Innovation of Women Garment Designs through Employing Geometrical Pleats Fixed by Heat Setting

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Abstract:

Pleating is the art of folding fabrics with different shapes which results in various densities and textures of fabrics. Pleats have been used to clothe the human body for thousands of years. Furthermore, pleating became effective in decorating clothes, in addition to its functional feature those who wears pleated clothes has better freedom in movement more than who wears clothes that does not include pleats.

The history of pleated fabrics dates back to the middle kingdom in Egypt, as well as in ancient Greek during the fifth century B.C. and continued throughout history in several civilizations and eras. In the twentieth century, a number of fashion designers began in designing and implementing hand crafted pleats with more precision and new innovative methods, using different fabrics which helped in giving more flexibility in movement to the person who is dressing it, and it has kept its shape for many years.

In recent decades, simple pleats were developed rapidly by using new manufacturing techniques. With the introduction of new materials and the takeover of origami techniques into design, pleats have become one of the most innovative contemporary designs. Modern designers use pleats in their work such as in fashion, architecture, jewelry and furniture; furthermore, pleats are used with a wide array of sheet materials as in fabric, plastic, metal and laminated wood.

This research explains different types of pleats and the basic pleating patterns in details in order to generate new ideas, and how to pleat fabrics permanently by different methods. The experimental work in this research is carried out on different types of fabrics to measure the efficiency of heat setting and to what extent the pleats are stable. This is achieved through conducting experimental tests such as thickness, weight, draping, wettability, wicking, dimensional stability after washing and air permeability on pleated fabrics of organza, brocade, taffeta, satin, chiffon and Rosaline. Lastly, the conclusion of this research tests the hypotheses and offers a comprehensive explanation for the most preferable fabrics used in making geometrical pleats without affecting its mechanical or physical properties.

Keywords:

pleats, pleating patterns, synthetic fabrics, origami, shadow folds.

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الملخص:

الطي هو فن ثني القماش بأشكال مختلفة مما يحدث أختلافات لكثافات وملامس الأقمشة. استخدمت الكسرات ككساء للأجساد منذ آلاف السنين. وأصبح الطي فعال في زخرفة الملبس ، بالأضافه إلى ميزتها الوظيفية حيث أن مرتدي الملابس ذات الكسرات تكون له حرية الحركة أكثر من مرتدي الملابس التي لا تحوي تلك الكسرات.

يرجع تاريخ الأقمشة ذات الكسرات الي الدولة الوسطي في مصر القديمة، وكذلك في الدولة الأغريقية القديمة أثناء القرن الخامس ق.م وأستمر على مر التاريخ في عدة حضارات وعصور مختلفة. وفي القرن العشرين قام عدد من مصممين الأزياء بتصميم وتنفيذ الكسرات يدويا بدقة اكثر وبطرق جديدة وفعالة باستخدام أقمشة مختلفة مما ساعد في إعطاء مرونة أكثر فى الحركة لمرتدي الملابس مع الأحتفاظ علي شكلها لسنوات عديدة.

في العقود الأخيرة، تم تطوير الكسرات البسيطة بصورة سريعة في بلاد الغرب وذلك باستخدام تقنيات تصنيع وخامات جديدة وبتوظيف الأورجامي في التصميم وأصبحت الكسرات إحدي التصميمات المعاصرة الأكثر ابتكارًا. ويستخدم المصممون المعاصرون الكسرات في أعمالهم مثل الأزياء، العمارة، المجوهرات والأثاث؛ علاوة على ذلك، تم استخدام الكسرات مع مجموعة واسعة من الخامات كالقماش، البلاستيك، المعدن والخشب الرقائقي.

يوضح هذا البحث أنواع الكسرات المختلفة وأنماط الطي الأساسية بالتفصيل من أجل أبتكار أفكار جديدة، وكيفية طي الأقمشة بشكل دائم بطرق مختلفة. تم إجراء العمل التجريبي في هذا البحث على أنواع مختلفة من الأقمشة لقياس كفاءة التثبيت الحرارى ومدى ثبات الكسرات. سيتم تحقيق ذلك من خلال إجراء اختبارات معملية كالسمك، الوزن، الانسدالية، أمتصاص الماء، الابتلال، ثبات الأبعاد بعد الغسيل و نفاذية الهواء علي الأقمشة المطوية كالاورجانزا، بروكار، تفته، الستان، الشيفون و روزالين. واخيرا، الاستنتاج لهذا البحث يختبر الفروض ويقدم شرح شامل لأفضل الأقمشة المستخدمة فى عمل كسرات هندسية دون ان تتأثر خواصها الميكانيكية أو الفيزيقية.

الكلمات المفتاحية:

الكسرات، انماط الطي، الأقمشة الصناعية، الأورجامي ، الطيات المتبقية بالخيط.

Introduction

For millennia, pleats have been used to clothe the human body and became helpful in decorative and functional clothing. (1)

Pleats in ancient Egyptian garments:

Hand craft pleated fabrics were found long ago in ancient Egyptian times in frescoes, which prove that Egyptians made folds in their clothes (2). Linen fabric was the most common used fabric; it was woven from fibers of the flax plant and was left in its natural color or bleached white in the sun (3). Linen is a light fabric suitable for hot weather and easy to starch and fold to decorate the clothing of both men and women. (4)

Figure (1) Pleated robe

The process of pleating in ancient garments is not clearly understood till now about how it was accomplished, boards have been found cut with a series of parallel ridges that have been used to position the pleats but this is not proved yet, also there has been a discussion that starch has been used to make the pleats last but this has not been proved either (5), they used heated stones to pleat heavily starched fabrics but the pleats were semi- permanent, not stable. (15) as shown in figure (1)

Pleats in Ethiopian garments:

