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A study on the thermo-pressing sewing method for prevention of allergen penetration through micropore fabric

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Abstract−Micropore fabrics have been proposed to reduce exposure to house dust mite allergens in the field of environmental management methods. However, there is not an adequate method for verifying allergen impermeability of these micropore fabrics yet. In this study a particle penetration device was developed to test the allergen barrier performance of micropore fabrics against house dust mite allergens. The weight reduction rate of each micropore fabric was measured using the particle penetration device. At the given pressure and 90 seconds, the weight reduction ratio reached 35.6% for 6550 fabric, 13.6% 6560 fabric and 6.8% for 6563 fabric compared to 99.9% of 6060 fabric. In addition, a thermos-pressing sewing method, in which the bonding thread and the stitching portion were pressed using a thermos-pressing device, was proposed. The fabric made by the thermo-pressing sewing method effectively prevented particle penetration compared with the fabric made by the general sewing process.

Keywords: House Dust Mite, Allergen, Micropore Fabric, Bonding Thread, Thermo-pressing Sewing Method

INTRODUCTION

Since scientists discovered that house dust mites are the main cause of allergy in 1967, many studies have been conducted on the relationship between house dust mites and respiratory allergies [1-4]. In many studies, 50-80% of patients with respiratory allergies have been positive for allergic skin tests for house dust mites [5,6]. Environmental management methods have been proposed using air purifiers or bedding with micropore fabrics to reduce exposure to house dust mite allergens. Products of general bedding are the major source of dust and allergen from house dust mites, so large numbers of allergens are directly exposed during sleep at night [7-10].

Recently, the most effective way to reduce house dust mite allergens in bedding was to make products such as bedclothes, pillows and mattress covers using micropore fabrics to prevent house dust mite allergen from passing through. Initially, the method of covering the bedding with a material such as a vinyl film or a coating fabric was suggested for the bedding. Because the hygroscopicity of the film or the coating material and the impermeability to the air caused the problem of obstructing the sound sleeping environment, such a method is not used at present.

As an alternative, allergen impermeable bedding made of fabric with pore size smaller than the diameter of house dust mite allergen is widely used in the bedding market [11]. However, there is no convenient and adequate method for verifying the impermeable effect of these micropore fabrics; a method of verification on the allergen impermeable effect of micropore bedding is needed. In this study the particle penetration device was developed to test the allergen barrier performance of various micropore fabrics against house dust mite allergens. The weight reduction rate of various micropore fabrics was measured to evaluate the ability of blocking allergen. In the previous study, microporous membrane filters were used to remove bacteria and particulates from fluid streams [12-15]. In particular, bubble point type tests have been used for membrane filter to correlate pore size and pressure [16,17]. But the test instrument is not simple and adequate to use in the field of fabric analysis and processing. Therefore, weight reduction rate was presented as a simple and economical test method for measuring the pore size of micropore fabrics.

Also, in the course of making bedding, a sewing machine is the main apparatus. It is inevitable that puncturing occurs in the micropore fabric by the sewing needle of the sewing machine. In this study, a bonding thread was developed to seal the perforation holes made by the needle. Thermo-pressing device was designed to compress the bonding thread. Therefore, the thermo-pressing sewing method can be effectively used to block the perforation holes caused by needles in micropore fabrics. Also, the effect of allergen-proof fabrics made by thermo-pressing sewing method was tested using the apparatus developed.

EXPERIMENTAL MATERIALS AND APPARATUS

1. Experimental Materials

We tested four kinds of micropore fabrics which are used as allergen impermeable begging as experimental materials. The microscope photographs of the surface of the experimental fabrics are shown in Fig. 1. The fabric was named according to the type of warp and weft used for each fabric. (a) 6550 fabric was made using 50 De (g/9000meter) 144 filler warp and weft; (b) 6560 fabric using 65 De 256 filler warp and 60 cotton weft; (c) 6563 fabrics using 65 De 204 filler warp and weft, (d) 6060 fabric was made using 60 count

