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Innovations in the Design of Pleated Clothing Using Digital Printing and Dyeing Technology

Wei Chang[1,2], & Xubing Xu[1]

[1] College of Fashion and Design; Key Laboratory of Clothing Design & Technology, Ministry of Education; Shanghai "the Belt and Road" International Joint Laboratory of Textile Intelligent Manufacturing and Engineering, Donghua University, Shanghai, China

[2] School of Fashion Design, Jiangxi Institute of Fashion Technology, Nanchang, China

Correspondence: Xubing Xu, Professor, College of Fashion and Design, Donghua University, Shanghai, China. Tel:133-1166-5979. E-mail: 1041295342@qq.com

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Abstract

Pleating technology plays a major role in the design of pleated clothing. Also known as wrinkle clothing design, pleating is a high temperature process that has been significantly influenced by progress in science and technology. The combination of pattern design and pleating through the use of digital printing and dyeing technology has become a key aspect of the visual presentation, embodiment of style, and decorative art associated with pleated clothing. This paper explores the historical background and performance of the technologies used in the pleating process, and examines the various modeling techniques that have been brought to bear. The principal innovations in the pleating process can be divided up into shaping, shrinking, and decorative technologies. The relationship between changes in pleating and clothing patterns is also discussed, together with how design thinking has approached the craft of overlaying patterns on pleated clothing. Depending on the clothing and kind of technology being used, there are three main ways in which innovative design can be applied to the pleating process: to create geometric clothing patterns; to create basic clothing patterns; and through the superposition of shrinking technology. A Chinese design case is presented to illustrate how the integration of technology and art can be realized. This paper may serve as a source of future reference for technological innovation in the design of pleated clothing.

Keywords: Pleated clothing, Digital printing and dyeing technology, Pleating technology, Pattern design, Innovative clothing design

1. Introduction

Digital printing and dyeing technology, as a kind of high-tech machinery controlled by computing systems, has undergone continual development since it first appeared in the mid-1990s (Melliand-China, 2005). Visual graphic design geared towards printing and dyeing found that technological progress in this area provided it with a good opportunity to improve the printing and dyeing process. This included basic digital printing, 3D printing and dyeing, and the development of modern design concepts integrating modern textile technology and traditional patterns (Wei Hui, 2021). Digital inkjet printing can be applied to the primary and secondary design of a range of clothing fabrics. For example, the main approaches to the secondary design of clothing fabrics include a variety of treatments, such as folding, hollowing out, the creation of mosaics, and other 3D treatments, where digital printing can help to create unique decorative and functional effects (Liu, 2013). At present, the principal types of digital printing technology used in this domain are digital printing straight on to fabrics, digital paper printing, scanning, and Sing-Pass digital printing. Digital printing can be used on different types of clothing fabrics but is primarily used on polyester fiber, commonly known as "polyester", because of its excellent resistance to creasing and wear and shape preservation. Together these properties have given polyester a leading position in the clothing market. Digital printing, then, offers new ways of achieving pattern design and meeting diverse requirements for the customization of clothing (Zhang, 2023).

An important focus of innovation in clothing design is the combination of pleating and printing in suit design (Feng Lei, 2016). To meet increasingly challenging requirements in clothing production, clothing manufacturers have begun to look at the growing potential of intelligent digital printing and dyeing technology. For the design

of new printed patterns, intelligent digital printing offers significant opportunities for the development of new applications (Wang, 2023).

