

Performance Evaluation of Water and Oil Repellent Finishes on Plain Weave Cotton Fabrics

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Conflicts of Interest

There are no conflicts to declare.

ABSTRACT

Water and oil repellent treatment is done on cotton cloth by pad -dry -baking process. The influences of baking temperature, baking time, pH value and concentration of finishing liquid on water and oil contact position (angle) of fabric are analyzed. The result shows that the optimized water/oil repellent finishing process of cotton cloths is as follows: the concentration of finishing agent is 30g/L, pH value is 6.67, Pick up rate is 80%, and the baking time is 8 minutes under 140°C. After finishing, the oil and water contact position (angle) of the cotton fabrics can reach up to 143.33 degrees and 134 degrees respectively, and at this time the finishing effect is the best. Scanning electron microscopy (SEM) reveals that after water and oil repellent finishing, the external of the cotton fiber becomes smooth, the finishing agent has good film-forming ability, and it has well water and oil repellent performance.

Keywords: COTTON FABRIC; WATER PROOF; OIL REPELLENT TREATMENT; FINISHING PROCESS.

1 Introduction

The main component of cotton fiber is cellulose, which has good hydrophilic property, is easily wetted by water, and is easily stained by oil[1]. In order to make the fabric have certain water and oil repellency, the fabric is subjected to water and oil repellent finishing. Fluorine-containing finishing agent is currently the main water and oil repellent agent due to the fluorine atom has a small diameter, a large electronegativity, and a high C-F bond energy[2]. The immersion process is used to adhere the fluorine-containing compound to the external of the cloth, which can expressively decrease the surface pressure of the fabric and impart good water and oil repellency to the fabric[3]. The surface morphology of the cotton fabric before and after finishing was observed using a

scanning electron microscope (SEM).

2. Materials and methods

2.1 Test material

Plain weave bleached cotton fabric: 21 tex × 21 tex, 108 / 10 cm × 58 / 10 cm, fabrics were collected from the (CCEL) Chemistry and Chemical Engineering lab. The waterproof and oil repellent treatment chemical Swiss-clariant three anti-finishing agent. All the, dyestuffs, basic chemicals etc.(hydrochloric acid - analytical grade, sodium hydroxide - analytical grade), received from the Chemical Engineering examination center for Clean Production of Textile Dyeing and Printing, Ministry of Education lab.

2.2 Fabric preparation

Plain weave bleached cotton fabric roll were collected from the chemical lab .To inspect the fabric cleanliness and to check the hole mark, crease mark, GSM cut in to many pieces as A4 size (8 x 11 inch).

2.3 Experimental equipment

Scissors, Beakers, Dropper, Petridis, Glass rods, Electrical balances, Safety glass, Mask, Apron, Hand gloves, Padding machine, Small dryer machine, Curing machine, Washing machine, Contact angle instrument.

2.4 Test methods

Bleached cotton fabric → two-dip two-pad (Pick up rate of 80%) → pre-baking (80°C, 5 min) → baking (160°C, 3 min)→washing (60°C ×15 min) →dry (75-80°C) naturally 4-5 min → Measurement of contact angle (CA)

3. Measurement of contact angle (CA)

The name of the instrument KRÜSS easy drop Shape analyzer-(DSA) and software was DSA20contact angle measuring instrument was used, and deionized water and oil were used as water and oil test liquid[4]. Tested 3 times in different quantities of the same sample, the usual value of CA is the contact position (angle) of the sample .The external morphology of the fabric was observed- the finished fabric was sprayed with gold by a gold-plated instrument, and its surface morphology was observed by a turf emanation scanning electron microscope[5].

4. Results and discussion

The outcome of the pH value of the finishing liquid on the water and oil repellent treatmenteffect of the cloth. Prepare 30 g/L finishing solution and measure the pH value of 6.67. Adjust with 6 mol/L HCl and 2 g/L NaOH to adjust the pH value. Change the pH vale at 2, 4, 6, 8, and 10, the cotton cloth was finished according to the finishing process; the water-oil contact position (angle) of the fabric was tested. The results which are stated below in Table 1 & 2 and Table 3 &4

Table 1. Effect of pH value of finishing liquid on water repellency of fabric.

pH	water contact angle (°)
2.00	136.33
4.00	138.33

6.00	140.00
6.67	143.67
8.00	140.67
10.00	98.67

Table 2. A graphical illustration of the effect of pH value of finishing liquid on water repellency of fabric

