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Applying New Textile Materials and Technology to Panties and Sanitary Pads to Ensure Women's Menstrual Health according to Sustainable Development

Ngoc Nguyen Thi Thuy, Trang Ngo Thi Thu, Huong Chu Dieu*
Hanoi University of Science and Technology, Ha Noi, Vietnam
**Corresponding author email: huong.chudieu@hust.edu.vn*

Abstract

Menstrual panties, sanitary pads, menstrual cups, and tampons are essential products to protect women's health during menstruation. Menstrual panties and cloth sanitary pads are currently highly appreciated because they ensure health and hygiene for women's bodies, can be reused, helping to limit waste to the environment. This article presents the research on the application of new textile materials and technology to panties and sanitary pads to ensure women's menstrual health according to sustainable development. A terry cotton knitted fabric with a spatial structure was used as an absorbent and menstrual fluid storage layer. A polyester textured knitted fabric with good absorbency, and capillary properties, quick drying was the inner layer in directly contact with the wearer's body. A waterproof knitted fabric was the two outer layers to prevent fluid from moving out. The adhesive method and seam tape were applied to connect the textile layers ensuring the seams were also waterproof. Four samples of menstrual panties and cloth sanitary pads with different thicknesses of fluid storage layer were created, tested and evaluated. The evaluation results show that the panties and pads samples can absorb and contain up to 50 ml of liquid without leakage to the outer surface. The results also show that the product samples can be easily cleaned and dried quickly. These research results are the basis of the commercial development of menstrual panties and cloth sanitary pads products in sustainable trend.

Keywords: Menstrual health, menstrual panties, sanitary pads, textile materials and technology, textile sustainable development.

1. Introduction

The menstrual period of women usually starts at around 14÷15 years old and ends between 45÷55 years old. About 6÷7 years in a woman's life is menstruation. A menstrual cycle usually lasts from 3÷7 days, the time between cycles is usually 28÷30 days apart depending on the person.

During this time, women have to deal with the effects of menstruation on their lives such as menstrual cramps, bloating, flatulence, lower back pain, chest pain, headaches, difficulty sleeping, insomnia, irritability, mood swings, etc. Normally, the amount of blood lost after each menstrual cycle is about 50÷80 ml. The actual amount of blood in menstruation accounts for about 36%, the remaining 64% is other components such as uterine lining, cervical mucus, and vagina.

Currently, popular products that help women ensure safety and hygiene during menstruation are disposable sanitary napkins and tampons. In addition, there are other reusable products that are recommended for use such as menstrual cups, menstrual panties, and cloth sanitary napkins. These products are considered to help save and reduce waste to the environment, in line with the current trend of sustainable development. In particular, menstrual panties and cloth sanitary napkins are products used outside the vagina [1, 2].

In high-income countries most popular product of menstrual care were one-used pads and tampons. One woman can expect to use about 10,000 menstrual products in her lifetime. But tampons and pads are usually from synthetic materials which are over 90% plastic and causes the serious environmental impacts [3]. Meanwhile, these kinds of products seem to expensive for the rural women.

To avoid the environmental impacts many researchs forcused on designing reused product or the biomaterial for menstrual care product [4-7]. Chakwana C. *et al.* had investigated a low-cost reusable microfibre sanitary pad with good performance properties and low cost maintenance, affordable to poor women [4]. The design was reusable rectangular shape sanitary pads used polyester microfibre materials. It has a pocket for an insert of another material that will enhance the collection of blood. The wicking, leakage, and strike through properties were tested and the authors reported that their product exhibits better properties but cheaper than the commercial disposable pads [4]. In the other hand, in rural areas, most preferred were the natural sanitary products made from materials like banana fibre, bamboo fibre, sea sponges, water hyacinth, and so on [6].

Jasmin Foster *et al.* had investigated the low-cost natural materials such as cotton terry cloth, linen, hemp cloth, and bamboo wadding for menstrual product. They

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reported that bamboo wadding showed the highest absorptivity index (7.86), followed by linen (1.57), hemp cloth (1.4) and cotton terry cloth (0.84), while the commercial sanitary pad were 4.38 [7-8].

