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Designing layer-to-layer angular interlock weaves for body-border superimposed reversible double-face figured fabrics

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This study aims to develop and analyse a new weave structure for producing Double-Face Figured (DFF) reversible fabrics that overcome the limitations of existing designs. DFF fabrics, composed of two interlaced layers displaying distinct images on either side, are traditionally woven using self-stitched double cloth or four-weft orthogonal weaves. However, these methods yield coarse textures or require dual warp beams. To address these issues, a Layer-to-Layer Angular Interlock (LLAI) weave structure is proposed and evaluated for its suitability in DFF weaving. The LLAI weave is designed on a 6-end × 8-pick grid, resulting in four cloth parts formed by superimposed images. Corresponding weaves are developed for each part, with additional variations created by interchanging picks to achieve balanced lifting in a body-border style. Computer-aided design tools are used for motif creation, guide graph development, superimposing, and weave application. Fabric samples are woven using both electronic and mechanical jacquards to validate the structure. Results confirm that the LLAI weave enables the smooth interchanging of plain structures without any weave prominence and can be woven using a single warp beam. The new weave structure thus offers improved texture, design flexibility, and production efficiency, making it suitable for reversible garments, dress materials, home furnishings, carpets, and technical textiles.

Keywords: Angular interlock, Body-border style, Computer-aided superimposing, Double-face figured fabric, Figured motifs, Reversible fabric

1 Introduction

Simple woven figured fabrics generally display a design in two or more colours with a weave on one side. The same design appears on the reverse, but with interchanged colours and opposite weave effects[1]. Figured fabrics, which are woven with weaves such as plain, twill, sateen, double cloth, and backed cloth, are reversible and can be used on either side, with the same figure. In contrast, the figures produced using extra warp or extra weft weaves are non-reversible and can only be used on one side[1].

Previous studies have reported the development of 'Double-Face Figured (DFF) Fabrics' capable of expressing independent full-colour effects on both sides, where in the backing structure is concealed within the face structure. The DFF fabrics have emerged as an innovative category featuring two stitched layers bearing distinct images on either side[2]. Such fabrics ensure balanced interlacement and pose no problems in industrial production due to the application of the regular face, backing, and stitch weaves[2]. Double-face fabrics have also been employed as tailorable, puncture-resistant solutions compared to conventional woven structures, such as plain, matt, and satin[3]. Similarly, weft-backed and warp-wadded double-face jacquard fabrics have achieved full-colour shading effects and high colour purity on both sides[4].

They are also referred to as 'Two-in-one Figured Fabrics' and 'Face-Flip-Face Figured Fabrics'[5]. The DFF concept enables reversible use, enhancing aesthetic versatility and functional value. For instance, a carpet designed with two distinct images using DFF principles offers visual variety and increased thickness due to its dual-layered weave. Many fabric designing experts have been conducting experiments to derive different weaves for producing DFF fabrics.

So far, the DFF fabrics have primarily been developed using two weaves: 'Self-stitched double cloth weave'[6] and 'Four wefts orthogonal weave'[7]. However, these exhibit notable limitations. The former yields a rougher texture due to binding stitches when woven in coarser counts, while the latter requires two warp beams for coarser and finer ends, increasing weaving

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complexity. Consequently, there is a clear need for a third weave structure that eliminates these shortcomings.

Therefore, this research aims to develop a new set of weaves for DFF fabrics that can be woven without any weave prominence of stitching and require only a single series of warp taken from one warp beam. The weaves could produce two stitched layers of cloth with two different images, one on the top side and the other on the bottom side, backing each other. It is also known that there are different structures for weaving 3D fabrics[8]. Out of these, the orthogonal structure and the 'Angular Interlock (AI) Structure' are promising[9]. Different AI structures, including four picks, six picks, and eight picks, as well as their perspective projections, are studied[10,11]. The comparison of the different AI structures showed that the eight picks 'Layer-to-Layer Angular Interlock (LLAI) Structure' is suitable for weaving DFF fabric. Accordingly, this study analyses the LLAI structure to design and weave DFF fabrics through the following steps:

- Analysing the Angular Interlock Structure
- Deriving four different cloth parts of the DFF fabric
- Designing of LLAI weaves for the body and border
- Developing layout and preparing figured graph for jacquard weaving
- Recording the structures and appearance of the woven DFF fabric

The algorithms of computer-aided figured graph designing[12,13] are employed throughout the process to ensure precision in weave construction and motif development.

2 Materials and Methods

2.1 Analysis of the Angular Interlock Structure

The study first noted that the cross-section of 'Self-stitched double cloth weave'[Fig. 1(a)] and'Four wefts

