4.RESULTS & DISCUSSION

4. Results and Discussion

For a given yarn composition, increase in loop length causes a decrease in fabric weight, fabric thickness and the number of courses and wales per unit length. This is in accordance with established understanding of knitted fabric behaviour.

4.1. Porosity

Porosity is one of the key properties influencing thermo-physiological comfort of the wearer[157].

4.1.1 Cotton knitted fabrics

The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 4.1 and 4.2). They show that the mass per square meter of single jersey fabrics was in the range from 162.60 g/m^2 to 104.93 g/m^2. The pique fabrics are characterized by a surface mass slightly higher than single jersey in the range from 176.98 g/m^2 to 105.99 g/m^2. Thickness increases with the fabric tightness for both structures, but not linearly.

Out of two fabric structures the pique variety shows more porosity values and the two variants of pique knitted fabrics made of 20Tex yarn with stitch length 3.1mm and 3.3mm have high porosity values. The thickness and mass per square meter of the fabrics reduces as the yarn becomes finer, which is quite obvious. For single jersey knitted fabrics the mass per square meter of the fabrics reduced from 162.60 g/m^2 to 104.93 g/m^2 i.e. by 35.47% (Table 4.1) and for pique knitted fabrics the mass per square meter of the fabrics reduced from 176.98 g/m^2 to 105.99 g/m^2 i.e. by 40.11% (Table 4.2). However, the corresponding reduction in terms of fabric thickness was from 0.633 mm to 0.587 mm, i.e., by 7.27% for single jersey knitted fabrics and from 0.833 mm to 0.628 mm, i.e., by 21.61% for pique knitted fabrics. This analysis bolsters the fact that when yarn is becoming finer, mass per square meter is reducing at a faster rate as compared to that of fabric thickness. Therefore, the porosity of the fabric increases. (Figure 4.1) shows the results of porosity of single jersey and pique fabrics.

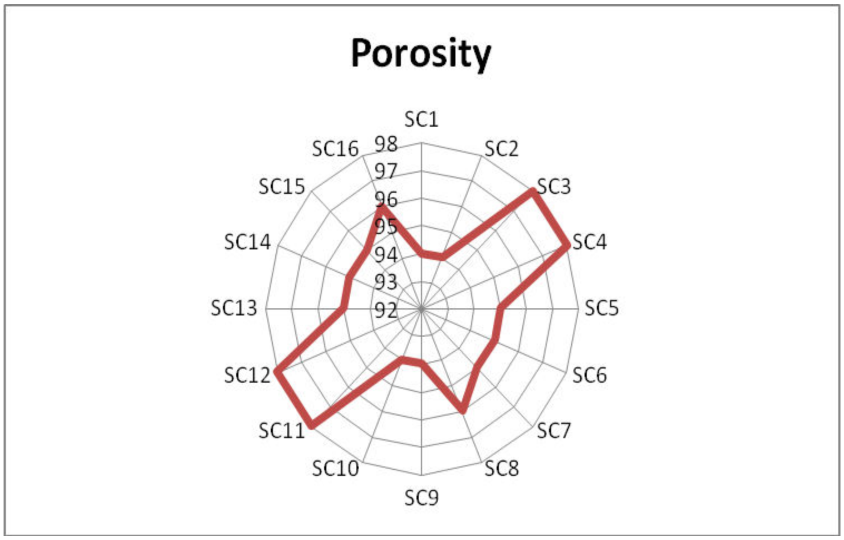

Figure 4.1: The values of porosity for different variants of single jersey and pique cotton knitted fabrics: denotations as in Table 3.8.

4.1.2 Viscose Knitted Fabrics

The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 4.3 and 4.4). It shows that thickness increases with the fabric tightness for both structures, but not linearly. Out of two fabric structures the pique variety shows more porosity values and the two variants of pique knitted fabrics made of 15Tex yarn with stitch length 3.1 and 3.3 have high porosity values. The thickness and mass per square meter of the fabrics reduces as the yarn becomes finer, which is quite obvious. For single jersey knitted fabrics the mass per square meter of the fabrics reduced from 145.85 g/m^2 to 91.57 g/m^2i.e. by 37.21% (Table 4.3) and for pique knitted fabrics the mass per square meter of the fabrics reduced from 160.6 g/m^2 to 85.40 g/m^2 i.e. by 46.82% (Table 4.4). However, the corresponding reduction in terms of fabric thickness was from 0.574 mm to 0.448 mm, i.e., by 22% for single jersey knitted fabrics and from 0.740 mm to 0.575 mm, i.e., by 22.3 % for pique knitted fabrics. This analysis bolsters the fact that when yarn is becoming finer, mass per square meter is reducing at a faster rate as compared to that of fabric thickness. Therefore, the porosity of the fabric increases[82]. (Figure 4.2) shows the results of porosity of single jersey and pique fabrics.

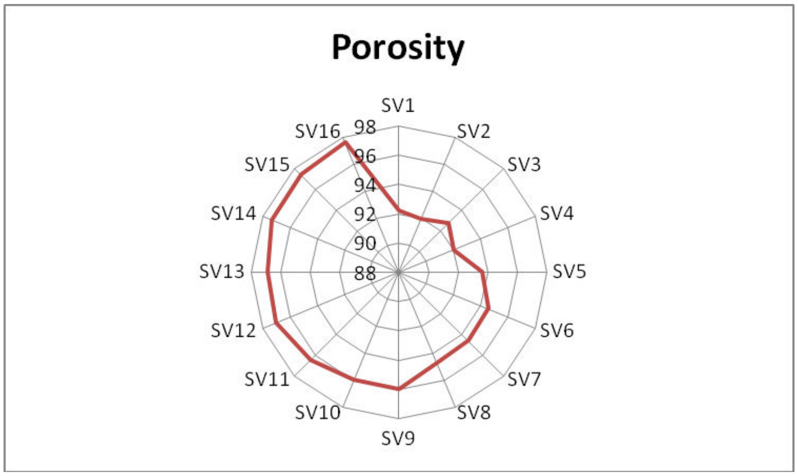

Figure 4.2: The values of porosity for different variants of single jersey and pique viscose knitted fabrics: denotations as in (Table 3.9)

4.1.3 Modal Knitted fabrics

The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 4.5 and 4.6). It shows that thickness increases with the fabric tightness for both structures, but not linearly. Out of two fabric structures the pique variety shows more porosity values and the three variants of pique knitted fabrics made of 15Tex yarn with stitch length 2.9, 3.1 and 3.3mm have high porosity values. The thickness and mass per square meter of the fabrics reduces as the yarn becomes finer, which is quite obvious. For single jersey knitted fabrics the mass per square meter of the fabrics reduced from 141.95 g/m^2 to 78.74 g/m^{2}i.e. by 44.53% (Table 4.5) and for pique knitted fabrics the mass per square meter of the fabrics reduced from 151.16 g/m^2 to 88.31 g/m^2 i.e. by 41.58% (Table 4.6). However, the corresponding reduction in terms of fabric thickness was from 0.47 mm to 0.389 mm, i.e., by17.23% for single jersey knitted fabrics and from 0.658 mm to 0.557 mm, i.e., by 6.1 % for pique knitted fabrics. This analysis bolsters the fact that when yarn is becoming finer, mass per square meter is reducing at a faster rate as compared to that of fabric thickness. Therefore, the porosity of the fabric increases[82].

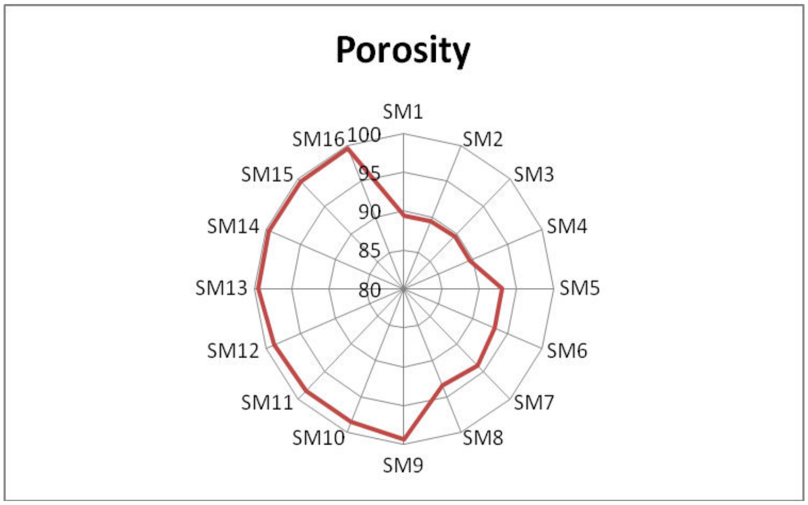

Figure 4.3: The values of porosity for different variants of single jersey and pique modal knitted fabrics: denotations as in (Table3.10).

4.1.4 Excel Knitted fabrics

The basic dimensional properties of both types of knitted fabrics are enumerated in (Table 4.7 and 4.8). It shows that thickness increases with the fabric tightness for both structures, but not linearly. Out of two fabric structures the pique variety shows more porosity values and the two variants of pique knitted fabrics made of 15Tex yarn with stitch length 3.1 and 3.3 have high porosity values. The thickness and mass per square meter of the fabrics reduces as the yarn becomes finer, which is quite obvious. For single jersey knitted fabrics the mass per square meter of the fabrics reduced from 136.78 g/m^2 to 76.45 g/m^2i.e. by 44.11% (Table 4.7) and for pique knitted fabrics the mass per square meter of the fabrics reduced from 148.16 g/m^2 to 82.06 g/m^2 i.e. by 44.61% (Table 4.8). However, the corresponding reduction in terms of fabric thickness was from 0.5729 mm to 0.484 mm, i.e., by 15.52% for single jersey knitted fabrics and from 0.715 mm to 0.602 mm, i.e., by 15.80 % for pique knitted fabrics. This analysis bolsters the fact that when yarn is becoming finer, mass per square meter is reducing at a faster rate as compared to that of fabric thickness. Therefore, the porosity of the fabric increases[82].

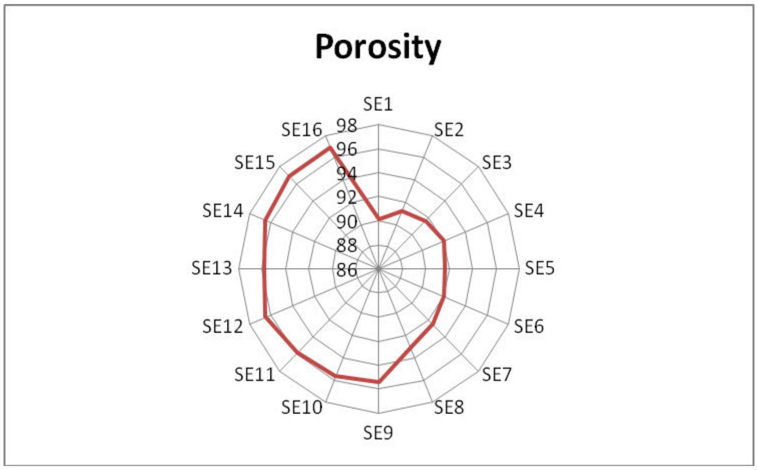

Figure 4.4: The values of porosity for different variants of single jersey and pique excel knitted fabrics: denotations as in (Table3.11).

The porosity of knitted single jersey structure is between 85% and 94.7% and that of knitted pique structure is between 94% and 99.6 %. The best regression equation for porosity is given in Table 4.9.

Table 4.9: The regression equation between porosity and fabric parameters

Porosity = 102 - 0.931 Tightness factor, k - 0.0455 Stitch density + 0.720 Yarn Count + 2.53 Thickness

Table 4.10 shows the regression analysis for knitted fabrics. Statistical evaluation showed that together, tightness factor, stitch density, yarn count and thickness accounted for 79.2 % of the variance of the porosity. As per regression analysis, it was found that the equation obtained is a good equation as the R^2 value is 79.2% and all these parameters gives p values of 0.000 and are significant. Porosity is affected by yarn number or yarn count number[160]. The increase in yarn number influences porosity by decreasing the space of the pores. In fact, by increasing the yarn number, the volume of pores decrease and the yarns are flattened on the surface. When the thickness increases, the loop length decreases enormously and the pores volume consequently increases.

4.2 Air permeability

To address a mathematical relationship between the thickness of fabric, tightness factor, porosity of the knitted samples and air permeability, a linear regression equation was used and apllied on the air permeability values.

4.2.1 Cotton knitted fabrics

The cotton is thin, the fibres are confined to a thin plate, the volume occupied by the fibres is small, there is little air space between the fibres and the air permeability is consequently low compared to other fibres considered. (Figure 4.5) present the research results of air permeability. The range of values obtained is significant, ranging from 83.3 to 412.5 $cm^3/cm^2/s$, and the highest values are found with piques knitted fabrics. The porosity determines the variation of air permeability. Fabrics having low porosity values shows the lowest value for air permeability. Previous research showed that air permeability of fabrics was mainly affected by the porosity of the fabrics[98]. Increasing fabric tightness by machine setting decreased the air permeability in both fabrics. Coarser yarn produce fabrics with more intra-yarn air spaces but with fewer inter-yarn air spaces resulting in lower air permeability in both the single jersey as well as pique knitted fabrics. Air permeability increases for the fabrics made from finer yarns as expected (Table 4.1 and 4.2). The lower thickness and mass per square meter also facilitate the passage of air through the fabric. The lower hairiness of the finer yarn may be another contributing factor towards the better air permeability. As the loop length increases, the course spacing and wale spacing increase as well because of which the fabric surface becomes loose i.e. it increases the size of pores through which the airflow permeates, therefore the air permeability value also increases.

A close look at the (Table 4.1 and 4.2) reveals that as for the same yarn linear density the thickness was increased by increasing the fabric tightness. Thicker yarns increased thickness in both fabrics. It can be seen that the thickness was higher for pique fabrics.

The barrierability of knitted fabrics to the air as fabrics thickness function, is presented in (Figure 4.6) for single jersey knitted fabrics, had a negative correlation for 15Tex, where the correlation factor is 0.76 and for 20Tex , the correlation factor is 0.89 which means that the regression

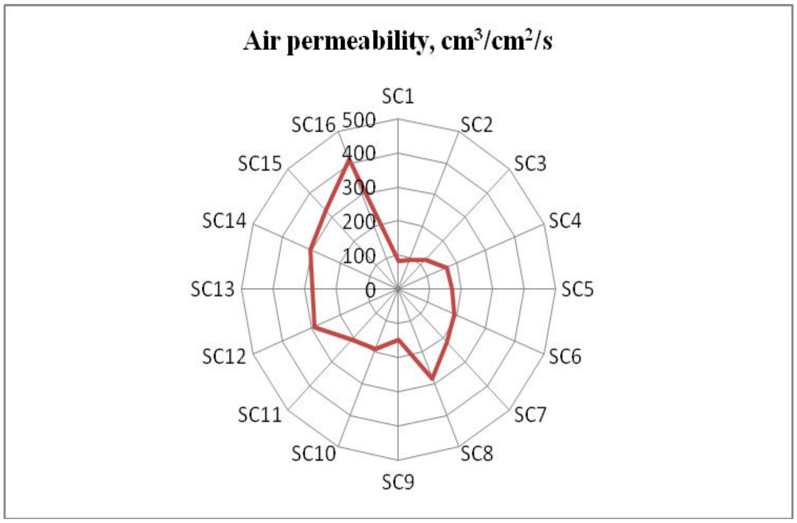

Figure 4.5: Air permeability of different variants of single jersey and pique cotton knitted fabrics: denotations as in Table 3.8.

equation is reliable for prediction of the air permeability in fabric thickness range using single jersey structure. The reason may be attributed to the fact that the increase in bulkiness of yarn structure increases the availability of air passage within as well as in between yarns, leading to increase in fabric air permeability in case of 20Tex. For the pique fabrics (Figure 4.7) for 15Tex the correlation factor is 0.99 which is higher and shows the influence of fabric structure on the air permeability value and for 20Tex the correlation factor is too low 0.42.

This means that the regression equation is reliable more for prediction of the air permeability in fabric thickness range using pique fabric knitted with 15Tex yarn. This was expected to some extent as air has to travel a more complex path and faces higher frictional forces during its passage through the fabric.

Air permeability is inversely related with fabric tightness; it decreased with increase of compactness and decrease of air space[157]. It must be emphasized that tightness factor correlates more with air permeability than knitted fabric thickness. This is documented by the test results and statistical analysis presented in (Figure 4.8 and 4.9), where the estimated value of linear correlation index between air permeability and the tightness factor of knitted fabric is R = 0.95 for

15Tex and 0.96 for 20Tex for single jersey knitted fabrics and 0.95 for both counts `for the pique fabrics.

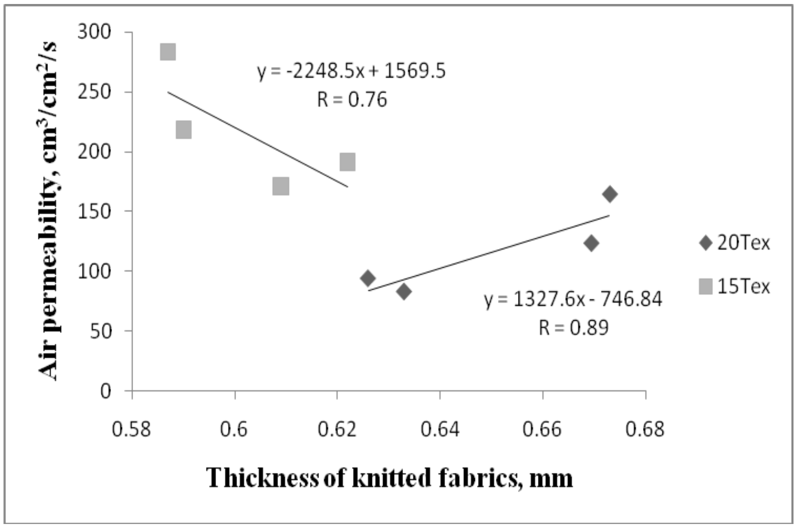

Figure 4.6: Air permeability in function of thickness of single jersey cotton knitted fabrics.

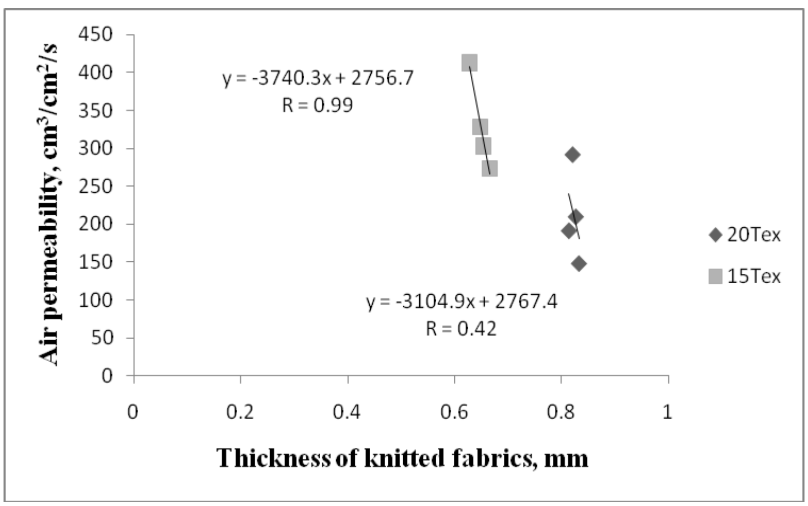

Figure 4.7: Air permeability in function of thickness of pique knitted cotton fabrics.

As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and structures.

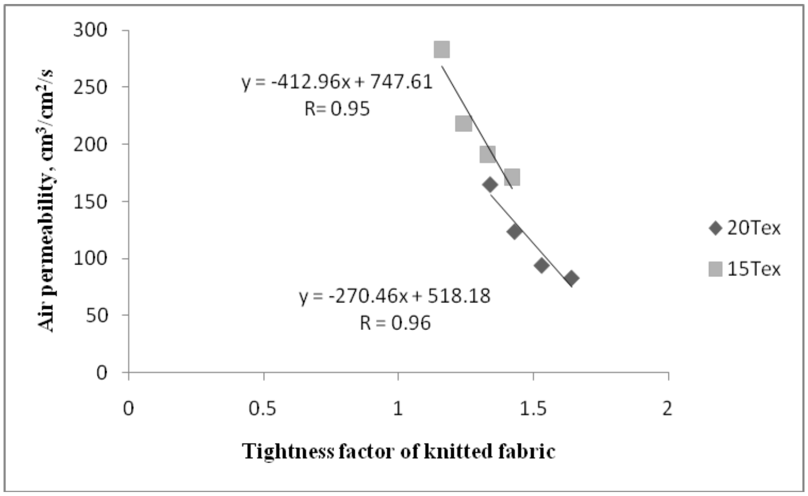

Figure 4.8: Air permeability in function of tightness factor of single jersey cotton knitted fabrics.

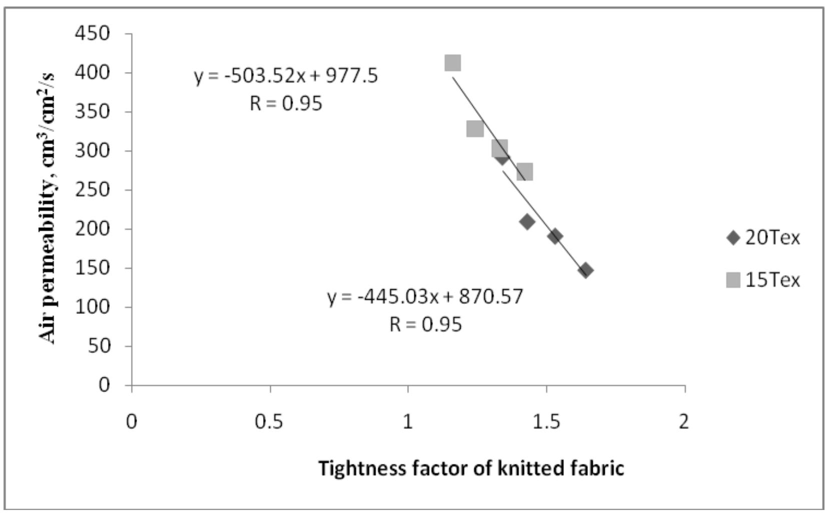

Figure 4.9: Air permeability in function of tightness factor of pique knitted cotton fabrics.

A close look at the (Tables 4.1 and 4.2) reveals that as for the same yarn linear density increasing tightness factor increased the fabric weight. This is documented by the test results and statistical analysis presented in (4.10 and 4.11) where the estimated value of linear correlation index between fabric weight and the tightness factor of knitted fabric is R= 0.98 for 20Tex and 0.96 for 15Tex in case of single jersey knitted fabrics and R=0.99 for 20Tex and 0.97 for 15Tex in case of pique knitted fabrics. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and structures.

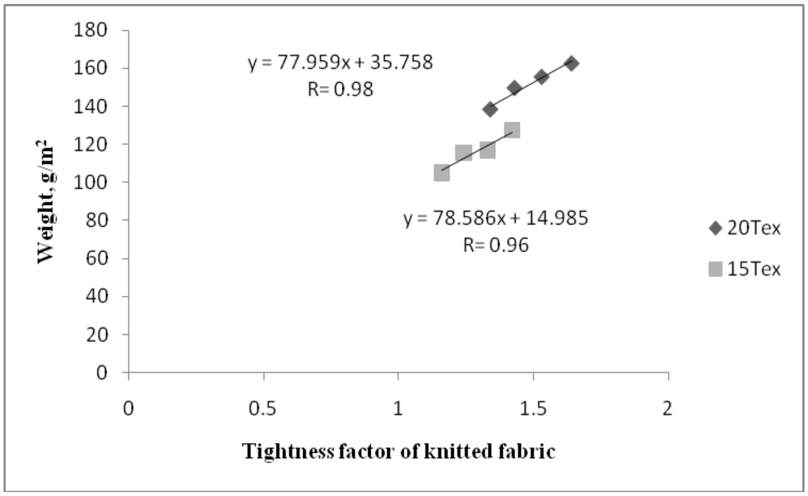

Figure 4.10: Fabric weight in function of tightness factor of single jersey cotton knitted fabrics

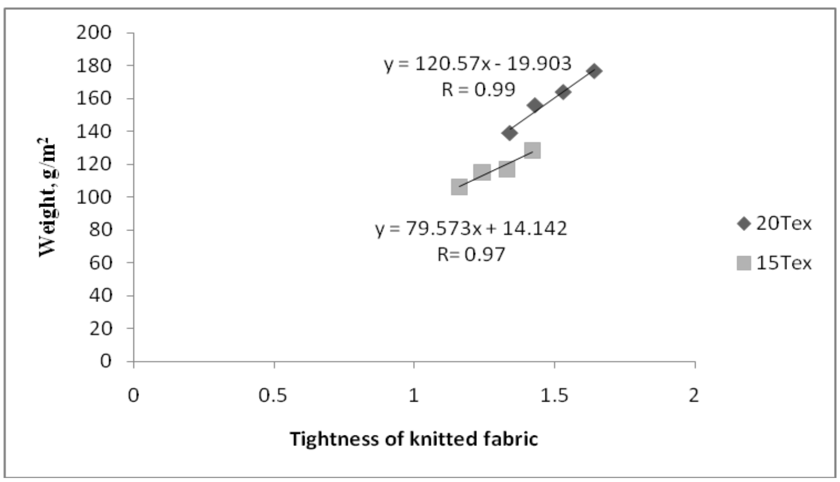

Figure 4.11: Fabric weight in function of tightness factor of pique knitted cotton fabrics

(Figure 4.12 and 4.13) shows that significant influence of the fabric porosity on air permeability. With 15Tex high correlation is obtained in both the single jersey and pique knitted fabrics. Lowest is seen in case of pique fabric knitted with 20Tex. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the porosity (%) range using both the yarn counts and structures.

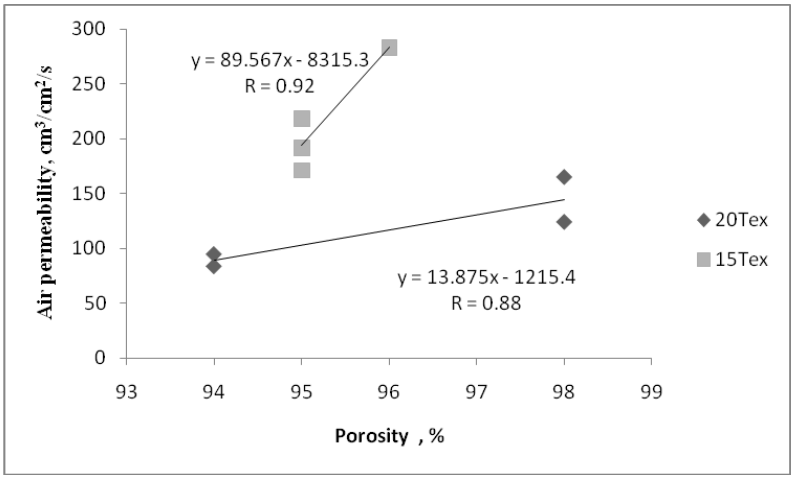

Figure 4.12: The relation between air permeability and surface porosity for single jersey cotton knitted fabrics.

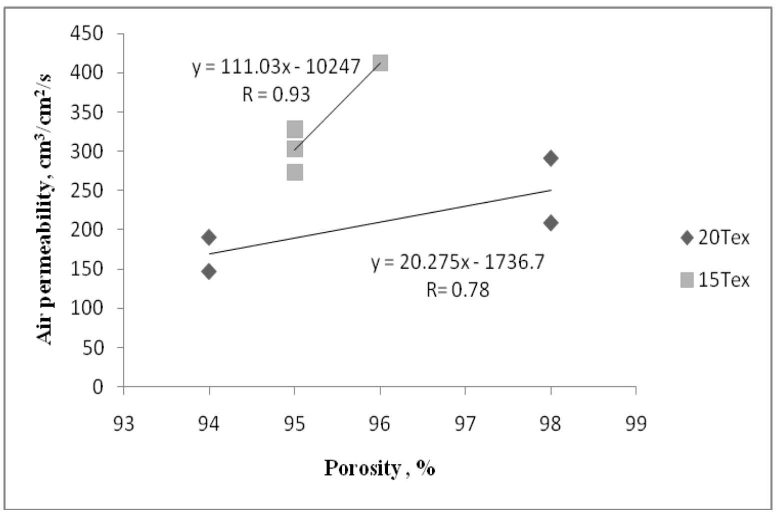

Figure 4.13: The relation between air permeability and surface porosity for pique knitted cotton fabrics.

4.2.2 Viscose Knitted fabric

(Figure 4.14) present the research results of air permeability. The range of values obtained is significant, ranging from 287 to 690 $cm^3/cm^2/s$ for single jersey fabric and the highest values are found with pique knitted fabrics ranging from 396.1 to 729.2 $cm^3/cm^2/s$. The porosity determines the variation of air permeability. Fabrics having low porosity values shows the lowest value for air permeability. Increasing fabric tightness by machine setting decreased the air permeability in both fabrics. Coarser yarn produce fabrics with more intra-yarn air spaces but with fewer inter-yarn air spaces resulting in lower air permeability in both the single jersey as well as pique knitted fabrics.

Air permeability increases for the fabrics made from finer yarns as expected. The lower thickness and mass per square meter also facilitate the passage of air through the fabric. The lower hairiness of the finer yarn may be another contributing factor towards the better air permeability. As the loop length increases, the air permeability value also increases porosity of knitted fabrics[159].

A close look at the (Tables 4.3 & 4.4) reveals that as for the same yarn linear density the thickness was increased by increasing the fabric tightness. Thicker yarns increased thickness in both fabrics. It can be seen that the thickness was higher for pique fabrics.

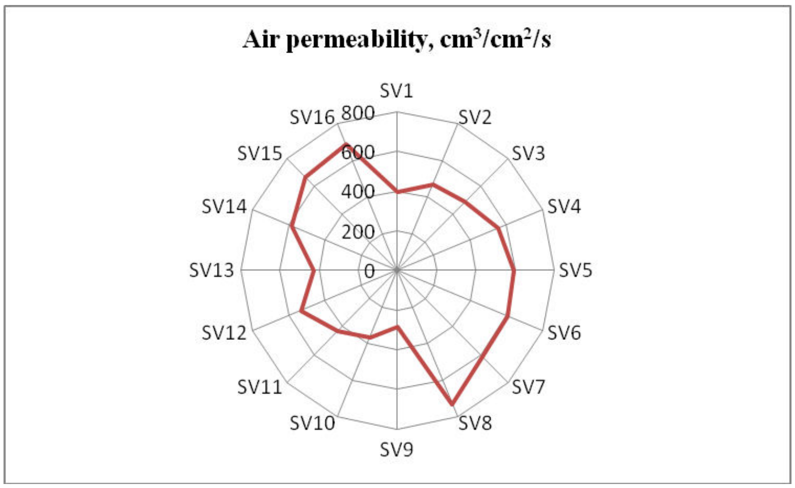

Figure 4.14: Air permeability of different variants of single jersey and pique knitted viscose fabrics: denotations as in (Table 3.9).

The barrierability of knitted fabrics to the air as fabrics thickness function, is presented in (Figure 4.15 and 4.16). It shows that Single jersey 20Tex (R= 0.9810), Single jersey 15Tex (R= 0.1928), Pique 20Tex (R= 0.9612) and Pique 15Tex (R= 0.6269) have negative correlation between air permeability and thickness. This was expected to some extent as air has to travel a more complex path and faces higher frictional forces during its passage through the fabric. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the fabric thickness range using both the yarn counts in single jersey structure and for 20Tex in pique structures.

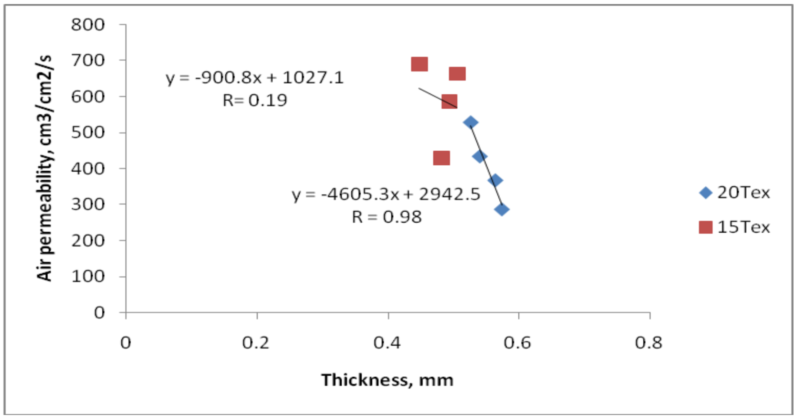

Figure 4.15: The relationship between air permeability and thickness of single jersey viscose knitted fabrics.

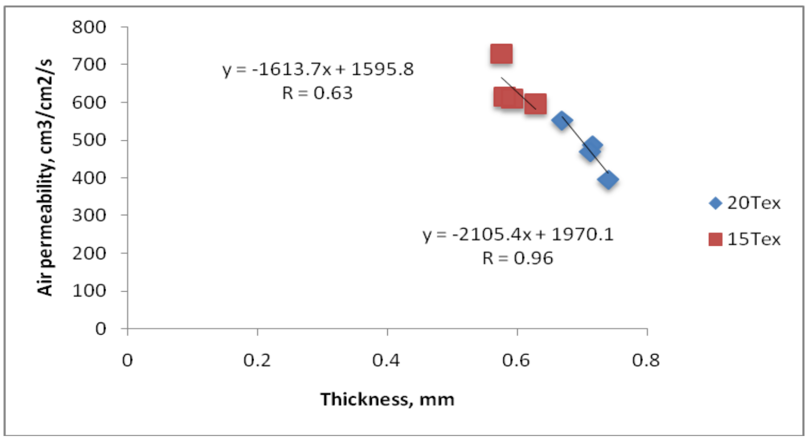

Figure 4.16: The relationship between air permeability and thickness of pique knitted viscose fabrics.

Air permeability is inversely related with fabric tightness; it decreased with increase of compactness and decrease of air space. It must be emphasized that tightness factor correlates more with air permeability than knitted fabric thickness. This is documented by the test results and statistical analysis presented in (Figure 4.17 and 4.18), where the estimated value of correlation index between air permeability and the tightness factor of knitted fabric is R = 0.95378 for 15Tex and 0.9950 for 20Tex for single jersey knitted fabrics and 0.98 for 15Tex and 0.83 for 20Tex for the pique fabrics. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and structures.

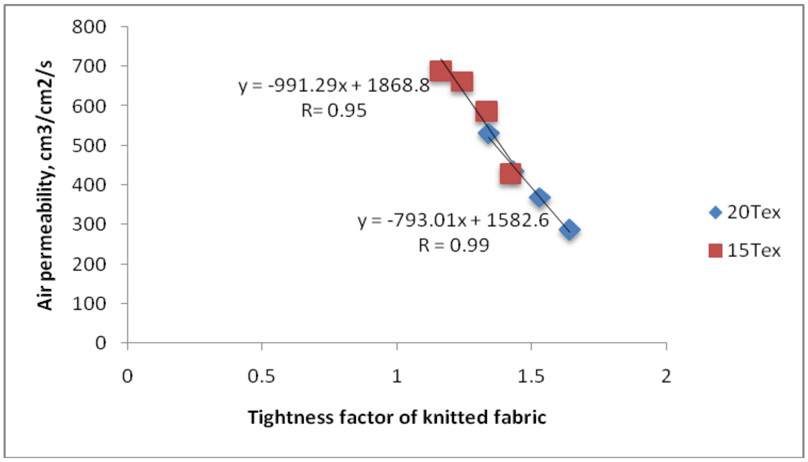

Figure 4.17: The relationship between air permeability and tightness factor of Single jersey viscose knitted fabrics.

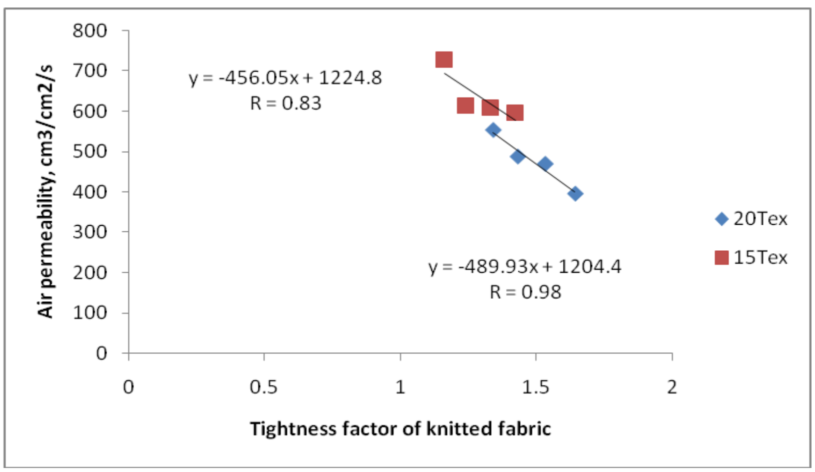

Figure 4.18: The relationship between air permeability and tightness factor of pique knitted viscose fabrics.

(Figure 4.19 and 4.20) shows the influence of the fabric porosity on air permeability. Poor correlation observed in case of single jersey fabrics while high correlation was obtained in pique fabrics. Previous research also showed that air permeability of fabrics was mainly affected by the porosity of the fabrics. Lowest is seen in case of single jersey fabric knitted with 20Tex which may be attributed to increase in yarn count and hairiness. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the porosity (%) range using both the yarn counts in pique structures only.

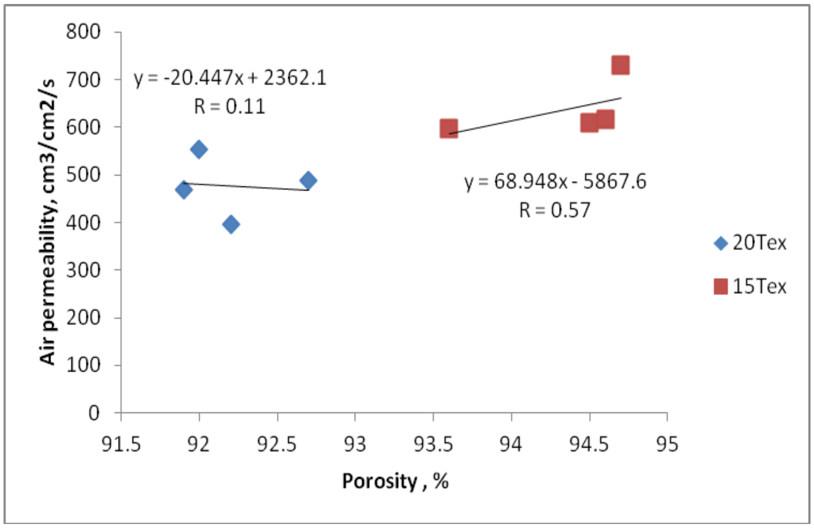

Figure 4.19: The relationship between air permeability and porosity of single jersey viscose knitted fabrics.

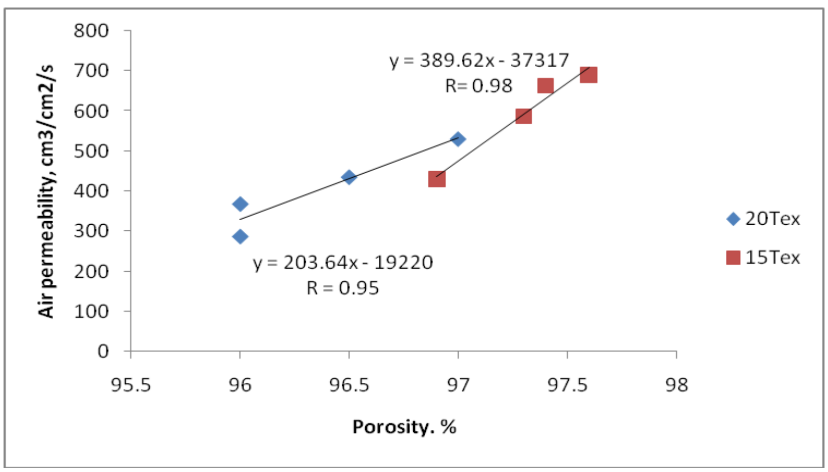

Figure 4.20: The relationship between air permeability and porosity of pique knitted viscose fabrics.

4.2.3 Modal Knitted fabric

(Figure 4.21) present the research results of air permeability. The range of values obtained is significant, ranging from 408.8 to 805.3 $cm^3/cm^2/s$ for single jersey fabric and the values are found with pique knitted fabrics ranging from 412.1 to 801.8 $cm^3/cm^2/s$. Fabrics having low porosity values shows the lowest value for air permeability. Increasing fabric tightness by machine setting decreased the air permeability in both fabrics. Coarser yarn produce fabrics with more intra-yarn air spaces but with fewer inter-yarn air spaces resulting in lower air permeability in both the single jersey as well as pique knitted fabrics. Air permeability increases for the fabrics made from finer yarns as expected. The lower thickness and mass per square meter also facilitate the passage of air through the fabric. The lower hairiness of the finer yarn may be another contributing factor towards the better air permeability. As the loop length increases, the air permeability value also increases porosity of knitted fabrics[159].

A close look at the (Tables 4.5 & 4.6) reveals that as for the same yarn linear density the thickness was increased by increasing the fabric tightness. Thicker yarns increased thickness in both fabrics. It can be seen that the thickness was higher for pique fabrics.

The barrierability of knitted fabrics to the air as fabrics thickness function, is presented in (Figure 4.22 and 4.23). It shows that Single jersey 20Tex (R= 0.77), Single jersey 15Tex (R= 0.81), Pique 20Tex (R= 0.21) and Pique 15Tex (R= 0.10) have negative correlation between air permeability and thickness.

This was expected to some extent as air has to travel a more complex path and faces higher frictional forces during its passage through the fabric. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the fabric thickness range using both the yarn counts only in single jersey structures.

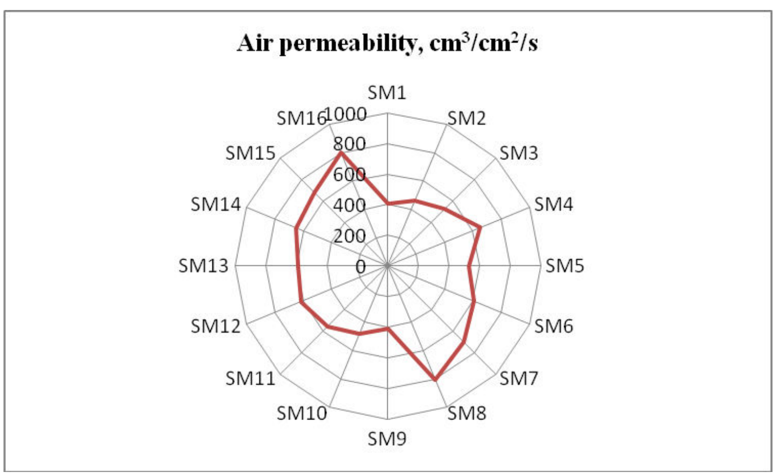

Figure 4.21: Air permeability of different variants of single jersey and pique modal knitted fabrics: denotations as in (Table 3.9)

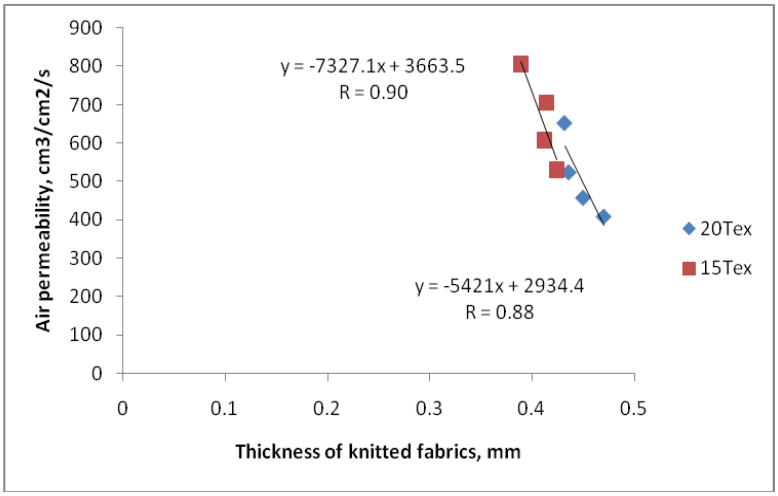

Figure 4.22: Air permeability in function of thickness of single jersey modal knitted fabrics.