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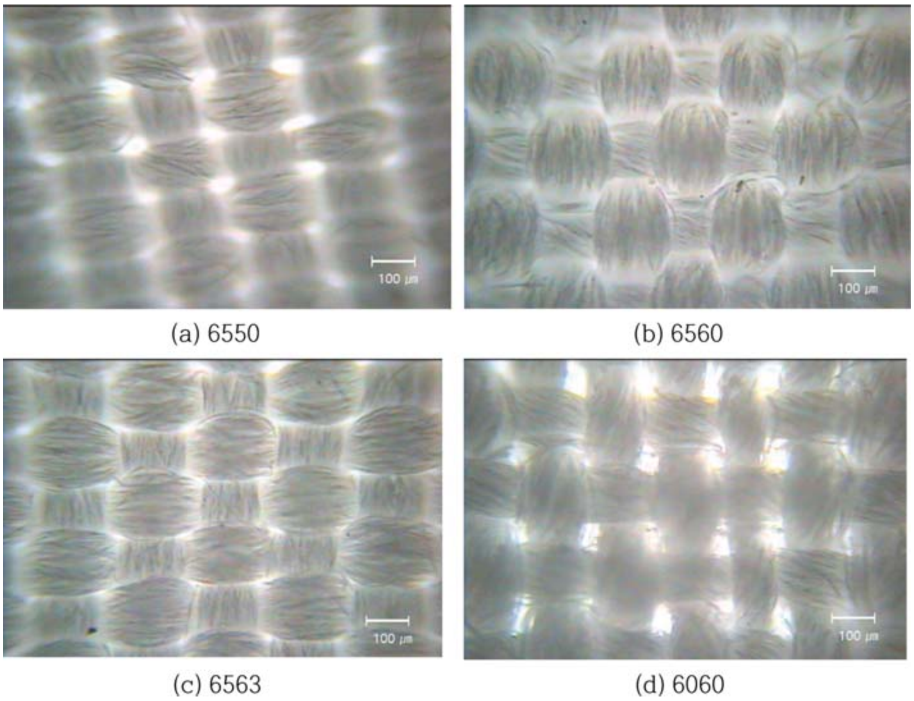


Fig. 1. Microscope images of fabrics (a) 6550, (b) 6560, (c) 6563, (d) 6060.

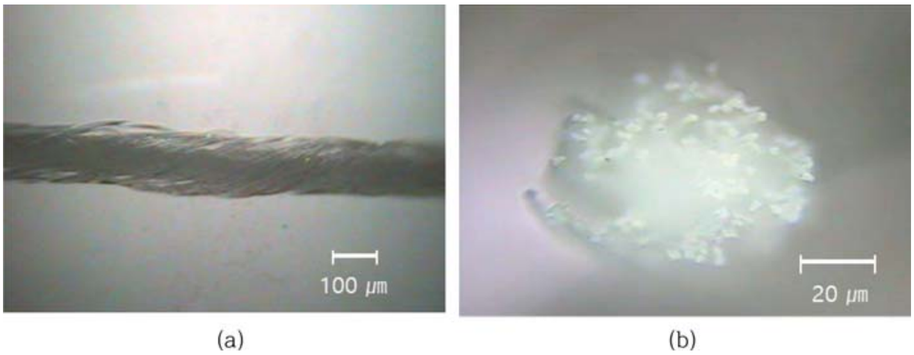


Fig. 2. Microscope images of bonding fiber (a) length side, (b) cutting section.

cotton yarn warp and weft. The small allergens in house dust mites are about 10-50 μm, which is about ten-times less than the size of house dust mites (100-400 μm). Particles of micro-sized proteins from house dust mite feces and dead bodies are main allergens that cause allergies. These house dust mite allergens are inhaled in large quantities by allergic patients with weak immunity, and lead to allergic diseases such as dermatitis, rhinitis, asthma and conjunctivitis [18-20].

It is common to use sewing machines to make futons, mattress covers, pillows and the like by using micropore fabrics. The diameter of the needle used in the sewing machine is about 800-1,200 μm, which is larger than size of the house dust mite. Therefore, when micropore fabric is stitched using such needles, large pores are generated by the punching. Through these holes, there is a passage through which the house dust mites can pass, and it is obvious that allergens smaller than ten-times of the house dust mites cannot be blocked.

We developed specially fabricated bonding thread to weld holes made by the sewing needle. In the process of fabricating the thread, two twisted yarns and core yarn were used to make a bonding thread. Polyester 65 De yarn was used for core yarn, and low melting point LM (low melting) yarns were used to twist yarn. The three yarns are twisted under condition of 750 TM (750 turn/meter). The yarn produced by this method was used as the bonding thread for the sewing process. Fig. 2 shows the side and cross-section of the bonding thread.