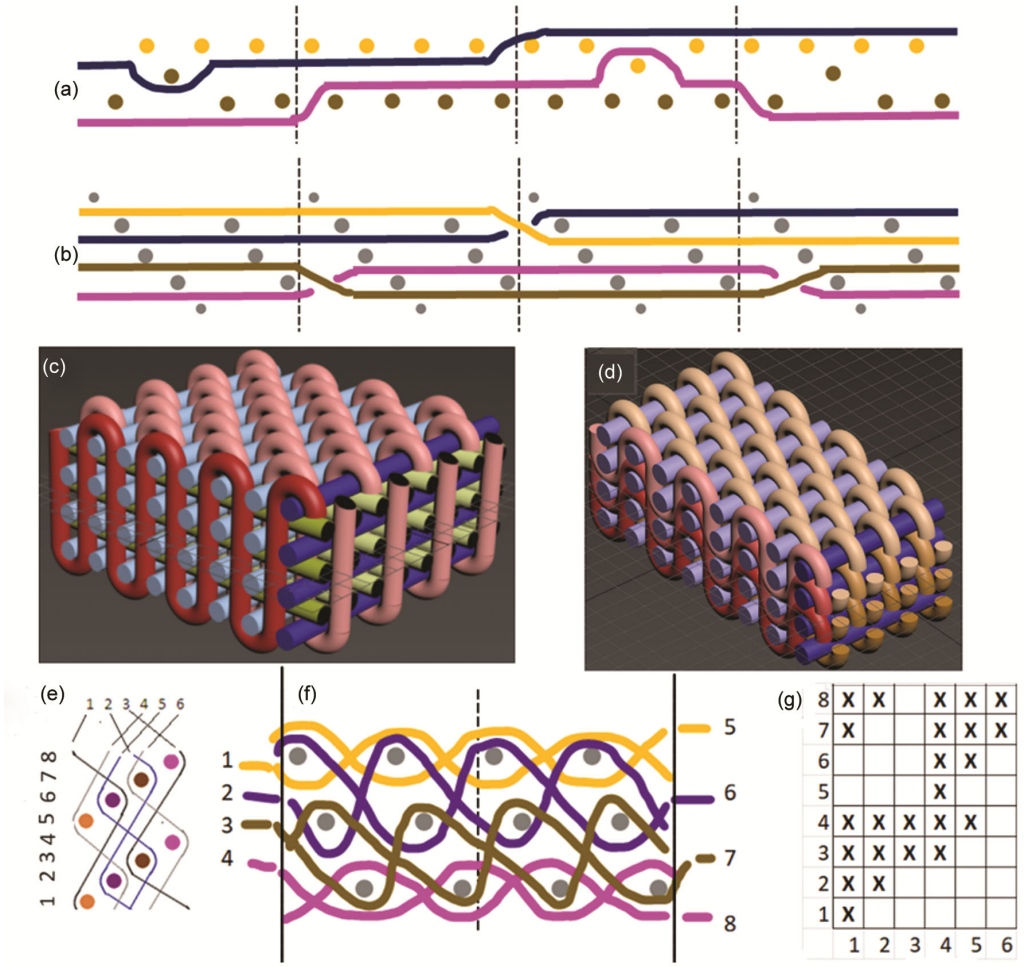

Fig. 1 — Past and present weave structures used for developing DFF fabric (a) cross-section of self-stitched double cloth weave, (b) cross-section of 4 picks orthogonal weave, (c) 3D view of basic orthogonal structure, (d) 3D view of AI structure, (e) warp cross-section (6 ends) of AI structure, (f) weft cross-section (8 picks) of AI structure, and (g) AI weave in 6 ends × 8 picks

orthogonal weave'[Fig. 1(b)],which are the two weaves being used to develop DFF fabrics. The 3D view of the basic eight-pick orthogonal structure, woven using two warp beams, is shown in Fig. 1(c). The study began with an analysis of the warp and weft cross-sections of the eight-pick AI structure. The first weave, designed with 6 ends and 8 picks, confirmed the suitability of this structure for producing DFF fabric. The 3D view of the basic eight-pick AI structure, woven with a single warp beam, is shown in Fig.1(d).

In the AI structure, eight picks formed three layers, stitched in an angular path. Hence, this structure was named 'Layer-to-Layer Angular Interlock (LLAI)' structure. The warp consisted of a single series taken from one beam, and the weft was a single series of identical count. The warp cross-section of the LLAI structure [Fig. 1(e)] shows the interlacement of a six-end with eight picks repeat, while the weft cross-section [(Fig.1(f)] shows the corresponding arrangement of the eight picks across six ends. The complete weave repeat of the LLAI structure on six ends × eight picks is illustrated in Fig. 1(g).

An analysis of the interlacements revealed that, within each repeat, two picks formed a plain weave on the top layer, two picks formed a plain weave on the bottom layer, and the remaining four picks interlaced centrally to produce an invisible plain structure. These central picks stitch the top and bottom plain layers alternately and bind them firmly together. This balanced interlacing confirmed that the LLAI structure was suitable for designing DFF fabrics.

2.2 Derivation of the Four Cloth Parts of the DFF Fabric

In a conventional figured fabric, such as one woven using weaves like satin or double cloth, the ground and figure portions appear identical on both sides. In contrast, DFF fabrics display distinct images on either side: the top image (T) visible during weaving, and the bottom image (B) visible on the reverse.

Since these two images are superimposed, each part of the DFF fabric consists of a combination of top and bottom layers, forming four distinct cloth parts: Top-ground backed by Bottom-figure (Tg/Bf), Top-ground backed by Bottom-ground (Tg/Bg), Top-figure backed by Bottom-ground (Tf/Bg), and Top-figure backed by Bottom-figure(Tf/Bf).To weave these four different cloth parts, four LLAI weave structures were designed from the first weave by using four differently coloured wefts and arranging the picks in the order of two top image picks and two bottom image picks.

2.3 Designing the First Set of Four Weaves of the LLAI Structure

In the LLAI structure, both warp and weft were of the same count, while four different weft colours — yellow (1), blue (2), brown (3), and magenta (4) — were inserted sequentially. The four weft cross-sections used to produce the four cloth parts are shown at the top of Figs. 2(a)–(d). In these cross-sections, the four colours are interchanged in four different ways to form the four different cloth parts. Designing of four weaves on 6 ends × 8 picks from the cross-sections of the LLAI weaves is shown in the middle of Figs. 2(a)–(d). The final four cloth parts, formed with four different colours, are given at the bottom of Figs. 2(a)–(d). In all these four weaves,

Colour 1-yellow is the first pick and represents the ground of the to cp image (Tg – yellow 1)

Colour 2-blue is the second pick and represents the figure of the top image (Tf – blue 2).

Colour 3-brown is the third pick and represents the ground of the bottom image (Bg – brown 3).

Colour 4-magenta is the fourth pick and represents the figure of the bottom image (Bf- magenta 4).

In these weaves, colours 1 and 2 formed the top image. These two top picks interchange only on the top side to produce the ground and figure of the top image. Colours 3 and 4 formed the bottom image and interchanged only at the bottom side to produce the ground and figure of the bottom image.

Table 1 summarises the different cloth parts, colour picks, and resulting combinations corresponding to the cross-sections shown in Fig. 2(a)—(d). It revealed that the top picks interchanged only within the top layer, and the bottom picks interchanged within the bottom layer, thus independently producing two figured weft layers. The warp performed two functions: binding the weft in plain weave and maintaining positional accuracy for layer formation. The resulting structure allowed the creation of two independent figures, one on each side of the fabric.