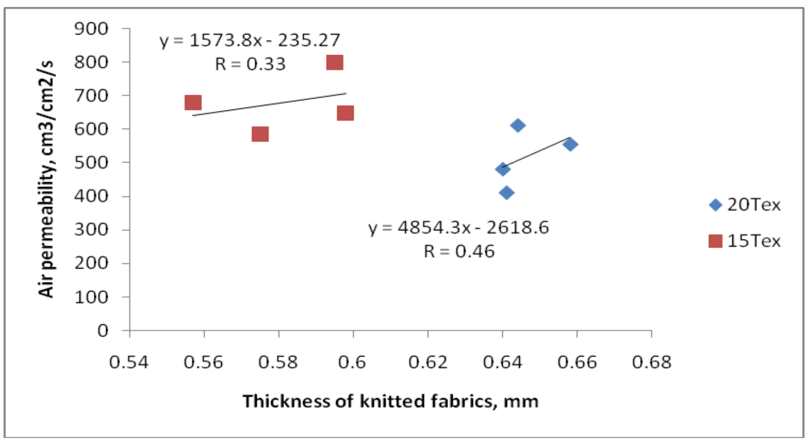

Figure 4.23: Air permeability in function of thickness of pique modal knitted fabrics.

Air permeability is inversely related with fabric tightness; it decreased with increase of compactness and decrease of air space. It must be emphasized that tightness factor correlates more with air permeability than knitted fabric thickness.

This is documented by the test results and statistical analysis presented in (Figure 4.24 and 4.25), where the estimated value of correlation index between air permeability and the tightness factor of knitted fabric is R = 0.996 for 15Tex and 0.96 for 20Tex for single jersey knitted fabrics and 0.96 for 15Tex and 0.99 for 20Tex for the pique fabrics. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and structures. (Figure 4.26 and 4.27) shows the influence of the fabric porosity on air permeability. Low correlation observed in case of single jersey fabrics with 20Tex.

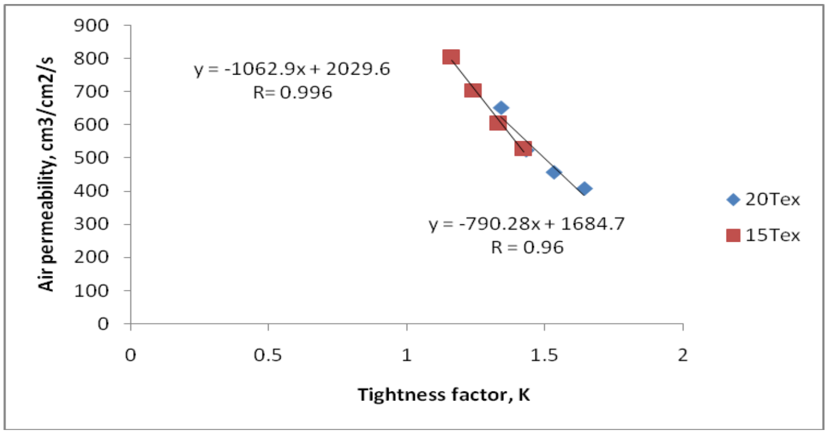

Figure 4.24: Air permeability in function of tightness factor of single jersey modal knitted fabrics.

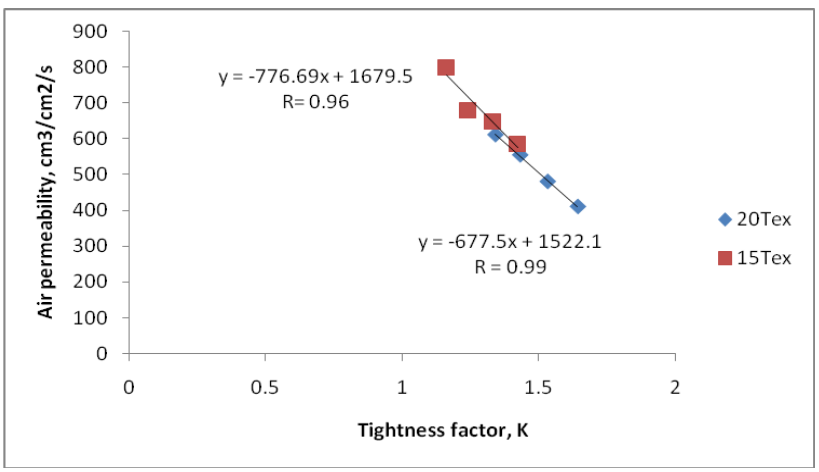

Figure 4.25: Air permeability in function of tightness factor of pique modal knitted fabrics.

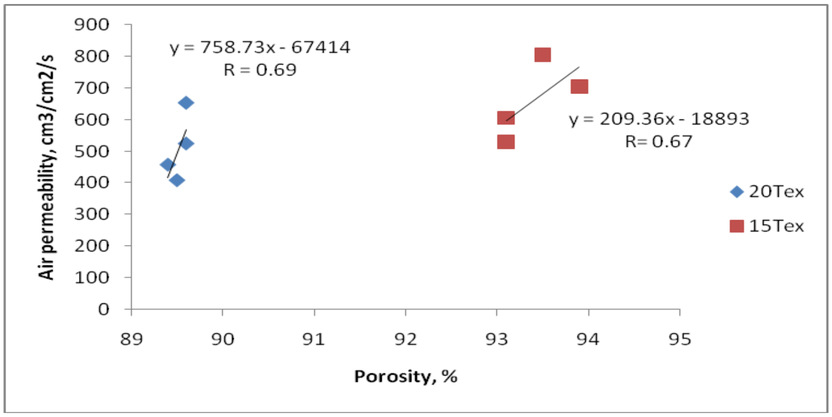

Figure 4.26: The relation between air permeability and surface porosity for single jersey modal knitted fabrics.

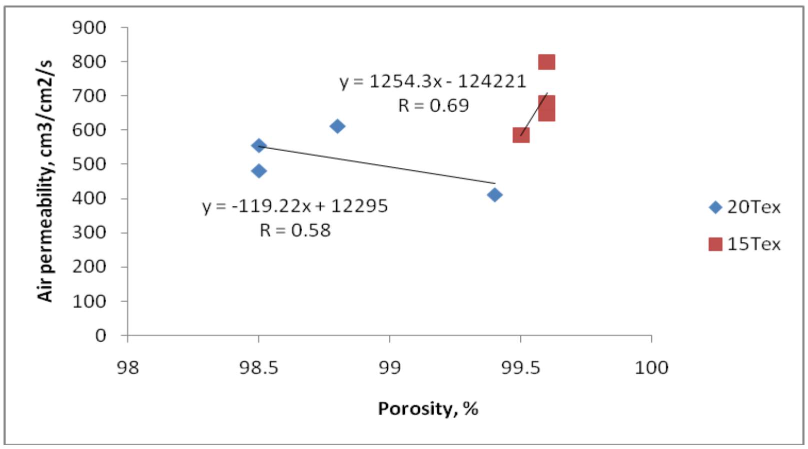

Figure 4.27: The relation between air permeability and surface porosity for pique modal knitted fabrics.

4.2.4 Excel Knitted fabric

(Figure 4.28) present the research results of air permeability. The range of values obtained is significant, ranging from 331 to 723 $cm^3/cm^2/s$ for single jersey fabric and the values are found with pique knitted fabrics ranging from 405.6 to 719.4 $cm^3/cm^2/s$. Fabrics having low porosity values shows the lowest value for air permeability. Increasing fabric tightness by machine setting decreased the air permeability in both fabrics. Coarser yarn produce fabrics with more intra-yarn air spaces but with fewer inter-yarn air spaces resulting in lower air permeability in both the single jersey as well as pique knitted fabrics. Air permeability increases for the fabrics made from finer yarns as expected. The lower thickness and mass per square meter also facilitate the passage of air through the fabric. The lower hairiness of the finer yarn may be another contributing factor towards the better air permeability. As the loop length increases, the air permeability value also increases porosity of knitted fabrics[159].

A close look at the (Tables 4.7 & 4.8) reveals that as for the same yarn linear density the thickness was increased by increasing the fabric tightness. Thicker yarns increased thickness in both fabrics. It can be seen that the thickness was higher for pique fabrics. The barrierability of knitted fabrics to the air as fabrics thickness function, is presented in (Figure 4.29 and 4.30). It shows that Single jersey 20Tex (R= 0.61), Single jersey 15Tex has very poor (R= 0.014), Pique 20Tex (R= 0.38) and Pique 15Tex (R= 0.96) have negative correlation between air permeability and thickness.

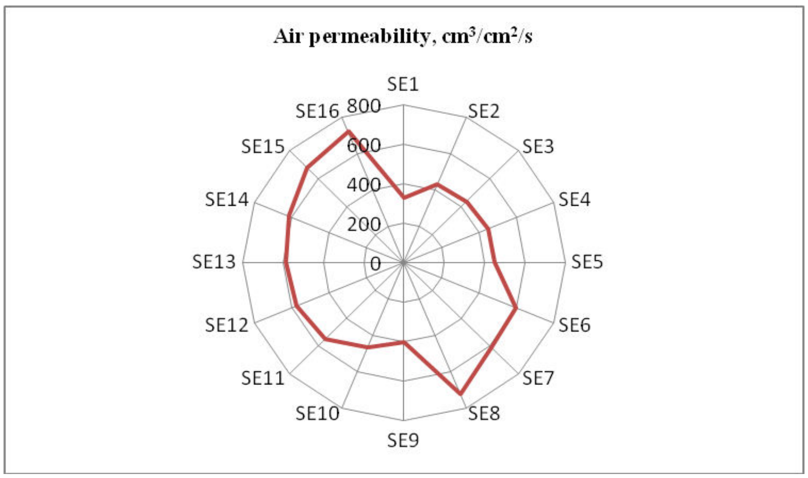

Figure 4.28: Air permeability of different variants of single jersey and pique excel knitted fabrics: denotations as in (Table 3.11)

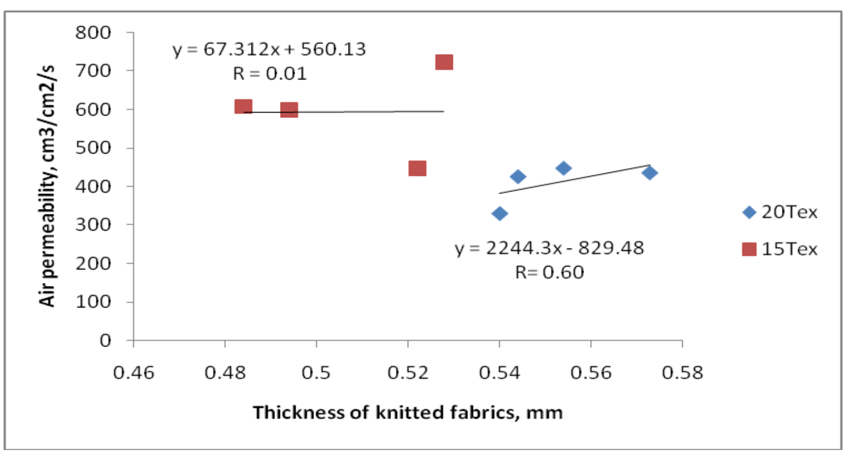

Figure 4.29: Air permeability in function of thickness of single jersey excel knitted fabrics.

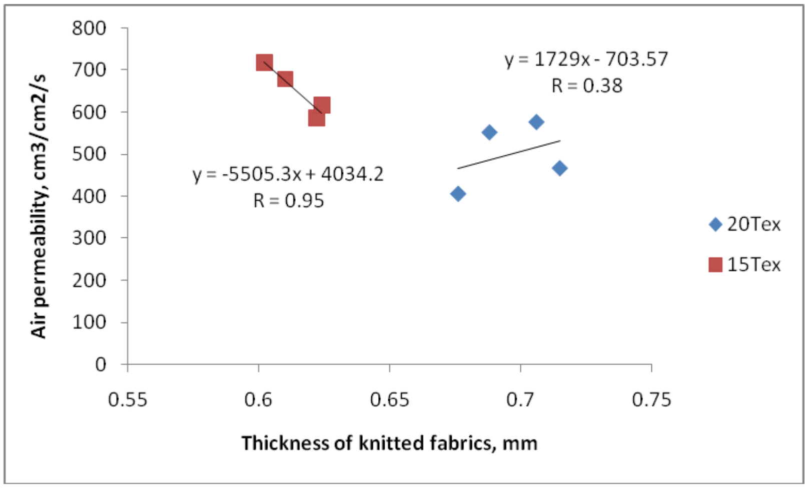

Figure 4.30: Air permeability in function of thickness of pique excel knitted fabrics.

This was expected to some extent as air has to travel a more complex path and faces higher frictional forces during its passage through the fabric. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the fabric thickness range using yarn count 15Tex for pique structure only. Air permeability is inversely related with fabric tightness; it decreased with increase of compactness and decrease of air space. It must be emphasized that tightness factor correlates more with air permeability than knitted fabric thickness. This is documented by the test results and statistical analysis presented in (Figure 4.31 and 4.32), where the estimated value of correlation index between air permeability and the tightness factor of knitted fabric is R = 0.95 for 15Tex and 0.89 for 20Tex for

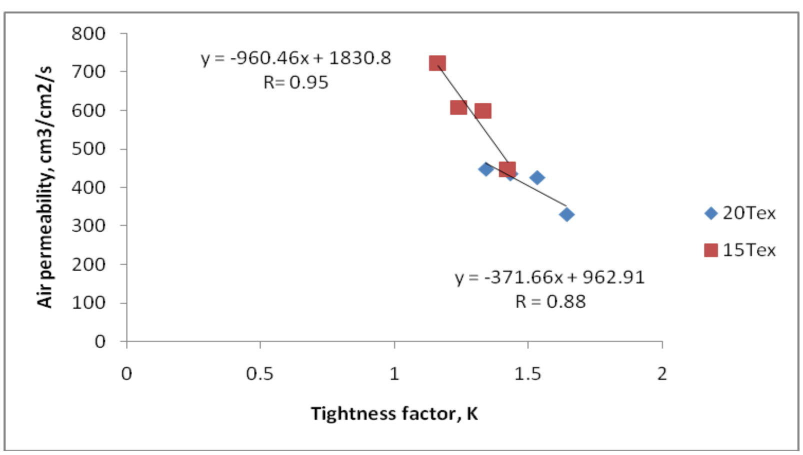

Figure 4.31: Air permeability in function of tightness factor of single jersey excel knitted fabrics.

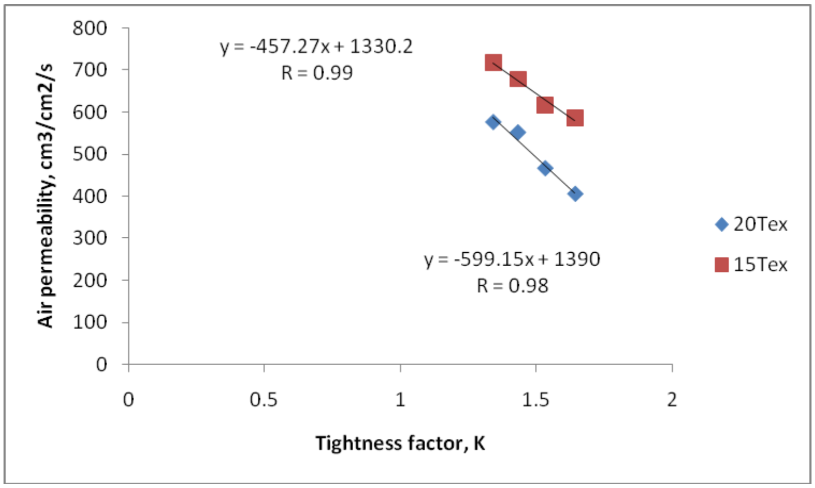

Figure 4.32: Air permeability in function of tightness factor of pique excel knitted fabrics.

single jersey knitted fabrics and 0.99 for both 15Tex and 20Tex for the pique fabrics. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the tightness factor range using both the yarn counts and structures.

(Figure 4.33 and 4.34) shows the influence of the fabric porosity on air permeability. Slightly lower correlation observed in case of pique fabrics compared with single jersey. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the air permeability in the porosity (%) range using both the yarn counts and structures.

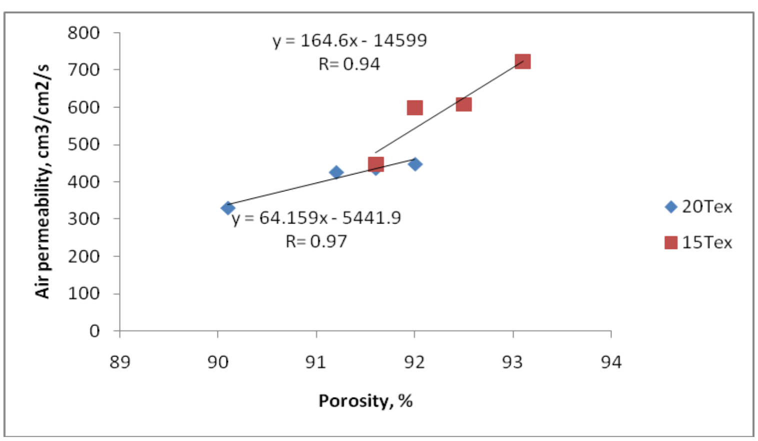

Figure 4.33: The relation between air permeability and surface porosity for single jersey excel knitted fabrics.

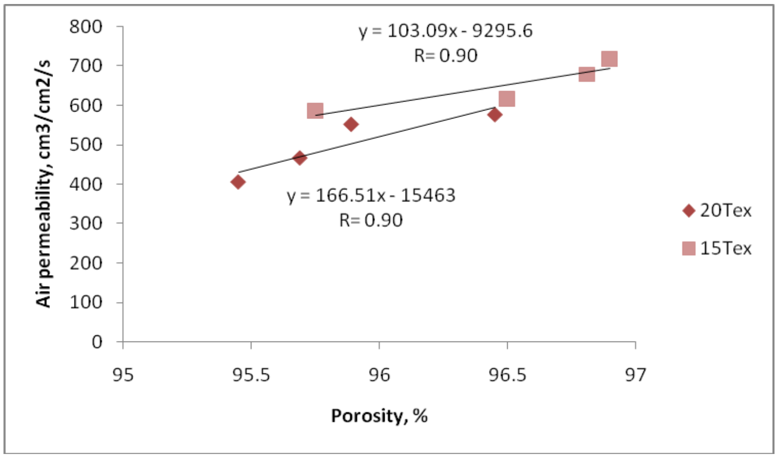

Figure 4.34: The relation between air permeability and surface porosity for pique excel knitted fabrics.

The results (expressed as means/standard deviation) of all assays were compared using ANOVA in order to investigate the effect of fibre type and fabric structure, on air permeability. ANOVA for air permeability indicated that there was significant impact of fibre type and fabric structure on air permeability. Together, fibre type and fabric structure accounted for 82.31% of the variance in air permeability (Table 4.11).

As a result of research, it is seen that the air permeability of fabric knitted with 15Tex is determined higher. Air permeability has a direct relationship with the count of the yarn. Coarser yarns produce fabrics with more intra-yarn air spaces with fewer inter-yarn air spaces resulting in lower air permeability[56]. Air permeability, is a function of knitted fabric thickness, tightness factor and porosity[157]. Air permeability showed a negative correlation with fabric thickness and tightness factor. Increase in yarn fineness and more open structure of the knitted fabric improved air permeability. Both the structures shows better correlation index in fabric weight and tightness factor. Better correlation is obtained between air permeability and porosity in case of both the single jersey and pique fabrics knitted with 15Tex. Tightness factor which can be used for fabric air permeability forecasting. The high correlation between the permeability to air and tightness factor confirms that. Increasing loop length, looser the structure and so the values of air permeability increases. The rising loop length resulted in a looser surface on the fabric, thereby increasing the air permeability[165].

From the results it can be stated that the highest air permeability value was obtained for, modal fabric knitted with 15Tex with tightness factor 1.16 in both single jersey as well as pique structure; this was followed by excel fabric knitted with 15Tex with tightness factor 1.16 in both single jersey as well as pique structure which could be because of lower fabric cover factor. Air permeability is of importance in windy conditions only, as it determines body protection against wind which improves the thermal comfort especially in winter conditions[169]. For summer wear or sportswear modal could be used as it is characterized by higher air permeability, creating a cool feeling to the wearer by allowing more air to penetrate through to bring the heat away from the body and accelerate the sweat evaporation at the skin and fabric surface[170]. And for winter garments the choice could be cotton as it is characterized by lower air permeability, creating, warm feeling for the wearer. Moreover, the experimental data suggested that in addition to fabric thickness, air permeability was a property also related to the surface characteristics of the fibres. The convolutions in the cotton fibres and the striations over the longitudinal surface of viscose fibres might have also increased the friction between the fibre surface and the air permeability of fabrics from these fibres[171].

4.3 Thermal comfort properties

Two fabric characteristics which obviously have a marked effect on the thermal properties of the fabric are:

i).In cold weather, the thermal insulation of the fabric. The ability of the fabric to keep the body heat in. The fabric property which is most important in this respect, is the fabric thickness.

ii).In warm weather, the ability of the fabric to transport heat from the body. At first sight this would appear to be exactly the opposite requirement to (i), so that any fabric with low thermal insulation would be ideal in this feature. However, air flow is of greater significance in this respect than under cold conditions, in that the air permeability of the fabric is high, air will circulate from the body, taking excessive perspiration with it.

It is obvious that heat transfer through a fabric is a complex phenomenon affected by many factors. The three major factors in normal fabrics appear to be thickness, entrapped still air and external air movement. To address a mathematical relationship between the fabric thickness, fabric weight on thermal properties, a linear regression equation was used and applied on the thermal properties. Multiple Regression analyses were made between thermal properties and fabric parameters. Thermal properties are defined as dependent variables (Y), and yarn count, loop length, tightness factor, fabric thickness and porosity are defined as independent variables (X). Multiple linear regression analysis have been applied to the measured values and obtained the best fit equations using MINITAB16. To deduce whether the parameters were significant or not, p values were examined. Ergun emphasized that if p value of a parameter is greater than 0.05 ($p>0.05$), the parameter will not be important and should be ignored[172].

4.3.1 Cotton knitted fabrics

4.3.1.1 Thermal conductivity

Table 4.12 and 4.13 shows the thermal comfort properties of cotton knitted fabrics. Thermal conductivity is an intensive property of a material that indicates its ability to conduct heat. According to figure 4.35 & 4.36, thermal conductivity decreases with the openness of structure in the case of Single jersey and Pique fabric knitted with 15Tex yarn. The single jersey structure shown overall higher thermal conductivity. This situation can be explained by the amount of entrapped air in the fabric structure. The amount of fibre in the unit area increases and the amount of air layer decreases as the weight increases. As is known, thermal conductivity values of fibres are higher than the thermal conductivity of entrapped air. So heavier fabrics that contain less air have higher thermal conductivity values. Also single jersey structure is the tightest and have lowest porosity among the two. Therefore, single jersey fabrics show the maximum thermal conductivity. Better correlation coefficient found for 20Tex knitted fabrics. Poor correlation was observed in case of Single jersey and Pique fabrics knitted with 15Tex. This may be attributed to the fact that even the variety of the same fibre type may influence the changes in the heat transfer. Since physical and chemical treatments of cellulose fibres, such as the alkaline treatment of cotton can cause changes of the fibre morphology, changes in their thermal properties can also be expected. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the thermal conductivity in the fabric weight range using 20Tex in both the fabric structures. Cotton pique fabrics shown lowest thermal conductivity values among all fabrics investigated.

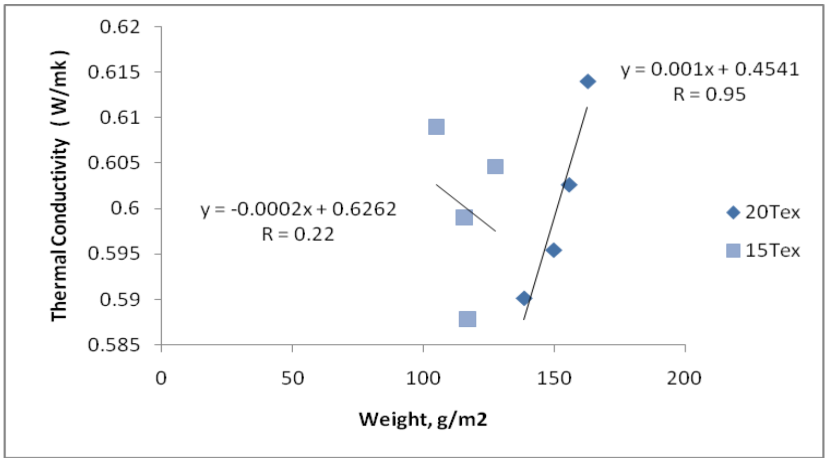

Figure 4.35: The relation between Thermal conductivity and weight for single jersey cotton knitted fabrics.

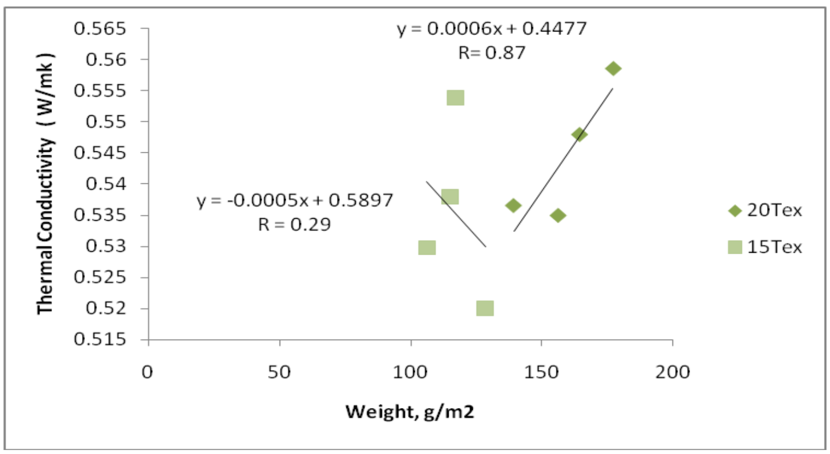

Figure 4.36: The relation between Thermal conductivity and weight for pique cotton fabrics

4.3.1.2 Thermal resistance

Thermal resistance is a measure of the body's ability to prevent heat from flowing through it. Under a certain condition of climate, if the thermal resistance of clothing is small, the heat energy will gradually reduce with a sense of coolness[55]. It mainly depends on thickness, air porosity nature in the fabric, thermal conductivity of the fibres and moisture content[98, 171, 173, 174].

The warmth of the fabric is governed by the entrapped air, the greater is the amount of entrapped air, the greater is thermal resistance of the fabric. It may be said that the chief factor that determines the thermal resistance value of the fabric is its thickness, excluding the projecting fibres.

Another important factor is weight. The 'warmth-to-weight' factor of a material is defined as the ratio of its thermal resistance in togs to its mass in $gmcm^{-2}$. A high value for this factor is obviously desirable for the provision of 'lightweight warmth'.

In fact the general expectation was to register an inverse relation between thermal resistance and thermal conductivity ($R = h / \lambda$; where R is the thermal resistance, h is the thickness and λ is the thermal conductivity). However, the test results revealed that as the thermal resistance decreases the thermal conductivity decreases as well. This contradiction might be explained by the fabric thickness. When finer yarn is used in fabric, yarn diameter and therefore fabric thickness decreases. If the amount of decrease in thickness is more than the amount of decrease in thermal conductivity, thermal resistance also decreases. As a result of statistical evaluation, fabric tightness does not have an important effect on thermal resistance and thermal conductivity.

As can be seen from the results (Figures 4.37 and 4.38), as the fabric thickness increases the thermal resistance increases. Pique knitted fabrics had higher thermal resistance than single jersey due to its higher thickness. Better correlation has been observed in case of single jersey knitted fabrics with both 20Tex followed by the one knitted with 15Tex. The results show that there is no correlation between thermal resistance and fabric thickness of pique fabrics investigated. As R, the correlation is considered high which means that the regression equation is reliable for prediction of the thermal resistance in the fabric thickness range using both the yarn counts in single jersey structures. Increasing air permeability, a reduction in thermal resistance takes place. Thickness has a decisive effect on thermal – insulation properties under free-convection conditions resembling those pertaining in a clothing assembly and demonstrates a linear relationship between warmth retention and fabric thickness under these conditions[62].

In fact the general expectation was to register an inverse relationship between thermal conductivity and thermal resistance, as for idealized conditions $R = h/\lambda$; where R- thermal resistance, h-thickness, λ thermal conductivity.

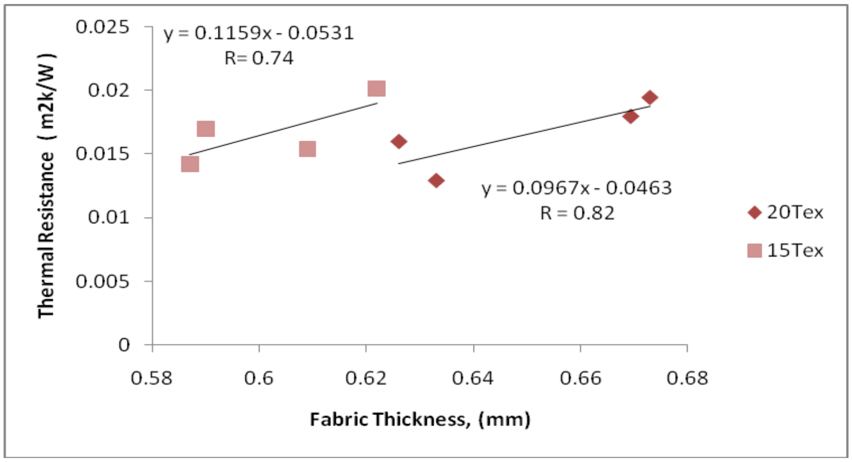

Figure 4.37: The relation between Thermal resistance and thickness for single jersey cotton knitted fabrics.

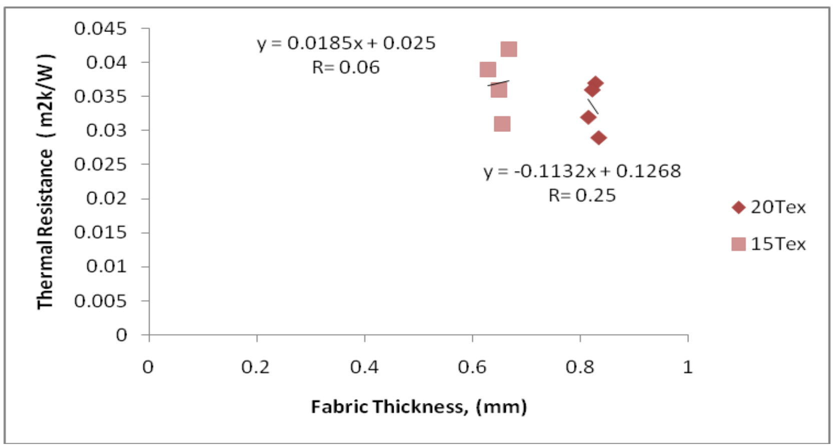

Figure 4.38: The relation between Thermal resistance and thickness for pique cotton knitted fabrics.

The test results also revealed that as thermal conductivity increases thermal resistance decreases but not linearly. This might be explained by the fabric thickness. If the amount of increase in fabric thickness is more than the amount of increase in thermal conductivity, thermal resistance will also increase[141]. The amount of increase observed in case of single jersey fabric in thickness is 7.27 % while in thermal conductivity is 4.27% and in case of pique knitted fabric amount of increase in thickness is 21.61% while in thermal conductivity increase is only 6.9%. It was found that as the yarn gets finer the thermal resistance and thermal conductivity decrease which could be ascribed to the higher porosity value of fabrics made from the finer yarns. Previous work reveals that for fabrics made from finer yarns, the air entrapped is less and hence lowers thermal insulation[175]. The best regression equations for each thermal property for single jersey fabric are given in Table 4.14.

Table 4.14: The regression equations between thermal properties and fabric parameters of the single jersey cotton fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor
Thermal resistance	R = - 0.170 + 0.00138 P + 0.105 h
Thermal conductivity	λ = 1.26 – 0.00489 P – 0.372 h
Air permeability	AP = 622 - 359 t + 2.97 P - 349 h

Table 4.15, 4.16 and 4.17 shows the regression analysis. Statistical evaluations (Table 4.15 and 4.16) showed that the P value corresponding to the coefficient of porosity is very large, which indicates that in the equation of thermal resistance and thermal conductivity, the porosity factor can be avoided since its coefficient is non-significant. Together, porosity and thickness accounted for 58.2% of the variance in the thermal resistance and 57.3% of the variance of the thermal conductivity. As per regression analysis (Table 4.17) it was found that the equation obtained is a good equation as the R^2 value is 96.1%. The best regression equations for each thermal property for pique fabric are given in Table 4.18. Table 4.19, 4.20 and 4.21 shows the regression analysis. Statistical evaluation showed (table 4.19 and 4.20) that the effect of porosity and thickness on thermal resistance is insignificant for pique fabrics. Together, porosity and thickness accounted for only 48 % of the variance in the thermal resistance and 43% of the variance of the thermal conductivity. As per regression analysis (table 4.21), it was found that the equation obtained is a good equation as the R^2 value is 96.0% for pique knitted fabrics and all these three parameters gives p value of 0.003 and are significant.

Table 4.18: The regression equations between thermal properties and fabric parameters of the cotton pique fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor
Thermal resistance	R = - 0.0903 + 0.00151 P - 0.0258 h
Thermal conductivity	λ = 0.911 - 0.00441 P + 0.0691 h
Air permeability	AP = 1281 - 484 t - 2.55 P - 130 h

4.3.2 Viscose knitted fabrics

4.3.2.1 Thermal conductivity

Table 4.22 and 4.23 shows the thermal comfort properties of viscose knitted fabrics. According to figure 4.38 & 4.39, thermal conductivity decreases as the fabric weight increases in both the structures knitted with 15Tex. No clear trend has been observed in case of fabrics knitted with 20Tex with poor correlation. The pique structure shown overall higher thermal conductivity. As R, the correlation is considered too high which means that the regression equation is reliable for prediction of the thermal conductivity in the fabric weight range using the yarn count 15Tex in both the structures. Results showed that there is no correlation between thermal conductivity and fabric weight of the pique knitted fabric with 20Tex investigated. Viscose single jersey fabrics shown lowest thermal conductivity values among all fabrics investigated.

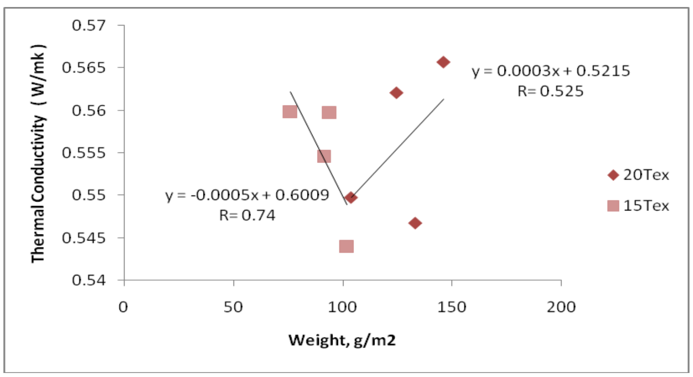

Figure 4.39: The relation between Thermal conductivity and weight for single jersey viscose knitted fabrics.

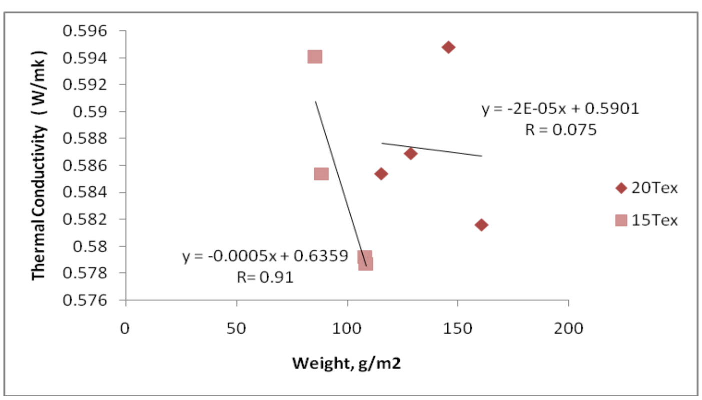

Figure 4.40: The relation between Thermal conductivity and weight for viscose pique fabrics

4.3.2.2 Thermal resistance

As can be seen from the results (Figures 4.41 and 4.42), as the fabric thickness increases the thermal resistance increases except in case of single jersey fabric knitted with 20Tex. Better correlation has been observed in case of pique fabrics with 15Tex. Results showed that there is no correlation between thermal conductivity and fabric thickness of the single jersey fabrics and pique knitted fabric with 20Tex investigated. As R, the correlation is considered better which means that the regression equation is reliable for prediction of the thermal resistance in the fabric thickness range using the yarn count 15Tex only in pique structures. Consequently, to maintain that thickness is the main factor determining the heat transfer through knitted fabric is not right.

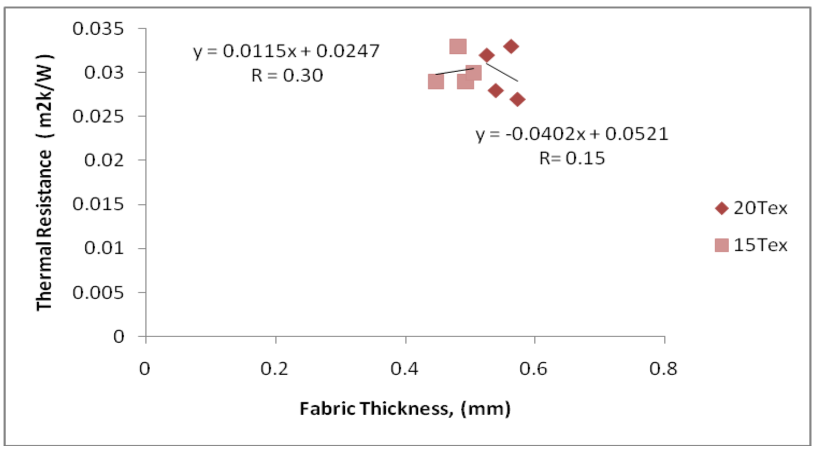

Figure 4.41: The relation between Thermal resistance and thickness for single jersey viscose knitted fabrics.

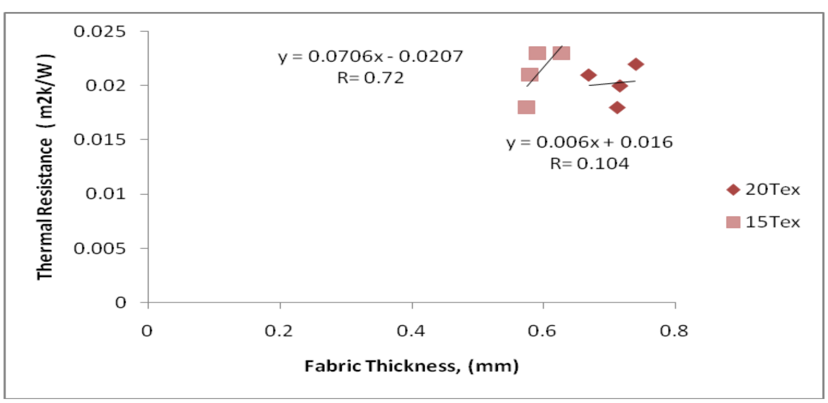

Figure 4.42: The relation between Thermal resistance and thickness for pique viscose knitted fabrics.

In fact the general expectation was to register an inverse relationship between thermal conductivity and thermal resistance, as for idealized conditions $R = h/\lambda$; where R- thermal resistance, h-thickness, λ thermal conductivity. The test results also revealed that as thermal conductivity increases thermal resistance decreases but not linearly. This might be explained by the fabric thickness. If the amount of increase in fabric thickness is more than the amount of increase in thermal conductivity, thermal resistance will also increase[97]. The amount of increase observed in case of single jersey fabric in thickness is 22% while in thermal conductivity is 3.8% and in case of pique knitted fabric amount of increase in thickness is 22.3% while in thermal conductivity increase is only 2.7%. The best regression equations for each thermal property for single jersey fabric are given in Table 4.24.

Table 4.24: The regression equations between thermal properties and fabric parameters of the single jersey viscose fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor)
Thermal resistance	$R = 0.222 - 0.00179\ P - 0.0482\ h$
Thermal conductivity	$\lambda = - 0.051 + 0.00563\ P + 0.157\ h$
Air permeability	$AP = - 1434 - 974\ t + 29.5\ P + 1028\ h$

Table 4.25, 4.26 and 4.27 shows the regression analysis for single jersey fabrics. Statistical evaluations (Table 4.25 and 4.26) showed that the P value corresponding to the coefficient of porosity is more, which indicates that in the equation of thermal resistance and thermal conductivity, the porosity factor can be avoided since its coefficient is non-significant. Together, porosity and thickness accounted for 28.5% of the variance in the thermal resistance and 25% of the variance of the thermal conductivity. As per regression analysis (Table 4.27) it was found that the equation obtained is a good equation as the R^2 value is 98.9%. The best regression equations for each thermal property for pique fabric are given in Table 4.28.

Table 4.28: The regression equations between thermal properties and fabric parameters of the viscose pique fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length, t: tightness factor)
Thermal resistance	R = 0.040 - 0.00016 P - 0.0045 h
Thermal conductivity	λ = 0.66 - 0.0008 P - 0.000 h
Air permeability	AP = 4127 - 398 t - 25 P - 871 h

Table 4.29, 4.30 and 4.31 shows regression analysis for pique knitted fabrics. Statistical evaluations (Table 4.29 and 4.30) showed that the P value corresponding to the coefficient of porosity and fabric thickness are very large, which indicates that in the equation of thermal resistance and thermal conductivity, the porosity and fabric thickness factor can be avoided since its coefficient is non-significant. As per regression analysis (Table 4.31) it was found that the equation obtained (Table 4.28) is a good equation as the R^2 value is 93.6%.

4.3.3 Modal knitted fabrics

4.3.3.1 Thermal conductivity

Table 4.32 and 4.33 shows the thermal comfort properties of modal knitted fabrics. According to figure 4.43 & 4.44, the correlation of thermal conductivity with the fabric weight is better for both the structures.

