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# Evaluating the effect of structural and parametric change of weft knitted polyester fabrics over the performance of sportswear

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ABSTRACT

Using the 100% polyethylene Terephthalate (PET) 75/72 DTY semi-intermingle yarn, three different weft-knitted structures are manufactured on similar gauge circular weft knitting machines. All the manufactured structures are tested using standard methods so that the influence of knitting parameters and optimization of structures on the overall performance of sportswear can be analysed. The structural characteristics including, stitch length, stitch density, thickness, GSM, dimensional stability, spirality, pilling, abrasion, and bursting strength are measured. Similarly, OMMC, air permeability, and stretch and growth properties were evaluated to assess the functional performance and relative hand value of the developed knitted fabric. It was found that the structural and knitting parameters have an adequate influence over the functional properties of sportswear which should be designed and optimized as per the need and intensity of sports.

## 1. Introduction

The tremendous growth in the development of activewear has been seen as driven by increasing awareness of physical and mental fit. To fulfill the need for better performance of athletic wear and the need of customer and market demand, the use of inventive textile technology in the manufacturing of sportswear is frequently enhancing day by day. A major increment has been seen in the consumption of fibers and fabrics for sportswear or casual wear along with different functional properties. Active sportswear fabrics are specially designed in terms of geometry, structure, and construction to ensure the end requirement [1]. Many factors influence the overall properties of the produced knitted fabrics including course density, wales density, stitch length, type of structure, etc. The structural parameters affect the physical appearance, mechanical performance, and stability of the resultant fabric [2]. The required end properties can be achieved by altering the conditions and process parameters. The overall mechanical and physical properties of fabric depend mainly upon the structural parameters [3]. Stitch length, also known as loop length, is also one of the most critical parameters of the knitted fabric production process which influences the dimensional and physical properties of the end product. The properties like air permeability, abrasion resistance, course per inch, absorbency, Wales per inch, dimensional stability, bursting strength, etc. mainly depend upon the stitch length [4].

Several researchers have discussed the impact of stitch length, yarn, and fabric structure on the structural and functional properties of fabric [5-10]. Kejkar and Dhore found that increasing stitch length decreases the stitch density of the fabric, resulting in a reduction of loop formation per unit area, which in turn leads to decreased bursting strength and absorbency. Similarly, the shrinkage in length and width of the fabric increases with the increment in stitch length while the incorporation of spandex leads to the increment of compactness of the fabric which results in a decrement of absorbency and a slight increment of weight [4]. Chakroun et al. presented that the stitch length is directly proportional to the air permeability and is inversely proportional to water vapor resistance. Similarly, the fabrics with different stitch lengths may also have the same drying rate properties [11]. At the same time, a slight number of pills can be generated with the higher stitch length mainly for single jersey fabrics but not for all types of structures. The stitch length is also directly proportional to the spirality of the fabric, while as per the structure of the fabric, the dimensional stability may also vary [3]. Megeid et al. reported that the loop length is inversely proportional to the overall GSM and the thickness of the fabric due to the increase in stitch density. Similarly, as the stitch length increases, the abrasion resistance of the fabric decreases because due to decrement the stitch length the fabric becomes more compact. The count of yarn also influences the abrasion resistance, the finer the yarn the lesser the abrasion resistance [12].

Similarly, the structures of knitted fabrics also impact the end properties of the fabric. Interlock structures are balanced structures that also provide good softness properties [13]. Interlock fabric is preferred due to its balanced extension in lengthwise and widthwise directions for various applications. It is also used in sports fabric due to its moisture management and good tactile properties [14]. Similarly, the plaited interlock fabrics are preferred for next-to-skin application and active wear because of their exceptional moisture management properties [15].

The requirements of functionality and comfort have increased. The appropriate requirements can also be met by optimizing the structural design of fabric and yarn. Stitch type, location, and percentage of particular stitches in a repeat influence the properties as well. Jamshaid et al. concluded that for the application of activewear, the interlock sample with the double tuck incorporated in the structure provides the highest air permeability, elasticity, softness, and overall moisture management properties [16]. Assefa and Govindan also claimed in their research that the induction of tuck stitch in the structure will result in a decrement in length-wise elasticity of the overall fabric, increment in the stability by retaining the shape of the fabric, increment in air permeability and provide moderate drape ability on the fabric [17].

