Suitability of Bi-Layer Knitted Fabric for Sportswear Application

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***Abstract*--Sportswear fabric need to provide a comfortable environment for the wearer and consequently able to handle moisture vapour and sweat produced by the body during strenuous activity in sports to feel good. Modern sportswear's are mostly made from wicking fibers like polyester and polypropylene. They provide only good strength and wicking of sweat but are not good at absorption and comfort point of view whereas the hydrophilic fibers like cotton and viscose are recognized as having excellent absorbency and breathability.**

The objective of this work is to use combination of wicking and hydrophilic fibers to enhance the moisture handling and other properties of sportswear fabrics while at the same time improving the aesthetics. To fulfill requirements of sportswear with proper comfort, bi-layer knitted fabrics are manufactured and tested for different properties. On the basis of testing results its suitability for the sportswear application is decided.

Keywords: Bi-layer knitted fabric, Hydrophilic fiber, Sportswear, Wicking fiber

1. INTRODUCTION

Active sportswear fabrics are the fabrics which are used in that sports where lot of sweat generation occurs and clothing is an important issue for athletes and for those who practice sports just for fitness in their leisure time. During the strenuous activity in sports, human body perspires in two forms insensible and sensible perspiration and to be in comfortable state, the sportswear which will be worn should be allow both the type of perspiration to transmit perspiration from the skin to the outer environment [1]. Moisture produces during the sports present on surface of fabric and which cling to human skin can often produce uncomfortable sensation and it may produce skin problem like itching and finally it affects the performance of the wearer. Hence moisture transport in textiles fabrics is one of the critical factors affecting physiological comfort [2]. Thus this sportswear must have ability to transport moisture away from the skin to the fabric surface for evaporation.

In this work attempt has been done to made bi-layer weft knitted fabric which can able to transfer moisture from skin to the environment. This bi-layer knitted fabric made on circular double jersey knitting machine with interlock structure. This bi-layer knitted fabric having two layers of yarn, inner layer of fabric is made up of wicking fibers i.e. polyester and polypropylene which wicks away the perspiration from skin and transfer it to the outer layer which made up of evaporating fibers i.e. cotton and viscose which evaporates perspiration into atmosphere while doing so proper moisture management is done.

2.MATERIALS AND METHODS

2.1 Material

Polyester (fully drawn yarn): 240 Denier with 48 filaments
Polypropylene (fully drawn yarn): 240 Denier with 48 filaments
Cotton: 30^s Ne
Viscose: 30^s Ne
were used for the manufacturing of Bi-layer knitted fabric.

2.2 Method

2.2.1 Texturising of filament yarn

The main aim behind the texturising of filament yarn is that, we cannot use synthetic material against skin directly as it may cause irritation of skin to the wearer or it may be allergic to the skin. Texturising of yarn was done on Air-jet Texturising machine (model Himson HJT-1000) with overfeed of 20% for both filament yarn. The texturising speed of 300m/min with the stabilizing heat temperature of 180ºC for polyester and 100^0C for polypropylene as polypropylene having lower melting point as compared to polyester. The air pressure to jet at 8KgF/sq.cm was maintained. The Textured Polyester and Polypropylene were used for the manufacturing of bi-layer knitted fabrics.

2.2.2 Fabric production

Textured filament yarn i.e. Polyester, Polypropylene and spun yarn i.e. Cotton and Viscose were used to manufacture the Bi-layer knitted fabrics. There are four samples made with different combination of yarn viz. Polyester-cotton, Polyester-viscose, Polypropylene-cotton, Polypropylene-viscose where filament yarn produces inner layer and spun yarn produces outer layer. The Bi-layer knitted fabric samples are shown in following figure

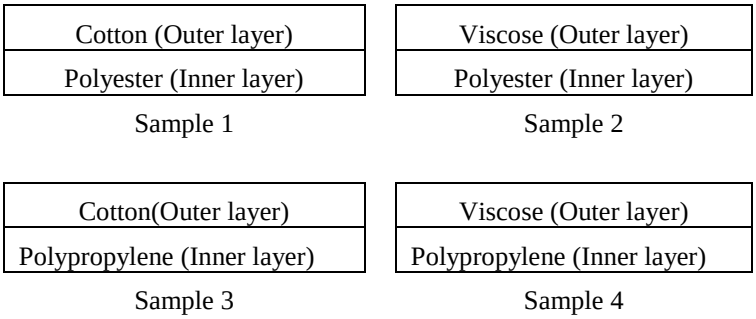


Fig2.1 Bi-layer knitted fabric samples

Manufacturing of Bi-layer knitted fabrics were done on Pai-lung Circular knitting machine with gauge of 24 and diameter 30 inches. The course & wales per inch of Bi-layer knitted fabrics were 46 and 28 respectively and the loop length was 3.5mm. All parameters were same for all four samples

