

Design of Rascheltronic Vamp Fabric with Double-Color Pitting Effect

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Abstract

Applications of Piezo jacquard and CAD technology in warp-knitting have provided traditional jacquard fabrics with the possibility of innovating the structure design. Research on innovative design and fabrication is conducted aiming at knitting jacquard vamp fabric with the double-colour pitting effect on a technical back. By utilising Piezoelectric jacquard's performance of displacing both underlapping and overlapping, new structures are formed, such as mesh stitches, koper stitches and float structures. Based on threading with yarns in two colors, jacquard bars in split execution create a pattern with a double-colour effect. To realize a highly efficient design, the paper proposes a computer-aided jacquard design method covering technical parameters and jacquard pattern design modules. Additionally, to pursue convenience and efficiency, mathematic models are built in terms of an automatic borderline design, loop stitching inspection and structure database. The method of jacquard vamp fabric design with a double-colour pitting effect has been proven practically by illustrating a vamp design example which meets the requirement of fashion and performance well.

Key words: warp knitting, rascheltronic, vamp fabric, double-colour pitting effect, CAD.

and air permeability. Warp-knitted spacer fabric, a 3-D fabric formed on a double-needle bar warp-knitting machine, has won out with its remarkable mechanical properties of moisture permeability [1] and compression behavior [2-3]. However, with labor costs increasing, the traditional mode of production is gradually revealing its downsides in terms of cutting, sewing and shaping procedures. In this case, more attention is focused on shaping technology along with the application of jacquard technology in the knitting industry, which eliminates the procedures of cutting and sewing to improve efficiency. Moreover various functional structures can be seamlessly stitched together to meet wearable requirements and physiological characteristics. Flat-knitting technology clearly shows merits in shaping techniques by its specific narrowing and widening method in producing shaped fabrics [4-6]. The characteristic yarn carrier mechanism makes it possible to form colorful structures, such as the new MACH2XS WHOLEGARMENT special machine produced by SHIMA SEIKI®, and the CMS ADF-3 machine produced by STOLL®, Germany. However, low efficiency and structural instability are the stumbling blocks which limit flat-knitting from being widely used in shoe production. Therefore warp-knitted jacquard spacer fabrics make up the highest proportion of sports shoes fabrics formed on a double-bar Raschel machine with jacquard technology, such as RDPJ7/1, produced by Karl Mayer®. Numerous scholars have conducted researches on

knitting technology [7] and computer-aided design methods [8]. To extend patterning possibilities, spacer fabrics with the double-faced jacquard effect was studied by Han [9] and Yang [10]. With customers' higher requirements for shape retention and the popularity of Rascheltronic functional fabric [11-12], single-faced jacquard vamp fabric knitted on a Rascheltronic machine is becoming more popular. In addition, with yarns in two colours respectively threaded in two half-gauge jacquard bars, the double-color effect [13] is created and then bonded with another warp-knitted plain fabric in a third colour to give a more fashionable appearance and stiffness, such as the new designs of Nike, Adidas and Under Armour. However, for these vamp fabrics referred above, the technical face is used as a practical face. Hence the fabric effect is restricted to a uniform structure made up of loop wales. When designing a double-color effect, only small colourful dots can be shown on the technical face and covered by ground pillar loops; however, the occurrence of double-colour loops is impossible to predict and ensure, as *Figure 1* presents.

Therefore, in this paper, an innovated design method for Rascheltronic vamp fabric with the double-color pitting effect is introduced based on knitting technology and Piezoelectric jacquard principles. A technical back is used as the practical face and jacquard displacement signals are controlled when overlapping to form koper stitches and float stitches, which results in a 3-D pitting effect.

Introduction

With people's concept of health and exercise deeply rooted, more importance is attached to sports shoes, which make up two fifths of shoe consumption. Knitted fabrics are the main source of favourable wear performance for sports shoes, such as structural stability, heat dissipation