Wasim et al. reported that the increment of tuck stitch in the fabric structure results in the increment of the areal density because the stitch has only two connecting points due to which the accumulation of yarn occurs and the weight of the fabric increases. Similarly, by introducing a tuck loop in only the Wales direction of the structure, fabric width also increases [18].

Asif et al. also reported in their research that the structures containing tuck loops are wider compared to plain knit structures. An increase in width-wise shrinkage and a decrease in length-wise shrinkage were reported for tuck loop structures. Similarly, spirality has an inverse relation with the increment of tuck loops in the structure, as the fabric becomes more stable and its density increases [19]. In the case of a float loop, the spirality increases with the increases in the float loop in the structure [20]. The bursting strength is also inversely related to the tuck stitch in the structure. The tuck stitch, either in the Wales direction or in the course direction, tends to reduce the bursting strength of the fabric [21]. Similarly, the thermo-physiological comfort properties of knitted fabrics used next to the skin are also studied, and it was concluded that structural parameters such as tightness factor, thickness, fabric porosity, stitch density, and loop length had a strong effect [22].

Salopek et al and Ramratan et al. studied the influence of yarn and fabric parameters including composition, GSM, evenness, and thickness over the thermal characteristics and air permeability and determined that these parameters have the greatest impact on heat resistance and air permeability.

Čubrić et al. investigated the comfort characteristics of knitted fabrics developed by using functional and conventional polyester yarns. For this, they developed single-plaited and double-jersey knitted structures with and without elastane. It is concluded that especially for fabrics that do not contain elastane having higher GSM and thickness tend to have lower air permeability. Also, the double jersey and single jersey with and without elastane fabrics are found to have an inverse correlation between water vapour permeability and thickness of fabrics [23, 24].

Necef et al. investigated the comfort properties of different types of knitted fabrics for the cycling sportswear. They developed five types of fabrics and determined that the clothing comfort is mainly influenced by the structures. They recommended that in order to develop quality sportswear, the fabric should have higher permeability, thermal conductivity, OMMC, and water vapor permeability while the overall fabric should be lightweight [25].

The objective of this study is to investigate the impact of various weft-knitted structures on the performance properties of fabrics. To isolate the effects of the knitted structures, the study will maintain consistency in yarn type, denier, and machine gauge. This research aims to provide insights into the selection of fabrics for sportswear tailored to different sports. Additionally, the study will examine specific characteristics of the knitted structures that influence fabric handle and moisture management properties, which are critical factors in determining wearer comfort.

## 2. Material and Methods

### *2.1 Material*

Multifilament semi-intermingle 100% PET drawn textured (DTY) yarn of linear density 75 deniers containing 72 filaments in a cross-section is utilized to develop samples. Polyester is the commonly used fiber for sportswear due to enhanced moisture management properties, appearance, and overall comfort properties of fabric.

### *2.2 Method*

Three weft-knitted samples are produced using 100% polyester 75D/72F DTY semi-intermingle yarn on a similar gauge circular weft knitting machine with different machine parameters. Needle notation and structure type of the produced samples are presented in Table 1 along with the appearance of the samples on technical front and back. The interlock and plaited sample have similar appearances while interlock mesh has a different appearance on the technical front and back. Specifications of circular weft knitting machines used for the development of samples are given in Table 2.

### *2.3 Testing*

All the testing procedures for the determination of physical, mechanical, and functional characteristics are performed in a greige state under a controlled and conditioned environment as per the standard of ISO 139:2005.

#### *2.3.1 Determination of structural and mechanical characteristics*

The wales density and course density of the developed fabrics are calculated according to the BS EN 14971:2006, stitch length is calculated according to the EN 14970:2006, thickness is measured according to ISO 5084 and the grams per square meter (GSM) of a fabric is calculated as per the standard EN 12127:1997.

The overall performance, durability, and appearance of sportswear are linked to its mechanical and functional properties, including bursting strength, abrasion resistance, pilling resistance, spirality, and dimensional stability. The bursting strength of developed weft knitted fabrics is calculated according to ISO 13938-2 while pilling and abrasion resistance are calculated according to ASTM D4970. The dimensional stability is determined in both the course and Wales direction is calculated as per ASTM D 6207. Similarly for the Spirality, the fabric is marked as per the standard of AATCC 179. By using the following Eq. (1), the spirality of the fabric is determined.

