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Research on the Pleating Technique by Using Cardboard Pleat and Kraft Paper

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ABSTRACT

Currently, the pleating technique is favored by famous fashion houses in the world and Vietnam because of its beauty and sophistication. This study aims to study pleating techniques, testing papers, and several polyester fabrics to form pleats under paper mold pressing by the manual heat-pressing method with three types of heat-pressed equipment such as steam iron, oven, and homemade heated box. One of the experiment results is a parameter table of the ability of fabrics and paper to pleat under certain conditions of temperature and time. Besides, a set of paper molds, a set of pleated fabric samples, and the above data table are also reference sources for major students or those who are interested in research, a collection, or a fashion project involving pleating techniques. The study is not only to add knowledge about new processing methods to the content of the material handling subject, but also to increase the ability to self-study, improve the subjectivity dynamic, and shorten self-study time in the process of creating new fashion models based on existing factory conditions.

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1. Introduction

Pleated fabric is a fabric commonly used in most of the designs of costumes with many different purposes. Currently, the creation of pleated fabrics is usually done by hand or processed at facilities in Ho Chi Minh City and other cities in our country. Moreover, the styles of pleating when processed at the facilities are usually limited to a few basic and simple styles. Some famous Vietnamese designers such as Lam Gia Khang, Nguyen Minh Cong, and Le Thanh Hoa, used pleating techniques to treat the surface on a variety of thick to thin materials [1], [2]. Or a young stylist Huu Anh, whose designs were published in Italian Vogue in the style of Avant Garde, creatively using pleated fabrics. However, the designers and stylists had just mainly used basic pleats such as accordion pleats, knife pleats, and box pleating styles [3].

Figure 1. *Pleated designs of Vietnamese designers*

Regarding the source of teaching materials at Universities in Ho Chi Minh City, the author Tran Thanh Huong, lecturer at Ho Chi Minh University of Technology and Education, Faculty of Fashion and Tourism, has written the textbook Costume Design 5, in 2007. This is a textbook on sewing technology, the author gives theories and illustrations about folding patterns, from simple to complex, and the various applications and creations of the pleating technique along with the development of ideas for pleating technique in teaching. However, the pleats are mainly formed by stitches, blocked at one end in the styling of knife pleats, box pleats, and accordion pleats [4], [5].

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Around the world, the pleating technique is used by world-famous fashion houses such as Christian Dior, Chanel, and Valentino... For example, the Christian Dior Haute Couture Spring Summer 2015 collection shows, the Valentino Fall 2019 Fashion show... Famous fashion houses all have workshops that process the fabric of the heat-pressed pleating technique to make cardboard pleat by using kraft paper and modern heat-pressed machine system [5]. This is also the method of pleating that the team is researching because the pleating styles are extremely creative, diverse, and sophisticated, no longer revolving around the 3 basic styles of box pleats, knife pleats, and accordion pleats [6], [7]. There had also been researched by authors Takizawa, and Naoki on applying twisting and heat treatment techniques to create folds, create unique aesthetic effects, increase flexibility, and increase comfort for costumes, but do not use a cardboard [8].

Figure 2. *Fashion models with pleating technique by cardboard [9], [10]*

With the manual method of pleating using paper molds through heating or steam pressing [4], [8, p.30], [11], [12], [13], authors Lee Euna and Kim Jongjun studied "Change the shape of the pleat and suitable fabric" in 2014. The study selected a "diamond" pleated pattern for testing, and the result was a summary table of testing and comparing of hardness, tensile strength, and ability to form pleats on a variety of fabrics such as silk, linen, and polyester [14].

