Effect of Fabric Construction Parameters on Air Permeability and Thermal Resistance of Commercially Produced Denim Fabric

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Abstract—Denim is the most widely preferred fabric mainly for younger generation throughout the globe. So, studies of denim comfort related properties are necessary. A few studies carried out so far relate mainly to controlled trials done by changing weft material, its count and picks per inch. In the current study an attempt has been made to investigate some of the comfort related properties of denim fabric used commercially. Care is taken to keep GSM and weave of all the fabric samples same. The comfort parameters of denim such as air permeability, moisture management properties and the thermal properties were measured and evaluated. Also effect of few commercial finishing treatments was analyzed. Studies reveal that fiber type, yarn structure, fabric thickness etc play important role in deciding one or the other property.

Key words: Denim, Air Permeability, Thermal Resistance, Cover Factor

I. INTRODUCTION

Customers of textile and clothing products are becoming increasingly aware of importance of comfort. Comfort is “freedom from pain and from discomfort as a neutral state”. Under the conditions of comfort, the production of heat is equal to loss of heat without any action necessary by the heat control mechanism[1]. Clothing creates micro-climate between skin and environment. Microclimate is an important factor for wear comfort and depends on properties, such as moisture and heat transport through the material, and on physiological and environmental conditions. For humans to feel comfortable, a fairly narrow surface temperature and humidity must be maintained in the air immediately surrounding the body. Therefore, clothing plays an important role in regulating body temperature and controlling heat loss. The vapour form of perspiration is known as insensible perspiration and the liquid form is known as sensible perspiration. During vigorous activity, the heat production rate is high and for the heat transmission from skin to the atmosphere to reduce, the sweat glands are activated to produce liquid perspiration as well. When the perspiration is transferred to atmosphere, it carries heat thus decreasing the body temperature. The fabric being worn should allow the perspiration to pass through, otherwise it will create discomfort. Therefore, both in cold and hot weather and during normal and high activity levels, moisture transmission through clothing plays major role in maintaining the comfort of wearer[2].

Mangat[3] analysed the thermal properties of denim fabric under highly wet and cold conditions. It was summarized that denim made by using spun PP provides better thermal and sensorial comfort to wearer under dynamic wet condition. Celik et al.[4] carried out study on Angora rabbit/cotton blended knitted fabrics and they concluded at least 25% angora fibre required for better comfort. G. Durur[5] tried to establish the methods of identifying and improving the comfort properties of terry woven fabric by using cotton and polypropylene yarn. They concluded that PP fibers will be used on the surface that touches the skin, and CO fibers inside which have a high ability of moisture absorption. So the PP fibers that touch the skin will remain dry. An in-depth study carried out to understand over all wear-ability of cotton fabric by Sreenivasan et al.[6]. They noted that by selecting either longer or finer fibers for preparing yarns and therefore fabrics will help in realizing greater extensibility and higher tensile energy, of course at the expense of tensile recovery or resiliency. S. Saharkhiz et al.[7] studied the impact of different spinning system on the thermal properties of worsted fabric and concluded as fabric thickness and yarn bulkiness increase fabric thermal insulation Surjit[8] & others focused on the plain and twill woven fabrics made out of bamboo/lyocell union fabrics with different blend proportions. They found that the thermal insulation of 1/3 twill is higher when compared to plain and 2/2 twill weave structures, the reason may be attributed to higher fabric density, packing factor and higher yarn floating in twill weave structures.

Thermal comfort compression of athletic wear were investigated by A. das et al.[9] and concluded that by increasing elastane% and elastane stretch, fabric becomes compact and thick with higher thermal resistance and lower air and moisture vapour permeability. The wicking height, absorption and overall moisture management were found to be higher for lower range of elastane stretch and elastane%. Behra[10] focused on comfort behaviour of linen blended fabrics. He concluded that linen and linen blended fabrics have higher thermal insulation values and higher moisture transport properties than cotton, due to its higher affinity to moisture and higher air permeability.

In earlier studies, work has been done on the study of effect of moisture on thermal comfort using cotton and polypropylene but it appears that work on comfort related properties of commercially used denim has not been taken up yet. Hence, the basic objective of present work is to investigate comfort related properties of commercially used denim. So, an investigation of different fabric construction parameters of commercially produced and widely used denim fabrics has been taken up in the current study. An attempt has been made to test some of the comfort related properties.

II. MATERIAL AND METHOD

In the present work an attempt has been made to analyze commercially used denim samples. Five samples having different fabric construction, but same weight and weave were selected for the study. The weight of samples was from 11 to 12 ozs per Yd² and the weave of all samples was 3/1
The ability of fabric to conduct the heat. Thermal resistance of commercially produced denim fabric

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**Table 1: Detail of Samples**

