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# Physical properties of novel co-woven-knitted fabrics

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**Abstract:** Co-woven-knitted (CWK) fabrics have been reported previously. Historically these unique structures have been used to develop composite and shielding fabrics. In this study, novel CWK structures with unique appearances was developed with a modified machine using wool and polyester yarns. The physical properties of these fabrics were compared with conventional woven and knitted fabrics. The thickness of the CWK fabrics was similar to knits. The fabrics showed a unique tensile strength, with higher bending rigidity, and performed better in abrasion resistance.

**Keywords:** fabrics, co-woven-knitted, physical properties, novel fabric structures

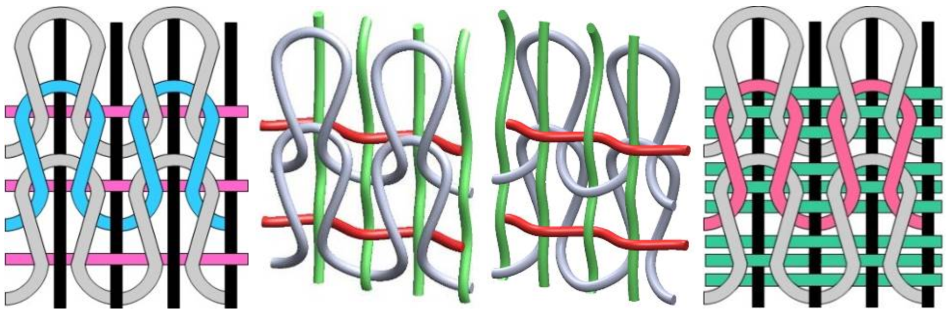
## 1. Introduction

Combination of the weaving and knitting machines has been previously reported to produce fabrics with both woven and knitted structures [1]. The improved method and a modified flat knitting machine was developed to produce co-woven-knitted (CWK) fabrics [2, 3], with focuses on reinforced composites [3] and shielding [2] applications. However, application of CWK fabrics in clothing category has received little attention, where the advantages of both woven and knitted fabrics can be considered. The main aim of this research is to investigate physical properties (thickness, tensile strength, abrasion resistance, bending stiffness and rigidity) of novel CWK fabrics designed for use in clothing.

## 2. Experimental details

### 2.1. Structural design of fabrics

A basic structure of CWK was designed as illustrated in Fig. 1 a. The loop yarns (marked in blue and grey) were knitted as shared yarns in both woven and knitted structures. The pink yarns were woven as normal weft yarns to enhance the density and the fabric's appearance on the back. In addition, the black lines represent warp yarns. The Fig. 1 b and c show 3D pictures of the basic structure made with SolidWorks software. Fig. 1 b and c show the face and the back side of the basic structure. An improved structure, in which the number of weft yarns (marked in green) is increased to three yarns, is shown in Fig. 1 d.



a) b) c) d)

Fig. 1: The designed structures. a) basic structure; b) & c) 3D sketches of basic structure; d) improved structure

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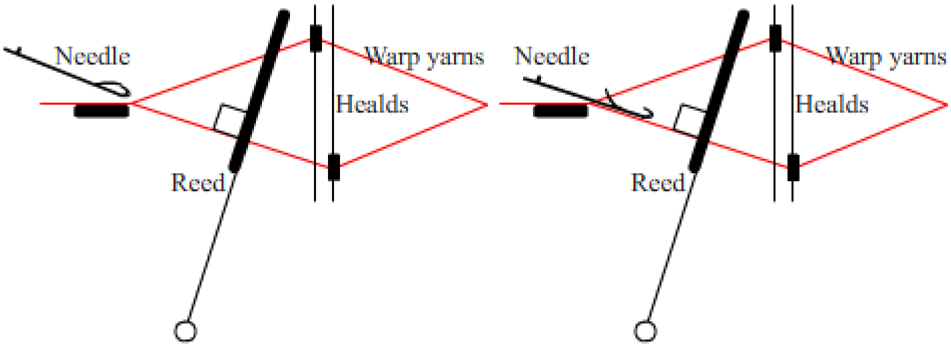
## 2.2. Fabrication of novel CWK fabrics

In order to make fabrics (Table 1) with designed structures, a flat knitting machine was modified and combined with a weaving machine. The method is presented in Fig.2. Needles were placed on the fabric with their tips of hooks close to the fell of cloth (Fig. 2 a), and they were paralleled to the lower layer of warp yarns. When weaving, needles stayed at the back (Fig. 2 a). While knitting, needles were pushed forward by cams (Fig. 2 b), and needles caught the weft yarns (loop yarns) in their hooks. Following, needles pulled loop yarns out of warp yarns and old loops to shape new loops.