Ethiopia's territory being in the south of Egypt, their costumes were influenced and almost identical with that of the Egyptians. As the Ethiopian civilization developed, the styles of costumes were gradually improved and became entirely different from the Egyptian style. Ethiopian costumes were made of opaque materials; they were worn by both men and women. [17] as shown in figure (2)

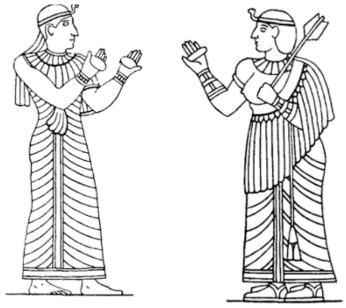

Figure (2) Costume of Ethiopian noblemen and women

Pleats in ancient Greek garments:

In Ancient Greece, during the 5th century B.C., both men and women wore the Ionic chiton, the most popular Greek garment, which was complicatedly draped garment with many folds and pleats. [4] Ancient Greek clothes were never sewn; they were draped and wrapped around the body. Ancient Greeks created their own style by arranging drapes and pleats; they were not interested in fashionable garments, their style remained the same for many centuries but their fabrics changed. [10] as shown in figure (3)

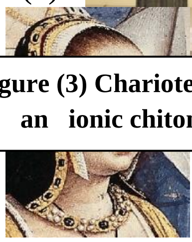

Figure (3) Charioteer in an ionic chiton

About 1200 B.C. the fabrics in ancient Greece were stiff and heavy, and in the year 800 B.C., they became lighter as linen, then they began to produce colored fabrics. Subsequently around 500 B.C., they began to decorate women clothes with fine pleats. [10] They made pleats by stitching on the upper seam or by pressing and ironing. [11] Greek women accomplished the art of pleating, which allowed them to create permanent pleats and added beauty to the texture of the fabric. [12]

Pleats in Middle Ages:

Fragments of finely pleated woolen fabrics were found at Gamla Lodose, a town famous with its trading center on the west coast of Sweden, north of Gothenburg which was engaged in trade with French communities. These fragments of about 89 cm long finely pleated in the warp direction were discovered in the archaeological layer dated 1100 - 1350. [18]

They pleated the fabric by binding and boiling the bound fabric, to make the pleats permanent, and also the crisp ridges of the pleats were found at Gamla Lodose which might have been fixed by stitches. [18]

In the mid-12th century, bliauts girones illustrated the artwork of delicate pleating which appeared to be made of fine linen or silk. Tailors were able to produce minuscule pleating in silk cloth with slightly rounded folds, [18]
as shown in figure (4).

Figure (4) Bliaut skirt at Chartres Cathedral worn by the Chartres west portal women column figures

Pleats during Renaissance period:

In early renaissance, tailors began to play an essential role in the construction of garments as skilled pleating cloth. (19)

From the period (1521-1590) pleated fabrics began to appear in crepine in some French hoods which is a pleated head cover made of fine linen or silk, it can be worn by a coif or without, (20) as shown in figure (5).

Figure (5) Anne of Brittany's French hood, 1500-1510

From the period (1615 - 1640) the falling ruff was worn; it was gathered without being set in formal pleats like oval ruff which was worn by women from the period (1625 - 1650). Oval ruff is a large closed ruff set in formal tubular pleats covering the shoulders, (20) as shown in figure (6).

Figure (6) Lady in a ruff

Pleats in the 18th century:

In the early 18th century, loose and unstitched pleats appeared in the sack dress which had a fashionable form in this period.

In the 1730's the pleats were set into two double box pleats at the center back of the dress and the bodice was fitted closer to the body, (20) as shown in figure (7).

Figure (7) Robe a' la Français (1750- 1775) made of silk cloth has two expansive pleats from the neckline at the back.

During the 1760's, paper mold was introduced by Martin Petit, the French fan maker, and from that moment pleating's presence became strong in fashionable clothing, during the mid-nineteenth century, this technique was developed by Edward Petit, who was the descendant of Martin Petit, and is still used till now by métiers as Lognon. (6)

The main method used for pleating is the pleating mold which consists of two layers of cardboard, the fabric is placed between this two layers, and both the fabric and the paper mold are exposed to heat and moisture in a vapor oven, then both of them are left clothed for a period of time to dry, which allows the pleat to take its shape and settle before removing the fabric from the paper mold. (6)

Pleats in the 19th century:

There were documents found from that period written about the patents that in the nineteenth century, that domestic tools use for pleating began to be introduced and improvements were applied to the tools such as flutters, crimping machines and the goffering iron for home use, (6) as shown in figures (8), (9), and (10).

Figure (8) The Dudley Flutter **Figure (9) Hand Flutter** **Figure (10) Goffering iron**
a fluting machine patented by Charles F. Dudley in 1876

At the end of the nineteenth century, the rotary pleating machine was introduced in the industrial field, this machine consists of rollers which are provided with dual dies similar to gears, and pleats are formed when the fabric passes through these rollers, (7) (8) as shown in figure (11).

Figure (11) Rotary pleating machine

There is another type of machine pleating known as Blade pleating machine, the action of the blades form creases in the fabric and by passing it through a pair of rollers, setting heat and pressure on fabric forming fixed pleats. (7) (8) The pleating machine has the ability of combining various pleats to produce perfect pleating patterns and varieties of patterns can be made, (7) as shown in figure (12).

Figure (12) Blade pleating machine

Nowadays, large mass production companies have their own machines ' in-house' to do all their processes while small designer companies often send their fabrics to pleating companies, as professional tailors can create a large variety of pleating styles. (9)

Pleats in the twentieth and twenty first century:

In the twentieth century, fashion designers began to develop pleating techniques with technological progress. The Spanish designer Mariano Fortuny improved the hand crafted method of pleating that remains until now shrouded in mystery. Fortuny's pleats were not settled permanently, but the first permanently set pleating techniques were improved after the evolution of synthetic fabrics such as nylon and polyester which have a thermoplastic property of the polymer based fibers, (6) (21) as shown in figure (13).