The ability to block the allergen of house dust mites was tested using particles with an average size of less than 10 μm. Fig. 3 shows the distribution of the average size of the particles and the microscope image of the particles used in this study. The particles named MD100, which is supplied by Sunjin Beauty Science Co. Ltd., were used as particles representing the small size of house dust mite

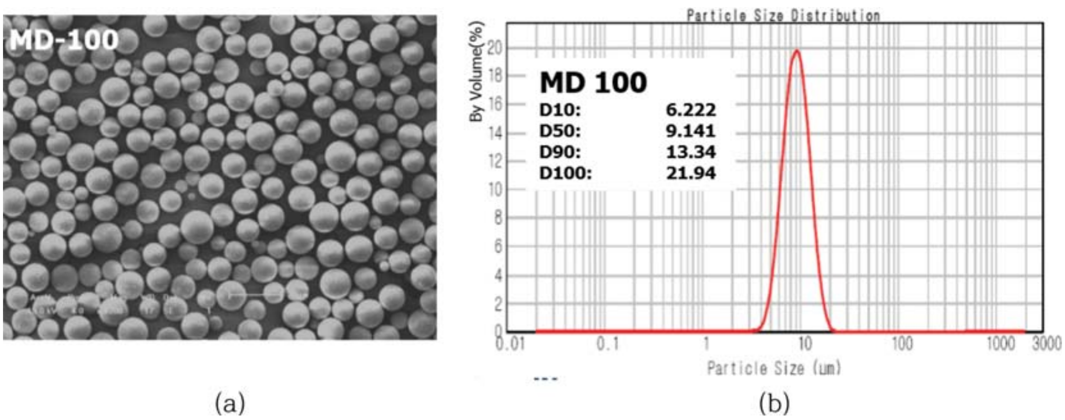


Fig. 3. Particles used in this study (a) microscope image, (b) size distribution.

allergen.

2. Experimental Apparatus

TMA (thermo-mechanical analysis) analysis and DSC (differential scanning calorimeter) analysis were performed on the bonding thread used in this study. Sinco TMA N800 and Sinco DSC N650 were used for analyzing thermo-mechanical analysis and differential scanning calorimeter analysis, respectively.

An experimental apparatus was developed to test the ability of allergen blocking performance of the various micropore fabrics. This device is designed to measure the weight reduction ratio of the particles injected to the filter kit. After the particles were injected into the experimental kit equipped with the fabric, suction and vibration were applied. Fig. 4 shows the structure and photograph of the experimental tool for carrying out the microscopic particle penetration experiment. A filter kit 1 in which small amount of micro particles was put into the micropore fabric 2 was designed to be mounted on an experimental tool. After experiments the filter kit produced the information data of the weight reduction rate of the kit. The particle penetration test system is equipped with measuring devices 3 and 4 for measuring the flow rate and pressure of the intake air. The inhaled micro particles are contacted and filtered with the liquid 5. The micro particles in the discharged air are contacted with water and rotated at the rotary pipes 7 and 8 so as not to be discharged to the outside. When high-pressure air flows into the tube 6, the particles in the experimental kit pass through the fabric together with the air sucked into the inflow pipe according to the pressure difference. At this time, a vibrating device was used to disperse the particles of the filter, and a microscope was installed to observe the shape of the filter.