$$X = 100\% \times [2(AC-BD)/(AC+BD)] \quad (1)$$

Where,

X = Percentage change in skew

AC = Length of the first diagonal line

BD = Length of the second diagonal line

#### *2.3.2 Determination of functional characteristics*

Similarly, the functional testing results of weft-knitted fabric samples are also obtained by using the testing standards. The relative hand value of the fabrics is determined according to the AATCC TM 202 and liquid moisture management properties of samples are determined according to the AATCC 195. The air permeability of developed samples is determined according to ISO 9237 under the pressure of 100 Pa on the fabric of 20 cm2. The stretch properties of knitted fabrics are evaluated by ASTM D 2594 by using the following equations (2), (3) and (4).

$$\text{Fabric stretch} = 100 \times (D-A)/A \quad (2)$$

$$\text{Growth after 1 min} = 100 \times (B-A)/A \quad (3)$$

$$\text{Growth after 60 mins} = 100 \times (C-A)/A \quad (4)$$

Where,

A = Sample’s original length

B = Sample’s length after application of load for 2 hours and 1 minute of relaxation

C = Sample’s length again after 1 hour

D = Sample’s length after the cyclic load application

**Table 1**

Needle notation and appearance of developed weft knitted samples

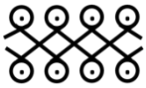
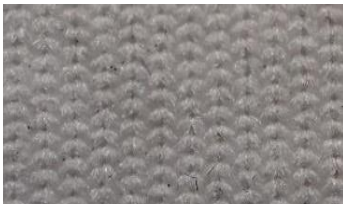
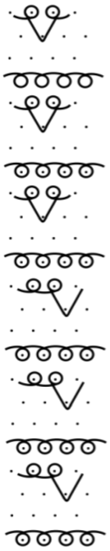
| Sample no. | Structure | Needle notation of knitted fabrics | Appearance | |
|---|---|---|---|---|
| | | | Front | Back |
| 1 | Interlock |  |  |  |
| 2 | Interlock Mesh |  |  |  |
| 3 | Plaited |  |  |  |

**Table 2**

Specifications of circular weft knitting machines used for the development of samples

| Machine Specifications | Interlock and Plaited | Interlock Mesh |
|---|---|---|
| Machine brand | Dragan | Huixing |
| Total beds | 2 | 2 |
| Total feeders | 68 | 72 |

| | | |
|---|---|---|
| Total needles | 2976 | 2640 |
| Diameter of Cylinder | 34” | 30” |
| Gauge | 28 | 28 |

**3. Results and Discussion**

*3.1 Evaluation And Comparison Of Structural Characteristics Of Knitted Samples*

The structural characteristics of developed weft knitted samples are measured according to the above-described standards and a comparative study of the developed samples is conducted in greige form, as shown in Table 3. Variations in the results can be seen concerning wales density, course density, stitch density, stitch length, thickness and GSM of the fabric. As the yarn and machine gauge are kept constant for all the samples, the observed change is due to the difference in type of structure and change of knitting parameters during the manufacturing of samples.

**Table 3**

Structural characteristics of developed samples in greige state

| Structural Characteristics | Interlock | Interlock Mesh | Plaited |
|---|---|---|---|
| Wales Density | 40 | 39 | 39 |
| Course Density | 46 | 46 | 50 |
| Stitch Density | 1840 | 1794 | 1950 |
| Stitch Length (mm) | 2.5 | 2.6 | 2.4 |
| Thickness (mm) | 0.48 | 0.43 | 0.48 |
| GSM | 118 | 107 | 104 |

*3.2 Evaluation And Comparison Of Mechanical Characteristics Of Knitted Samples*

The mechanical characteristics of developed weft knitted samples are also measured and a comparative study of the developed samples is conducted in greige form including dimensional stability, spirality, and bursting strength of the fabrics, as shown in Table 4.

The presented characteristics of the structure play a crucial role in determining the behaviour of fabric during wearing which ultimately influences the performance of an athlete.

**Table 4**

Structural characteristics of developed samples in greige state

| Mechanical Characteristics | | Interlock | Interlock Mesh | Plaited |
|---|---|---|---|---|
| Dimensional Stability | | | | |
| Avg. % | Wale | -0.198346 | -4.143882 | -3.728070 |
| | Course | 0.896860 | -0.749996 | -2.507374 |
| Spirality (%) | | | | |
| in % | | -1.136363 | -1.759530 | 0 |
| Pilling | | 4,5 | 4,5 | 4,5 |
| Abrasion | | no breakage till 7000 Cycles | no breakage till 7000 Cycles | no breakage till 7000 Cycles |
| Bursting Strength (Kpa) | | 1094 | 870 | 1104 |

The stitch length of the developed samples is maintained within an optimal range to control the stitch density, thickness, and GSM (grams per square meter) within the desired limit for sportswear. If the stitch length is significantly reduced, it would result in increased GSM, leading to a denser fabric that could negatively impact its performance properties.