2.2.3 Antimicrobial finishing of Bi-layer knitted fabrics

After manufacturing of bi-layer knitted fabrics, these fabrics were given antimicrobial finishing. Antimicrobial finishing of Bi-layer knitted fabrics were done with YOGFIN SANT of Yogeshwar chemicals. Finishing of fabric is done with direct application method i.e. dipping method with 40GPL, after application samples were dried for 12 hrs and curing of fabrics was done at 120^0C for 60 sec.

2.3 Testing

The following tests were carried out for grey and finished Bi-layer knitted fabrics.

- **Air permeability**: - Using Air-Permeability tester as per the standard ASTM D737.
- **Wicking height:** - As per German standard DIN 53924.
- **Moisture vapour transmission rate:** - Using the cup method according to the ASTME96-66 standard.
- **Drop absorbency:** - As per AATCC test method TS-018.
- **Thermal insulation Value (Thermolabo II)**
- **Strechability:-** As per ASTM D2594-04
- **Antimicrobial Assessment:-** As per AATCC-147

3. RESULT AND DISCUSSION

The following constructional details of gray and finished bi-layer knitted fabrics were observed.

Table3.1 Characteristics of Gray Bi-layer knitted fabrics

Samples (Gray)	C.P.I.	W.P.I.	Thickness(mm)	G.S.M.	Tightness Factor(cm)
Polyester-cotton	46	28	1.12	240	14.23
Polyester-viscose	46	28	1.13	238	14.23
Polypropylene-cotton	46	28	1.15	236	14.23
Polypropylene-viscose	46	28	1.14	234	14.23

TABLE3.2 CHARACTERISTICS OF FINISHED BI-LAYER KNITTED FABRICS

Samples (Finished)	C.P.I.	W.P.I.	Thickness(mm)	G.S.M.	Tightness Factor(cm)
Polyester-cotton	50	32	1.13	270.1	14.23
Polyester-viscose	50	32	1.14	268.2	14.23
Polypropylene-cotton	50	32	1.19	265.7	14.23
Polypropylene-viscose	50	32	1.15	263	14.23

From the above tables it is observed that, there is increase in C.P.I., W.P.I., thickness, G.S.M. and tightness factor of finished fabrics. Increase in C.P.I. and W.P.I. is due to finishing and curing of fabrics causes to shrinkage of fabrics. Increase in thickness and G.S.M. of finished fabric it is due to the finish applied to the fabric as it gets absorbed by the cellulosic yarns present in the structure of the fabric. Cotton and viscose, having greater percentage of cellulose contain which gives more absorption power to the yarn. Finish used also having strong adhesion capacity which ultimately increases the G.S.M. and thickness of the fabric.

3.1 Air permeability

The air permeability of fabric play very important role as per the comfort point view. The fabric having high air permeability gives better comfort to the wearer by maintaining the proper body temperature up to the 33.3^0c. The active sportswear also required good air permeability.

The air permeability of grey and finished bi-layer knitted fabric is shown below.