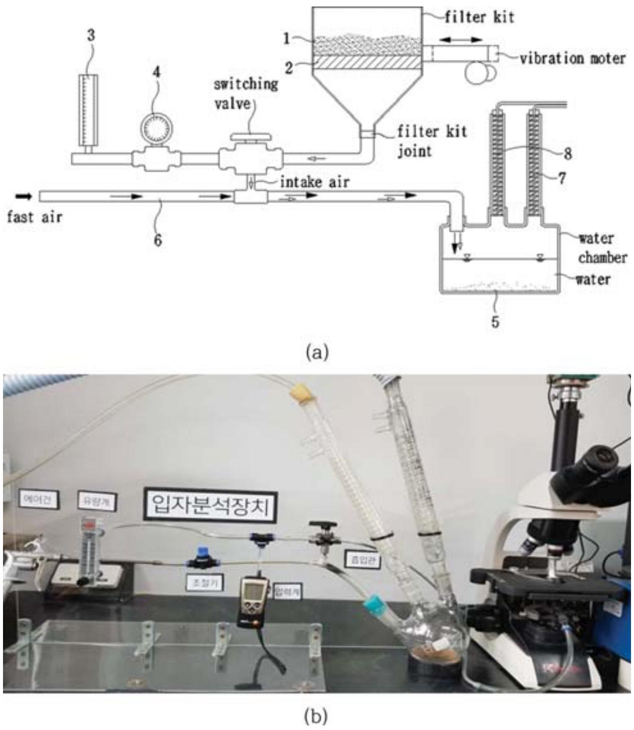
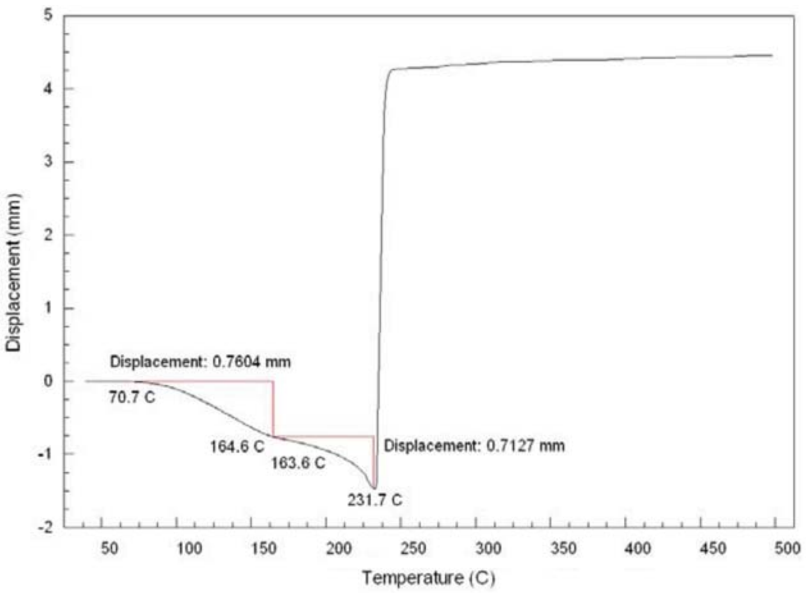


Fig. 4. The experimental system for measuring the weight reduction rate of particles (a) diagram of apparatus (b) picture of system.

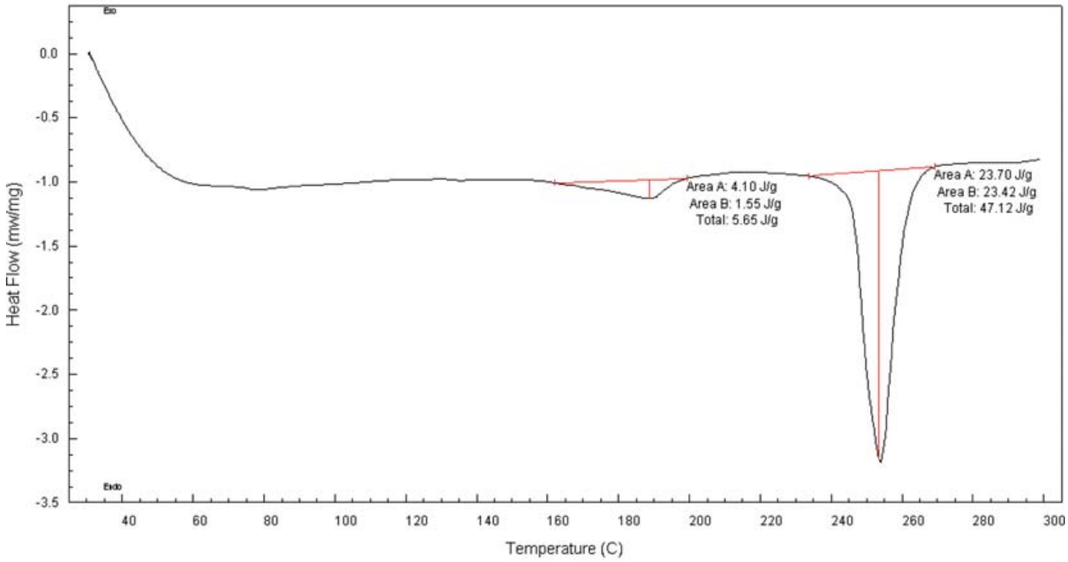
To properly seal the perforation hole by the needle of the sewing machine, a thermo-pressing tool capable of pressing the pathway of the needle at a constant temperature and pressure was manufactured. The thermo-pressing device was constructed so that an aluminum bar capable of controlling a certain temperature was installed on the upper and lower sides. The upper aluminum bar was moved toward the lower aluminum bar by a pneumatic cylinder. Also, it is designed to press the sewing pathway with heat and pressure for a certain time at a certain temperature by attaching the pressing time control device and the temperature control device. Since the polymer material has a high viscosity at the state of liquid, it is designed to make the liquified polymer easily flow by attaching a vibration device to the press bar. The stitched part was pressed for 30 seconds with a thermo-pressing device at 180 °C.