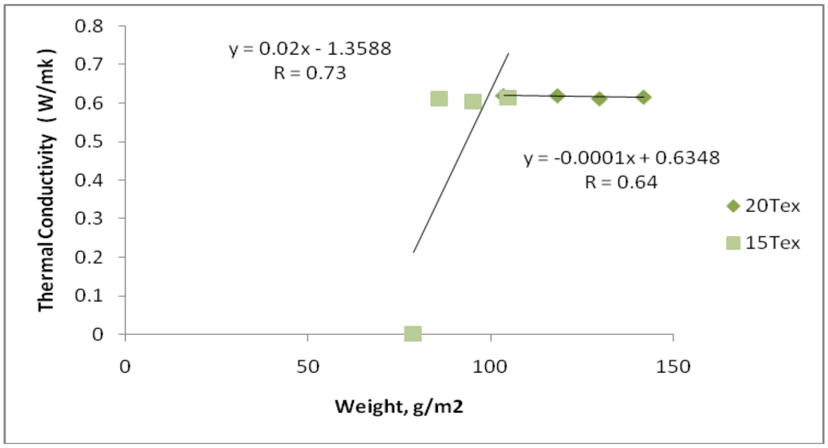

Figure 4.43: The relation between Thermal conductivity and weight for single jersey modal knitted fabrics.

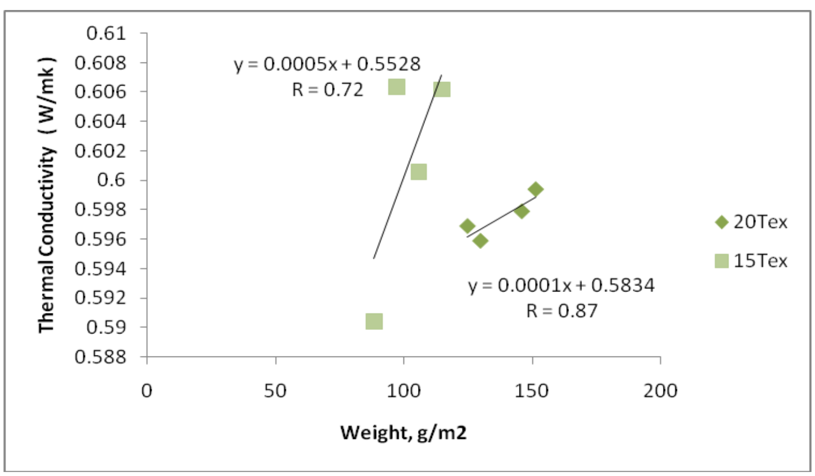

Figure 4.44: The relation between Thermal conductivity and weight for modal pique fabrics

Modal single jersey and pique fabrics shown highest thermal conductivity values among the fabrics investigated. As R, the correlation observed is considered good which means that the regression equation is reliable for prediction of the thermal conductivity in the fabric weight range using both the yarn counts in both the structures.

4.3.3.2 Thermal resistance

As can be seen from the results (Figures 4.45 and 4.46), as the fabric thickness increases the thermal resistance increases in both the fabric structures considered. Correlation has been observed in case of pique fabrics with 15Tex and single jersey fabrics with 20Tex. Results showed that no correlation exists between the thermal resistance and fabric thickness for single jersey fabrics knitted with 15Tex and pique fabric knitted with 20Tex, proving that the heat transfer process depends not only on the thickness of the fabric but also on the knitting structure, because the amount of air in the knitted fabric also depends on the order of loops ranged in the fabric. Consequently, to maintain that thickness is the main factor determining the heat transfer through knitted fabric is not right.

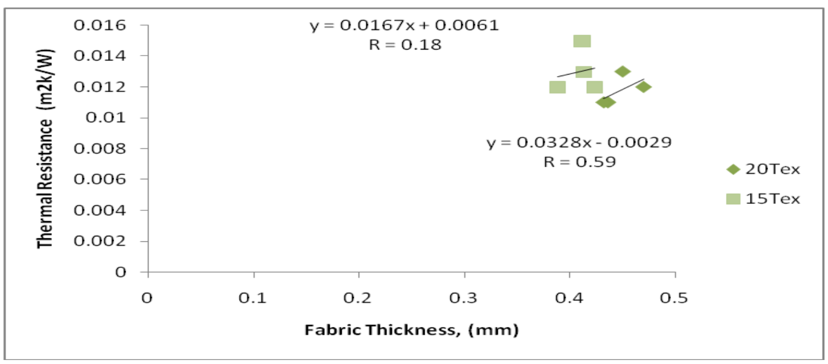

Figure 4.45: The relation between Thermal resistance and thickness for single jersey modal knitted fabrics.

In fact the general expectation was to register an inverse relationship between thermal conductivity and thermal resistance, as for idealized conditions $R = h/\lambda$; where R- thermal resistance, h-thickness, λ thermal conductivity[30]. The test results also revealed that as thermal conductivity increases thermal resistance decreases but not linearly. This might be explained by the fabric thickness. If the amount of increase in fabric thickness is more than the amount of increase in thermal conductivity, thermal resistance will also increase. The amount of increase observed in case of single jersey fabric in thickness is 17.23 % while in thermal conductivity is 2.3% and in case of pique knitted fabric amount of increase in thickness is 6.1% while in thermal conductivity increase is only 2.6%.

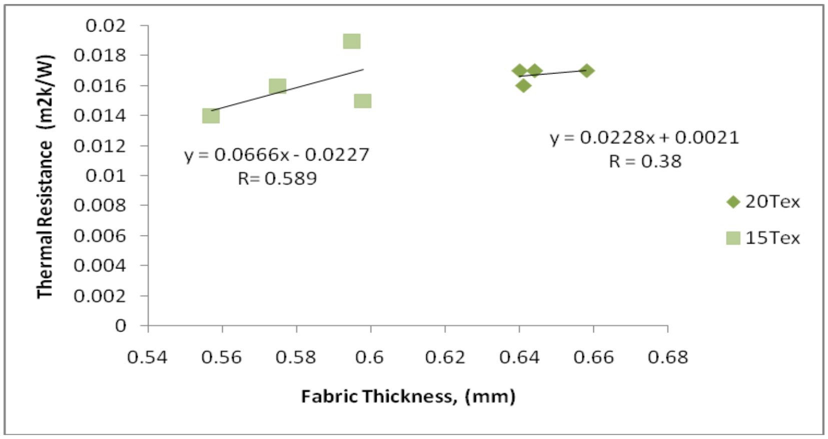

Figure 4.46: The relation between Thermal resistance and thickness for pique knitted modal fabrics.

It was found that as the yarn gets finer the thermal resistance and thermal conductivity decrease which could be ascribed to the higher porosity value of fabrics made from the finer yarns. The best regression equations for each thermal property for single jersey fabric are given in Table 4.34.

Table 4.34:The regression equations between thermal properties and fabric parameters of the single jersey modal fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length, t: tightness factor)
Thermal resistance	R = - 0.0463 + 0.000529 P + 0.0241 h
Thermal conductivity	λ = 0.809 - 0.00182 P - 0.065 h
Air permeability	AP = 1629 - 1115 t - 2.2 P + 1650 h

Tables 4.35, 4.36 and 4.37 shows regression analysis for modal single jersey fabrics. Statistical evaluation showed that the effect of porosity and thickness on thermal resistance is insignificant for single jersey fabrics. Together, porosity and thickness accounted for 29.4 % of the variance in the thermal resistance and 32.9% of the variance of the thermal conductivity. As per regression analysis (table 4.37) for single jersey it shows that the considered parameter are significant (p=0.002) and the equation obtained is a good equation as the R^2 value is 96.0%. The best regression equations for each thermal property for pique fabric are given in Table 4.38.

Table 4.38: The regression equations between thermal properties and fabric parameters of the pique knitted modal fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor)
Thermal resistance	$R = -0.016 + 0.00020\,P + 0.0203\,h$
Thermal conductivity	$\lambda = 1.03 - 0.00362\,P - 0.120\,h$
Air permeability	$AP = -2131 + 36.1\,P + 358\,h - 772\,t$

Tables 4.39, 4.40 and 4.41 shows the regression analysis for pique modal fabrics. Statistical evaluations showed that the effect of porosity and fabric thickness on thermal resistance and thermal conductivity is insignificant for pique fabric. Together, porosity and thickness accounted for 20.0% of the variance in the thermal resistance and 36.1% of the variance of the thermal conductivity. As per regression analysis (table 4.41) it was found that the equation obtained is a good equation as the R^2 value is 98.3% (p value = 0.001).

4.3.4 Excel knitted fabrics

4.3.4.1 Thermal conductivity

According to figure 4.47 & 4.48, the correlation of thermal conductivity with the fabric weight is good for both the structures. The single jersey structure shown overall higher thermal conductivity. As R, the correlation observed is considered good which means that the regression equation is reliable for prediction of the thermal conductivity in the fabric weight range using the yarn count 20Tex pique and 15Tex in the single jersey structures.

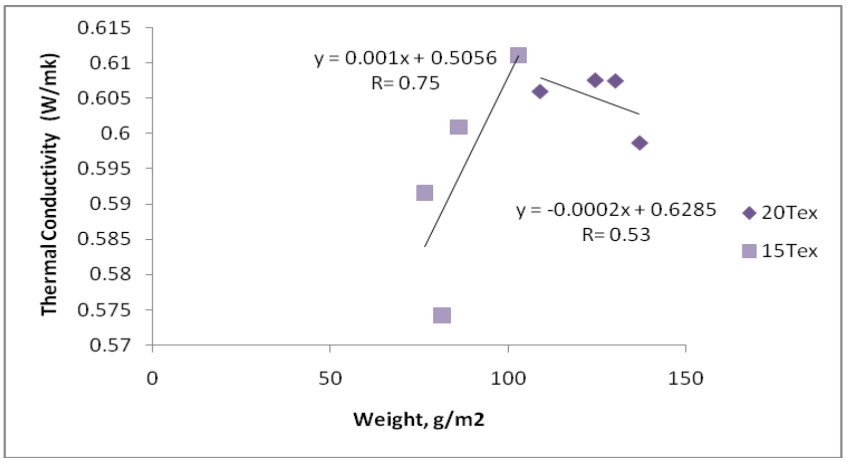

Figure 4.47: The relation between Thermal conductivity and weight for single jersey excel knitted fabrics.

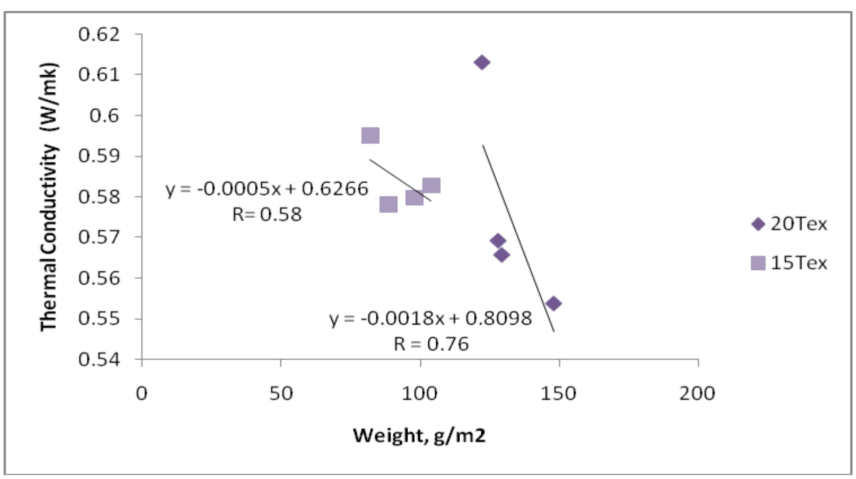

Figure 4.48: The relation between Thermal conductivity and weight for pique knitted excel fabrics

4.3.2.2 Thermal resistance

As can be seen from the results (Figures 4.49 and 4.50), as the fabric thickness increases the thermal resistance decreases except for the pique knitted fabric with 15Tex. In fact the general expectation was to register an inverse relationship between thermal conductivity and thermal resistance, as for idealized conditions $R = h/\lambda$; where R- thermal resistance, h-thickness, λ thermal conductivity.

The test results also revealed that as thermal conductivity increases thermal resistance decreases but not linearly. This might be explained by the fabric thickness. If the amount of increase in fabric thickness is more than the amount of increase in thermal conductivity, thermal resistance will also increase. The amount of increase observed in case of single jersey fabric in thickness is 15.52 % while in thermal conductivity is 6 % and in case of pique knitted fabric amount of increase in thickness is 15.80% while in thermal conductivity increase is only 9.7%. The best regression equations for each thermal property for single fabric are given in Table 4.42.

Tables 4.43, 4.44 and 4.45 shows the regression analysis for excel single jersey fabrics. Statistical evaluation showed that the effect of porosity and thickness on thermal resistance is insignificant for single jersey fabrics.

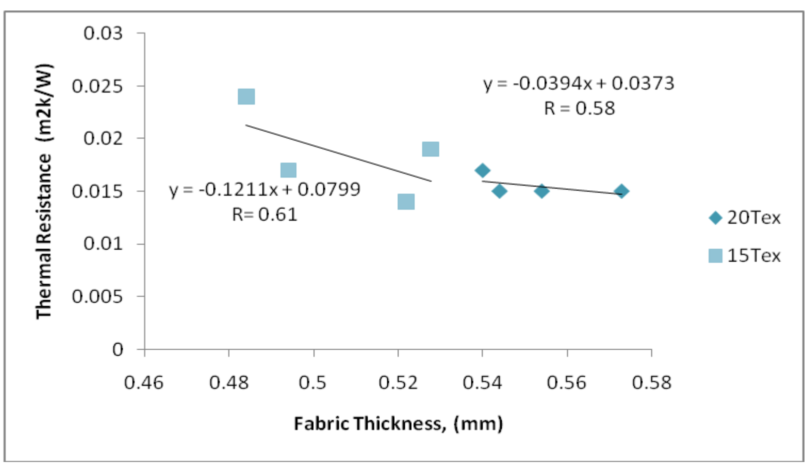

Figure 4.49: The relation between Thermal resistance and thickness for single jersey knitted excel fabrics.

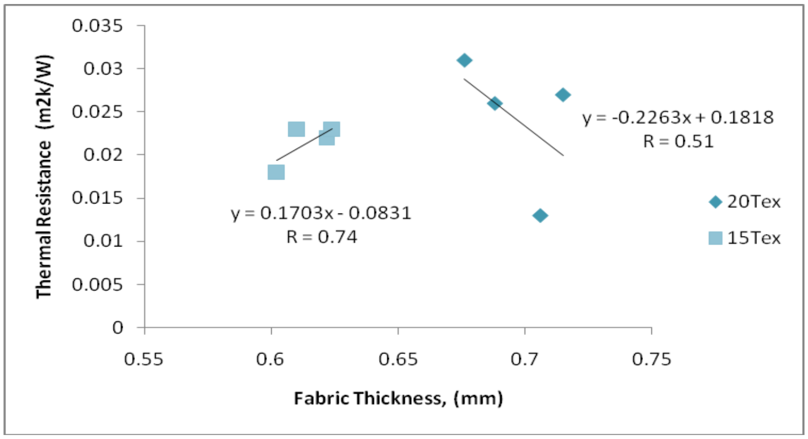

Figure 4.50: The relation between Thermal resistance and thickness for pique knitted excel fabrics.

Table 4.42: The regression equations between thermal properties and fabric parameters of the single jersey excel fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor)
Thermal resistance	R = - 0.156 + 0.00207 P - 0.0323 h
Thermal conductivity	λ = 1.21 - 0.00732 P + 0.117 h
Air permeability	AP = 73 - 534 t + 19 P - 1151 h

Together, porosity and thickness accounted for 48.3 % of the variance in the thermal resistance and 45.8 % of the variance of the thermal conductivity. As per regression analysis (table 4.45) it was found that the equation obtained is a good equation as the R^2 value is 89.2%. The best regression equations for each thermal property for pique fabric are given in Table 4.46.

Table 4.46: The regression equations between thermal properties and fabric parameters of the pique knitted excel fabrics

Thermal property	Regression equation (P:porosity h: thickness, ℓ:loop length , t: tightness factor)
Thermal resistance	R = - 0.024 + 0.00020 P + 0.0418 h
Thermal conductivity	λ = 0.760 - 0.00096 P - 0.134 h
Air permeability	AP = 168 - 540 t + 14.6 P - 378 h

Tables 4.47, 4.48 and 4.49 shows the regression analysis of excel pique fabrics. Statistical evaluations showed (tables 4.47 and 4.48) the p value corresponding to the coefficient of porosity is very large, which indicates that in the equation of thermal resistance and thermal conductivity, the porosity factor can be avoided since its coefficient is non-significant. Together, porosity and thickness accounted for 30.7% of the variance in the thermal resistance and 30.4% of the variance of the thermal conductivity. As per regression analysis (table 4.49) it was found that the equation obtained is a good equation as the R^2 value is 98.8% (p value = 0.000).

The results (expressed as means/standard deviation) of all assays were compared using ANOVA in order to investigate the effect of fibre type and fabric structure, on thermal conductivity and thermal resistance. ANOVA for thermal conductivity and thermal resistance indicated that there was significant impact of fibre type and fabric structure on thermal conductivity and thermal resistance. Together, fibre type and fabric structure accounted for 85.41% of the variance in the thermal conductivity and 85.75% of the variance in the thermal resistance (see Table 4.50).

The higher the fabric weight and thickness, the better the thermal insulation of fabrics. Nevertheless, a higher fabric weight and thickness can lead to a worsening of utility comfort, especially the freedom of movement[72]. The lowest thermal resistance obtained is for modal knitted fabric. These fabrics were followed by excel, cotton and viscose, in turn. Thanks to the fibre surface and cross-sectional properties and higher fabric thickness and higher fabric cover factor which contribute to heat retention by entrapping still air, the cotton and viscose knitted fabrics featured higher thermal resistance than the others. The lower thermal resistance obtained for the cotton knitted fabric than viscose can be attributed to its regain (the highest) and also to the cotton fibre itself since, as is known from the literature, cotton fibre is a good conductor of heat and draws heat away from the skin to keep the body cool, making it comfortable to wear[171, 176]. Because of their structural properties, pique fabrics have remarkably lower thermal conductivity and higher thermal resistance values in all the fibre types investigated. According to the results pique structures, being thicker, due to their high thermal insulation values, could be preferred for winter garments in order to protect from cold. On the other hand, single jersey structures should be chosen for active sports or summer garments for better moisture management properties that gives a cooler feeling at first contact with the skin. However, as they demonstrated fair drying ability, fabrics can become wet and damped, creating discomfort to the user (heavy, sag, feel cold when activity ends). Therefore, different solutions must be proposed, according to the activity level. If the wearer performs mild activities, skin wetness is very low and thermal comfort is managed by skin temperature. In this case, fabrics' air permeability and thermal resistance are determining properties for thermal comfort. Fabrics must have high air permeability and low thermal resistance. Modal fabrics with single jersey structure fulfill these requirements.

As regards fabrics, the results pointed to a preferential use on sportswear applications for colder ambient conditions, particularly due to their high thermal resistance together with high wicking and diffusion ability. SM16 have the highest thermal resistance which makes them the best choice for cold weather sports activities. The air permeability strongly depends on the porosity of the fabric through which air is permitted, whereas fabric porosity has an influence only to a certain level of the thermal resistance of the fabric. This once again proves that the heat transfer process strongly depends on the structure of the knit.

The heat transfer process depends on the knitting pattern because the structure of the knit determines the amount of air therein, which depends on the order of loops ranged in the fabric. Many researchers state that heat transfer immediately depends on fabric thickness. Thermal resistance showed a decrease with increase in air permeability in case of excel knitted structures of both counts, single jersey structures of both counts in case of modal and pique structure for both counts in viscose and single jersey structures for 15Tex in case of cotton and viscose only. Thus the results obtained show that such a dependence is not strong, proving that the use of air permeability or thickness for the prediction of the thermal properties of knits is an insufficient method because the thermal properties also depend on the structure of the knit. An increase in air permeability of the fabric means that more air will be able to penetrate through the fabric, which will enhance heat and vapour transfer from the guarded hot plate surface. Hence, a fabric with high air permeability implies a more open structure, which will give a cooler perception to the wearer in comparison to a less permeable one. In other words, lower air permeability thus implies a superior cover and hence improved fabric warmth[56]. As a result of statistical evaluation, fabric tightness does not have an important effect on thermal resistance and thermal conductivity[97].

4.4 Moisture Management properties

Moisture management often refers to the transport of both moisture vapour and liquid away from the body.

4.4.1 Cotton knitted fabrics

4.4.1.1 Single Jersey fabrics

Liquid moisture transport test results of cotton knitted single jersey fabrics in value are given in Table 4.51 and the results converted into grades are given in Table 4.52 where grades range from 1 to 5 – poor to excellent.

Wetting time

The wetting time of top surface (WTt) and bottom surface (WTb) are the time periods in which the top and bottom surfaces of the fabric just start to get wetted, respectively, after the test commences, which are defined as the time in second (s), when the slope of total water content at the top and bottom surfaces become greater than Tan (15^0). As can be seen from Table 4.51 and figure 4.51 the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

It is interesting to observe the differential behavior of the top and bottom surfaces of the single jersey cotton knitted fabric: a comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) shows that the WTt is smaller than the WTb, suggesting that it took longer for the liquid water to be transferred to the bottom layer.

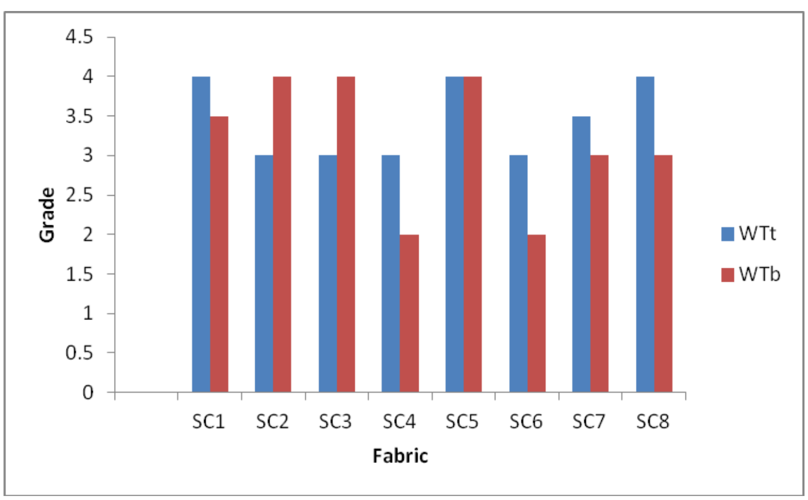

Figure 4.51: Top and bottom wetting time grades of the single jersey cotton knitted fabrics.

Table 4.51: MMT results of Cotton knitted Single Jersey fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SC1	Mean	8.9856	98.1902	316.8058	2.5626	5	1	0.5496	0.0898	-1174.2134	0.0016
	S.Deviation	0.9543	48.7682	121.1425	5.7301	0	2.2361	0.0549	0.2008	17.0267	0.0035
	CV	0.1062	0.4967	0.3824	2.2361	0	2.2361	0.0999	2.2361	0.0145	2.2361
SC2	Mean	8.4988	34.8568	238.3519	7.4719	5	5	0.5876	0.4949	82.0412	0.1477
	S.Deviation	1.3522	39.6783	99.7125	4.0206	0	0	0.0974	0.2796	15.9484	0.0174
	CV	0.1591	1.1383	0.4183	0.5381	0	0	0.1658	0.5651	0.1944	0.1176
SC3	Mean	8.555	33.8834	292.9853	4.5907	5	5	0.5723	0.2731	25.9553	0.0844
	S.Deviation	0.2527	25.9319	96.2435	3.0552	0	0	0.0165	0.2228	15.1425	0.0168
	CV	0.0295	0.7653	0.3285	0.6655	0	0	0.0288	0.816	0.5834	0.199
SC4	Mean	9.2478	55.5068	326.4316	1.8819	5	5	0.5304	0.2914	-57.2784	0.0011
	S.Deviation	0.2991	58.9055	134.6226	1.7205	0	0	0.0167	0.1732	9.6776	0.0025
	CV	0.0323	1.0612	0.4124	0.9142	0	0	0.0315	0.5945	0.169	2.2361
SC5	Mean	5.148	5.6344	73.8905	21.1964	19	18	3.2658	2.5924	451.9518	0.6629
	S.Deviation	2.2271	1.8061	20.8584	4.3191	2.2361	2.7386	2.2217	0.8531	18.1936	0.0694
	CV	0.4326	0.3206	0.2823	0.2038	0.1177	0.1521	0.6803	0.3291	0.0403	0.1046
SC6	Mean	9.2666	67.3756	406.3354	1.976	5	5	0.531	0.2251	-56.7902	0.0039
	S.Deviation	0.6717	49.7521	61.3006	1.8077	0	0	0.0371	0.1496	25.3556	0.0052
	CV	0.0725	0.7384	0.1509	0.9148	0	0	0.0699	0.6643	0.4465	1.3427
SC7	Mean	6.9264	18.1956	301.7767	8.8871	5	7	4.0434	0.5433	22.1682	0.0904
	S.Deviation	4.2241	9.5945	184.7312	7.0586	0	2.7386	7.6885	0.3694	39.223	0.0395
	CV	0.6099	0.5273	0.6121	0.7943	0	0.3912	1.9015	0.6799	1.7693	0.4375
SC8	Mean	5.373	8.1246	77.9549	10.2765	13	12	7.1505	1.1764	440.5118	0.5144
	S.Deviation	8.6027	3.4318	55.4378	4.3057	2.7386	2.7386	7.8928	0.7472	68.0707	0.0805
	CV	1.6011	0.4224	0.7112	0.419	0.2107	0.2282	1.1038	0.6352	0.1545	0.1565

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.52: MMT results of Cotton knitted Single Jersey fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SC1	1.64	4	3.5	2.5	2	2.5	3	2.5	3	4	3
SC2	1.53	3	4	3	1	1	1	1	2	2	1
SC3	1.43	3	4	3	1	1	2	2	1.5	1.5	1
SC4	1.34	3	2	5	1	1	1	1	1	1	1
SC5	1.42	4	4	4	2	4	3	3	3	5	4
SC6	1.33	3	2	5	1	1	1	1	1	1.5	1
SC7	1.24	3.5	3	5	1	1	1	2	1	2	1
SC8	1.16	4	3	2	2	3	3	2	3	4	3

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

These phenomena could be due to the factor that the moisture diffusion into a fabric through air gaps between yarns and fibers is a fast process, while moisture diffusion into fibres is coupled with the heat-transfer process, which is much slower and is dependent on the ability of fibres to absorb moisture[51]. It is notable that fabric SC4 and SC6 has the smallest mean WTb, demonstrating that it has a better liquid transfer ability from the top to the bottom layer. It can be seen that fabric SC5 has the fastest wetting time in both top and bottom surfaces and have equal grades in top and bottom wetting time.

Cotton fiber is a good moisture absorber. Contrary to synthetic fiber, it does not transport water from the surface by using the capillarity, but uses the absorption method, which let water to penetrate into the fibre. The results of that generally wetting time of the bottom surfaces are higher than top surfaces for all fabrics as expected. In the scope of this explanation, it can be stated that, the wetting time value is related with the water absorbency of the fabric.

It can be stated that the finer the yarn, the lower the wetting time is. As the yarns get finer, the thickness of the fabric decreases. When the results of thin and thick fabrics from same type of material compared, thinner fabrics shown faster wetting than thicker ones, when equal amount of water are applied. Since the number of fibres in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid.

Absorption rates

Absorption rates on the top and bottom surfaces (% / sec) are the average moisture absorption ability of the specimen, in the pump time. It can also be seen from Table 4.51 and figure 4.52 that the absorption rate values change according to yarn count and tightness factor. Because of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases. Therefore the absorption rate values of the thinner fabrics become higher. As can be seen from Table 4.51, the bottom absorption rates of the fabrics are generally lower than top surfaces. Fabrics SC4, SC6 and SC7 have an extraordinarily higher absorption rate on top surface (ARt) which may be because of the liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content of the top surface (see figure 4.53).

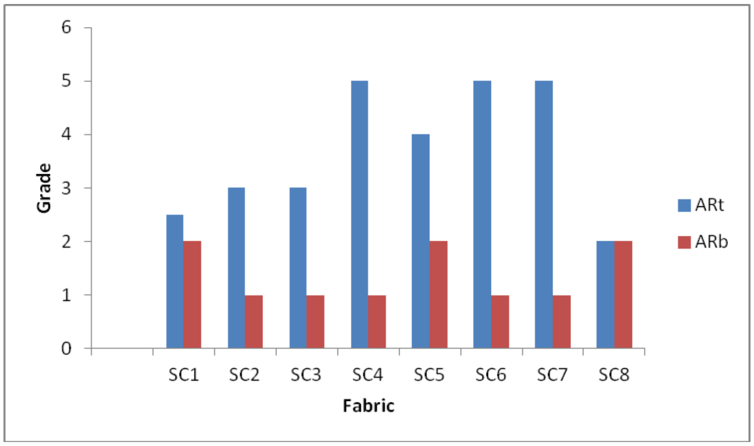

Figure 4.52: Top and bottom absorption rate grades of the single jersey cotton knitted fabrics.

Spreading speed

Spreading speed is associated with the moisture transport, which occurs parallel to the fabric surface. As the spreading speed values are compared it can be clearly seen that, higher the yarn count, higher the spreading speed is. Figure 4.54 shows the top and bottom spreading speed grades of single jersey fabrics knitted with cotton yarn. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the fabric shorten. SC5 has medium spreading speed grade while SC6 has very slow spreading speed grade among others.

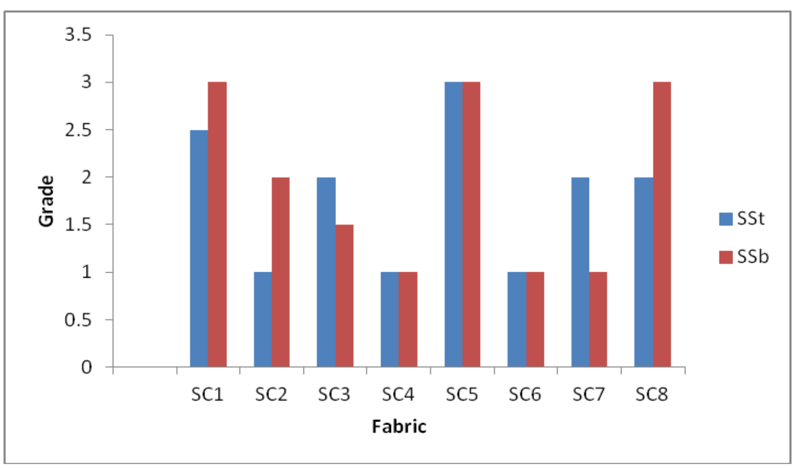

Figure 4.54: Top and bottom spreading speed grades of the single jersey cotton knitted fabrics.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. The MWR values are lower in cotton single jersey knitted fabrics because of the hydrophilic character of cotton fibres, some of the test liquid is absorbed by the fibres and penetrates into the fibre structure, which results in lower moisture spreading along the fabric[114]. According to the maximum wetted results, the value increases for the fabrics made from 15Tex yarn. In single jersey knitted fabrics SC5 have large maximum wetted radius, while SC2, SC4, SC6 and SC7 have grade 1, which means no wetting. Water location versus time can be obtained as a colourful simulation which is given in figure 4.53. Figure 4.55 shows the typical liquid moisture content change versus test time on the fabrics top layer measured by the MMT for single jersey knitted fabric:SC5. This figure shows the dynamic moisture management process of a particular fabric during the test time. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

In the test equipment the top surface of the fabric is designed as inner surface that will be in touch with the human skin. Therefore, lower top MWR means lower wet touch, lower chilly feeling, and high skin comfort. Since SC1, SC2, SC3, SC4 and SC6, SC7 fabrics have the lowest top wetted radius value, which also indicate their good moisture transport property, they will give a dry feeling.

Figure 4.56 shows the mean grade of the top and bottom wetted radius of all eight single jersey knitted fabrics.

For fabrics SC5 and SC8, the water content of the bottom layer was significantly higher than that of the top layer as soon as the fabrics were wetted by liquid water, indicating that liquid water was transferred quickly to the bottom layer from the top layer. For other fabrics, the water content of top layer was higher than that of bottom layer lasting for seconds in duration of pumping; it then decreased dramatically. Figure 4.57 shows the accumulative one-way transport index grades and overall moisture management capacity of single jersey fabrics knitted with cotton.

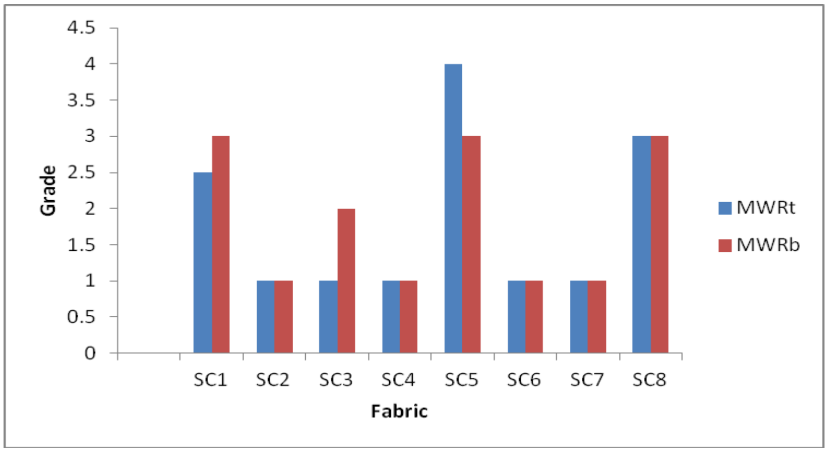

Figure 4.56: Top and bottom maximum wetted radius grades of the single jersey knitted cotton fabrics.

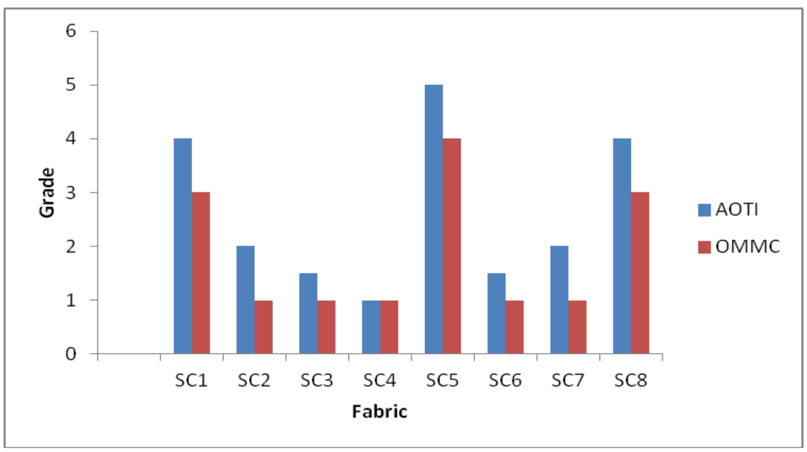

Figure 4.57: Accumulative one-way transport index grades and overall moisture management capacity of the single jersey fabrics knitted with cotton.

Relationship between Tightness factor and the moisture management properties

To find the possible relationship between tightness factor and moisture management properties of knitted fabrics, scatter plots with regression lines of MMT indices and Tightness factor were generated. The scatter plots of tightness factor versus Top wetting time (WTt) and tightness factor versus Bottom wetting time (WTb) reflect that relationships between tightness factor and Top wetting time (WTt) were not similar in both the counts and between tightness factor and Bottom wetting time (WTb) were relatively similar in both the counts. Both Top wetting time (WTt) and Bottom wetting time (WTb) increased as tightness factor increased in case of single jersey fabrics

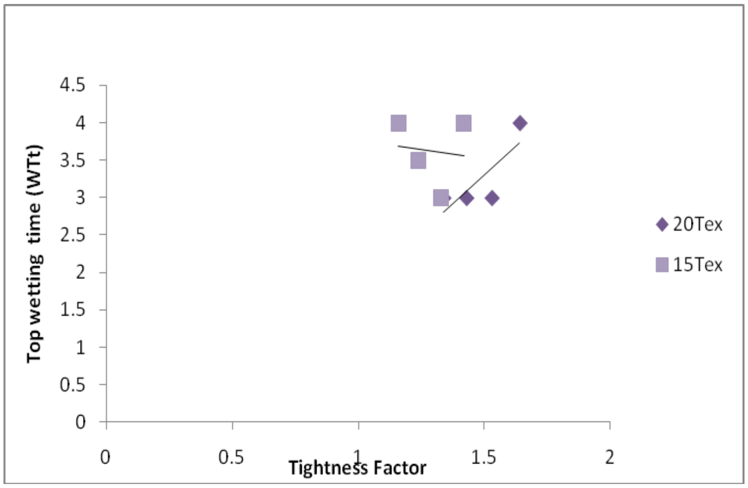

Figure 4.58: Top wetting time (WTt) versus tightness factor in Single Jersey Cotton Knitted fabrics.

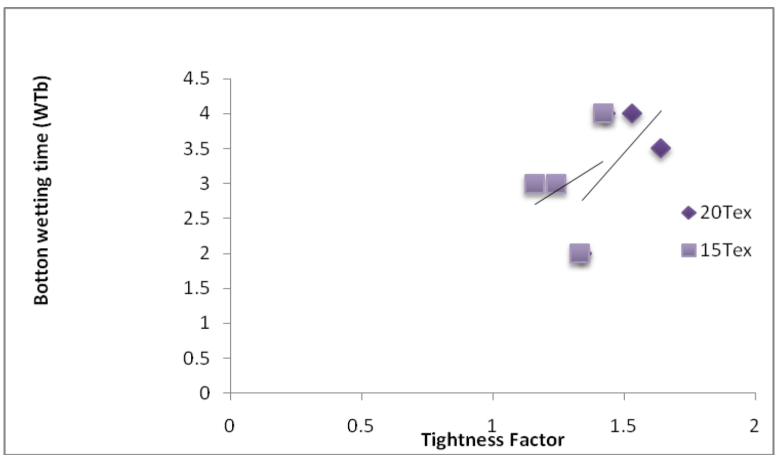

Figure 4.59: Bottom wetting time (WTb) versus tightness factor in Single Jersey Cotton Knitted fabrics.

knitted with 15Tex. This is probably due to the size difference in inter-loop pores: as the size of inter-loop pores is large due to the low tightness factor, it takes less time to wet the fabric surface[137].

In regard to the maximum wetted radius, the relationships between tightness factor and Top maximum wetted radius (MWRt) and between tightness factor versus Bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus Top maximum wetted radius (MWRt) (see figure 4.60) and of tightness factor versus Bottom maximum wetted radius (MWRb) (see figure 4.61). No clear trend observed.

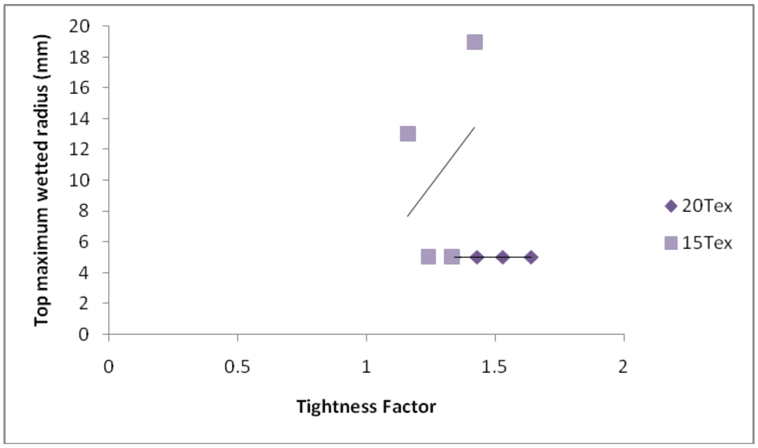

Figure 4.60: Top maximum wetted radius (MWRt) versus tightness factor in single jersey cotton knitted fabrics.

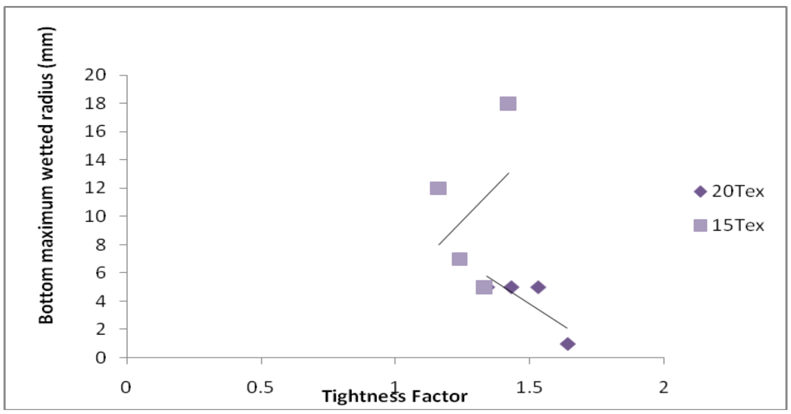

Figure 4.61: Bottom maximum wetted radius (MWRb) versus tightness factor in single jersey cotton knitted fabrics.

The scatter plot of tightness factor versus Top absorption rate (ARt) depicts the relationship between tightness factor and Top absorption rate (ARt): Top absorption rate (ARt) decreased as tightness factor increased in the case of fabric knitted with 20Tex. This is probably caused by low fabric porosity. Similarly to the above, as in fabrics with low porosity, the inter-loop pore size is smaller, so it takes more time for a liquid to wet the fabric, and thus, the absorption of it by the fabric during the testing time is relatively less in comparison with an open-structure fabric with high porosity[137].

While in case of fabric knitted with 15Tex both Top absorption rate (ARt) and Bottom absorption rate (ARb) increased with increase in tightness factor (see figure 4.62 and 4.63).

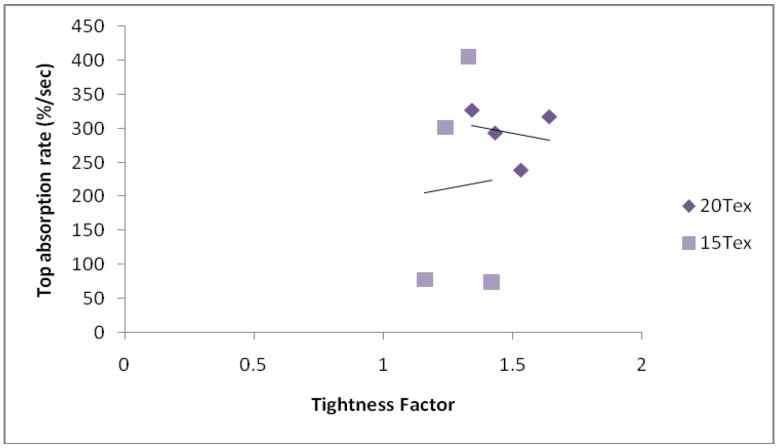

Figure 4.62: Top absorption rate (ARt) versus tightness factor in single jersey knitted cotton fabric.