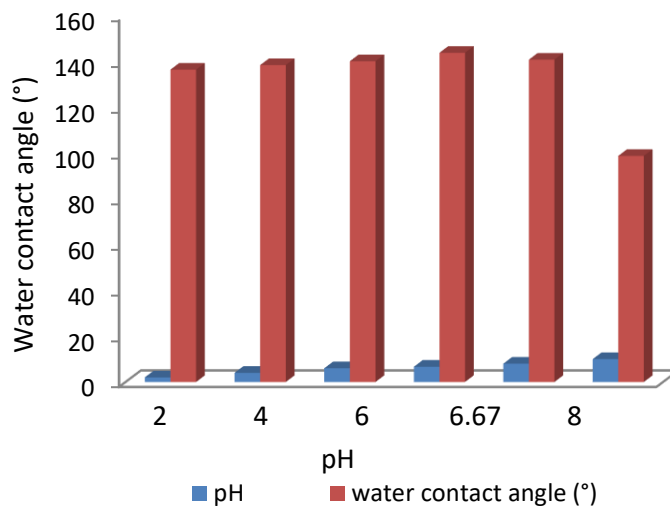
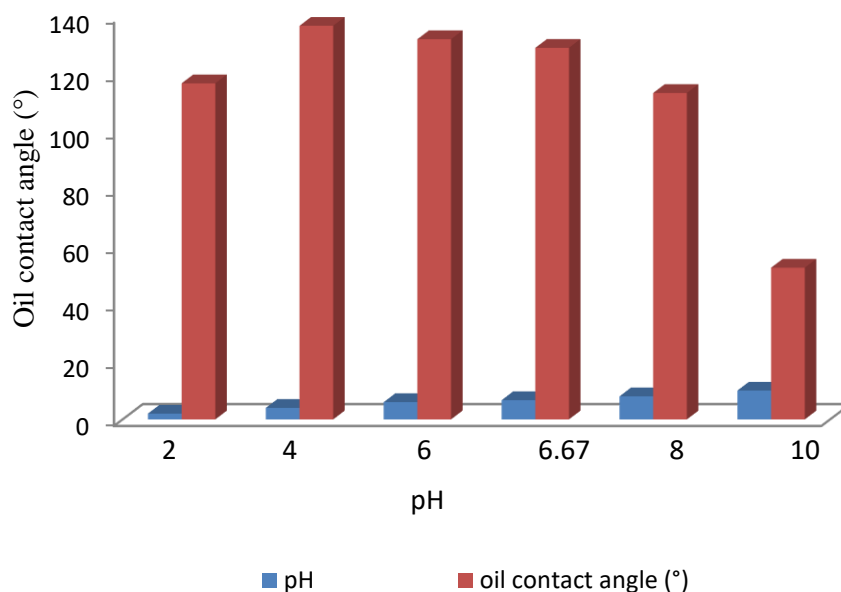


Table 3. Effect of pH value of finishing liquid on oil repellency of fabric

pH	oil contact angle (°)
2.00	116.67
4.00	136.67
6.00	132.00
6.67	129.00
8.00	113.33
10.00	52.67

Table 4. A graphical representation of the effect of pH value of finishing liquid on oil repellency of fabric



It can be realized from Table 2 and Table 4 that, as the pH value of the finishing liquid increases, the water-oil contact angle of the cotton fabric first increases and then decreases. When the pH is 4~6, the water-oil contact angle of the cotton fabric after finishing is about 140°, which has good water and oil repellent effect; at pH=10, the oil-water contact angle is small, especially the oil contact angle. Only 52.67°, indicating that the fabric after alkaline finishing has basically no water and oil repellency. Considering the high temperature baking after acid treatment, the cotton fiber is damaged, and the test results of water and oil contact position (angle) are taken into consideration. When the finishing liquid is not adjusted by acid and alkali, the cotton cloth has the best water and oil repellent finishing effect, and the pH is 6.67. Effect of baking temperature on water and oil repellent finishing effect of fabrics 30 g/L finishing liquid, pH value of 6.67, changing baking temperature, finishing cotton fabric according to the finishing process and testing the water and oil of fabric Contact angle, the results are shown in Table 5 & 6 and Table7 & 8.