Not studying as many materials as the author Lee Euna, in this article, the research focused on studying the temperature and time conditions affecting the quality of the paper and the ability to shape the pleats for certain polyester fabrics, from which to establish a parameter table of the above conditions to serve as a basis for the creations of fashion design students. To achieve the research results, the team conducted experiments to make pleating molds on two types of kraft paper and cardboard - often used to make fashion patterns. Next, we measured the thickness of some polyester materials capable of thermoforming, in accordance with the research criteria of the topic. Then we pressed the fabric into the paper mold to perform heat pressing. With each heat-pressing experiment according to time and temperature parameters, the research team evaluated the paper mold and the fabric's ability to form pleat. Finally, we proceed to set up a parameter sheet of fabric thickness, paper type, temperature, and time conditions. The research results not only have engaged teachers and students with new knowledge about material handling but also have saved time and money for students when applying this processing technique to fashion collections in course projects as well as graduation projects.

The presentation of the paper has the following layout: Section 1 presents an overview of the contributions of the topic; section 2 presents the experimental methods and conditions the team used for testing; section 3 presents results and discussion; and concludes in section 6.

2. Experimental methods and conditions

2.1. Heat-pressed pleating technique by paper mold

The pleating technique is the technique of creating folds for the fabric.

Regarding the origin, according to the source document Fashion - The Definitive History of Costume and Style, the pleating technique has appeared since ancient times, used to make costumes for queens and Pharaohs. Moreover, in the Renaissance, this technique continued to be used to sew pleated details, especially the ruffle neck, made of lace material, the symbol of royalty and aristocracy

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during the reign of Queen Elizabeth in England, which lasted until the 17th century [15]. Until the early 20th century, the 1900s designer Mariano Fortuny of Spain invented a unique pleating technique to create the Delphos dress - a gently pleated silk dress delicately inspired by Greek costumes, showing off the natural curves of the female body. Furthermore, Delphos has become the iconic dress for pleated fashion [12]. By the 1980s, the pleating technique had undergone innovations through the design of designer Issey Miyake. Designers began experimenting and designing pleated costumes that could easily move with the dancer's body. In 1988, the designer's outstanding pleated fashion collection "Pleats Please" was born; with light clothes, permanent pleats, no dry cleaning and can be folded into a compact size for easy storage and carry, has become a brand with an elegant pleated fashion line, practical, easy to wear, easy to maintain and travel [12].

There are many methods of pleating such as: using a sewing machine to create pleats; using chemicals for pleated finishing; hand pleating on a dress form or smocking; and pleating by heat-pressed. According to the heat-pressed pleating method, there are two types: industrial pleating - using a machine and another ones is cardboard pleating by hand. Heat-pressing can be combined with steaming to create durable pleats [10]. However, within the scope of the study as well as the existing factory and equipment conditions, the team chose the method of pleating by paper molds, which only uses heating to form the fabric placed between two of cardboard or kraft paper molds

To make a paper mold, it is necessary to know how to draw a diagram of the folds. There are 3 division methods for creasing: linear, rotational, and grid division [16].

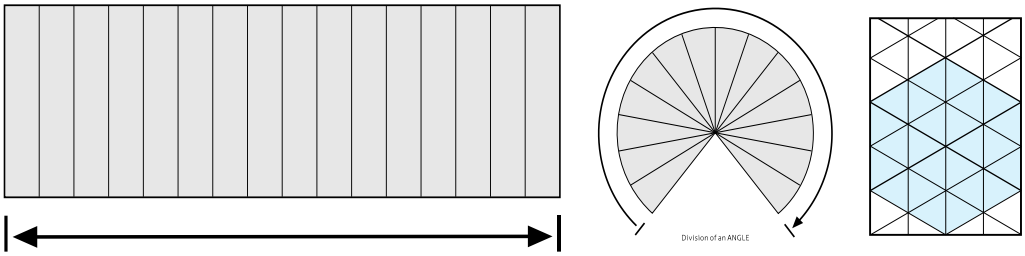

Figure 3. *Linear, Rotary, and Grid Split Types*

From the above 3 types of division, when we combine lines together, it will create different types of pleats. Within the scope of studying the conditions of fabric, paper, temperature, and time, the team studied how to make a paper mold in the basic Accordion style to conduct experiments.