M. Pohlmann focused on analyse design and materials for sanitary pads. The spectra generated by FTIR/ATR suggest that the samples were composed of polypropylene. top sheets were composed by nonwoven fabric, and they were manufactured by spunbond. There was not a pattern of water absorption by capillarity of evaluated materials [9].

In this study the design of reused panties and sanitary pads with new approach was investigated to limit the environmental impact of menstrual product.

2. Requirements and Materials

Cloth sanitary pads are no different in appearance from regular disposable sanitary napkins. The difference is that they are made of highly absorbent fabric and have a waterproof outer layer, so they can be cleaned and reused many times.

Menstrual panties look similar to regular underwear. However, they are designed with a wide crotch, an inner layer that can absorb menstrual blood similar to a disposable sanitary napkin or tampon, and a waterproof outer layer that prevents passing of menstrual blood from escaping. In addition, some brands of menstrual panties use antibacterial fabrics to reduce the risk of infection and reduce odor. The shelf life of menstrual panties or cloth sanitary napkins can be from 6 months to 2 years depending on the quality of the product.

2.1. General Requirement

A sanitary napkin or menstrual panty product must meet the following requirements: 1) Be able to absorb a certain amount of menstrual blood and prevent menstrual blood from seeping out after at least 2 to 4 hours; 2) Ensure comfort in terms of thermal- humidity sensation, contact sensation, and movement for the wearer; 3) Ensure safety when in contact with the body's skin surface; 4) Be easily cleaned and dry quickly.

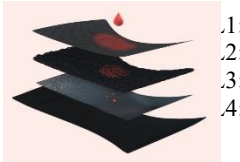


Fig. 1. Functional material layers of menstrual panties

To ensure the first and most important requirement, a menstrual panty must have functional material layers from the inside out including: a fabric layer with good liquid capillary ability; a fabric layer with good liquid absorption ability; a fabric layer that prevents liquid from seeping through; a main fabric layer (Fig. 1). Compared to menstrual panties, cloth sanitary napkins will not have a main fabric layer because when used, they will be placed inside the crotch of regular underwear.

2.2. Materials

L1: Liquid capillary fabric layer

This was the layer of material that directly contact with the wearer's skin. This fabric layer needs to have good liquid absorption and capillary properties, be soft and safe for the wearer. Currently, knitted fabrics made from modified polyester fibres meet these requirements very well. A fabric sample proposed for use in menstrual panties in this study is interlock fabric L1 (SV62791) with a composition of 80% polyester and 20% spandex, weight of 240 g/m^2, and thickness of 0.6 mm.

The test showed that this fabric sample had a capillary velocity of 0.062 cm/min in the row direction and 0.084 cm/min in the column direction, the air permeability at 125 Pa pressure was 69.34 l/m^2/s.

L2: Liquid absorption layer

Currently, based on the flow rate of menstrual blood of most women and the requirement to prevent the growth of bacteria from the fluid entering the body's private area, disposable sanitary pads are recommended to be used continuously for only about 4 hours. The same requirement is also required for menstrual panties and cloth sanitary pads. Therefore, this material layer needs to be able to absorb and contain a certain amount of liquid to ensure a minimum continuous use time of 2 to 4 hours.

To ensure the above requirements, fabrics with spatial and porous structures are often recommended for use such as cotton, polyester, and wool with thick knit patterns. A Terry L2 fabric sample (SV627921) was selected for the liquid absorbent layer with 100% recycled polyester, fleecy fabric, weight of 270 g/m^2, thickness of 1.2 mm, water absorption of 739%, and air permeability of 525.4 l/m^2/s.

