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Negative Poisson's Ratio Based on Weft knitted Fabric with Different Loop Length

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Abstract— *Auxetic textile materials have become a point of developed knitted structures produced using high performance yarns and showing strong auxetic effects. The Negative Poisson Ratio based on Weft knitted fabric have huge potential for applications, especially in personal protection materials like bullet proof vest, and many industries application such as airspace, automobile, and so on. The present work reports auxetic structures using polypropylene filament yarn through weft knitted technology. The polypropylene filament yarn were knitted on a 5-gauge flat knitting machine (Passap Deumatic 80), using a 2-cam system with a pattern based on a (rib knitting) structure on the face and back loops. Three types of different loop length with same structural (fisherman's rib) are used (LL3, LL4, and LL5). The effected of different Loop length on negative Poisson's ratio (NPR) was investigated in the wale and courses direction. The results show that all knitted fabrics have the NPR effect, for the both direction (wale and course). It was observed that NPR improved strongly with the increase in loop length of knitted structures.*

Keywords— Negative Poisson Ratio, Weft Knitted, Loop Length, wale and course)

1. INTRODUCTION

Auxetic textiles are materials which possess negative Poisson's ratio, this implies that in contrast to conventional textile materials if they are stretched in longitudinal direction, a marginal expansion will results in transversal direction. Auxetic textile materials have become a point of focus for many researchers in recent past years. There are achievements in the area of auxetic textile materials including fibers, yarns, fabrics and textile reinforcements for composite applications [1, 2].

Conventional fabrics usually exhibit a positive poisons ratio (P R), (they laterally shrink when stretched and laterally expand when compressed. Auxetic fabrics exhibit a negative (P R),(they laterally expand when stretched or laterally shrink when compressed [3].

The NPR effect of a material normally comes from its special structural arrangement. To date, a variety of special geometrical structures have been discovered for making NPR materials from the macroscopic level down to the molecular level. Among the most important classes of these NPR structures, it is possible to cite re-entrant structures [4], chiral structures [5], rotating units[6], angle-ply laminates[7], hard molecules[8], micro porous polymers [9], and free rod liquid crystalline polymers [10].

Bertoldi, K., et al. [11] produced large negative Poisson's ratio (ν) from ultra-high molecular weight polyethylene (UHMWPE) because of its complex microstructure. It was found that the presence of a negative Poisson's ratio resulted in enhancements of the hardness by up to a factor of two over conventional UHMWPE. Alderson.A et al. [12] produced polymeric monofilaments displaying auxetic behavior. The structure and deformation mechanisms at the micro scale, rather than at the molecular level (as compared to conventional filaments) are responsible for enhanced mechanical properties, including the auxetic effect. In another study produced auxetic poly propylene fibers by using thermal processing technique [13]. A large value of Poisson's ratio (v = -0.6) was obtained when measured by using video extensometer.

Ugbolue et al in the pedant paper fabricate knit structures made of conventional yarns by using chain and filling yarn inlays. They combined the principles of geometry, fabric structural characteristics and conventional elastic yarn to engineer hexagonal knit structures with negative Poisson's ratio [14].

A new kind of negative Poisson's ratio weft-knitted fabric was firstly designed and fabricated on a computerized flat-knitting machine. Then the NPR values of these fabrics were evaluated and compared with those from the theoretical calculations. The results show that all knitted fabrics have the NPR effect, which decreases with increased strain in the course direction [15].

Flat knitting technology was exploited to fabricate auxetic fabrics which laterally expand when stretched. Hu, H et al, [16] investigated three kinds of geometrical structures, i.e. foldable structure [17], rotating rectangle [18]and re-entrant hexagon [19].

The results reveal that except the folded fabric formed with the face loops and reverse loops in a rectangular arrangement, of which the auxetic effect firstly increases and then decreases with the axial strain.
The aims of this article to fabricate Negative Poisson ratio based on Weft knitting fabric (by different loop length) with polypropylene yarn to evaluate and compared the value of the Passion Ratio.

2. MATERIALS AND METHODS

Knitted fabrics with auxetic behavior were produced from high tenacity and ductile polypropylene (PP) yarn (100 Tex, 72 monofilaments), supplied by Guangzhou Lanjing Chemical Fiber Co., Ltd. Table I shown the main properties of the PP monofilament yarn used in this study. As observed that the extension of PP yarn was very high (ductile).

Table 1: PP yarn properties.

properties	PP
Linear density [tex]	100
Number of filaments	72
Tensile strength [N]	35.40
Extension [%]	176.9

2.1 Fabric Knitted Structures

Auxetic weft-knitted textile structures were manufactured on flat knitting machine (Passap Deumatic 80) , using a 2-cam system with a pattern based on a (rib knitting) structure on the face and back loops, knit fabric structure was produced using 120 needles (60 in front-60 at back and 5 per/inch) , as it shown in Figure (1).The equipment allows controlling the needle selection, cam setting, and supporting the production of specimen structures. Three different loops length knitting fabric was produced as illustrated in Figure (2).

