Master’s Thesis

Title: Coating on Viscose Fabric with Respect to Environmental Aspect.

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Preface:

The final thesis work has been done at Swedish school of Textile, University of Boras, Sweden, during course 2010-2011. It was a collaboration project work between Textile school and Domsjoe Fabriker AB, Sweden. The thesis work would have not been possible to complete without the cordial assistance of some persons.

First we would like to thanks the project supervisor Anders persson and programme coordinator Professor Nils Krister Persson for their support and guidance during the project.

We would also like to thanks company supervisor, Magnus Lundmark, Domsjoe Fabriker AB, Sweden, who has given us support to work in such an important project.

We would like to thank Arne Lennartsson (Consultant, Rudolf Chemical) who supplied the entire chemicals, also Catrin Tammjarv and Maria Bjorklund for their cooperation in laboratory works.

And finally special thanks go to our families and friends who always encourage us to have a positive approach in all aspects of life.
Abstract:

Cotton as a dominating natural fibre imparts a major contribution in the whole textile market including natural and artificial fibres. The demand of this cellulosic fibre is increasing rapidly day by day, on the other hand supply cannot fulfill its demand, and as a result price goes higher in world market. Now people are looking for alternatives to cotton in different applications. Viscose as cellulosic origin, the cheapest of all cellulosic fibres could be the best alternative. Viscose fibre exhibits some similar properties compared to cotton except its poor wet strength. In this thesis work different chemical finishes were applied to improve the wet strength of viscose fabric. For this purpose water repellent and soil release finishes were applied. Both water repellent and soil release finishes helped in reducing the molecular barrier around the individual fibres that lowered the surface tension of the fibre. It reduces the absorbency of viscose fibre hence leads to higher wet strength. Water repellent finish was applied alone as well as in combination with soil release finish. It was seen that viscose fibre exhibited better wet strength after applying water repellent and soil release finishes on it. This improved property of viscose could replace the cotton fibre in certain applications like bed linen.

Key words: Cotton, cellulose, viscose, wet strength, water repellent, soil release.
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1. Introduction

1.1 Background:

From thousands of years humans have been using natural fibers obtained from both plants and animal sources, these natural fibers are used in different industries for making useful products and having different types of applications. According to Hearle (2001), among all the textile fibres, cellulose fibres have the wide range of structures and properties. Even apart from the variety of natural cellulose fibres, with their highly crystalline fibrillar structures in various helical forms of lay-down, the less highly ordered regenerated cellulose fibres have many different structures, which lead to different properties and applications. Cellulose is mainly obtained from wood pulp and cotton. The cellulosic fibre market is part of the total fibre market, which includes natural and synthetic as well.
Cotton, the dominating cellulosic fibres, is abundantly used in textile for its unique properties and performances. As a result the global demand of cotton is increasing rapidly day by day.

Figure 1: World Consumption of cotton in million tonnes. [Source: the fibre year 2010.]

From the above figure 1, it is seen that the global consumption of cotton has doubled by last 30 years.
Production of cotton could not follow its huge demand for last few years. World cotton production (million tonnes) from 1980/81 to 2010/2011 shown below.

![Graph of cotton production from 1980/81 to 2010/2011]

Figure 2: Cotton production (million tonnes) globally from 1980/81 to 2010/2011

[Source: UNCTAD secretariat, based on International Cotton Advisory Committee (ICAC) statistics.]

It is suspected by some experts in fibre year 2010 that the production rate of cotton has already reached its peak. According to fibre year 2010, Latest estimates for current season’s world cotton production account for 22.3 million tonnes. This would be a decline of 4.8% over the last season or about 1.1 million tonnes lower than 2007/08 session. World consumption of cotton is projected to increase by 5.4% to 23.4 million tonnes.
Due to the shortage of supply, cotton price goes higher in all over the world. In the figure 3, the price of cotton is observed for last ten years; here the price is mentioned in US cents per kilogram.

![Figure 3: Cotton price over last ten years in US cents per kilogram. [Source: World Bank commodity price data.]](image)

Viscose is another important cellulosic fibre mostly used in textile. Today there is a renaissance for viscose. Viscose is made from cellulose, a constituent of all land growing plant life. A variety of dissolving grade wood pulps is used as cellulose source to produce viscose rayon. Johnson (2001) suggests that being cellulose based, viscose is supposed to give an answer to the steadily increasing problems of:

1) Higher world market cotton prices

2) Higher demand for fibers, including a chase for new fiber material sources and

3) A need for a broadening of the market for wood and pulp industry.
According to Wilke (2001), Viscose or rayon enjoys the unique position of being the most versatile of all man-made fibers. Viscose is available in continuous filament yarn and staple fibre yarn. Beside these viscose filament has wide range of denier (60000 denier) where as staple fibre has lower denier (1-50 deniers). It exhibits the feel and texture of silk, wool, cotton and linen. Viscose fibers are subjected as easily dyed in a wide range of colors. These fibers are soft, smooth, cool, comfortable, and highly absorbent, but they do not insulate body heat, making them ideal for use in hot and humid climates. The durability and appearance retention of regular rayon are low, especially when wet; also rayon has the lowest elastic recovery of any fiber.