■ Knitting method and jacquard principles

Knitting method

Rascheltronic shoe fabric with a double-colour pitting effect is formed on a Rascheltronic machine with jacquard bars in split execution. Two ground guide bars are equipped as the foremost one and the hindmost one with jacquard bars in the middle. Ground bars are both driven by chains data 1-0/0-1// to form a pillar structure for more strength and durability. Comparatively jacquard bars are driven by basic chains 1-0/1-2// to create a tricot stitch structure. Under the newest control system of Piezoelectric jacquard, any of the jacquard guide needles can independently displace right and left when overlapping and underlapping to make thick, thin and mesh effects. As favourable heat dissipation and air permeability is the primary performance of sports shoes, Rascheltronic shoe fabric is characterised by various meshes by means of Piezo jacquard technics. Moreover koper stitch and float stitch structures are formed to fully take advantage of Piezo technology, and yarns in two colours are respectively threaded on two half-gauge jacquard bars to create a distinguished double-colour effect. Shown in **Figure 2**, the koper stitch and float stitch are mostly shown in pairs. The koper stitch is formed on two continuous groove needles to ensure jacquard loops on each needle and bind the two wales together, while the float stitch is inserted under the pillar's underlap to make a tiny mesh. These two structures with yarns in two colours make uneven double-colour pitting effects.

Jacquard principles

Piezoelectric jacquard technology features displacement of both overlapping and underlapping in one course. As basic driven data are 1-0/1-2// in two courses, there are four displacement controlled signals in a lapping repeat. Grids are normally employed for jacquard technology design and one jacquard grid means one lapping repeat, namely two courses and four controlled signals. H is used to represent a right displacement in the red displaced grid, and T is a left displacement in the white displaced grid. Shown in **Figure 3** are the lapping movement figures of jacquard structures and their corresponding displacement signals. As two options for one signal, there are 16 forms of jacquard lapping movement. Especially, among all the 16 structures,

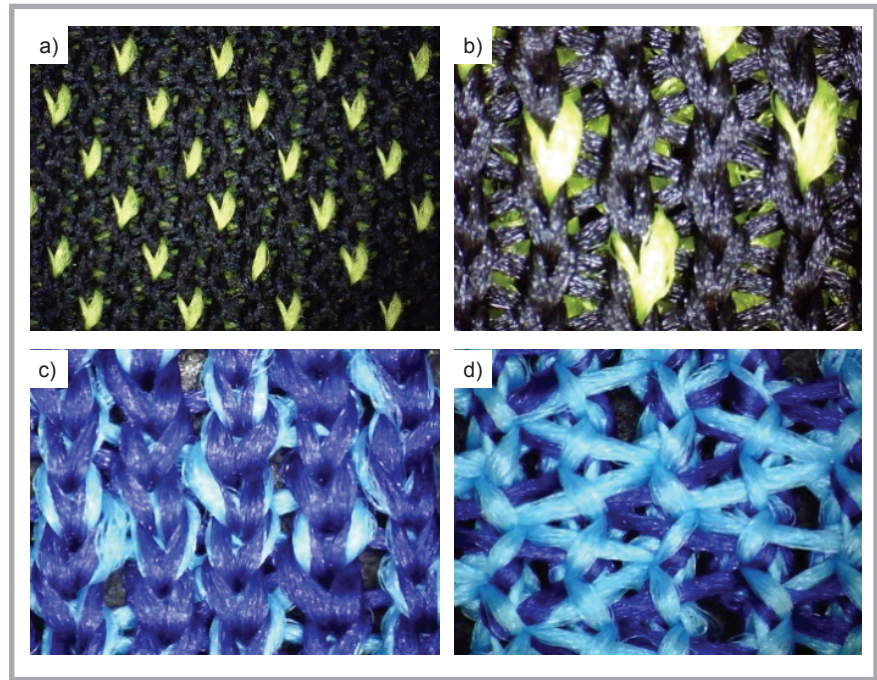


Figure 1. Jacquard vamp fabric with double-color effect: a) overall view and b) detailed view of jacquard spacer fabric with double-color effect on technical face; c) common Rascheltronic vamp fabric with double color effect on technical face and d) technical back.

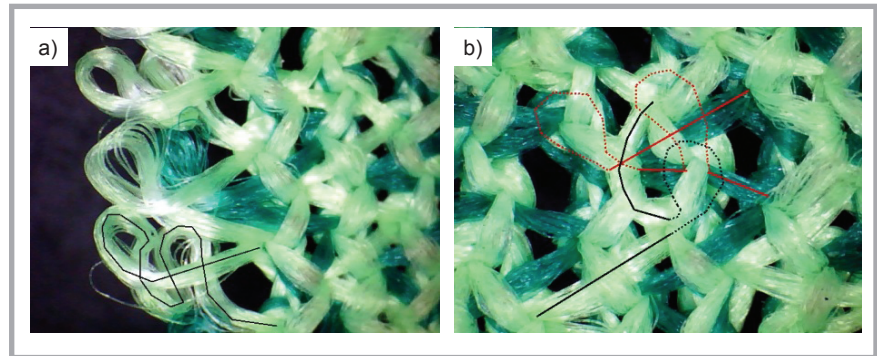


Figure 2. Rascheltronic stitches with double-colour pitting effect: a) koper stitches, b) koper stitch and float stitches.

koper stitches and float stitches are typical ones which fully show the particular performance of Piezoelectric jacquard technology.

