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Two-color Double-cloth Development in Alignment with Subtractive CMYK Color Theory by Deploying Digital Technology

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ABSTRACT

This study aims to introduce new aesthetic values of modern double-cloth by resolving the current restriction in woven textile coloration. Previously, realizing pictorial images on both sides of a fabric was experimented with two weft yarns and further possibility was suggested to extend an applicable number of weft yarns for which a prototype of two-color double-cloth was tested and fabricated by employing four weft yarns. In this study, therefore, reproduction of highly complicated patterns in a two-color shading effect is aimed to further develop the current double-cloth design capability. The core principle lies on weave structure design to interweave two sets of warps and wefts into separate layers whilst two distinctive images are designed in alignment with CMYK color theory to enlarge a feasible weave color scope by using the subtractive primary yarn colors. Details of digital weave pattern design and weave structure development are explained based on empirical experiment results.

Keywords: Two-color double-cloth, digital weave pattern design, subtractive color theory, double-cloth weave structure, new color expression

Introduction

Digital technology employed in modern weaving greatly enhanced production efficiency and convenience (Ishida, 1994). In modern digital weaving, however, an applicable number of weft yarn color resources is limited by the performance characteristics of existing electronic loom machinery. Automated modern weaving looms are often arranged with one end of ground and utilized for continuous styles. Therefore, colors of image patterns are relied on weft yarn colors whereas an applicable number of color resources in weft is also constrained (Watson & Grosicki, 1997). As a result, the color accuracy level to be able to correspond to high-quality imagery designs has been highly limited. To resolve the current limitation, realizing a wide weave color scope by using a small number of weft yarn colors is vital to enhance the current woven textile design capability and its production efficiency (Kim, 2014).

In previous research, diverse approaches have been made to maximize a feasible weave color scope in which the importance of making a mutual interaction between weave structure and weave pattern is discovered so as to correspond to highly complex designs (Zhou, 2011; Kim, 2014). Through many investigations in weave pattern design made with diverse color theories to align with weave structures, an interesting yarn color mixing effect is revealed in relation to the subtractive CMYK color theory. For instance, when the pair of CMY colored yarns are juxtaposed, generating their secondary color ranges is feasible despite using non-transparent yarn materials (i.e. [C]+[Y]=[G], [C]+[M]=[B] and [M]+[Y]=[R]). In contrast, when CMY are paired with black, creating different chroma levels of CMY is attainable. Based on the yarn color mixing effects, novel weaving methods have been introduced and proved its significance in multi-color reproduction. Successful cases of pictorial image reproduction have been introduced by using only four primary colors of CMYK color system (e.g., cyan, magenta, yellow and black) (Kim, 2014; Kim, Ng, Zhou and Hu, 2017). Therefore, the color theory applied to multi-color reproduction is examined in multi-layer structure format to enhance the current double-cloth design capability. Previously, generating pictorial images in a single-color effect was explored in double-cloth format and the relevance of the applied weave structure was verified through reproducing delicate details of image patterns in a high-quality natural shading effect. Based on the achievement, a prototype of two-color double-cloth fabrication was experimented with four weft yarn colors (e.g., cyan, magenta, yellow and black) (Kim, 2018). In this study, therefore, it is aimed to further investigate the potential in CMYK color theory and the weave structure when they are applied to highly complex pictorial image reproduction. By pairing [M]+[Y] and [C]+[K], two distinctive pictorial images are designed with the varied color shades that are anticipated to be produced by juxtaposing the two pairs of the subtractive primary yarn colors.

In weave structure design, as each end is threaded in an individual hook on an electronic loom, unlimited shedding is possible to interlace warp and weft. In traditional weaving, as shed creation is limited with a number of shafts, a plain weave structure is widely applied and used for double-cloth fabrication, but the weave structure is limited in producing varied levels of color shades (Shenton, 2014). In contrast, in digital weaving basic weave structures (i.e., plain, twill and satin/sateen) are possibly developed into diverse derivatives to correspond not only to intricate design patterns but also different levels of color shades. In this study, based on the previous experiment result, a sateen weave is selected and investigated as the structure format is proved its capability to fabricate complex double-cloth designs (Kim, 2018). Several weave structure experiments are firstly designed to understand the core principle of creating two layers in a two-color effect and then they are further applied to examine the relevance for two-color double-cloth fabrication designed with intricate image patterns (Figure 1).