L3: Liquid permeability barrier layer

Currently, waterproof technology for garment fabrics has produced fabrics that are both waterproof and still allow sweat to escape thanks to the micro-pore structure of polymer-coated membranes. There are two types of waterproof coated knitted fabric structures, which are three-layer fabrics and two-layer fabrics. Three-layer fabrics consist of two layers of 100% polyester knitted fabric and a layer of PU adhesive film in the middle. The two-layer fabric consists of a 100% polyester knitted fabric layer and an outer polymer coating layer. The three-layer fabric has a more durable waterproof layer structure, so it was chosen for use in this menstrual underwear product. Specifically, a three-layer knitted fabric sample (SV627931) was selected for the functional layer L3 to prevent liquid from seeping through (Fig. 2). The waterproof PU adhesive film has been tested to not contain PFC

according to Nike brand standards. The biggest limitation of this material is that the temperature limit during use should not exceed 150 ºC, no dry cleaning and no bleaching. The selected waterproof fabric sample has air permeability at 125 Pa pressure of 2.6 l/m^2/s.

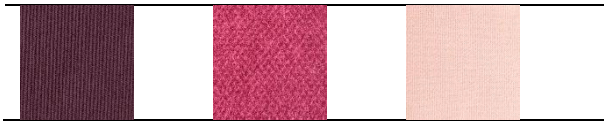
Fig. 2. Structure of waterproof fabric for L3 layer

L4: Main fabric layer

This is also the layer of material that directly contacts the wearer's skin, similar to the innermost layer of the crotch. The main fabric layer also needs to have good sweat absorption and release, ensuring comfortable contact and movement for the wearer. With the same requirements, the fabric sample SV62791 used for the innermost layer was used for the main fabric layer in this study. The fabric samples used for this product were displayed in Table 1.

Table 1. Fabric samples

L1 and L4: Inner and outer fabric layers (SV62791)	L2: Liquid absorbent fabric layer (SV627921)	L3: Fabric layer prevents liquid from penetrating (SV627931)

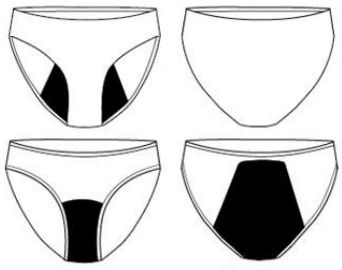


3. Product Structure

3.1. Product Shape and Fabric Layer Structure

Menstrual panties are designed with a focus on functionality and fit, so the style is less fashion-forward and more casual to suit most users. The classic panties style is shown in Fig. 3.

The structure of the material layers of the crotch is shown in Fig. 4. Layers L1 and L3 are designed to be extended backwards to increase the ability to prevent menstrual blood from seeping out of layer L3. Menstrual panties and sanitary pads are designed with two levels of menstrual blood so that users can choose according to the time of their menstrual cycle. With such requirements, the L2 layer is designed with different thicknesses, specifically the thin type of L2 layer has 1 layer of fabric and the thick type has 2 layers of fabric stacked on top of each other. Layer L2 of thick type designed to consist of 2 component layers of different sizes, layer L2.1 on the inside is smaller and shorter than layer L2.2 on the outside.



a) Outside face b) Inside face

Fig. 3. Technical description of menstrual panties

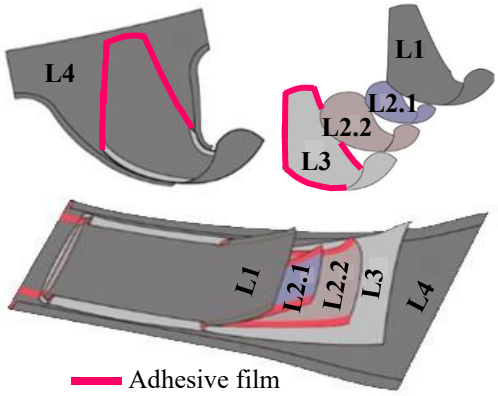


Fig. 4. Crotch structure

The side seam bonding uses an overlap seam. The waistband and leg seams use a foldover hem. The crotch material layers are bonded using a thread and adhesive seam (Fig. 5).