The Accordion pleating is done by the method of linear division, "Linear division divides the length of a sheet of material into equal segments in a straight line from one end to the other. The length can be is any size and it can be divided into any equal number of segments". According to the Complete Pleats Pleating Techniques for Fashion, Architecture, and Design by Jackson, Paul.

Principle of division [16]

- Divide the paper into two halves, then quarters, then eighths... and similarly into sixteenth, thirty-two, or sixty-fourth parts.

- The blue line represents the fold forming a valley-like fold, originally "valley folds", and the red line represents the fold with a high elevation like a mountain peak - "mountain folds".

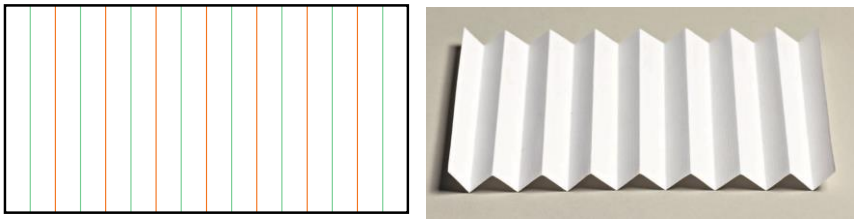

Figure 4. *Accordion-style paper template with 16 folds*

2.2. Materials, equipment, and conditions used in testing for the topic

2.2.1. The fabric used in the test

Thermoplastic fiber concept

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According to the information that the author Nguyen Tuan Anh has written in the textbook Textile Materials, thermoplastic fibers have the characteristics of softening at high temperatures, when the temperature is raised too high, the fibers are softened, melted, and then destroyed. The thermoplastic fiber group includes synthetic fibers (PA, PET, PAC...), acetate, and triacetate fibers [17, page 14].

Thermal resistivity

When processing at high temperatures, even if the fabric strength is lower, the strength of the fabric is still reduced. Characteristic showing heat resistance depending on the nature of fibers [1, page 31].

Table 1. *Thermal properties of textile fibers*

Type of fiber	Reduced durability Temp. (ºC)	Decomposition Point Temp. (ºC)	Softening Point Temp. (ºC)	Melting Point Temp. (ºC)
Cotton	120	150	-	-
Linen	120	-	-	-
Wool	-	130-150	-	-
Silk	-	150-170	-	-
Viscose	120-130	160-200	-	-
Cupro	120	150	-	-
Acetate	95-105	-	200	230
Zein	177	-	-	243-246
Polyethylene		-	-	110-120
Polyacrylonitrile	180-200	-	235	-
Polyamide	90-100	-	170-235	215-255
Polyester	160-170	-	230-240	250-255
Clorin	70-80	-	95-100	-
Glass	315-350	-	500-815	1200-1600
Amian	200-400	-	-	1450-1550

Selection of experimental fabric

As an introduction to the principle of shaping pleats with a paper mold, the fabric was pressed into a paper mold, then heated by iron or furnace, so the fabric is shaped and fixed. According to the theory of thermoplastic materials and the principle of pleated shaping of the paper mold heat press method, the research team selected a thermoplastic textile material – specifically, 100% PET fabric [14, page 2, line 11].

Within the scope of the study, the research team selected 100% PET fabrics of thin to medium thickness. Fabric thickness was determined based on the method of measuring fabric thickness according to ASTM D177 standard, the thickness gauge instrument is made at the Materials Laboratory of the Fashion & Tourism Faculty of Ho Chi Minh City University of Technology and Education.

Figure 5. *Measuring tools and how to measure*

How to measure: Cut a piece of fabric in the shape of a 10cm circle, and measured 10 times at the center of 10 different locations. Took the average of 10 measurements. Based on the standard scale according to the document "The experiment to determine the fabric thickness" issued at the data laboratory of Materials Laboratory of the Fashion & Tourism Faculty of Ho Chi Minh City University of Technology and Education.