Pleating in clothing can make use of both modern and traditional technologies. The fabric (mostly polyester) is extruded for folding and high temperature shaping is used to get permanent wrinkles that reflect particular categories of clothing. Pleated clothing has a unique shape, a unique and rich textural effect, and folds that differ from those that can be formed by fixing. Pleated clothing can maintain a stable spatial shape for a long time without the help of any external force or attachments. The clever application of pattern design and visual language to shape the expression of pleated clothing not only enhances the hierarchical sense of the spatial form, but also highlights the style and design orientation of different types of pleats. This is a key aspect of the design of pleated clothing. At present, systematic studies regarding the combination of the technology used to pleat clothing and the innovative design of digital printing and dyeing patterns are extremely scarce. There are a few studies that look at the combination of colors and patterns in "Issey Miyake" pleated clothing. These refer to the works of the Japanese designer, Issey Miyake, which combine decorative clothing patterns with the human body and the structure of their clothing (Wang Lei, 2006). Based on the expression techniques and style characteristics of Miao nationality pleated skirts in Guizhou, another paper makes a comparative study between them and "Issey Miyake pleating" to examine the inheritance and development of different design techniques (Li, 2022). One further study looks at the traditional Japanese aesthetics embodied in the colors of Issey Miyake clothing, and examines the balance between traditional culture and contemporary design, with the goal of improving design (Jiang, 2023).

In view of the paucity of research regarding pattern design and the use of pleating technology in clothing, this paper takes the design process involved in pleating and its combination with pattern innovation as a starting point. With reference to the demands of the modern Chinese market, it conducts a detailed exploration of the methods involved in design conception, planning, and implementation. By taking the different application cases of geometric patterns, basic patterns, systolic pleating, and superimposed decorative pleating, it examines the innovations and cultural trends in clothing patterns and reflects on the design thinking required for a more diversified integration of technology, patterns, and processes.

2. Historical Background and the Characteristics of the Pleating Process

In ancient China, a "pleat" was called "bi ji"「襞积」. Over the course of time, there have been many ideas of what a "pleat" might include, such as pleats, folds, wrinkles, etc. The main characteristics of a "pleat" are a reconstruction of the fabric's texture, the artful folding of a piece of cloth, and adaptation to the human silhouette. Costume dictionaries suggest that "pleat" refers to a natural fold formed by the shrinkage of part of the garment's material to suit the body shape and modeling needs. A "fold" aims to achieve the same purpose, with part of the cloth being folded regularly and ironed to form. Pleat deformation combined with different human body shapes involves forming a pleated textural effect, full of vivid, three-dimensional, rhythmic sense and diverse beauty. It is recorded in historical materials that darts appeared in clothing in the Gothic period, during the 13th century, in order to meet the functional requirements of different parts of the human body and to realize a transformation from two-dimensional to three-dimensional space in clothing design. However, the relationship between pleats and darts is inseparable, and the dart structure in clothing plate-making can be offset by pleating, which is both decorative and functional. An early pleating technique, inspired by a classical Greek statue of the Warrior of Delphi, is captured in the Delphos dress, which was invented around 1907 by Mariano Fortuny y Madrazo (1871-1949). In September 1933, Schaparelli developed a pleated texture in rayon material that was shaped like bark, known as "bark pleats". In the 1970s, Issey Miyake explored adding a new technique to the traditional fabric preparation process, which was a kind of "pleating" technique. Up until the 1980s, pleated elements in the Chinese clothing market were often used in clothing design for specific details, but could also cover the entire item. Nowadays, pleating in clothing design has become more abundant and can feature directly in the secondary processing of the fabric. In other words, an increase in the use of pleating in clothing has followed innovations in fabric technology. It is now widely appreciated by consumers and has become a unique selling point for clothing.

The main outcomes of the pleating process are: an embossed effect in the fabric; no change after washing at a high temperature setting; a visual impact on the spatial form; and strong body responsiveness. In craft production, pleating includes techniques such as machine pleating, manual pleating, and combined manual and machine pleating. In its form, pleating can incorporate a regular arrangement of pleats, a repeated cycle of pleat units, and folding composed of patterns. Pleated art crosses Eastern and Western cultures. Western costumes focus on the externalization of humanity's cultural spirit and individuality, while Eastern costumes emphasize etiquette and discriminate significantly between different human relations. The cultural aspects of pleated clothing, when combined with the fabric and cutting technology, reflect trends such as postmodernism and other philosophical

ideas according to changes over time. Against a background of both inherited notions of costume design and innovation, combined with the compositional forms of pattern design, and borrowing heavily on Eastern "naturalism" and Western "Cubism" and "expressionism", traditional Chinese pleating and decorative techniques continue to be used for reference in clothing design. This creates richer designed experiences that enhance the beauty of people's inner and outer bodies.