Table 1: The details of specimens

| Fabric | Warp yarns | | Weft yarns | |
|---|---|---|---|---|
| | Material | Count | Material | Count |
| Woven | 100% polyester | 59 tex | 35% acrylic/65% wool | 66 tex |
| Knitted | N/A | | 35% acrylic/65% wool | 66 tex |
| Red CWK | 100% polyester | 59 tex | 35% acrylic/65% wool | 66 tex |
| Black CWK | 35% polyester/65% cotton | 28 tex | 35% polyester/65% cotton | 56 tex |
| Black improved | 35% polyester/65% cotton | 28 tex | 35% polyester/65% cotton | 56 tex |




a) b)

Fig. 2: The process of fabrication. a) needles at the back position; b) needles at the forward.

## 2.3. Physical properties measurements

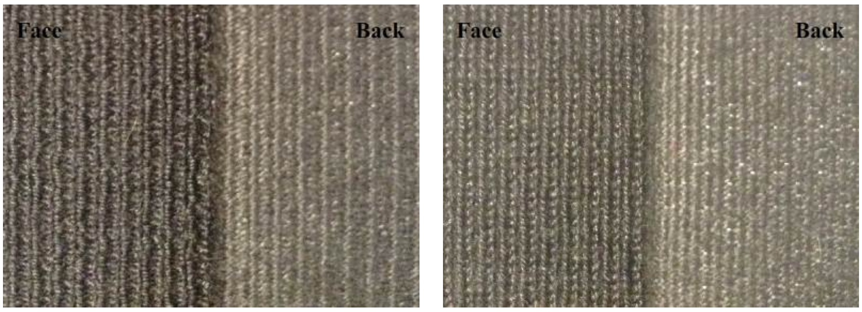
All fabrics were conditioned at a standard condition (20±2℃ and 65±2% relative humidity, ASTM D1776 - 08e1). The thickness of different CWK fabrics was measured according to ASTM D1777-96(2011) using the Absolute Digimatic ID-C 1012PB thickness gage made by the Mitutoyo Corp, where the foot diameter and pressure was 56.42mm and 1KPa, respectively.

Tensile strength tests were carried out using Instron 30KN tensile tester (Instron5567, America) and the width and length of samples were 25mm and 150mm (ASTM D5035-11), respectively. Abrasion resistance (ASTM D4966-12e1) was measured using a Martindale Abrasion and pilling Tester (Gester international Co., LTD, China). Bending stiffness and rigidity (ASTM D1388-08(2012)) tests were carried out on a Fabric Stiffness Tester (TESTEX, China). Four specimens (25×150mm, ±1 mm) from the warp direction and four specimens from the weft direction were tested. The face and back of both ends of each specimen were tested and the average of four readings along the same direction on the same side of four specimens was reported as the Length of Overhang.

# 3. Results and discussion

## 3.1. Observation of novel CWK fabrics

These novel CWK fabrics show unique appearance: the knitted structure on the face and the woven structure on the back of the fabric. The basic structure is exhibited as Fig. 3 a and b is the improved structure. Although the appearances of these two samples are similar, there is still some differences. The first one is that the wales in the improved structure are closer together and more well-distributed than the basic structure on the face of the fabric, which give the latter a better appearance. The second is that the surface on the back of the improved structure feels smoother than the basic structure. The vertical lines on the back side of the basic structure cannot be seen clearly on the latter one. Because the weft yarns of the latter in one repetition are more than the former and these weft yarns are woven as normal weft yarns in a woven structure which hold the warp yarns effectively and make them bend regularly as an ordinary woven fabric.




a) b)

Fig. 3: Two sides of novel CWK fabrics. a) the basic structure; b) the improved structure

## 3.2. Structural properties

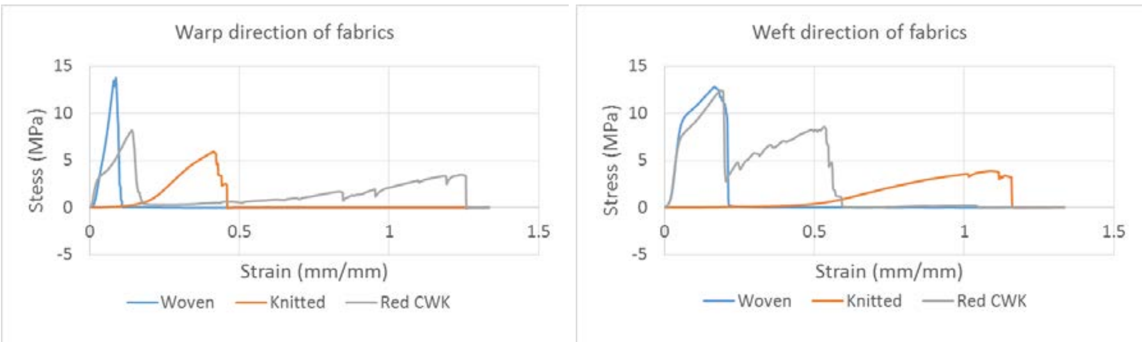
As Table 2 shows, the mass per unit area (g/m$^2$, GSM) and thickness of red CWK fabrics are higher than woven and knitted fabrics, but less than them together. However, the warp density of red CWK fabrics is similar to woven fabrics. It can be also found that the GSM of novel CWK fabrics are much higher than the woven and knitted fabrics, due to their higher weft density.