RESULTS AND DISCUSSION

The bonding thread used in this study was analyzed using Sinco TMA N800 and Sinco DSC N650. Fig. 5(a) shows the data of displacement versus temperature. The shrinkage of thread is typical for semicrystalline stretched fibers; as a result of the production process, the crystals are all oriented in the same direction. This orientation is lost after the glass transition, and the fibers shrink in the direction of tension at the given force (0.01 Newton). Fig. 5(b)



(a)



(b)

Fig. 5. Analysis results of bonding thread using (a) TMA and (b) DSC.

shows the data of heat flow versus temperature. Two peaks of data show that LM yarn liquefied at 170 °C and polyester yarn liquefied at 250 °C, respectively.

From these thermo-mechanical analyses, it was expected that the needle holes generated during the sewing process could be effectively sealed with the bonding thread. After the sewing process, the thermo-pressing device compressed the bonding thread at 180 °C during 30 seconds. The perforation holes created by the sewing needle were filled with the LM yarn liquified at 180 °C. Generally, even though the polymer material is softened and liquified, its viscosity is relatively high so it is necessary to apply pressure with a thermo-press to make a flow that can prevent the holes generated in the sewing process.

The microscopic photograph of the micro-pore fabric is shown in Fig. 6(a). A large hole with a diameter of about 100 μm was observed. It acts as a hole through which house dust mites as well as house dust mite allergens can pass. These holes are an important cause of inhibiting the efficacy of the allergen blocking bedding. Therefore, it is impossible to expect an environmental management effect to prevent allergy by using the micropore fabric. In addition, since the bedding is used after washing for a certain period of time, such holes are further enlarged by the frictional force generated in washing, and the anti-allergic function is inhibited. To properly seal the perforation hole made by the needle of the sewing machine, a thermo-pressing device was manufactured. This device is capable of pressing the pathway of the needle at a constant temperature and pressure. It is constructed so that an aluminum bar capable of controlling a certain temperature is installed on the upper and lower

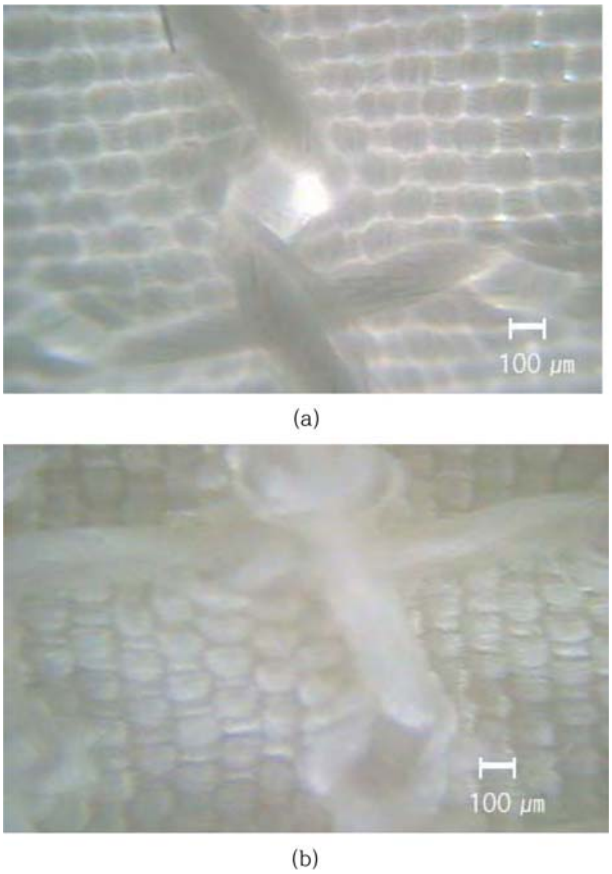


Fig. 6. Microscope images (a) after sewing (b) after thermo-pressing.

sides, and the upper part is moved by a pneumatic cylinder.