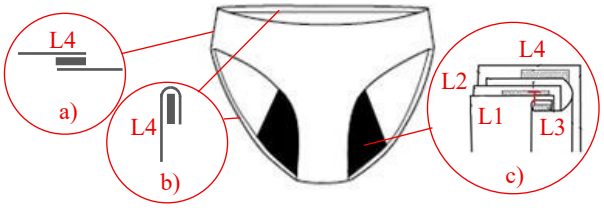


Fig. 5. Overlap seam on side lines (a), foldover hem seam on waistline and bottom lines (b), adhesive bonding on crotch (c)

The detail technical design of the menstrual panties was developped to ensure a perfect fit and maximum coverage of the human body surface from the groin-crotch area to the back waist. The cloth sanitary pads were designed in the same way as the crotch structure, that was, without the L4 material layer. The patterns were designed for women with a hip circumference of 90 cm and a waist circumference of 66 cm. The cutting patterns of the panties and sanitary

pad with two absorbent layers was shown in Fig. 6.

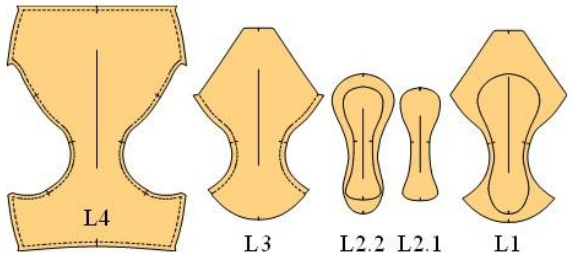


Fig. 6. Patterns of menstrual panties (L1, L2.1, L2.2, L3, L4) and cloth sanitary pad (L1, L2.1, L2.2, L3)

3.2. Technology Parameters in Adhesion

The adhesive method is used for most of the fabric layer bonding (shown in Fig. 4) to ensure the ability to prevent liquid from permeating, reduce the thickness and stiffness of the product at the connection locations.

The pieces are preliminarily bonded with a heat iron and fixed with a Heat Seal machine (Fig. 7a). Bemis adhesive films are selected for these products. The technical parameters of adhesive films and bonding technology parameters are shown in Table 2.

a) b)

Fig. 7. Equipment used: a) Heat Seal laminating machine, b) CRE breaking machine

Table 2. Technical parameters of adhesive films

Adhesive film	Code	Position	Film thickness (mm)	Adhesive materials	Adhesive thickness (µm)	Mass (g/m^2)	Bonded temperature (°C)	Heat pressing time (s)	Cool pressing time (s)	Pressure (kg)
3916.6	A1	Foldover hem seam on waist line	10	Elastic Polyurethane	152	30	155÷160	20	5	4
3913.3	A2	Foldover hem seam on bottom lines	8	Elastic Polyurethane	89	30	145÷150	20	5	4
		Overlap seam on side lines	10							
3415.3	A3	Overlap seam between fabric layers on crotch	10	Ester Polyurethane	75	31	145÷150	20	5	4

Table 3. Tests for bonding seams

(H: horizontal direction, V: vertical direction, BB: back-back fabric sides, FB: face-back fabric sides)

Code	Position	T-Peel Test	Modulus and Recovery Test
A1	Foldover hem seam on waist line	L1-L1 (BB/V)	L1-L1 (BB/VH)
A2	Foldover hem seam on bottom lines	L1-L1 (BB/H)	L1-L1 (BB/H)
	Overlap seam on side lines	L1-L1 (FB/H)	L1-L1 (FB/V)
A3	Overlap seam between fabric layers on crotch	L1-L3 (BB/V), L1-L2 (BB/V)	L1-L3 (FB/H)
	Foldover hem seam on crotch edges	L3-L3 (BB/H)	L3-L3 (BB/V)

The prototype of menstrual panties and cloth sanitary pad with two absorbent layers is shown in Fig. 8.

a) b)

Fig. 8. Prototypes of menstrual panties (a) and cloth sanitary pad (b)