Table 2: The structural properties of specimens

| Fabric | Woven side | | Knitted side | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Warp/cm | Weft/cm | Course/cm | Wale/cm | Loop length (mm) | GSM (g/m$^2$) | Thickness (cm) | Fabric density (g/cm$^3$) |
| Woven | 9 | 20 | N/A | N/A | - | 190 | 0.09 | 0.22 |
| Knitted | N/A | N/A | 10 | 7 | - | 222 | 0.13 | 0.17 |
| Red CWK | 9 | 34 | 17 | 4.5 | - | 393 | 0.19 | 0.21 |
| Black CWK | 11 | 42 | 21 | 6 | 5.36 | 559 | 0.17 | 0.34 |
| Black improved | 11 | 44 | 11 | 6 | 6.78 | 517 | 0.15 | 0.34 |

## 3.3. Tensile strength

As illustrated in Fig. 4 a and b, the novel CWK fabrics showed two peaks. According to the observation when testing, yarns in the woven structure broke first and then the one in the knitted structure along both directions. Therefore, the first peak represents the woven structure and the second peak is the knitted structure.

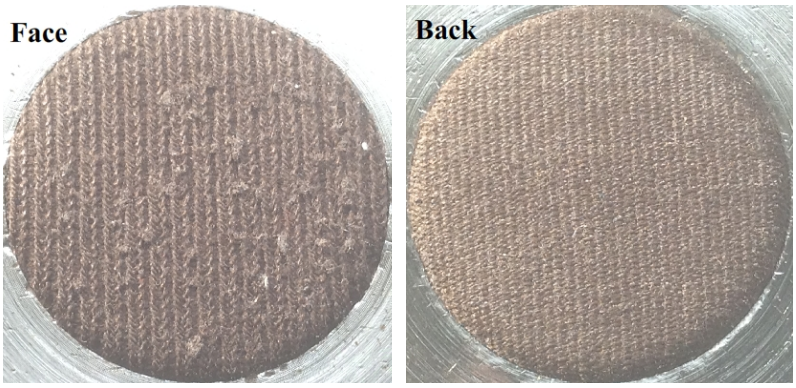



a) b)

Fig. 4: Stress-strain curves of woven, knitted and CWK fabrics. a) warp direction; b) weft direction

## 3.4. Abrasion resistance

The appearance of the face and back of novel CWK fabrics (black improved structure) are presented in Fig. 5, after more than 50,000 abrasion circles. While any breakages on the back (the woven side) was not observed, there were a few broken loops on the face (the knitted side). However, damage on the knitted side did not affect the appearance of the woven side, and the fabric still has the strength of the woven structure.




a) b)

Fig. 5: Appearance of the face and back sides. a) face side; b) back side

### 3.5. Bending stiffness and rigidity

The CWK fabrics showed generally being stiffer than woven fabrics, as illustrated in Fig. 6. As for the black CWK and black improved structure, with the number of weft yarns increasing in the woven structure of CWK fabrics, the bending length on the knitted side increased. However, the bending length along the warp direction on the woven side decreased, because of the wales tension on the knitted side. And the wales, when the warp density of CWK fabrics are not changed, are also the reasons why those yellow strips of novel CWK fabrics are similar to each other.

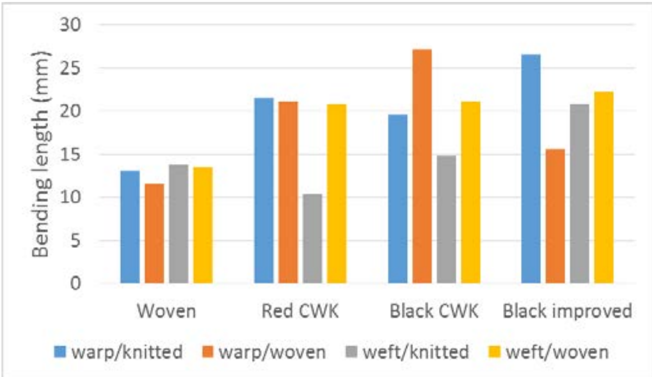



Fig. 6: Bending length of four fabrics

## 4. Conclusion

The thickness of novel CWK fabrics was found to be less than the thickness of woven and knitted fabrics together. The novel CWK fabrics showed unique appearances: the woven structure on one side and the knitted structure on the other. As shown by the abrasion test, CWK fabrics showed a strong stand up to wear. The novel CWK fabrics showed two breakages along both the warp and the weft direction. The performance of the bending stiffness of the novel CWK fabrics was significantly different in two direction and on the face and back of the fabric.

## 5. References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