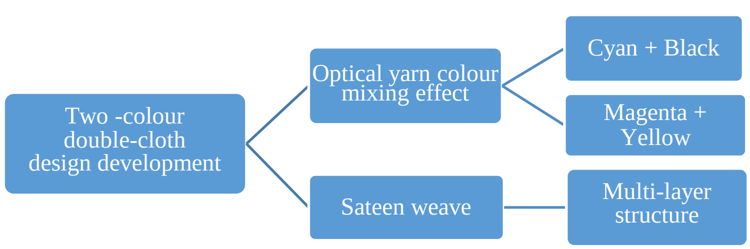


Figure 1: Two-color double-cloth development with CMYK color theory and multi-layer structure

Currently, double-cloth design limits not only its patterns to abstract styles (i.e., stripes, geometric shapes and color blocks) but also the color expression. To realize a highly intricate pictorial images, a basic sateen weave structure is investigated in multi-layer structure format to generate discontinuous thread floats in a stable condition. Furthermore, when designing image patterns, the subtractive color theory is applied to enlarge a feasible weave color scope in conjunction with a sateen weave structure to resolve the existing constrains. In this study, the details of the weave pattern design aligned with CMYK theory and the weave structure development process is explained based on the experiment results to introduce a new form of color expression for double-cloth fabric design.

Methodology

In two-color double-cloth development, empirical experiments are designed in focus of weave pattern and weave structure design. They are the core parts of digital weaving to resolve the current color restriction in double-cloth design. In weave pattern design, CMYK color theory is adopted and two distinctive images are designed by paring the primaries (e.g., [C]+[K] and [M]+[Y]) to embrace a wider color range whereas in weave structure design, a sateen weave structure is investigated to understand the core principles of transforming the basic weave into multi-layer weave structures and to increase an applicable number of weft yarn colors for double-cloth fabrication.

Digital Weave Pattern Exploration

In digital weaving, image patterns are used to allocate each yarn color in an accurate place in correspondence to design images and different color shades are reproduced in woven form by controlling amount of yarn colors exhibited on the surface. 8-bit color mode is suggested appropriate for a high-quality Jacquard design reproduction as it represents a colorful image within 256 colors (Zhou, Tang, & Hu, 2011). Subsequently, converting a colorful image into to grey-scale mode is important as it assists in identifying individual color shade levels to align with weave structures.

In previous study, a prototype of two-color double-cloth experiment was conducted to examine the possibility to produce a natural shading effect on both side of a fabric. As Figure 2 shows below, two images were designed to combine the pairs of CMYK to observe the juxtaposed yarn color effect. When mixing a pair of CMY, it was expected to generate their secondary hues in different levels of shades whereas by juxtaposing CMY with black, presenting varied chroma levels of CMY was anticipated. As Figure 3 shows the fabrication result, the reproduction of the images paired with the subtractive primary colors was successfully fabricated in double-cloth format and it indicated further possibility to develop the two-color shading effect with more intricate motif involvement (Kim, Ng, Zhou and Hu, 2017; Kim, 2018).

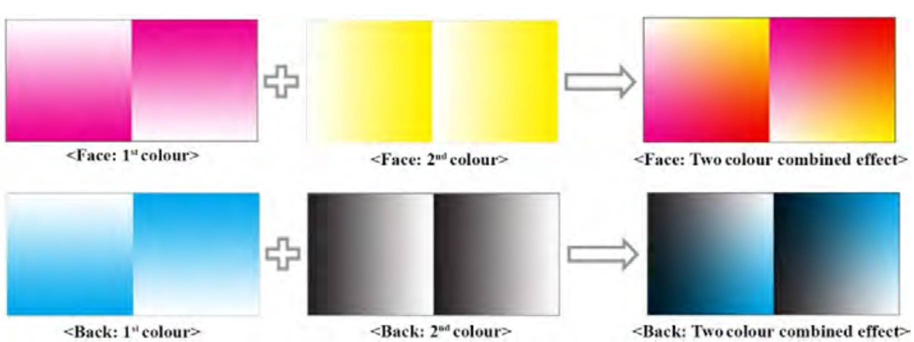
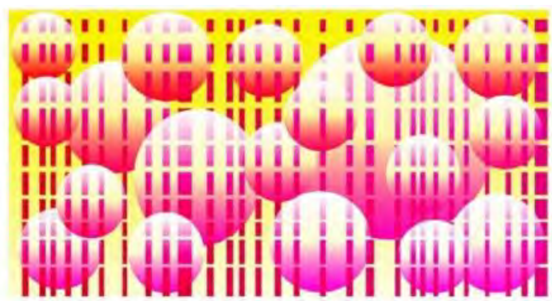