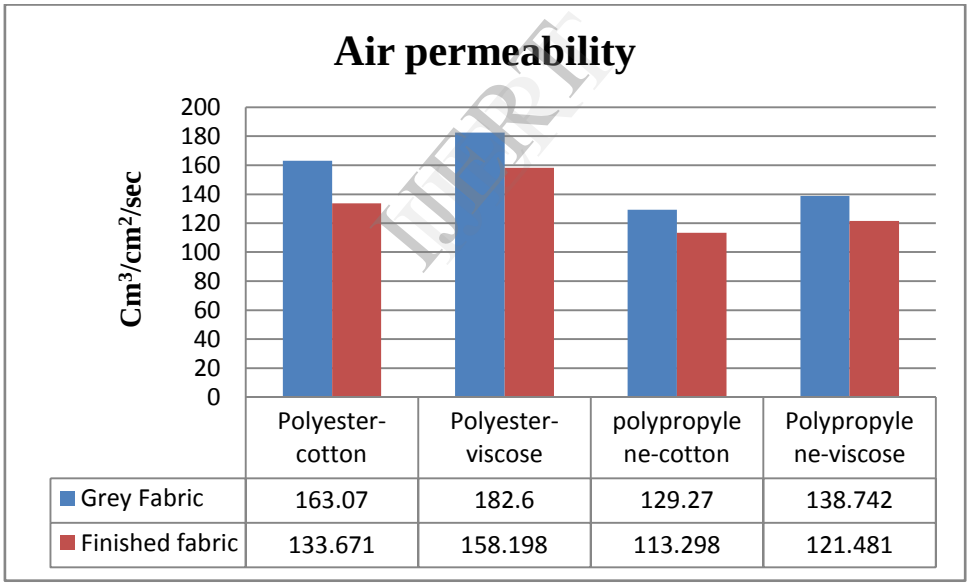


Fig3.1 Air permeability of Grey and finished Bi-layer knitted fabrics

From the above figure3.1 it is observed that grey bi-layer knitted fabric shows higher air permeability as compared to the antimicrobial finished bi-layer knitted fabric. In both gray and finished condition polyester-viscose bi-layer knitted fabric shows the higher air permeability as compared to the other bi-layer knitted fabrics. When finishing of bi-layer knitted fabric is done, the porosity of the bi-layer knitted fabrics get reduced because of reduction in space within the knitted loops and it obstructs the air flow within the fabric structure. Since a good air permeability means a better interaction with the atmosphere which provide better comfort to the wearer. Statistical analysis shows there is significant difference for air permeability of gray and finished bi-layer knitted fabric within and between the samples, two-way analysis of variation statistical tool is used for the analysis.

3.2 Wicking behavior of bi-layer knitted fabric

Wicking height test determines the liquid transporting ability of a fabric. Faster the rate of wicking, better will be the sweat transporting ability and more comfortable will be the fabric.

This is because as soon as a drop of sweat will form on the skin, the fabric will transfer it through capillary action and excess sweat would not standing on the skin.

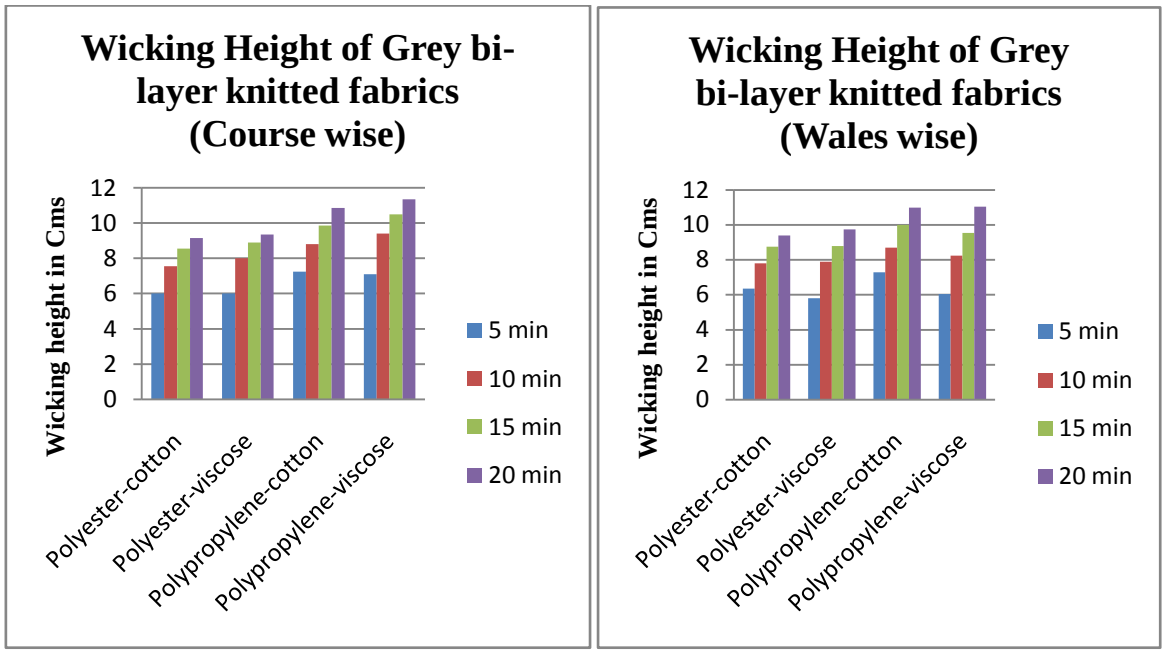


Fig3.2 Wicking Behavior of Grey Bi-layer knitted fabrics

The result of wicking test of grey fabric are shown in fig3.2. From results it is found that polypropylene-viscose bi-layer knitted fabrics shows the higher wicking as compared to the other fabric samples. This is due to the polypropylene having higher wicking property as compared to the other yarns.