■ Computer-aided design model

Jacquard design model

The computer-aided design of Rascheltronic shoe fabric with a double-colour effect includes two necessary parts: the technical parameter design and jacquard pattern design. The former one covers chain data and threading cycles, which have been modelled by Zhang [14]. While for the jacquard design, specific design models need to be built to meet the special technology requirements.

Jacquard grids is the most common way in pattern design to define different colours as corresponding lapping movements. The 16 lapping movements shown in **Figure 3** are separately attached with colours, each of which covers four displacement signals. If the signal H is denoted as 0 and T as 1, then $C_1=0011$, $C_2=0110$, $C_4=0000$, $C_5=1010$, $C_6=1000$, $C_7=1110$, $C_8=1111$, $C_{10}=0010$, $C_{11}=0101$, $C_{12}=1100$, $C_{15}=1011$, $C_{16}=0001$, $C_{23}=0100$, $C_{25}=1001$, $C_{33}=0111$ and $C_{41}=1101$. A 2-D mathematical matrix is employed to represent jacquard displacement signals in one repeat, as shown in **Equation (1)**, where j_{mn} means the jacquard colour in the wale m and course $2n-1$ and $2n$, $j_{mn} \in \{C_1, C_2, C_4, \dots, C_{33}, C_{41}\}$, $1 \leq m \leq M$, $1 \leq n \leq N$, M the number of wales in one repeat, namely