3. Modeling Techniques Used in the Pleating Process

In modern design, the boundaries between "art" and "technology" are becoming more and more blurred as they become inseparable and organic components of the design process. Typically, the design of clothing involves certain core considerations, such as the fabric, process, pattern, color, and pattern. Contemporary design thinking attaches importance to the application of a variety of processing technologies, drawing upon new advances in science and technology.

From a technical point of view, the modeling techniques associated with the pleating process make use of three kinds of technology relating to shaping, shrinking, and decoration. The pleating process itself has two principal forms: mechanical shaping; (see Figure 1); and manual shaping (see Figure 2). High temperature shaping technology is the core tool for mid-compression pleating. Depending on whether there is plasticizer water being used in the process, this itself can be divided into two categories: dry heat setting; and wet heat setting. Dry heat setting is primarily a machine-based shaping process, with a professional high temperature pleating machine being used to fulfill the process. Here, the fabric is kept in a dry state and no water is used for the heat treatment. Wet heat setting uses a high-pressure hot steam setting machine. This is primarily a manual process, with the setting temperature being closely related to the type and shape of the fabric fibers. Given these conditions, the fabric is typically made of polyester or a polyester fiber blend, in which polyamide and polyacrylonitrile fibers predominate. Polyester-based fabrics are almost always subjected to a wet heat setting process because the temperature is lower than it is in dry heat setting. The pleating process, not only needs to consider how to keep the fabric hanging and moving in a lasting shape after washing, but also how to keep the shape beautiful. This involves paying close attention to the pressing machine temperature, speed, and strength control, so as to avoid any unnecessary loss of fabric, yellowing, or burn holes. High temperature molding is required to ensure a regular arrangement and repeated cycle of pleats. As many people prefer skin-friendly natural fibers, such as cotton, silk, wool, and hemp, the solution is to blend these natural fibers with synthetic fibers. This improves the fabric's capacity to hold its crimped shape. In addition to the use of hand-assisted sewing, the process commonly uses technical approaches, such as fixed sewing.

Figure 1. Curved pleats and straight pleats created by machine-based shaping technology