Figure (13) Delphos dress designed by Mariano Fortuny in the 1920

In 1975, Mary Mcfadden the American designer adopted Fortuny's pleating method by patenting her own permanent pleating technique that she applied to the synthetic that was woven in Australia, dyed in Japan, and pleated in the United States, [6] as shown in figure (14).

Figure (14) Mary McFadden's dress, made of polyester fabric (1990)

Issey Miyake, the Japanese designer whose creative approach depends on pleating garments rather than fabrics, this process requires constructing garments larger than their intended size two or three times, the sewn ensembles are folded and ironed properly, then the garment is sandwiched between the two layers of paper and then exposed to heat, as shown in figure (15).

Figure (15) Pleats Please designed by Issey Miyake, made of 100 percent polyester jersey

In recent decades, humble pleats were developed rapidly by using new manufacturing techniques, new materials and the takeover of origami techniques into design, so pleats have become one of the most innovative contemporary designs; designers use them in their work, as in fashion, architecture, jewelry and furniture in various sheet materials as fabric, plastic, metal and laminated wood, [1] as shown in figure (16).

Figure (16) Origami paper art

Research problem

From a field visit to one of the specialized workshops in Egypt that make geometrical pleats, it was observed that the patterns of the geometrical pleats that are implemented, are purchased from abroad and copies are made from these patterns, but there is no capability in making primary geometrical pleats patterns.

In this research the problem is represented in the following questions:

- What is the possibility in extracting geometrical pleats patterns and implementing the patterns on the fabrics by using heat setting in industry?
- What are the possible effects of the use of heat setting on the mechanical and physical properties of the pleated fabrics?

Research significance

The research significance is concerned with creating geometrical pleats patterns and applying these pleats patterns in garments design through heat setting technique. Since pleating is an essential skill throughout history in fashion design, the need to find better techniques in order to generate new ideas, and how to pleat fabrics permanently by different methods is highly desirable. Moreover, the research aims to offer a comprehensive understanding on pleating with a greater focus on which fabrics are better in maintaining their shapes and that their properties are not greatly affected after applying heat setting in terms of thickness, weight, draping, wettability, wicking, dimensional stability after washing and air permeability. Ultimately, the findings of this research will help fashion manufacturers and fashion designers, through applying the recommended approach derived from the results of this research, to make better decision when choosing which fabric is better to be used for pleating.

Research objectives

- Trying to create geometrical pleats patterns on paper and implementing the patterns on the fabrics by heat setting techniques, using these pleats in fashion design field.
- Measuring the efficiency of heat setting and to what extent the pleats are stable through conducting experimental tests on the mechanical and physical properties of the pleated fabrics such as thickness, weight, draping, wettability, wicking, dimensional stability after washing and air permeability.
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Research hypotheses

The research hypothesizes two statements that will be tested but essentially used to guide the research process. These include the following:

1. There is a statistical significant difference between dimensional stability of different pleated fabrics used in the research and the temperature degrees of washing.
2. There is a statistical significant difference between dimensional stability of different pleated fabrics used in the research and the type of pleat.
3. There is an effect of using heat setting on the mechanical and physical properties of the pleated fabrics used in the research.

Research limitation

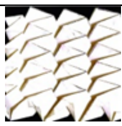
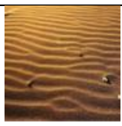
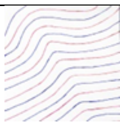
The limitations of the research are:

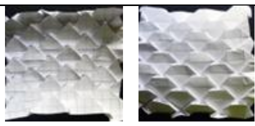
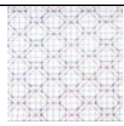
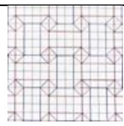
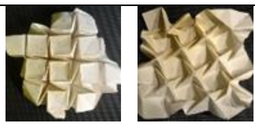
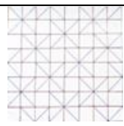
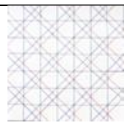
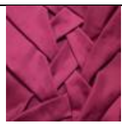
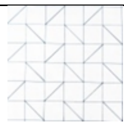
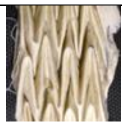
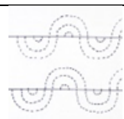
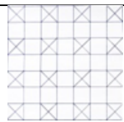
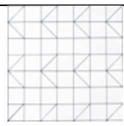
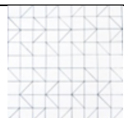
- The types of fabrics used in this research are: organza (polyester), chiffon (polyester), brocade (polyester), satin (polyester), Rosaline (nylon), taffeta (nylon).
- Experimental tests that were carried out in this research are: thickness, weight, drapability, wettability, wicking, dimensional stability after washing and air permeability.