1.2 Other regenerated cellulose fibres:
Viscose fibres with improved wet tenacity and improved elastic recovery called High wet modulas viscose fibres (HMW). The brand names of these viscose fibres are High Wet Modulas fibres, Modal fibres. The properties of these fibres are same as the regular viscose fibre (however lower water absorption), in addition to high wet strength. These fibres are often mixed with cotton fibres. They stand most cotton finishing processes as for example mercerization. HMW fibre fabric performs like cotton and can be machine washed without any severe shrinkage. (Woodings, 2001)

A more recent and environmentally friendly rayon derivative is lyocell. Lyocell is a regenerated cellulose fibre made from dissolving pulp (bleached wood pulp).Lyocell process is complicated compare to viscose and it is very expensive. Lyocell fibres are the strongest cellulose fibres, almost twice as cotton fibres (especially for tear strength). These are as strong as cotton even in wet stage. The fabrics made from these fibres have very soft hand and good drapability properties. The reason for better properties of lyocell and modal than regular viscose is due to their higher DP, higher degree of orientation and higher crystalinity. (Woodings, 2001)
Table: 2 Comparison of various cellulosic fibres properties (Woodings, 2001)

<table>
<thead>
<tr>
<th>Fibre type</th>
<th>Cotton</th>
<th>Viscose</th>
<th>Modal</th>
<th>Lyocell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titre dtex</td>
<td>1.8</td>
<td>1-100</td>
<td>1.0-3.3</td>
<td>0.9-3.3</td>
</tr>
<tr>
<td>Tear strength cond. cN/tex</td>
<td>24-28</td>
<td>20-24</td>
<td>34-36</td>
<td>40-44</td>
</tr>
<tr>
<td>Elongation cond. %</td>
<td>7-9</td>
<td>20-25</td>
<td>13-15</td>
<td>34-38</td>
</tr>
<tr>
<td>Wet tear strength cN/ tex</td>
<td>25-30</td>
<td>10-15</td>
<td>19-21</td>
<td>34-38</td>
</tr>
<tr>
<td>Rel.wet strength %</td>
<td>105</td>
<td>55</td>
<td>57</td>
<td>85</td>
</tr>
<tr>
<td>Elongation wet %</td>
<td>12-14</td>
<td>25-30</td>
<td>13-15</td>
<td>16-18</td>
</tr>
<tr>
<td>Degree of polymerization</td>
<td>2000-3000</td>
<td>250-350</td>
<td>300-600</td>
<td>550-600</td>
</tr>
<tr>
<td>Fabrication tendency</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4-6</td>
</tr>
<tr>
<td>Water retentivity %</td>
<td>45-55</td>
<td>90-100</td>
<td>75-85</td>
<td>65-70</td>
</tr>
<tr>
<td>Crystalinity %</td>
<td>77-80</td>
<td>25</td>
<td>25</td>
<td>40</td>
</tr>
</tbody>
</table>

Figure: 4 Comparison on wet strengths in cN/Tex (Woodings, 2001)

Viscose has lower average wet strength as compared to modal, cotton and lyocell seen in the figure 4.
2. Scope

There is an increasing global lack of cotton. Based on the structural similarities and property profiles regenerated cellulose fibers could be an alternative to cotton in certain applications. One such application is bed linen. However, some regenerated cellulose fibers, in particular viscose, has poor wet strength. The aim of this thesis is to try to address this property flaw by chemical finishes. Thereby fabrics from regenerated cellulose fibers could be a feasible alternative to cotton.

To apply and improve the coating of viscose fibre by application of polymeric material and different chemicals, a number of literature reviews, published book and articles were studied. Different companies like Rudolf, BASF etc. websites gave good information about chemicals and polymer that was used in the project work. As the project aim to improve the existing and proceeding coating of viscose fibre, so a deep study was considered in the literature review to clear the concept about coating. (Iqbal, 2009)

3. Aim:

The aim of this thesis is to improve the wet strength of viscose by means of applying chemical finishes like water repellent and soil release finishes.
4. Delimitations

In this research work, coating was applied on 100 % cotton and 100 % viscose woven fabric rather than any blends. Chemical finishes like water repellent and soil release were applied to cover the aim of this thesis. The chosen coating method was dip coating to get better performance for viscose, easy to use and availability. Tensile properties, water repellency, durability and dimensional stability of viscose and cotton fabric were measured.

5. Methodology

According to Iqbal, 2009, the approach was kept in mind by making different chemical layer on the substrate concerning coating. The chemical layer was comprised of soil release finish and fluorocarbon to acquire the properties of durability, to improve the tensile strength, dimensional stability, abrasion resistance, elongation and conformability of end product. The coating methodology was developed in the lab as by dip coating as described in detail in coating method section.

Iqbal, 2009, assured that the coating could be done on one side or both side depending on the requirement and results. The project work had focused on dip coating because this facility was available in textile school. The coating material was given different functional and aesthetic properties like resistance to soil and water repellency.

Iqbal, 2009 suggests that after the application of coating material on both 100% cotton and 100% viscose fabric, the durability of fabric was checked by Martindale tester by adjusting different number of abrasion cycles, the tensile strength and elongation was measured by tensile tester, the dimensional stability was checked by washing test and the water repellency was checked by spray tester. Here again the reliability was checked by taking reading at different spots and average was taken. Finally the conclusion was drawn on complete study and results from experimental work.
6. Theory

6.1 Coating:

Coated fabric exhibits some improved physical properties like tensile strength, tear strength, adhesion etc, in addition some functional properties like water repellency, flame retardancy, moisture breathability or permeability, cleaning durability, antibacterial etc. Coated fabrics are now used for diverse applications. They are found in defense, transportation, healthcare, space, sports, environmental pollution control, and many other diverse end-product uses. (Sen., 2001)

After coating the basic fabric properties that are mostly required are mentioned by Shishoo (2005).