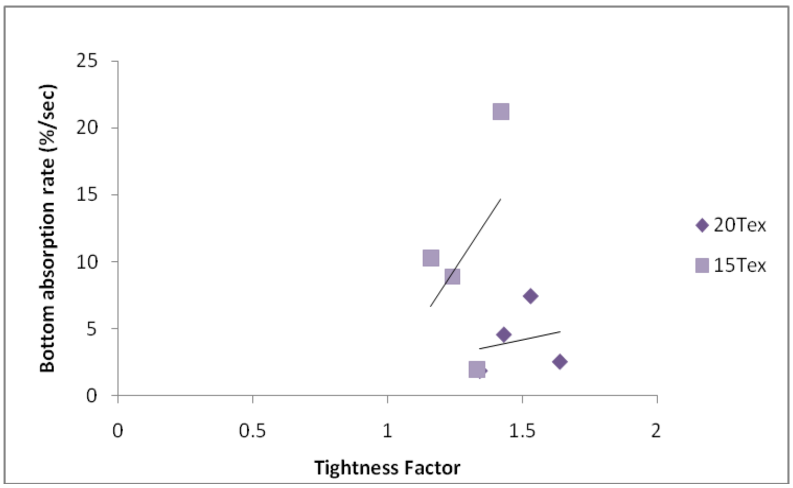

Figure 4.63: Bottom absorption rate (ARb) versus tightness factor in single jersey knitted cotton fabric.

The scatter plot of tightness factor versus Top spreading speed (SSt) and of tightness factor versus Bottom spreading speed (SSb) indicate the relationships between tightness factor and Top spreading speed (SSt) and between tightness factor and Bottom spreading speed (SSb). No clear trend observed (see figure 4.64 and 4.65). Accumulative one-way transport index exhibits the liquid transport from top surface to bottom surface of fabric. If the AOTI value of one fabric is between 200 and 400 it means that the one-way transport is very good. Also for the fabric having the value higher than 400, one-way transport is defined as excellent.

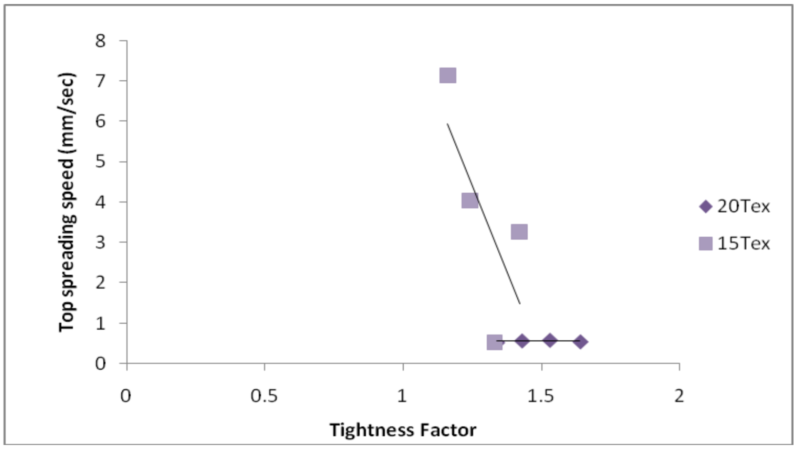

Figure 4.64: Top spreading speed (SSt) versus tightness factor in single jersey cotton knitted fabric.

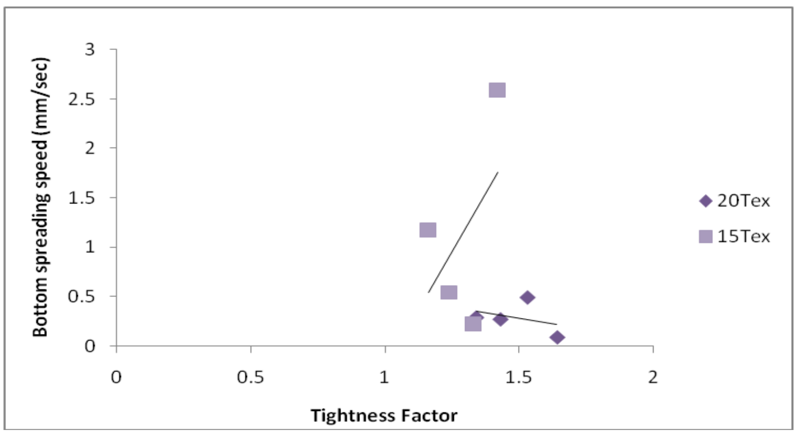

Figure 4.65: Bottom spreading speed (SSb) versus tightness factor in single jersey cotton knitted fabric.

In light of this knowledge when table 4.51 and Figure 4.66 examined AOTI values of SC5 and SC8 showed excellent AOTI because values are approximately above 400. However as the fabrics are cellulosic based, in this case one-way liquid transport is limited. Overall moisture management capacity (OMMC) is an index to indicate the overall capability of the fabric to manage the transport of liquid moisture. The larger the OMMC is, the higher the overall moisture management capability of the fabric.

Liquid moisture management capacity shows that liquid sweat can be easily and quickly transferred from next to the skin to the outer surface to keep the skin dry. If the OMMC of a fabric is in 0.6-0.8 range it means that the liquid moisture management capacity is very good.

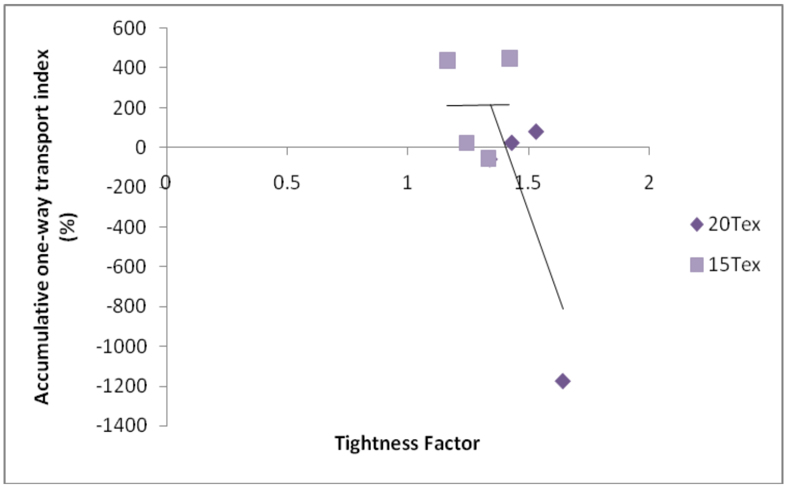

Figure 4.66: Accumulative one-way transport index (AOTI) versus tightness factor in single jersey cotton knitted fabric.

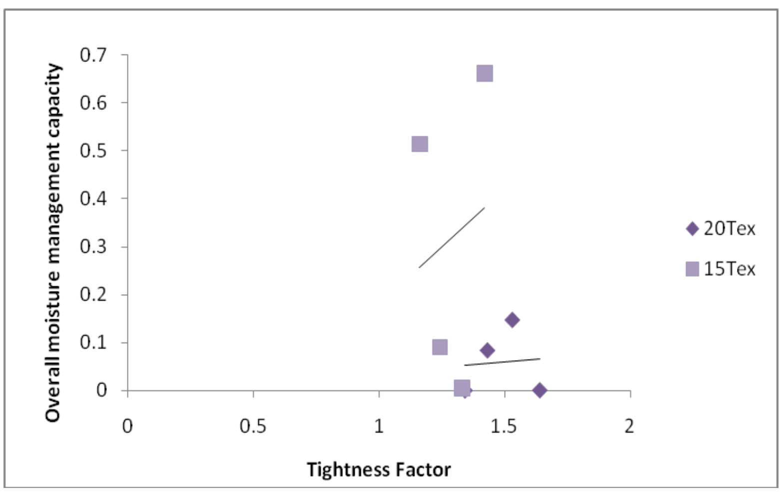

Figure 4.67: Overall moisture management capacity (OMMC) versus tightness factor in single jersey cotton knitted fabric.

Also, for the fabric having the value higher than 0.8, the overall capability of the fabric is defined as excellent. OMMC increased as the tightness factor increased in both the counts (see figure 4.67). SC5 showed good result ranging in 0.6-0.8.

For the evaluation of the statistical importance of the tightness factor on the moisture management properties of the knitted fabrics, Pearson correlation was found. In order to decide the statistical significance of the variable on the related property, p value is also used. The higher the p-value, the less it can be believed that the observed relation between variables in the sample is a reliable indicator of the relation between the respective variables in the population. Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.53.

Table 4.53: Pearson correlations and p-values of tightness factor versus MMT indices of Single Jersey Cotton Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.474	0.235
2.	T.F., WTb	0.604	0.113
3.	T.F. ARt	0.235	0.576
4.	T.F., ARb	-0.170	0.688
5.	T.F., MWRt	-0.232	0.580
6.	T.F., MWRb	-0.428	0.29
7.	T.F., SSt	-0.716	0.046
8.	T.F., SSb	-0.199	0.636
9.	T.F., AOTI	-0.636	0.67
10.	T.F., OMMC	-0.298	0.473

Top wetting time (WTt), Bottom wetting time (WTb), Bottom maximum wetted radius (MWRb) and Overall moisture management capacity (OMMC) are not linearly related with tightness factor. This is probably due to the difference in accumulative moisture content between the two surfaces of the fabric in the given testing time, the moisture content on the top fabric surface is more than that on the bottom surface, and at times, the opposite is true. It can be observed that the Pearson correlations are not close to +1 or -1. This indicates that for single jersey fabric knitted with cotton yarn with tightness factor does not influence the overall moisture management fabric properties except Top spreading speed (SSt). Figure 4.68, show example of the typical fingerprint of moisture management properties of fabric sample-SC5. It can be seen that the fabrics can be classified into fabric type, based on grades, in order to give a direct overall evaluation and result for their liquid moisture management properties if required.

4.4.1.2 Pique fabrics

Liquid moisture transport test results of cotton pique knitted fabrics in value are given in Table 4.54 and the results converted into grades are given in Table 4.55 where grades range from 1 to 5 – poor to excellent. As can be seen from Table 4.54, the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

Wetting time

A comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the pique knitted fabric shows that the wetting time of the top surface (WTt) is smaller than the wetting time of the bottom surface (WTb) similar to single jersey fabrics, suggesting that it took longer for the liquid water to be transferred to the bottom layer. It is notable that fabric SC11has the smallest mean wetting time of the bottom surface (WTb) , demonstrating that it has a better liquid transfer ability from the top to the bottom layer. Figure 4.69 shows the mean grade of the top and bottom wetting time of the pique knitted fabrics. It can be seen that fabric SC11has the fastest wetting time in both top and bottom surfaces, and SC13 have equal grades in top and bottom wetting time.

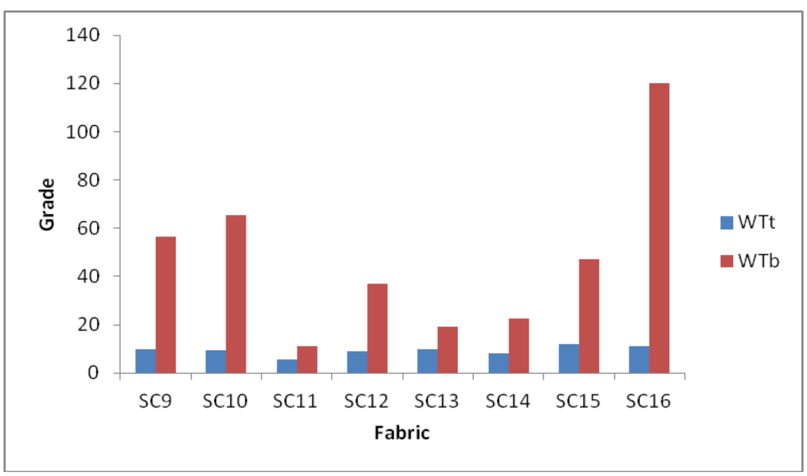

Figure 4.69: Top and bottom wetting time grades of cotton pique fabrics.

Table 4.54: MMT results of Cotton knitted Pique fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SC9	Mean	9.8098	56.4422	382.0193	2.7386	5	4	0.5033	0.2216	-249.7617	0.0962
	S.Deviation	0.8763	54.6792	139.9547	1.7357	0	2.2361	0.0447	0.1932	385.2366	0.1335
	CV	0.0893	0.9688	0.3664	0.6338	0	0.559	0.0889	0.8722	1.5424	1.3883
SC10	Mean	9.5284	65.4088	252.5281	3.6961	5	5	0.5229	0.2884	191.8413	0.2687
	S.Deviation	1.267	51.4761	164.7928	3.3128	0	0	0.0792	0.2336	52.8102	0.0587
	CV	0.133	0.787	0.6526	0.8963	0	0	0.1516	0.8102	0.2753	0.2184
SC11	Mean	5.6348	11.1572	180.4675	4.1432	5	8	1.5056	1.3551	700.5378	0.5572
	S.Deviation	3.6992	5.3375	150.2651	2.1134	0	2.7386	1.298	1.4574	297.3965	0.1008
	CV	0.6565	0.4784	0.8326	0.5101	0	0.3423	0.8621	1.0755	0.4245	0.1809
SC12	Mean	9.0794	36.8422	186.5374	3.6465	5	5	0.5399	0.3386	490.5595	0.5
	S.Deviation	0.2645	47.6968	66.8107	2.2386	0	0	0.0153	0.2262	8.7741	0
	CV	0.0291	1.2946	0.3582	0.6139	0	0	0.0284	0.668	0.0179	0
SC13	Mean	9.828	19.1508	319.6268	4.8643	5	4	0.5414	0.192	716.7353	0.5007
	S.Deviation	1.589	8.6278	164.9818	3.626	0	2.2361	0.0492	0.1415	276.2416	0.0017
	CV	0.1617	0.4505	0.5162	0.7454	0	0.559	0.0909	0.7368	0.3854	0.0033
SC14	Mean	8.0312	22.6142	215.7077	3.3741	5	8	0.6109	0.7444	1078.4586	0.5247
	S.Deviation	0.5897	13.8122	127.3445	0.4688	0	2.7386	0.0439	0.9822	86.4005	0.0552
	CV	0.0734	0.6108	0.5904	0.1389	0	0.3423	0.0719	1.3194	0.0801	0.1051
SC15	Mean	11.8498	47.0434	342.5419	3.4139	5	6	0.4406	0.3964	1146.9651	0.5
	S.Deviation	2.7601	33.4856	140.003	0.4489	0	4.1833	0.1384	0.2653	41.6883	0
	CV	0.2329	0.7118	0.4087	0.1315	0	0.6972	0.3141	0.6693	0.0363	0
SC16	Mean	11.1386	120	290.9236	0	5	0	0.4619	0	379.8267	0.4748
	S.Deviation	2.6834	0	181.9279	0	0	0	0.1086	0	24.109	0.0224
	CV	0.2409	0	0.6253	0	0	0	0.2352	0	0.0635	0.0472

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.55: MMT results of Cotton knitted Pique fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	WRt	WRb	SSt	SSb	AOTI	OMMC
SC9	1.64	3	2	5	1	1	1	1	1	2	1
SC10	1.53	3	2	5	5	1	1	1	1	3	2
SC11	1.43	4	3	4	1	1	1	2	2	5	2
SC12	1.34	3	2.5	5	1	1	1	1	1	5	3
SC13	1.42	3	3	5	1	1	1	1	1	5	3
SC14	1.33	3.5	3	5	1	1	2	1	1	5	3
SC15	1.24	3	2	5	1	1	1	1	1	5	3
SC16	1.16	3	1	5	1	1	1	1	1	5	3

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Absorption rates

It can also be seen from Table 4.54 that the absorption rate values change according to yarn count and tightness factor. Because of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases. Therefore the absorption rate values of the thinner fabrics become higher. As can be seen from Table 4.54, the bottom absorption rates of the fabrics are generally lower than top surfaces. Fabrics SC9, SC15 have an extraordinarily higher top absorption rate (ARt) which may be because of the liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content of the top surface. In Pique knitted fabrics with 20Tex, as the tightness factor increases, the top absorption rate (ARt) of the fabric increases, ranging from slow to very fast. Figure 4.70 shows the absorption rates grades of cotton pique fabrics.

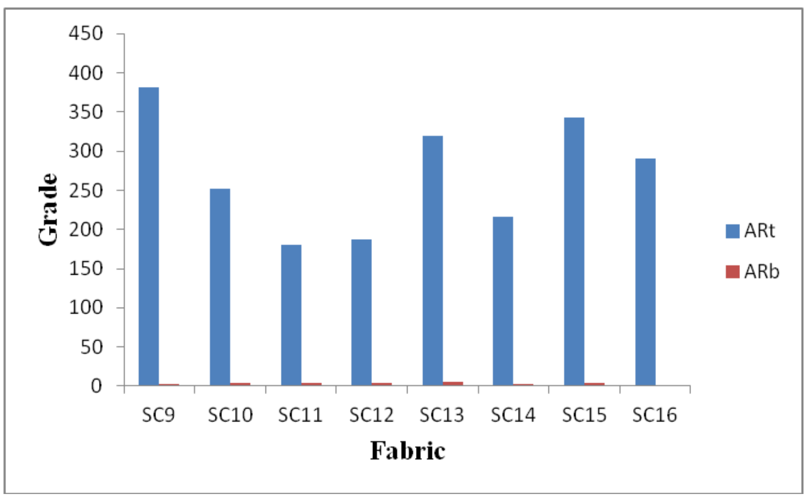

Figure 4.70: Top and bottom absorption rate grades of cotton pique fabrics.

SC11 has slow spreading speed grade and others have very slow spreading speed grade. In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. Pique knitted fabrics have grade 1, which means no wetting. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20^{th} second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

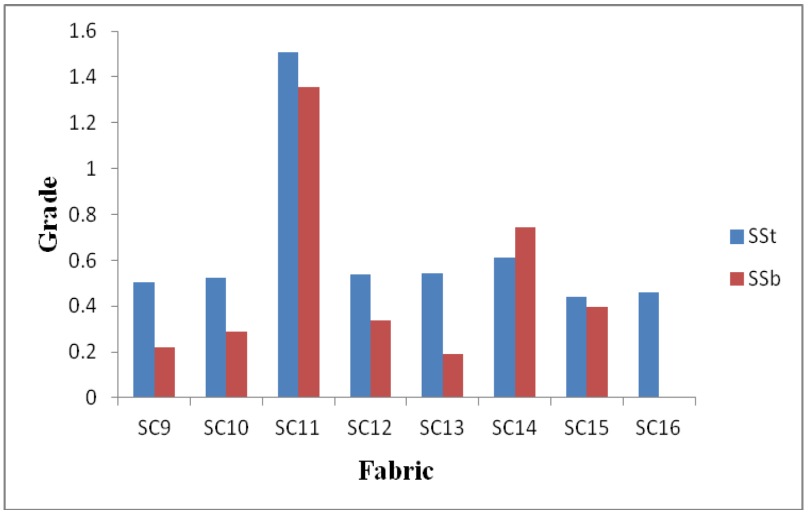

Figure 4.71: Top and bottom spreading speed grades of cotton pique fabrics.

Figure 4.71 shows the top and bottom spreading speed grades of cotton pique fabrics. For pique knitted fabrics in all except SC9, the water content of bottom layer was significantly higher than that of the top layer as soon as the fabrics were wetted by liquid water, indicating that the liquid water was transferred quickly to the bottom layer from the top layer. Figure 4.72 shows the maximum top and bottom wetted radius grade for pique fabrics. Figure 4.73 shows the accumulative one-way transport index grades and overall moisture management capacity of cotton pique fabrics.

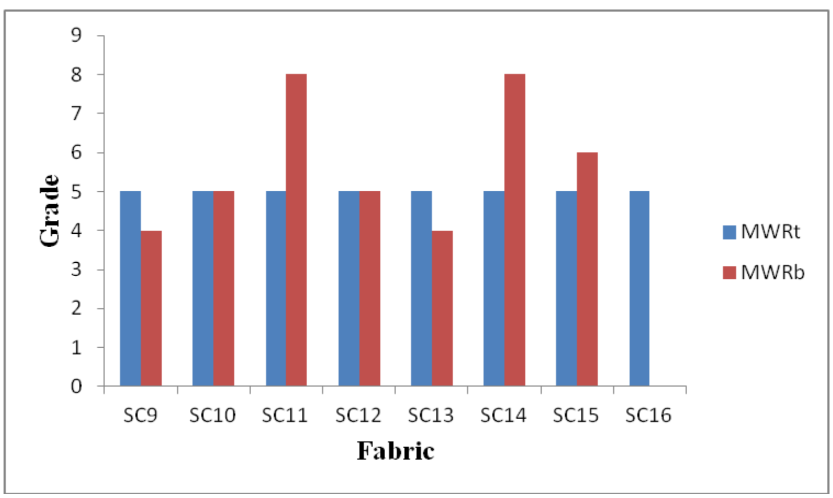

Figure 4.72: Top and bottom maximum wetted radius grade of cotton pique fabrics.

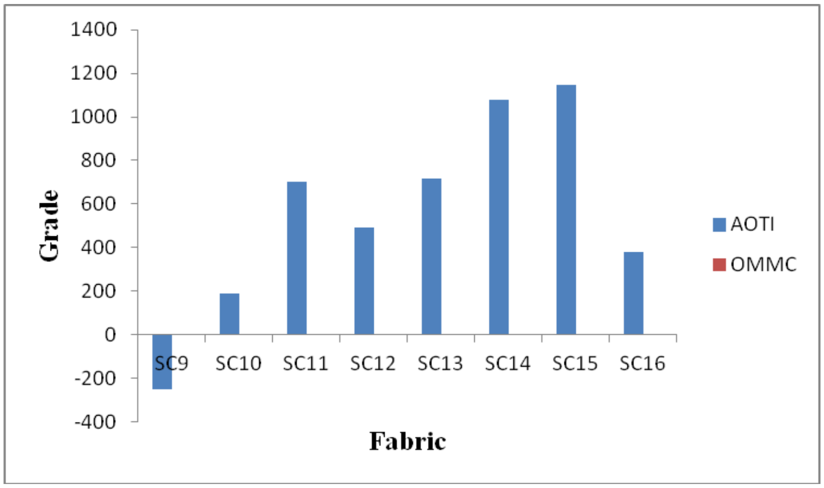

Figure 4.73: Accumulative one-way transport index grades and overall moisture management capacity of cotton pique fabrics.

Relationship between Tightness factor and the moisture management properties

To find the possible relationship between tightness factor and moisture management properties of knitted fabrics, scatter plots with regression lines of MMT indices and Tightness factor were generated. The scatter plots of tightness factor versus top wetting time (WTt) and tightness factor versus bottom wetting time (WTb) reflect that relationships between tightness factor and top wetting time (WTt) and bottom wetting time (WTb) and tightness factor.

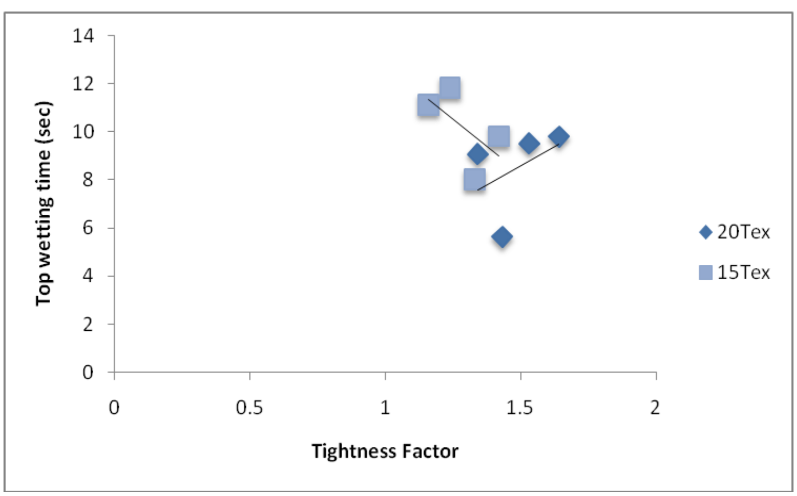

Figure 4.74: Top wetting time (WTt) versus tightness factor in Pique Cotton Knitted fabrics.

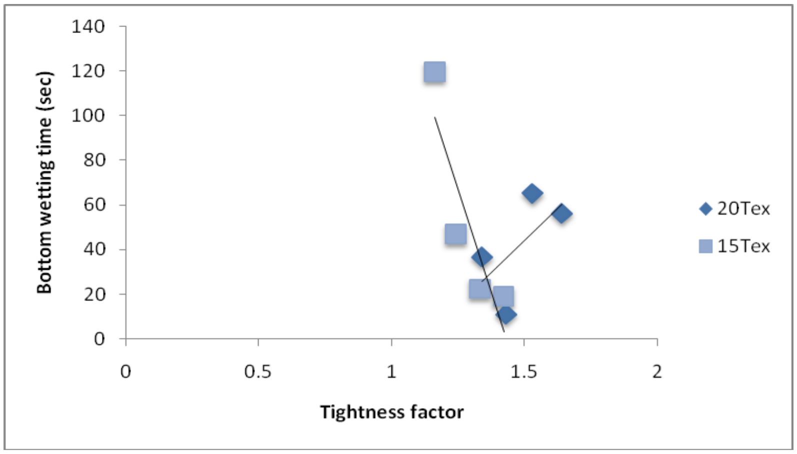

Figure 4.75: Bottom wetting time (WTt) versus tightness factor in Pique Cotton Knitted fabrics.

It was observed that both top wetting time (WTt) and bottom wetting time (WTb) decreased with increase in tightness factor in case of fabric knitted with 20Tex. While for fabric knitted with 15Tex indicate reverse trend. In regard to the maximum wetted radius, the relationships between tightness factor and top maximum wetted radius (MWRt) and between tightness factor versus bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus top maximum wetted radius (MWRt) and of tightness factor versus bottom maximum wetted radius (MWRb). No clear trend observed similar to single jersey knitted fabrics (see figure 4.76 and 4.77).

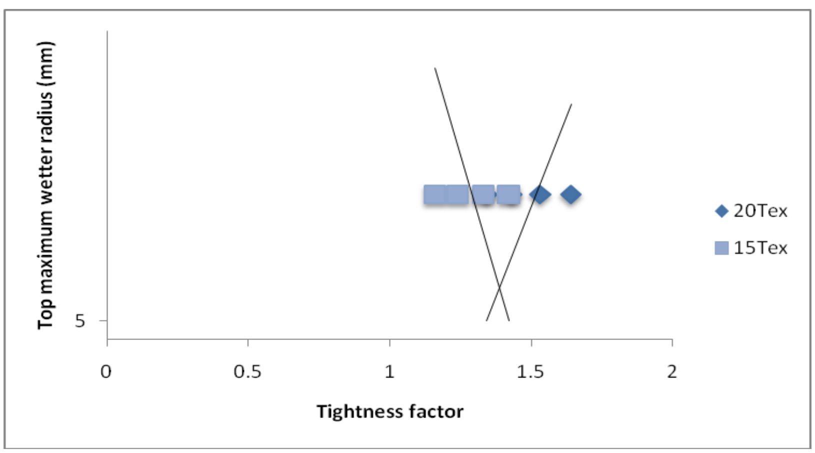

Figure 4.76: Top maximum wetted radius (MWRt) versus tightness factor in Cotton Pique knitted fabrics.

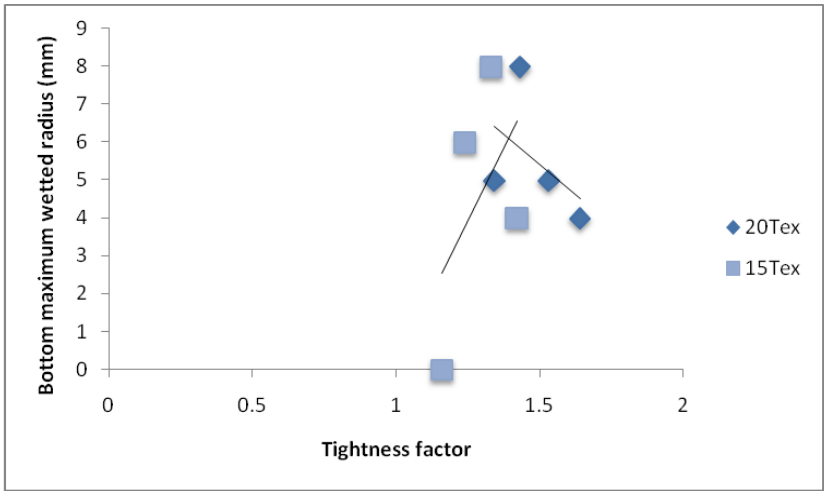

Figure 4.77: Bottom maximum wetted radius (MWRb) versus tightness factor in Cotton Pique knitted fabrics.

The scatter plot of tightness factor versus top absorption rate (ARt) depicts the relationship between tightness factor and top absorption rate (ARt): top absorption rate (ARt) decreased and bottom absorption rate (ARb) increases as tightness factor increased in the case of fabric knitted with 15Tex. While in case of fabrics knitted with 20Tex both decreases (see figure 4.78 and 4.79).

The scatter plot of tightness factor versus top spreading speed (SSt) and of tightness factor versus Bottom spreading speed (SSb) indicate the relationships between tightness factor and top spreading speed (SSt) and between tightness factor and Bottom spreading speed (SSb) were relatively similar for pique fabric knitted with 15Tex and 20Tex (see figure 4.80 and 4.81).

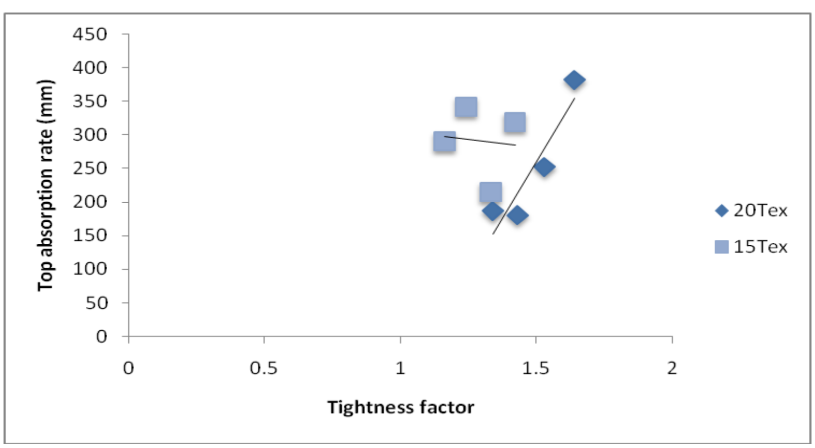

Figure 4.78: Top absorption rate (ARt) versus tightness factor in Cotton Pique knitted fabric.

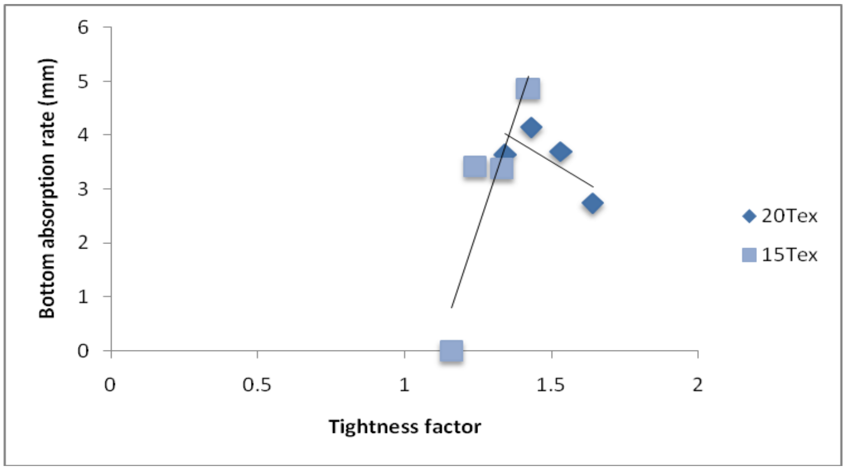

Figure 4.79: Bottom absorption rate (ARb) versus tightness factor in Pique knitted cotton fabric.

Both top spreading speed (SSt) and Bottom spreading speed (SSb) decreased as tightness factor increased in case of 20Tex while increased with increase in tightness factor in case of 15Tex knitted pique fabric. When table 4.54 and Figure 4.82 examined Accumulative one-way transport index (AOTI) values of SC9 and SC16 showed very good AOTI because values are approximately near 400. AOTI values of SC11, SC12 and SC13 showed excellent AOTI with values above 700 and better to these were showed by SC14 and SC15 with values above 1000.

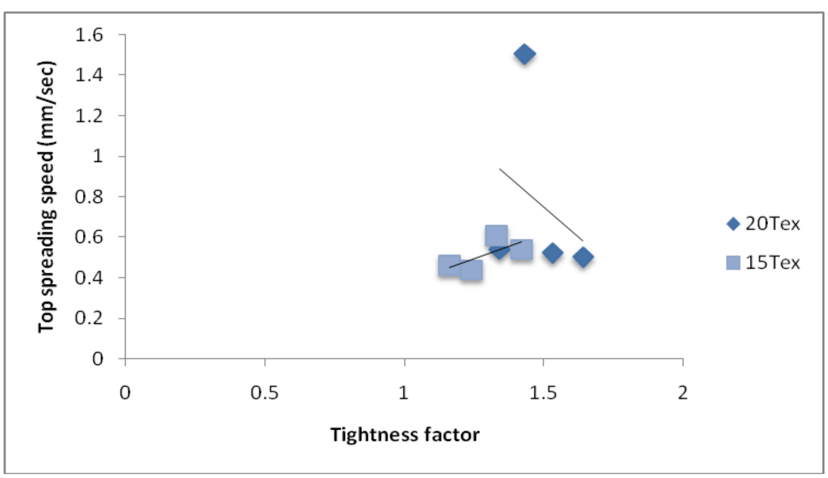

Figure 4.80: Top spreading speed (SSt) versus tightness factor in pique knitted cotton fabric.

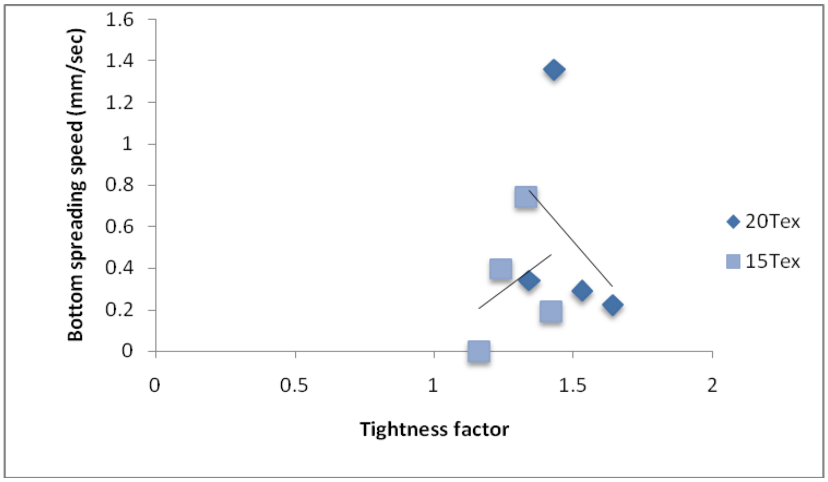

Figure 4.81: Bottom spreading speed (SSb) versus tightness factor in pique knitted cotton fabric.

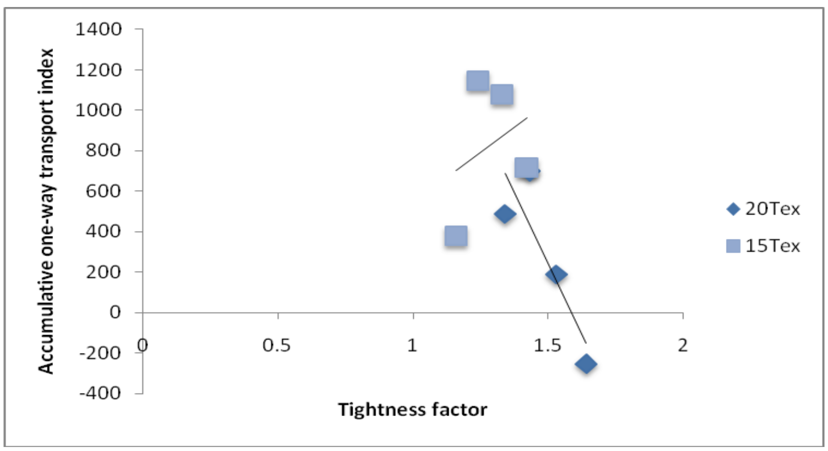

Figure 4.82: Accumulative one-way transport index (AOTI) versus tightness factor in pique knitted cotton fabric.

Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.56. Accumulative one-way transport index (AOTI) and Overall moisture management capacity (OMMC) are influenced by tightness factor since the Pearson correlation of Accumulative one-way transport index (AOTI) and tightness factor and Overall moisture management capacity (OMMC) and tightness factor are linearly related. Except SC9 which is classified into water repellent fabric, all other pique knitted are classified into water penetration fabric.

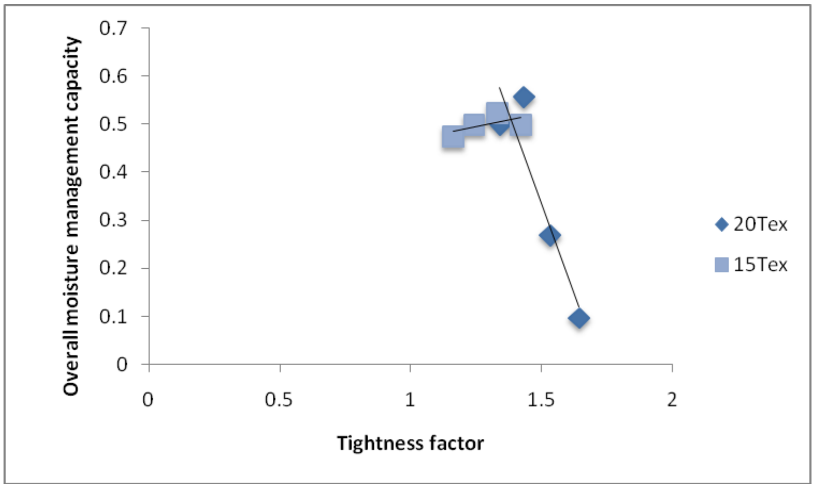

Figure 4.83: Overall moisture management capacity (OMMC) versus tightness factor in pique knitted cotton fabric.

Table 4.56: Pearson correlations and p- values of tightness factor versus MMT indices of Pique Knitted cotton fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	-0.245	0.525
2.	T.F., WTb	-0.230	0.551
3.	T.F. ARt	0.381	0.311
4.	T.F., ARb	0.331	0.385
5.	T.F., MWRt	*	*
6.	T.F., MWRb	0.134	0.731
7.	T.F., SSt	0.062	0.874
8.	T.F., SSb	-0.003	0.993
9.	T.F., AOTI	-0.736	0.024
10.	T.F., OMMC	-0.819	0.007

*All value identical

It is important to note that classification into type 1 – type 7 (water proof, water repellent, slow absorbing, slow drying, fast absorbing, quick drying, water penetration and moisture management) fabrics could sometimes be somewhat too simplified and thus misleading, and is not suitable for research purpose or for in-depth commercial evaluation.

Knitted fabrics in single jersey and pique construction with different counts and tightness factors have different moisture management properties and performance attributes, thus potentially it is possible to engineer fabrics of such construction to the required moisture management performance.

Single jersey cotton knitted fabrics were classified as water proof, water repellent and moisture management fabrics with key properties of slow-to-fast wetting, very –slow- to very-fast absorption, no wetting to small spreading area, very slow to very fast spreading and poor to excellent one-way transport properties.

Pique knitted fabrics were classified as water repellent and water penetration fabrics with key properties of medium –to-very fast wetting, very slow-to-fast absorption, no wetting area, very slow-to-slow spreading and poor-to excellent one-way transport properties.

4.4.2 Viscose knitted fabrics

4.4.2.1 Single jersey fabrics

Liquid moisture transport test results of viscose knitted single jersey fabrics in value are given in Table 4.57 and the results converted into grades are given in Table 4.58 where grades range from 1 to 5 – poor to excellent.

Wetting time

As can be seen from Table 4.57 and figure 4.84 the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

Figure 4.84: Top and bottom wetting time grades of the single jersey viscose knitted fabrics.

A comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the single jersey knitted fabric shows that the wetting time of the top surface (WTt) is slightly smaller than the wetting time of the bottom surface (WTb), suggesting that it took longer for the liquid water to be transferred to the bottom layer. It is notable that fabric SV8 has the smallest mean wetting time of the bottom surface (WTb), demonstrating that it has a better liquid transfer ability from the top to the bottom layer. It can be seen that fabric SV8 has the fastest wetting time in both top and bottom surfaces, and all the single jersey viscose fabrics have equal grades in top and bottom wetting time. It can be stated that the finer the yarn, the lower is the wetting time which is similar to the results observed in cotton knitted fabrics.

Table 4.57: MMT results of Viscose knitted Single Jersey fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SV1	Mean	2.5832	2.9576	63.4898	52.7908	19	18	3.5668	3.2936	-135.5023	0.2982
	S.Deviation	0.8893	0.8868	3.3564	4.1981	2.2361	2.7386	0.7761	0.8205	16.7317	0.0338
	CV	0.3443	0.2998	0.0529	0.0795	0.1177	0.1521	0.2176	0.2491	0.1235	0.1132
SV2	Mean	3.2262	3.2012	62.11034	55.86112	17	18	3.01942	3.04718	-97.297	0.29798
	S.Deviation	0.118047	0.139021	1.181553	0.449161	2.738613	2.738613	0.248375	0.219914	13.58973	0.017061
	CV	0.03659	0.043428	0.019023	0.008041	0.161095	0.152145	0.082259	0.07217	-0.13967	0.057257
SV3	Mean	3.0328	3.089	65.4876	56.93224	20	19	3.586	3.46162	-96.818	0.33576
	S.Deviation	0.125667	0.162236	1.876367	1.284001	0	2.236068	0.229868	0.327191	8.098006	0.026783
	CV	0.041436	0.052521	0.028652	0.022553	0	0.117688	0.064101	0.09452	-0.08364	0.079767
SV4	Mean	2.9202	2.9576	68.0739	57.8334	20	20	3.8332	3.7346	-125.7868	0.3608
	S.Deviation	0.1673	0.182	2.0604	2.1293	0	0	0.254	0.2303	7.8176	0.0187
	CV	0.0573	0.0615	0.0303	0.0368	0	0	0.0663	0.0617	0.0621	0.0517
SV5	Mean	2.8828	2.864	64.7902	58.6309	20	20	3.8336	3.7489	-123.6952	0.3629
	S.Deviation	0.2991	0.2529	3.2689	2.1365	0	0	0.2128	0.2125	25.5609	0.0165
	CV	0.1037	0.0883	0.0505	0.0364	0	0	0.0555	0.0567	0.2066	0.0455
SV6	Mean	2.8266	2.8456	66.7183	59.8149	21	21	3.9609	3.9034	-110.7839	0.3691
	S.Deviation	0.2025	0.194	3.7634	1.8453	2.2361	2.2361	0.501	0.4567	19.8789	0.0161
	CV	0.0717	0.0682	0.0564	0.0309	0.1065	0.1065	0.1265	0.117	0.1794	0.0436
SV7	Mean	2.6584	2.6768	65.0745	56.0339	22	21	4.1963	4.1222	-113.2427	0.3703
	S.Deviation	0.2527	0.244	2.533	2.5856	2.7386	2.2361	0.3872	0.367	12.0815	0.0117
	CV	0.0951	0.0912	0.0389	0.0461	0.1245	0.1065	0.0923	0.089	0.1067	0.0315
SV8	Mean	2.5458	2.5646	60.3387	56.973	22	24	4.3149	4.3041	-108.0637	0.3805
	S.Deviation	0.122	0.0835	4.6901	2.6561	2.7386	2.2361	0.2842	0.2152	18.937	0.0074
	CV	0.0479	0.0326	0.0777	0.0466	0.1245	0.0932	0.0659	0.05	0.1752	0.0194

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.58: MMT results of Viscose knitted Single Jersey fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SV1	1.64	5	5	4	3.5	4	3.5	4	4	1	2
SV2	1.53	4.5	4.5	4	3.5	3	4	4	4	1	2
SV3	1.43	4.5	4.5	4	3.5	4	4	4	4	1	2
SV4	1.34	5	5	4	3.5	4	4	4.5	4.5	1	2.5
SV5	1.42	5	5	4	3.5	4	4	4	4	1	2
SV6	1.33	5	5	4	3.5	4	4	4	4	1	2.5
SV7	1.24	5	5	4	3.5	4	4	5	5	1	2.5
SV8	1.16	5	5	4	3.5	4	5	5	5	1	2.5

(WTt : Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

As the yarns get finer, the thickness of the fabric decreases. When the results of thin and thick fabrics from same type of material compared, thinner fabrics shown faster wetting than thicker ones, when equal amount of water are applied. Since the number of fibres in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid.