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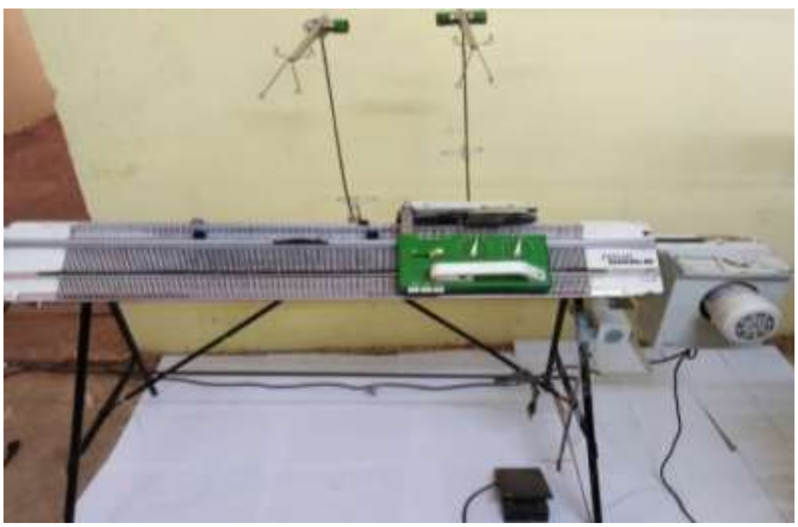

Figure 1. Flat knitting machine (Passap Deumatic 80).

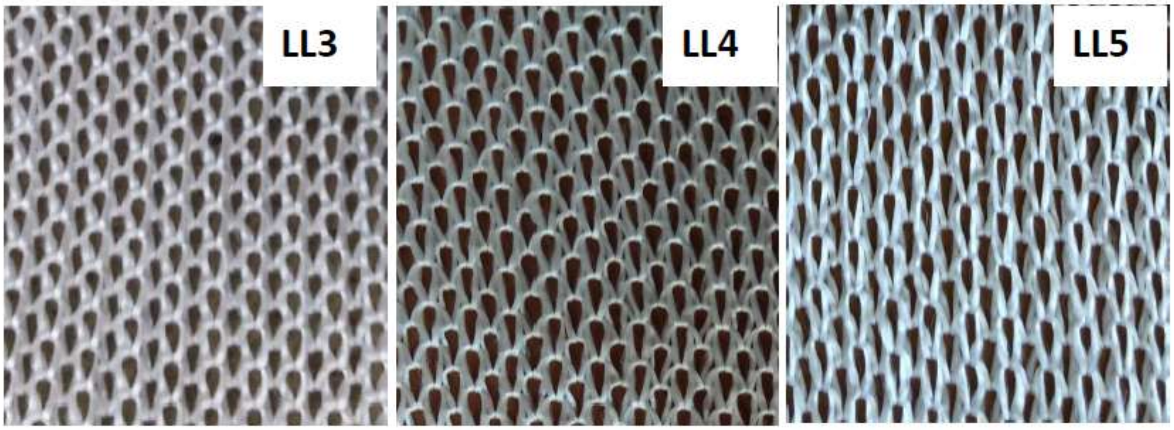

Figure 2. Three different loops length knitting fabric.

3. RESULTS AND DISCUSSIONS

3.1 Evaluation of the Poisson's ratio

In the literature, it was possible to find the different ways to evaluate the deformation of auxetic specimens produced from knitted fabrics. For the evaluation of NPR of the knitted structures, the specimens were clamped at their two ends in the testing device and extended manually along the course and wale direction .The distance between the reference points along the course and wale directions was 80 mm and the change was observed in the specimen form as shown in figure (3).

The strains in the course and wale direction were calculated for three samples. The following equations was used:

$$\epsilon_x = {}^{\Delta L}/_{L} \qquad (1)$$

$$\epsilon_y = {}^{\Delta W}/_{W} \qquad (2)$$

The values of ϵ_x and ϵ_y were determined by using Eq 1 and 2 that as shown in table (2).The Poisson's ratio is calculated through the relation between the strain in the transverse direction and the strain in the longitudinal direction using Eq (3).

$$v_{xy} = -\epsilon_y/\epsilon_x \qquad (3)$$

3.2 Poisson's ratio

Figure 3 show that the change in length for the different loop length under stretched state for both direction wale and course under Fryma Dual Extensimeter instrument. It was shown that the length increases as the length loop decreases, and the width changes increases as the loop length increases for the three different structures in the both direction wale and course.
The strain in the longitudinal and transverse direction was inversely and directly proportionate with the loop length, respectively. Due to the negative Poisson ratio knitted fabric.
The shorter loop length need longer elongation until a significant change in the transfer direction occurs.