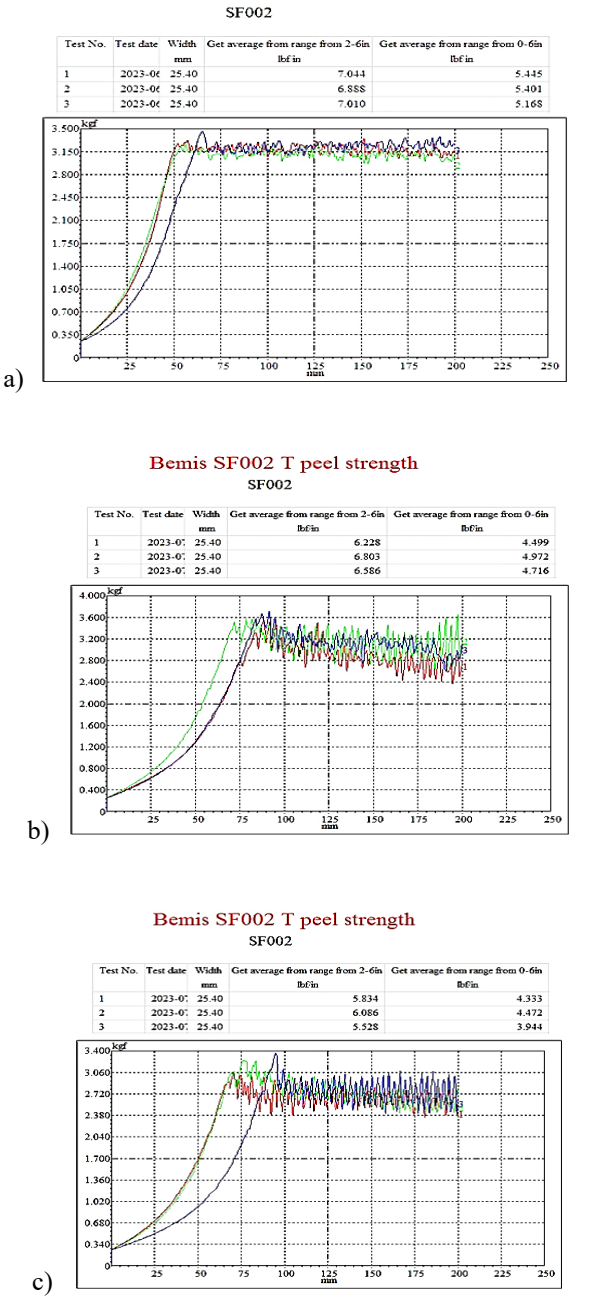
4. Function Assessment of Product

The seams and edge processing on menstrual panties and sanitary pads must ensure the criteria for the bonding strength of the material layers, the stretch and recovery, and the absorbency and water resistance. The mechanical criteria are tested and evaluated by Peel Bond Strength Test (T-Peel Test), Modulus and Recovery Test according to ASTM D1876-01 and ASTM D4964-96 standards [10-11] on a tensile machine (Fig. 7b) for bonding seams shown in Table 3. Water Resistance Test of the crotch and sanitary pads are checked by direct visual testing on the product. All tests to evaluate the quality of the seams are performed with samples after 20 washes, water temperature 40 °C.

4.1. Mechanical Properties of Seam Samples on Waist Line, Bottom Line, and Side Line of Menstrual Panties

The measurement results of T-Peel Test on with L1 fabric, A1 and A2 adhesive were shown in Fig. 9. The measurements for all specimens showed that the peel force was greater than 3 lbf/in that is a common requirement for the peel strength of casual garments. Both A1 and A2 adhesives provided the required peel strength for the product. A1 adhesive had a higher peel force, indicating that it was more suitable for use on foldover hem on waistband line.

The results of determining the elongation and recovery of the seam samples were shown in Fig. 10, Fig. 11, and Table 4.



a)

b)

c)

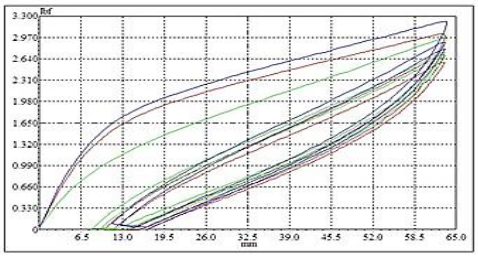
Fig. 9. The results of T-Peel Test with L1 fabric: a) A1 adhesive, BB bonding in vertical direction, b) A2 adhesive, BB bonding in horizontal direction, c) A2 adhesive, FB bonding in horizontal direction