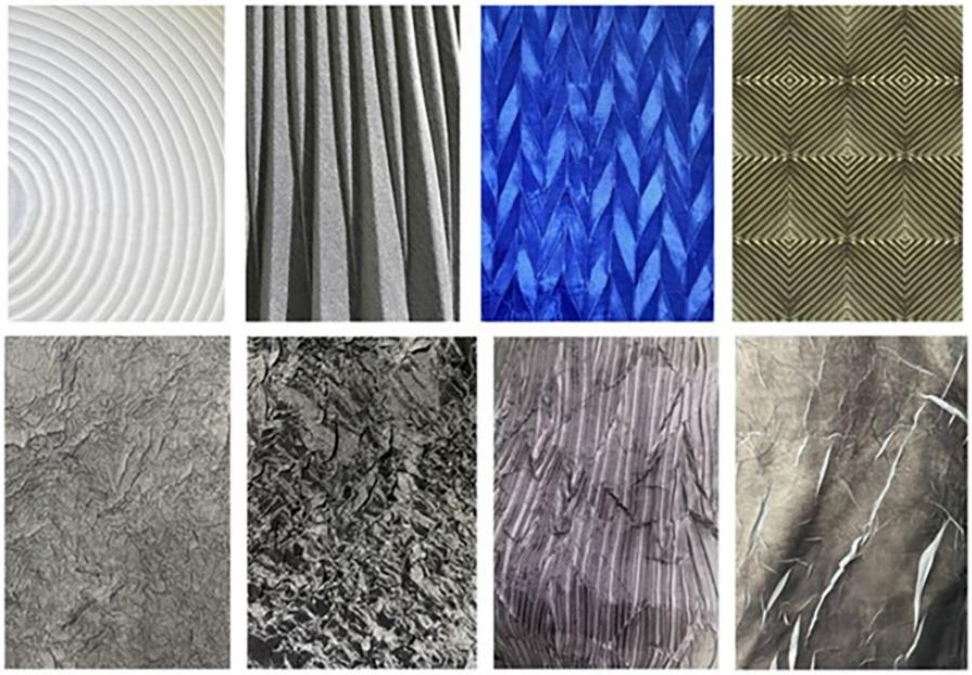

Figure 2. Paper mold pleats and steam pleats created by hand-based techniques

Shrinking technology, and the associated shrinking process, is a new approach to pleating that grew out of the ideas promoted by Issey Miyake in Japan. At present, this has been taken up by two pleating factories in China, one in Nantong and the other in Guangzhou. These factories use traditional Chinese pattern composition, with tangled branches and surrounded by rattan. This is a narrow, long arrangement, whose precise configuration has been arrived at through research and development (Figure 3). The technology, here, requires special crumpling materials and crumpling machinery as a part of the process. The high temperature pressing and machine embroidery processes are typically integrated, to produce a repeated cycle of pleat units and patterns according to the pleat design. The obvious structure of traditional Chinese patterns makes it easy for them to be divided into single pattern pleats, two square continuous pattern pleats, and four square continuous pattern pleats (see Figure 4).

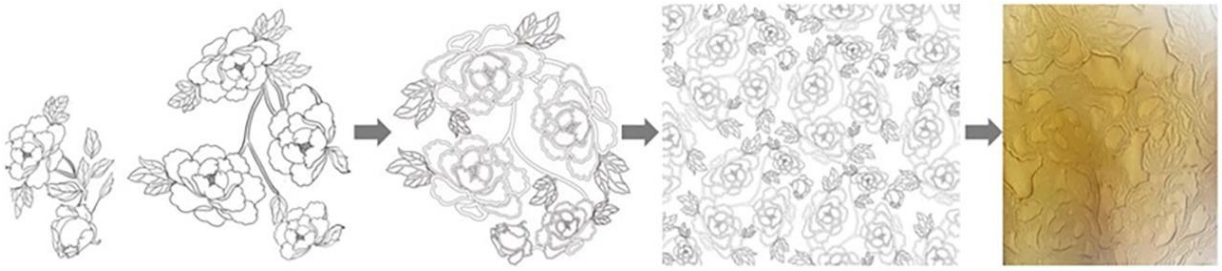

Figure 3. Traditional Chinese flower pattern designs

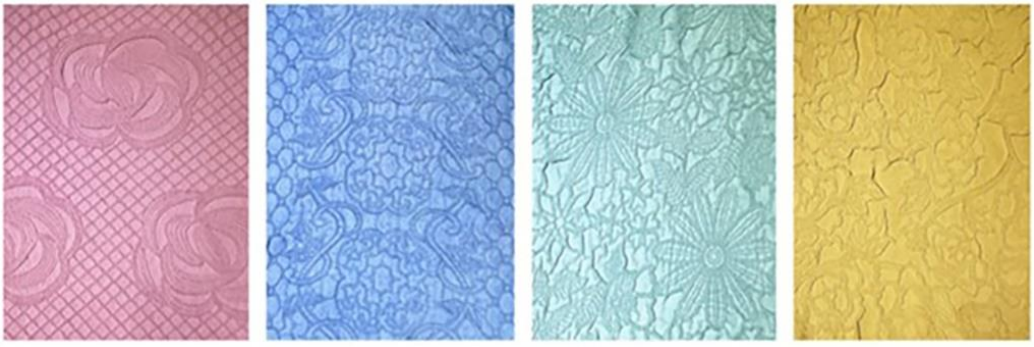

Figure 4. Pleats created through the use of shrinking technology

There are various decoration technologies that can be used for pleated clothing, including compression decoration and splice decoration (see Figure 5). Decoration technologies are used to beautify the clothing. They are considered a form of fabric reconstruction and are mostly used after the pleating process. They include manual secondary superposition, such as stitching, mosaics, splicing, intersections, and pearl embroidery. The decorative process can make the style of the shape more complete. The use of different colored sewing threads is akin to adding the icing on a cake.