Also, it was designed to press the sewing pathway with heat and pressure for a certain time at a certain temperature by attaching the pressing time control device and the temperature control device. Since the polymer material has a high viscosity at the state of liquid, it is designed to make the liquified polymer easily flow by attaching a vibration device to the aluminum bar. The stitched part was pressed for 30 seconds with a thermo-press machine at 180 °C. As shown in Fig. 6(b), LM yarn effectively blocked the hole.

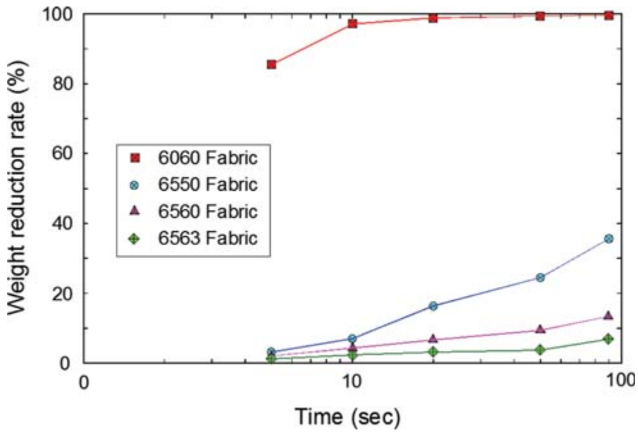


Fig. 7. Weight reduction rate vs. time of various fabrics.

The weight reduction rate of four kinds of bedding fabrics was measured using a particle-permeable device. In Fig. 7, 6060 fabric for ordinary bedding passed almost all the particles after several seconds. The effect of allergen prevention is not shown in this experiment because 6060 fabric gives out the particles before the suction pressure is applied in the micro particle permeation experiment.

At the given pressure and 90 seconds, the weight reduction ratio was measured as 35.6% for 6550 fabric, 13.6% for 6560 fabric, and 6.8% for 6563 fabric compared to that of 6060 fabric. In case 6563 fabric, the average diameter of the pores was 5 μm. By comparing the values of the other fabrics based on the weight reduction ratio, the average size of the pores can be obtained by regression analysis under the given conditions. The results will be shown in the subsequent studies.

The micropore fabrics used in this experiment were sewn using a sewing machine with bonding thread. Fig. 8 shows photographs of fabrics of cloth 6550, 6560, 6563 that were sewn with a sewing machine. Each fabric was sewn at intervals of about 1 mm. The weight reduction ratio by particle penetration of each sewn fabric was measured using a particle-permeable device.

The measured weight reduction ratio was 58.5%, 30.5% and 14.9% at 90 seconds in 6550, 6560 and 6563 fabrics, respectively.

Fig. 8. Sewn fabrics using in this experiments (a) 6550 fabric (b) 6560 fabric (c) 6563 fabric.

