AUXETIC SELF-FOLDING KNITTED FABRICS FOR PROTECTIVE APPLICATION

Yanping Liu[1]
[1] *Donghua* University, *College* of Textiles, *Shanghai*, *China*
liuyp@dhu.edu.cn

ABSTRACT

Two types of purl stitches (V-shaped and Z-shaped) forming auxetic self-folding knitted structures were developed based on miura-ori pattern on a computerized flat knitting machine for impact protective applications. Three kinds of yarns including polyester multifilament, aramid and low-temperature melting polyester multifilament yarns (LTMY) were used. After heat treatment with an oven, the developed fabrics become semi-rigid flexible composite materials. The Poisson's ratios, compression and bending properties were evaluated. The negative Poisson's ratio of Z-shaped vertical folding fabric decreased as the amount of LTMY increases. The results of V-shaped fabrics are just the inverse as that of Z-shaped fabrics. LTMY increased the compression stress, energy absorption and bending rigidity.

Key Words: AUXETIC, KNITTED STRUCTURE, NEGATIVE POISSON'S RAITO, ENERGY ABSORPTION

1. INTRODUCTION

Negative Poisson's ratio (NPR) materials are different from most conventional materials. They exhibit the very unusual property of becoming wider when stretched and narrower when compressed [1]. This counterintuitive behavior gives NPR materials various beneficial effects, such as enhanced shear stiffness, increased plane strain fracture toughness, increased indentation resistance, and improved energy absorption properties [2,3]. Liu and Hu proposed a weft knitted auxetic structure based on Miura-ori pattern [4] using purl stitch and the structure showed remarkable auxetic behavior with Poisson's ratio up to -0.5. Since then, a lot of following up studies have been conducted to investigate the effects of materials and structural parameters on the auxetic behavior and mechanical properties of the auxetic fabrics [5,6].

Based on Miura-ori pattern, two types of purl stitches (V-shaped and Z-shaped) which can form auxetic self-folding knitted structures were developed in this work for impact protective applications by using three kinds of yarns: polyester multifilament, aramid and low-temperature melting polyester multifilament yarns (LTMY). After heat treatment with an oven, the developed fabrics become semi-rigid flexible composite materials with negative Poisson's ratio. The Poisson's ratios, compression properties and bending properties were evaluated. This type of flexible composites has great potential in developing human body impact equipment due to high energy absorption in through-the-thickness direction and low in-plane and out-of-plane stiffness.

2. EXPERIMENTAL

2.1 Materials

Three types of yarns were used in this study, i.e., polyester multifilament, aramid and low-temperature melting polyester multifilament yarns (LTMY). The specifications of the yarns are listed in Table 1.

Table 1. Specificaitons of the yarns used

Code	Yarn materials	Linear density (Denier)	No. of filaments (F)	Strength (cN)	Tenacity (cN/tex)	Elongation (%)
A	Polyester multifilament	300	72	1351.6	40.6	42.3
B	Aramid	400	267	6250.3	140.8	5.8
C	Low temperature melting polyester yarn	150	48	188.6	11.3	61.4

2.2 Knitted structures

Two purl stitches as shown in Figure 1 were used to produce Miura-ori pattern. After the fabrics were removed from the machine, they were self-fold into Miura-ori pattern. Ten samples were produced by using different number of LTMY. The sample codes V_0, V_1, V_2, V_3, V_4 and V_5 denote fabrics with the pattern in Figure 1(a) and the number of LTMY in the fabrics are 0, 1, 2, 3, 4, and 5, respectively, while The sample codes Z_0, Z_1, Z_2, Z_3, Z_4 and Z_5 denote fabrics with the pattern in Figure 1(b) and the number of LTMY in the fabrics are 0, 1, 2, 3, 4, and 5, respectively.