2.4 Designing the Second Set of Four Weaves of the LLAI Structure

From the analysis of Fig. 2(a)–(d) and Table 1, it was noted that in the LLAI structure, picks 1, 2, 5, and 6 formed the top image, while picks 3, 4, 7, and 8 formed the bottom image. The end lifting percentage for the top image was 25% (6 marks out of 24 spaces), whereas for the bottom image, it was 75% (18 marks out of 24 spaces). During single-lift mechanical jacquard weaving, this imbalance in end lifting caused uneven tension. To address this, a border style was introduced alongside the

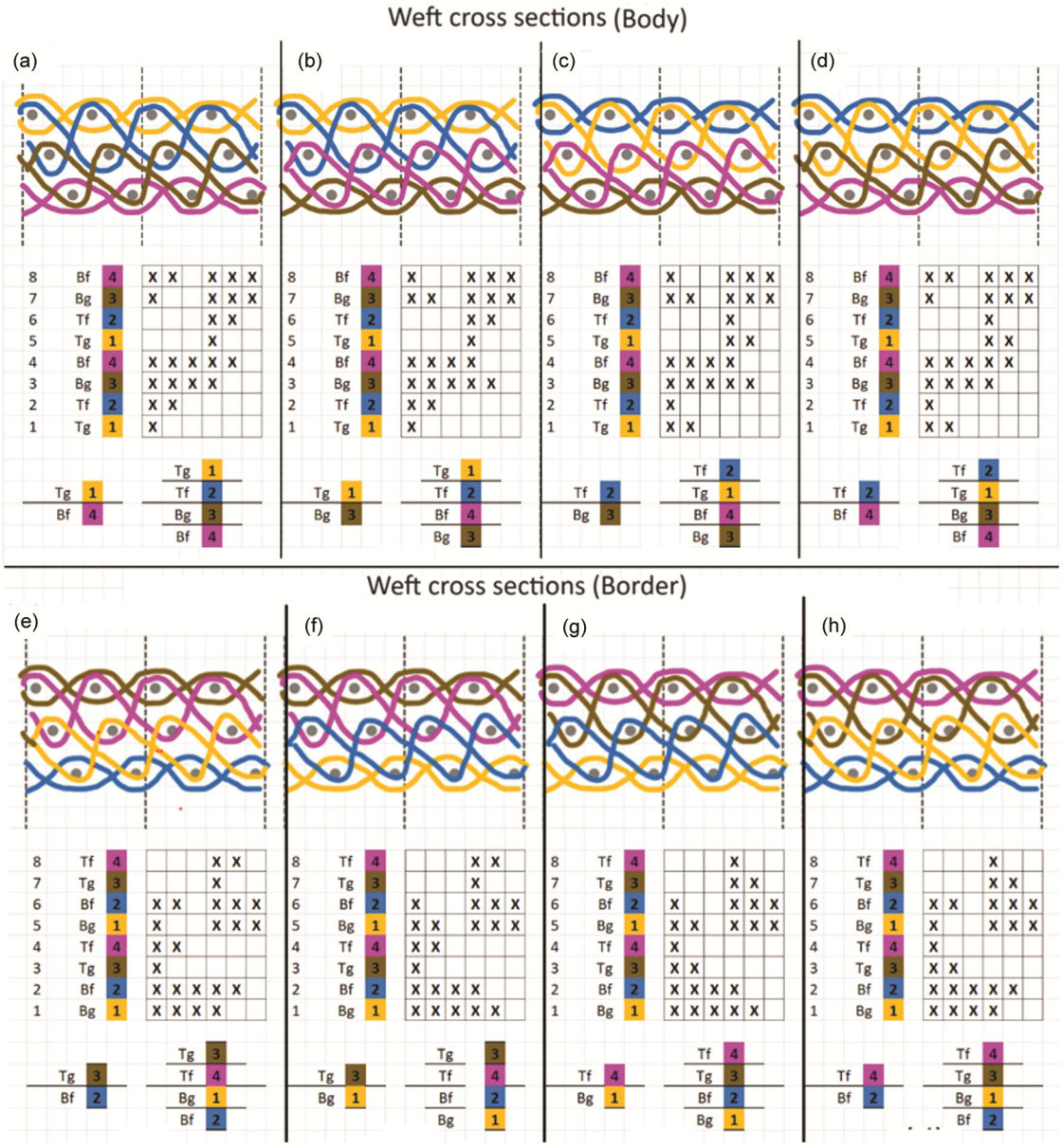

Fig. 2— (a)—(d) Four LLAI weft cross-sections illustrating the colour–layer combinations for body (a) Tg–yellow1/Bf–magenta4, (b) Tg–yellow1/Bg–brown3, (c) Tf–blue2/Bg–brown3, and (d) Tf–blue2/Bf–magenta4. Figs. 2(e)—(h) LLAI weaves derived for the border based on corresponding weft cross-sections (e) Tg–brown3/Bf–blue2, (f) Tg–brown3/Bg–yellow1, (g) Tf–magenta4/Bg–yellow1, and (h) Tf–magenta4/Bf–blue2

Table 1 — Combined final four cloth parts and corresponding colour placements of LLAI structure

Reference Fig. 2(a)—(d)	(a)	(b)	(c)	(d)
Cloth-part description	Top-ground backed by Bottom-figure	Top-ground backed by Bottom-ground	Top-figure backed by Bottom-ground	Top-figure backed by Bottom-figure
Cloth-part representation	Tg/Bf	Tg/Bg	Tf/Bg	Tf/Bf
Colour combination (Top/Bottom)	Yellow1 / Magenta4	Yellow1 / Brown3	Blue2 / Brown3	Blue2 /Magenta4
Four-pick colour order	(Tg–yellow1 / Tf–blue2) over (Bg–brown3 / Bf–magenta4)	(Tg–yellow1 / Tf–blue2) over (Bf–magenta4 / Bg–brown3)	(Tf–blue2 / Tg–yellow1) over (Bf–magenta4 / Bg–brown3)	(Tf–blue2 / Tg–yellow1) over (Bg–brown3 / Bf–magenta4)

body design. The set of four weaves from Fig. 2(a)–(d) was used for the body, while another set of four LLAI weaves was derived for the border by interchanging the top and bottom image picks. Specifically, the top image picks (1, 2, 5, and 6) of the body weaves became the bottom image picks in the border weaves, and vice versa. Four border weaves thus derived, their cross-sections, and final cloth parts are shown in Fig. 2(e)–(h). Table 2 shows the combined final cloth parts formed with colours both in the body and border.