Figure 5. Decoration technologies used for pleated clothing

4. Application of innovative clothing design in the pleating process and the digital printing of patterns

When using digital printing and dyeing technology, the color and pattern are reproduced on blank white cloth to present a particular artistic form on the fabric. Designing patterns when using pleating technology is different from general clothing design. This is because the pleating process has to take into account the composition of the pattern and color matching. Over recent years, dyeing and finishing technology has become increasingly rich, with manual and machine-based dyeing being used together to provide consumers with different kinds of visual dressing experience. Pleated clothing applications mostly use polyester fabric, where the color and pattern are usually realized by digital printing. The principle is to use a high temperature roller for the digital printing and high temperature pleating mechanism for the pleating in such a way as to make the most of the advantages of the two techniques. One can pleat the fabric while doing positive digital printing, but also reverse print color to the positive. These two production methods are commonly used for pleated pattern design. At present, digital printing patterns for pleated clothing focus on the fabric texture and color composition. Commonly-used fabric textures include digital denim, digital tweed, and digital tie-dye patterns. The idea, here, is to use digital printing to deliver a visual illusion following the principles of graphic art. Using the relationship between cold and warm colors and distance, and the principles of perspective and tone in painting, the goal is to engage in spatial modeling, using the dyeing pattern in the creases and finishing process to encourage certain kinds of visual perception. Recently, as a way of protecting intangible cultural heritage, innovations based on traditional Chinese culture have reshaped the traditional handicrafts associated with fabrics. innovation, For instance, "iterated ® polyester" allows the manual dyeing and finishing process for polyester fabric to be combined with the compression process to obtain a visual plane effect that elaborates upon the beauty of two-dimensional categories of dyeing, such as dip dyeing, infusion dyeing, and hang dyeing. Tie dyeing is a traditional Chinese hand dyeing technology where the use of different tying techniques results in unique fold-based art. However, the concave-convex texture beauty formed by tie dyeing can also be realized during the pleating process with digital printing. Clothing patterns are commonly divided into two types: concrete patterns; and realistic patterns. Concrete patterns are those associated with the concrete images formed by perception, memory, emotion, etc. Realistic patterns focus on the accurate rendering of real things.

Influenced by the current trend for pleated clothing in fashion, we are going to use a design case over the following subsections that select a realistic pattern inspired by watercolor art, combined with patterns based on geometric concretions and traditional Chinese patterns. The pleats used in the design case are box pleats, patterned texture pleats, and double superimposed decorative pleats. The fabric is a unified 30D polyester fabric. Innovative clothing design in the pleating process is combined with digital printing and the design thinking is shaped by three different approaches to clothing patterns, namely geometric clothing patterns, basic clothing patterns, and shrinking technology-based superposition.