Figure 2: Image pattern design for a prototype of two-color double-cloth (Kim, 2018)

Figure 3: Prototype two-color double-cloth fabrication (Kim, 2018)

In this study, therefore, two distinctive image patterns are designed with highly complex imagery patterns and the colors expected in the pair combinations (e.g., [C]+[K] and [M]+[Y]) are considered when designing the patterns to enrich the color expression of the double-cloth. As Figure 4 shows, the colors of the face pattern are designed to comprise of varied color shades combined with cyan and black whereas the back pattern is developed in reflection of the secondary color ranges expected in magenta and yellow yarn color juxtaposition.

<Pattern for Face>



<Pattern for Back>

Figure 4: Image pattern design for two-color double-cloth fabrication

Weave Structure Exploration

Sateen Weave

Due to the stable condition to exhibit discontinuous yarn floats on surface a sateen weave has been preferred for generating natural shading effect in woven form (Kim, 2014) for which diverse derivatives are created based on a basic sateen to develop into shaded weave structure format (Kim, Ng, Zhou & Hu, 2017). In this study, a 12 x 12 sateen is selected and developed into a series to correspond to varied shade levels. Transforming the derivatives into double-cloth weave structure format is essential to realize two-color double-cloth fabrication with four weft yarn colors (Figure 5 and 7).

Shaded weave

Shaded weave structure is the derivatives of a sateen weave that is transformed by adding interlacing points on a regular basis. In a series development, the interlacement addition is continuously made until a weave repeat is left with a minimum stitching point in each pick (Watson & Grosicki, 1977; Kim, 2014). For instance, as Figure 5 shows one example of the shaded weave series, a 12x12 sateen weave is transformed by adding 12 interlacing points each time and the process generates different levels of shaded weaves. In this development 11 individual weaves are attained to align with digital image patterns. When developing a shaded weave series, a number of interlacement additions made at a time is considered important as it enables to attain a sufficient number of individual weaves in a series to make a small reduction of color shades in an image pattern for fabrication (Kim, Ng, Zhou and Hu, 2016).

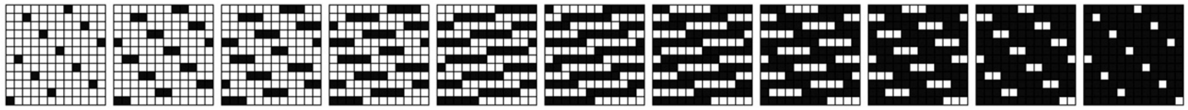


Figure 5: 12x12 shaded weave structure series

By juxtaposing varied lengths of thread floats on surface the weave structure format is not only capable of representing different levels of color shades but also creating new colors through a smooth gradation effect (Kim, Ng, Zhou & Hu, 2016a; Kim, Ng, Zhou & Hu, 2017). To depict complex pictorial images in double-cloth format, different levels of shaded weaves in a series are all transformed either to be a face or back layer and aligned with appropriate a level of color shades in an image pattern. The core principle of transforming the weave structures into double-cloth format lies the same as the traditional handweaving, but its process become highly complicated as it requires different weave structure response to each color shade in an image pattern (Ng, & Zhou, 2009b).

Firstly, a preliminary experiment is designed to produce two-color double-cloth by exchanging two weft yarns (Figure 6). The initial experiment is explored with two compound weave structures that are transformed either to be a face or back layer. Applying a different starting point and step movement to a sateen weave (Figure 7 a & b) is considered to evenly distribute stitching points as it assists in stabilizing structural balance in production when two weaves are combined and applied as a compounded weave(Figure 7 c & d) (Kim, Ng, Zhou & Hu, 2016).