2.5 Materials Used

After deriving the LLAI weaves, the materials required for weaving DFF fabric were selected. The body and border sections were woven using two independent 480-hook jacquards. The warp consists of 70 denier silk yarn, arranged at 100 ends per inch (EPI), and the weft is 140 denier silk yarn, arranged at 200 picks per inch (PPI). The weft comprised four colours, inserted in a 1:1:1:1 order. The fabric width consisted of four 4.8-inch repeats for the body, two 4.8-inch repeats for the left-side border, and two 4.8-inch repeats for the right-side border, resulting in a total woven width of 38.4 inches.

Each motif measured 4.8 × 4.8 inches, corresponding to a guide graph size of 160 × 240. The weave repeat size was 6 × 8, and the final weave graph was 480 × 960 for both face and back sides of the fabric.

3 Results and Discussion

3.1 Designing the Body and Border Layout for the DFF fabric

Fig. 3 illustrates the top and bottom sides colour simulation layout of the DFF shawl developed for the body–border configuration. Fig. 3(a) illustrates the colour simulation layout for the top side of the body–border. Fig. 3(b) illustrates the colour simulation layout for the bottom side of the body–border. Two separate

Table 2 — Combined final cloth parts and colour placements for body and border sections

Body	Reference Figs. 2(a)–(d)	(a)	(b)	(c)	(d)
	Top/Bottom cloth parts	Tg–yellow1 / Bf–magenta4	Tg–yellow1 / Bg–brown3	Tf–blue2 / Bg–brown3	Tf–blue2 / Bf–magenta4
	Four-pick colour order	(Tg–yellow1 / Tf–blue 2) over (Bg–brown3 / Bf–magenta4)	(Tg–yellow1 / Tf–blue2) over (Bf–magenta4 / Bg–brown3)	(Tf–blue2 / Tg–yellow1) over (Bf–magenta4 / Bg–brown3)	(Tf–blue2 / Tg–yellow1) over (Bg–brown3 / Bf–magenta4)
Border	Reference Figs. 2(e)–(h)	(e)	(f)	(g)	(h)
	Top/Bottom cloth parts	Tg–brown3 / Bf–blue2	Tg–brown3 / Bg–yellow1	Tf–magenta4 / Bg–yellow1	Tf–magenta4 / Bf–blue2
	Four-pick colour order	(Tg–brown3 / Tf–magenta4) over (Bg–yellow1 / Bf–blue2)	(Tg–brown3 / Tf–magenta4) over (Bf–blue2 / Bg–yellow1)	(Tf–magenta4 / Tg–brown3) over (Bf–blue2 / Bg–yellow1)	(Tf–magenta4 / Tg–brown3) over (Bg–yellow1 / Bf–blue2)

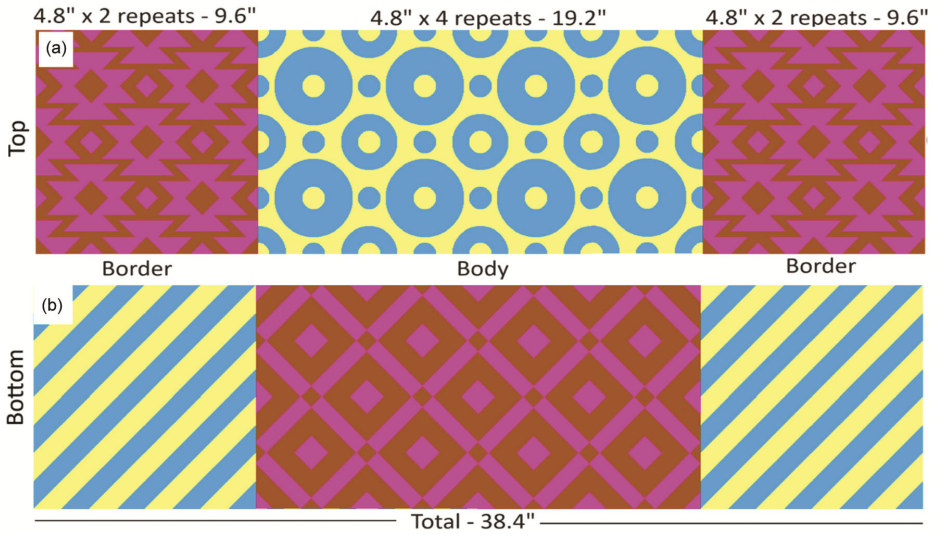

Fig. 3 — Colour simulation layout of body and border motifs for DFF fabric (a) top-side layout (two pick-way repeats) of body and border, and (b) bottom-side layout (two pick-way repeats) of body and border

480-hooks jacquards are employed—one for the body and the other for the border. At 100 EPI, the repeat of the motif measures 4.8". For example, for a shawl width of 38.4", the design comprises two repeats of the border on each side and four repeats across the body [Left border = 9.6″(2 repeats) + Body = 19.2″ (4 repeats) + Right border = 9.6″ (2 repeats)]. Two independent motifs are created for the body, one for the top layer and the other for the bottom layer. For example, a circle-based image is drawn for the top, and a diamond-based image is drawn for the bottom, as shown in Figs. 3(a)–(b). Similarly, two separate motifs are developed for the border, one for the top layer and the other for the bottom layer. For example, a wavy diamond-based image is drawn for the top, and a diagonal line-based image is drawn for the bottom, as shown in Fig. 3(a)–(b).

3.2 Procedure for Developing the Figured Graph

Designing the final figured graph requires preparation and superimposition of guide graphs for the top and bottom motifs. The computer-aided graph-designing procedure involves: (i) noting the EPI and PPI and calculating the size of the motif, final figured graph, and guide graph; (ii) drawing two different motifs and preparing guide graphs; (iii) superimposing the guide graphs; (iv) resizing the guide graph size to the final full-size graph; and (v) applying the weave marks and preparing the final figured graph.

3.2.1 Calculating the Final Figured Graph Size and Guide Graph Size

For illustration, a DFF silk shawl of 70 denier warp and 140 denier weft, woven at 100 EPI and 200 PPI, is considered. With a 480-hook jacquard, the repeat width is 4.8 inches (480/100). A motif length of 4.8 inches results in 960 picks per repeat. The final figured graph, therefore, measures 480 × 960. As the weave repeat is 6 × 8, the guide graph uses one-third of the warp ends (160) and one-fourth of the picks (240), resulting in a guide-graph size of 160 × 240 and a graph count of 8:12.