- Handle/drape/flexibility.
- Tear and tensile strength.
- Abrasion resistance.
- Dimensional stability (to cold water and washing).
- Resistance to delamination (good coating or laminate adhesion)
- Water repellency.
- Breathability.
- General durability.
- Easy care (preferably machine washable).

Today, coated fabrics are essentially polymer-coated textiles. Different coating techniques or methods for viscose fabrics are knife coating, roller coating, spread coating, dip coating, screen coating, melt coating, dry coating etc. Dip coating and spread coating methods are mostly used. Generally, different coating materials are used for viscose fabric. Normally coatings are polymeric materials like rubber (both natural and synthetic), poly vinyl chloride (PVC), poly acrylic, polyurethane, clay particles and so on. Among the entire polymers PVC, polyurethane and polyacrylic are widely used for coating on textiles. (Sen., 2001)
These coating materials have few adverse effects on the environment. Oily or gel polyurethane cause some environmental problems due to organic solvent like toluene, acetone etc. Basically they contain formalin. New research and developments are going on to find out the eco-friendly coating materials. Now-a-days, aqueous or water dispersed polyurethane and polyacrylic have been proved the most eco-friendly coating materials with excellent water resistance, moisture permeability and cleaning durability.

There were different coatings methods by which chemical material could be applied to textile and this classification was based on the basis of equipment used, methods of metering and the form of coating material and these coating methods that could be employed are described below, (Iqbal, 2009)

6.1.1 Coating methods:

1. Fluid coating in which the coating material would be applied in the form of paste.
   - Knife coating
   - Roll coating, reverse coating, kiss coating, dip coating etc.
   - Impregnation
   - Spray coating

2. Coating with dry compounds.
   - Melt coating
   - Calendering
   - Lamination

There could be several factors on which selection coating methods depending that were listed below

- Form and viscosity of coating material
- Nature of substrat
- Accuracy of desired coating
The choice of proper fabric according to Sen. (2001, pp.52) for proper fabric coating was as important as the selection of the material, because it offered the primary physical property to the end product. For proper selection of fabric, the proposed aspects need to be considered:

- Strength and modulas
- Creep behaviour
- Resistance to acid and chemicals
- Adhesion requirement
- Resistance to microbiological attack
- Environment to use
- Durability
- Dimensional stability
- Cost

**6.2 Repellent finishes:**

The finishes that repel water, oil and dirt are important in every segment of textile. Water repellency is achieved by applying different chemical and oil repellency is only achieved by applying fluorocarbon on textile. There are lot of modification in it to achieve different properties according to demand of customer and the required purposes. And this is one of the great developments of textile finishing. (Hauser & Schindler, 2004)

The previous repellent finishes were only repellent to water and this one of the great self evident. In it the drop of water would not spread on the surface of fabric and do not wet the surface of fabric. The drop of water would not stay on the surface of fabric and it is easily drip off from the surface of fabric. Similarly, the oil droplet should not stay on the surface of fabric and not to wet
the fabric. In a similar way the soil repellent should also protect the fabric from soil in both dry and wet conditions. But in all cases, the air permeability of the fabric should not be reduced significantly and it is not covering the water proofing in depth. A water proof fabric should withstand the hydrostatic pressure exerted by at least one meter height by column of water and it is before the first drop of water penetration into the fabric surface. And it is mostly achieved by coating of fabric but it has some draw backs like stiff handle, air and vapour permeability and also poor wear comfort.  

(Hauser & Schindler, 2004)

6.2.2 Mechanism of repellency:
The repellence properties are achieved by repellent finishes by reducing the free energy at fibre surface. If the adhesive forces between a fibre and a liquid drop are greater than internal cohesive forces in between the liquids, the drop will spread. However, if the adhesive forces between a fibre and liquid drop are less than internal cohesive forces in between the liquids, the drop will not spread. Surfaces that have low interaction with liquids are referred to as low surface energy. And their critical surface tension should be less than the surface tension of liquids that is to be repelled. Therefore, oil repellency with fluorocarbon always achieves water repellency but it is difficult to achieve with fluorine free products like silicone based products. The surfaces with low energy surface tension also provide a measure of dry soil repellency by preventing soil particles by adhering to the fibre surfaces. Due to these low interaction forces, the soil particles to be easily dislodged and removed by mechanical action.  

(Hauser & Schindler, 2004)

6.3 Soil release finishes:
Recent research on soil release (Shalini, 2011) has shown that to achieve the desired properties of viscose fabric such as soil release, the chosen method was dip coating. Actually, the soil release that was chosen for the viscose fabric reduced the moisture regain. The applied hydrophobic soil release was used to improve water repellency that was responsible for the improving the wet strength of viscose fabric. Water and soil resistant treatment helped in reducing the molecular barrier around the individual fibres that lowered down the critical surface tension of the fibres. This reduced surface tension of viscose fabric helped in improving its wet strength.
Figure 5: water and soil repellent fabric

In the above figure 5, repellent finish is seen on the fabric.