Furthermore, the results indicate that the interlock structure, produced with optimized parameters, is the most dimensionally stable compared to others and possesses adequate bursting strength and minimal spirality. On the other hand, the plaited structure, with a slightly reduced stitch length, yields the lowest GSM due to its different structure but exhibits some instability in both the wale and course directions and lacks spirality. Despite having the lowest GSM among the structures, the plaited structure offers the highest bursting strength.

In the case of the interlock mesh structure, a longer stitch length is maintained compared to others due to the incorporation of tuck stitches, leading to an increase in fabric GSM and resulting in relatively higher instability in the wale direction, increased spirality, and relatively lower bursting strength compared to other structures.

The functional performance of the developed samples is evaluated using standard testing methods in the greige form. The testing includes assessing the relative hand feel, moisture management properties, air permeability, and stretch properties, all of which significantly impact the fabric's performance and feel. The variation in values observed is generally attributed to the knitting parameters depending on the type of structure.

While these properties can also be enhanced at the finishing stage by applying desirable finishes in optimum quantity, this work focuses on analyzing and comparing the overall functionalities to evaluate the effect of structural and parametric changes.

### *3.3. Evaluation And Comparison Of Comfort Characteristics Of Knitted Samples*

#### *3.3.1 Relative hand value*

The property of relative hand value plays a vital role in providing the fabric feel and determining the comfort level of the wearer. It can be observed from the results, as shown in Fig. 1, that the structure having higher GSM tends to have relatively higher resilience, smoothness, and drape as compared to other structures. Similarly, the wrinkle recovery rate of the plaited structure is highest as compared to others mainly due to the lower GSM and compact structure. While the interlock mesh structure has relatively higher softness mainly due to the lower stitch length. From the observation, it can be said that the structures with lower GSM would tend to give more softness but relatively lower drape and resilience results depending upon the type of structure.

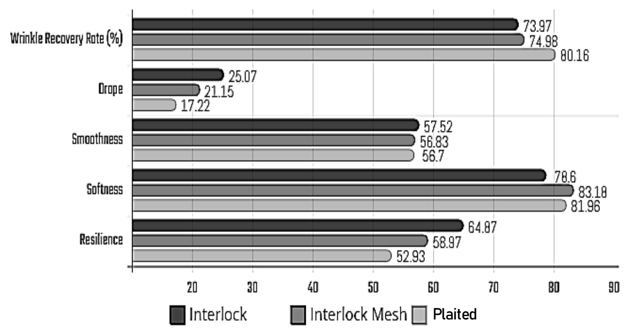



**Fig. 1.** Comparison Of Relative Hand Value Of Developed Weft Knitted Structures

#### *3.3.2 Liquid moisture management properties*

The overall moisture management capacity (OMMC) is also one of the core elements of clothing comfort. It is apparent from Fig. 2 that the interlock mesh has the highest moisture management properties due to the presence of tuck stitches in the structure while the plaited structure offers the lowest of all when developed with the above-discussed parameters. It can be said that the addition of tuck stitches in the structure would enhance the OMMC and that fabric can be used as a next-to-skin fabric for the swift transfer of sweat from the body to the fabric. The interlock structure provides good moisture management properties due to the higher contact area of the fabric with the body, decrement of stitch length, and compact structure which directly enhances the wickability of the fabric with the higher wicking rate.

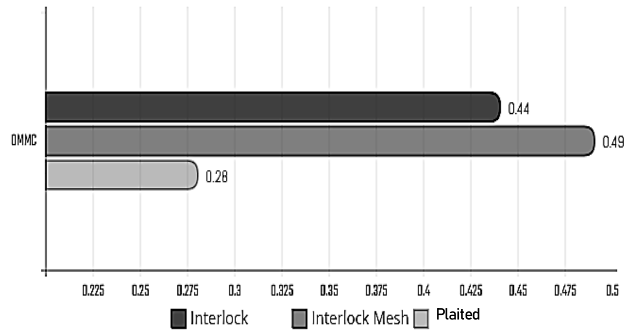



**Fig. 2.** Comparison Of OMMC Values Of Developed Weft Knitted Structures

#### *3.3.3 Air permeability*

Air permeability is also one of the major requirements which influences the thermo-physiological comfort of the wearer and is known as the extent to which the fabric permits air to flow through it. It is apparent from the results, shown in Fig. 3, that the interlock mesh structure offers the highest air permeability because the incorporation of a tuck stitch into the fabric would ultimately make the fabric much more porous and open. While the interlock fabric has the lowest air permeability due to the compact structure. The plaited structure, despite the highest stitch density and lowest stitch length and GSM, has reasonably acceptable air permeability values due to the nature of the structure which allows air to pass through it.