Table 4. Stretch and recovery of bonding seams

Adhesive	**A1**		**A2**		**A3**	
Direction	**V**	**H**	**V**	**H**	**V**	**H**
Tensile strength 30% (N)	10.183	9.210	7.226	6.424	7.989	6.748
Tensile strength 50% (N)	13.637	12.560	8.734	8.735	10.271	9.852
Stretch recovery (%)	96.8	98.0	96.0	98.7	90.4	95.2

a)

Test No.	Test date	Width mm	Tensile strength 30% N	50% N
1	2023-0	25.400	10.798	13.461
2	2023-0	25.400	9.333	13.344
3	2023-0	25.400	11.419	14.305



b)

Test No.	Test date	Width mm	Tensile strength 30% N	50% N
1	2023-0	25.400	8.867	12.116
2	2023-0	25.400	9.603	13.023
3	2023-0	25.400	9.160	12.540

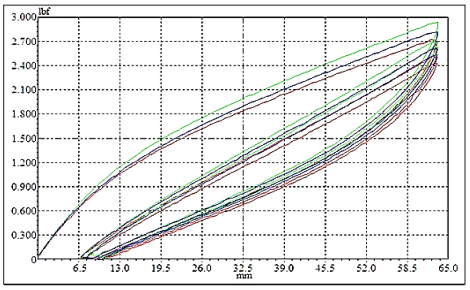
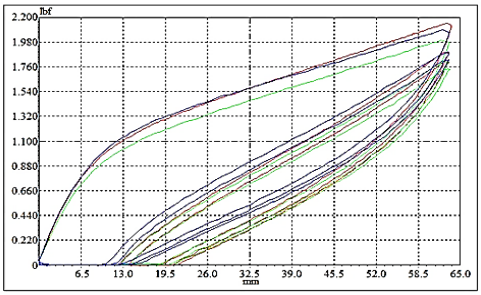


Fig. 10. The results of Modulus and Recovery Test with A1 adhesive, L1-L1 fabric, BB bonding in vertical direction (a), in horizontal direction (b)

a)

Test No.	Test date	Width mm	Tensile strength 30% N	50% N
1	2023-0	25.400	7.418	9.543
2	2023-0	25.400	6.889	8.934
3	2023-0	25.400	7.370	9.317



b)

Test No.	Test date	Width mm	Tensile strength 30% N	50% N
1	2023-0	25.400	7.004	9.409
2	2023-0	25.400	6.170	8.493
3	2023-0	25.400	6.097	8.304

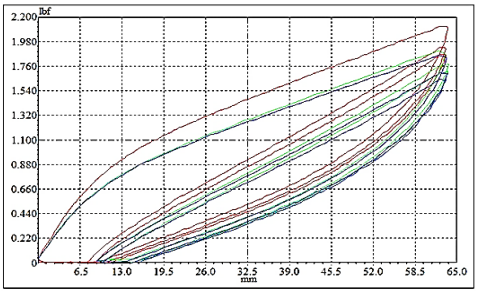


Fig. 11. The results of Modulus and Recovery Test with A2 adhesive, L1-L1 fabric, FB bonding in vertical direction (a), BB bonding in horizontal direction (b)

The results showed that the seams using A1 adhesive have both high elastic modulus and high elongation recovery in both directions, which was suitable for the requirements of the waistband which requires good elongation and recovery. The seam using A2 adhesive had a smaller elastic modulus, but the stretch recovery is almost the same as that of A1 adhesive. Using A2 adhesive for the seam along the pants and hem ensures good stretch and stretch recovery, the pressure on the body was not too great.

Foldover hem seam on waistline and bottom lines, and overlap seam on side lines only need to ensure the same mechanical durability as common underwear products. In this case of using A1 and A2 adhesive, peel strength of seams exceeds 3 lbf/in and stretch recovery exceeds 96%. These show that requirements of this product have ensured. Therefore, using A1 and A2 glue for both areas is appropriate in the case of this product.