Recent research on soil release (Shalini, 2011) explained that the most common methods used for soil release are mentioned below,

- Oleophilic treatments
- Hydrophilic substance treatments

Recent research on soil releases (Shalini, 2011) according to that there were different factors that influence soil release finish;

- Nature of soil
- Kind of fibres
- Nature of textile
- Effects of preparation
- Effects of other finishes
- Washing conditions

According to Recent research on soil releases (Shalini, 2011) different properties achieved by soil release:

- It added more care to the garments
- It permitted better wear ability by improving soil release and soil removal
- It permitted relatively easily removal of oil borne stains from permanent press garments
• It provided better comfort in hot weather condition
• It also helped in improving the anti static properties

According to Recent research on soil releases (Shalini, 2011) advantages achieved by soil release finish:

• It was protecting the fabric from further soiling things, water, oil and stains
• It was preventing the redposition of impurities from the solution that is already dispersed in the solution
• It was further preventing the dust particles to collect on the fabric surface by creating of electrical charge
• The finish was permanent and durable for a number of washes

According to Recent research on soil releases (Shalini, 2011) different finishing agent that could be used with soil release finish:

• Fluorocarbons
• Flour chemicals
• Pyridinum compounds
• Resins
• Silicone
• Triazine compounds
• Wax and its derivatives

6.3.1 Fluorocarbon-based repellent Finishes:

According to Hauser & Schindler, Water repellency can be improved by lowering the critical surface tension of fabric below the surface tension of liquids. Fluorocarbon creates a surface with low surface tension of all the finishes in application, and both oil and water repellency can be achieved. The fluorocarbons are the carbon compound containing pre-fluorinated carbon chains and their application is to form barrier around the fibers and not allowing the water penetrate into the surface of fabric by lowering the critical surface tension of fabric.
Fluorocarbon finishes can be prepared by incorporating a perfluoro alkyl group into acrylic or urethane monomers that can be polymerized to form a fabric finish. The chain length of perfluorinated side chain is in between 8-10 carbons atoms. The final end product applied to the fabric usually forms a dense structure of CF₃ that provide a maximum repellency to the outer surface.

6.4 Environmental aspects:

The chemical finishes traditionally used to make textiles water and soil repellent involved conventional long chain fluorocarbons (FCs) that is suspected to harm humans as well as environment. The conventional fluorocarbon (C₈- based fluorocarbons) means that polymer consists of 8 carbons and 17 fluorine atoms. These are (C₈- based fluorocarbons) are suspected to release bio-persistent and toxic component Perfluorooctanoic acid (PFOA) and Perfluorooctane sulfonate(PFOS).They affect the human reproduction, hormone system and cell processes.

Modern research and development in water, oil and soil resistant treatment has been done to find the alternative of conventional C₈ technology. After immense research and development chemists succeeded to replace C₈ chemistry with C₆ by using short 6 carbon-fluoro chains. They excluded the possibility of fluorocarbon products broke down into PFOA. The compound Perfluorohexanoic acid (PFHA) obtained from C₆ technology has 40 times less bioaccumulative effects than PFOA.
Domsjo Fabriker AB is a developing, producing, selling and marketing the raw material supplier for customer from the energy and textile industry. They offer bio-fuel based products and specialty cellulose used for textile material viscose from renewable wood raw material.

In 1903, they started to produce sulphite pulp, but now a days they are also producing bio ethanol, cellulose, lignin etc. a wide range products for the petroleum and textile industry.

The annual turnover of Domsjo is 2 billion SEK and the number of employee is 370 in Ornskoldsvik and 25 in three Baltic daughter companies. Since April 2011 the Domsjo Fabriker are included in the Indian business group, Aditya Birla group.

**Vision and mission**

Sustainable product development in order to meet the world’s need as well as invest to increase the production and be able to develop the products and increase the innovative strength.

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8 Practical works:

8.1 Material

Fabric Specifications:

Cotton: 100% mercerized cotton with plain weave.

*0.74 g/m²*: Count: 32 threads per cm in warp direction and 32 threads in weft direction.

Viscose: 100% spun rayon, scoured plain weave.

*1.35 g/m²*: Count: 38 threads per cm in warp direction and 38 threads in weft direction.

Both type of fabrics were commercially prepared: mercerized cotton and scoured viscose from Whaley (Bradford) LTD, U.K.

8.1.1 Coating material:

Water repellent finish (Ruco dry DHN), soil release finish (C₆ based fluorocarbon-Ruco guard AFB), and acetic acid (24 % conc.). We have done the practical works for four different recipes that are given below.

8.1.2 Ruco dry- DHN:

Ruco-dry DHN is wax-based dendrimer. It has specific properties including cationic, ecological water repellent with dendrimer, better abrasion resistance, environmentally friendly, APEO-free, solvent-free and fluorochemicals-free.

8.1.3 Ruco-guard AFB₆ Conc.:

Ruco-guard AFB6 is an ecological optimized agent, oil and soil-repellent finish, gives very good resistance to washing and dry cleaning. It is also free of Perfluorooctanoic acid (PFOA) and Alkyl phenol ethoxylates (APEO). [Rudolf Chemical]

Table 2: The contents of the finishing bath and the conditions of the finishing with soil release and fluorocarbon (Chemicals manufactured by Rudo Chemi)
W (water repellent) g/l 25, 50, 100
W (soil resistant-AFB-6) g/l 40
Acetic acid g/l 1
W liquor pick up (%) 100
Drying Temperature, $T_{\text{drying}}$ ($^0$ C) 130
Drying time, $t_{\text{dry}}$ (min) 4
Cross linking temperature, $T_{\text{cross}}$ ($^0$ C) 160
Cross linking time, $t_{\text{cross}}$ (min) 1.5 min

For further discussion we would like to use some abbreviations like
Ruco-dry DHN= DHN and Ruco guard AFB$_6$ conc. = AFB$_6$

<table>
<thead>
<tr>
<th>Batch</th>
<th>Chemicals</th>
<th>Amount(g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DHN</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Acetic acid</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>DHN</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Acetic acid</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>DHN</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Acetic acid</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>DHN</td>
<td>50</td>
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<tr>
<td></td>
<td>AFB$_6$</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Acetic acid</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3: Recipes for coating in impregnation bath.