3.2.2 Drawing Two Different Motifs and Preparing Guide Graphs

The sizes of the body motifs are 4.8" × 4.8". The guide graph of 160 ends × 240 picks is prepared for the top image, and another guide graph of 160 ends × 240 picks is completed for the bottom image. The guide graph of the top image shows the formation of only the Top-ground (Tg– yellow1) and Top-figure (Tf – blue2). The colour simulation of this graph is shown in Fig. 4(a). Similarly, the guide graph of the back image shows the formation of only the Bottom-ground (Bg – brown3) and Bottom-figure (Bf – magenta4). The colour simulation of this graph is shown in Fig. 4(b).

Likewise, the sizes of the border motifs are also 4.8" × 4.8". The guide graph of 160 ends × 240 picks is prepared for the top image, and another guide graph of 160 ends × 240 picks is completed for the bottom image. The guide graph of the top image shows the formation of only the Top-ground (Tg – brown 3) and Top-figure (Tf – magenta 4). The colour simulation of this graph is shown in Fig. 4(c). Similarly, the guide graph of the back image shows the formation of only the Bottom-ground (Bg – yellow 1) and Bottom-figure (Bf – blue 2). The colour simulation of this graph is shown in Fig. 4(d).

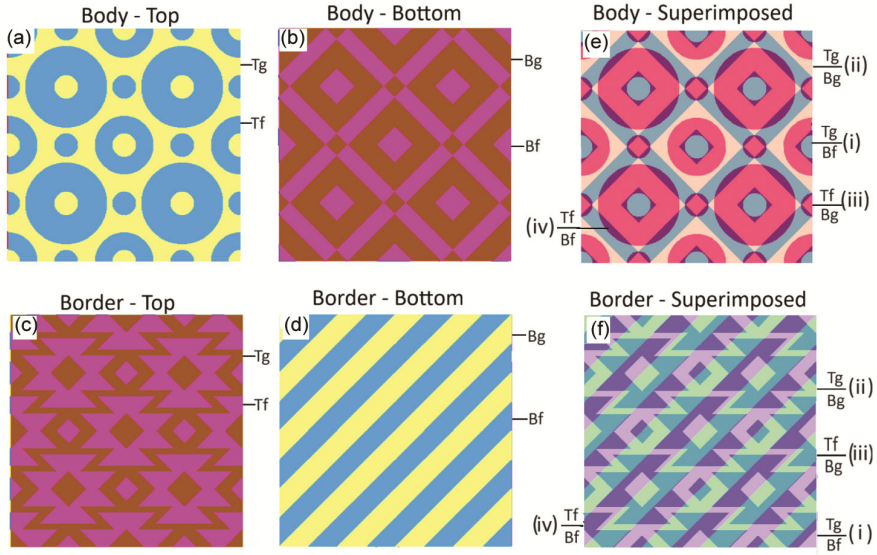

Fig. 4 — Guide graph preparation and superimposition (a) body - top motif guide graph, (b) body - bottom motif guide graph, (c) border - top motif guide graph, (d) border - bottom motif guide graph, (e) body - superimposed guide graph showing (i) Tg/Bf, (ii) Tg/Bg, (iii) Tf/Bg, and (iv) Tf/Bf parts, and (f) border - superimposed guide graph showing (i) Tg/Bf, (ii) Tg/Bg, (iii) Tf/Bg, and (iv) Tf/Bf parts

3.2.3 Superimposing the Guide Graphs

The next step is to superimpose the guide graph of the face image with the guide graph of the back image. It is carried out by following the steps using the tools of computer-aided graph designing software's) open the first image graph, ii) open the second image graph as a layer and move it exactly over the first image graph, and iii) click on the merge layer option. By merging the guide graphs of 160 × 240 size, the colours in both graphs get superimposed, resulting in a superimposed guide graph of 160 × 240 size in four colours, which represent the formation of four different cloth parts, viz. $\left(\frac{\text{Tg}}{\text{Bf}}\right)$, $\left(\frac{\text{Tg}}{\text{Bg}}\right)$, $\left(\frac{\text{Tf}}{\text{Bg}}\right)$, and $\left(\frac{\text{Tf}}{\text{Bf}}\right)$. The colour simulation of the superimposed graph for the body is shown in Fig.4(e), which is obtained by superimposing the body guide graphs shown in Figs. 4(a) and (b). The colour simulation of the superimposed graph for the border is shown in Fig. 4(f), which is obtained by superimposing the border guide graphs shown in Figs. 4(c) and (d).

3.2.4 Developing the Final Figured Graph for the Body

The 160 × 240 superimposed body guide graph [Fig. 4(e)] is resized to the full-figured graph dimensions (480 ends × 960 picks) using the resize tool. Each end in the superimposed guide graph is multiplied by 3 ends, and each pick in the guide graph is multiplied by 4 picks. A part of a superimposed body graph (24 × 32) in four colours is shown in Fig. 5(a). The four body weaves of four-figure parts (i, ii, iii, and iv), which are derived in Figs. 2(a)–(d) are shown in Fig. 5(b). In these weaves, weave marks are marked in white, and the ground is shown in the colours of the respective cloth part colour in the superimposed graph. A portion of the superimposed graph (24 × 16) resized to 72 ends × 64 picks is shown in Fig. 5(c).

Finally, the four body weaves shown in Fig. 5(b) are applied to the respective colour parts in the resized graph. The weave application tools of the computer-aided design software for figured graphs are used for this purpose. A part of the final body graph, 72 ends × 64 picks, applied with weaves, is shown in Fig. 5(d). It is to be noted that the graph grid size of the resized graph and the final weave graph are used as 6 × 8 to facilitate the application of weaves, which are repeated on 6 × 8. In the final weave graph, the white marks indicate ends up and all the colour marks indicate ends down.

3.2.5 Developing the Final Figured Graph for the Border

The procedure followed for developing the final border-graph mirrors that of the body, but uses a different set of motifs and the weaves presented in Fig. 2(e)–(h). The 160 × 240 border superimposed guide graph [Fig. 4(f)] is resized to the full-figured graph dimensions (480 ends × 960 picks) using the resize tool. Each end in the superimposed guide graph is multiplied by 3 ends, and each pick in the guide graph is multiplied by 4 picks. A part of a superimposed graph (24 × 32) in four colours is shown in Fig. 6(a). The four weaves of four-figure parts (i, ii, iii, and iv), which are derived in Figs. 2(e)–(h) are shown in Fig. 6(b). In these weaves, weave marks are marked in white, and the ground is shown in the colours of the respective cloth part colour in the superimposed graph. A portion of the superimposed graph (24 × 16) resized to 72 ends × 64 is shown in Fig. 6(c).