Absorption rates

As can be seen from Table 4.57, the top absorption rates of the fabrics are higher than bottom surfaces similar to what observed in single jersey cotton fabrics which may be because of liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content on the top surface. Figure 4.85 shows top and bottom absorption rate grades of single jersey viscose fabrics. It can be seen clearly that the top absorption rate (ARt) and bottom absorption rate (ARb) grades of all single jersey viscose fabrics are same.

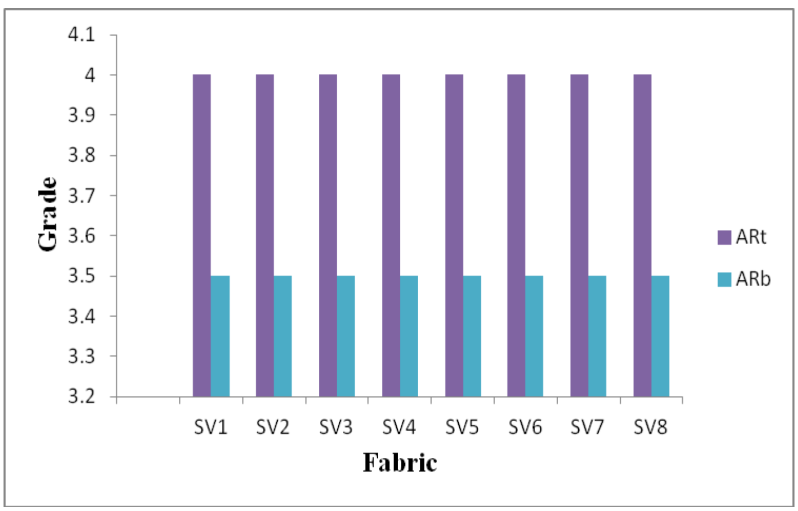

Figure 4.85: Top and bottom absorption rate grades of the single jersey viscose knitted fabrics.

Spreading speed

As the spreading speed values are compared it can be clearly seen that, higher the yarn count, higher the spreading speed is. Figure 4.86 shows the top and bottom spreading speed grades of single jersey fabrics knitted with viscose yarn. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the fabric shorten. SV7 and SV8 have very fast spreading speed grade while others have fast spreading speed grade.

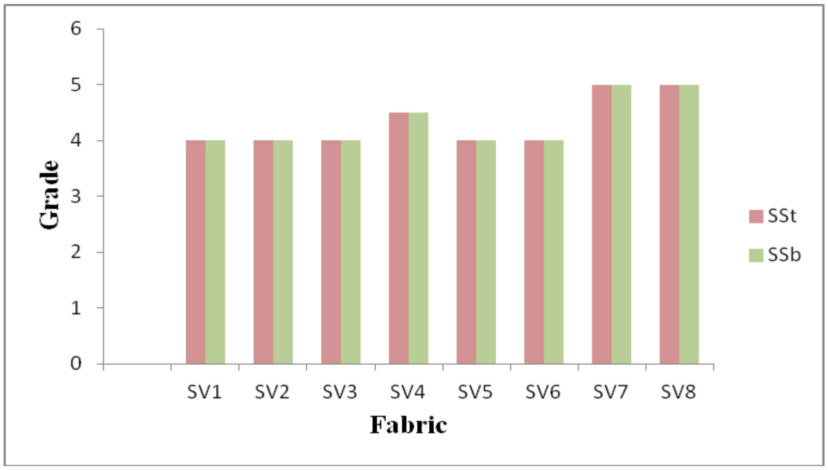

Figure 4.86: Top and bottom spreading speed grades of the single jersey viscose knitted fabrics.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. According to the maximum wetted results, the value increases for the fabrics made from 15Tex yarn. All single jersey viscose knitted fabrics have large maximum wetted radius. The wetter areas of the fabric on both sides are very high due to the good capillary transfer property. The MWR values are higher in viscose single jersey fabrics, as they are compared with entirely cotton single jersey fabrics. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The initial slopes of water content curves are similar for all single jersey fabrics knitted with viscose yarn. The water content of the top layer was higher than that of bottom layer throughout the test time. It then decreased dramatically, with the water content of the bottom layer evidently increasing, followed by a significant, gradual decrease to equilibrium after reaching a peak at about 26th second. This indicates that the liquid water accumulated at the top surface of the fabrics for a while after being injected by a pump through a needle and was then suddenly transferred to the bottom layer; it is notable that for viscose single jersey fabrics most of the liquid water was transferred and distributed in the bottom layer.

Since SV2 fabric has the lowest top wetted radius value, which also indicate its good moisture transport property, it will give a dry feeling. Figure 4.87 shows the mean grade of the top and bottom maximum wetted radius of all eight single jersey knitted fabrics. Figure 4.88 shows the accumulative one-way transport index grades and overall moisture management capacity of single jersey viscose fabrics.

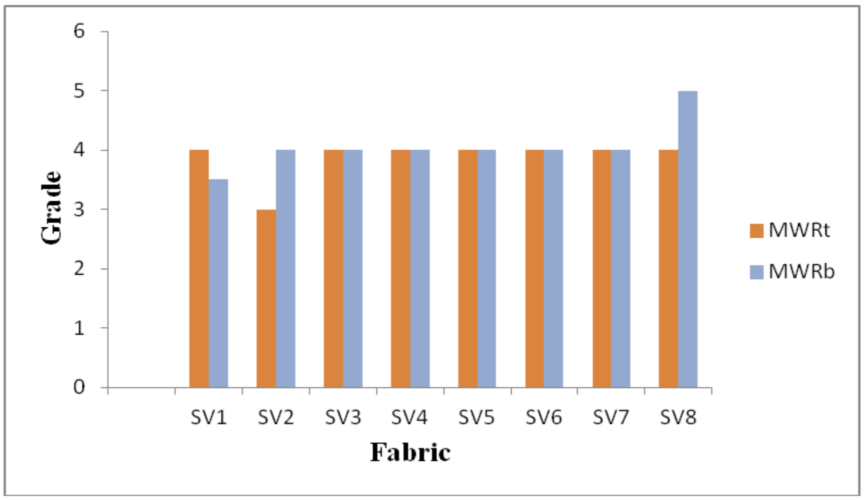

Figure 4.87: Top and bottom maximum wetted radius grades of the single jersey knitted viscose fabrics.

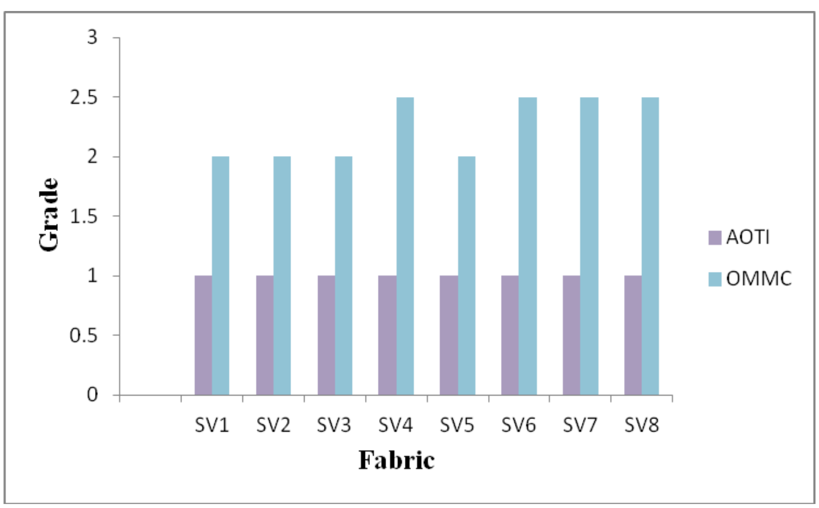

Figure 4.88: Accumulative one-way transport index grades and overall moisture management capacity of the single jersey fabrics knitted with viscose.

Relationship between Tightness factor and the moisture management properties

To find the possible relationship between tightness factor and moisture management properties of knitted fabrics, scatter plots with regression lines of MMT indices and Tightness factor were generated. The scatter plots of tightness factor versus top wetting time (WTt) and tightness factor versus bottom wetting time (WTb) reflect that relationships between tightness factor and top wetting time (WTt) and bottom wetting time (WTb). Top wetting time (WTt) and bottom wetting time (WTb)increased as tightness factor increased in case of single jersey fabrics knitted with 15Tex. While in case of 20Tex similar trend observed with WTb only (see figure 4.89 and 4.90). This is probably due to the size difference in inter-loop pores: as the size of inter-loop pores is large due to the low tightness factor, it takes less time to wet the fabric surface[137].

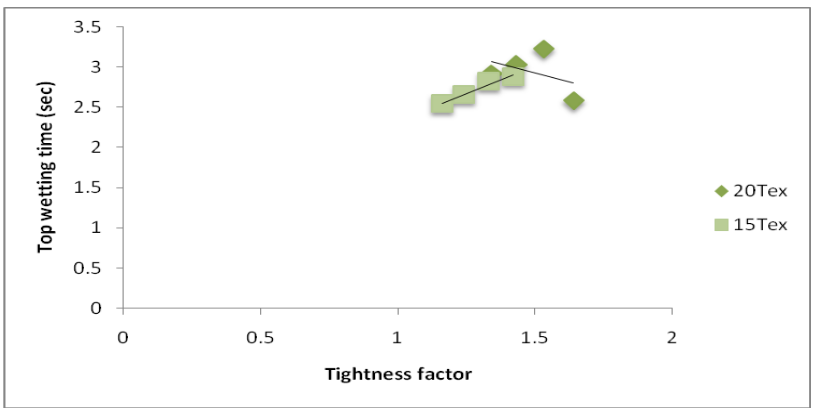

Figure 4.89: Top wetting time (WTt) versus tightness factor in Single Jersey Viscose Knitted fabrics.

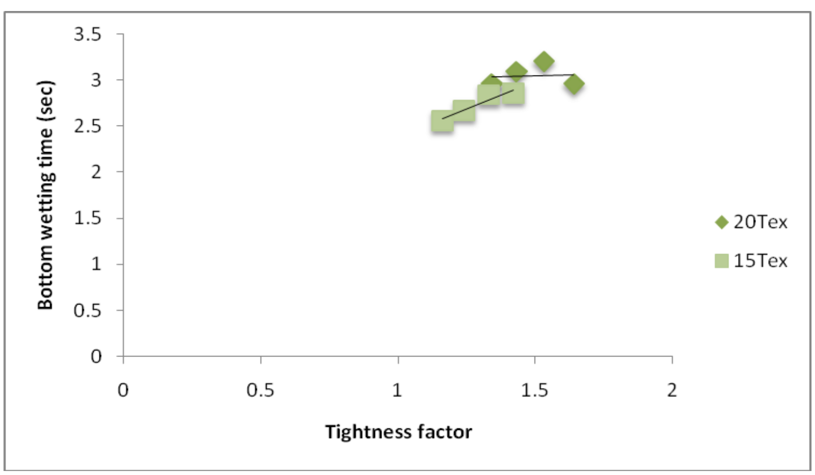

Figure 4.90: Bottom wetting time (WTt) versus tightness factor in Single Jersey Viscose Knitted fabrics.

In regard to the maximum wetted radius, the relationships between tightness factor and top maximum wetted radius (MWRt) and between tightness factor versus bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus top maximum wetted radius (MWRt) and of tightness factor versus bottom maximum wetted radius (MWRb). Both top maximum wetted radius (MWRt) and bottom maximum wetted radius (MWRb) decreases with the increase in tightness factor (see figure 4.91 and 4.92).

Graphs presented in figures 4.89 – 4.92 display different trends: as the tightness increases, the wetting time also increases, but at the same time the maximum wetted radius decreases. It means that it takes more time to wet a fabric with a closer structure. The scatter plot of tightness factor versus top absorption rate (ARt) depicts the relationship between tightness factor and top absorption rate (ARt): top absorption rate (ARt) decreased as tightness factor increased only in the case of fabric knitted with 20Tex. This is probably caused by low fabric porosity.

Similarly to the above, as in fabrics with low porosity, the inter-loop pore size is smaller, so it takes more time for a liquid to wet the fabric, and thus, the absorption of it by the fabric during the testing time is relatively less in comparison with an open-structure fabric with high porosity. While in case of fabric knitted with 15Tex both top absorption rate (ARt) and bottom absorption rate (ARb) increased with increase in tightness factor which are similar to the results observed for the single jersey cotton knitted fabrics.

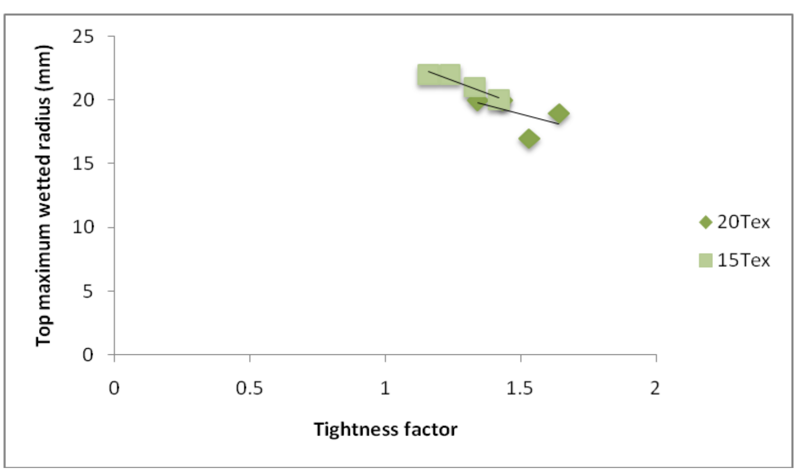

Figure 4.91: Top maximum wetted radius (MWRt) versus tightness factor in single jersey viscose knitted fabrics.

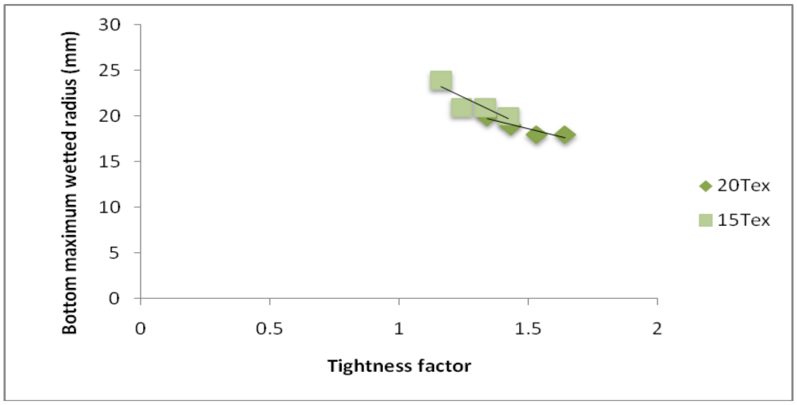

Figure 4.92: Bottom maximum wetted radius (MWRb) versus tightness factor in single jersey viscose knitted fabrics.

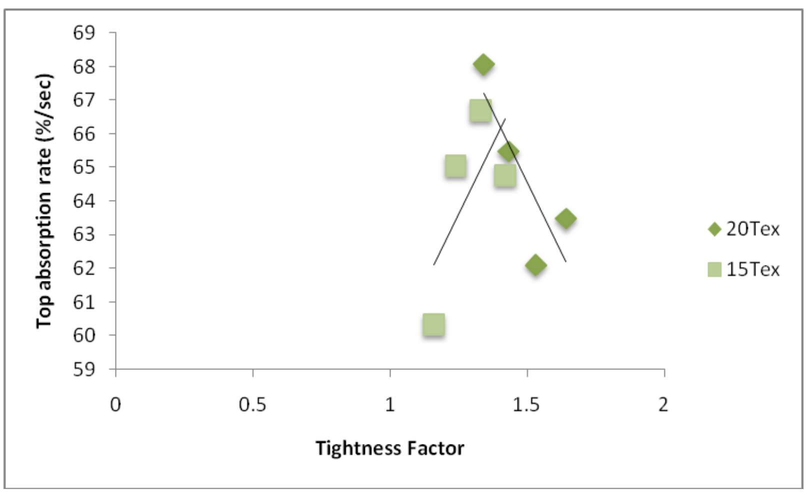

Figure 4.93: Top absorption rate (ARt) versus tightness factor in single jersey viscose knitted fabric.

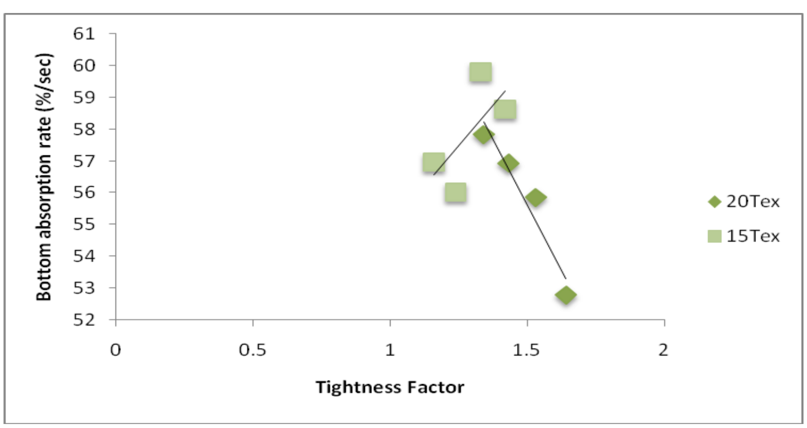

Figure 4.94: Bottom absorption rate (ARb) versus tightness factor in single jersey viscose knitted fabric.

The scatter plot of tightness factor versus top spreading speed (SSt) and of tightness factor versus bottom spreading speed (SSb) indicate the relationships between tightness factor and top spreading speed (SSt) and between tightness factor and bottom spreading speed (SSb) were relatively similar for single jersey fabric knitted with both counts. Both top spreading speed (SSt) and bottom spreading speed (SSb) decreased as tightness factor increased (see figure 4.95 and 4.96). This is probably also caused by low fabric porosity as discussed previously. When table 4.57 and Figure 4.97 examined Accumulative one-way transport index (AOTI) values of all single jersey viscose knitted fabric were found poor and shows decreasing trend with the increase in tightness factor for both the counts.

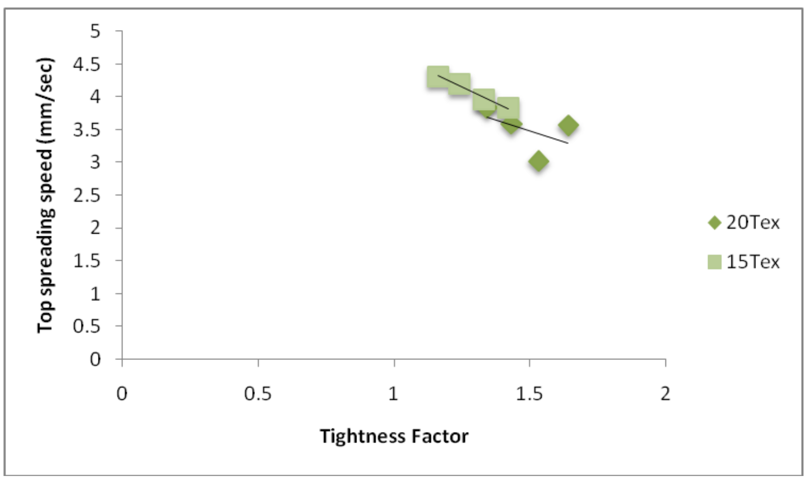

Figure 4.95: Top spreading speed (SSt) versus tightness factor in single jersey viscose knitted fabric.

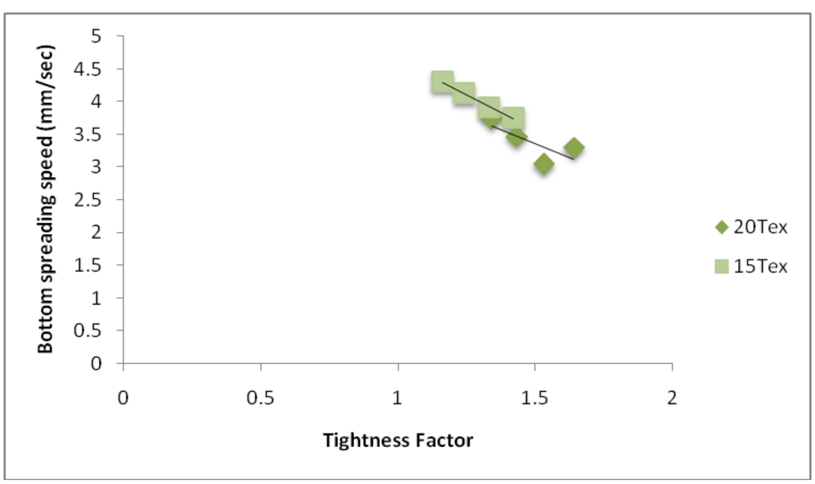

Figure 4.96: Bottom spreading speed (SSb) versus tightness factor in single jersey viscose knitted fabric.

The relationship between tightness factor and the rest of the indexes (AOTI and OMMC) can be observed in the last two scatter plots (Figures 4.97 and 4.98). Overall moisture management capacity (OMMC) decreased as the tightness factor increased in both the counts.

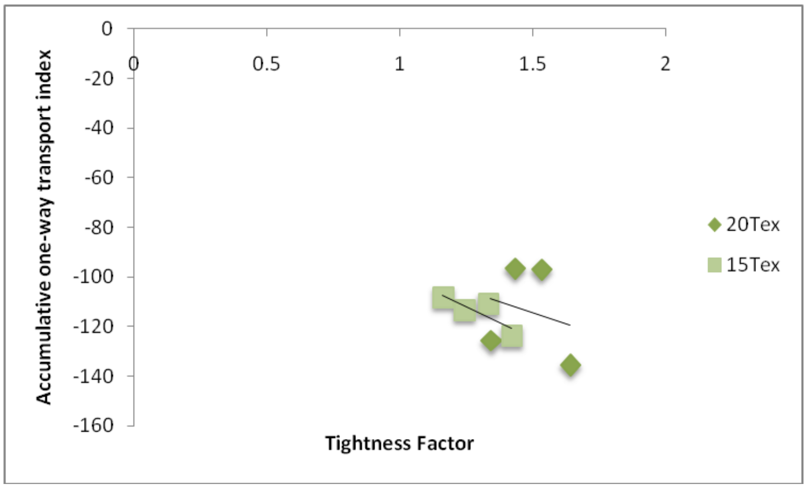

Figure 4.97: Accumulative one-way transport index (AOTI) versus tightness factor in single jersey viscose knitted fabric.

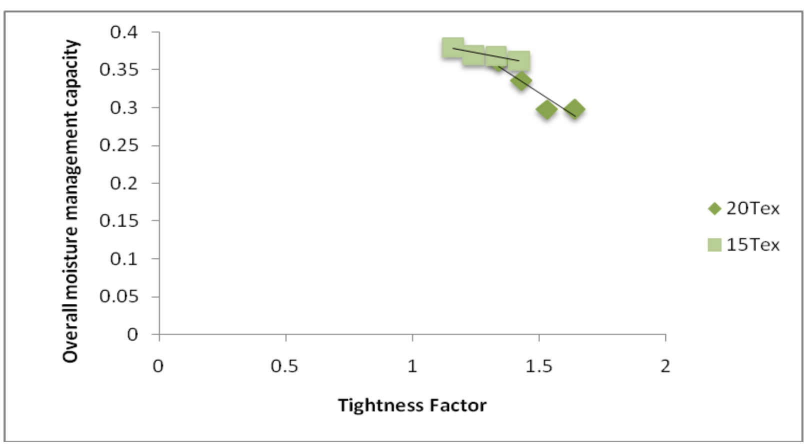

Figure 4.98: Overall moisture management capacity (OMMC) versus tightness factor in single jersey viscose knitted fabric.

Single jersey viscose fabrics showed fair result ranging in 0.2-0.4. Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.59. It can be observed that the Pearson correlations are close to +1 or -1 for Bottom wetting time (WTb), Top maximum wetted radius (MWRt), Bottom maximum wetted radius (MWRb), Top spreading speed (SSt), Bottom spreading speed (SSb) and Overall moisture management capacity (OMMC). This indicates that for single jersey fabric knitted with viscose yarn, tightness factor influence the overall moisture management fabric properties. The high value of the correlation index shows that the influence of the tightness factor on Overall moisture management capacity (OMMC) as compared to cotton single jersey fabrics is high and expressiveness of the relationship is also high and meaningful statistically.

Table 4.59: Pearson correlations and p-values of tightness factor versus MMT indices of Single Jersey Viscose Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.108	0.782
2.	T.F., WTb	0.723	0.028
3.	T.F. ARt	-0.067	0.864
4.	T.F., ARb	-0.672	0.048
5.	T.F., MWRt	-0.824	0.006
6.	T.F., MWRb	-0.924	0.000
7.	T.F., SSt	-0.800	0.010
8.	T.F., SSb	-0.916	0.001
9.	T.F., AOTI	-0.437	0.239
10.	T.F., OMMC	-0.933	0.000

4.4.2.2 Pique fabrics

Liquid moisture transport test results of viscose pique knitted fabrics in value are given in Table 4.60 and the results converted into grades are given in Table 4.61 where grades range from 1 to 5 – poor to excellent. As can be seen from Table 4.60, the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

Wetting time

A comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the pique knitted fabric shows that the wetting time of the top surface (WTt) is smaller than the wetting time of the bottom surface (WTb) as expected, suggesting that it took longer for the liquid water to be transferred to the bottom layer. In the scope of this explanation, it can be stated that, the wetting time value is related with the water absorbency of the fabric. The finer the yarn, the lower the wetting time is. As the yarns get finer, the thickness of the fabric decreases. When the results of thin and thick fabrics from same type of material compared, thinner fabrics shown faster wetting than thicker ones, when equal amount of water are applied. Since the number of fibres in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid.

Figure 4.99 shows the mean grade of the top and bottom wetting time of the pique knitted fabrics. It is notable that fabric SV15 has the smallest mean wetting time of the bottom surface (WTb), demonstrating that it has a better liquid transfer ability from the top to the bottom layer. Fabric SV15 has the fastest wetting time in both top and bottom surfaces, and SV9, SV10, SV11, SV14, SV15 and SV16 have equal grades in top and bottom wetting time.

Absorption rates

It can also be seen from Table 4.60 that the absorption rate values change according to yarn count and tightness factor. Because of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases.

Table 4.60: MMT results of Viscose knitted Pique fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SV9	Mean	3.4636	3.7628	51.1277	48.608	15	15	2.6127	2.4526	-79.5509	0.2283
	S.Deviation	0.3174	0.3588	2.4179	2.5177	0	0	0.1174	0.1108	8.0068	0.0106
	CV	0.0917	0.0954	0.0473	0.0518	0	0	0.045	0.0452	0.1007	0.0465
SV10	Mean	3.6128	3.8564	51.531	52.3753	15	16	2.5516	2.4945	-80.0359	0.2422
	S.Deviation	0.2155	0.3767	4.3211	2.8967	0	2.2361	0.126	0.1239	16.7544	0.0088
	CV	0.0597	0.0977	0.0839	0.0553	0	0.1398	0.0494	0.0497	0.2093	0.0365
SV11	Mean	3.3322	3.482	53.1944	49.7447	15	16	2.6119	2.57	-95.9949	0.2412
	S.Deviation	0.3661	0.1537	3.9564	3.509	0	2.2361	0.1247	0.0646	6.3046	0.0129
	CV	0.1099	0.0441	0.0744	0.0705	0	0.1398	0.0477	0.0251	0.0657	0.0533
SV12	Mean	3.1824	3.351	56.6044	51.6966	20	19	3.3223	3.112	-112.653	0.2918
	S.Deviation	0.1873	0.1225	5.7636	2.3746	0	2.2361	0.3432	0.356	12.7245	0.0355
	CV	0.0588	0.0366	0.1018	0.0459	0	0.1177	0.1033	0.1144	0.113	0.1215
SV13	Mean	3.2012	3.2388	62.0758	55.1719	20	20	3.4079	3.3491	-103.505	0.3212
	S.Deviation	0.1671	0.2695	2.3805	1.0921	0	0	0.2583	0.2543	8.6342	0.0235
	CV	0.0522	0.0832	0.0383	0.0198	0	0	0.0758	0.0759	0.0834	0.073
SV14	Mean	3.0512	3.0886	61.8504	56.1249	20	20	3.5595	3.5194	-89.3291	0.3381
	S.Deviation	0.084	0.0665	3.2701	0.8788	0	0	0.1787	0.1542	6.1496	0.0145
	CV	0.0275	0.0215	0.0529	0.0157	0	0	0.0502	0.0438	0.0688	0.0429
SV15	Mean	2.808	2.9018	65.4458	47.8318	21	20	3.9388	3.7257	-201.157	0.3266
	S.Deviation	0.2095	0.1986	4.0382	2.514	2.2361	0	0.4923	0.3594	30.1743	0.0202
	CV	0.0746	0.0684	0.0617	0.0526	0.1065	0	0.125	0.0965	0.15	0.062
SV16	Mean	2.864	2.939	58.9946	55.3758	21	21	3.7497	3.736	-86.7181	0.3509
	S.Deviation	0.1564	0.1569	1.5809	1.2551	2.2361	2.2361	0.3026	0.3468	11.4841	0.0266
	CV	0.0546	0.0534	0.0268	0.0227	0.1065	0.1065	0.0807	0.0928	0.1324	0.0758

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.61: MMT results of Viscose knitted Pique fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SV9	1.64	4	4	3.5	3.5	3	3	3	3	1	2
SV10	1.53	4	4	3.5	3.5	3	3	3	3	1	2
SV11	1.43	4	4	3.5	3.5	3	3	3	3	1	2
SV12	1.34	5	4.5	4	3.5	4	4	4	4	1	2
SV13	1.42	5	4.5	4	3.5	4	4	4	4	1	2
SV14	1.33	5	5	4	3.5	4	4	4	4	1	2
SV15	1.24	5	5	4	3.5	4	4	4	4	1	2
SV16	1.16	5	5	3.5	3.5	4	4	4	4	1	2

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

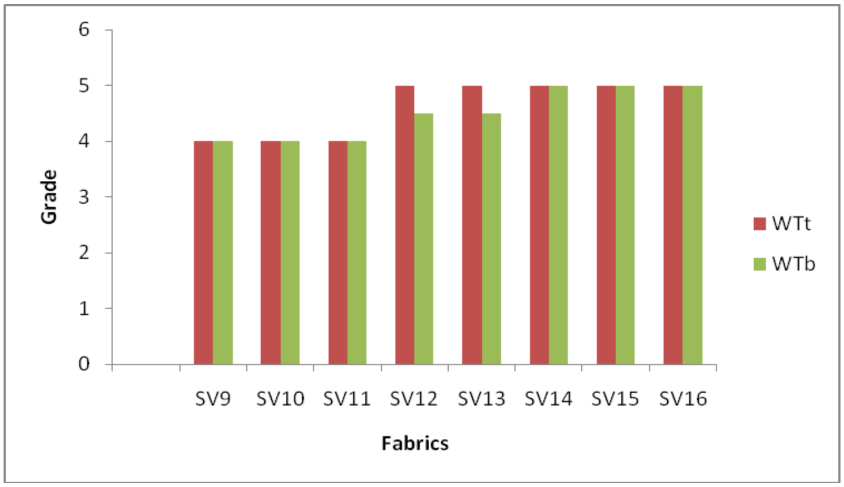

Figure 4.99: Top and bottom wetting time grades of Viscose pique fabrics.

Therefore the absorption rate values of the thinner fabrics become higher. The absorption rate values of bottom surface were found higher than absorption rate values of top surface (ARt). Figure 4.100 shows the absorption rates grades of viscose pique fabrics. SV12, SV13, SV14 and SV15 shows fast absorption rate with higher grades in absorption rate values of top surface (ARt).

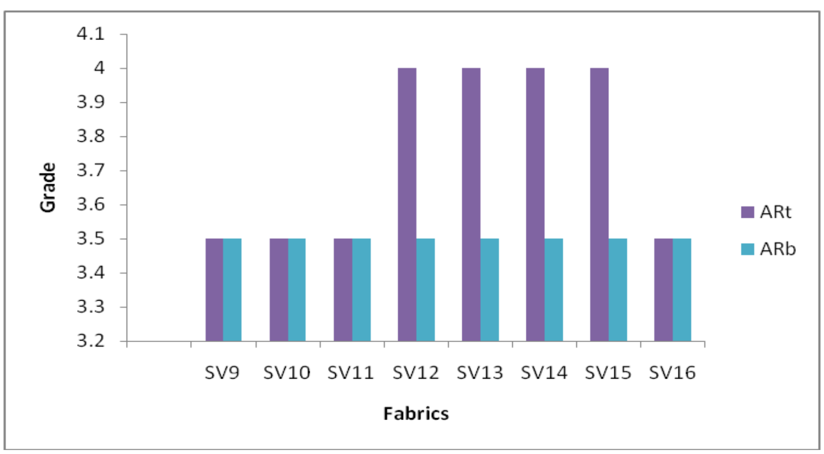

Figure 4.100: Top and bottom absorption rate grades of viscose pique fabrics.

Spreading speed

As the spreading speed values are compared it can be clearly seen that, higher the yarn count, higher the spreading speed is. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the fabric shorten. Figure 4.101 shows the top and bottom spreading speed grades of pique knitted fabrics. All pique knitted fabrics of viscose yarn

Figure 4.101: Top and bottom spreading speed grades of viscose pique fabrics.

shows same grades in top and bottom spreading speed ranging from medium to fast spreading speed grade.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. Figure 4.102 shows the maximum top and bottom wetted radius grade for pique fabrics. According to the maximum wetted results, the value increases for the fabrics made from 15Tex yarn. Pique knitted fabrics have grades ranging from 3 to 4, which means medium to large wetting. Since SV9 fabrics has the lowest top wetted radius value, which also indicates its good moisture transport property, it will give a dry feeling. Water location versus time can be obtained as a colourful simulation, according to which, the wetted areas of the fabric on both sides are very high due to the good capillary transfer property. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The initial slopes of water content curves are similar for all pique fabrics knitted with viscose yarn. The water content of the top layer was higher than that of bottom layer throughout the test time. It then decreased dramatically, with the water content of the bottom layer evidently increasing, followed by a significant, gradual decrease to equilibrium after reaching a peak at about 26^{th} second. This indicates that the liquid water accumulated at the top surface of the fabrics for a while after being injected by a pump through a needle and was then suddenly transferred to the bottom layer; it is notable that for viscose pique fabrics most of the liquid water was transferred and distributed in the bottom layer. Figure 4.103 shows the accumulative one-way transport index grades and overall moisture management capacity of viscose pique fabrics.

Figure 4.102: Top and bottom maximum wetted radius grade of viscose pique fabrics.

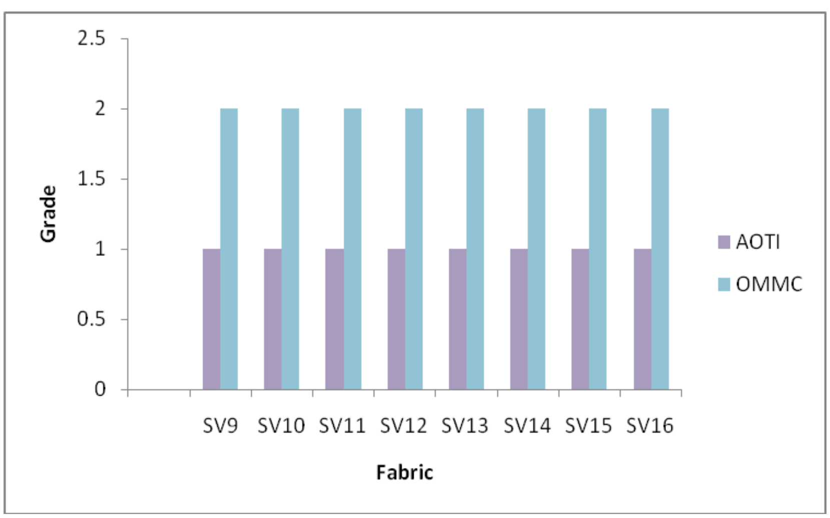

Figure 4.103: Accumulative one-way transport index grades and overall moisture management capacity of viscose pique fabrics.

Relationship between Tightness factor and the moisture management properties

The scatter plots of tightness factor versus Top wetting time (WTt) and tightness factor versus Bottom wetting time (WTb) reflect the relationships between tightness factor and Top wetting time (WTt) and Bottom wetting time (WTb) and tightness factor. It was observed that both Top wetting time (WTt) and Bottom wetting time (WTb) increased with increase in tightness factor in case of fabric knitted with both the counts (see figure 4.104 and 4.105).

In regard to the maximum wetted radius, the relationships between tightness factor and Top maximum wetted radius (MWRt) and between tightness factor versus Bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus Top maximum wetted radius (MWRt) and of tightness factor versus Bottom maximum wetted radius (MWRb) as shown in figures 4.106 and 4.107. Both Top maximum wetted radius (MWRt) and Bottom maximum wetted radius (MWRb) deceases with increase in tightness factor in both the counts.

Graphs presented in figures 4.104 – 4.107 display different trends: as the tightness increases, the wetting time also increases, but at the same time the maximum wetted radius decreases. It means that it takes more time to wet a fabric with a closer structure.

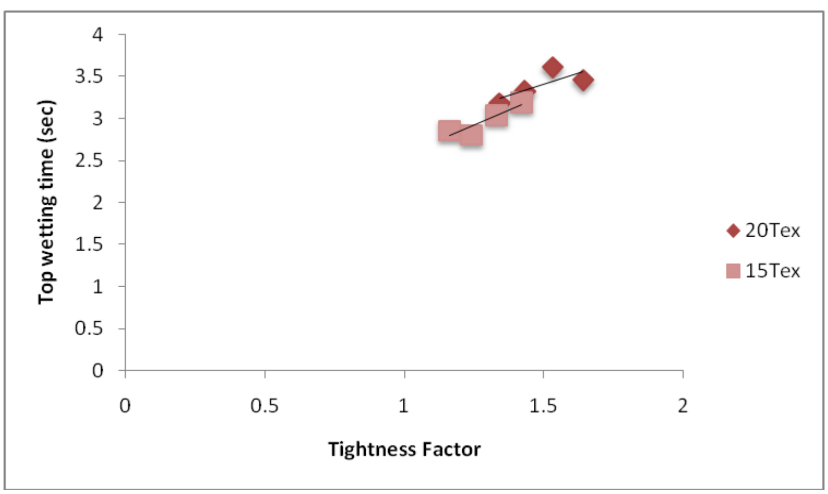

Figure 4.104: Top wetting time (WTt) versus tightness factor in Pique Viscose Knitted fabrics.

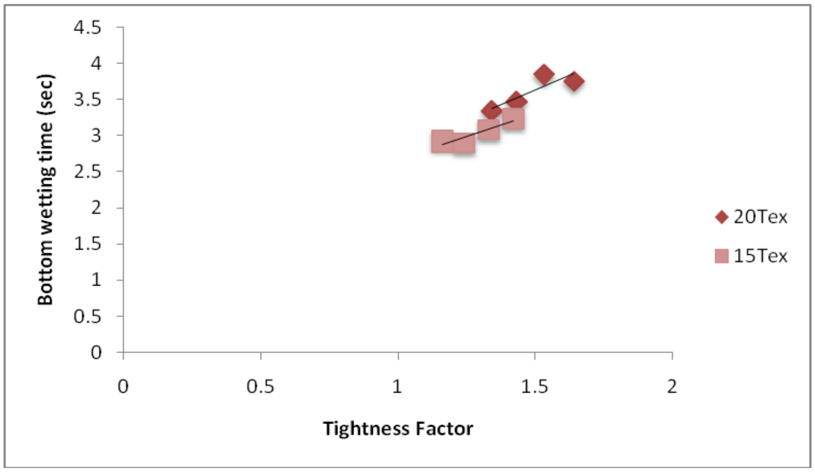

Figure 4.105: Bottom wetting time (WTb) versus tightness factor in Pique Cotton Knitted fabrics.

The scatter plot of tightness factor versus absorption rate on top surface (ARt) depicts the relationship between tightness factor and absorption rate on top surface (ARt) and tightness factor and absorption rate on bottom surface (ARb) shows that both absorption rate on top surface (ARt) and absorption rate on bottom surface (ARb) increases as tightness factor increased in the case of fabric knitted with 15Tex. While fabrics knitted with 20Tex show exactly reverse trend (see figure 4.108 and 4.109).

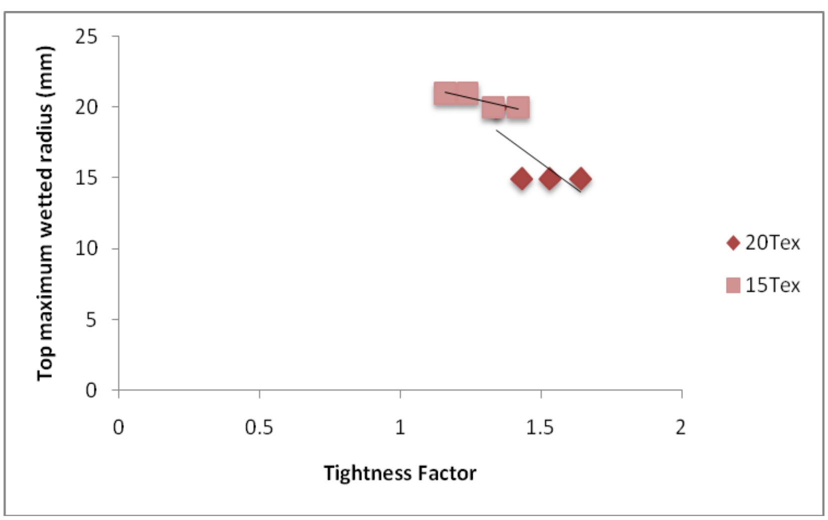

Figure 4.106: Top maximum wetted radius (MWRt) versus tightness factor in Pique knitted viscose fabrics.