Every batch was prepared based on one liter solution in total.
8.2 Machine:

Pad mangle: Brand name: ERNST BENZ, Textile machine
Type: LQ 350/2, R 2227.65.15
Country Switzerland

Dryer:
Brand name: ERNST BENZ, Textile machine
Type: MT-D
Country Switzerland

8.3 Method:

Samples were coated following the procedure of dip coating. This included impregnation, drying and curing. The contents of the finishing bath and the condition of drying and curing are shown in table 1. All the samples were cut according to 35 cm in length and 28 cm in width size. The above four recipes were applied to both cotton and viscose fabrics.

After coating the samples were conditioned for 24 hours at room temperature. All the samples were tested after proper conditioning.

8.4 Tensile test:

Measurement of maximum force and elongation were carried out using the stripe method in a standard atmosphere (T=20°C and RH=65%) using tensile tester.

Specification of tensile tester:
Brand name: Tinius Olsen
Model: THE-5000 N
Capacity: 5000N
Serial number: 180496

All samples were taken 15 cm in length and 2.5 cm in width. We measured 5 samples for each test. All the samples were measured in both warp and weft directions. As the count of viscose in both directions was equal, so the same values for warp and weft directions were observed. That was also seen for cotton fabric. For measuring the wet strength the samples were soaked for one min.
Table 4: Machine settings for tensile test

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Parameter</th>
<th>Setting range</th>
<th>Applied setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load, N</td>
<td>50-5000</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>Extension, mm</td>
<td>0.1-2000</td>
<td>400</td>
</tr>
<tr>
<td>3</td>
<td>Gauge length, mm</td>
<td>1-1000</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Test speed, mm</td>
<td>0.007-1000</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Approach speed, mm/min</td>
<td>0.001-1000</td>
<td>50</td>
</tr>
</tbody>
</table>

8.5 Spray test:

The standard test method for the water repellency measurement of woven textile fabrics was used (SIST EN 24920).

8.5.1 Equipments:

- Spray stand
- Volumetric flask
- Thermometer
- Fabric clip holder
- Rating chart

8.5.2 Method:

In this method, coated fabric was adjusted on the fabric clipper and the clipper was put on spray stand at 45 degree angles. 250 ml distilled water was taken in a volumetric flask that was temperature 20\(^\circ\) C. The water poured in spinneret keaf from it water is showered on stretch fabric. After doing the showering we have matched it with rating chart by visual assessment. We measured 3 samples for each test of cotton and viscose.
Table 5: AATCC standard rating for spray test.

<table>
<thead>
<tr>
<th>AATCC standard rating</th>
<th>Note:</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ISO 5</td>
<td>100: No sticking or wetting of upper surface.</td>
</tr>
<tr>
<td>90 ISO 4</td>
<td>90: Slight random sticking or wetting of upper surface</td>
</tr>
<tr>
<td>80 ISO 3</td>
<td>80: Wetting of upper surface at spray points.</td>
</tr>
<tr>
<td>70 ISO 2</td>
<td>70: Partial wetting of whole of upper surface.</td>
</tr>
<tr>
<td>50 ISO 1</td>
<td>50: Complete wetting of whole surface.</td>
</tr>
<tr>
<td>0</td>
<td>0: Complete wetting of whole upper and lower surface.</td>
</tr>
</tbody>
</table>

8.6 Wear and abrasion resistance:

The purpose of this method is to check the fabric durability and colour change by applying different load on the round test sample that are going to be abraded against viscose and cotton. After abrasion we checked the thread breakage of abraded sample on microscope. By microscopic observation we counted the thread breakage value that should be stand as Martindale value for that fabric.


Round fabrics were taken according to holder, 4 cm for small holder and 16cm for large holder. The same fabric was used against abraded sample and same load was applied for each test. The tests were performed at different cycles to check the weight loss of fabrics. After that threaded breakage of abraded samples were observed on electronic microscope and recorded all the values.
**8.7 Dimensional stability:**

The objective of this test method (SS EN ISO 3759) is to measure fabric shrinkage/stretch after washing and drying. For both directions (warp and weft) dimensional change in viscose and cotton are calculated and reported as percentage (%) values.

Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Spun viscose rayon fabrics shrink more with repeated laundering than fabrics made of the filament yarns.

Washing condition: Temperature 60 °C, Time 40 mins.

All the samples were taken according to 35 cm in length and 28 cm in width. We scaled the length and width of coated fabric before washing for all recipes, both cotton and viscose fabrics. Then washed the samples and dried at room temperature. After washing and drying the samples were again scaled and recorded the shrinkage in both directions for viscose and cotton. All the samples were measured in three distances for each direction.
9. Result and Discussion:

9.1 Determination of mechanical Properties:

By tensile tester, we measured the dry and wet strength of cotton and viscose.

![Bar chart showing maximum force (N) of cotton and viscose (dry condition)](chart.png)

Student's t-test is a method in statistics to determine the probability (p) that two samples are same in respect to the variable that are testing. If p<0.005, then the two samples are statistically significantly different. If p>0.005, then the two samples are statistically significantly not different.

*: p = 0.01177 for untreated cotton and viscose.