Research methodology

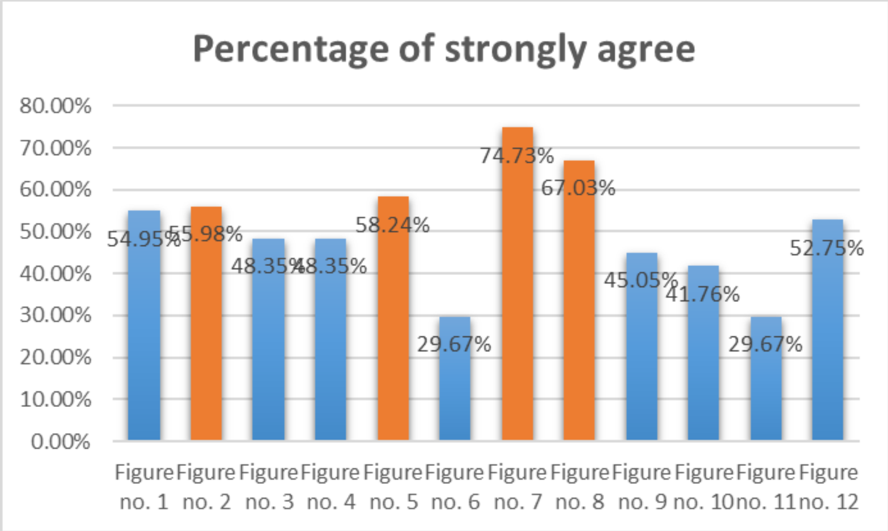
- Analytical method
- Experimental method

Table (1) Consolidated table for inspired pleat designs and diagrams

Figure no.	Inspiration	Design	Diagram
1.			
2.			

3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

The research will be based on a quantitative method in form of a survey that was made for 12 designs of pleats and distributed to a sample of 13 professors from faculty of applied arts department of ready-made garments to choose the most preferable designs according to their aesthetical and functional value. Based on the results of the statistical analysis, the highest percentages of the four strongly agreed designs were chosen as shown in graph (1). The four chosen designs will be experimented to assess the effect of drapability, air permeability, wettability, wicking and dimensional stability after washing when applied on different fabrics.



Graph (1) the highest percentage of the strongly agree on design of pleats

The implementation of the chosen pleats on fabric

Design pleat no. 2 and 5 both are implemented by paper; while design pleat no. 7 and 8 are implemented by thread.

Design pleat no 2 and 5

- The pattern design of the pleat is drawn on paper, two identical pleating molds of the pleat pattern are made and both are folded.
- The fabric is placed between the two molds and the sides of the molds are gathered together.
- The molds are bound all around with a cotton thread and a knot is tied to hold the two molds and the fabric tightly together.
- Then it is rolled up with an aluminum foil and is put into preheated oven between 1٦0 and ١٨٠ C°, with a tray full of water placed underneath it to produce steam.
- The timing of heat setting differs according to the type and weight of the fabric. For instance, 55-60 minutes in heavy weighted fabrics (as satin and brocade), 45 min. in medium weighted fabrics (as Rosaline and taffeta) and 25-30 min. in light weighted fabrics (as organza and chiffon).

Design pleat no 7 and 8

- The pattern design of the pleat is drawn on fabric as dots and each pair of dots are gathered up with the thread then are tied together with a knot and the knot is pulled very tightly.
- After tying all the paired dots together, the fabric is rolled up with an aluminum foil and is put into preheated oven between 1٦0 and ١٨٠ C°, a tray full of water is placed underneath it to produce steam and a heavy weight is put over it to make pressure on the pleat.
- The timing of heat setting differs according to the type and weight of the fabric. For instance, 55-60 min. in heavy weighted fabrics (as satin and brocade), 45 min. in medium weighted fabrics (as Rosaline and taffeta) and 25-30 min. in light weighted fabrics (as organza and chiffon).

Finally, the folds are left to cool down, and then the threads are removed.

Experimental work

Tested fabrics

Experimental work was carried out on six synthetic pleated fabrics: organza (polyester), brocade (polyester), taffeta (nylon), satin (polyester), chiffon (polyester) and Rosaline (nylon).

Experimental tests

The conducted tests aimed to evaluate the physical properties of the pleated synthetic fabrics, these tests were experimented in standard temperature and humidity (20 ± 2°C and 65 ± 2%). These physical properties were weight, thickness, drapability, air permeability, wettability, wicking and dimensional stability after washing.

Fabric weight

Weight of fabric measurements were carried out according to ASTM D1919-64 (1970) standards.

- Purpose of the test: to determine the weight of fabric.
- Specimen preparation:

- Specimens of pleated fabrics were taken randomly from the width of the fabrics, away from the fabric selvedge, and are cut by area 10X10 cm.
- 22 specimens were cut from six different fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline) each pleated fabric has four different pleated designs.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

Fabric thickness

Thickness of fabric measurements were carried out according to ISO 5084 standards.

- Purpose of the test: to determine the thickness of fabric.
- Test apparatus: Heal thickness gauge.
- Specimen preparation:

- Specimens of pleated fabrics were taken randomly from the width of the fabrics, away from the fabric selvedge, and are cut by area 10X10 cm.
- 22 specimens were cut from six different fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline) each pleated fabric has four different pleated designs.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

- Test procedure:

- Five readings were taken scattered from only one specimen of each pleated fabrics.

- Calculation:

- To calculate the average of the results of the five readings of each specimen, divide the five readings of each specimen by 5, to give the average of fabric thickness (m.m2).

Drapability test

Drapability test was carried out according to ASTM D4032-75 standards.

- Purpose of the test: to determine which fabric has the lowest drapability that will help the pleat to maintain its stability and keep its shape.
- Test apparatus: Shirley stiffness apparatus.

Specimen preparation:

- Specimens of pleated fabrics were taken from the six fabrics; eight samples were cut from each specimen; four in weft direction and four in warp direction, away from the fabric selvedge, and are cut by area 2.5X20 cm.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

Figure (17) Drapability test

- Test procedure:
- Four readings were taken from each specimen of pleated and not pleated fabrics; four in weft direction and four in warp direction.
- Calculation:
- To calculate the average of the results of the four readings of each specimen in weft and wrap direction, divide the four readings of each specimen by 4, to give the average in weft direction and warp direction.
- Average calculation in weft direction:

$$C = \frac{The\ sum\ of\ four\ readings\ of\ specimen\ in\ weft\ direction}{4}$$

- Average calculation in warp direction:

$$C = \frac{The\ sum\ of\ four\ readings\ of\ specimen\ in\ warp\ direction}{4}$$

- G in weft direction= 4.73 × C3 = A
- G in warp direction= 4.73 × C3 = B
- Factor of fabric stiffness = $\frac{A+B}{2}$

Air permeability test

Air permeability test was carried out according to ASTM D737-٠٤ (2012) standards.