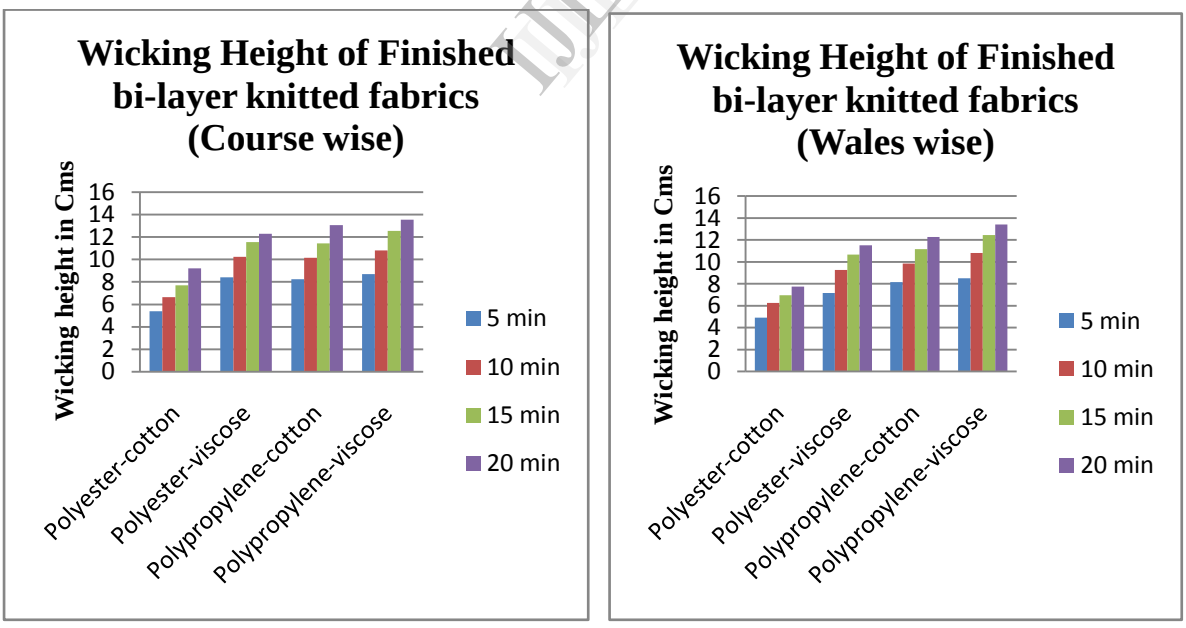


Fig3.3 Wicking Behavior of Finished Bi-layer knitted fabrics

Fig3.3 shows that there is increase in wickability of all bi-layer knitted fabric after finishing, finishing causes to pressure difference between the fabric and the yarns present in the fabric structure. It increases the pressure in the yarns which ultimately increase the wickability of the bi-layer knitted fabrics. The statistical analysis also shows that there is significant difference found for wickability of grey and finished bi-layer knitted fabrics and also within the samples.

3.3 Moisture vapour Transfer rate

In sporting activity whenever the body temperature increases due the heavy activities in sports body generates the sweat, sweating occurs to cool down the body. In this sweating moisture transfer occur in both state i.e. vapour state and liquid state also. To feel the wearer comfortable this sweat in both state must be transfer away from the skin through the fabric structure. Thus the ability of the fabric to transfer water vapour to atmosphere, is of prime importance. Higher the water vapour permeability of the fabric, better the fabric is from physical point of view. To measure the moisture vapour transfer through bi-layer knitted fabric the cup method was used, as per the ASTM E96-66 Standard.

The moisture vapour transfer test results are shown in fig3.4 and they reveals that there is reduction in moisture vapour permeability of finished fabric. Within the finished fabric Polypropylene-cotton shows the highest moisture vapour permeability, as this is having higher thickness as compared to other combination. The other combination having more compact structure than polypropylene-cotton hence this combination shows higher moisture vapour permeability.

