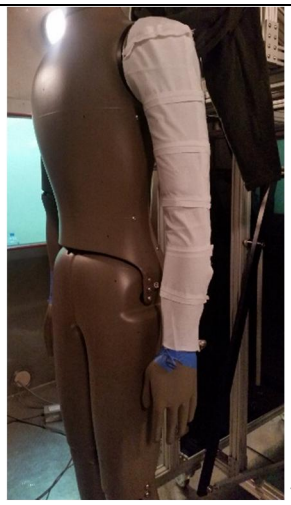
b) Silver duct tape covered shrink wrap and markings were transfer to duct tape

c) 3D molding was flattened and ready to be traced onto the brown paper



d) 3D molding traced the outline on brown paper

e) Finalized 2D pattern pieces ready to be used for making a sleeve



f) First fitted sleeve sample with minimum air gaps

Figure 3 The procedures for arm pattern development

Table 4 The total increase in each sample's circumference and the increase in each sample's front and back pattern pieces

Sample number	Radius increase and total increase in sample's circumference	Equal amount increases in the front piece and back piece
sample 1	r = 144.8 mm (no increase), 910 mm	0
sample 2	r + 3 mm = 147.8 mm, 928.65 mm	18.65 mm/2 = 9.3 mm
sample 3	r + 5 mm = 149.8 mm, 941.22 mm	31.22 mm/2 = 15.61 mm

3 GRADING SAMPLE TO DIFFERENT SIZES

Assuming the cross-section of the thermal manikin is a geometrical shape of a circle (Figure 4), hence; the following equation applies to any cross-section of the manikin's torso:

$$Manikin\ Body\ Circumference\ (MBC) = 2.\pi.r \quad (1)$$

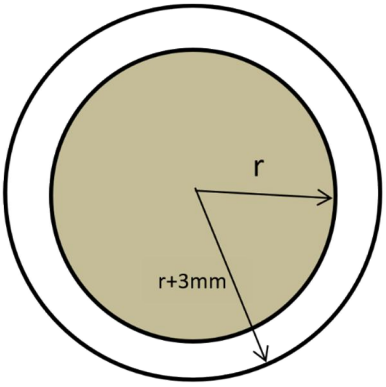


Figure 4 Assuming the grey part is the geometrical shape of the body. The white part is the air gap between the body and the clothing sample. Increase in radius affects the sample size increase, hence; air gap sizes increase

By tape measure, the chest circumference of the manikin is 910 mm, hence; using equation (1) the radius of the chest is 144.8 mm. Based on the clothing pattern of the first sample with minimum air gaps, the clothing pattern of other sizes each will have an increase in the radius of the manikin body circumference. For example, the increase in the radius is 0; 3 and 5 mm and so on. Hence, the total increase of the pattern sizes is calculated as follow:

$$Grading\ Size\ of\ Shirt = 2.\pi.(r + i) \quad (2)$$

where: i is the increase of the radius: 0; 3 and 5 mm and so on.

The increase of the body circumference from each of the samples will be divided equally and distributed to the front and back on the pattern pieces as shown in Table 4.

4 CONCLUSION

The technique of making the closely fitted shirt pattern for the sweating thermal manikin is a simple and effective method for the researchers. It is because the researchers not just knowing how much the air gaps are built in the garment, also they can decide the air gap size to suit their needs for the experiment. More, this technique can be applied to any model of sweating thermal manikin: male, female, child, hand, head or leg, and the finished clothing can be transferable to other labs for repetitive experiments or for comparison verification.

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Note [1] "Redefining Men's Shirt Pattern" is an ongoing project by means of four major parameters: thermal insulation, water vapor permeability, air permeability and movement; to redefine the traditional men's shirt pattern that was developed hundreds of years ago through draping techniques or try and error method but with no strong scientific data to prove that how the sizes and shapes of the pattern pieces can provide warmth and wearing comfort.