- Purpose of the test: to determine the fabric ability in allowing the passage of air through it.
- Test apparatus: Shirley for fabric air permeability apparatus.
- Specimen preparation:

- Specimens of pleated fabrics were taken from the width of the fabrics, away from the fabric selvedge.
- 22 specimens were cut from six different fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline) each pleated fabric has four different pleated designs.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

- Test procedure:
- Three readings were taken from only one specimen of each pleated fabrics.
- Calculation:
- To calculate the average of the results of the three readings of each specimen, divide the three readings of each specimen by 3, to give the average of air permeability of fabric (cm3/cm2/s).

Wettability test

Wettability test was carried out according to B.S (4554).

- Purpose of the test: to determine the fabric ability in absorbing water.
- Specimen preparation:
- Specimens of pleated fabrics were taken from the width of the fabrics, away from the fabric selvedge.
- Specimens are cut in squares with different length and width, according to the diameter of the beaker attached to it.
- 22 specimens were cut from six different fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline) each pleated fabric has four different pleated designs.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

- Test procedure:
- Each specimen is placed on a beaker horizontally and is attached by a rubber band.
- A burette filled with distilled water is placed over the specimen and is clamped 5 cm above the horizontal surface.
- A stopwatch is used and it starts as a drop of water is allowed to fall from the burette, and the stopwatch stops as the specimen absorbs the drop of water.
- Record the time of each specimen to give the measurements of the most preferable fabric that has high wettability.

Figure (18) Wettability test

Wicking test

Wicking test was carried out according to B.S (3424).

- Purpose of the test: to determine the wick ability of the fabric.

- Specimen preparation:

- Specimens of pleated fabrics were taken from the width of the fabrics, away from the fabric selvedge, and are cut by area 5X20 cm.
- 22 specimens were cut from six different fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline), each pleated fabric has four different pleated designs.
- The test was carried out under standard temperature and humidity conditions (20 ± 2°C and 65 ± 2%).

- Test procedure:

- Each specimen lower edge is marked with 1 cm, and is suspended vertically with its lower edge in a vessel filled with distilled water.
- The marked edge of the 1 cm is dipped into the water, and a timer is set to two minutes to measure the height of the absorbed water above the 1 cm, as the timer stops.

The measured height of the absorbed water above the 1 cm, within the set time is an indicator for wick ability of the fabric.

Figure (19) Wicking test

Dimensional stability after washing test

Dimensional stability after washing test was carried out according to B.S (4323).

- Purpose of the test: to determine to what extent the pleats in the fabrics are stable and the change of color of fabrics after the washing process.

- Specimen preparation:

- Specimens of pleated fabrics were taken from the width of the fabrics, away from the fabric selvedge, and are cut by area 4X10 cm.
- 22 specimens were cut from six different pleated fabrics (organza, brocade, taffeta, satin, chiffon and Rosaline), each pleated fabric has four different pleated designs.

- Test procedure:

- Put each specimen in a soap solution, 5 gm of soap on every 1 liter of water, with four different temperatures; 40°C, 50°C, 60°C, 80°C.
- Leave each specimen in the soap solution for a period of time as shown in table no (2), with stirring the specimens during this period of time.
- Measure the change in pleats stability.

Table (2) Specification of dimensional stability after washing test [26]

Temperature	Time	Soap	L.R
40°C	30 min	5 g/l	50:1
50°C	45 min	5 g/l	50:1
60°C	30 min	5 g/l	50:1
80°C	30 min	5 g/l	50:1

Figure (20) Dimensional stability after washing test at 60°C

Heat setting test

Heat setting the fabrics after pleating process were subjected to fixation by steaming at 105°C for 35 minutes, using the steaming machine of FAA, produced by Edward Kuster Machine Fabric, Germany 1984 and fabrics fixated by thermal fixation at 160°C for 45 seconds.

Results and discussion

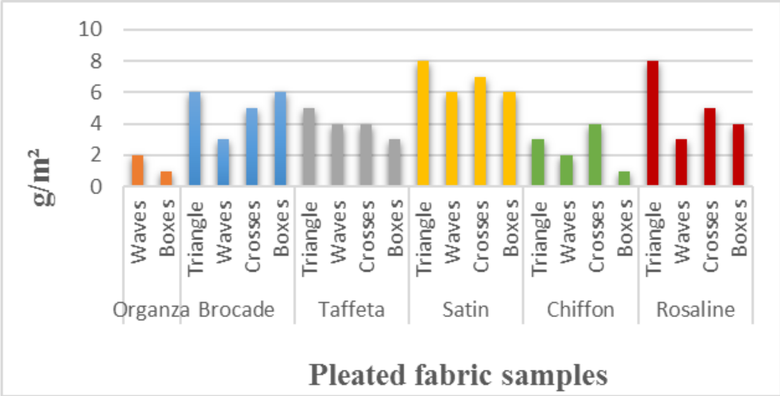
Physical properties of the tested fabrics

The results of the tested fabrics from the experimental tests on the pleated samples are as shown in the following table (3)

Table (3) Consolidated table for the results of experimental tests on pleated fabrics