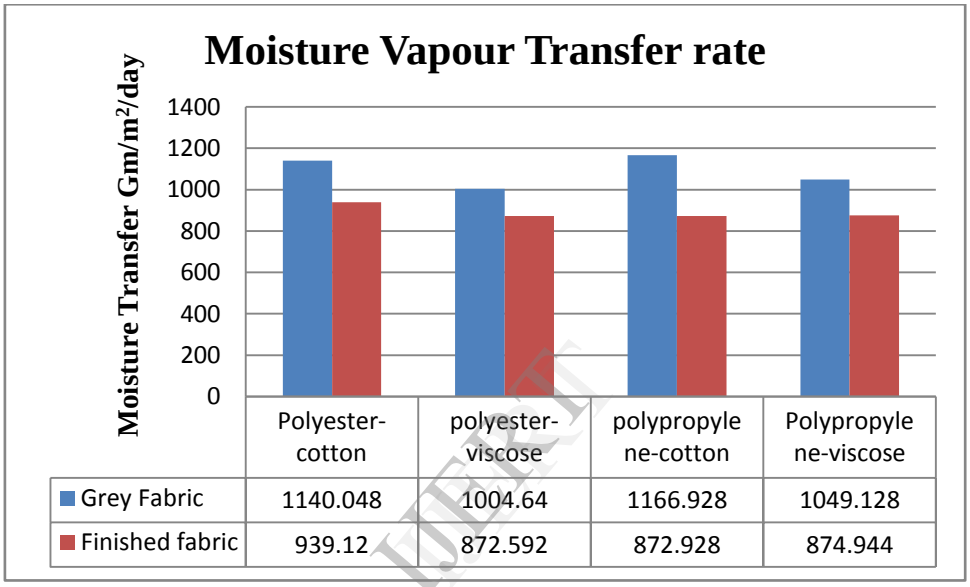


Fig3.4 Moisture vapour permeability of Grey and finished bi-layer knitted fabrics

The reduction in moisture vapour permeability is due to finishing of bi-layer knitted fabrics, finishing causes to decrease the spaces between the loops in fabric structure which ultimately reduce moisture vapour permeability of bi-layer knitted fabric. Statistical analysis also shows that there is significant difference between the moisture vapour permeability of grey and finished bi-layer knitted fabrics and within the samples also.

3.4 Drop Absorbency Test

The time taken for a drop of liquid to get completely absorbed by a fabric is indicative of its ability to absorb liquid sweat from the body surface. Lesser the time that the fabric takes to completely soak up a drop of liquid, faster will be its response time in providing comfort to the wearer in heavy activities. Following figure shows the drop absorbency test results. It is observed from fig3.4 that the finished fabrics shows higher absorbency as compared to the grey fabrics. The grey fabrics contain viscose also shows very good drop absorbency in both states. This may be due the absorption property of viscose which is higher than that of cotton.