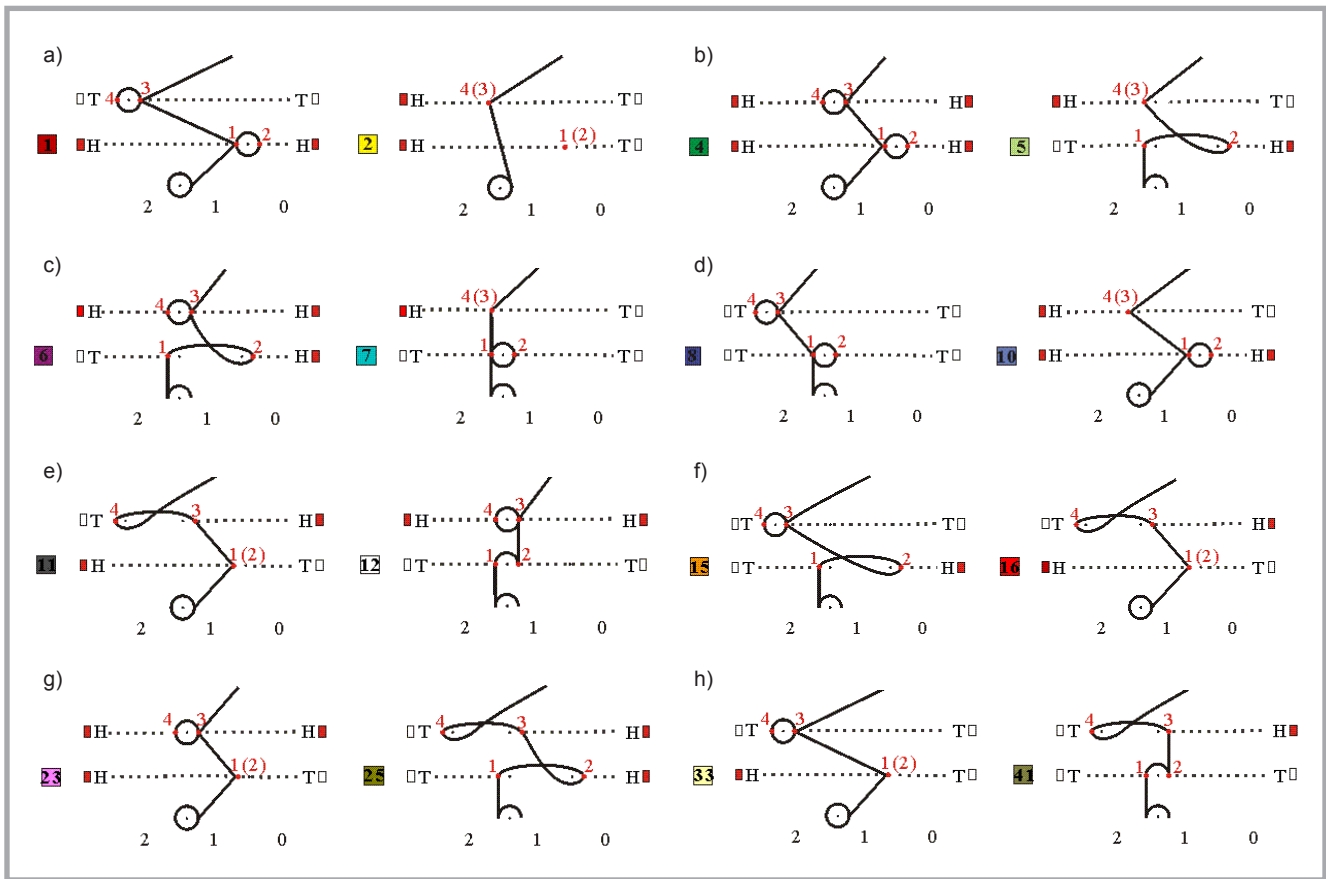


Figure 3. Signals of basic jacquard lappings.

the width; and N is half of courses in one repeat. Since driven devices are usually equipped on the right side when an observer stands in front of the warp-knitting machine, m is numbered from right to left and n from bottom to top, the same as the knitting direction.

$$J_{M \times N} = \begin{bmatrix} j_{MN} & \dots & j_{1N} \\ \vdots & \ddots & \vdots \\ j_{M1} & \dots & j_{11} \end{bmatrix} \quad (1)$$

Automatic borderlines design model

A pattern with various meshes is the most obvious and primary feature of jacquard fabrics. To ensure meshes in a jacquard pattern coincident with real fabric, borderlines need to be designed to keep them from being affected by surrounding structures. In common Rascheltronic technol-

ogy, meshes are formed by displacement signals of TTHH, white colour numbered C_{12} (1100), which is merely surrounded by the thick effect with red colour numbered C_1 (0011), thin effects with green color numbered C_4 (0000), and blue colour numbered C_8 (1111), thus making borderline design easy. However, in this special Rascheltronic technology, mesh structures are possibly surrounded by 15 structures. Hence the function of automatic borderline design will greatly improve efficiency and accuracy. The value of Raschel technology (RT) in this jacquard design equals 0 (RT=0), meaning that final lapping movements are totally coincident with the grid displacement signals. Borderline design is based on three fundamental principles, including no underlaps in white grids, no two jacquard loops on the same needle, and all the needle looped by the jacquard bar. If the mesh grid is denoted as $g(m, n) = C_{12}$, the first principle is guaranteed by accessing signals of $g(m-1, n)$, while the last two principles by signals of $g(m+1, n)$, shown in Figure 4.

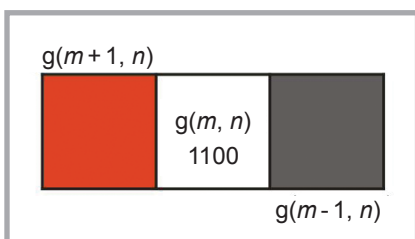


Figure 4. Borderline design.

The borderline design method is concluded as follows, and corresponding

lapping movements are shown in Figure 5:

1. When $g(m-1, n) = C_1, C_5, C_{10}, C_{15}$, $g(m-1, n)$ is changed into C_5 ;
2. When $g(m-1, n) = C_4, C_6, C_{16}, C_{25}$, $g(m-1, n)$ is changed into C_6 ;
3. When $g(m-1, n) = C_2, C_7, C_8, C_{33}$, $g(m-1, n)$ is changed into C_7 ;
4. When $g(m-1, n) = C_{11}, C_{12}, C_{23}, C_{41}$, $g(m-1, n)$ is changed into C_{12} ;
5. When $g(m+1, n) = C_1, C_5, C_{10}, C_{15}$, $g(m, n)$ is changed into C_{11} ;
6. When $g(m+1, n) = C_4, C_6, C_{16}, C_{25}$, $g(m, n)$ is changed into C_{23} ;
7. When $g(m+1, n) = C_2, C_7, C_8, C_{33}$, $g(m, n)$ is changed into C_{41} ;
8. When $g(m+1, n) = C_{11}, C_{12}, C_{23}, C_{41}$, $g(m, n)$ is not changed.