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From the thickness measurement results, the research team selected 03 types of materials, the thinnest is 05mm, the medium is 17mm and the thickest is 24.5mm to conduct experimental research under the time and temperature conditions. Besides, based on the experimental results, the above fabrics will be applied to create pleated patterns to create a set of saved samples for later teaching.

Table 2. *Table of thickness measurement of testing fabrics*

No.	Fabric Code	Average (mm)	Comment
16	0094	24.5	The material is soft, smooth, with a lot of drapes, the right side should be light and shiny
20	8242	17	Thin material, flying, iridescent, see-through
21	8206	05	Thin, soft, light, see-through mesh material

2.2.2. The paper used in the test

According to research, designer Issac Miyake used Japanese washi paper in creating pleated designs. This is a handmade paper made from the bark of trees such as gampi, bamboo, hemp, rice, and wheat. Paper has toughness, light, durable, textured surface, used in many fields, especially paper folding. However, this type of paper is expensive, small in size, and must be imported from Japan, so it is difficult for the research team to access this material. Therefore, the research team was interested in choosing another type of paper - cement paper - also known as kraft paper, which is also a natural product made from wood pulp with additives. Previously, this type of paper was used to make packaging for cement, but now this type of paper is also used to make paper bags, envelopes, gift wrapping paper, packages, and linings, preserving items to avoid scratches during transportation. transportation, food preservation, etc. Characteristics of cement paper are rough, and quite tough. The common size is 72x102cm, 75grams, typical brown color. At the same time, the team also used the type of paper that students often use in pattern making to create pleating molds [8 page 41]. This is also kraft paper but thicker and has 2 different sides, smooth surface and tough.

Figure 6. *Thin kraft paper and thick kraft paper (cardboard paper)*

2.2.3. Experimental conditions of pleating technique of the topic

In this study, the experiments were mainly carried out under the conditions of existing equipment at the factory or at home, so we only focused on the conditions of temperature and time.

Temperature conditions

According to the theory of heat resistance, PET will decrease in durability if it exceeds 160^0C, and it is recommended by iron manufacturers to iron PET fabrics in the range of 120^0 - 160^0C.

Therefore, the research team selected the thermal parameter as:

120^0C ±10^oC

140^0C ±10^oC

160^0C ±10^oC

Equipment conditions

Use a steam iron

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The team's initial test was based on factory conditions, so the team used Naomoto brand steam irons, which are hanging steam irons, equipped and used in teaching at the workshop of the Faculty of Fashion and Tourism of Ho Chi Minh City University of Technology and Education. However, the team only used the heating function, not the hot steam function in order to ensure uniform thermal conditions for all kinds of experiments with iron, home ovens, and homemade heating box.

Using SANAKY VH509N household oven

The experiments were done with a household oven in order to get the research aim that changing the pleated fabric's size, shortening the heating time, and ensuring the heating process's stability for the pleated pattern. Therefore, the research team selected the thermal parameter:

Figure 7. *Naomoto steam iron*

Figure 8. *Sanaky Oven VH509N*

Use a homemade heat-pressed box

Most of the pleated fabrics used in fashion products were large in size, at least equal to shirt length, pants length, skirt length, etc. So, to better support for the research and application of the pleating technique of product fashion, the research team designed a heating box with dimensions of 200cmx40cmx40cm. The barrel works on the same principle of radiating heat as an oven.

Figure 9. *Homemade heat-pressed box*

Time conditions

Because the fabric is pressed into the paper molds, then positioned with a high heat-resistant cotton rope, wrapped around, and pressed molds tightly. Therefore, the molds after pressing and fixing would have a relatively high thickness, preventing the heat from entering the fabric. And when heating, there should be enough time for the temperature to diffuse from the outside to the core of the paper molds. From there, the group selected the time for each heating time to be 5 minutes. After heating for 5 minutes, we waited for the molds completely cool down and took the fabric out of the molds.

2.3. Experimental method

2.3.1. Making paper molds

Proceed to make a paper mold in the style of an Accordion, with the necessary tools to make the mold such as a pencil, ruler, paper, three kinds of fabric thickness (thin, medium, and thick), and cotton rope to tie the fabric.