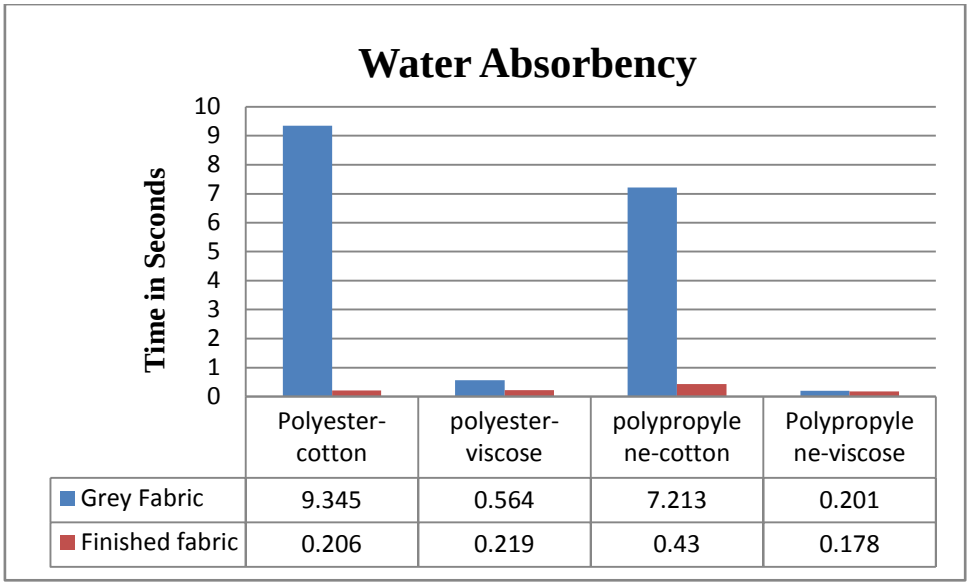


Fig3.5 Drop Absorbency Test of Grey and finished bi-layer knitted fabrics

Finishing causes to increase the surface tension of bi-layer knitted fabrics which is responsible to increase in absorbency of fabrics. All the finished fabric samples having drop absorbency time less than 1 second. Statistical analysis also shows that there is significant difference between water absorbency of grey and finished bi-layer knitted fabrics.

3.5 Thermal Insulation value

The thermal insulation value is again important parameter from the sportswear point of view. Due to heavy sweating of body lot of moisture accumulated on the skin and when it get dried there may be chances that body temperature get decrease very rapidly which causes hypothermia to the wearer, hence the sportswear must also provide proper thermal insulation in cold conditions also.

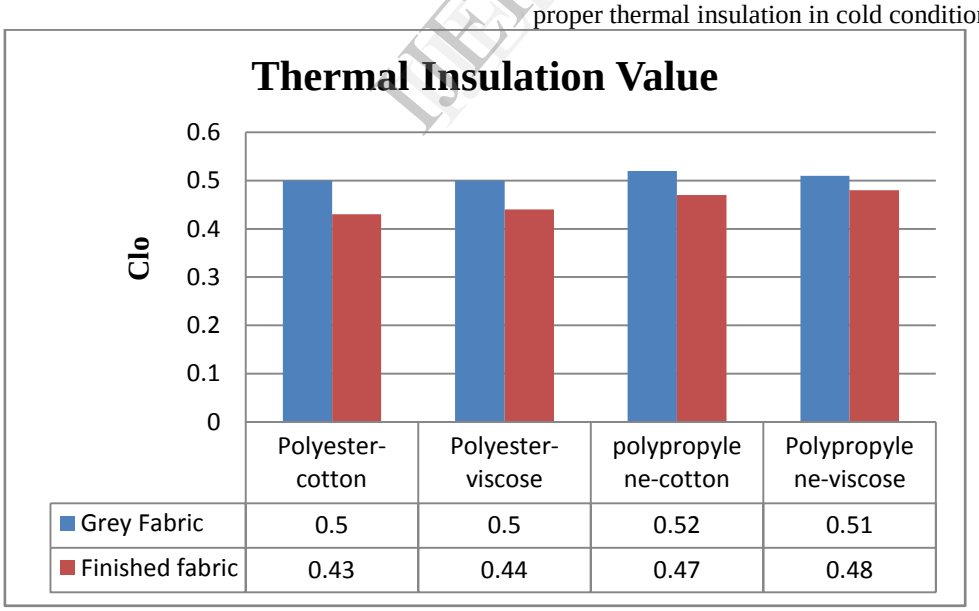


Fig3.6 Thermal Insulation Value of Grey and finished bi-layer knitted fabrics

Above fig3.6 shows the result of thermal insulation value for different bi-layer knitted fabrics. The test results of thermal insulation value of bi-layer knitted fabrics shows that the polypropylene-cotton has highest thermal insulation value in both grey and finished stage and followed by polypropylene-viscose and other bi-layer knitted fabric also shows good thermal conductivity. There are two reason behind this, first one is thickness of Polypropylene-viscose and Polypropylene-cotton is higher than the other bi-layer knitted fabrics. If higher is the thickness then greater is the air trapped in the loop structure which gives better thermal insulation value and second one is that the polypropylene fiber itself is having low thermal conductivity.

3.6 Strechability Testing

Strechability is also very important in sportswear because higher the strechability given by the fabric more freedom given to the body of wearer during the sporting activity.