4.2. Mechanical Properties of Seam Samples on Crotch

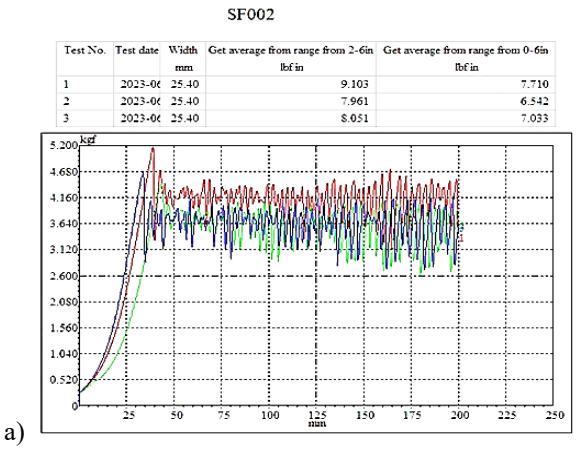
The results of T-Peel Test with L1-L3 fabric, L1-L2 fabric, L3-L3 fabric, A3 adhesive were shown in Fig. 12. The results of determining the elongation and recovery of the seam samples on crotch were shown in Fig. 13 and Table 4.

The measurements for all specimens show that the adhesive peel force of L1-L3 seams and L1-L2 seam exceeds the value of 3 lbf/in by a large margin (Fig. 12a and Fig. 12b). The peel force average of L3-L3 seams is 2.757 lbf/in that is slightly lower than the value of 3 lbf/in (Fig. 12c). The L3-L3 seam is in the closed and fixed area, and is hardly subjected to direct peel force, so lower peel strength can be accepted.

The seams with A3 adhesive have low stretch recovery ability (Table 4) because A3 is a type of adhesive with low elasticity and stretch recovery ability. A3 adhesive was suitable for these bonding seams, which was also more popular and less expensive than the other two adhesives. Therefore it was used for seams in the crotch area of panties that often stretch less and must ensure the ability to prevent liquid from seeping through even when the pants stretch when worn.

4.3. Liquid Absorbent and Impermeability of Cloth Sanitary Pad Samples

The experiment was designed based on a real simulation. Two samples of cloth sanitary pads with one layer and two absorbent layers were placed horizontally on a white absorbent paper. The liquid used was water. Water was introduced into the material layer L1 at a rate of 10 ml in 3 minutesThe phenomenon of water absorption and seepage to the outer surface of layer L3 was observed. The amount of water introduced when there was a phenomenon of water seeping out of layer L3 was determined.



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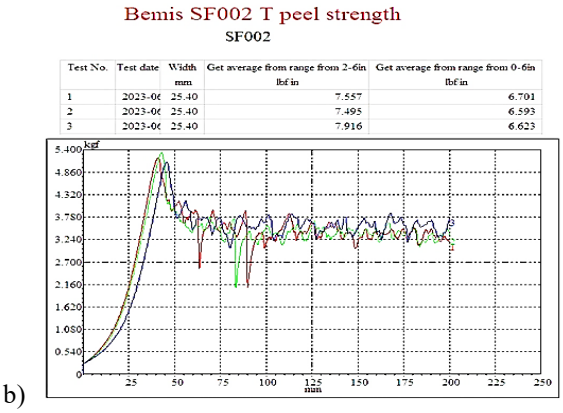

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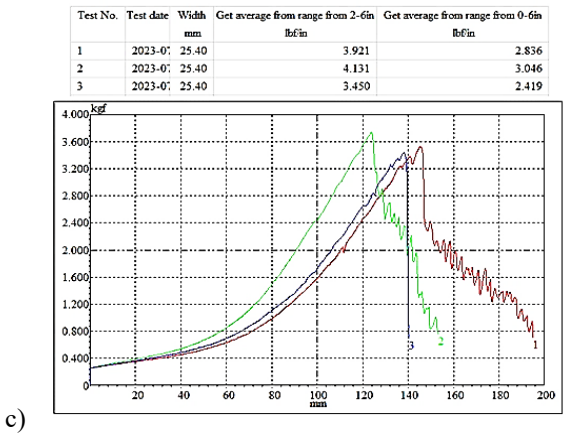
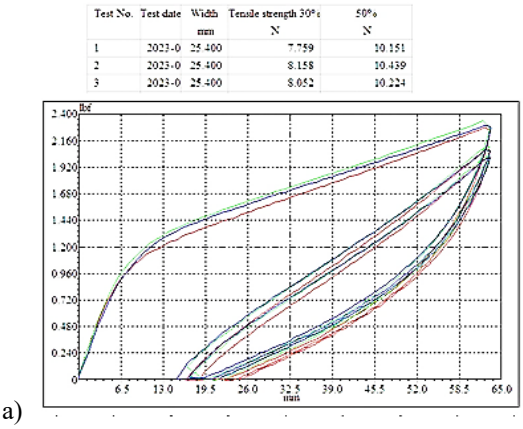


c)