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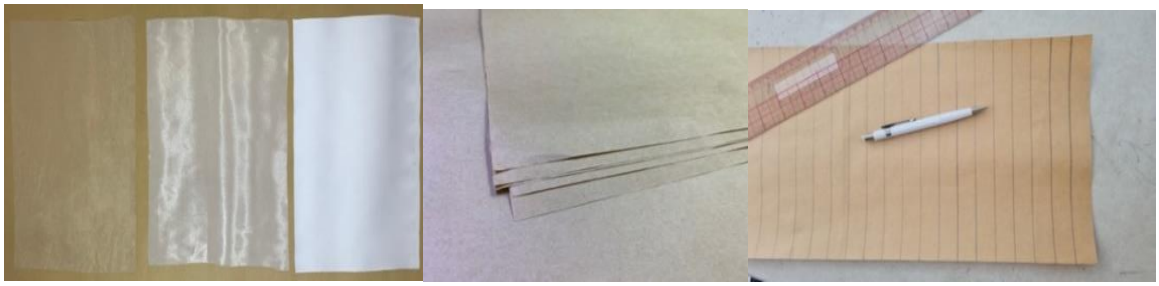

Figure 10. *Three types of fabrics and drawing tools*

The Process to make a paper mold

The steps to draw the folding diagram to make the mold are done in the following steps:

Step 1: Draw the dividing lines.

Step 2: Make wrinkles by drawing with a ballpoint pen out of ink.

Step 3: Fold along the lines to create valley and mountain folds.

Step 4: Make the same 2nd paper mold.

After having the paper mold, to conduct the test, we perform the next steps: Step 5: put the fabric between 2 paper molds and fold the pattern to press the fabric; Step 6: Wrap the fabric around the pattern tightly; Step 7: put the paper mold into the heating device.

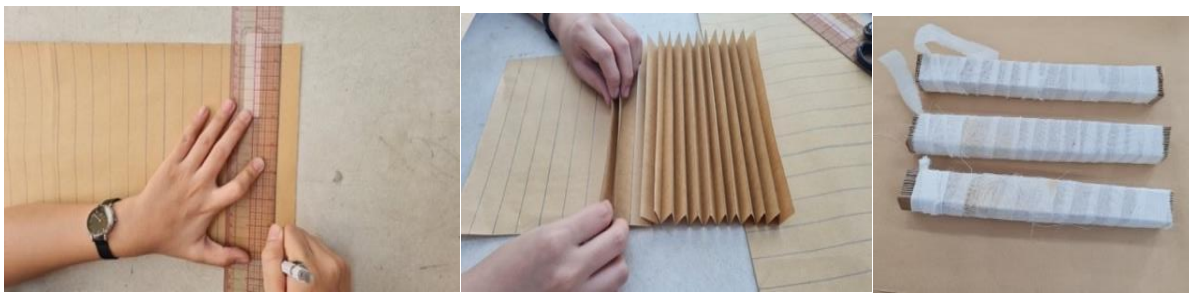

Figure 11. *Steps to make a paper mold and prepare for the experiment*

2.3.2. Heat-pressed experiments

The fabric is pressed into the paper molds, then positioned with a high heat-resistant cotton rope, wrapped around and pressed molds tightly. The molds are put into heating devices such as iron, household oven and homemade heat-pressed box according to the temperature levels of 120^0C, 140^0C, and 160^0C for 5 minutes. The conditions have been studied in section 2.2.3

Experiment with steam iron under workshop conditions

First is about the material. Forming pleats with an iron was applied to three kinds of fabric thickness (thin, medium, and thick) from 100% polyester material using Accordion pleated pattern molds.

The second is about the temperature and time conditions. According to factory conditions, a steam iron was already equipped, so the research team used a steam iron for the study of pleating shaping. However, the team only used the heating function, not the hot steam function in order to ensure the uniform thermal conditions for all kinds of experiments with iron, home ovens, and homemade heating box. The molds will be heated at temperatures of 120^0C, 140^0C, and 160^0C for 5 minutes on one side. The total time for the 4 sides of the molds will be 20 minutes.