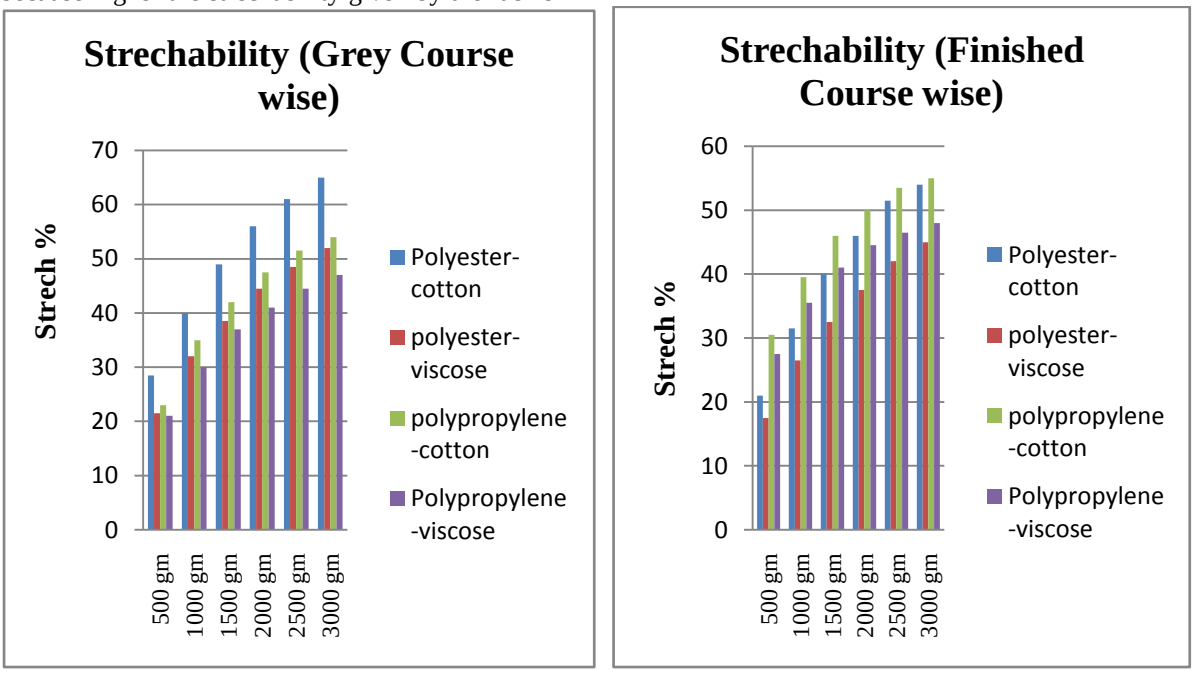


Fig3.7 Strechability of Grey and finished bi-layer knitted fabrics course wise

Fig3.7 shows the strechability test result of both grey and finished bi-layer knitted fabrics course wise. From the test results it is found that in finished state polypropylene-cotton bi-layer knitted fabric shows higher strechability as compared to grey state.

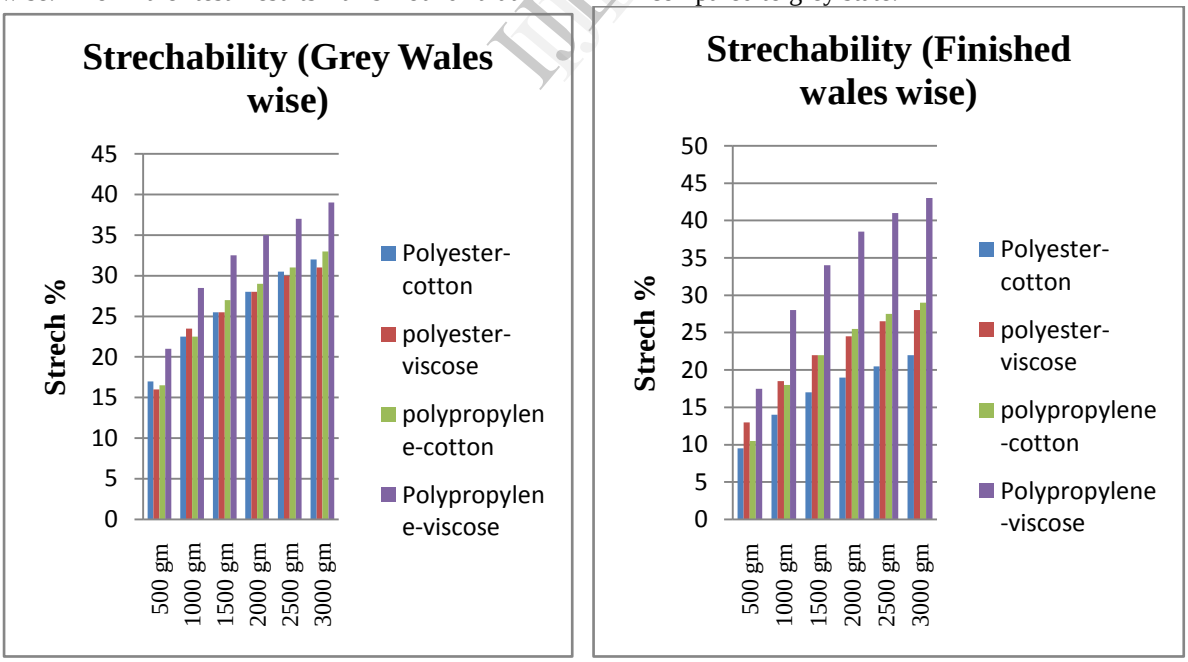
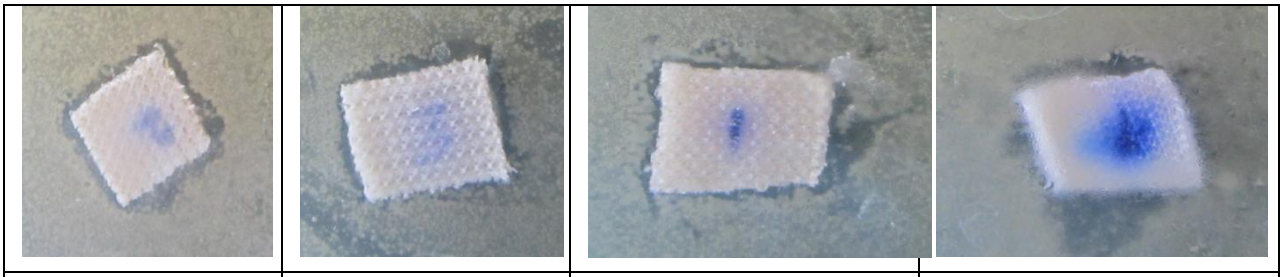