4.1 Geometric Clothing Patterns

Pleated clothing is both decorative and functional. The pleats help the clothing to conform to the body and the pleated fabric is flexible and easy to move. Characteristically, pleated clothing patterns have a two-dimensional geometric form that obscures the path of the "darts". The geometric pattern in Issey Miyake's classic design work "A-POC" reflects his interest in exploring the infinite possibilities of clothing. Miyake's 2023/24 Autumn/Winter collection of women's wear adopts a design language based on moving squares that transform and create irregular shapes that enhance the formal beauty of the clothing's visual aesthetics. Geometric patterns in pleated clothing are well-suited to providing regular vertical, horizontal, and oblique proportional amplification of the regular straight pleated design. The production process is relatively simple, as a pattern following the same direction as the warp, weft, and skew of the fabric's yarn will have the same proportional amplification and shrinkage. The half skirt in Miyake's collection, for example, can be seen as a simple rectangle, ignoring the dart at the waist. As the pleats are box pleats with a regular fold direction, the hip circumference of the largest dimension of the lower body can be seen to form the long side of the rectangle. The skirt's length is then the short side of the rectangle. According to technicians, the pleating machine can then be set to a uniform high temperature. Taking polyester chiffon 30D fabric as an example, the warp direction is amplified by 2.7, so design of the pattern needs to allow for a lengthening of the original pattern by 2.7. At the same time, when doing the digital printing, the fabric is subject to a certain amount of shrinkage at high temperatures, so the raw edge of the fabric needs to be increased by 3 cm. Overall, the following rectangular conversion data was obtained (see Figure 6): posterior plate = 115.1 cm × 84 cm; front plate = 97.46 cm ×84 cm and 18.06 cm × 84 cm; lower fork length = 14 cm; pocket = 33.33 cm × 27 cm. Only the warp direction was larger; the weft was unchanged. The color saturation of the digital printing needs to be adjusted accurately in advance. Under normal circumstances, digitally printed colors on fabrics become darker after passing through a high temperature pleating machine. This affects the visual aesthetics of the clothing design. The design elements form a realistic pattern that gives the impression of watercolor art, promoting an elegant, quiet, and gentle atmosphere (see Figure 7).

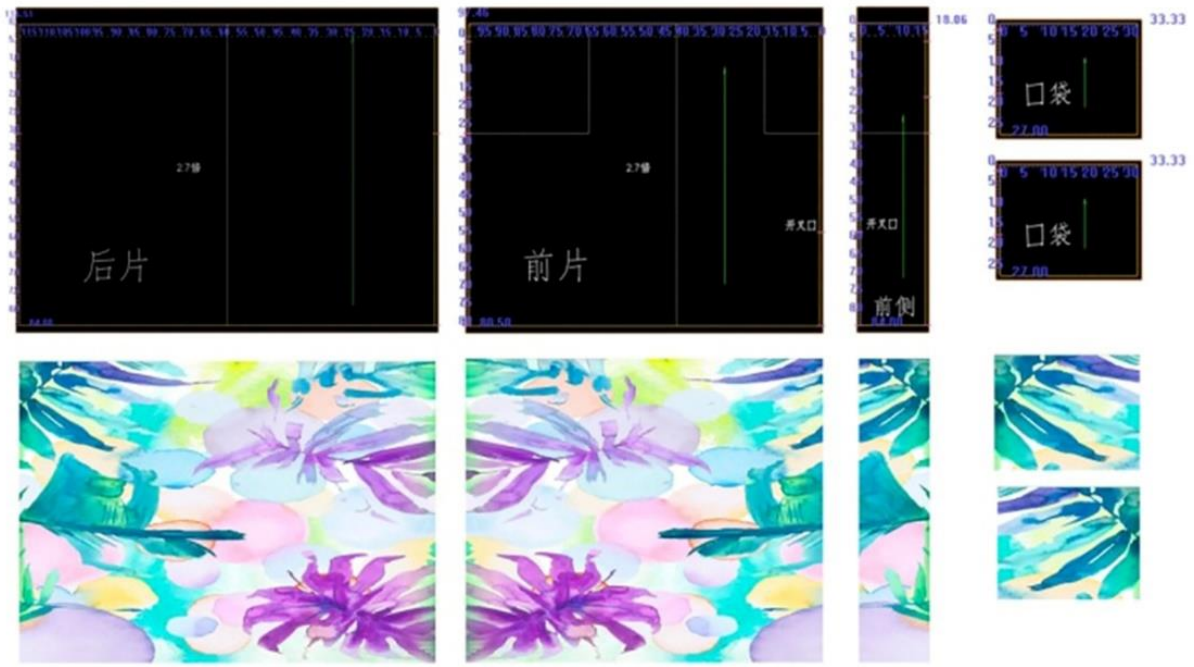

Figure 6. The pleated fabric design process for a geometric clothing pattern

Figure 7. Innovative digital printing combined with pleating technology for clothing design