Besides, we were also interested in the length of the paper mold. Because of the limited heating surface area of the iron, choose a test paper mold size with an edge corresponding to the length of the iron surface of 20cm.

Finally, after heat pressing by iron, we let the paper molds cool down, observed the molds then open the molds to take out the pleated fabric, and assessed the ability to shape the pleats.

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Figure 12. *Experiment with a steam iron at the workshop*

Experiment with home oven SANAKY VH509N

Forming pleats with Sanaky VH509N common household oven was applied to three kinds of fabric thickness (thin, medium, and thick) from 100% polyester material using an Accordion pleated pattern mold. The preparation is similar to that of iron.

The oven frame has a wide width and can accommodate many paper molds, so it is possible to make many molds at the same time at the same temperature. Therefore, the research team placed the same type of paper mold, put three types of fabrics in, and heated them at the same temperature. So, in 1 test, there would be 3 thin paper molds for 3 thin and thick fabrics, averaging at 1200C degrees in 5 minutes. Similarly, there were 3 thin molds for 3 fabrics at 1400C degrees and 1600C degrees at the same time. Then we changed to a thick paper mold with 3 fabrics in the same way.

Figure 13. *Heating molds with a home oven*

Experiment with a homemade heating box

Heating box is outer dimensions 200cmx40cmx40cm, thickness 5cm, and base 5cm high. The box structure consists of an electrical box linked to the resistors; which are mounted on the lid of a box. The heating box is fitted with insulation around it to ensure safety during testing. The temperature is adjusted up and down by an electric box, which can clearly show the maximum and minimum temperatures. The heating box is in the form of a sealed container, which retains heat during the test.

Procedure: Same as the iron and oven test, the experiment with a homemade heating box was done at 3 kinds of temperature levels: 1200C, 1400C, and 1600C degrees. We used two kinds of thick and thin paper for making molds and 3 kinds of fabric which are thin, medium, and thick fabric.

3. Results and discussion

3.1 The results of heating by steam iron

The results of heating by steam iron are illustrated in table 3:

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Table 3. *Summary of parameters with the condition of a steam iron*

Type of fabri	Kind of paper	Temperature (^{0}C)	Total time (minute)	Paper results	Fabric results
Thin	Thin	120	20	Stable paper mold	Shaping the folds, pleat without sharp edges
		140	20	Stable paper mold	Shaping the folds, pleats are sharp
		160	20	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		160	20	Stable paper mold	Shaping the folds, pleats without sharp edges
Medium	Thin	120	20	Stable paper mold	Shaping the folds, pleats are sharp
		140	20	Stable paper mold	Shaping the folds, pleats are sharp
		160	20	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		160	20	Stable paper mold	Shaping the folds, pleats without sharp edges
Thick	Thin	120	20	Stable paper mold	Shaping the folds, pleats are sharp
		140	20	Stable paper mold	Shaping the folds, pleats are sharp
		160	20	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	20	Stable paper mold	Shaping the folds, pleats without sharp edges
		160	20	Stable paper mold	Shaping the folds, pleats without sharp edges

Evaluation: The results of heating by iron are forming pleats and high pleating stability. However, it took a long time and labor to finish all four sides. If the pleated area is longer and wider, the amount of ironing time will increase. Therefore, it is very difficult to ensure the quality of manual ironing at all positions, consuming a lot of heat and labor. From the experimental results on the iron, the team turned their research to a machine that can provide an even temperature for a long time and with the least amount of labor.