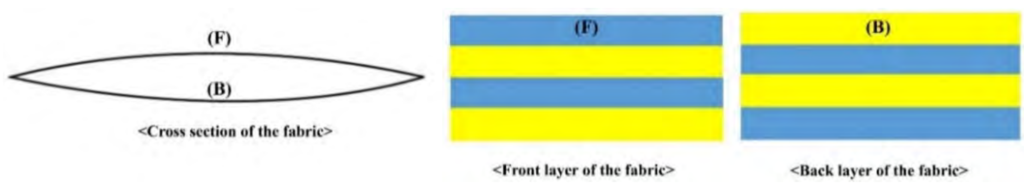


Figure 6: Two-layer creation in two-color strips by exchanging two weft yarns

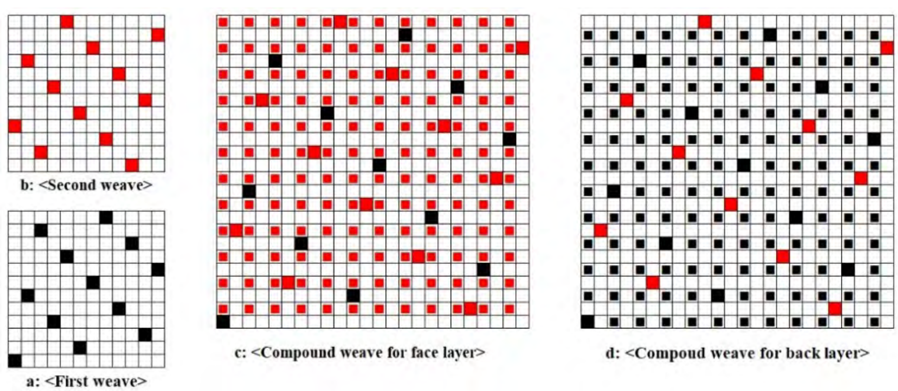


Figure 7: Double-cloth weave structure design for exchanging two sets of warps and wefts

Figure 7 shows the two compound structures that are alternately applied to two different color regions in the image patterns (Figure 6) within which two weft yarn colors are interchanged to make two-color strips. In production, the warp yarns assigned for a face is only lifted followed by the stitching points of the face weave (c) while the warp yarns allocated for a back layer is lowered to create a separate layer underneath of the face layer (d).

As Figure 8 shows the experiment result, the compound weaves converted into a face and back layer successfully exchange the two wefts and generate separate layers in two-color strips. To interchange the weft yarns, the digital image patterns (Figure 6) are used to allocate two compound weave structures in projected regions to manage the interlacements of two sets of warps and wefts.

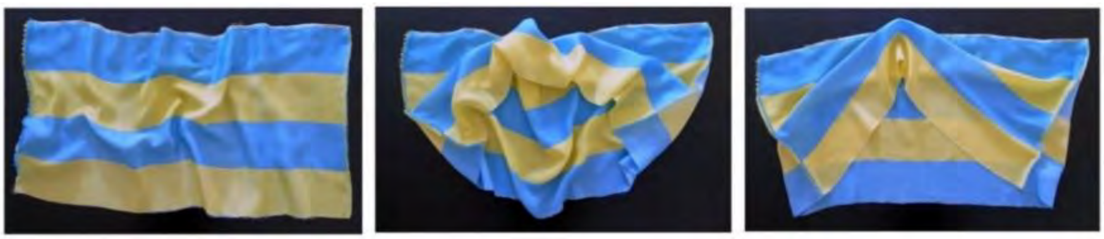


Figure 8: Preliminary double-cloth fabrication based on two wefts exchange

Further exploration is made to examine the difference between a single compound weave and double-cloth compound weave. As Figure 9 shows the experiment specification, two different compound weaves are applied to generate both a single layer and double layer in a single cloth fabrication. As the cross section of the fabric shown in Figure 9, two sets of warps and wefts are designed either to be united (A) or separated (B).

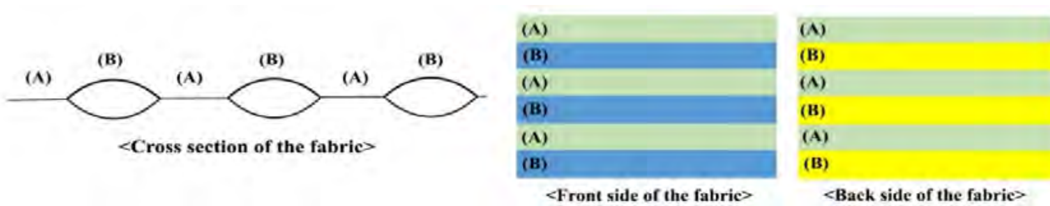


Figure 9: Fabrication design to combine with a single compound weave and double-cloth weave