**: p = 7.40981811892E-07 combination recipe cotton and viscose

***: p = 0.07131 DHN-50 and DHN+ AFB6 for cotton.

As shown in the bar chart 6, there is a difference between dry strength of untreated cotton and viscose [Statistically significantly different, as p*< 0.05]. Initially, untreated cotton and viscose had dry strengths 145.6N and 174.4N respectively. After applying water repellent finish the
strength of Viscose was gradually increased (233.8N and 246.4N at DHN-25 and DHN-50g/l respectively). Further addition of DHN followed downward result (207.4N for DHN-100) and combination of DHN and AFB₆ showed better result (225.6N). Cotton has a very low effect over DHN and AFB₆ at dry condition**. The dry strength of cotton is decreased slightly after coating. For combination recipe it is seen that viscose has better dry strength than cotton***. [Statistically significantly different, as p< 0.05]

![Figure 7: Maximum force (N) of cotton and viscose (wet condition)](image)

*: p = 7.64249788175E-09 for untreated cotton and viscose.

**: p = 2.00345309491E-05 combination recipe for viscose and cotton.

***: p = 8.59871357194E-06 for untreated cotton and combination recipe for viscose.
As illustrated in figure 7, untreated viscose has poor wet strength compared to untreated cotton (86.2N and 186N respectively)* [Statistically significantly different, as p< 0.05]. By applying water repellent finish wet strength of viscose was increased dramatically (117.4N and 137.6 for DHN-25 and DHN-50) and with the addition of fluorocarbon achieved highest value (163.8N) that can be compared to untreated cotton. On the other hand, the wet strength of cotton is gradually decreased after coating. Finally, for combination recipe viscose showed higher wet strength than cotton and it is comparable to wet strength of untreated** [statistically significantly different, as p< 0.05].

Viscose has higher moisture regain properties compare to other cellulosic fibres. When it is wetted it absorbed much water and swollen that makes it weaker. After applying the water repellent finishes the surface tension of the fabric becomes lower. Thus it absorbs less water and improves wet strength.

Water and soil resistant, (fluorocarbon) treatment helps in reducing the molecular barrier around the individual fibres that lowered down the critical surface tension of the fibres. This reduced surface tension of viscose fabric helped in improving its wet strength. And the combination of water repellent and soil release makes viscose stronger at wet condition.
Figure 8: Elongation (percentage) at ultimate force of cotton and viscose (dry condition)


**: p = 2.99749716331E-07 for untreated cotton and viscose.

As plotted in figure 8, elongation of untreated cotton and viscose at dry state has big difference* (10% and 17.6% respectively) [statistically significantly different, as p< 0.05]. After applying coating the elongation was improved for viscose (28.8%, 22.2%, 19.4% and 25.2% respectively). It was a negligible change to cotton. For combination recipe viscose has improved elongation at ultimate force compared to cotton*[statistically significantly different, as p< 0.05].
As it is seen from figure 9, untreated viscose has the wet elongation compare to cotton*(15.6% and 17% respectively) [statistically significantly different, as p< 0.05]. It was improved for DHN-25 and DHN-50g/l (19.8% and 17% respectively) but further addition of DHN decreased the elongation of viscose. For the combination of water repellent and soil release finish elongation was also improved (18.8%). For cotton, the wet elongation was decreased after coating except the recipe DHN-100 g/l. Viscose exhibited higher wet elongation compare to cotton after applying combination recipe.
9.2 Water repellency:

![Figure 10: spray rating of cotton and viscose](image)

As it is seen from the above figure 10, untreated Cotton and viscose was totally wetted in upper and lower surface when water sprayed on it, spray rating for untreated cotton and viscose was zero (o rating). After applying coating both cotton and viscose exhibited improved spray rating*(2 for both cotton and viscose at DHN-25) [statistically significantly not different, as p>0.05]. Viscose performed higher water repellency than cotton at DHN-50 and DHN-100(3&4 for viscose and 2&3 for cotton). For combination recipe both viscose and cotton had the optimum value and same spray rating (4 for both).

Water repellent finishes increase the hydrophobicity of the cellulosic fabric; fluorocarbon also increases the water repellency of cotton and viscose and therefore decreases the absorbency of the fabric.
9.3 Durability:

Table 6: Weight loss of viscose and cotton for different cycles.

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Viscose-Wt. Loss (100 cycles)</th>
<th>Viscose-wt.Loss (500 cycles)</th>
<th>Cotton-Wt.Loss (100 cycles)</th>
<th>Cotton-Wt.Loss (500 cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>No Loss</td>
<td>1.15%</td>
<td>No Loss</td>
<td>No Loss</td>
</tr>
<tr>
<td>25g/l DHN</td>
<td>No Loss</td>
<td>1.0%</td>
<td>No Loss</td>
<td>No Loss</td>
</tr>
<tr>
<td>50 g/l DHN</td>
<td>No Loss</td>
<td>1.0%</td>
<td>No Loss</td>
<td>No Loss</td>
</tr>
<tr>
<td>100g/l DHN</td>
<td>No Loss</td>
<td>0.5%</td>
<td>No Loss</td>
<td>No Loss</td>
</tr>
<tr>
<td>50g/l DHN+40 g/l AFB₆</td>
<td>No Loss</td>
<td>No Loss</td>
<td>No Loss</td>
<td>No Loss</td>
</tr>
</tbody>
</table>

As stated on the above table 6, untreated viscose and cotton has no weight loss at 100 cycles. But untreated viscose showed 1.15% weight loss for 500 cycles where as untreated cotton has no weight loss after abrasion. After applying coating the weight loss of viscose was reduced (1.0% at DHN-50 and 0.5% at DHN-100). In combination recipe viscose enjoyed no weight loss after abrasion. Throughout the entire recipe cotton enjoyed no weight loss after abrasion at 100 cycles and 500 cycles.