3.2 The results of heating with a home oven

The results of heating with a home oven are illustrated in table 4:

Table 4. *Parameter table of conditions affected by household ovens*

Type of fabric	Kind of paper	Temperature (^{0}C)	Total time (minute)	Paper results	Fabric results
Thin	Thin	120	5	Stable paper mold	Shaping the folds, pleats are sharp
		140	5	Stable paper mold	Shaping the folds, pleats are sharp
		160	5	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		160	5	Stable paper mold	Shaping the folds, pleats without sharp edges
Medium	Thin	120	5	Stable paper mold	Shaping the folds, pleats are sharp
		140	5	Stable paper mold	Shaping the folds, pleats are sharp
		160	5	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleat without sharp edges
		140	5	Paper mold dry hard	Shaping the folds, pleat without sharp edges
		160	5	Paper mold dry hard	Shaping the folds, pleat without sharp edges
Thick	Thin	120	5	Stable paper mold	Shaping the folds, pleats are sharp
		140	5	Stable paper mold	Shaping the folds, pleats are sharp
		160	5	Stable paper mold	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		160	5	Stable paper mold	Shaping the folds, pleats without sharp edges

Evaluation: The results of heating with a home oven are pleated quality is stable, easy to implement, less labor intensive, and uniform quality. Through the combined results in the table, the research team found that thin cement paper mold results in better pleat shaping than thick paper mold. In the framework of the study applied to the class size, it is possible to use a baking machine instead of iron in shaping pleats, stabilizing the quality, and achieving high homogeneity. Simultaneously, it is easy to operate and reduces execution time. However, if applied to create pleated products with a length of more than 0.4m, the home oven cannot meet the requirements. Therefore, the research team conducted research on industrial toasters (the type that can hold a maximum length of 190 cm), which

are not available on the market, need to be ordered, and cost nearly 100 million. This is too high a cost for the research team. Therefore, the research team, combined with former electrical students designed a closed oven with a length of 2m, which has a more reasonable price of nearly 20 million Vietnam Dong. So, in the third pleating test, the group used a long baking box for 100% polyester fabric.

3.3. The results of the experiment with the homemade heating box

The results of heating with homemade heating box are illustrated in Table 5.

Table 5. *Parameter table of test conditions with homemade heater*

Type of fabric	Kind of paper	Temperature (^{0}C)	Total time (minute)	Paper results	Fabric results
Thin	Thin	120	5	Stable paper mold	Shaping the folds, pleats are sharp
		140	5	Paper mold hard, gold	Shaping the folds, pleats are sharp
		160	5	Protected paper mold is stable	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleat without sharp edges
		140	5	Paper mold hard, gold	Shaping the folds, pleat without sharp edges
		160	5	Protected paper mold is stable	Shaping the folds, pleat without sharp edges
Medium	Thin	120	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	5	Paper mold hard, gold	Shaping the folds, pleats are sharp
		160	5	Protected paper mold is stable	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleat without sharp edges
		140	5	Paper mold hard, gold	Shaping the folds, pleats without sharp edges
		160	5	Protected paper mold is stable	Shaping the folds, pleat without sharp edges
Thick	Thin	120	5	Stable paper mold	Shaping the folds, pleats are sharp
		140	5	Paper mold hard, gold	Shaping the folds, pleats are sharp
		160	5	Protected paper mold is stable	Shaping the folds, pleats are sharp
	Thick	120	5	Stable paper mold	Shaping the folds, pleats without sharp edges
		140	5	Paper mold hard, gold	Shaping the folds, pleats without sharp edges
		160	5	Protected paper mold is stable	Shaping the folds, pleats without sharp edges

Evaluation

Regarding the durability of the paper: both paper molds are stable at a temperature of 1200C. When heated at 1400C degrees, the paper mold has deformation, hardening, and yellowing. The group had overcome the dryness of the paper by wrapping the mold surface evenly with cotton rope to fix and protect the mold. Applying this method when heated at 1600C temperature, the cotton rope was yellowed, but the paper molds were stable, the positions of the head and tail of the paper molds which weren't covered by cotton rope, became dry and darker.