Fig. 12. The results of T-Peel Test with A3 adhesive: a) L1-L3 fabric, BB bonding in vertical direction, b) L1-L2 fabric, BB bonding in vertical direction, c) L3-L3 fabric, BB bonding in horizontal direction



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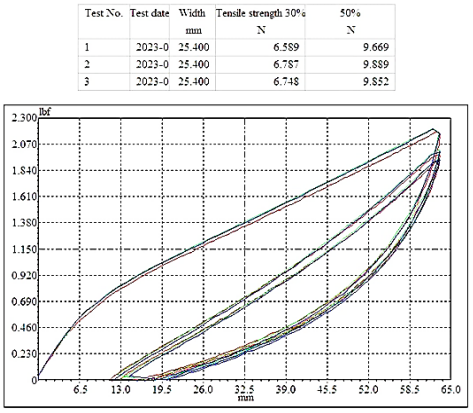

b)

Fig. 13. The results of Modulus and Recovery Test with A3 adhesive, L3-L3 fabric và BB bonding in vertical direction (a), L1-L3 fabric và FB bonding in horizontal direction (b)

The results showed that the absorbent single-layer sanitary pad sample had a phenomenon of water seeping through the L3 layer when 40 ml of water is added. This phenomenon occurs for the absorbent double-layer sanitary pad sample after 60 ml of water is added. The first seepage positions are located at the foldover hem of crotch for both samples. The images of the inside and outside of the two sanitary pad samples when water seeps through are shown in Fig. 14. Thus, the maximum absorption and leakage prevention capacity of the absorbent single-layer sanitary pad sample is only 30 ml of water, for the absorbent double-layer pad it is 50 ml of water under these simulated test conditions.

The absorbency of menstrual panties and cloth sanitary pads can be increased by enlarging the area of the L2 absorbent material layer and adding L2 absorbent fabric layers.

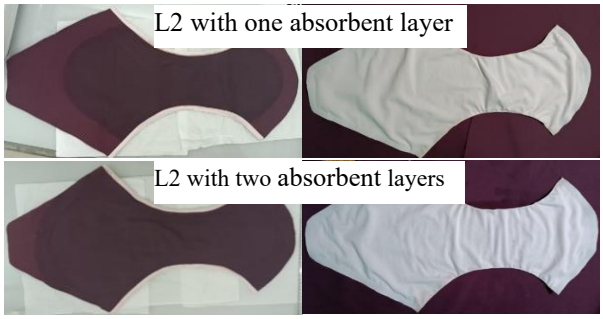

Fig. 14. Photos of two cloth sanitary pad samples with water seepage

5. Conclusion

Textile materials with good capillary and liquid absorption functions, and liquid repellent functions have been studied and applied in menstrual underwear and cloth sanitary pads. Along with that, garment processing technology by adhesive method has been applied to successfully manufacture samples of menstrual underwear and cloth sanitary pads. The results of testing and evaluating the durability of the adhesive bonding using 3 types of Bemis adhesives showed that the products met the requirements and can continue to be tested in industrial production models. The ability to stretch and stretch recovery of the adhesive bonding showed that the adhesive method was suitable for tight-fitting products made from knitted fabrics. The results of evaluating the ability to absorb and prevent liquid from penetrating showed that it depends a lot on the absorbent fabric layer inside and the waterproof fabric layer outside. This evaluation result has been still limited because the simulated test model hasn't been completely similar to the actual use of the product. However, this study also showed the direction to improve and continue to develop menstrual panties and cloth sanitary pads product in the future.

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