Automatic inspection model

Although single-faced jacquard vamp fabric produced on a single-bar Rascheltronic machine has met the requirements for lightweight and comfort, concerns about strength and stiffness have emerged, being the main criteria of judging shoe functional performance. Hence two ground bars are used to form double pillar loops to increase gram weight and

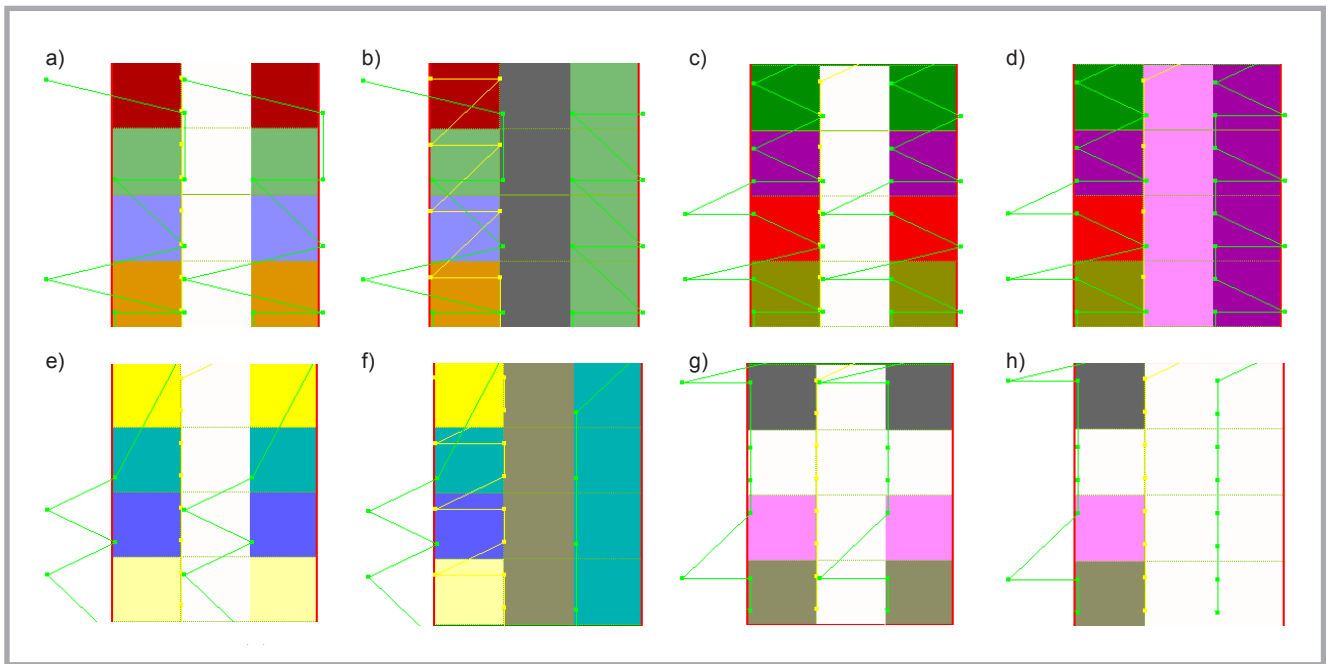


Figure 5. Lapping movements of jacquard structures a), c), e), g) and corresponding structures after borderlines b), d), f), h).

improve stiffness performance. Due to the existence of the jacquard koper stitch and double pillar loops, there is a great possibility that four loops are stitched on one needle, which is adverse to the knitting process. Stitching inspection is necessary to obviate the occurrence of two jacquard loops stitched on one needle. An automatic inspection module is constructed by computing each jacquard yarn's stitching location and then checking whether two jacquard yarns are stitched at the same location. The stitching distribution of each jacquard yarn is represented as a 2-D mathematical matrix, shown in **Equation (2)**:

$$S_i = \begin{bmatrix} y_{iM2N} & \dots & y_{i12N} \\ \vdots & \ddots & \vdots \\ y_{iM1} & \dots & y_{i11} \end{bmatrix} \quad (2)$$

where S_i is the stitching distribution of jacquard yarn threaded in wale No. i , $i \in (1, M)$, and y_{imn} is the stitching logical value of yarn No. i on course n and wale m , $y_{imn} \in \{0, 1\}$. The value of y_{imn} lies in the jacquard displacement signal. For example, if j_{mn} equals C_4 , then $y_{mm(2n-1)} = 1$, $y_{mm(2n)} = 0$, $y_{m(m+1)(2n-1)} = 0$ & $y_{m(m+1)(2n)} = 1$. When all jacquard grids in one repeat are designed, the overall stitching distribution for all jacquard yarns is computed by summing up all matrixes, shown in **Equation (3)**.