4.2 Basic Clothing Patterns

When pleated garments adopt a basic clothing pattern the defining characteristic is the absence of a dart structure. The general process, here, is to first of all come up with a stylish shape design that can be combined with pleats in the folding process. Then, according to the weight of the fabric's yarn, the shrinkage of the pattern is calculated. After that, an appropriate technology is selected for the pattern planning. Taking a dress structure as an example, if the warp direction is elongated, a regular box pleat would be compressed by about 2.5 to 3 times depending on the fabric. The key technical point of concern in the design of the pleated garment is the pre-shrinking of the fabric. The design process generally passes through two pre-shrinking phases. The first is the shrinkage of the fabric under high temperature during the digital printing. The other is the shrinkage under high temperature in the pleating machine. The key to solving this problem is to embed the pattern in the overall pattern of the clothing to ensure regularity in the pattern shrinkage. In the selection of geometric patterns shown here, with bright contrasting colors that are suitable for summer fun, the most critical problem in the production process is the positioning of the pattern within the overall clothing pattern, such as at the sleeve seams and body structure dividing line (see Figure 8). In the process of drawing the patterns, it is necessary to solve the problem of getting the flowers to match in the clothing pattern.

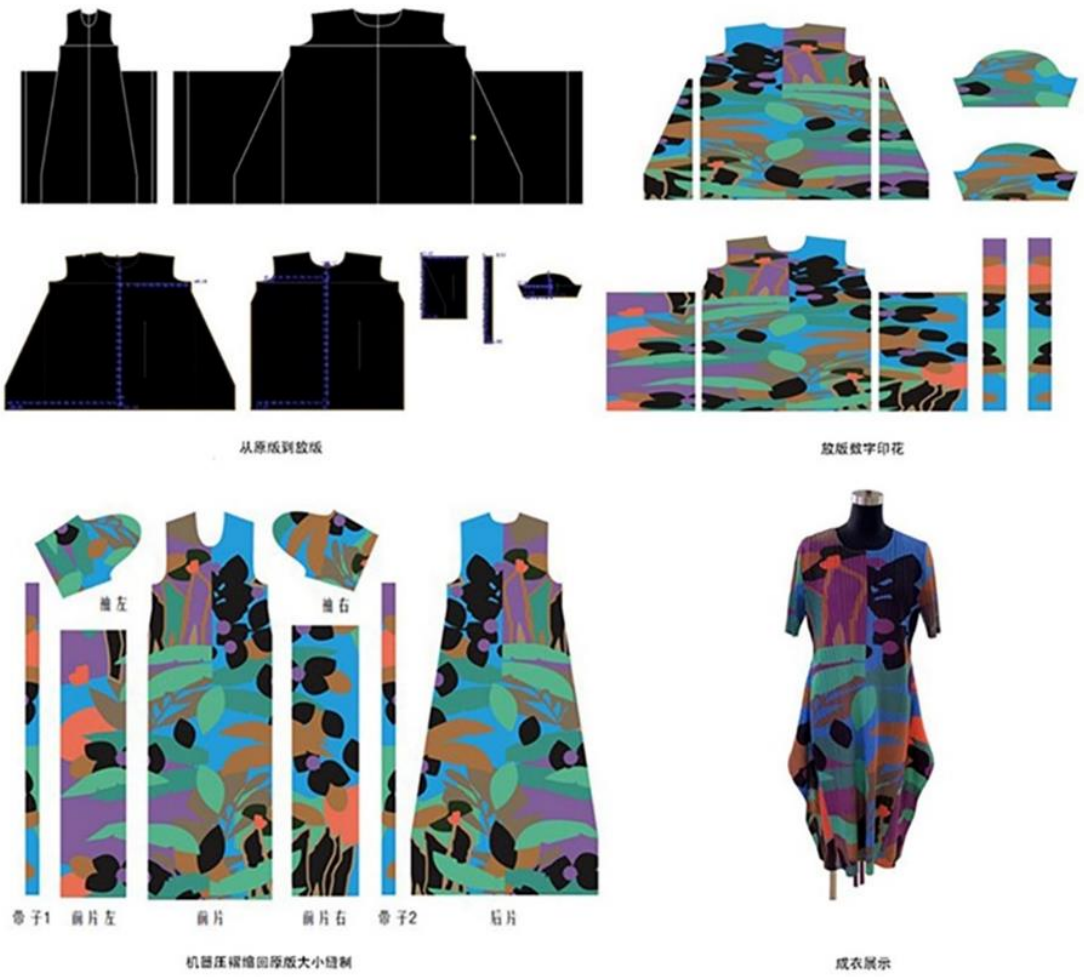

Figure 8. Innovative digital printing combined with pleating technology for a basic clothing pattern

4.3 Shrinking Technology-Based Superposition

There were many kinds of ancient, pleated clothing that used traditional decorative techniques, such as inlaying, piping, stitching, embroidery, sewing, and so on. Taking the Ming Dynasty horse-face skirt as an example, the position and quantity of decorative pleats and their shape varied in specific ways. The decorative techniques and number of pleats combined with jacquard flowers also varied. There were four main types: no decorative pleats at all; a single decorative pleat; two decorative pleats; and multiple decorative pleats. When there was no decorative pleat, there were no jacquard flowers, only simple flowers that were mostly hidden. When there was a single decorative pleat, the skirt was usually decorated with jacquard flowers at the bottom. As the economic situation improved and stabilized, double decorative pleats started to appear that were heavily decorated and the two-layer jacquard splicing was not uncommon. The fabric used when there were multiple decorative pleats was more elaborate, often full of flowers to accompany the pleats. Nowadays, with the development of digital printing and dyeing technology, along with the particular characteristics of the era and