Fig3.8 Strechability of Grey and finished bi-layer knitted fabrics Wales wise

Fig3.8 shows the strechability test results of both grey and finished bi-layer knitted fabrics wales wise. From figure we can see that polypropylene-viscose bi-layer knitted fabric shows higher strechability as compared to the other bi-layer knitted fabrics wales wise. Both grey and finished bi-layer knitted fabrics shows less strechability in wale direction than course. All bi-layer knitted fabrics shows poor elastic recovery because knitted fabric has natural tendency that they are not able to recover as like woven fabrics.

3.7 Antimicrobial Assessment

Sweating in sports may start the microbial activity and which is harmful to the skin and to avoid such microbial activity these bi-layer knitted fabrics are finished with antimicrobial finishing. Antimicrobial agar diffusion assessment is done according to AATCC-147 and the zone of inhibition for the bacteria is shown in millimeters



Polyester-cotton	**Polyester-viscose**	**Polypropylene-cotton**	**Polypropylene-viscose**

Fig3.9 Antimicrobial Assessment of finished bi-layer knitted fabrics

Table3.3 Zone of inhibition for finished Bi-layer knitted fabrics

Samples	Bacteria	Zone of Inhibition (mm)
Polyester-cotton	**Staphylococcus Aureaus**	**20**
Polyester-viscose	**Staphylococcus Aureaus**	**21**
Polypropylene-cotton	**Staphylococcus Aureaus**	**20.33**
Polypropylene-viscose	**Staphylococcus Aureaus**	**24.33**

Samples are placed in agar diffusion and placed in incubator for 24 hrs at 33.2^{o}c. After 24 hrs the samples are assessed for the antimicrobial activity. On the basis of antimicrobial assessment we can see that Polypropylene-viscose finished sample shows more inhibition zone than the other bi-layer knitted fabrics.

CONCLUSION

From this study following conclusion can be drawn

- Bi-layer fabrics are comfortable in moisture vapour transmission and absorption, both are benefited due to hydrophobic and hydrophilic fibers.
- Antimicrobial finish to the bi-layer knitted fabric improves some of the properties like water absorbency, wicking and strechability while air permeability, moisture vapour transfer and thermal insulation value are affected.
- Polypropylene-viscose bi-layer knitted fabric is found better from the point of view wicking behavior, drop absorbency and strechability property.
- Air permeability of Polyester-viscose bi-layer knitted fabric found better.
- Thermal properties of Polypropylene-cotton bi-layer knitted fabric is found better.
- Overall Polypropylene-viscose bi-layer knitted fabric found better suitable for the sportswear application.

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