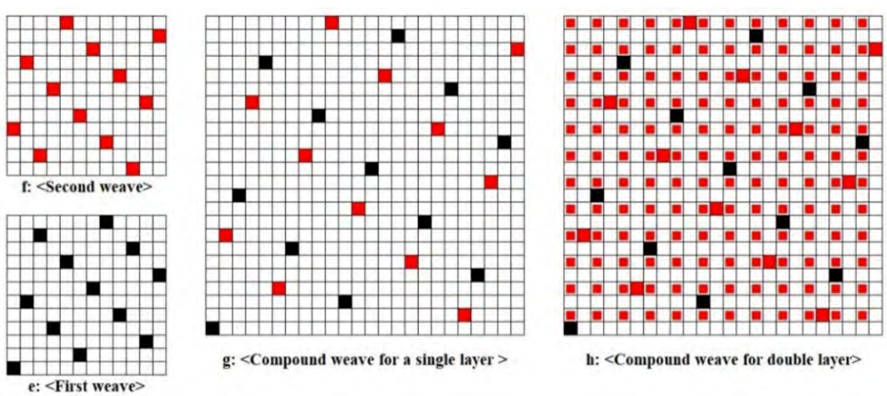


Figure 10: Comparison between a single compound weave and double-cloth weave

For a single layer, the two 12x12 sateen weaves (f and e) are merged into one and it arranges the two weft yarns to be alternately juxtaposed (Figure 10 (g)) in which warp and two weft yarns are interwoven together and generate a single layer cloth. In contrast, the 24 x 24 weave (h) resulted in combining two individual weaves is transformed to make a clear division in warp by separating it into two groups to pair with each weft yarn. The weaves (g & h) present the different compound weave structures required between double-cloth (h) and multi-color reproduction (g) (Ng, & Zhou, 2009a; Kim, 2018).

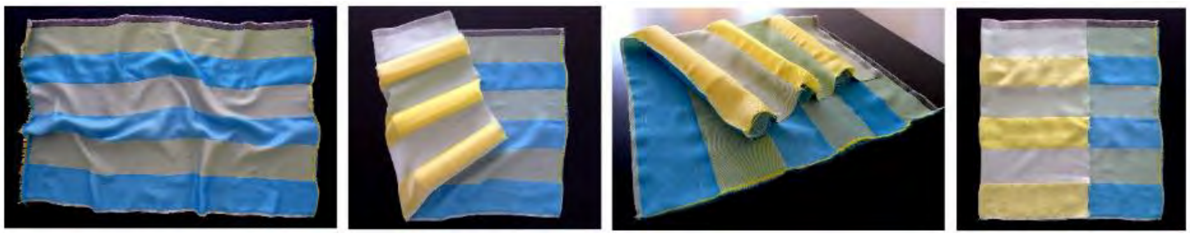


Figure 11: Double-cloth fabrication combined with a single compound and double-cloth weave

As Figure 11 shows the result of the experiment, the single compound and double-cloth weave applied to two different color sections (Figure 9) successfully interweave the two wefts yarns to preserve a single and double-layer in a single cloth. In production, weave structures are balanced and stabilized despite the complex interlacement arrangement resulted in combining different forms of compound weave structures. The colors of the fabric appeared between the two colors regions are visibly dissimilar as the way of interlacing two weft yarns is entirely different to each other.