No.	Pleated fabrics	Designs of pleat	Experimental tests													
			Weight g/m^2	Thick-ness $m.m^2$	Drape-ability gm/cm	Wet-ability Sec.	Wicking Cm	Air permeability $cm^3/cm^2/s$	Dimensional stability after washing (cm)							
									40°C		50°C		60°C		80°C	
									H	W	H	W	H	W	H	W
1	Organza	Waves	2	20	372.7	5487	0	621.6	10	10	10	10	10	10	10	10
		Boxes	1	18.6	850.5	2599	0.4	561.6	10	10	10	10	10	10	12	12
2	Brocade	Triangles	6	45.6	824.56	4312	0.5	101	10	10	10	10	10	11	10	11
		Waves	3	40	177.23	1933	0.5	80.2	10	10	10	10	10	11.5	10	13
		Crosses	5	42.8	556.5	3194	0	80	10	10	10	10	10	10.5	12	11
		Boxes	6	43.2	27	1921	0.4	45.6	10	10	10	10	10	10	12	14
3	Taffeta	Triangles	5	30.4	800.84	126	2	137.3	10	10	10	10	10	10.5	10	11.5
		Waves	4	28	775.15	19	5	130.6	10	10	10	10	10	10.5	12	12
		Crosses	4	58.8	750.8	142	0.5	85.6	10	10	10	10	10	10	10	10
		Boxes	3	30.2	378.5	555	0.5	82.4	10	10	10	10	10.5	11	12	13
4	Satin	Triangles	8	44.8	457.3	5307	0	32.7	10	10	10	11	10	11	10	11
		Waves	6	45.8	184	3087	0.4	27.4	10	10	10	10	10	10.5	10	11.5
		Crosses	7	53.2	447	5056	0	38.4	10	10	10	10	10	10.5	13	13
		Boxes	6	45	156.8	2430	0	15.8	10	10	10	10	11	11	13	13
5	Chiffon	Triangles	3	25.8	121.5	2955	0	612	10	11	10	11	10	11	10	11
		Waves	2	25.8	39.3	3362	0	596.6	10	11	10	11	10	11.5	11	12.5
		Crosses	2	46.4	187.8	1987	0	520	10	11	10	11	14	12	14	14
		Boxes	1	25.4	35.1	21270	0	577.6	10	11	10	11	10	11	11	13
6	Rosaline	Triangles	8	54.4	1680	5322	0.1	42.6	10	10	10	10	10	10	10	12
		Waves	3	54.8	221.8	1474	0.1	23.7	10	10.5	10	10.5	10	10.5	10	10.5
		Crosses	5	75.4	305	10824	0.1	35.25	10	10	10	10	10	10	11	11
		Boxes	4	52.4	231.16	3960	0.1	12.36	10	10	10	11	11	11	13	13

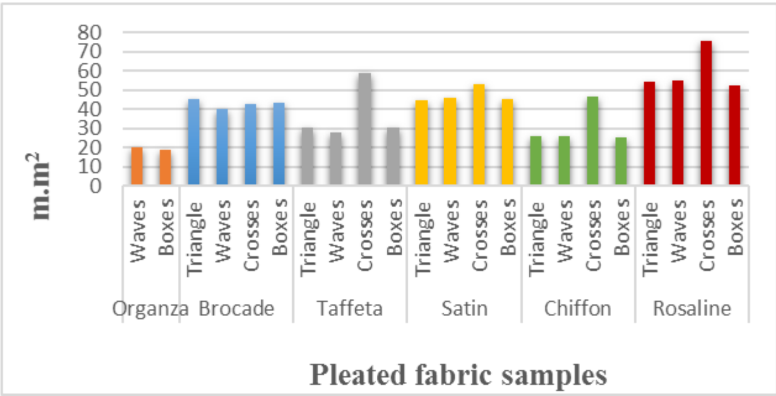
Fabric weight



Graph (2) the results of weight of pleated fabrics

Graph (2) shows that organza, in pleated fabric samples, has the lowest measurement of weight when compared to the other fabrics; while triangle sample in Rosaline and satin fabrics shows the highest measurement of weight.

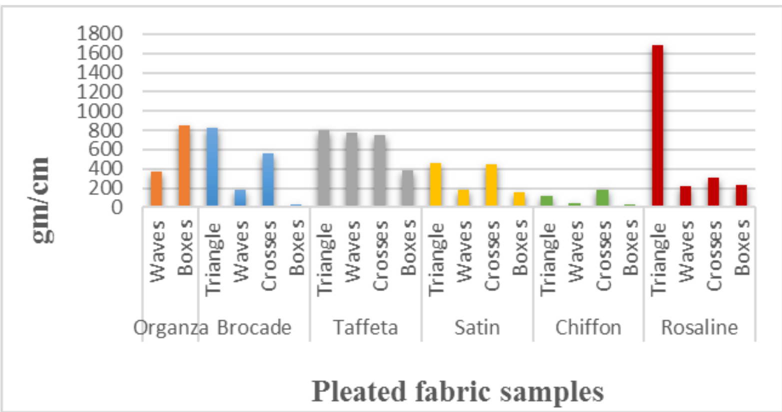
Fabric thickness



Graph (3) the results of thickness of pleated fabrics

Graph (3) shows that organza, in pleated fabric samples, has the lowest measurement of thickness when compared to the other fabrics; while Rosaline fabric shows the highest measurement of thickness.