About the ability of the fabric to form folds: heating with a homemade heating box formed good folds in the temperature range from 1200C -1600C, with a time of 5 minutes. However, if a thin paper mold was used for all three fabrics, the folds were well-shaped and sharp. When using a thick paper mold, the edge of the pleats often gave a not-sharp result. The reason is that the two layers of thick paper molds overlap with the thickness difference between the two layers creating a small space so the edge is not sharp.

Orientation: From the experimental results for the above 3 types of pressed heat generators, the research team found that the thin kraft paper had high heat resistance, durability, and shaping a good fold, so the team chose the thin kraft paper to continue testing with basic and advanced styles of pleats.

After testing multiple pleated patterns on multiple polyester fabric samples, the team found: Thin kraft paper could shape a good fold for many thermoplastic fabrics with different styles of pleats. With pleating styles having many folds and many edges intersecting at one position, the paper mold also showed signs of tearing at places with many intersection points.

In terms of toughness: both types of paper have good toughness with basic patterns, including parallel folds, a few intersecting folds, and a few corners. However, with thin cement paper, the toughness is superior when making patterns with many folds, and many angles at one position. As for the hard embossed paper when performing advanced forms, it is easy to break corners or appear cracks and striations at locations with many intersections.

About the ability to shape fabric folds: Thin paper with thin fabric created folds with sharp edges, but thin paper with thick fabric was difficult to shape pleats because of the softness and weakness of the paper. As for thick paper, if using thin fabric, it still created beautiful pleats, but the sharpness was not as good.

In terms of thermal stability: after many heating cycles, in general, both types of paper were highly durable with 2 heaters with an iron and an oven, while with a homemade heating box, both types of paper started to decrease quality at 140-degree.

It can result that, both types of paper can be good to use for pleating. However, in some cases, thin cement paper had more advantages, although the thickness still has not met the requirements of the research team.

Regarding the type of fabric used: all 3 kinds of fabrics could shape fine folds. Depending on the type of paper mold, the quality of the edge of the pleat was sharp or round. If thin cement paper was used, all three fabrics had sharp edges. And, the degree of sharpness was proportional to the temperature. But when using thick paper, most of the edges of the pleats were not sharp.

4. Conclusions

In this paper, the research team learned about pleating techniques using paper molds, some types of pleating shaping, and heating methods to shape pleats with paper molds. And then our team run tests under our workshop conditions to evaluate the effectiveness of materials and equipment such as kraft paper, thick and thin paper, 3 kinds of polyester fabrics, an iron, an oven, and a homemade heated box. The results were compiled into a spec sheet of conditions of temperature and time, type of fabrics, and paper. This has been a resource for students and individuals interested in pleating techniques.

Conclusions about the paper mold: For cement paper is tough and durable when heated, and gave well-shaped folds. For thick paper, it also had toughness, durability, and gives good pleat shaping but it became less durable, and easily torn and broken if in complicated pleat styles. Conclusions on the polyester fabrics all were shaped in sharped pleats by thin cement paper molds.

One of the experiment results was a parameter table of the ability of fabrics and paper to pleat under certain conditions of temperature and time. Besides, a set of paper molds, a set of pleated fabric samples, and the above data table have been a reference source for major students or those who are interested in research, doing a collection, or a fashion project involving pleating techniques. In addition, the study is not only to add knowledge about new processing methods to the content of the material handling subject, but also to increase the ability to self-study, and improve the subjectivity dynamic. Furthermore, it will shorten self-study time in the process of creating new fashion models based on existing factory conditions.

The result of our experiments can be used by many people who are interested in pleating techniques. With lecturers, results can be used in education such as teaching Handling material subjects. With students, they can be used in students' course projects or final graduate projects. For those who want to study pleating techniques outside my university, the results can be a useful reference for them. It shortens self-study time in the process of creating new fashion models based on the conditions of time, temperature, material, and paper.

Further research: First, the team will study a wider variety of polyester materials and more complex pleat styles. Second, we will study patterned fabric to evaluate the surface aesthetic effect. Finally, fabrics of natural origin or a blend of natural and synthetic fibers will be used to experiment with the pleating ability under similar study conditions.

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