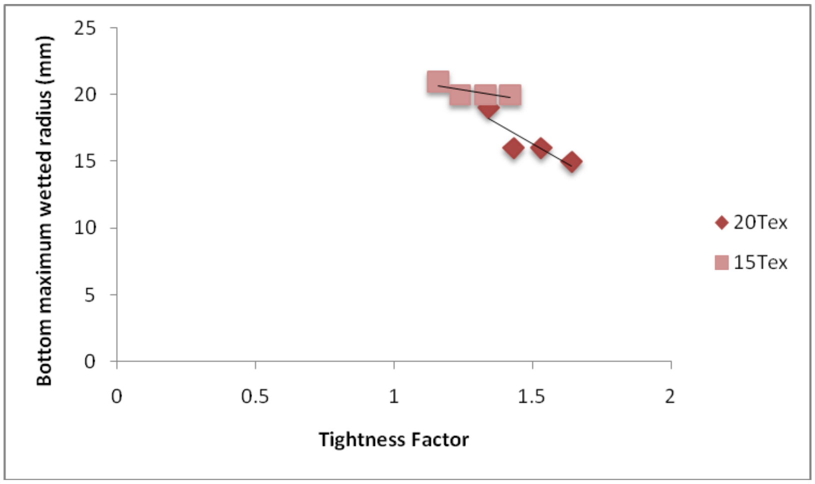

Figure 4.107: Bottom maximum wetted radius (MWRb) versus tightness factor in Pique knitted viscose fabrics.

The scatter plot of tightness factor versus Top spreading speed (SSt) and of tightness factor versus Bottom spreading speed (SSb) indicate the relationships between tightness factor and Top spreading speed (SSt) and between tightness factor and Bottom spreading speed (SSb) were relatively similar for pique fabric knitted with 15Tex and 20Tex. Both Top spreading speed (SSt) and Bottom spreading speed (SSb) decreased as tightness factor increased in case of both the counts (see figure 4.110 and 4.111).

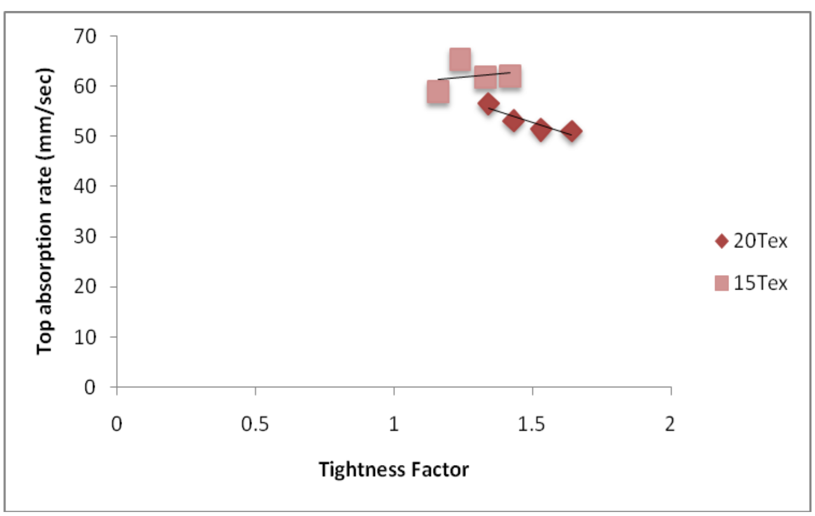

Figure 4.108: Top absorption rate (ARt) versus tightness factor in Pique knitted viscose fabric.

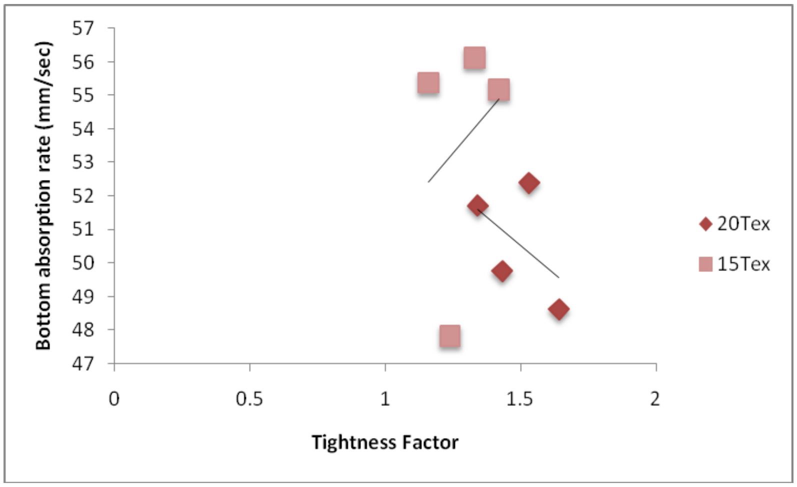

Figure 4.109: Bottom absorption rate (ARb) versus tightness factor in Pique knitted viscose fabric.

When table 4.61 and Figure 4.112 examined Accumulative one-way transport index (AOTI) values of viscose knitted fabrics showed poor Accumulative one-way transport index (AOTI) because values are approximately more than -50. The relationship between tightness factor and the rest of the indexes (AOTI and OMMC) can be observed in the last two scatter plots (Figures 4.112 and 4.113). Overall moisture management capacity (OMMC) decreased as the tightness factor increased in case of both the counts.

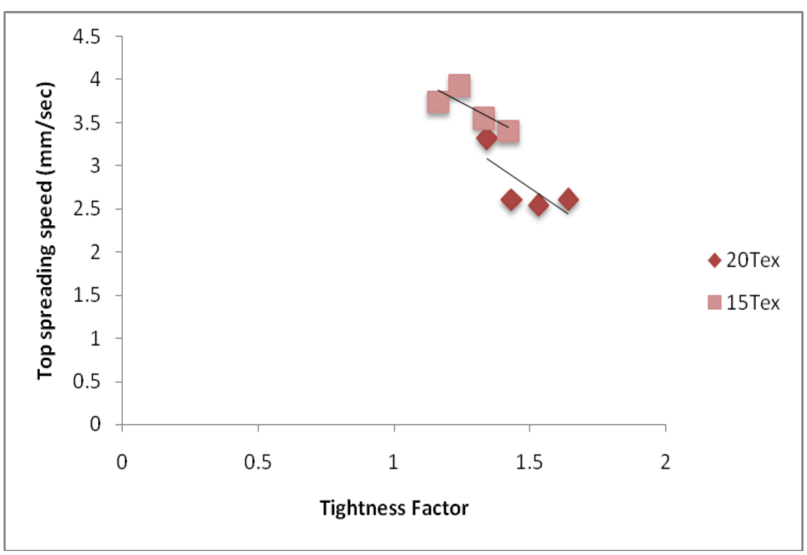

Figure 4.110: Top spreading speed (SSt) versus tightness factor in pique knitted viscose fabric.

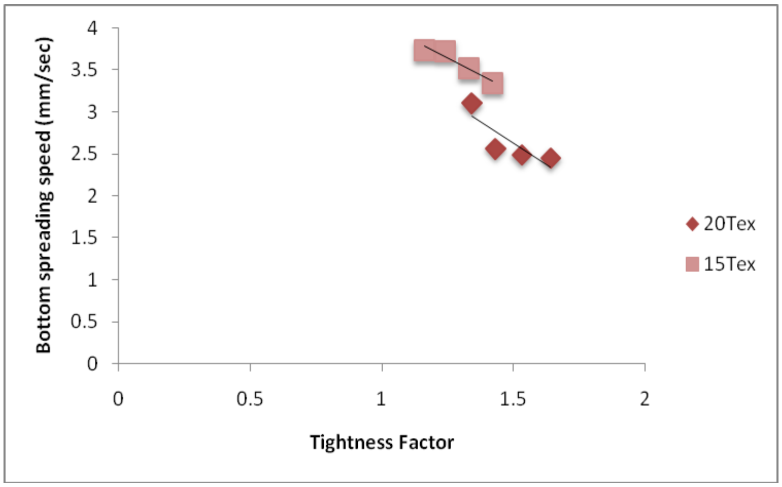

Figure 4.111: Bottom spreading speed (SSb) versus tightness factor in pique knitted viscose fabric.

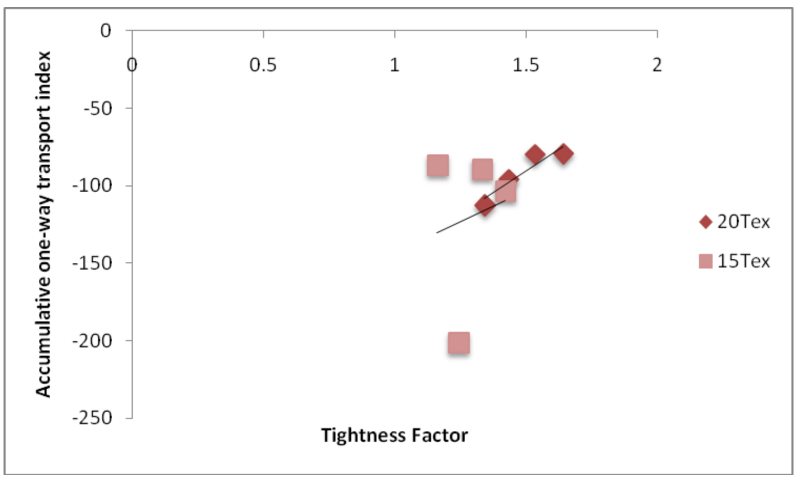

Figure 4.112: Accumulative one-way transport index (AOTI) versus tightness factor in pique knitted viscose fabric.

Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.62. It can be observed that almost all except absorption rate on bottom surface (ARb) and Accumulative one-way transport index (AOTI), correlations between tightness factor and the indices are linearly related since the Pearson correlations are close to +1 and -1. This indicates that for pique viscose knitted fabrics, tightness factor influenced the overall moisture management fabric property. Except SV9, SV10, and SV11 which are classified into fast absorbing and slow drying, all other are classified into fast absorbing and quick drying fabric, all other pique knitted are classified into water penetration fabric.

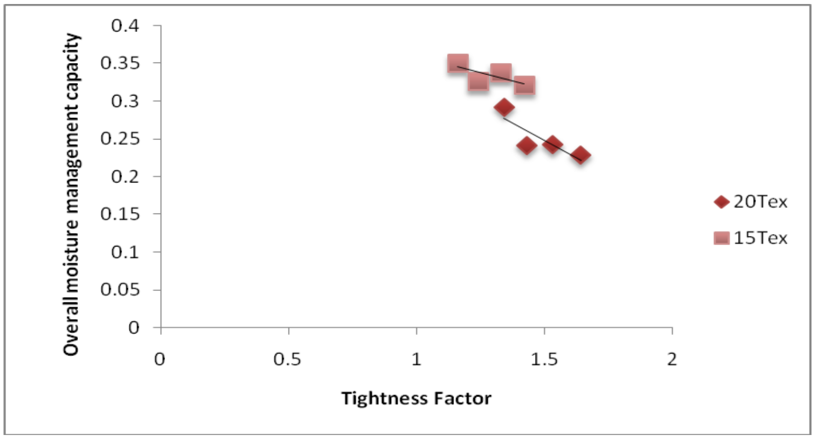

Figure 4.113: Overall moisture management capacity (OMMC) versus tightness factor in pique knitted viscose fabric.

Table 4.62: Pearson correlations and p- values of tightness factor versus MMT indices of Pique Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.913	0.002
2.	T.F., WTb	0.917	0.001
3.	T.F. ARt	-0.730	0.040
4.	T.F., ARb	-0.337	0.414
5.	T.F., MWRt	-0.847	0.008
6.	T.F., MWRb	-0.877	0.004
7.	T.F., SSt	-0.870	0.005
8.	T.F., SSb	-0.891	0.003
9.	T.F., AOTI	0.461	0.251
10.	T.F., OMMC	-0.863	0.006

All Single jersey viscose knitted fabrics were classified as fast absorbing and quick drying fabrics with key properties of fast-to-very fast wetting, medium–to-fast absorption, medium-to-large wetting, fast-to-very fast spreading and poor one-way transport properties. Pique knitted fabrics were classified as fast absorbing and slow drying and fast absorbing and quick drying fabrics with key properties of fast–to-very fast wetting, medium-to-fast absorption, medium-to-large wetting area, very medium-to-fast spreading and poor one-way transport properties.

4.4.3 Modal knitted fabrics

4.4.3.1 Single jersey fabrics

Liquid moisture transport test results of modal knitted single jersey fabrics in value are given in Table 4.63 and the results converted into grades are given in Table 4.64 where grades range from 1 to 5 – poor to excellent.

Wetting time

As can be seen from Table 4.63 and figure 4.114 the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

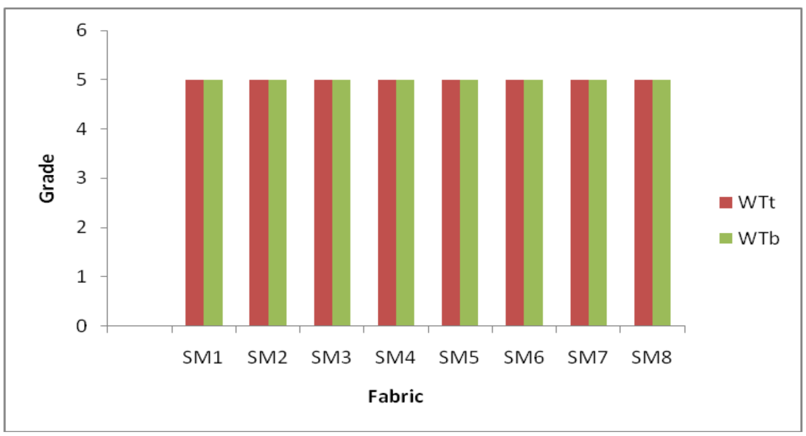

Figure 4.114: Top and bottom wetting time grades of the Modal single jersey knitted fabrics.

From the comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the single jersey knitted fabric shows that all the single jersey modal fabrics have equal grades in top and bottom wetting time, suggesting that it took very less time for the liquid water to be transferred to the bottom layer from top layer and vice versa.

Absorption rates

As can be seen from Table 4.63, the top absorption rates of the fabrics are higher than bottom surfaces which may be because of liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content on the top surface. Figure 4.115 shows top and bottom absorption rate grades of single jersey modal fabrics.

Table 4.63: MMT results of Modal knitted Single Jersey fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SM1	Mean	2.7332	2.8268	55.9278	52.1386	22	23	4.2681	4.1825	-72.6922	0.3649
	S.Deviation	0.1539	0.0786	1.7827	1.2194	2.7386	2.7386	0.2275	0.2431	13.6886	0.0031
	CV	0.0563	0.0278	0.0319	0.0234	0.1245	0.1191	0.0533	0.0581	0.1883	0.0084
SM2	Mean	2.5086	2.5646	55.2141	52.6018	22	24	4.5637	4.5215	-64.8978	0.3683
	S.Deviation	0.1801	0.1567	3.6619	0.81	2.7386	2.2361	0.1757	0.1838	10.3451	0.0022
	CV	0.0718	0.0611	0.0663	0.0154	0.1245	0.0932	0.0385	0.0407	0.1594	0.0061
SM3	Mean	2.808	2.8644	57.0374	53.3248	22	23	4.4164	4.3527	-78.1398	0.3703
	S.Deviation	0.1752	0.1067	4.1827	2.1652	2.7386	2.7386	0.3227	0.2469	17.0819	0.006
	CV	0.0624	0.0373	0.0733	0.0406	0.1245	0.1191	0.0731	0.0567	0.2186	0.0162
SM4	Mean	2.6208	2.7146	61.778	55.7586	25	25	5.1848	5.0261	-92.3867	0.3771
	S.Deviation	0.1478	0.1989	2.5477	3.7677	0	0	0.3994	0.4636	15.5397	0.0105
	CV	0.0564	0.0733	0.0412	0.0676	0	0	0.077	0.0922	0.1682	0.0278
SM5	Mean	2.4708	2.527	58.2037	54.5428	25	24	5.1289	4.9214	-94.128	0.3737
	S.Deviation	0.1253	0.1477	3.6491	2.2579	0	2.2361	0.3313	0.3905	9.4079	0.0063
	CV	0.0507	0.0584	0.0627	0.0414	0	0.0932	0.0646	0.0793	0.0999	0.0168
SM6	Mean	2.4336	2.4708	57.6513	54.0435	26	26	5.3879	5.2656	-86.8255	0.3723
	S.Deviation	0.0938	0.1069	3.3059	4.1824	2.2361	2.2361	0.5433	0.5574	18.8812	0.0116
	CV	0.0385	0.0433	0.0573	0.0774	0.086	0.086	0.1008	0.1059	0.2175	0.0312
SM7	Mean	2.733	2.7516	60.6901	54.1734	26	26	4.9932	4.8262	-113.439	0.3727
	S.Deviation	0.1804	0.1943	4.2389	2.6224	2.2361	2.2361	0.3853	0.3589	10.2214	0.0073
	CV	0.066	0.0706	0.0698	0.0484	0.086	0.086	0.0772	0.0744	0.0901	0.0195
SM8	Mean	2.5832	2.6208	59.9421	53.9015	25	26	5.3228	5.3061	-130.03	0.3719
	S.Deviation	0.3216	0.3243	6.9111	3.4934	0	2.2361	0.7656	0.8473	8.9808	0.0097
	CV	0.1245	0.1238	0.1153	0.0648	0	0.086	0.1438	0.1597	0.0691	0.0261

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.64: MMT results of Modal knitted Single Jersey fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SM1	1.64	5	5	3.5	3.5	4	5	5	5	1	2.5
SM2	1.53	5	5	3.5	3.5	4	5	5	5	1	2.5
SM3	1.43	5	5	4	3.5	4	5	5	5	1	2.5
SM4	1.34	5	5	4	3.5	5	5	5	5	1	2.5
SM5	1.42	5	5	4	3.5	5	5	5	5	1	2.5
SM6	1.33	5	5	3.5	3.5	5	5	5	5	1	2.5
SM7	1.24	5	5	4	3.5	5	5	5	5	1	2.5
SM8	1.16	5	5	4	3.5	5	5	5	5	1	2.5

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

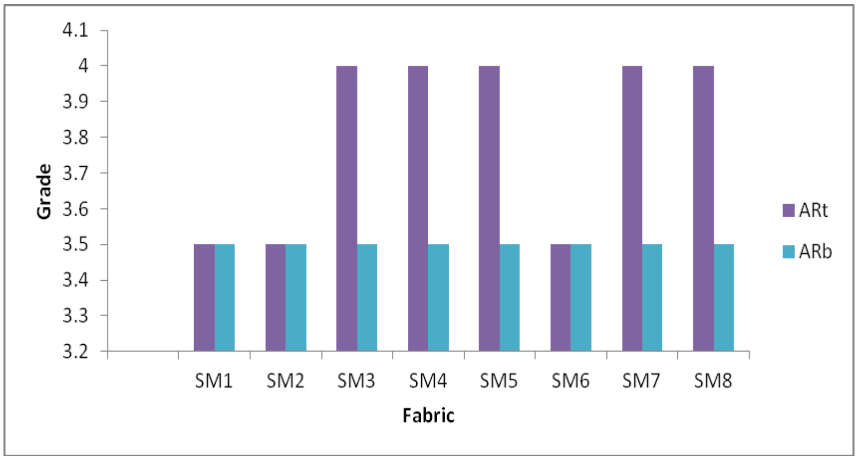

Figure 4.115: Top and bottom absorption rate grades of the single jersey modal knitted fabrics.

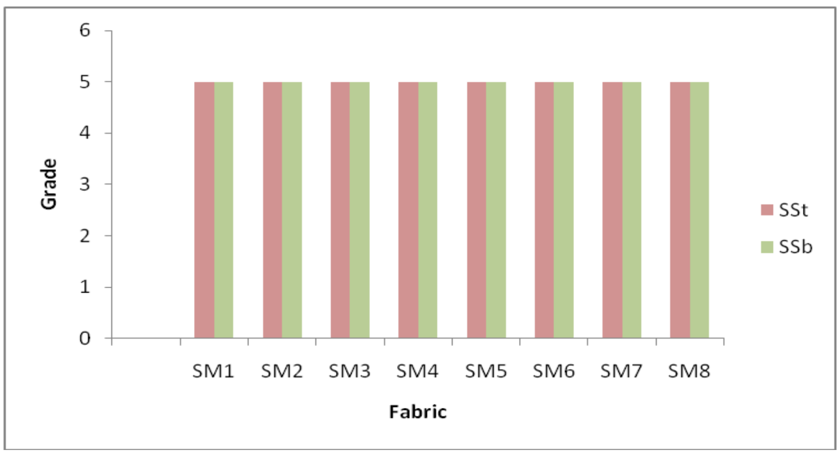

Figure 4.116: Top and bottom spreading speed grades of the Modal single jersey knitted fabrics.

Spreading speed

Figure 4.116 shows the top and bottom spreading speed grades of single jersey fabrics knitted with modal yarn. All have very fast spreading speed grade.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. According to the maximum wetted results, the values are higher for the fabrics made from 15Tex yarn. All single jersey knitted fabrics have large maximum wetted radius. The wetter areas of the fabric on both sides are very high due to the good capillary transfer property. The maximum wetted radius values are higher in modal single jersey fabrics, as they are compared with entirely cotton and viscose single jersey fabrics. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period.

At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177]. Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The initial slopes of water content curves are similar for all single jersey fabrics knitted with modal yarn. The water content of the bottom layer was higher than that of top layer throughout the test time. This indicates that the liquid water was transferred quickly to the bottom layer from the top layer. Figure 4.117 shows the mean grade of the top and bottom wetted radius of all eight single jersey knitted fabrics. Figure 4.118 shows the Accumulative one-way transport index grades and overall moisture management capacity of the single jersey fabrics knitted with modal.

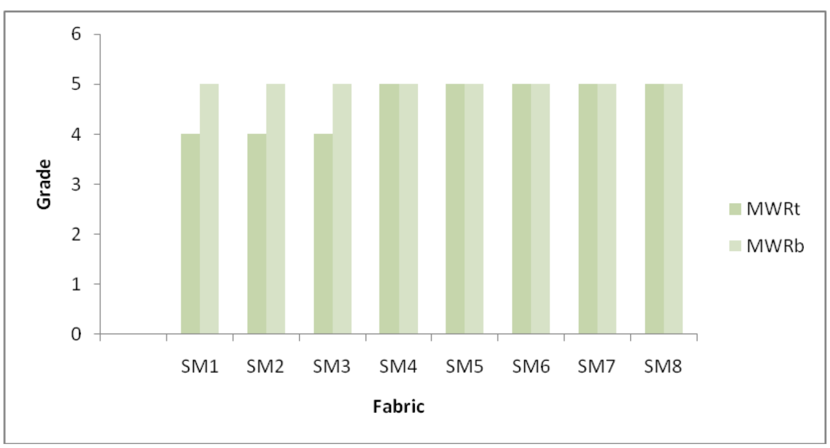

Figure 4.117: Top and bottom maximum wetted radius grades of the Modal single jersey knitted fabrics.

Figure 4.118: Accumulative one-way transport index grades and overall moisture management capacity of the single jersey fabrics knitted with modal.

Relationship between Tightness factor and the moisture management properties

To find the possible relationship between tightness factor and moisture management properties of knitted fabrics, scatter plots with regression lines of MMT indices and Tightness factor were generated. The scatter plots of tightness factor versus Top wetting time (WTt) and tightness factor versus Bottom wetting time (WTb) reflect that relationships between tightness factor and Top wetting time (WTt), Bottom wetting time (WTb). Top wetting time (WTt) and Bottom wetting time (WTb) decreased as tightness factor increased in case of single jersey fabrics knitted with 15Tex while in case of 20Tex both increases slightly (see figure 4.119 and 4.120). This is probably due to the size difference in inter-loop pores: as the size of inter-loop pores is large due to the low tightness factor, it takes less time to wet the fabric surface.

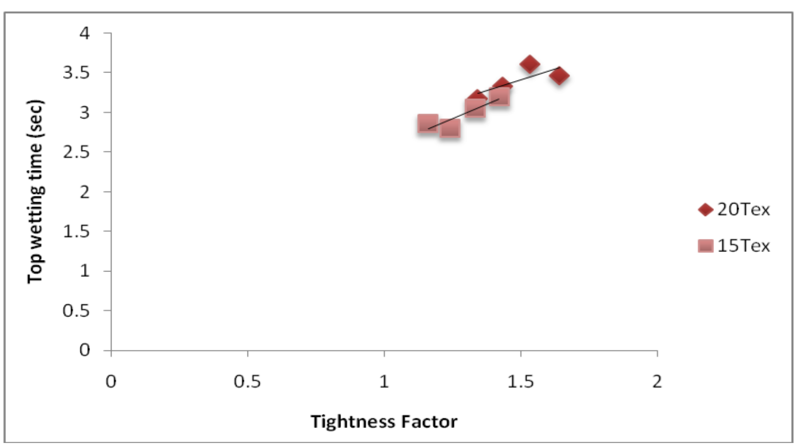

Figure 4.119: Top wetting time (WTt) versus tightness factor in Single Jersey Modal Knitted fabrics.

In regard to the maximum wetted radius, the relationships between tightness factor and Top maximum wetted radius (MWRt) and between tightness factor versus Bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus Top maximum wetted radius (MWRt) and of tightness factor versus Bottom maximum wetted radius (MWRb). Both Top maximum wetted radius (MWRt) and Bottom maximum wetted radius (MWRb) decreases with the increase in tightness factor (see figure 4.121 and 4.122).

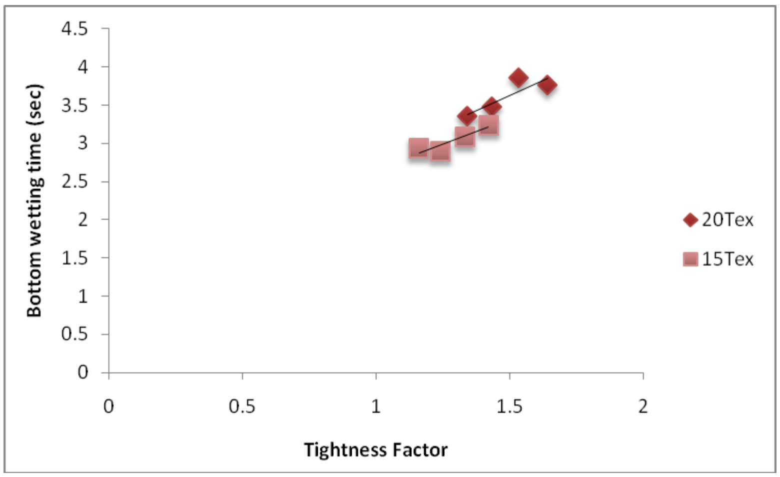

Figure 4.120: Bottom wetting time (WTt) versus tightness factor in Single Jersey Modal Knitted fabrics.

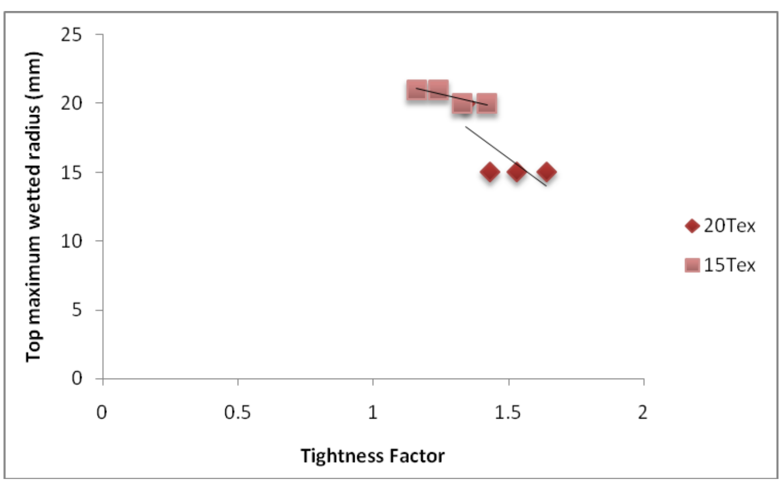

Figure 4.121: Top maximum wetted radius (MWRt) versus tightness factor in single jersey modal knitted fabrics.

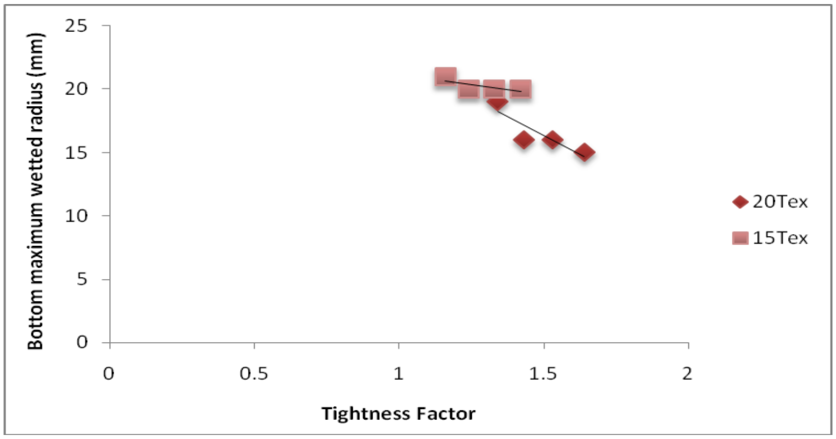

Figure 4.122: Bottom maximum wetted radius (MWRb) versus tightness factor in single jersey modal knitted fabrics.

The scatter plot of tightness factor versus absorption rate on top surface (ARt) depicts the relationship between tightness factor and absorption rate on top surface (ARt) : absorption rate on top surface (ARt) decreased as tightness factor increased in the case of fabric knitted with both counts. This is probably caused by low fabric porosity. Similarly to the above, as in fabrics with low porosity, the inter-loop pore size is smaller, so it takes more time for a liquid to wet the fabric, and thus, the absorption of it by the fabric during the testing time is relatively less in comparison with an open-structure fabric with high porosity. Absorption rate on bottom surface (ARb) increased with increase in tightness factor in the case of 15Tex while in case of 20Tex it decreases (see figure 4.123 and 4.124).

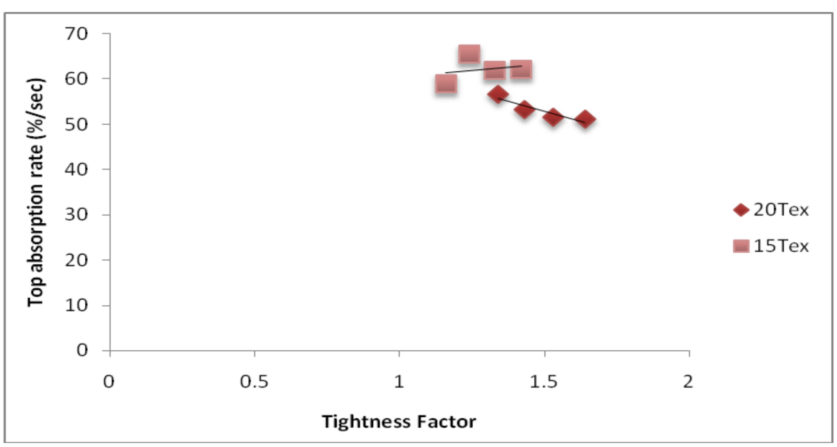

Figure 4.123: Top absorption rate (ARt) versus tightness factor in single jersey modal knitted fabric.

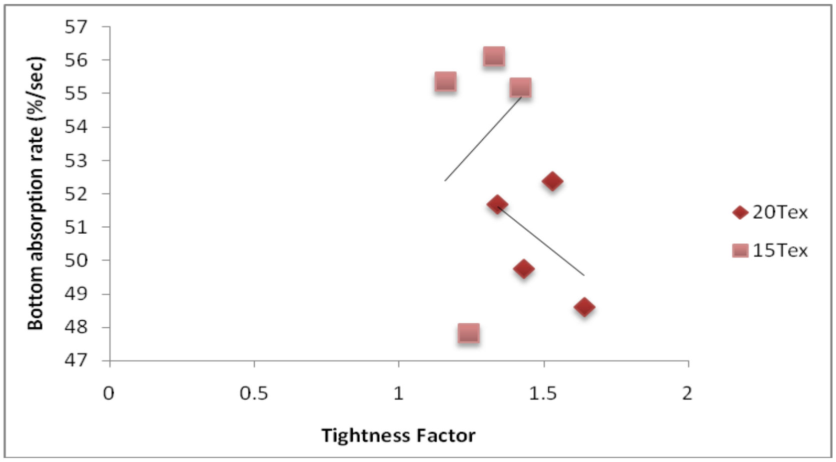

Figure 4.124: Bottom absorption rate (ARb) versus tightness factor in single jersey modal knitted fabric.

The scatter plot of tightness factor versus Top spreading speed (SSt) and of tightness factor versus Bottom spreading speed (SSb) indicate the relationships between tightness factor and Top spreading speed (SSt) and between tightness factor and Bottom spreading speed (SSb) were relatively similar for single jersey fabric knitted with both counts. Both Top spreading speed (SSt) and Bottom spreading speed (SSb) decreased as tightness factor increased. This is probably also caused by low fabric porosity as discussed previously (see figure 1.125 and 4.126).

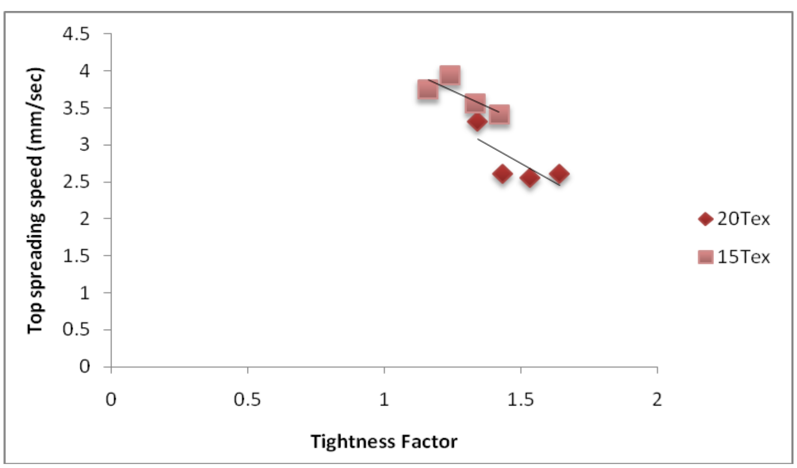

Figure 4.125: Top spreading speed (SSt) versus tightness factor in single jersey modal knitted fabric.

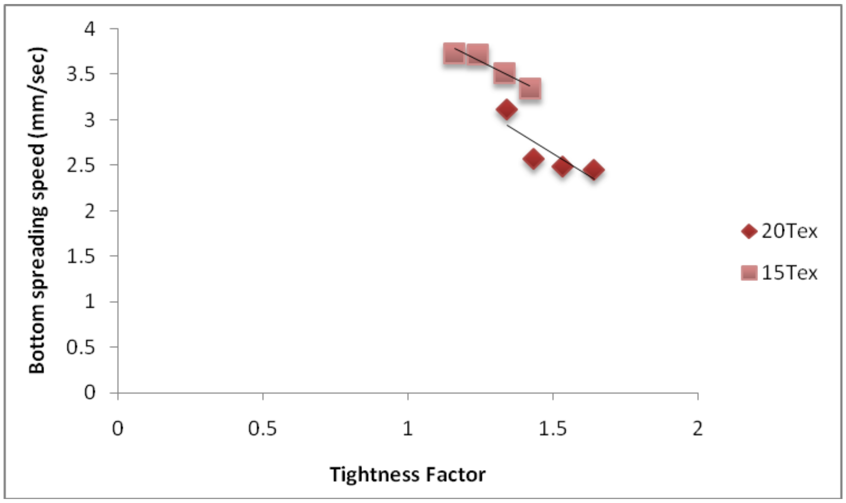

Figure 4.126: Bottom spreading speed (SSb) versus tightness factor in single jersey modal knitted fabric.

When table 4.63 and Figure 4.127 examined Accumulative one-way transport index (AOTI) values of all single jersey modal knitted fabric were found poor and shows increasing trend with the increase in tightness factor for both the counts. OMMC decreased as the tightness factor increased in 20Tex while in 15Tex it increases (see figure 4.128). Single jersey modal fabrics showed fair result ranging in 0.2-0.4. Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.65.

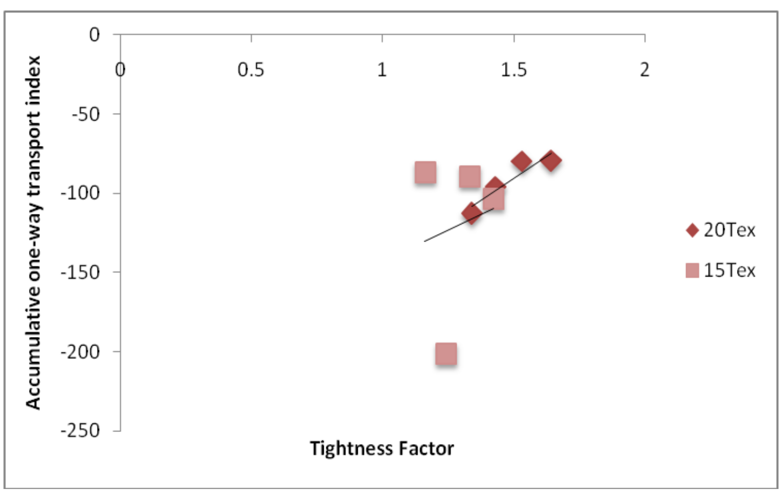

Figure 4.127: Accumulative one-way transport index (AOTI) versus tightness factor in single jersey modal knitted fabric.

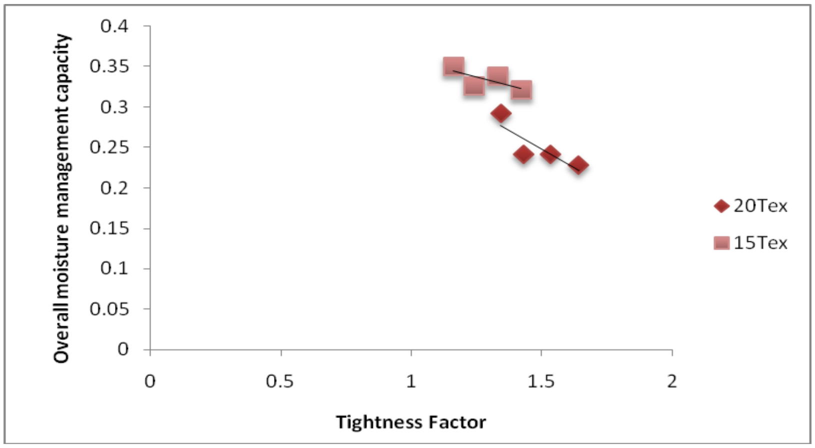

Figure 4.128: Overall moisture management capacity (OMMC) versus tightness factor in single jersey modal knitted fabric.

Table 4.65: Pearson correlations and p-values of tightness factor versus MMT indices of Single Jersey Modal Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.123	0.772
2.	T.F., WTb	0.237	0.573
3.	T.F. ARt	-0.780	0.023
4.	T.F., ARb	-0.631	0.094
5.	T.F., MWRt	-0.783	0.021
6.	T.F., MWRb	-0.856	0.007
7.	T.F., SSt	-0.799	0.017
8.	T.F., SSb	-0.823	0.012
9.	T.F., AOTI	0.897	0.002
10.	T.F., OMMC	-0.681	0.063

It can be observed that the Pearson correlations are close to +1 or -1 except for Top wetting time (WTt) and Bottom wetting time (WTb) . This indicates that for single jersey fabric knitted with modal yarn, tightness factor influence the overall moisture management fabric properties.

4.4.2.2 Pique fabrics

Liquid moisture transport test results of modal pique knitted fabrics in value are given in Table 4.66 and the results converted into grades are given in Table 4.67 where grades range from 1 to 5 – poor to excellent. As can be seen from Table 4.66, the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

Wetting time

A comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the pique knitted fabric shows that the wetting time of the top surface (WTt) is smaller than wetting time of the bottom surface (WTb) as expected, suggesting that it took longer for the liquid water to be transferred to the bottom layer. In the scope of this explanation, it can be stated that, the wetting time value is related with the water absorbency of the fabric.

It can be stated that the finer the yarn, the lower the wetting time is. As the yarns get finer, the thickness of the fabric decreases. When the results of thin and thick fabrics from same type of material compared, thinner fabrics shown faster wetting than thicker ones, when equal amount of water are applied. Since the number of fibres in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid. Figure 4.129 shows the mean grade of the top and bottom wetting time of the pique knitted fabrics.

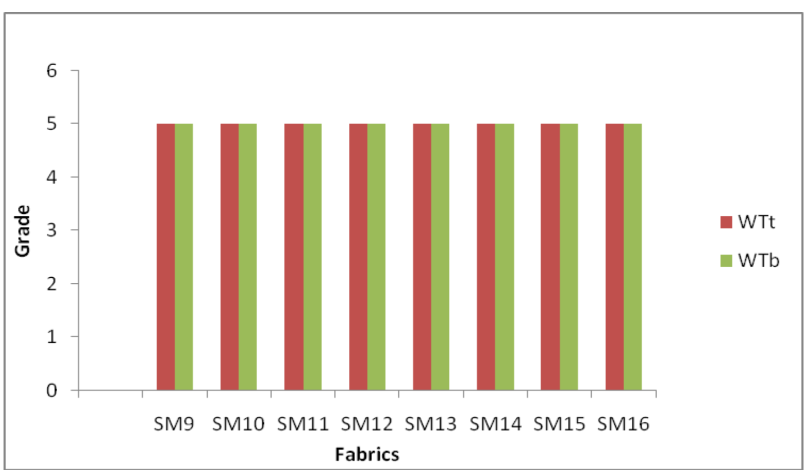

Figure 4.129: Top and bottom wetting time grades of modal pique fabrics.