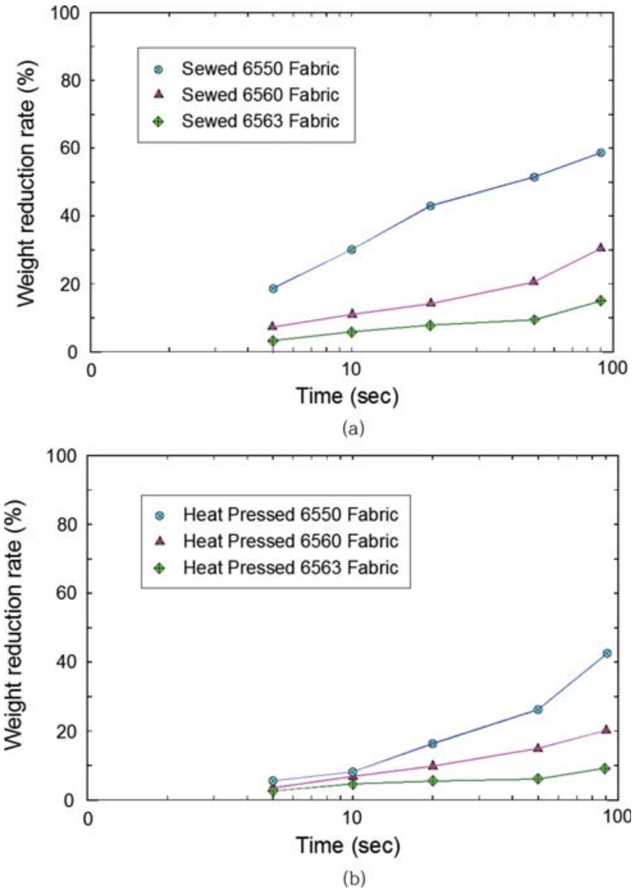


Fig. 9. Weight reduction rate vs. time of (a) Sewn fabrics (b) Thermo-pressed fabrics.

In Fig. 9(a), the increments of weight reduction ratio after sewing process were 23%, 17.1% and 8.2% at 90 seconds in 6550, 6560 and 6563 fabrics. Because the needle holes made by sewing make micro-particles pass through the fabric easily. The weight reduction ratio of 6550 and 6560 fabrics showed a tendency to increase more weight reduction than 6563 fabric. Fig. 9(b) shows the results of particle-permeability experiment using a fabric that was sewn with a bonding thread and thermo-pression bonded at 180 °C for 30 seconds using a thermo-pressing apparatus. Experimental results showed that the weight reduction rate was significantly reduced compared to the results obtained from all the sewed fabrics.

Compared to ratio before the sewing and pressing processes, the increments of the weight loss ratio were 7%, 6.8% and 2.1% from 6550, 6560 and 6563 fabrics, respectively. All three fabrics showed an increase in the weight reduction rate value of less than 10 percent compared to the values of ratio before sewing process. Therefore, we confirmed that when sewing and thermo-pressing processes are carried out using the bonding thread, the perforated part by the needle hole should be effectively sealed.

This study suggests a method to dramatically improve the sewing method of the bedding to block the house dust mite allergen. In addition, particle penetration test equipment was developed for the test of allergen blocking ability of the micropore fabric used for allergen impermeable bedding. By using the experimental method of this study, the criterion of performance evaluation was presented to verify whether allergen could pass through micropore fabric. This could be an important criterion for the standard test of environmental management bedding to prevent allergy.

CONCLUSION

A particle penetration device was developed to test the allergen barrier performance of various micropore fabrics. The MD 100 particles were used as particles representing the size of house dust mite allergens with the average diameter as small as 10 μm. The ability of micropore fabrics to block allergens of house dust mites can be tested by a particle penetration device. The particle penetration device developed in this study can be used as a standard experimental device to verify the allergen impermeable effect of micropore fabrics for allergen-proof bedding.

The weight reduction rate of a three micropore fabric, named 6550, 6560 and 6563 was measured using a particle penetration device. The 6563 fabric was able to block experimental particles with a weight reduction rate value of 6.8%. However, 6550 and 6560 showed higher values of 35.6% and 13.4%, respectively, than the value of 6563. The particle penetration device can be used to verify the allergen impermeability effect of micropore fabrics for allergen-proof bedding.

It is also a common practice to use a sewing machine when making bedding. However, the size of the perforations generated by the needles of the sewing machine is about 100 μm. Therefore, if a large pore is formed as a sewing portion even in a micropore fabric, the function as a house dust mite allergen-proof bedding could be remarkably deteriorated.

In this study, a bonding thread that was made by twisting polyester yarn and two LM (low melting) yarns was fabricated. The thermo-pressing sewing method was proposed in which the bonding portion was squeezed using a thermo-pressor at 180 °C for 30 seconds. As a result of the experiment, fabric treated by the thermo-pressing sewing method effectively prevented particle penetration compared with the fabric made by the general sewing method. In the thermo-pressing sewing method using the bonding thread, the increasing values of weight reduction rate were less than 10% compared with the values before sewing operation. It is considered that the thermo-pressing sewing method appropriately blocks the puncturing by sewing process.

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