its aesthetic demands, pleating technology continues to innovate. Modern pleating technology can make use of additive pattern designs. The most commonly used creates a special texture with wrinkled fabric. Known as shrinking technology, heat shrink film is used in the forming process, where there are three steps: applying the film; sewing; and wrinkling. The resulting texture has concave and convex features and typically adopts very decorative artistic patterns of formal beauty. By using an overlay to achieve the designed effect, the human tactile experience and visual presentation are both full of unique artistic beauty. It is difficult to design and make this kind of pattern because of the shrinkage of the fabric during the folding process when the shrink film is applied, before being inlaid and sewn. The example here shows a combination of Qipao style and the aesthetic sensibilities and textures associated with Chinese poetic culture. The use of secondary processing techniques, with the shrinking technology-based superposition of features, creates an irregular, hidden art form (see Figure 9).

Figure 9. Innovative design combining digital printing with pleating technology and shrink film-based superposition

5. Conclusion

Based on the technologies associated with pleating, digital printing, and dyeing, this paper has discussed technological innovation in the design of pleated clothing with reference to three distinct case studies. Its main conclusions are as follows:

(1) As a result of the development of digital printing and dyeing technology, innovation in the processes associated with pleated clothing has been substantially enriched. The pleating process generally involves the use of steam, paper molding, pleating, and shrinking. In terms of clothing modeling techniques, this can be divided up into the application of shaping, shrinking, and decorative technologies.

(2) The effective realization of digital printing during the pleating process is related to proper consideration of matters such as fabric shrinkage and the overall clothing pattern. On this basis, geometric clothing patterns, basic clothing patterns, and the superposition of decoration have all been subject to technological innovation.

(3) When it comes to pleating innovation drawing on traditional Chinese elements, shrink-film related technology and the superposition of decorative features can achieve significantly more diversification in the pleating design, while continuing to make effective use of the unique processing methods associated with digital printing and dyeing technology.

(4) This paper has sought to integrate and expand upon the design thinking associated with pleated clothing technology. It therefore stands as an effective reference for future innovation in the design of pleated clothing technology.

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Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.