$$S = \sum_{i=1}^M (imn)_{M \times 2N} \quad (3)$$

If y_{imn} equals 2, it needs to be shown in the error list when inspected, shown

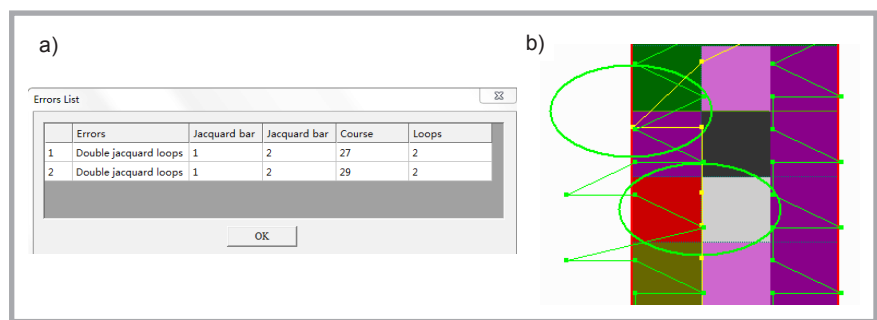


Figure 6. Automatic stitching inspection: a) errors list, b) errors location.

in **Figure 6.a**. When the error item is clicked, an ellipse is drawn surrounding the loop position y_{imn} to realize fast orientation shown in **Figure 6.b**.

Structure database

According to the principles of Piezoelectric technology and the requirements of shoe performance, jacquard structures with various meshes are mostly employed in pattern design. Therefore a structure database is built to offer designers specific choices to promote design efficiency and flexibility. Each jacquard structure is saved into a database by Microsoft Access, with seven fields picked as data fields, including 'ID', 'Category', 'Repeat X', 'Repeat Y', 'X×Y', 'Pattern' and 'Jname'. 'X' and 'Y' are the structure width and length and the 'Pattern' is detailed jacquard colours. All these structures can be easily found by typing in key data fields when designing a jacquard overlay unit.

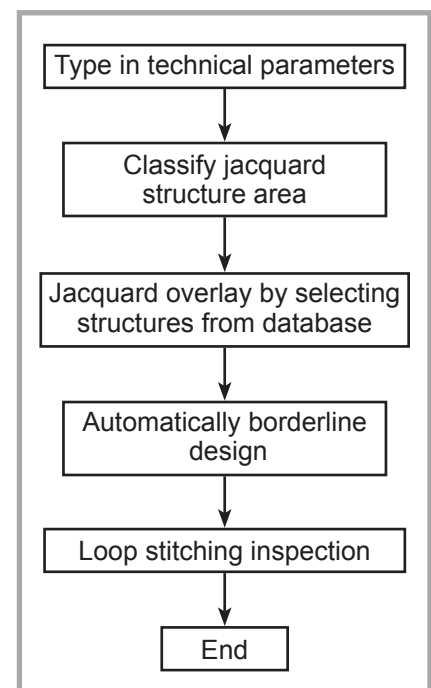


Figure 7. Design process.