So from the above result it was clear that the durability of viscose was improved after applying water repellent and soil release finishes.
Figure 11: Untreated viscose (a) and (b), (c), (d), (e) for four batches consecutively after abrasion (500 cycles).

From the above figures 11(a, b, c, d, e), microscopic structures of different viscose samples can be observed.
9.4 Dimensional stability:

As observed from the figure 12, coated viscose (at DHN-25g/l) has higher shrinkage percentage compare to cotton after washing (1% for viscose and 0.5 % for cotton)* [statistically significantly different, as p< 0.05]. The shrinkage remained same at DHN-50 for viscose and cotton. Further addition of water repellent finish increased the shrinkage of viscose. In combination recipe viscose showed optimum shrinkage after washing. Cotton has no shrinkage percentage after washing throughout the entire recipes.
Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Spun viscose rayon fabrics shrink more with repeated laundering than fabrics made of the filament yarns.

Figure 13: Shrinkage percentage for both cotton and viscose in weft direction

*: p = 6.00541915001E-07 for cotton and viscose at combination recipe.

As similar to warp direction, viscose exhibited higher shrinkage percentage compare to cotton in weft direction. In combination recipe viscose showed highest shrinkage percentage in weft direction after washing where as cotton remained unchanged* [statistically significantly different, as p< 0.05]
10. Cost analysis

Coating materials

Ruco-dry DHN  =  1 Euro per kilogram.
Ruco guard AFB₆ Conc.  =  25 Euro per kilogram.

Cost set up for drying /curing/ heat setting on stenter.

Total Cost per hour: 145 Euro
Energy  30%
Maintenance  15%
Overheads  10%
Service department  15%
Personnel  30%

In this project work drying time was 4 mins and curing 1.5 mins. Total time 5.5 mins.
So cost for drying and curing 5.5 mins is 13 Euro. (As 145 Euro for 1 hour)

Costing for one kilogram fabric:

Material and liquor ratio=1:6(suitable)
Total solution = 1X6 = 6 liters.

For 25 g/l DHN: The amount of DHN = 25 x6 =150 gm; cost for 150 gm DHN is 0.15 euro.
Cost for other batches is calculated below:

<table>
<thead>
<tr>
<th>Batch no.</th>
<th>Chemical finishes</th>
<th>Cost for chemical finishes (Euro)</th>
<th>Others (Euro)</th>
<th>Total cost for one kilogram fabric (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DHN-25 g/l</td>
<td>0.15</td>
<td>13</td>
<td>13.15</td>
</tr>
<tr>
<td>2</td>
<td>DHN-50 g/l</td>
<td>0.30</td>
<td>13</td>
<td>13.30</td>
</tr>
<tr>
<td>3</td>
<td>DHN-100 g/l</td>
<td>0.60</td>
<td>13</td>
<td>13.60</td>
</tr>
<tr>
<td>4</td>
<td>DHN-50 g/l + AFB₆ 40 g/l</td>
<td>1.9</td>
<td>13</td>
<td>13.90</td>
</tr>
</tbody>
</table>
**11. Conclusion**

The results lead to the following conclusion:

Viscose has poor wet strength due to higher moisture regain. The most desired property of viscose for this project was wet strength and it was improved to a large scale applying water repellent and soil repellent finishes. Elongation (dry and wet) of viscose was improved after applying the soil repellent and water repellent finishes.

Cotton was more durable than viscose over the water repellent finishes. Durability of viscose was also improved.

Viscose tends to shrink more than cotton and dimensional stability of viscose was improved after the application of water repellent and soil repellent finishes.

So, viscose had a potential to replace cotton as an alternative by applying water repellent and soil repellent finishes.
12. References:


Man-Made Textiles India (Anon., 2009)


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13. Attachments

Illustration 1: solution preparation

In the picture acetic acid, soil release and water repellent finishes are shown.
Illustration 2: Sample cutting machine

All the samples were cut by this cutting machine.
Illustration 3: Pad mangle.

Sample is dipping into the impregnation bath.
Illustration 4: Dryer.

Drying the sample in dryer has shown in the illustration.
Illustration 5: Drying and curing machine

All the samples were dried and cured in that machine.
Illustration 6: Tensile tester.

Measuring the tensile strength in tensile tester.
## Appendix

### Table A: Viscose elongation at dry condition.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Untreated</th>
<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50g/l DHN+ 40 g/l AFB&lt;sub&gt;6&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>32</td>
<td>22</td>
<td>20</td>
<td>26</td>
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<tr>
<td>2</td>
<td>16</td>
<td>23</td>
<td>21</td>
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<td>24</td>
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</tr>
<tr>
<td>5</td>
<td>19</td>
<td>33</td>
<td>26</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Mean &amp; Standard deviation</td>
<td>17.6</td>
<td>28.8</td>
<td>22.2</td>
<td>19.4</td>
<td>25.2</td>
</tr>
<tr>
<td></td>
<td>1.14018</td>
<td>4.86826</td>
<td>3.03315</td>
<td>1.14018</td>
<td>1.30384</td>
</tr>
</tbody>
</table>