<table>
<thead>
<tr>
<th>Sample no</th>
<th>Warp Count</th>
<th>Warp type</th>
<th>Weft Count</th>
<th>Weft type</th>
<th>EPI</th>
<th>PPI</th>
<th>Process route</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>10s Ne multi count / uneven</td>
<td>Multi count + Uneven Cotton</td>
<td>600D Polyester + 10s Ne cotton (1*1 mixing)</td>
<td>Polyester / Cotton</td>
<td>79</td>
<td>49</td>
<td>Opening- Singeing-Direct Monfort Finish</td>
</tr>
<tr>
<td>A2</td>
<td>7s Ne Amsler Cotton</td>
<td>Amsler Cotton</td>
<td>12 Ne Cotton</td>
<td>Linen</td>
<td>72</td>
<td>43</td>
<td>Wash only</td>
</tr>
<tr>
<td>A3</td>
<td>6.4s Ne multi count / 8s Ne</td>
<td>Multi count + unevenCotton</td>
<td>14s Ne Cotton + 70D Spandex</td>
<td>Cotton/Spandex</td>
<td>70</td>
<td>51</td>
<td>Opening- Singeing-Mercerize-Heatset-Monfort Finish</td>
</tr>
<tr>
<td>A4</td>
<td>8s Ne</td>
<td>Cotton Multi count</td>
<td>12s Ne Cotton + 70D Spandex</td>
<td>Cotton/Spandex</td>
<td>73</td>
<td>54</td>
<td>Opening- Singeing-Heatset-WetFinish</td>
</tr>
<tr>
<td>A5</td>
<td>8s Ne</td>
<td>Amsler Cotton</td>
<td>10s Ne Cotton + 70D Spandex</td>
<td>Cotton/Spandex</td>
<td>68</td>
<td>48</td>
<td>Desize - Heatset-Monfort Finish</td>
</tr>
</tbody>
</table>

**Table 2: Results of Air Permeability, Thermal Resistance and Thickness Tests**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Air permeability (l/m²/s)</th>
<th>Thermal resistance (m²K/W)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>160.33</td>
<td>0.0146</td>
<td>0.77</td>
</tr>
<tr>
<td>A2</td>
<td>125.83</td>
<td>0.0147</td>
<td>0.73</td>
</tr>
<tr>
<td>A3</td>
<td>083.11</td>
<td>0.0205</td>
<td>0.70</td>
</tr>
<tr>
<td>A4</td>
<td>064.21</td>
<td>0.0198</td>
<td>0.67</td>
</tr>
<tr>
<td>A5</td>
<td>082.2</td>
<td>0.0180</td>
<td>0.74</td>
</tr>
</tbody>
</table>

**Table 3: Effect of Fabric Construction Parameters on Air Permeability and Thermal Resistance**

- Following tests were carried out on all samples.

A. Air Permeability Test

Air permeability is described as the rate of air flow passing perpendicularly through a known area, under a prescribed differential between the two surfaces of a material.

Tests were performed according to standard ISO 9237-1995 using TEXTEST FX-3300 air permeability tester. The air pressure differential between the two surfaces of the material was 200Pa. The test area was 20cm² and plate capacity was 371 l/cm²/s.

B. Thermal Resistance Test

Thermal resistance properties were evaluated by guarded hot plate and test was performed according to standard ISO 11092-1993. The heat temperature was 20°C RH% was 60. Maximum air pressure was 100 PSI. Specimen size was 20*20 cm. Thermal resistance expresses the thermal insulation of fabrics and is inversely proportional to thermal conductivity. In dry fabric or containing very small amount of water it depends essentially on fabric thickness and lesser extent, on fabric construction and fabric conductivity.

C. Thickness Test

Thickness test was performed according to standard ASTM D1777. Thickness test was evaluated by Mitutoyo machine and thickness was measured in mm.

### III. RESULTS AND DISCUSSION

#### A. Air Permeability:

Samples A1 and A2 have shown higher values of air permeability as they are not treated with any chemical. Heat treatment causes dimensional changes in fabric and it affects pores in fabric. Chemical treatment also affects porous structure of fabric. Samples A3, A4 and A5 are given heat and chemical treatment. Samples A3 and A5 were finished by applying chemical in foam form so causing less effect on fabric surface. So, both samples had almost similar air permeability. Sample A4 was given wet finish, in which chemicals were applied in liquid form which may have createda layer on fabric surface. This layer will affect the porosity of fabric. Also heat treatment causes dimensional changes. Therefore A4 sample has lowest air permeability. Samples A3, A4 and A5 have elastane containing weft yarn causing the fabric to become thicker and compact and also results in reduced in air permeability.

#### B. Thermal Resistance:

Thermal conductivity is intrinsic property of the fabric and shows the ability of fabric to conduct the heat. Thermal resistance of fabric depends mainly on morphology of fibres, yarn structure, fabric structure including fabric thickness. Some yarn bulking processes will also have an effect on thermal resistance. Figure 2 shows the values of all five samples. Many studies have proved that the fabric thickness is the most important governing factor for thermal insulation. In the present study thermal resistance and thickness correlation regression value was found to be 0.79, which means that thermal resistance increases with increase in thickness. The relation of fabric thermal resistance against thickness is shown in fig. 3. Samples A3, A4 and A5 have cotton/spandex as weft, because of presence of spandex the bulk of the yarn increases on relaxation causing fabric thickness to increase leading to higher thermal resistance.
Fig. 2: Thermal Resistance Test Result

Fig. 3: Regression between Thermal Resistance and Thickness

IV. CONCLUSION

As discussed in the earlier section there has been strong relation between fabric construction parameters and air permeability and thermal resistance of denim fabric. Instead of controlled trials by changing weft yarn and varying picks density, commercial varieties of denim fabric as produced by mills are selected for the study. There is possibility of simulation of the fabric construction parameters for required denim fabric comfort.

V. ACKNOWLEDGEMENT

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REFERENCES