A part of the final graph in 36 ends × 64 picks, applied with weaves, is shown in Fig. 6(d). It is to be noted that the graph count of the resized graph and final weave graph is made as 6 × 8 to facilitate the application of weaves repeating in 6 × 8. In the final graph (480 ends × 960 picks), the white marks indicate ends up and all the colour marks indicate ends down. A portion of the body's final graph [36 ends × 64 picks of Fig. 5(d)] is shown in Fig. 6(e). With the border graph shown in Fig. 6(d) and the body graph shown in Fig. 6(e), understand the change in the weaves by comparing the picks of the border graph with the picks of the body graph. Also note how the marks and blanks get balanced, resulting in the balanced lifting of ends for each pick while weaving.

3.3 Preparing the Figured Graphs for Jacquard Weaving

The final figured graphs [Fig. 5(d) and Fig. 6(d)] are converted for mechanical or electronic jacquard systems. For mechanical jacquards with card punching, graphs are converted to black and white. The white colour weave marks are changed to black, and then the other four colours in the four-figure weave parts are changed to white. For the electronic card punching machine, these digital black-and-white files are transferred to the controller, and cards are punched directly. For the mechanical card punching machine, the graph sheets are printed from the digital graphs. The graph paper size is 48" width × 96" length for a 10 × 10 graph count. These two graph papers are used in the mechanical card-punching machine to punch the cards. Holes are punched for the black marks in the graph. Two sets of a total of 960 cards are punched. The punched cards are laced and made in a chain form. The body chain is mounted in the body jacquard, and the border chain is mounted in the border jacquard.

For the electronic jacquard, digital black-and-white files are transferred directly to the controller.

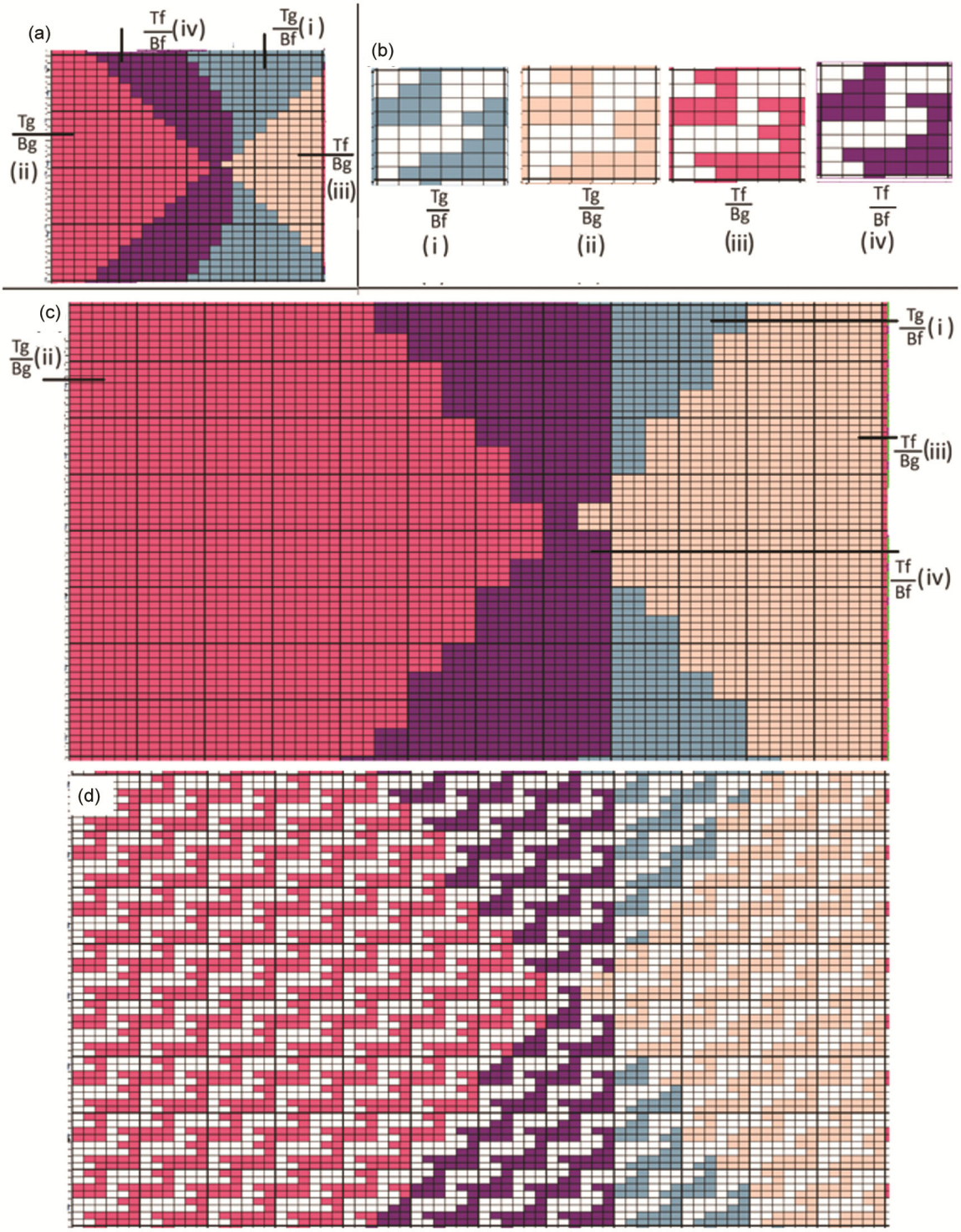

Fig. 5 — Resizing and weave-mark application for body figured graph (a) part of the superimposed graph (24 × 32), (b) four LLAI weaves applied, (c) resized graph (72 × 64), and (d) final figured graph (72 × 64)

Weaving uses a 1:1:1:1 pick order for the four weft colours. If a shuttle loom is used, four shuttles with four different colours are used. If a shuttle less loom is used, four different colour cones are used.