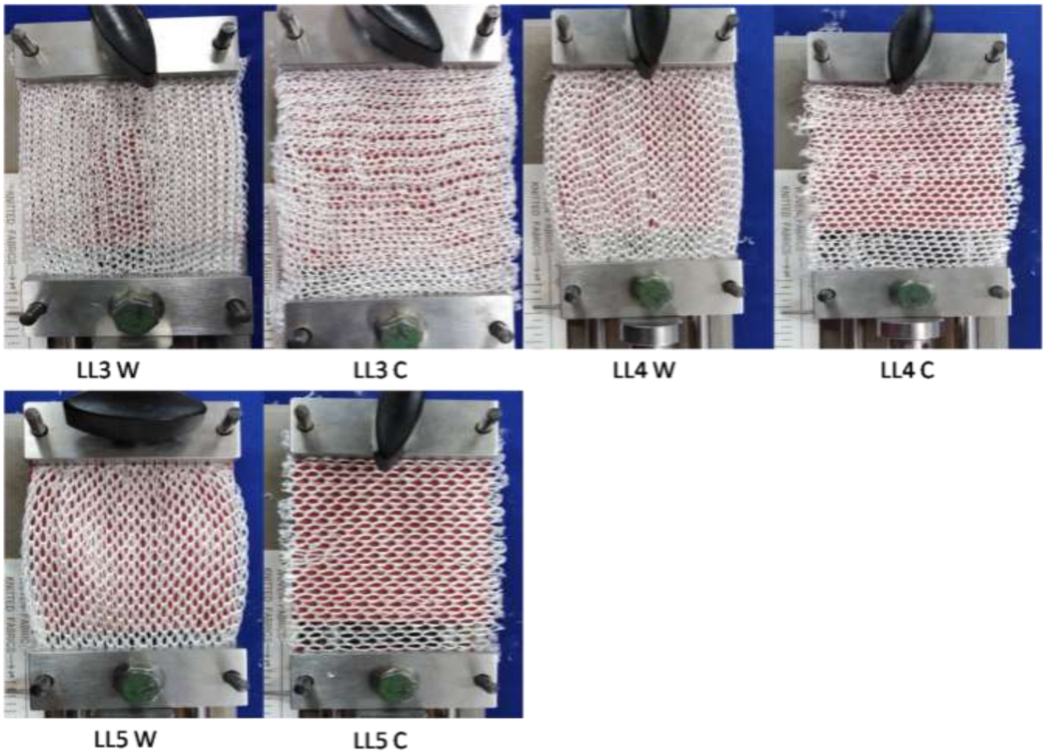

Figure 3. Different loop length under stretched state for both directions

Table 2.The change in length and width of the three loop length in the wale

L.L	L	ΔL	W	ΔW	ϵ_x	ϵ_y
L.L 3	8	+ 0.8	8	0	0.1	0
L.L 4	8	+ 1.5	8	+ 0.5	0.187	0.0620
L.L 5	8	+ 1.5	8	+ 0.7	0.187	0.087

Table 3. The change in length and width of the three loop length in the course

L.L	L	ΔL	W	ΔW	ϵ_x	ϵ_y
L.L 3	8	+ 2.6	8	+ 0.2	0.325	0.025
L.L 4	8	+ 2.0	8	+ 0.3	0.25	0.0375
L.L 5	8	+ 1	8	+ 0.4	0.125	0.05

The Negative Poisson's ratio of the knitted fabrics for three different loop lengths was measured. The values found were -0.076, -0.2 and -0.4 for the LL3, LL4 and LL5 knitted fabrics respectively. Which shows the auxetic behavior of the samples that illustrates in Table (4). The kind of loop length used, it can be observed that the maximum NPR obtained was for LL5 knitted fabrics and, the NPR in the wale direction was highest than course direction for the three different structures as show in table (4).
These results indicate that the fiber type in the construction of the knitted fabric also demonstrated significant influence on the auxetic behavior.
The use of high-tenacity and ductile yarn like PP and loop length provided the highest NPR value.

Table 4. Negative Poisson ratio for wale and course direction

LL	NPR (wale direction)	NPR (course direction)
LL3	0	-0.076
LL4	-0.33	-0.2
LL5	-0.46	-0.4

4. CONCLUSIONS

In this paper, auxetic fabrics using knitting technology has been developed using polypropylene yarns. From this study it can be concluded that, weft knitted fabrics with auxetic behavior were produced by using different loop length to evaluate the Negative Poisson Ratio. From tensile behavior the shorter loop length need longer elongation until a significant change in the transfer direction occurs. The results show that all knitted fabrics have the NPR effect, for the both direction (wale and course). It was observed that the NPR increase when the loop length increase, the LL5 has highest NPR and the LL3 have Lowest NPR.

5. ACKNOWLEDGMENT

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