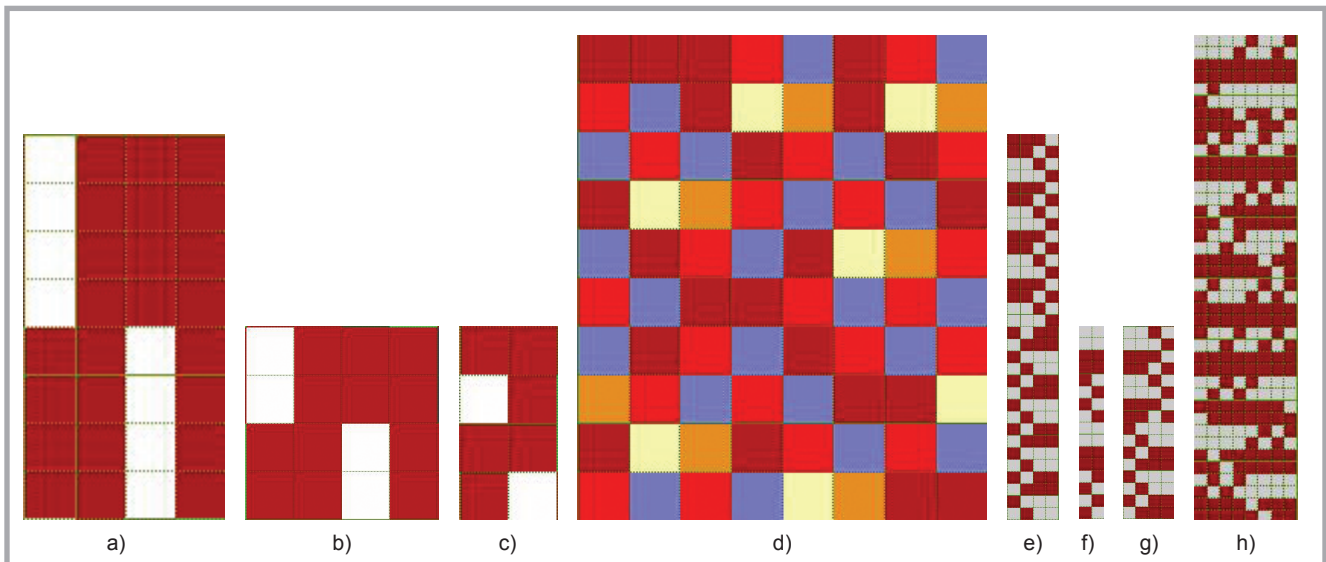


Figure 8. Jacquard structure design: a) large mesh and its displacement signals e), b) middle mesh and its displacements signals f), c) small mesh and its displacement signals g), d) ground structure and its displacement signals h).

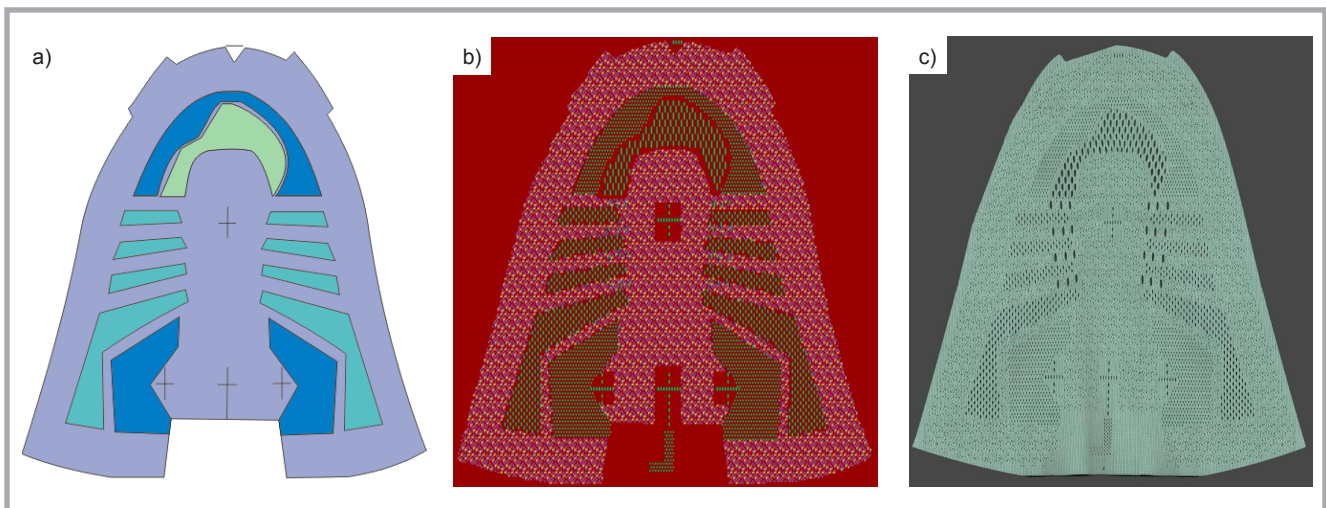


Figure 9. Design and real fabric: a) pattern design, b) jacquard structure combination, c) real fabric effect.

Based on the models built above, a computer-aided design program is designed with Visual C++ as the basic programming language. Via the design program, technical parameters are typed in first, including the width, length, chain data, threading cycles and Raschel technology value. After that, the jacquard pattern is designed by filling colors in jacquard grids and selecting structures from the database for overlaying. Borderlines are automatically designed when all pattern repeats with meshes are finished. The design process is detailed in **Figure 7**.

■ Design illustration

Given the design principles and requirements, appropriate illustrations are de-

signed referring to the detailed design process.