Table 4.66: MMT results of Modal knitted pique fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SM9	Mean	2.808	2.8454	58.5647	49.0484	23	22	3.99	3.9358	-95.9156	0.3445
	S.Deviation	0.2565	0.2855	2.1588	0.9557	2.7386	2.7386	0.3329	0.3475	16.0944	0.0177
	CV	0.0914	0.1003	0.0369	0.0195	0.1191	0.1245	0.0834	0.0883	0.1678	0.0514
SM10	Mean	2.677	2.7142	58.6489	49.4247	23	23	4.3393	4.2808	-95.5753	0.3595
	S.Deviation	0.1421	0.1149	1.7624	0.9583	2.7386	2.7386	0.2919	0.3093	7.0946	0.0027
	CV	0.0531	0.0423	0.0301	0.0194	0.1191	0.1191	0.0673	0.0722	0.0742	0.0074
SM11	Mean	2.8266	2.8268	55.3077	50.0865	22	22	4.0826	4.0588	-96.5118	0.3489
	S.Deviation	0.2915	0.2991	3.9914	1.2041	2.7386	2.7386	0.4159	0.4519	6.0314	0.0174
	CV	0.1031	0.1058	0.0722	0.024	0.1245	0.1245	0.1019	0.1113	0.0625	0.0499
SM12	Mean	2.7144	2.8642	57.7365	50.227	23	23	4.4763	4.3624	-94.264	0.3578
	S.Deviation	0.2563	0.17	3.4428	1.0214	2.7386	2.7386	0.4569	0.4599	10.0599	0.007
	CV	0.0944	0.0594	0.0596	0.0203	0.1191	0.1191	0.1021	0.1054	0.1067	0.0196
SM13	Mean	2.6954	2.7142	56.938	51.2926	25	25	4.479	4.3973	-95.7977	0.3647
	S.Deviation	0.0784	0.0938	2.409	1.3664	0	0	0.2412	0.2065	13.9422	0.0038
	CV	0.0291	0.0345	0.0423	0.0266	0	0	0.0539	0.047	0.1455	0.0104
SM14	Mean	2.5458	2.5834	56.7707	50.4239	25	26	4.8398	4.7788	-89.0766	0.3623
	S.Deviation	0.1918	0.2155	3.7721	1.5572	0	2.2361	0.2229	0.2892	15.2263	0.0043
	CV	0.0753	0.0834	0.0664	0.0309	0	0.086	0.0461	0.0605	0.1709	0.0119
SM15	Mean	2.5086	2.5272	56.8706	50.8621	25	25	4.7726	4.7339	-96.2017	0.3635
	S.Deviation	0.0785	0.148	2.8084	2.7532	0	0	0.2918	0.3962	11.9372	0.0076
	CV	0.0313	0.0586	0.0494	0.0541	0	0	0.0611	0.0837	0.1241	0.021
SM16	Mean	1.8532	2.6018	82.3646	34.5132	30	30	6.6901	5.8991	386.2741	0.7827
	S.Deviation	0.3204	0.1024	3.7782	3.6407	0	0	0.2722	0.3498	54.0094	0.0256
	CV	0.1729	0.0394	0.0459	0.1055	0	0	0.0407	0.0593	0.1398	0.0328

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.67: MMT results of Modal knitted pique fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SM9	1.64	5	5	3.5	3.5	5	4	5	5	1	2
SM10	1.53	5	5	3.5	3.5	5	5	5	5	1	2.5
SM11	1.43	5	5	3.5	3.5	4	4	5	5	1	2
SM12	1.34	5	5	3.5	3.5	5	5	5	5	1	2
SM13	1.42	5	5	3.5	3.5	5	5	5	5	1	2.5
SM14	1.33	5	5	3.5	3.5	5	5	5	5	1	2.5
SM15	1.24	5	5	3.5	3.5	5	5	5	5	1	2.5
SM16	1.16	5	5	4	2.5	5	5	5	5	4.5	5

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

It is notable that all modal pique fabrics have equal grades in wetting time of the bottom surface (WTb) and wetting time of the top surface (WTt) demonstrating the fastest wetting time in both top and bottom surfaces. It is notable that fabric SM15 has the smallest mean wetting time of the bottom surface (WTb) demonstrating that it has a better liquid transfer ability from the top to the bottom layer than other fabrics in the thickness direction of the fabric.

Absorption rates

It can also be seen from Table 4.66 that the absorption rate values change according to yarn count and tightness factor. Because of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases. Therefore the absorption rate values of the thinner fabrics become higher. The absorption rate values of top surface were found higher than bottom surface, indicating that the liquid water took a very short time to be transferred to the bottom layer after having been injected into the surface of the top layer, which was then sensed and recorded by the bottom sensor.

Figure 4.130 shows the absorption rates grades of modal pique fabrics. All fabrics except SM16 shows equal grades of absorption rate on top surface (ARt) and absorption rate on bottom surface (ARb). Fabric SM16 have an extraordinarily higher absorption rate on top surface (ARt) than other fabrics, which may be because of the liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content of the top surface.

Spreading speed

As the spreading speed values are compared it can be clearly seen that, higher the yarn count, higher the spreading speed is. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the fabric shorten. Figure 4.131 shows the top and bottom spreading speed grades of pique knitted fabrics.

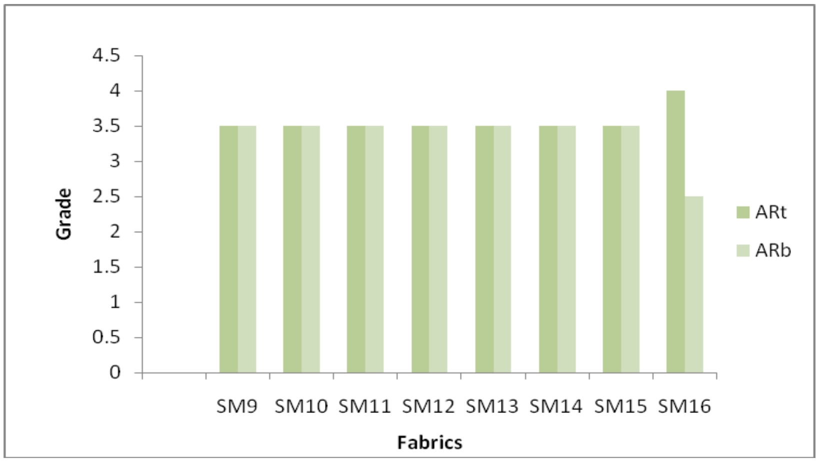

Figure 4.130: Top and bottom absorption rate grades of modal pique fabrics.

Figure 4.131: Top and bottom spreading speed grades of modal knitted pique fabrics.

All pique knitted fabrics of modal yarn shows same grades in top and bottom spreading speed demonstrating very fast spreading speed.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. Figure 4.132 shows the maximum top and bottom wetted radius grade for pique fabrics. According to the maximum wetted results, the value increases for the fabrics made from 15Tex yarn. Pique knitted fabrics have grades ranging from 4 to 5, which means large to very large wetting. Since SM11 fabrics has the lowest top wetted radius value, which also indicates its good moisture transport property, it will give a dry feeling.

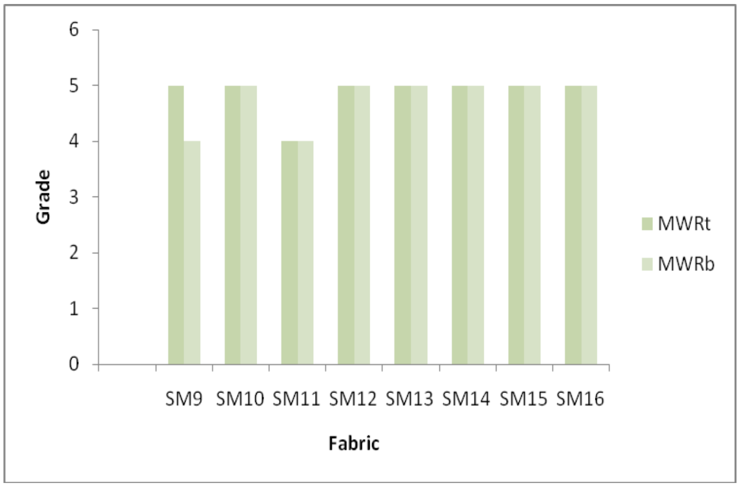

Figure 4.132: Top and bottom maximum wetted radius grade of modal pique fabrics.

Water location versus time can be obtained as a colourful simulation which is given in figure 4.133 according to which, the wetted areas of the fabric on both sides are very high due to the good capillary transfer property. Figure 4.134 shows the typical liquid moisture content change versus test time on the fabrics top layer measured by the MMT for pique knitted fabrics. This figure shows the dynamic moisture management process of a particular fabric during the test time. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The initial slopes of water content curves are similar for all pique fabrics knitted with modal yarn. The water content of the top layer was higher than that of bottom layer throughout the test time except for SM16. It then decreased dramatically, with the water content of the bottom layer evidently increasing, followed by a significant, gradual decrease to equilibrium after reaching a peak at about 26th second. This indicates that the liquid water accumulated at the top surface of the fabrics for a while after being injected by a pump through a needle and was then suddenly transferred to the bottom layer; it is notable that for modal pique fabrics most of the liquid water was transferred and distributed in the bottom layer. Figure

4.135 shows the accumulative one-way transport index grades and overall moisture management capacity of modal pique fabrics.

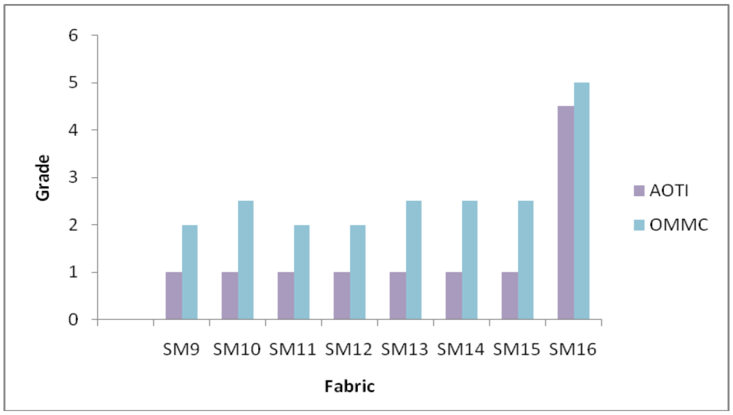

Figure 4.135: Accumulative one-way transport index grades and overall moisture management capacity of modal pique fabrics.

Relationship between Tightness factor and the moisture management properties

The scatter plots of tightness factor versus wetting time on top surface (WTt) and tightness factor versus wetting time on bottom surface (WTb) reflect the relationships between tightness factor and wetting time on top surface (WTt) and wetting time on bottom surface (WTb) and tightness factor. It was observed that both wetting time on top surface (WTt) and wetting time on bottom surface (WTb) increased with increase in tightness factor in case of fabric knitted with count 15Tex (see figure 4.136 and 4.137).

In regard to the maximum wetted radius, the relationships between tightness factor and the maximum wetted radius on top surface (MWRt) and between tightness factor versus maximum wetted radius on bottom surface (MWRb) can be observed from scatter plots of tightness versus maximum wetted radius on top surface (MWRt) and of tightness factor versus maximum wetted radius on bottom surface (MWRb)as shown in figures 4.138 and 4.139. Both maximum wetted radius on top surface (MWRt) and maximum wetted radius on bottom surface (MWRb) decreases with increase in tightness factor in count 15Tex.

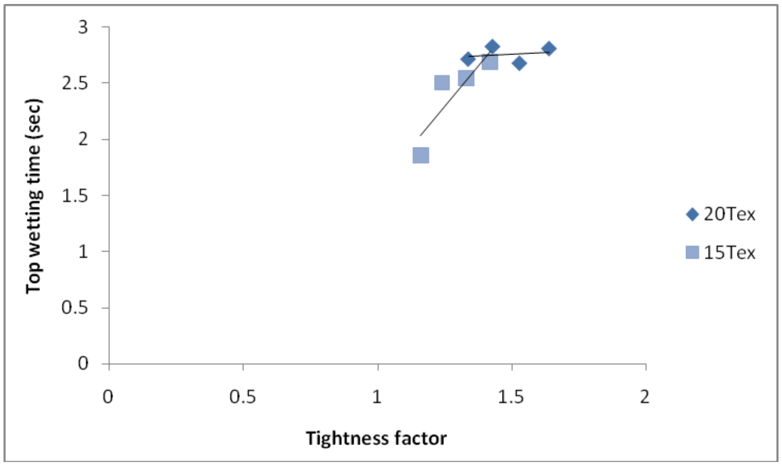

Figure 4.136: Top wetting time (WTt) versus tightness factor in Pique Modal Knitted fabrics.

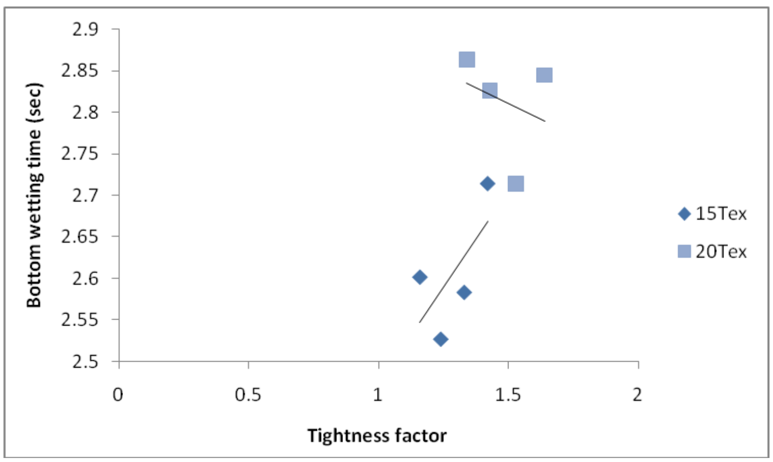

Figure 4.137: Bottom wetting time (WTb) versus tightness factor in Pique Modal Knitted fabrics.

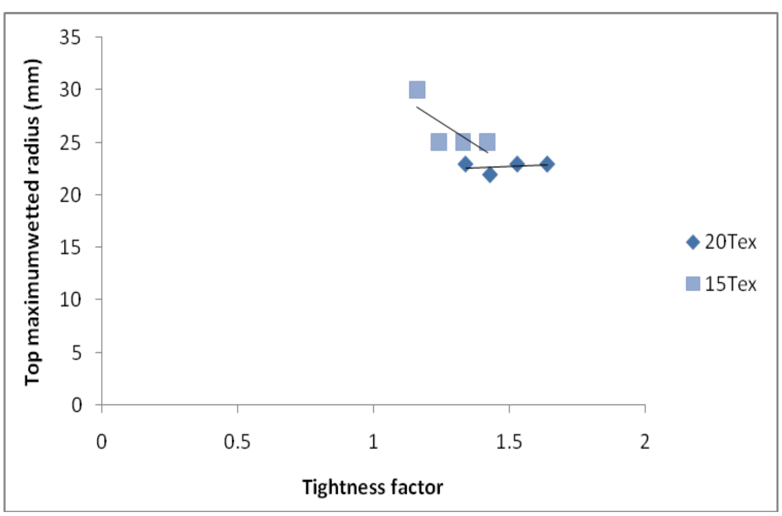

Figure 4.138: Top maximum wetted radius (MWRt) versus tightness factor in Modal Pique knitted fabrics.

Graphs presented in figures 4.136 – 4.139 display different trends: as the tightness increases, the wetting time also increases, but at the same time the maximum wetted radius decreases. It means that it takes more time to wet a fabric with a closer structure. The scatter plot of tightness factor versus absorption rate on top surface (ARt) depicts the relationship between tightness factor and absorption rate on top surface (ARt) and tightness factor and absorption rate on bottom surface (ARb) shows reverse trend for absorption rate on top surface (ARt) and absorption rate on bottom surface (ARb) in both counts (see figure 4.140 and 4.141).

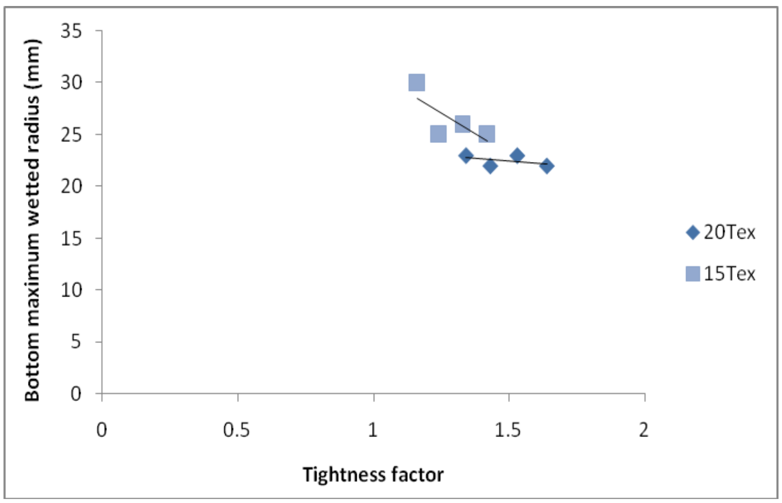

Figure 4.139: Bottom maximum wetted radius (MWRb) versus tightness factor in Modal Pique knitted fabrics.

The scatter plot of tightness factor versus top spreading speed (SSt) and of tightness factor versus bottom spreading speed (SSb) indicate the relationships between tightness factor and top spreading speed (SSt) and between tightness factor and bottom spreading speed (SSb) were relatively similar for pique fabric knitted with both counts. Both top spreading speed (SSt) and bottom spreading speed (SSb) decreased as tightness factor increased in case of both the counts, the decrease is much more rapid in 15Tex (see figure 4.142 and 4.143).

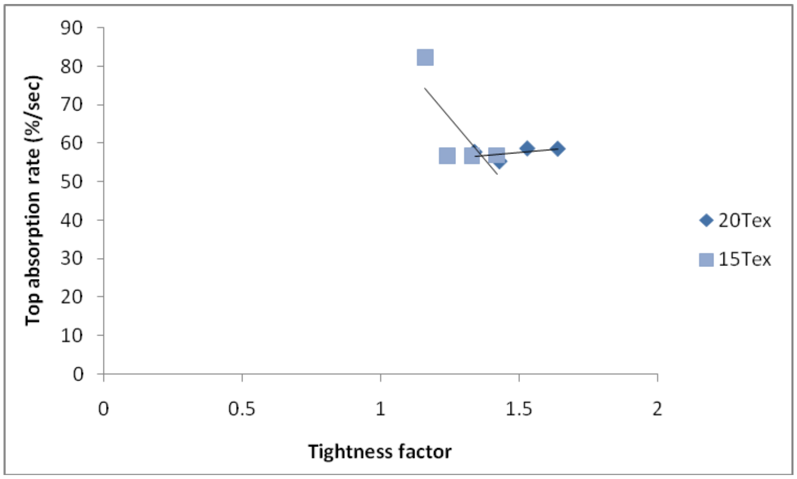

Figure 4.140: Top absorption rate (ARt) versus tightness factor in Modal Pique knitted fabric.

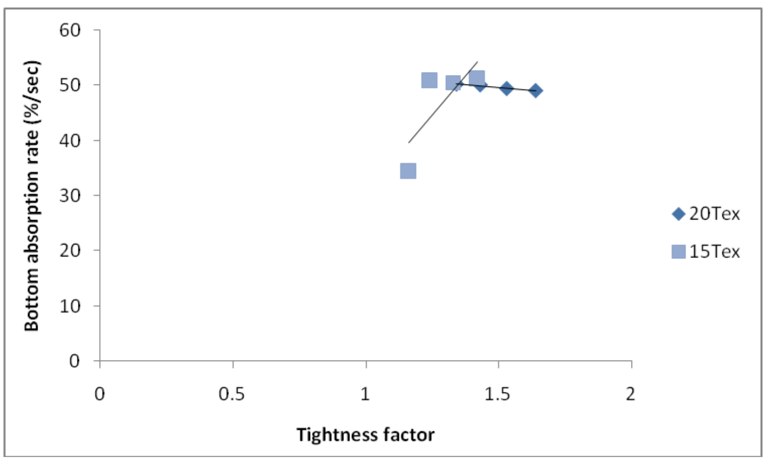

Figure 4.141: Bottom absorption rate (ARb) versus tightness factor in Modal Pique knitted fabric.

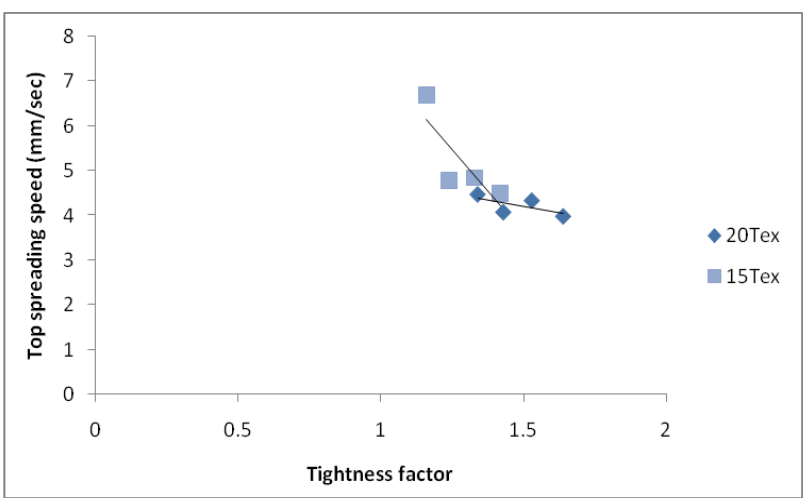

Figure 4.142: Top spreading speed (SSt) versus tightness factor in modal pique knitted fabric.

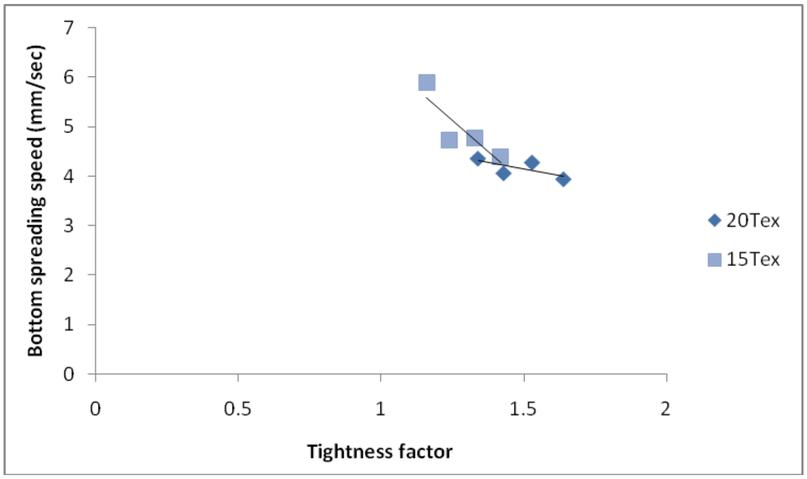

Figure 4.143: Bottom spreading speed (SSb) versus tightness factor in pique knitted modal fabric.

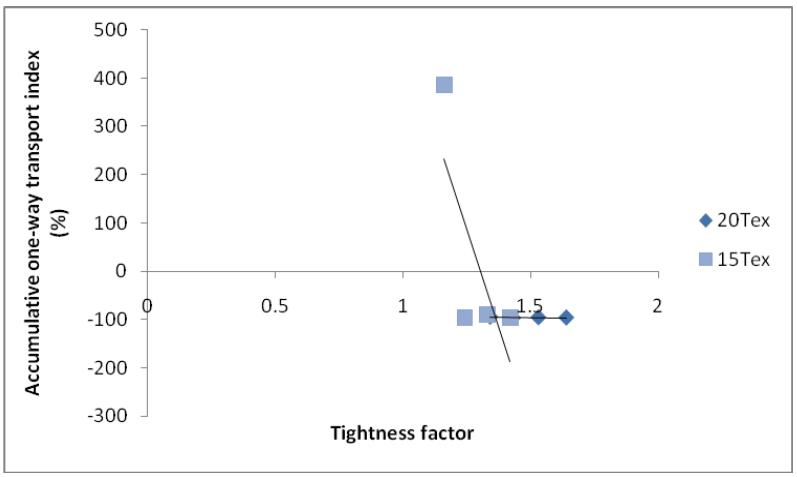

Figure 4.144: Accumulative one-way transport index (AOTI) versus tightness factor in pique knitted modal fabric.

When table 4.66 and Figure 4.144 examined accumulative one-way transport index (AOTI) values of modal knitted fabrics showed poor accumulative one-way transport index (AOTI) because values are approximately more than -50 except fabric SM16 which showed very good one- way transport capacity. Overall moisture management capacity (OMMC) decreased as the tightness factor increased in case of both the counts (see figure 4.145). Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.68. It can be observed that almost all except wetting time on bottom surface (WTb) and accumulative one-way transport index (AOTI), correlations between tightness factor and the indices are linearly related since the Pearson correlations are close to +1 and -1. This indicates that for pique modal knitted fabrics, tightness factor influenced the overall moisture management fabric property.

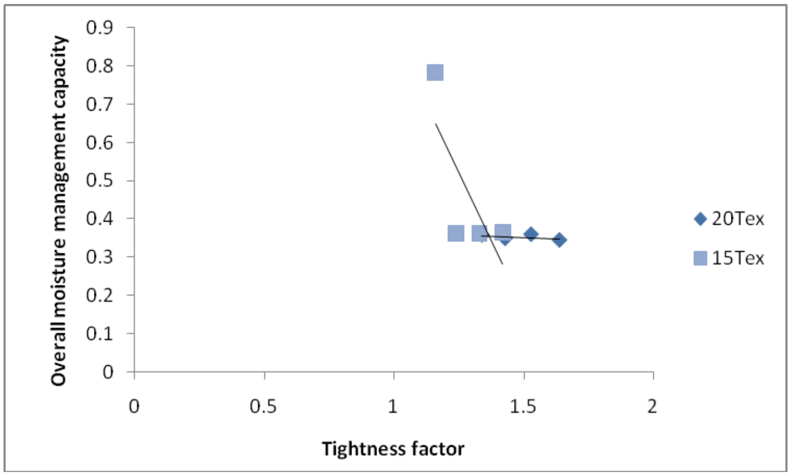

Figure 4.145: Overall moisture management capacity (OMMC) versus tightness factor in pique knitted modal fabric.

Table 4.68: Pearson correlations and p- values of tightness factor versus MMT indices of Pique Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.108	0.782
2.	T.F., WTb	0.723	0.028
3.	T.F. ARt	-0.067	0.864
4.	T.F., ARb	-0.672	0.048
5.	T.F., MWRt	-0.824	0.006
6.	T.F., MWRb	-0.924	0.000
7.	T.F., SSt	-0.800	0.010
8.	T.F., SSb	-0.916	0.001
9.	T.F., AOTI	-0.437	0.239
10.	T.F., OMMC	-0.933	0.000

Figure 4.146 shows typical fingerprint of moisture management properties of modal pique knitted fabric. Except SM16 which is classified into moisture management fabric, all other are classified into fast absorbing and quick drying fabric. All Single jersey and pique modal knitted fabrics were classified as fast absorbing and quick drying fabrics with key properties of very fast wetting, medium–to-fast absorption, large-to-very large wetting, very fast spreading and poor one-way transport properties except for SM16 which has very good one-way transport properties.

4.4.4 Excel knitted fabrics

4.4.4.1 Single jersey fabrics

Liquid moisture transport test results of excel knitted single jersey fabrics in value are given in Table 4.69 and the results converted into grades are given in Table 4.70 where grades range from 1 to 5 – poor to excellent. In case where MMT indices values are close to the lower or upper limit of the value range for conversion into a grade, the values are converted into a half grade.

Wetting time

As can be seen from Table 4.69 and figure 4.147 the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

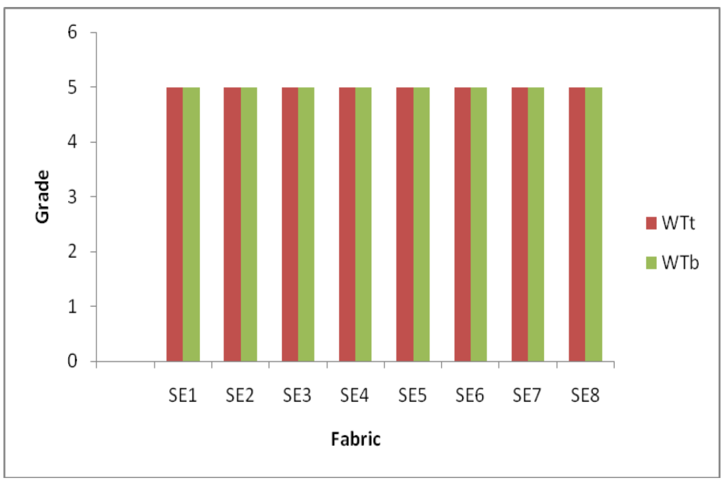

Figure 4.147: Top and bottom wetting time grades of the Excel single jersey knitted fabrics.

From the comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the single jersey knitted fabric shows that all the single jersey excel fabrics have equal grades in top and bottom wetting time as single jersey modal fabrics, suggesting that it took very less time for the liquid water to be transferred to the bottom layer from top layer and vice versa. All the single jersey excel knitted fabrics have excellent wetting time in both top and bottom surfaces due to the high attraction between the liquid and the fibre surface (known as the fibre surface energy).

Table 4.69: MMT results of Excel knitted Single Jersey fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SE1	Mean	2.6022	2.9952	71.5739	30.2214	25	21	5.1198	4.4691	708.5491	0.8062
	S.Deviation	0.1216	0.1322	4.1033	0.6921	0	2.2361	0.4439	0.2388	16.2215	0.0019
	CV	0.0467	0.0441	0.0573	0.0229	0	0.1065	0.0867	0.0534	0.0229	0.0024
SE2	Mean	2.4148	2.8266	66.2832	29.045	25	20	5.5461	4.779	759.1414	0.8029
	S.Deviation	0.1539	0.1391	1.2172	0.6744	0	0	0.3955	0.2042	22.6484	0.0019
	CV	0.0637	0.0492	0.0184	0.0232	0	0	0.0713	0.0427	0.0298	0.0023
SE3	Mean	2.2088	2.3214	64.2811	57.9556	26	25	5.5831	5.341	-10.3059	0.4273
	S.Deviation	0.4267	0.426	3.3573	0.7488	2.2361	0	0.7453	0.6944	8.2811	0.0077
	CV	0.1932	0.1835	0.0522	0.0129	0.086	0	0.1335	0.13	0.8035	0.018
SE4	Mean	2.387	2.418	65.198	59.4159	26.6667	27.5	5.4766	5.3614	0.9689	0.4439
	S.Deviation	0.1418	0.1376	2.7991	2.1171	2.582	2.7386	0.4409	0.4081	14.3989	0.0154
	CV	0.0594	0.05690	0.0429	0.0356	0.0968	0.0995	0.0805	0.0761	14.8610	0.0346
SE5	Mean	2.3633	2.4102	64.615	57.4874	26.25	26.25	5.6887	5.6271	-14.0141	0.4219
	S.Deviation	0.3273	0.279	1.5203	2.1518	2.5	2.5	0.7989	0.7577	18.2286	0.015
	CV	0.1385	0.1158	0.0235	0.0374	0.0952	0.0952	0.1404	0.1347	1.3007	0.0356
SE6	Mean	2.1902	2.2652	68.5519	59.319	30	29	6.7329	6.4968	-9.3681	0.4321
	S.Deviation	0.0837	0.0782	1.4398	1.5472	0	2.2361	0.7549	0.8047	13.1856	0.0178
	CV	0.0382	0.0345	0.021	0.0261	0	0.0771	0.1121	0.1239	1.4075	0.0412
SE7	Mean	2.0966	2.2092	66.7156	59.8881	30	30	6.9128	6.6876	-18.4679	0.4236
	S.Deviation	0.1567	0.1422	4.6311	0.3507	0	0	0.4567	0.4479	7.5025	0.0087
	CV	0.0747	0.0644	0.0694	0.0059	0	0	0.0661	0.067	0.4062	0.0204
SE8	Mean	2.0592	2.1344	65.4642	59.9726	30	30	6.6301	6.4698	2.6572	0.4473
	S.Deviation	0.1322	0.1537	4.5281	0.5601	0	0	0.4334	0.3968	9.2312	0.0105
	CV	0.0642	0.072	0.0692	0.0093	0	0	0.0654	0.0613	3.4741	0.0235

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.70: MMT results of Excel knitted Single Jersey fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SE1	1.64	5	5	4	2.5	5	4	5	5	5	5
SE2	1.53	5	5	4	2.5	5	4	5	5	5	5
SE3	1.43	5	5	4	3.5	5	5	5	5	2	2.5
SE4	1.34	5	5	4	3.5	5	5	5	5	2	3
SE5	1.42	5	5	4	3.5	5	5	5	5	2	2.5
SE6	1.33	5	5	4	3.5	5	5	5	5	2	2.5
SE7	1.24	5	5	4	3.5	5	5	5	5	2	2.5
SE8	1.16	5	5	4	3.5	5	5	5	5	2	3

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Absorption rates

As can be seen from Table 4.69, the top absorption rates of the excel fabrics are higher than bottom surfaces similar to that observed in modal single jersey fabrics which may be because of liquid water accumulating on the top layer surface for a very short while, causing an obvious increase in the water content on the top surface. Figure 4.148 shows top and bottom absorption rate grades of single jersey excel fabrics. The bottom absorption rate (ARb) observed was higher than in case of single jersey excel fabrics.

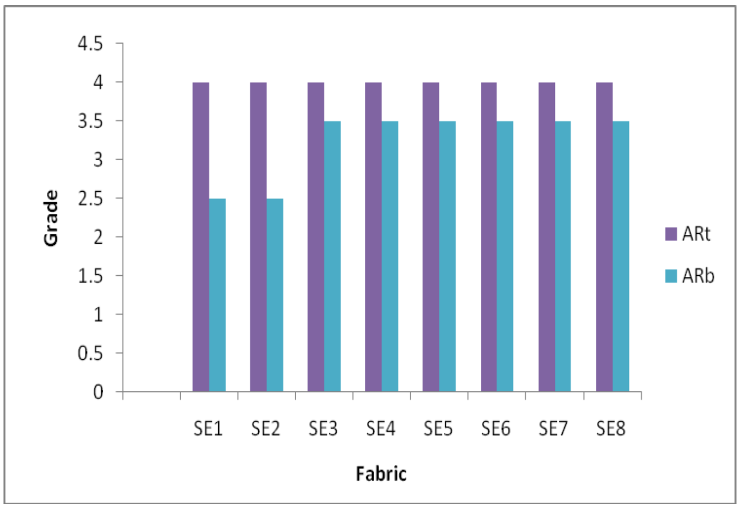

Figure 4.148: Top and bottom absorption rate grades of the single jersey excel knitted fabrics.

Spreading speed

Figure 4.149 shows the top and bottom spreading speed grades of single jersey fabrics knitted with excel yarn. All have very fast spreading speed grade similar to observed for single jersey modal fabrics.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. All single jersey knitted fabrics have large maximum wetted radius. The wetter areas of the fabric on both sides are very high due to the good capillary transfer property. The maximum wetted radius values are higher in excel single jersey fabrics, as they are compared with entirely cotton, viscose and modal single jersey fabrics.

Figure 4.149: Top and bottom spreading speed grades of the Excel single jersey knitted fabrics.

Water location versus time can be obtained as a colourful simulation which is given in figure 4.150. Figure 4.151 shows the typical liquid moisture content change versus test time on the fabrics top layer measured by the MMT for single jersey knitted fabrics. This figure shows the dynamic moisture management process of a particular fabric during the test time. During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The water content of the top layer was higher than that of bottom layer except for SE1 and SE2 fabrics after 26th second and then remain slightly higher during the test time. This indicates that the liquid water accumulated at the top surface of the fabric for a while after being injected by a pump through a needle and was then suddenly transferred to the bottom layer. Figure 4.152 shows the mean grade of the top and bottom wetted radius of all eight single jersey knitted fabrics. Figure 4.153 shows accumulative one-way transport index grades and overall moisture management capacity of single jersey excel fabrics.

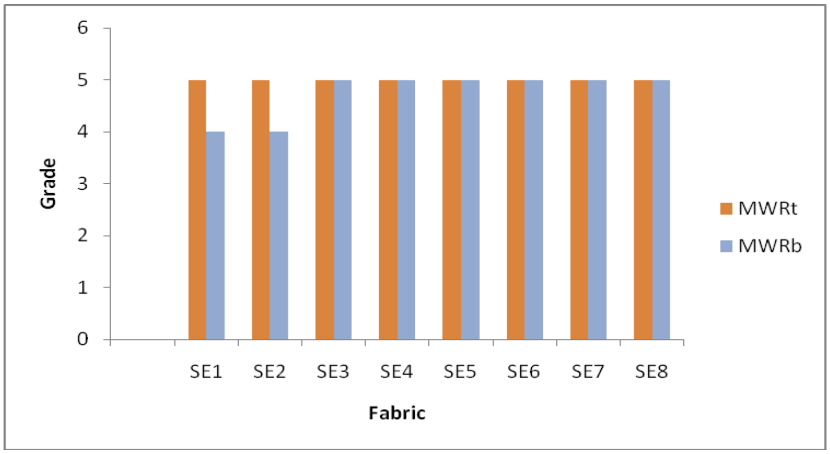

Figure 4.152: Top and bottom maximum wetted radius grades of the single jersey Excel knitted fabrics.

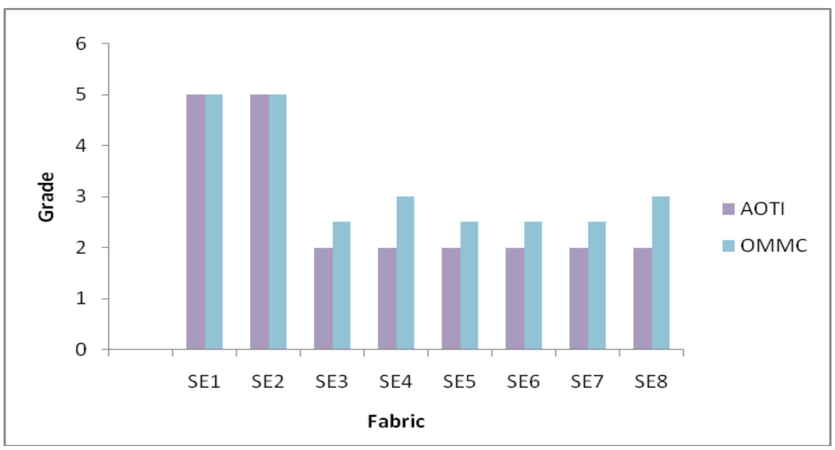

Figure 4.153: Accumulative one-way transport index grades and overall moisture management capacity of the single jersey fabrics knitted with excel.

Relationship between Tightness factor and the moisture management properties

To find the possible relationship between tightness factor and moisture management properties of knitted fabrics, scatter plots with regression lines of MMT indices and Tightness factor were generated. The scatter plots of tightness factor versus wetting time on top surface (WTt) and tightness factor versus wetting time on bottom surface (WTb) reflect that relationships between tightness factor and wetting time on top surface (WTt), wetting time on bottom surface (WTb). Wetting time on top surface (WTt) and wetting time on bottom surface (WTb) increased as tightness

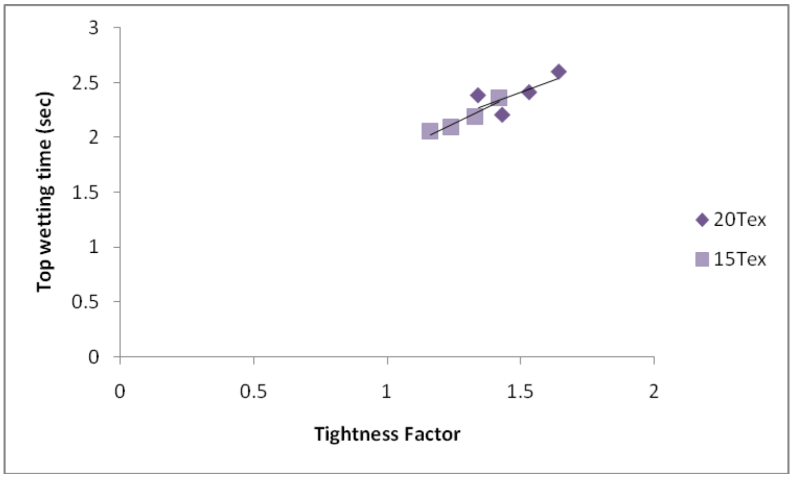

Figure 4.154: Top wetting time (WTt) versus tightness factor in Single Jersey Excel Knitted fabrics.

factor increased in case of single jersey fabrics knitted with both the counts (see figure 4.154 and 4.155). In regard to the maximum wetted radius, the relationships between tightness factor and maximum wetted radius on top surface (MWRt) and between tightness factor versus bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus maximum wetted radius on top surface (MWRt) and of tightness factor versus bottom maximum wetted radius (MWRb). Both maximum wetted radius on top surface (MWRt) and bottom maximum wetted radius (MWRb) decreases with the increase in tightness factor (see figure 4.156 and 4.157).

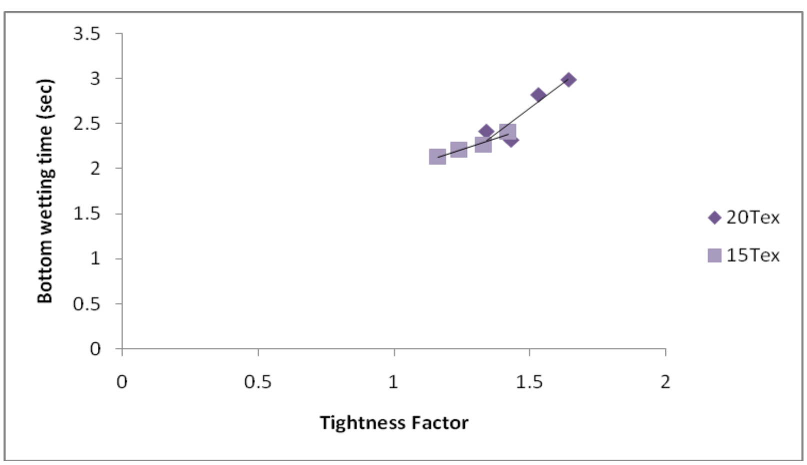

Figure 4.155: Bottom wetting time (WTt) versus tightness factor in Single Jersey Excel Knitted fabrics.

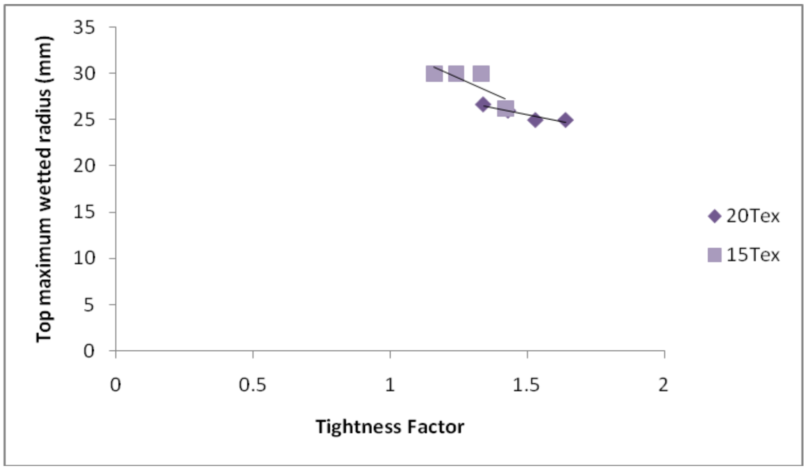

Figure 4.156: Top maximum wetted radius (MWRt) versus tightness factor in single jersey excel knitted fabrics.

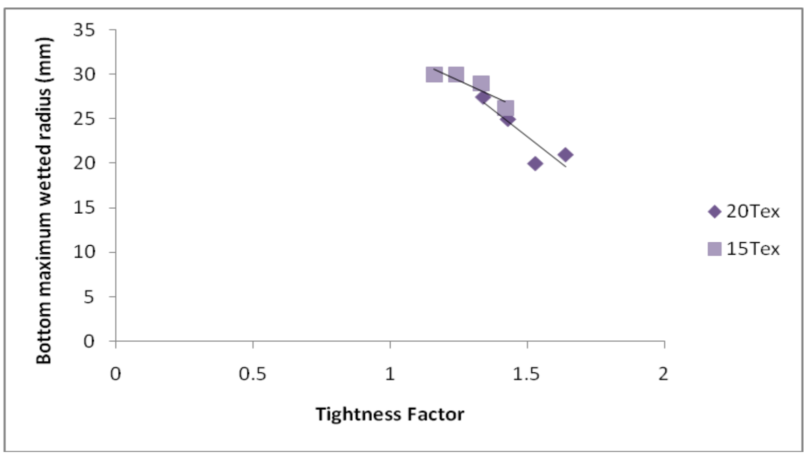

Figure 4.157: Bottom maximum wetted radius (MWRb) versus tightness factor in single jersey excel knitted fabrics.