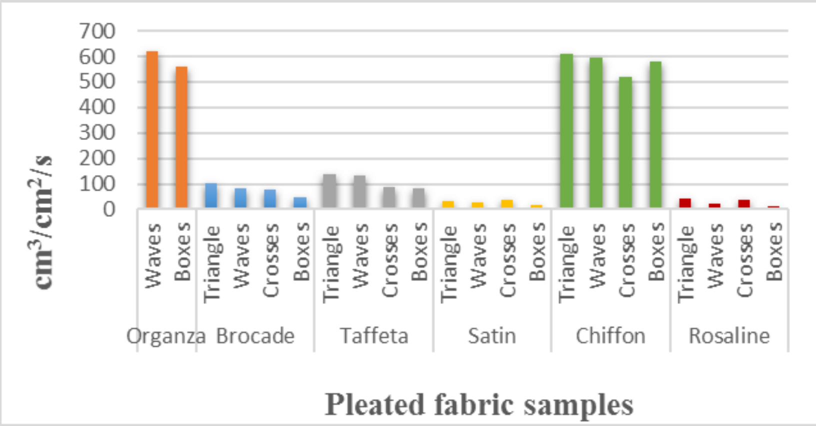
Drapability test



Graph (4) the results of drapability of pleated fabrics

Graph (4) shows that chiffon, in pleated fabric samples, has the lowest stiffness which indicates that chiffon has the highest drapability when compared to the other fabrics. In contrast, Rosaline triangle sample has the highest stiffness which indicates that this sample has the lowest drapability. The higher values of weight and thickness of fabric indicate an increase in stiffness value, as the fabric main structural properties have an effect on stiffness.

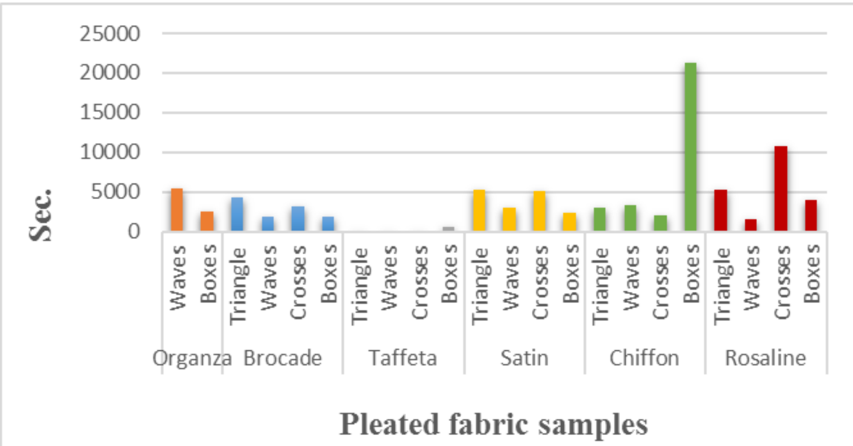
Air permeability test



Graph (5) the results of air permeability of pleated fabrics

Graph (5) shows that organza and chiffon, in pleated fabric samples, have the highest air permeability when compared to the other fabrics; while Rosaline and satin fabric shows the lowest air permeability. This indicates that organza and chiffon fabrics have the ability to allow the body to lose heat through the air gaps between the yarns in fabric to maintain its thermal balance.

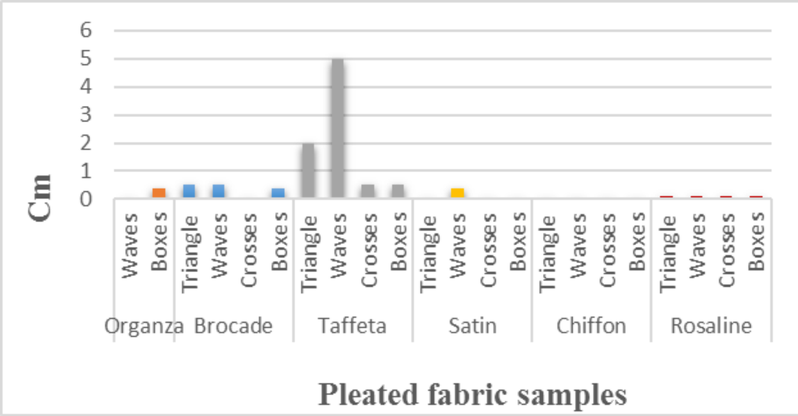
Wettability test



Graph (6) the results of wettability of pleated fabrics

Graph (6) shows that taffeta, in pleated fabric samples, have the highest wettability when compared to the other fabrics. In contrast, chiffon boxes sample has the lowest wettability. The higher values of weight and thickness of fabric indicate an increase in wettability value, as the fabric main structural properties have an effect on wettability.

Wicking test



Graph (7) the results of wicking of pleated fabrics

Graph (7) shows that chiffon, in pleated fabric samples, has the lowest wicking when compared to the other fabrics; while taffeta fabric shows the highest wicking. This indicates that the changes of fabric thickness and the water holding power of the fabric structure would affect the wicking of water.

Dimensional stability after washing test

Back to the first research hypothesis that there is a statistical significant difference between dimensional stability of different pleated fabrics used in the research and the temperature degrees of washing, according to Friedman test there is a difference < 0.05 and < 0.01 as shown in table (4) which proves that the first research hypothesis is accepted.

Table (4) Friedman test

Ranks	
	Mean Rank
Wash fastness (40°C)	3.17
Wash fastness (50°C)	3.17
Wash fastness (60°C)	2.67
Wash fastness (80°C)	1.00

Test Statistics [a]	
N	24
Chi-Square	65.143
df	3
Asymp. Sig.	0.000

The second research hypothesis argues that there is a statistical significant difference between dimensional stability of different pleated fabrics used in the research and the types of pleats in different temperatures applied for one fabric, according to Kruskal-Wallis test there is no difference as the results are > 0.05 as shown in table (5), which indicates that when applying different temperatures on one fabric with different types of pleats its appearance is not affected by the different temperatures, this proves that the second research hypothesis is refuted.