Table 5. Effect of baking temperature on water repellency of fabric

Temperature (°C)	water contact angle (°)
120	144.00
130	138.33
140	138.67

150	139.67
160	143.67

Table 6. A graphical illustration of the effect of baking temperature on water repellent of fabric

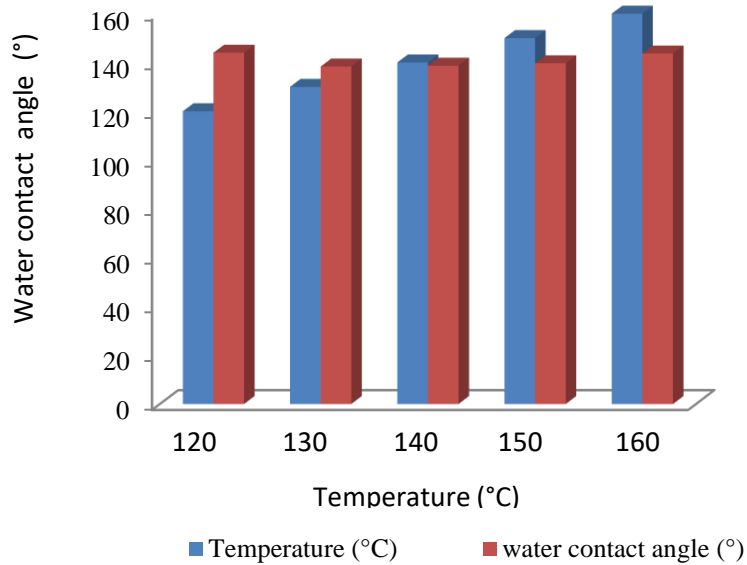
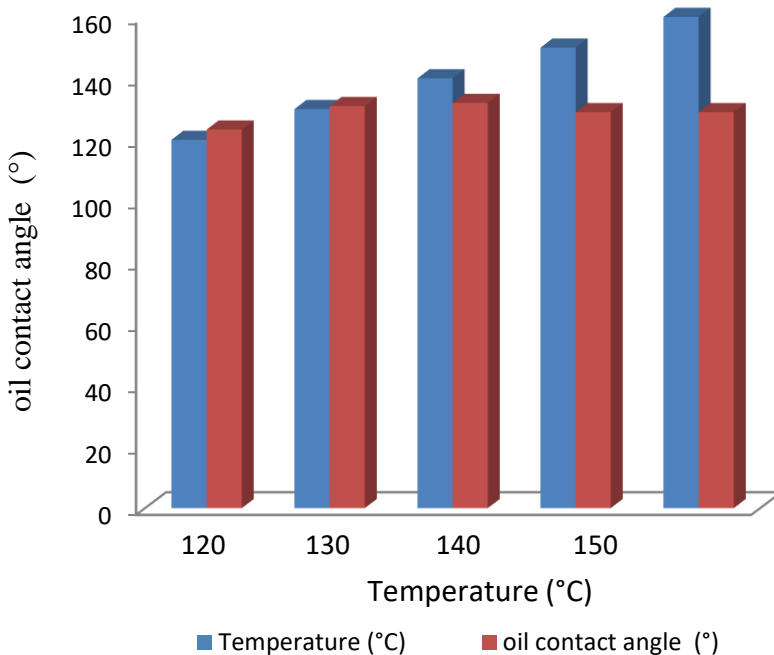


Table 7. Effect of baking temperature on oil repellency of fabric

Temperature (°C)	oil contact angle (°)
120	123.33
130	131.00
140	132.00
150	129.00
160	129.00

Table 8. A graphical representation of the effect of baking temperature on oil repellency of fabric



According to Table 6 & 8, when the baking temperature is 120-160 °C, the water contact angle of the cotton fabric after finishing is about 140°, and the oil contact angle is about 130°. Considering the excessive baking temperature, the fabric is yellowed, the fiber is damaged, and the test results of the water-oil contact angle are taken into consideration. The baking temperature with good water and oil repellency is 140 °C. Effect of baking time on water and oil repellent finishing effect of fabrics 30 g/L finishing liquid, pH value 6.67, baking temperature 140 °C, changing baking time, finishing cotton fabric according to the finishing process and the water-oil contact angle of the fabric was tested and the results are shown in Table 9 & 10 and Table 11 & 12.