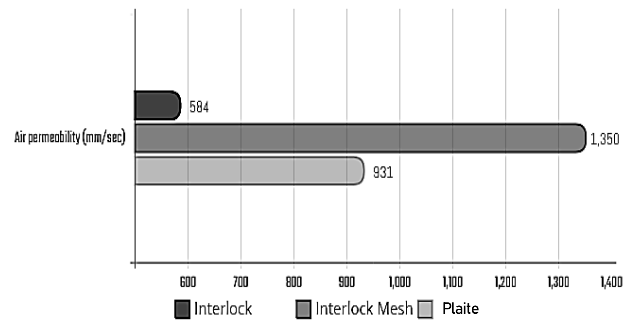



**Fig. 3.** Comparison Of Air Permeability Values Of Developed Weft Knitted Structures

The observed change is mainly due to the inherent characteristics of the fabric.

*3.3.4 Stretch and growth properties*

The ideal sportswear should have adequate stretch, as per the need and intensity of the sport, and lower growth values. The results shown in Fig. 4 and Fig. 5 confirm that the change of structure can also influence the stretch and growth properties of the fabric. The plaited fabric has the lowest stretch as compared to the other structures and has higher growth values as well, mainly due to the lower stitch length as compared to others. Both the interlock and interlock mesh fabrics have almost similar stretch and lowest growth values. The observed change is mainly due to the inherent characteristics of the fabric.

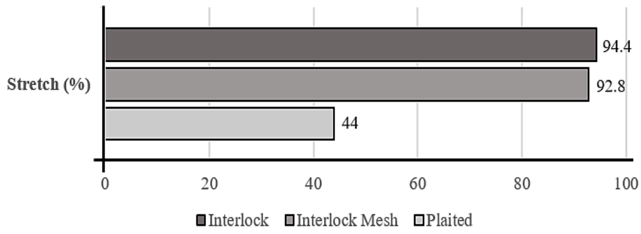



**Fig. 4.** Comparison Of Stretch Values Of Developed Weft Knitted Structures

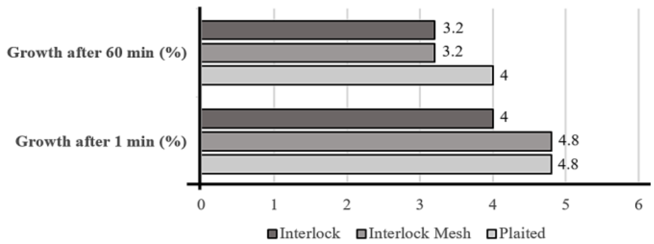



**Fig. 5.** Comparison Of Growth Values Of Developed Weft Knitted Structures

## 4. Conclusion

The research indicates that the selection of knitting parameters and structures has a significant impact on the overall performance of sportswear. When the stitch length is increased, it results in lower GSM, improved air permeability, increased softness, better moisture management, and enhanced stretch and growth properties. However, it also leads to reduced dimensional stability, lower bursting strength, decreased drape, and a lower wrinkle recovery rate. In simple terms, structures with higher stitch lengths are not suitable for sportswear due to their instability in dimension and growth properties.

Similarly, plaited fabric offers improved bursting strength despite having the lowest GSM and a lower stitch length, but it lacks in providing good moisture management, dimensional stability, and stretch and growth. On the other hand, interlock fabric offers exceptional dimensional stability along with good relative hand value, moisture management, stretch and growth, spirality, and bursting strength, but it lacks in providing good air permeability values due to the compactness of the structure.

The incorporation of various structural techniques, such as interlock and interlock mesh, during the garment manufacturing process is advisable to enhance the overall functionality of sportswear. This strategic approach ensures that the improvement of one functional characteristic does not detract from others, thereby contributing to greater comfort for athletes.

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