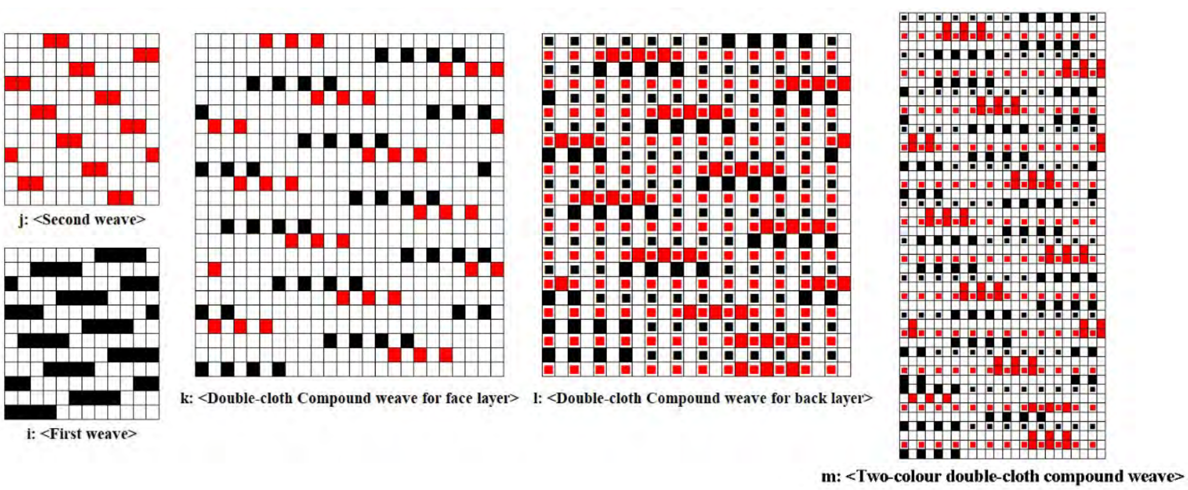


Figure 12: Compound weave structure developed for two-color double-cloth fabrication with four weft yarns

In two-color double-cloth fabrication with four weft yarns, the warp is separated into two groups and each warp group is paired with two weft yarn colors. To realize different levels of color shades (e.g., cyan, black, magenta and yellow), a 12x12 sateen weave is developed into a shaded weave series (Figure 5) and the individual shaded weaves are used to control the amount of yarn colors exhibited on the surface to reproduce different levels of color shades in woven form.

As Figure 12 shows one example of the shaded weave structures applied to embrace four weft yarns, to generate a face layer, the two weaves are combined (k) in a similar way to produce a single layer (Figure 10) whereas for a back layer the two wefts are designed to float underneath of the face and interlaced with the other warp group (l). When merging the compound weaves (k & l), the four weft yarns of a face and back layer are arranged to be alternately inserted in production to generate separate layers in a stable condition (m).

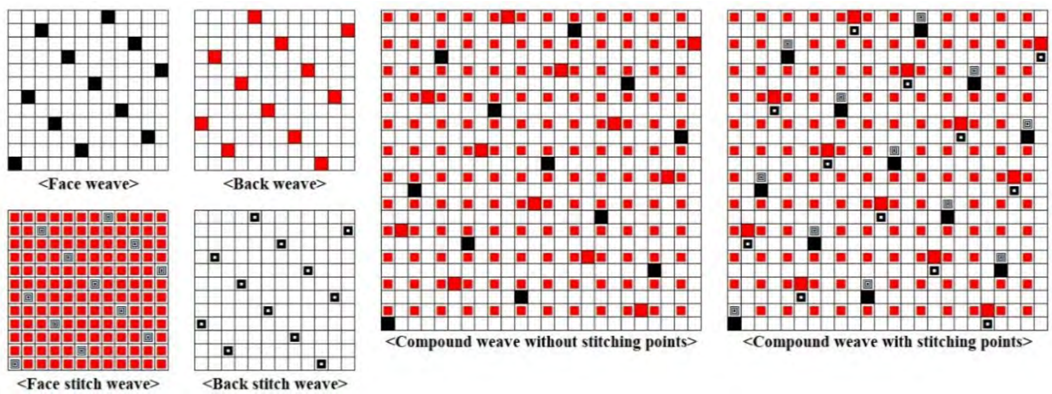


Figure 13: Double-cloth weave structure with or without stitching points

Self-stitching method

There are different ways of binding two layers together. In this study, however, self-stitching method is considered and applied as no additional threads are required in this approach (Watson & Grosicki, 1977). Firstly, the two sets of wefts and warps are organised to be completely seperated to each other, but by interachging several ends between a face and back layer the two layers are designed to be tied together. For instance, when raising the face warp over the back picks, several face ends are left to interweave together with back picks while when the face ends are lifted over back picks, a small number of back ends is raised together with face ends.

As Figure 13 shows the two compound weaves of double-cloth either with or without stitching points, the face and back layer of stitiching poins are assigned on a regular basis to maintain even tention in production. In addition, , applying a different starting point and step movement between the two layers are also reflectedfor the same motive when distributing self-stitching points. In contrast, a number of stitching points applied to each layer is related to the tightness to bind both layers that would depend on a different entity (Watson & Grosicki, 1977).