3.4 Recording the Structures and Appearance of the DFF Fabric Sample

Fig. 7 shows the different structures and appearance of a typical body-border DFF silk shawl sample woven

with Warp count × Weft count – (70 Denier silk × 140 Denier silk) and EPI × PPI – (100 × 200). The weight per square yard is 128 grams. The weft colours used are brown, red, purple, and blue. Ogee and diamond motifs appear on opposite sides [Figs. 7(a)–(b)]. Fig.7(c) shows the ground and figure structures of the ogee motif, woven on one side with brown and red colour picks. Fig.7(d) shows the ground and figure

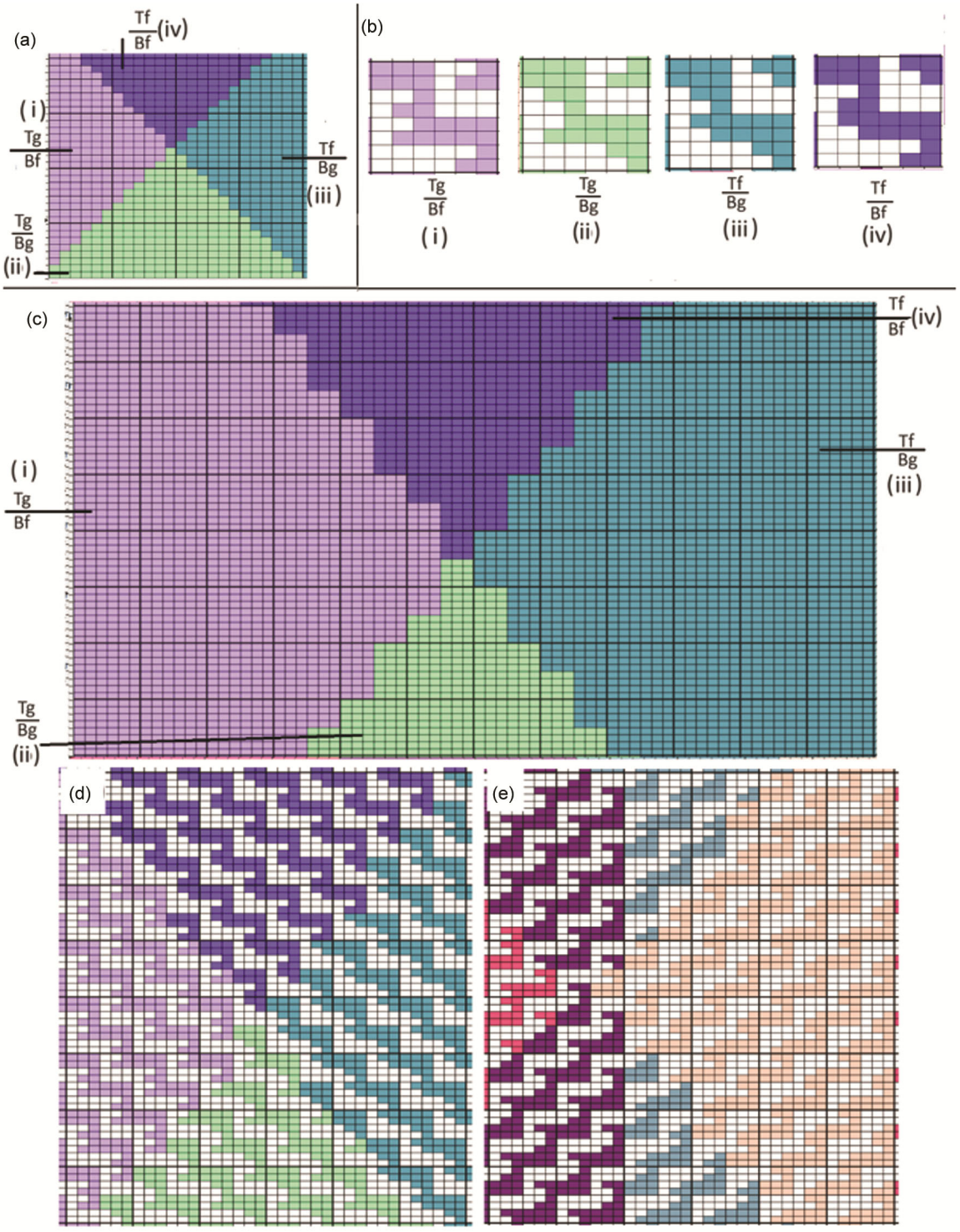

Fig. 6 — Resizing and weave-mark application for border figured graph (a) part of superimposed graph (24 × 32), (b) four LLAI weaves applied, (c) resized graph (72 × 64), (d) final border figured graph (36 × 64), and (e) corresponding body figured graph section