Table (5) Kruskal-Wallis test

Ranks			
Design of pleats		Fabrics N	Mean Rank
Wash fastness (40°C)	Triangles	6	11.50
	Waves	6	13.50
	Crosses	6	11.50
	Boxes	6	13.50
	Total	24	
Wash fastness (50°C)	Triangles	6	11.50
	Waves	6	13.50
	Crosses	6	11.50
	Boxes	6	13.50
	Total	24	
Wash fastness (60°C)	Triangles	6	11.17
	Waves	6	13.83
	Crosses	6	11.17
	Boxes	6	13.83
	Total	24	
Wash fastness (80°C)	Triangles	6	10.67
	Waves	6	14.33
	Crosses	6	10.67
	Boxes	6	14.33
	Total	24	

Test Statistics [a,b]				
	Wash fastness (40°C)	Wash fastness (50°C)	Wash fastness (60°C)	Wash fastness (80°C)
Chi-Square	2.091	2.091	1.076	1.925
df	3	3	3	3
Asymp. Sig.	0.554	0.554	0.783	0.588

At 40°C and 50°C the pleats in all the fabric samples are still stable and maintaining their shape, while at 80°C the pleats begin to lose their stability. This indicates that the most preferable temperature for washing are 40°C and 50°C.

Finally, the third research hypothesis argues that there is an effect of using heat setting on the mechanical and physical properties of the pleated fabrics used in the research. According to the results of the experimental tests carried out on the pleated fabrics, indicate that heat setting affected the mechanical and physical properties of the fabrics as shown in table (6). The difference is obvious when comparing the following factors: weight, thickness, drapability, wettability, wicking and air permeability between the fabrics before using heat setting and after using heat setting to pleat the fabric, which proves that the third research hypothesis is accepted.

Table (6) Consolidated table for the results of experimental tests before and after heat setting

No.	Pleated fabrics	Designs of pleat	Experimental tests											
			Weight g/m²		Thickness m.m²		Drivability gm/cm		Wettability Sec.		Wicking Cm		Air permeability cm³/ cm²/s	
			Not pleated	Pleated	Not pleated	Pleated	Not pleated	Pleated	Not pleated	Pleated	Not pleated	Pleated	Not pleated	Pleated
1	Organza	Waves	1	2	12	20	1677	372.7	5018	5487	0	0	542.6	621.6
		Boxes	1	1	12	18.6	1677	850.5	5018	2599	0	0.4	542.6	561.6
2	Brocade	Triangles	2	6	38.4	45.6	457.4	824.56	1020	4312	0.7	0.5	37.1	101
		Waves	2	3	38.4	40	457.4	177.23	1020	1933	0.7	0.5	37.1	80.2
		Crosses	2	5	38.4	42.8	457.4	556.5	1020	3194	0.7	0	37.1	80
		Boxes	2	6	38.4	43.2	457.4	27	1020	1921	0.7	0.4	37.1	45.6
3	Taffeta	Triangles	1	5	26.4	30.4	204.2	800.84	11	126	3.5	2	98.2	137.3
		Waves	1	4	26.4	28	204.2	775.15	11	19	3.5	5	98.2	130.6
		Crosses	1	4	26.4	58.8	204.2	750.8	11	142	3.5	0.5	98.2	85.6
		Boxes	1	3	26.4	30.2	204.2	378.5	11	555	3.5	0.5	98.2	82.4
4	Satin	Triangles	2	8	42.2	44.8	326	457.3	937	5307	1	0	11.8	32.7
		Waves	2	6	42.2	45.8	326	184	937	3087	1	0.4	11.8	27.4
		Crosses	2	7	42.2	53.2	326	447	937	5056	1	0	11.8	38.4
		Boxes	2	6	42.2	45	326	156.8	937	2430	1	0	11.8	15.8
5	Chiffon	Triangles	1	3	23.6	25.8	35.14	121.5	1146	2955	0	0	590	612
		Waves	1	2	23.6	25.8	35.14	39.3	1146	3362	0	0	590	596.6
		Crosses	1	2	23.6	46.4	35.14	187.8	1146	1987	0	0	590	520
		Boxes	1	1	23.6	25.4	35.14	35.1	1146	21270	0	0	590	577.6
6	Rosaline	Triangles	2	8	50.2	54.4	194.35	1680	1092	5322	0	0.1	12.76	42.6
		Waves	2	3	50.2	54.8	194.35	221.8	1092	1474	0	0.1	12.76	23.7
		Crosses	2	5	50.2	75.4	194.35	305	1092	10824	0	0.1	12.76	35.25
		Boxes	2	4	50.2	52.4	194.35	231.16	1092	3960	0	0.1	12.76	12.36

Conclusion

In conclusion, this research discussed the new ideas of pleat designs and patterns. The research raised two questions, with the first research question about the possibility to extract geometrical pleats patterns and implementing them on fabrics using heat setting; while the other research question speculated the possible effects of the use of heat setting on the mechanical and physical properties of the pleated fabrics. The research questions are examined mainly through testing the four highly recommended pleats that were chosen by the professors through a questionnaire,

and where used in conducting experimental tests on six synthetic fabrics (organza, brocade, taffeta, satin, chiffon and
Rosaline).

Based on the results of the experimental tests, it can be noticed that: organza has the lowest measurement of weight and thickness when compared to the other fabrics. Chiffon has the highest drapability when compared to the other fabrics. Organza and chiffon have the highest air permeability when compared to the other fabrics. Taffeta has the highest wettability and wicking when compared to the other fabrics. The most preferable temperature for washing are 40°C and 50°C in all the pleated fabric samples as their shape remain stable.

According to these results, organza is the most preferable fabric to be pleated as it has moderate drapability, low measurement in weight and thickness that helps in maintaining its stability and keeps its shape. In contrast, chiffon has high drapability which affects its stability and loses its shape. Pleated organza can be used as a design on another fabric that has high wettability and wicking, not close to the skin surface due to its low wettability and wicking.

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