Technical parameters

Major technical parameters of Raschel shoe fabric with a double-colour pitting effect are shown in **Table 1**. The fabric materials are 200D/48F polyester FDY (fully drawn yarn) and 200D/48F cationic dyed polyester FDY, the former of which is threaded in GB3 and JB2.1, while the latter in GB1 and JB2.2. The selection of materials mainly depends on product requirements, such as wearability, strength and stiffness, which are highlighted by polyester and cationic dyed polyester. Additionally the two materials have different dyeing properties and approximate shrinkage to form a double-color effect in the dyeing

process. The fabric is knitted on a Rascheltronic machine in gauge 24 and the machine density is 16 courses per centimeter ($cpc = 16$).

Jacquard structure

The most competitive advantage of Piezoelectric technology is the abundance of structures and seamlessly being combined together. With the aid of jacquard technology, a double-colour pitting effect and patterns of meshes are formed. Referring to the characteristics of feet movement and heat dissipation, the shoe pattern repeat is mostly separated into four structural areas, among which the upper area is the primary part, with meshes for favorable air permeability. The top upper area is designed with large meshes as it is the most important

part for heat dissipation. The side upper area is also an important part with a mesh structure. The toe cap area and heel area are designed with small meshes to offer air permeability and durability. The outer outline of the shoe pattern is designed with a dense structure to ensure the strength property when combined with the shoe sole. Between the outer outline and upper area is the main part showing a double-color pitting effect with koper stitches and float stitches. Jacquard structures employed in the design example are shown in *Figure 8*.

Structure combination and fabric effect

After the design of technical parameters and jacquard structures, the structure combination of the double-colour pitting effect follows. The finished pattern design, jacquard structure combination and its real fabric are respectively shown in *Figure 9* and four detailed jacquard effects are shown in *Figure 10*.

Conclusion

The design of Rascheltronic shoe fabric with a double-color pitting effect is approached by means of a computer-aided design system based on a specific knitting method and jacquard principles. With a mathematical matrix and model, the system covers the basic technical parameters of the design module, jacquard structure design module, jacquard borderline design module, loop stitching inspection module and structure database module, which cooperate to make fabric designed efficiently. Referring to the functional requirements of vamp fabric, jacquard structures with a variety of meshes are seamlessly combined on a Rascheltronic knitting machine with a gauge of E24, and 200D/48F polyester FDY and 200D/48F cationic dyed polyester FDY are dyed for a double-color effect. Results of this study have proved that the computer-aided design method benefited well the design of Rascheltronic sports vamp fabric with a double-color pitting effect, broadening the innovative possibility of jacquard design.

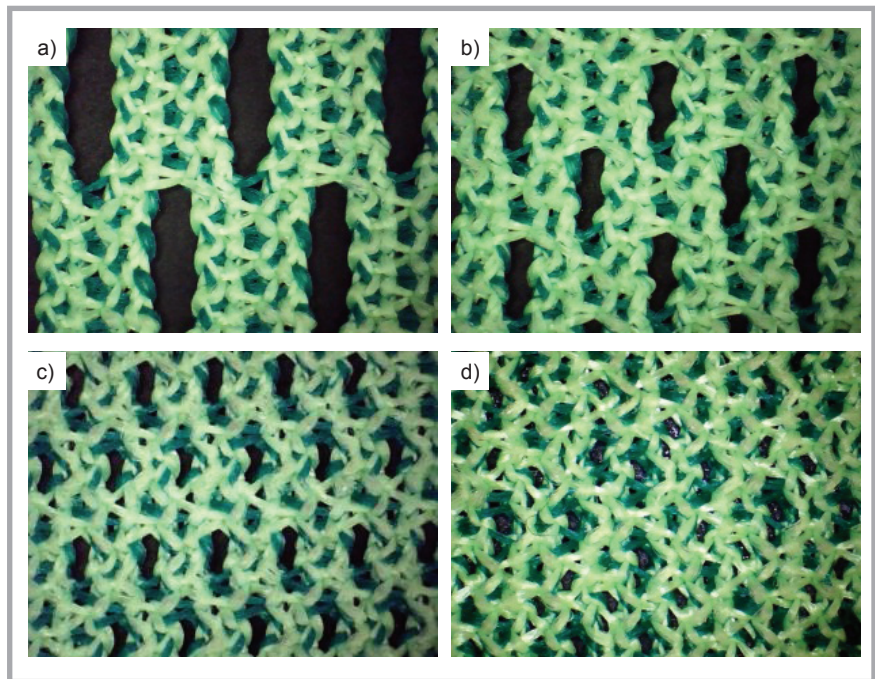


Figure 10. Detailed views of jacquard effects: a) large meshes, b) middle meshes, c) small meshes, d) ground structure.

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Disclosure statement

No potential conflict of interest was reported by the authors.