### Table B: Viscose elongation at wet condition.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Untreated</th>
<th>25 g/l</th>
<th>50 g/l</th>
<th>100 g/l DHN</th>
<th>50g/l DHN+ 40 g/l AFB&lt;sub&gt;6&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>18</td>
<td>13</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>19</td>
<td>11</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>25</td>
<td>23</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>18</td>
<td>27</td>
<td>13</td>
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</tr>
<tr>
<td>5</td>
<td>14</td>
<td>19</td>
<td>11</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Mean &amp; Standard deviation</td>
<td>15.6</td>
<td>19.8</td>
<td>17</td>
<td>13.4</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>1.14018</td>
<td>2.94958</td>
<td>7.48331</td>
<td>1.51658</td>
<td>2.38747</td>
</tr>
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</table>
Table C: Elongation (%) of cotton at dry condition.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Untreated</th>
<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50 g/l DHN+40 g/l AFB₆</th>
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</thead>
<tbody>
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<td>13</td>
<td>10</td>
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<td>2</td>
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<td>16</td>
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<td>12</td>
</tr>
<tr>
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<td>Mean &amp; Standard deviation</td>
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<td>11.2</td>
<td>13.6</td>
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<td></td>
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<td>1.58114</td>
<td>1.78885</td>
<td>3.36155</td>
<td>3.04959</td>
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Table D: Elongation (%) of cotton at wet condition.

<table>
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<tr>
<th>Sample</th>
<th>Untreated</th>
<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50 g/l DHN+40 g/l AFB₆</th>
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<td>11</td>
<td>22</td>
<td>12</td>
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<tr>
<td></td>
<td>Mean &amp; Standard deviation</td>
<td>17</td>
<td>14.4</td>
<td>10.8</td>
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<td></td>
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<td>3.80789</td>
<td>3.64692</td>
<td>3.49285</td>
<td>2.58844</td>
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Table E: Maximum force, N for Cotton at dry condition.

<table>
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<th>Sample</th>
<th>Untreated</th>
<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50 g/l DHN + 40 g/l AFB&lt;sub&gt;6&lt;/sub&gt;</th>
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<td>Mean &amp; S.D</td>
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<table>
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<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50 g/l DHN + 40 g/l AFB&lt;sub&gt;6&lt;/sub&gt;</th>
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<td>171</td>
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<td>Mean &amp; S.D</td>
<td>187.8</td>
<td>172.2</td>
<td>142.2</td>
<td>145</td>
<td>130.6</td>
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</table>

Table F: Maximum force, N for Cotton at wet condition.
Table G: Maximum force, N for viscose at dry condition.

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<tr>
<th>Sample no.</th>
<th>untreated</th>
<th>25 g/l DHN</th>
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<th>50g/l DHN+40 g/l AFB$_6$</th>
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<td>4</td>
<td>189</td>
<td>232</td>
<td>252</td>
<td>209</td>
<td>230</td>
</tr>
<tr>
<td>5</td>
<td>189</td>
<td>242</td>
<td>217</td>
<td>212</td>
<td>229</td>
</tr>
<tr>
<td>Mean&amp;S.D</td>
<td>174.4</td>
<td>233.8</td>
<td>246.4</td>
<td>207.4</td>
<td>225.6</td>
</tr>
</tbody>
</table>

Table H: Maximum force, N for viscose at wet condition.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Untreated</th>
<th>25 g/l DHN</th>
<th>50 g/l DHN</th>
<th>100 g/l DHN</th>
<th>50g/l DHN+40 g/l AFB$_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99</td>
<td>111</td>
<td>124</td>
<td>105</td>
<td>162</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>116</td>
<td>148</td>
<td>102</td>
<td>164</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>122</td>
<td>155</td>
<td>129</td>
<td>160</td>
</tr>
<tr>
<td>4</td>
<td>89</td>
<td>129</td>
<td>140</td>
<td>126</td>
<td>171</td>
</tr>
<tr>
<td>5</td>
<td>76</td>
<td>109</td>
<td>121</td>
<td>120</td>
<td>162</td>
</tr>
<tr>
<td>Mean&amp;S.D</td>
<td>86.2</td>
<td>117.4</td>
<td>137.6</td>
<td>116.4</td>
<td>163.8</td>
</tr>
<tr>
<td></td>
<td>8.58</td>
<td>8.20</td>
<td>14.80</td>
<td>12.25</td>
<td>4.266</td>
</tr>
</tbody>
</table>
Table I: spray rating for different samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscose (uncoated)</td>
<td>0</td>
</tr>
<tr>
<td>Viscose(DHN-25)</td>
<td>2 &amp; 3</td>
</tr>
<tr>
<td>Viscose(DHN-50)</td>
<td>2 &amp; 3</td>
</tr>
<tr>
<td>Viscose(DHN-100)</td>
<td>4</td>
</tr>
<tr>
<td>Viscose (DHN-50+ AFB₆-40)</td>
<td>4</td>
</tr>
<tr>
<td>Cotton (uncoated)</td>
<td>0</td>
</tr>
<tr>
<td>Cotton(DHN-25)</td>
<td>2</td>
</tr>
<tr>
<td>Cotton(DHN-50)</td>
<td>2</td>
</tr>
<tr>
<td>Cotton(DHN-100)</td>
<td>3</td>
</tr>
<tr>
<td>Cotton (DHN-50+ AFB₆-40)</td>
<td>4</td>
</tr>
</tbody>
</table>

Table J: Shrinkage (%) for cotton and viscose:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Warp(%)</th>
<th>Weft(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscose(DHN-25)</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Viscose(DHN-50)</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>Viscose(DHN-100)</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>Viscose(DHN 50 + AFB₆ 40)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Cotton(DHN-25)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cotton(DHN-50)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cotton(DHN-100)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>