Graphs presented in figures 4.154 – 4.157 display different trends : as the tightness increases, the wetting time also increases but at the same time the maximum wetted radius decreases. It means that it takes more time to wet a fabric with a closer structure. The scatter plot of tightness factor versus absorption rate on top surface (ARt) depicts the relationship between tightness factor and absorption rate on top surface (ARt): no clear trend was observed (see figure 4.158 and 4.159).

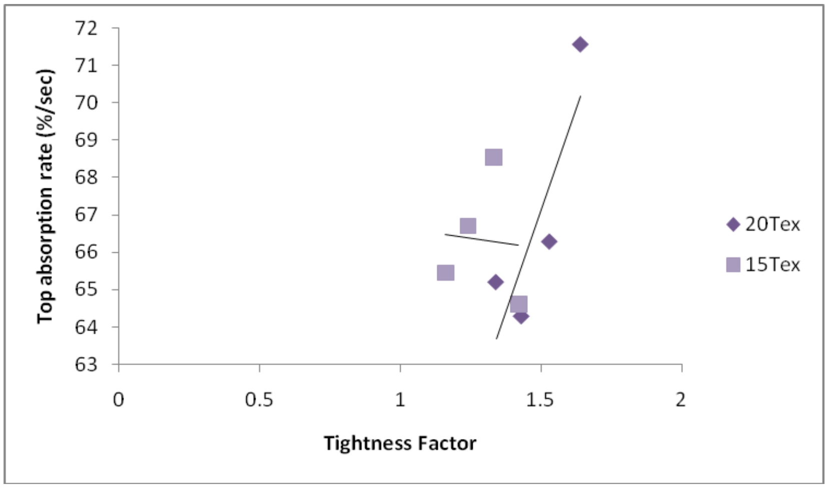

Figure 4.158: Top absorption rate (ARt) versus tightness factor in single jersey excel knitted fabric.

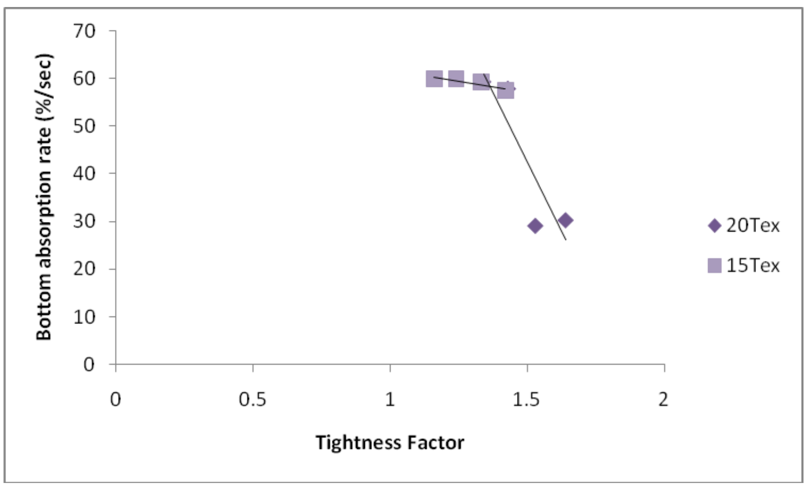

Figure 4.159: Bottom absorption rate (ARb) versus tightness factor in single jersey excel knitted fabric.

The scatter plot of tightness factor versus top spreading speed (SSt) and of tightness factor versus bottom spreading speed (SSb) indicate the relationships between tightness factor and top spreading speed (SSt) and between tightness factor and bottom spreading speed (SSb) were relatively similar for single jersey fabric knitted with both counts. Both top spreading speed (SSt) and bottom spreading speed (SSb) decreased as tightness factor increased (see figure 4.160 and 4.161). This is probably also caused by low fabric porosity as discussed previously.

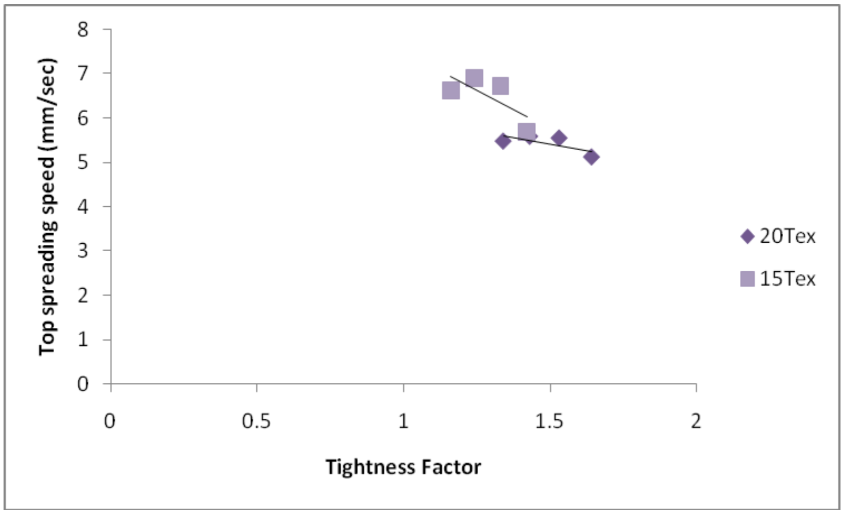

Figure 4.160: Top spreading speed (SSt) versus tightness factor in single jersey excel knitted fabric.

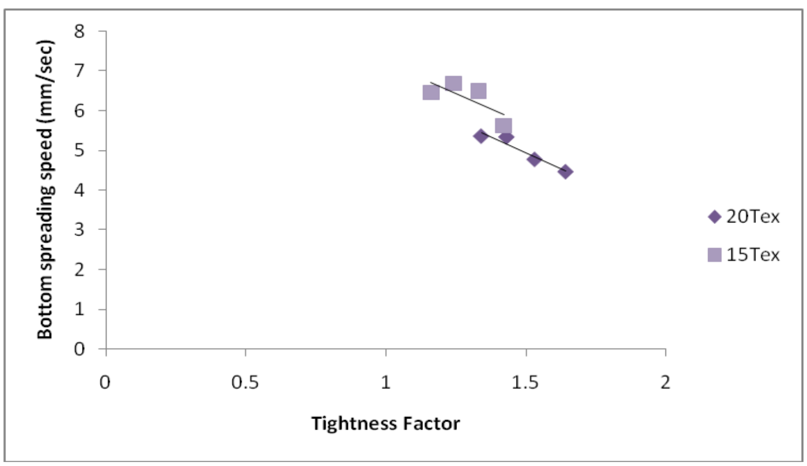

Figure 4.161: Bottom spreading speed (SSb) versus tightness factor in single jersey excel knitted fabric.

When table 4.649 and Figure 4.162 examined AOTI values of all single jersey excel knitted fabric were found ranging from poor to fair. OMMC decreased as the tightness factor increased in 15Tex while in 20Tex it increases (see figure 4.163). Single jersey excel fabrics showed good to very good result ranging in 0.4-0.8. Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.71.

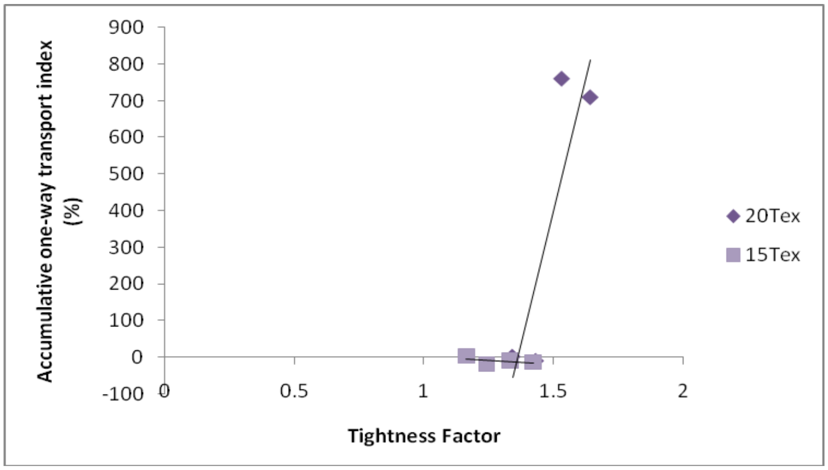

Figure 4.162: Accumulative one-way transport index (AOTI) versus tightness factor in single jersey excel knitted fabric.

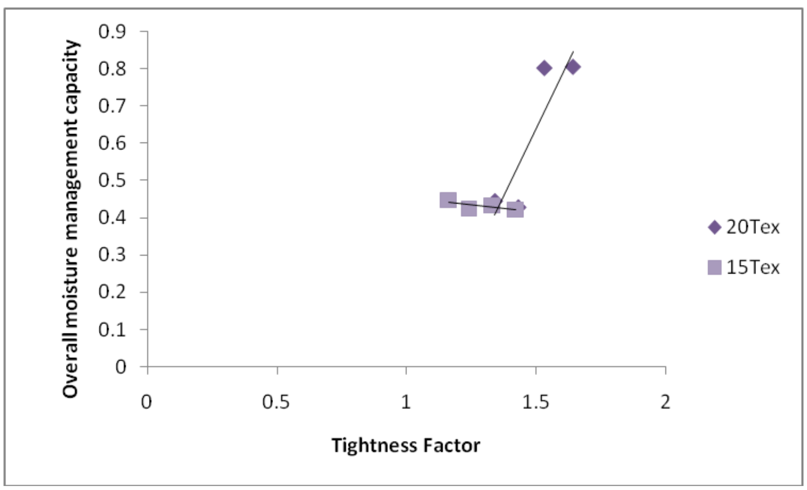

Figure 4.163: Overall moisture management capacity (OMMC) versus tightness factor in single jersey excel knitted fabric.

It can be observed that the Pearson correlations are close to +1 or -1 except for absorption rate on top surface (ARt). This indicates that for single jersey fabric knitted with excel yarn, tightness factor influence the overall moisture management fabric properties.

Table 4.71: Pearson correlations and p-values of tightness factor versus MMT indices of Single Jersey Excel Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	0.900	0.002
2.	T.F., WTb	0.926	0.001
3.	T.F. ARt	0.475	0.234
4.	T.F., ARb	-0.823	0.012
5.	T.F., MWRt	-0.878	0.004
6.	T.F., MWRb	-0.932	0.001
7.	T.F., SSt	-0.827	0.011
8.	T.F., SSb	-0.908	0.002
9.	T.F., AOTI	0.784	0.021
10.	T.F., OMMC	0.780	0.022

It is important to note that overall evaluation of the moisture management performance of the fabrics has to be given with holistic consideration of all the indices in value and / or grades. Figure 4.164, shows an example of the fingerprint of moisture management properties of fabric samples. It can be seen that the fabrics can be classified into fabric type, based on grades, in order to give a direct overall evaluation and result for their liquid moisture management properties if required. Except SE1 and SE2 all other single jersey excel knitted structures are classified into fast absorbing and quick drying fabrics.

4.4.2.2 Pique fabrics

Liquid moisture transport test results of excel pique knitted fabrics in value are given in Table 4.72 and the results converted into grades are given in Table 4.73 where grades range from 1 to 5 – poor to excellent. As can be seen from Table 4.72, the wetting time changes according to the yarn count and tightness factor on the top and bottom surfaces.

Wetting time

A comparison of the wetting time of the top surface (WTt) and that of the bottom surface (WTb) for the pique knitted fabric shows that the wetting time of the top surface (WTt) is smaller than the wetting time of the bottom surface (WTb) as expected, suggesting that it took longer for the liquid water to be transferred to the bottom layer. In the scope of this explanation, it can be stated that, the wetting time value is related with the water absorbency of the fabric.

It can be stated that the finer the yarn, the lower the wetting time is. As the yarns get finer, the thickness of the fabric decreases. When the results of thin and thick fabrics from same type of material compared, thinner fabrics shown faster wetting than thicker ones, when equal amount of water are applied. Since the number of fibres in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid.

Figure 4.165 shows the mean grade of the top and bottom wetting time of the pique knitted fabrics. It is notable that all excel pique fabrics have equal grades in wetting time of the bottom surface (WTb) and wetting time of the top surface (WTt) demonstrating the very fast wetting time in both top and bottom surfaces which is similar to modal single jersey and pique fabrics and excel single jersey fabrics.

Table 4.72: MMT results of Excel knitted Pique fabrics in value.

Fabric		WTt (sec)	WTb (sec)	ARt (%/sec)	ARb (%/sec)	MWRt (mm)	MWRb (mm)	SSt (mm/sec)	SSb (mm/sec)	AOTI (%)	OMMC
SE9	Mean	2.883	3.0516	60.4207	53.1985	22	20	3.8936	3.6734	35.4166	0.4377
	S.Deviation	0.233	0.17	5.2103	0.9955	2.7386	0	0.2375	0.1391	28.3673	0.0407
	CV	0.0808	0.0557	0.0862	0.0187	0.1245	0	0.061	0.0379	0.801	0.0931
SE10	Mean	2.6584	2.883	56.8543	51.768	20	20	3.9615	3.7291	37.4002	0.4406
	S.Deviation	0.2441	0.251	4.0639	2.2779	0	0	0.0977	0.094	31.2677	0.0423
	CV	0.0918	0.0871	0.0715	0.044	0	0	0.0247	0.0252	0.836	0.096
SE11	Mean	2.5832	2.733	53.5121	51.5307	23	23	4.472	4.3024	77.0375	0.5051
	S.Deviation	0.17	0.233	1.2959	1.8024	2.7386	2.7386	0.3639	0.3773	8.0727	0.0132
	CV	0.0658	0.0853	0.0242	0.035	0.1191	0.1191	0.0814	0.0877	0.1048	0.0261
SE12	Mean	2.4708	2.6582	57.4474	52.9109	22	21	4.5506	4.249	55.36	0.4848
	S.Deviation	0.1569	0.1417	2.502	1.3564	2.7386	2.2361	0.2899	0.2415	10.9815	0.0114
	CV	0.0635	0.0533	0.0436	0.0256	0.1245	0.1065	0.0637	0.0568	0.1984	0.0235
SE13	Mean	2.4524	2.6396	62.7302	54.3895	27	26	5.3105	5.0897	50.7444	0.4852
	S.Deviation	0.0785	0.0784	4.1536	1.1721	2.7386	2.2361	0.4616	0.4169	13.1372	0.0123
	CV	0.032	0.0297	0.0662	0.0216	0.1014	0.086	0.0869	0.0819	0.2589	0.0254
SE14	Mean	2.209	2.3772	62.529	55.674	27	28	6.1656	6.0029	20.0438	0.4547
	S.Deviation	0.5828	0.552	2.7515	3.4565	2.7386	2.7386	1.0268	1.1205	34.5346	0.0453
	CV	0.2638	0.2322	0.044	0.0621	0.1014	0.0978	0.1665	0.1867	1.723	0.0996
SE15	Mean	3.3884	2.733	55.303	47.8083	24	23	4.5505	4.9373	40.4966	0.4281
	S.Deviation	2.3942	1.2924	20.5256	14.8557	2.2361	4.4721	1.4256	1.9943	118.4152	0.0394
	CV	0.7066	0.4729	0.3711	0.3107	0.0932	0.1944	0.3133	0.4039	2.9241	0.092
SE16	Mean	2.6396	2.7706	62.4307	56.3533	25	25	4.8533	4.6595	1.3889	0.4359
	S.Deviation	0.1222	0.2443	4.7393	2.3705	0	0	0.2541	0.4029	8.5319	0.0125
	CV	0.0463	0.0882	0.0759	0.0421	0	0	0.0524	0.0865	6.143	0.0286

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Table 4.73: MMT results of Excel knitted pique fabrics in grade.

Fabric	Tightness Factor	WTt	WTb	ARt	ARb	MWRt	MWRb	SSt	SSb	AOTI	OMMC
SE9	1.64	5	5	4	4	4	4	5	4	2	3
SE10	1.53	5	5	4	4	4	4	5	4	2	3
SE11	1.43	5	5	4	4	5	5	5	5	3	3
SE12	1.34	5	5	4	4	4	4	5	5	2	3
SE13	1.42	5	5	4	4	5	5	5	5	2	3
SE14	1.33	5	5	4	4	5	5	5	5	2	3
SE15	1.24	5	5	4	3	5	5	5	5	2	3
SE16	1.16	5	5	4	4	5	5	5	5	2	3

(WTt: Wetting time on top surface; WTb: Wetting time on bottom surface; ARt: Top absorption rate; ARb: Bottom absorption rate; MWRt: Top maximum wetted radius; MWRb: Bottom maximum wetted radius; SSt: Top spreading speed; SSb: Bottom spreading speed; AOTI: Accumulative one-way transport index; OMMC: Overall moisture management capacity)

Figure 4.165: Top and bottom wetting time grades of excel pique fabrics.

Absorption rates

It can also be seen from Table 4.72 that the absorption rate values change according to yarn count and tightness factor. Because of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases. Therefore the absorption rate values of the thinner fabrics become higher. The absorption rate values of top surface were found higher than bottom surface, indicating that the liquid water took a very short time to be transferred to the bottom layer after having been injected into the surface of the top layer, which was then sensed and recorded by the bottom sensor. Figure 4.166 shows the absorption rates grades of excel pique fabrics. All fabrics except SE15 shows equal grades of absorption rate on top surface (ARt) and absorption rate on bottom surface (ARb).

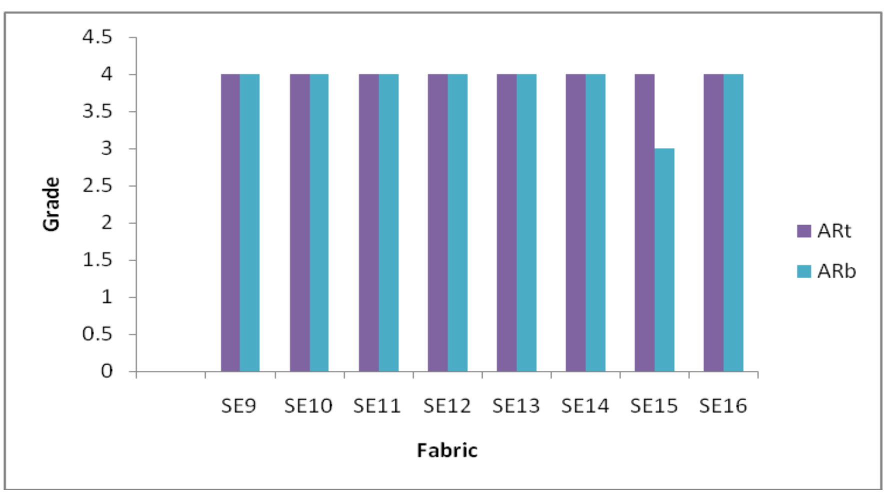

Figure 4.166: Top and bottom absorption rate grades of excel pique fabrics.

Spreading speed

As the spreading speed values are compared it can be clearly seen that, higher the yarn count, higher the spreading speed is. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the fabric shorten. Figure 4.167 shows the top and bottom spreading speed grades of pique knitted fabrics. All pique knitted fabrics of excel yarn except SE9 and SE10 shows same grades in top and bottom spreading speed demonstrating very fast spreading speed.

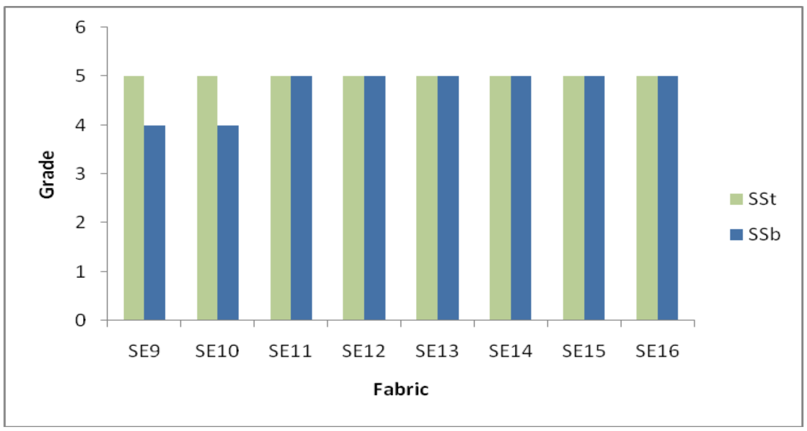

Figure 4.167: Top and bottom spreading speed grades of excel pique fabrics.

Maximum wetted radius

In the study, the maximum wetted radius of the fabrics wetted with the same amount of water is also investigated. Figure 4.168 shows the maximum top and bottom wetted radius grade for pique fabrics. According to the maximum wetted results, the value increases for the fabrics made from 15Tex yarn. Pique knitted fabrics have grades ranging from 4 to 5, which means large to very large wetting. Since SE9, SE10 and SE12 fabrics have the lowest top wetted radius value, which also indicates their good moisture transport property, they will give a dry feeling. Water location versus time can be obtained as a colourful simulation, according to which, the wetted areas of the fabric on both sides are very high due to the good capillary transfer property.

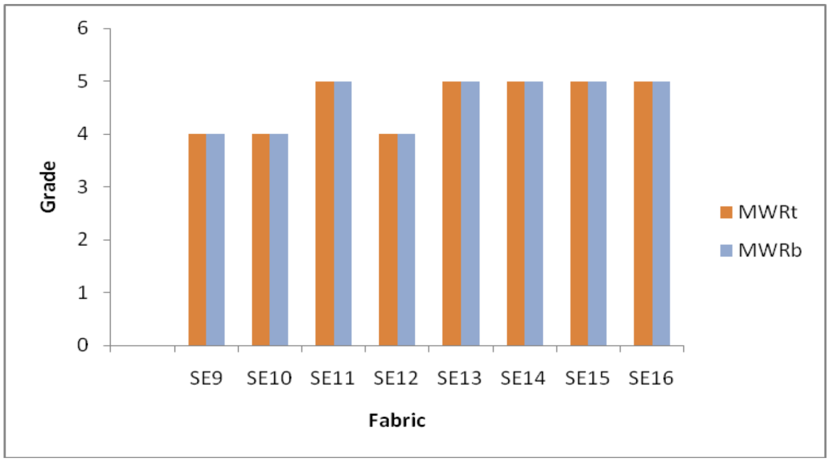

Figure 4.168: Top and bottom maximum wetted radius grade of excel pique fabrics.

During the first 20 seconds, the tester was pumping to inject liquid water into the top surface of the fabric, and it could be observed that the water content increased sharply in this period. At the 20th second, with the water injection having stopped, the water content began to decrease sharply and then gradually to equilibrium[177].

Owing to the quick water transfer, the water content curve of the bottom surface begins to increase. However, the water content curve for the bottom surface begins to increase after a delay that will also affect the wetting time values for the surfaces[114]. The initial slopes of water content curves are similar for all pique fabrics knitted with excel yarn. The water content of the top layer was higher than that of bottom layer initially. It then decreased dramatically, with the water content of the bottom layer evidently increasing, followed by a significant, gradual decrease to equilibrium after reaching a peak at about 26th second. This indicates that the liquid water accumulated at the top surface of the fabrics for a while after being injected by a pump through a needle and was then suddenly transferred to the bottom layer; it is notable that for excel pique fabrics most of the liquid water was transferred and distributed in the bottom layer. Figure 4.169 shows the accumulative one-way transport index grades and overall moisture management capacity of excel pique fabrics.

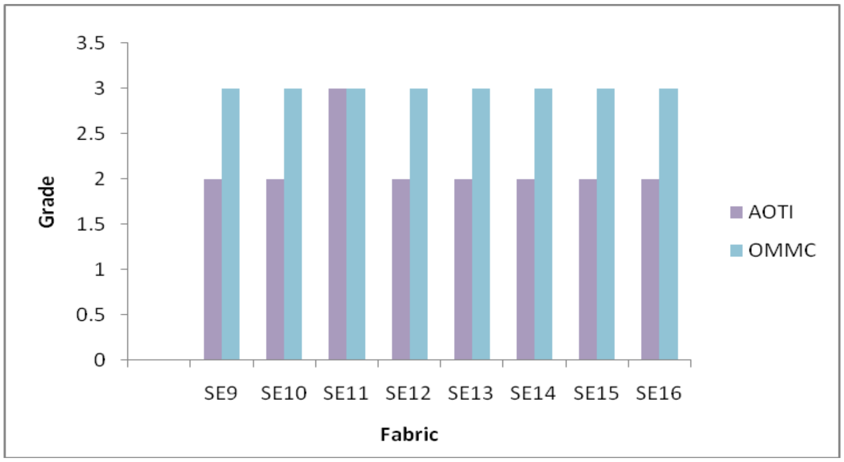

Figure 4.169: Accumulative one-way transport index grades and overall moisture management capacity of excel pique fabrics.

Relationship between Tightness factor and the moisture management properties

The scatter plots of tightness factor versus wetting time on top surface (WTt) and tightness factor versus wetting time on bottom surface (WTb) reflect the relationships between tightness factor and wetting time on top surface (WTt) and wetting time on bottom surface (WTb) and tightness factor. It was observed that both wetting time on top surface (WTt) and wetting time on bottom surface (WTb) increased with increase in tightness factor in case of fabric knitted with count 20Tex (see figure 4.170 and 4.171).

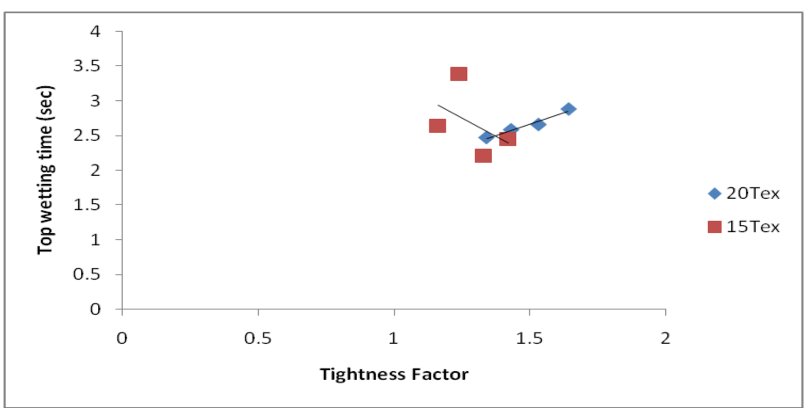

Figure 4.170: Top wetting time (WTt) versus tightness factor in Pique Excel Knitted fabrics.

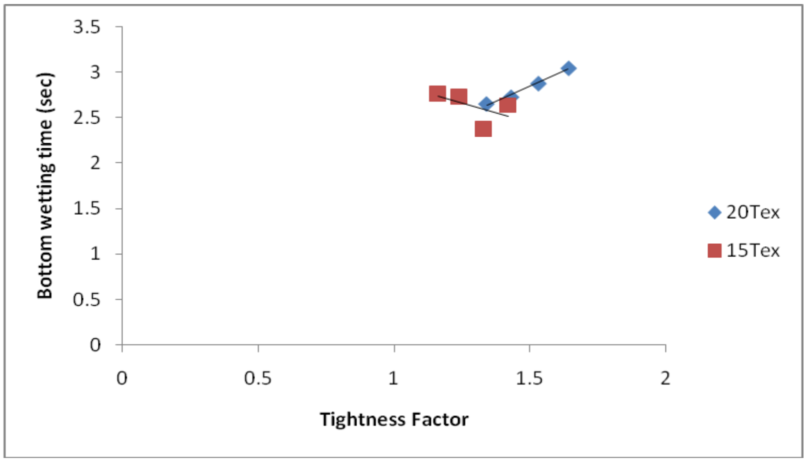

Figure 4.171: Bottom wetting time (WTb) versus tightness factor in Pique Excel Knitted fabrics.

In regard to the maximum wetted radius, the relationships between tightness factor and top maximum wetted radius (MWRt) and between tightness factor versus bottom maximum wetted radius (MWRb) can be observed from scatter plots of tightness versus top maximum wetted radius (MWRt) and of tightness factor versus bottom maximum wetted radius (MWRb) as shown in figures 4.172 and 4.173. Both top maximum wetted radius (MWRt) and bottom maximum wetted radius (MWRb) decreases with increase in tightness factor in count 20Tex.

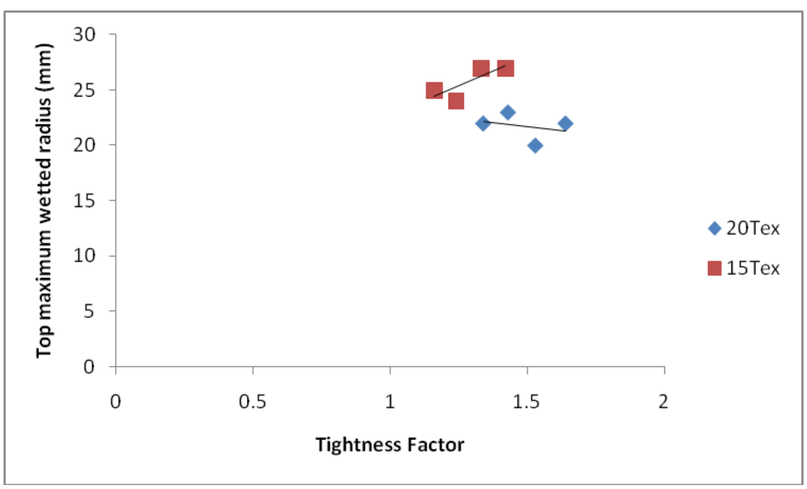

Figure 4.172: Top maximum wetted radius (MWRt) versus tightness factor in Pique knitted excel fabrics.

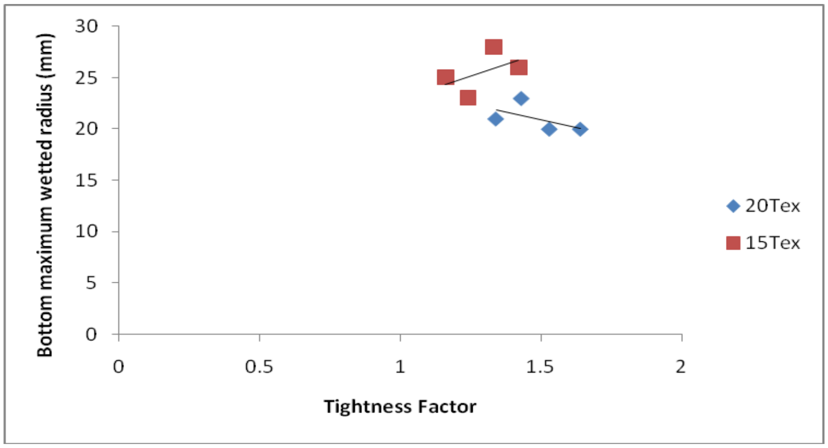

Figure 4.173: Bottom maximum wetted radius (MWRb) versus tightness factor in Pique knitted excel fabrics.

The scatter plot of tightness factor versus absorption rate on top surface (ARt) depicts the relationship between tightness factor and absorption rate on top surface (ARt) and tightness factor and absorption rate on bottom surface (ARb) shows same trend for absorption rate on top surface (ARt) and absorption rate on bottom surface (ARb) in both counts. Both increases with the increase in tightness factor (see figure 4.174 and 4.175).

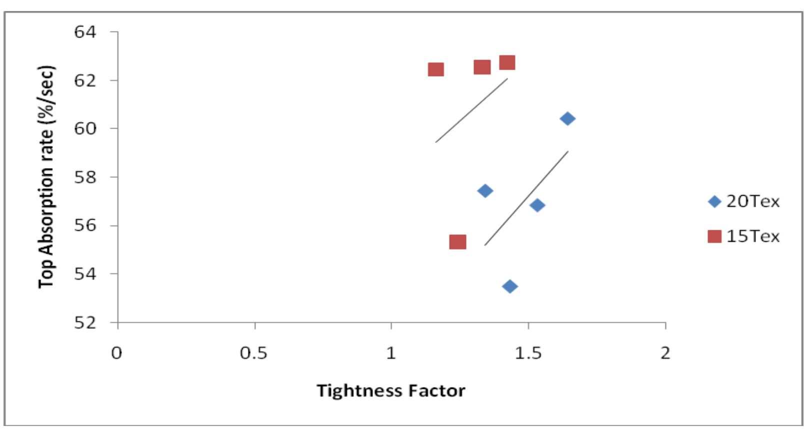

Figure 4.174: Top absorption rate (ARt) versus tightness factor in Pique knitted excel fabric.

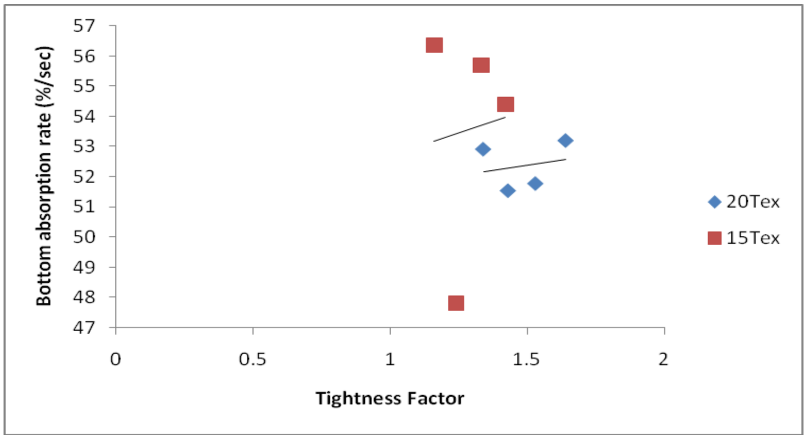

Figure 4.175: Bottom absorption rate (ARb) versus tightness factor in Pique knitted excel fabric.

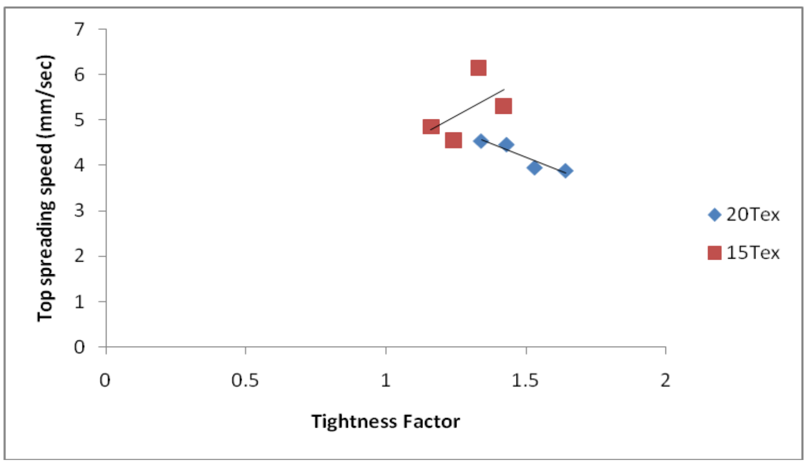

Figure 4.176: Top spreading speed (SSt) versus tightness factor in pique knitted excel fabric.

The scatter plot of tightness factor versus top spreading speed (SSt) and of tightness factor versus bottom spreading speed (SSb) indicate the relationships between tightness factor and top spreading speed (SSt) and between tightness factor and bottom spreading speed (SSb). Both top spreading speed (SSt) and bottom spreading speed (SSb) increased as tightness factor increased in case of 15Tex while decreased in case of 20Tex (see figure 4.176 and 4.177). When table 4.72 and Figure 4.178 examined accumulative one-way transport index (AOTI) values of excel knitted fabrics showed fair accumulative one-way transport index (AOTI) because values are approximately ranging between -50 to 100.

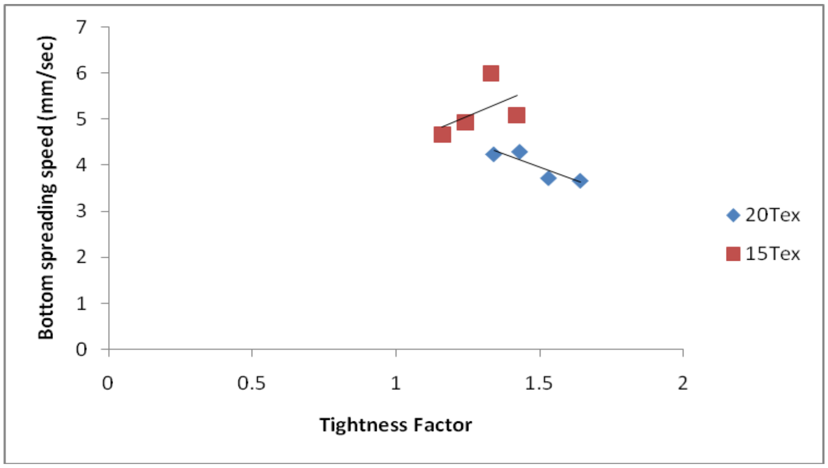

Figure 4.177: Bottom spreading speed (SSb) versus tightness factor in pique knitted excel fabric.

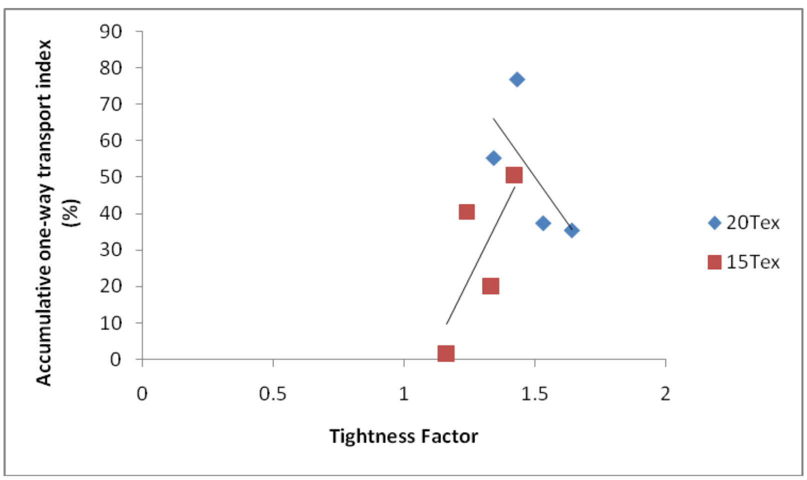

Figure 4.178: Accumulative one-way transport index (AOTI) versus tightness factor in pique knitted excel fabric.

Overall moisture management capacity (OMMC) decreased as the tightness factor increased in case of 20Tex (see figure 4.179). Pearson correlations between tightness factor and moisture management properties indices are given in Table 4.74. It can be observed that almost all correlations between tightness factor and the indices are not linearly related since the Pearson correlations are not close to +1 and -1. This indicates that for pique excel knitted fabrics, tightness factor does not influenced the overall moisture management fabric property.

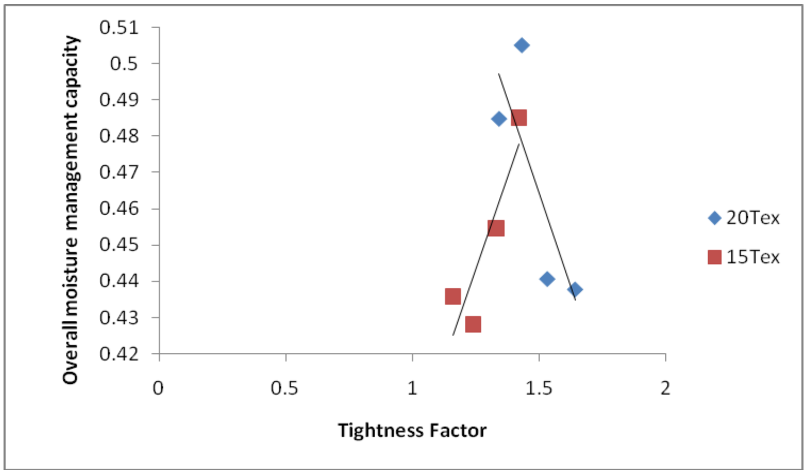

Figure 4.179: Overall moisture management capacity (OMMC) versus tightness factor in pique knitted excel fabric.

Table 4.74: Pearson correlations and p- values of tightness factor versus MMT indices of Pique Knitted fabrics.

No.	Predictors, responses	Pearson correlations	p-value
1.	T.F, WTt	-0.057	0.893
2.	T.F., WTb	0.543	0.164
3.	T.F. ARt	-0.109	0.797
4.	T.F., ARb	-0.100	0.814
5.	T.F., MWRt	-0.494	0.213
6.	T.F., MWRb	-0.551	0.157
7.	T.F., SSt	-0.487	0.221
8.	T.F., SSb	-0.581	0.131
9.	T.F., AOTI	0.387	0.343
10.	T.F., OMMC	0.118	0.781

For more detailed evaluation of the moisture management capabilities of the fabrics, their fingerprints have to be considered and evaluated. All Single jersey excel knitted fabrics were classified as fast absorbing and quick drying fabrics except SE1 and SE6 with key properties of very fast wetting, medium–to-fast absorption, large-to-very large wetting, very fast spreading and fair to excellent one-way transport properties. For all fabrics, the top layer was generally wetted earlier than the bottom layer, as tested and recorded by MMT. All pique knitted excel fabrics were classified as fast absorbing and quick drying fabrics with key properties of very fast wetting, fast–to-very fast absorption, large-to-very large wetting, fast-to-very fast spreading and fair one-way transport properties.

The results (expressed as means/standard deviation) of all assays were compared using ANOVA in order to investigate the effect of fibre type and fabric structure, on wetting time on top surface (WTt)/ wetting time on bottom surface (WTb), absorption rate on top surface (ARt)/ absorption rate on bottom surface (ARb), top maximum wetted radius (MWRt)/ bottom maximum wetted radius (MWRb), top spreading speed (SSt)/ bottom spreading speed (SSb), accumulative overall one-way transport index (AOTI), overall moisture management capacity (OMMC). ANOVA for these dependent variables indicated that there was significant impact of fibre type on all and of fabric structure on wetting time on top surface (WTt), absorption rate on bottom surface (ARb), top maximum wetted radius (MWRt), bottom maximum wetted radius (MWRb), top spreading speed (SSt), bottom spreading speed (SSb) (see Table 4.75). Table 4.76-4.79 shows the fabric classification results of all samples prepared.

It can be seen that the main contributing factors to fabrics being slow-drying or quick drying are their water spreading area and the spreading speed on the outer fabric surface. A slow-drying fabric has a small spreading area and slow spreading speed on the outer fabric surface which a quick drying fabric has a large spreading area and fast spreading speed on the outer fabric surface. It is clear that with the same amount of liquid being dropped on the fabric's inner surface during the testing time, if the liquid is spreading in a large area on the inner fabric surface with high spreading speed and then quickly transported to the outer fabric surface, the liquid content on the inner fabric surface will be small and the liquid moisture will move more easily from the outer fabric surface into the environment, thus, the fabric will dry in comparatively less time (quick drying fabric)[137].

Fabrics SC5, SM16, SE1 and SE2 were classified into moisture management fabrics according to the possible commercial classification and these fabrics are suitable for active sportswear. Knitted fabrics in single jersey and pique structure with different tightness factor, fibre type and yarn count have different moisture management properties and performance attributes, thus potentially it is possible to engineer fabrics of such construction to the required moisture management performance by varying their tightness factor and fibre type and yarn count.