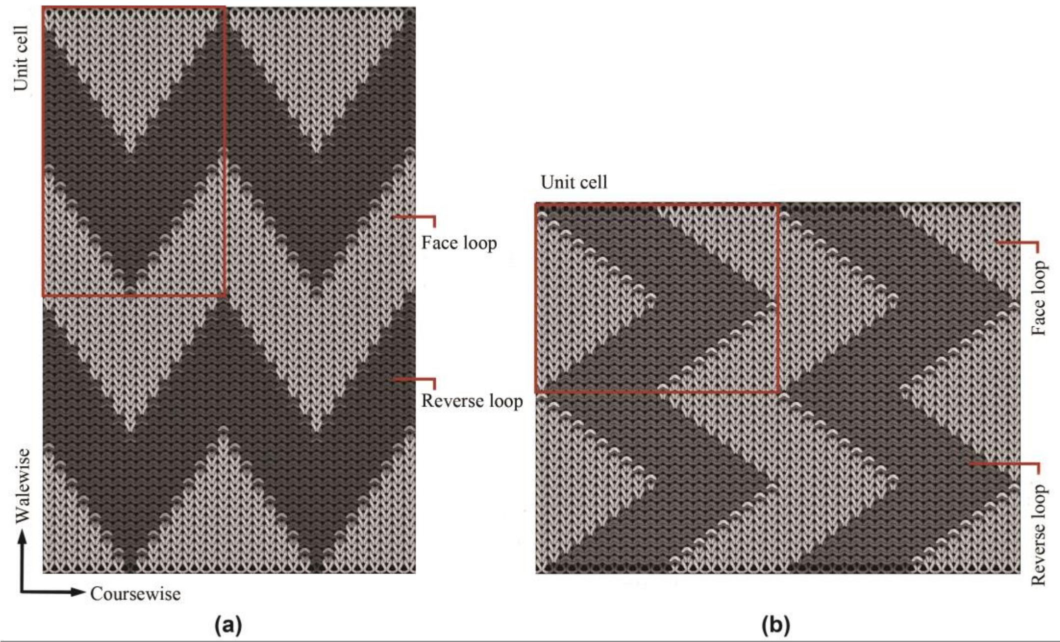

Figure 1. Knit pattern of the fabrics: (a) V-shaped; (b) Z-shaped.

3. Results and discussion

Tensile test results showed that the negative Poisson's ratio of the fabric increase as the amount of LTMY increases. The V-shaped fabrics are more auxetic than Z-shaped fabrics when the amount of LTMY in the fabrics is the same. For the Z-shaped fabrics, the side length of a unit cell is determined by the number of courses in a unit cell, while the fabric thickness depends on the number wales. The results of V-shaped fabrics are just the inverse as that of Z-shaped fabrics. The addition of LTMY increased the compression stress and energy absorption of the fabric as shown in Figure 2. Increasing the number of LTMY, the bending rigidity of the fabric was also increased.

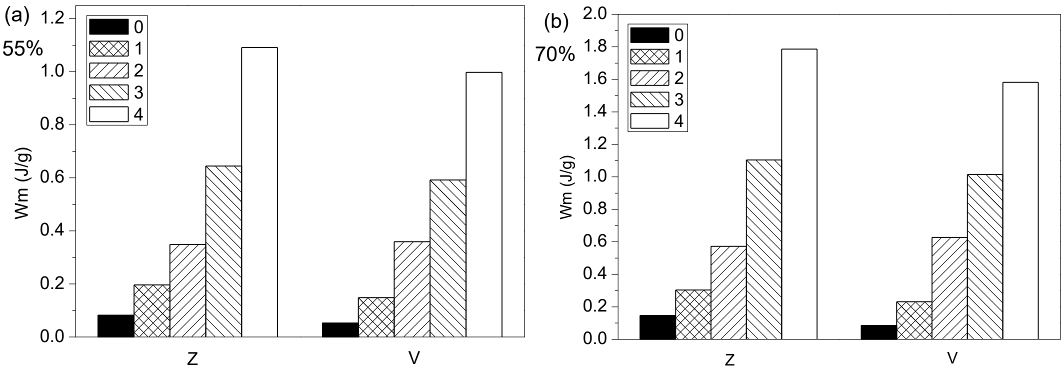

Figure 2. Energy absorption of the fabrics at a strain of (a) 55% and (b) 70%.

The in-plane and out-of-plane stiffness of the fabric is much lower than through-the-thickness stiffness. Such type of fabric exhibits a typical anisotropic feature and has good energy absorption and conformability. This type of flexible composites has great potential in developing human body impact equipment due to high energy absorption in through-the-thickness direction and low in-plane and out-of-plane stiffness.

3. REFERENCES

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Biography

Dr. Liu Yanping is an associate professor in knitting technology at Donghua University in Shanghai China. His research interests lie in development of new knitted structures and processes with unusual properties for special applications such as moisture management, impact protection, vibration isolation, and sound absorption using advanced experimental and numerical methods. He has worked as a part-time consultant for several leading knitting companies in China. He has invented several novel knitted structures which have been successfully commercialized. For instance, He designed a 3D spacer fabric with very low frictional surface which was adopted by KUKA Home for manufacturing a 3D mattress.