Experiment and Result

To examine the relevance of the subtractive color theory in weave pattern design and the two-color double-cloth weave structures, an actual sample fabrication is implemented to reproduce two distinctive pictorial images (Figure 4) in woven form. By adding three interlacements each time, a 12 x 12 sateen weave is developed into a shaded weave series in which 36 individual shade weaves are attained. To make a mutual interaction between weave patterns and weave structures the color shades of the four primaries (e.g., cyan, magenta, yellow and black) are reduced to 36 varieties and aligned with individual shaded weaves in a series. Applying different starting points and step movements is considered in weave structure design to evenly distribute interlacement points of two weft yarns floating on each side of a fabric. In this condition, interlacements of weave structures are balanced, and it evades a high compactness of interlacing points in production and assists in avoiding broken steaks and less favorable yarn color exhibition.

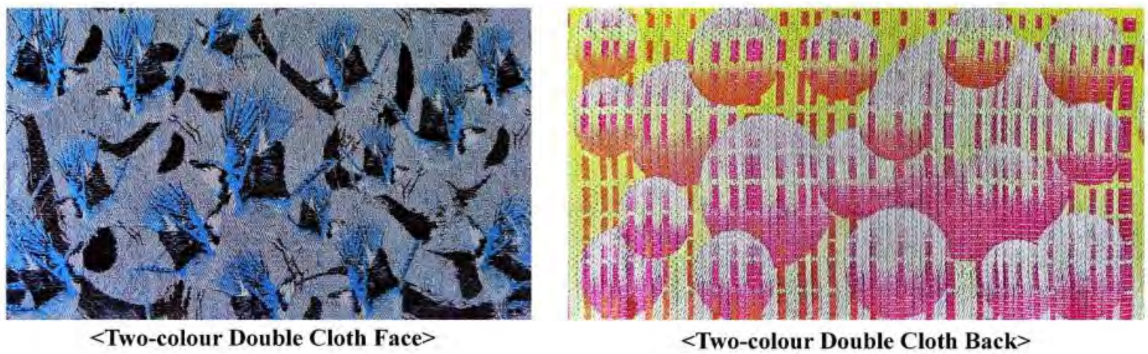


Figure 14: Two-color double-cloth fabrication result with four wefts

In this experiment, each warp group is paired with two wefts and generates two layers in a two-color effect whereas the four weft yarns for the face and back layer are alternately inserted in production to produce two layers simultaneously (Figure 12 (m)). To enlarge a feasible weave color scope, the weave patterns are designed in reflection of the subtractive CMYK color theory. As juxtaposing a pair of CMY produces their secondary color ranges, magenta and yellow primary is coupled for a back layer whereas cyan and black are paired for a face layer within which varied hue and chroma changes are anticipated to attain through the yarn color juxtapositions. As Figure 14 and 15 shows the reproduction of the digital images in woven Jacquard form, the two colorful images are successfully replicated on each side of a fabric by using the two pairs of the subtractive primary yarn colors.

Figure 15: Details of two-color double-cloth fabrication with four wefts

Interlacement points received through the individual weave structure combination was balanced during production and the applied self-stitching points securely tied the face and back layer together by making a clear division between the two layers (Figure 15). In comparison with a single-color double-cloth fabric (Kim, 2018), the color addition made to double-cloth fabrication improves aesthetic values and it suggests a great commercial potential to be developed into varied ornamental contexts.

Conclusion

In this study, the potential to increase a number of color resources in double-cloth design is explored and examined to improve the current woven textile design capability. Deploying digital technology in design and production process is necessary to be able to reproduce a high-level of complex patterns in double-cloth format. Individual hook setting on an electronic loom advances to correspond to highly intricate patterns, but as color resources are restricted in an existing machinery, realizing a wide scope of weave colors has been challenging. In this study, therefore, by applying the subtractive CMYK color theory, double-cloth format is investigated with CMYK colored yarns to enlarge a feasible weave color scope. As the four primaries (cyan, magenta, yellow and black) are capable of generating their secondary color ranges, they are paired and floated on each side of a fabric to reproduce colorful images in double-cloth format. To represent different color shades, a sateen weave is developed into a shaded weave series and transformed into double-cloth weave structure format in which interlacement points resulted in combining four individual weaves are considered to evenly distribute them in production. Based on the double-cloth weave structure and CMYK color theory, a new form of color expression for double-cloth design is introduced in this study. Based on this achievement, further development is advisable in relation with commercial values that would be applicable for fancy garment fabrics, furnishing fabrics and decorative materials with enriched color expression.

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