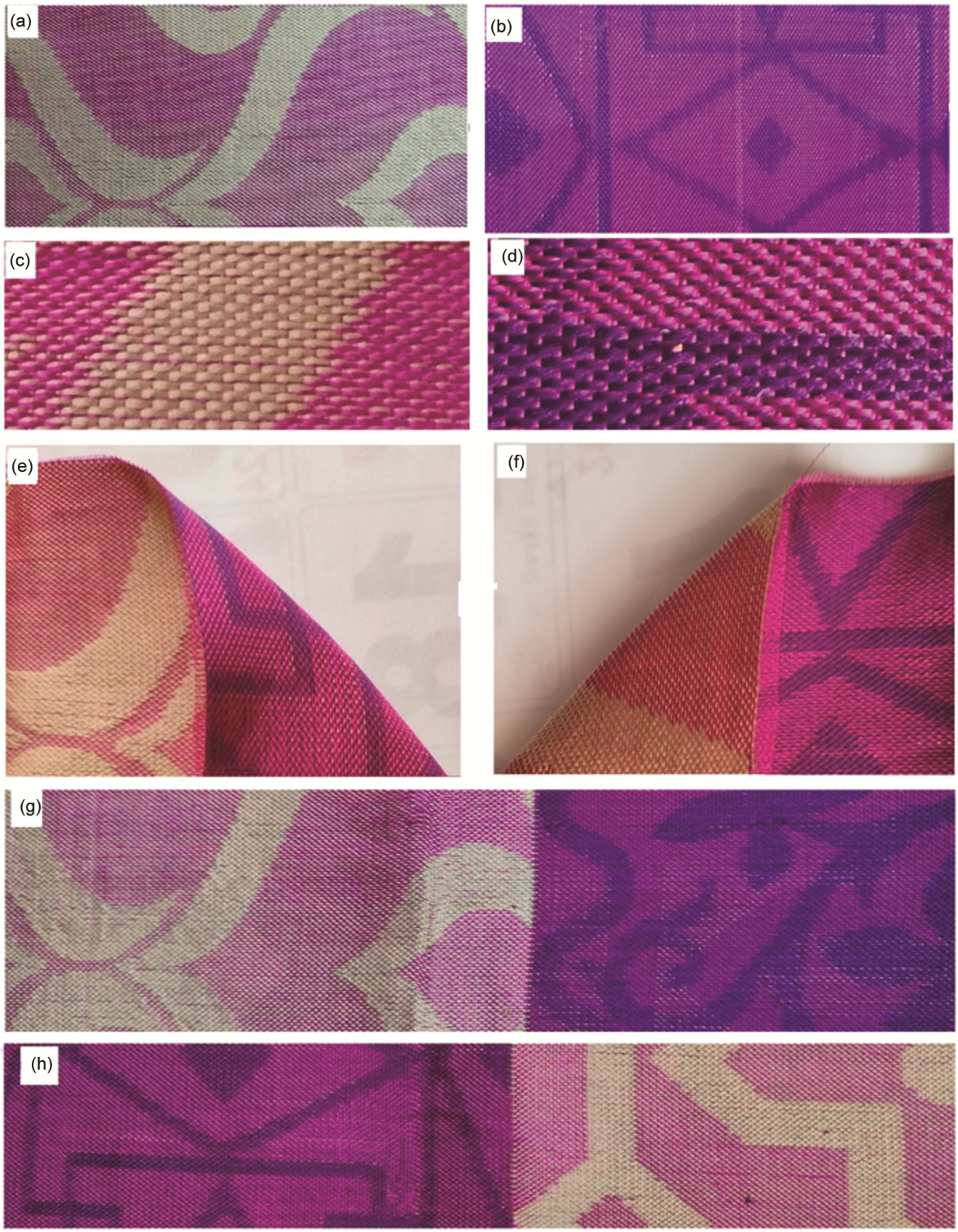

Fig. 7— Structures and appearance of DFF shawl fabric (a) ogee motif on top side, (b) diamond motif on the reverse, (c) ogee motif formed using brown and red colour picks, (d) diamond motif formed using purple and blue colour picks, (e) ogee motif on one side with the diamond motif on the reverse, (f) diamond motif on one side with the ogee motif on the reverse, (g) on the top side, interchange of brown–red picks of the ogee body with purple–blue picks of the border, and (h) on the bottom side, interchange of purple–blue body picks with brown–red border picks

structure of the diamond motif woven on another side with purple and blue colour picks. Figs 7(e)–(f) illustrate the reversibility, where each motif backs the other (diamond on one side and ogee on the other).

While Fig. 7(g) displays one side of the shawl with two different motifs in body and border, Fig. 7(h) shows another side of the same shawl with two different motifs in body and border. In Fig. 7(g), the left side shows the body with red and brown picks on the top side. The purple and blue picks are on the backside. The right side shows the border with the purple and blue picks on the top side. Red and brown picks are on the backside. In the centre, the interchange of the picks is visible as a vertical line. In Fig.7(h), which is the reverse side of the same shawl, the left side shows the body with the purple and blue picks on the top side. The red and brown picks are on the backside. The right side shows the border with the red and brown picks on the top side. Purple and blue picks are on the backside. In the centre, the interchange of the picks is visible as a vertical line.

3.5 Characteristics and Suitability of the Angular Interlock DFF Fabrics

From the weft cross-section of the LLAI weave, it is understood that the DFF fabric is formed by the interchanging of plain fabric on the top side and on the bottom side. The centre four picks also form the plain fabric with the ends at the centre. It also stitches the top layer and the bottom layer. They are neither visible on the top side nor the bottom side. Hence, the resulting DFF fabric has the following qualities:

i) no weave prominence;
ii) absence of stitching;
iii) suitability for all yarn counts, viz, finer, medium, and coarser;
iv) smooth fabric even with medium and coarser counts;
v) suitable for garments, dress material, home furnishings, carpets and technical textiles;
vi) reversible usability with two distinct motifs;
vii) single-beam operation, improving productivity compared with orthogonal systems, and
viii) potential for two-material technical textiles when using all-over designs on electronic jacquards.

3.6 Other Considerations

In this study, the first set of LLAI weaves is used for the body, and the second set of weaves is for the border. It can also bevice versa. If there is a restriction on using the four colours in a 1:1:1:1 order, only two colours can be used in a 1:1 order. When a 1:1order is used, both the top and bottom images will have the same colour combination. When electronic jacquard and mechanical jacquard with power lifting are used, the imbalance in lifting between the picks is not an issue. If so, the DFF fabric can be produced as an all over style instead of the body-border style.

4 Conclusion

The study successfully demonstrates that the Layer-to-Layer Angular Interlock (LLAI) structure is highly suitable for producing Double-Face Figured (DFF) fabrics, which exhibit improved structural balance, enhanced visual clarity, and greater versatility compared to self-stitched double cloth and orthogonal weaves used. By systematically developing body and border motifs, preparing guide graphs, superimposing and resizing these graphs, and applying the corresponding weave marks, a complete figured graph suitable for jacquard weaving is achieved. The approach allows the creation of four distinct cloth parts without weave prominence and without the need for stitching, owing to the interchanging plain-weave structure on both sides. The woven silk shawl sample confirms that the LLAI structure produces smooth, reversible fabrics with clear motifs on each face and clean colour transitions between body and border. The interchanging of weft colours in the centre results in balanced lifting of ends for every pick, ensuring stable weaving performance on both mechanical and electronic jacquards. The characteristics of the LLAI-based DFF fabric—namely, the absence of stitching, balanced structure, suitability for fine to coarse counts, and the ability to reverse the fabric for dual aesthetic use—make it suitable for various textile applications. Further, weaving with a single warp beam enhances productivity and simplifies loom preparation.

By following the steps and procedures given in this study, the jacquard graph designers can very well prepare graph designs to weave DFF fabrics using the new LLAIs, apart from using double cloth and orthogonal weaves for weaving not only the dress material, home furnishings, carpets and technical textiles but also design reversible garments using the DFF fabrics.

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