Table 9. Effect of baking time on water repellency of fabric

Time/min	water contact angle (°)
3	138.67
5	139.67
8	145.00
10	137

Table 10. A graphical illustration of the effect of baking time on water repellency of fabric

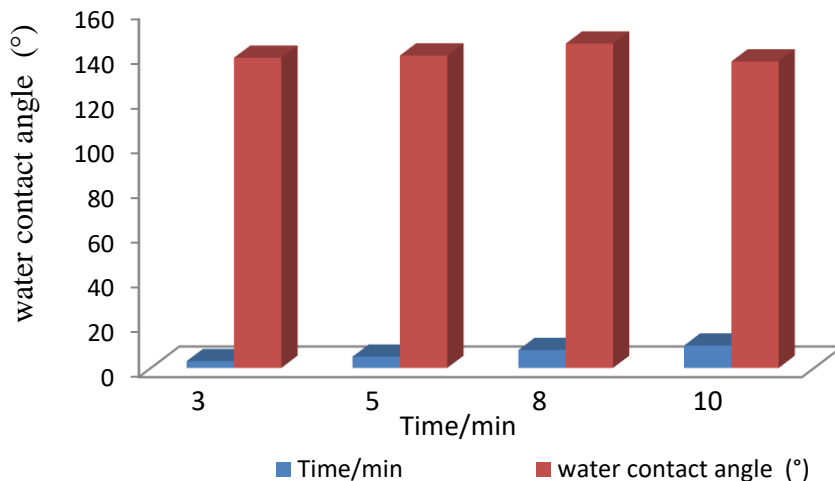
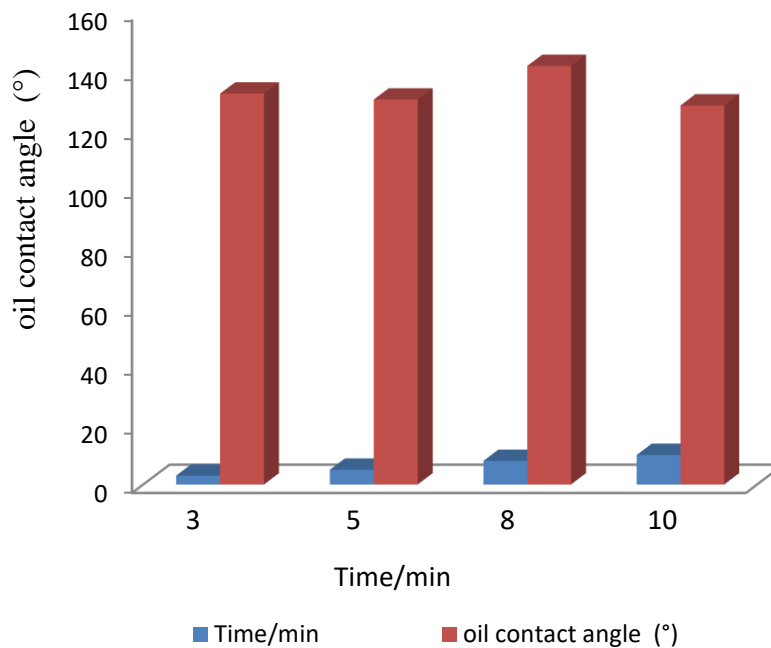


Table 11. Effect of baking time on oil repellency of fabric

Time/min	oil contact angle (°)
3	132.33
5	130.33
8	141.67
10	128.33

Table 12. A graphical illustration of the effect of baking time on oil repellency of fabric



The degree of polymerization or film formation of the fluoro finish on the fabric is directly affected by the baking time. The baking time is too short, the polymerization or crosslinking of the organic fluoride is

insufficient; the baking time is not too long, and the time is too long, which affects the whiteness, strength and process progress of the fabric. It can be seen from Table 10 and Table 12 that, as the baking time is extended, the water-oil contact position (angle) of the cotton fabric after finishing is first increased and then decreased. When the baking time is at 10 min, the water contact angle of the cotton fabric after finishing was significantly reduced, and the oil repellency was deteriorated. When the baking time was 8 min, the water-oil contact angle of the cotton fabric after finishing was the largest, and the water-repellent and oil-repellent effect was the best. Therefore, the preferred baking time of the cotton fabric for water and oil repellent finishing is 8 min. The effect of finishing agent concentration on the water and oil repellent finishing effect of the fabric When the pH value is 6.67, the baking temperature is 140 °C, and the baking time is 8 min, the concentration of the finishing agent is changed, and the cotton fabric is finished according to the finishing process. The water-oil contact angle of the fabric was tested and the results are shown in Table 13 & 14 and also in Table 15 & 16.

Table 13. Effect of finishing agent concentration on water repellency of fabric

Concentration (g/L)	Water contact angle (°)
1	0
5	0
10	129.33
20	137.33
30	143.33
40	136.33
50	137.67
60	132.33

Table 14. A graphical illustration of the effect of finishing agent concentration on water repellency of fabric

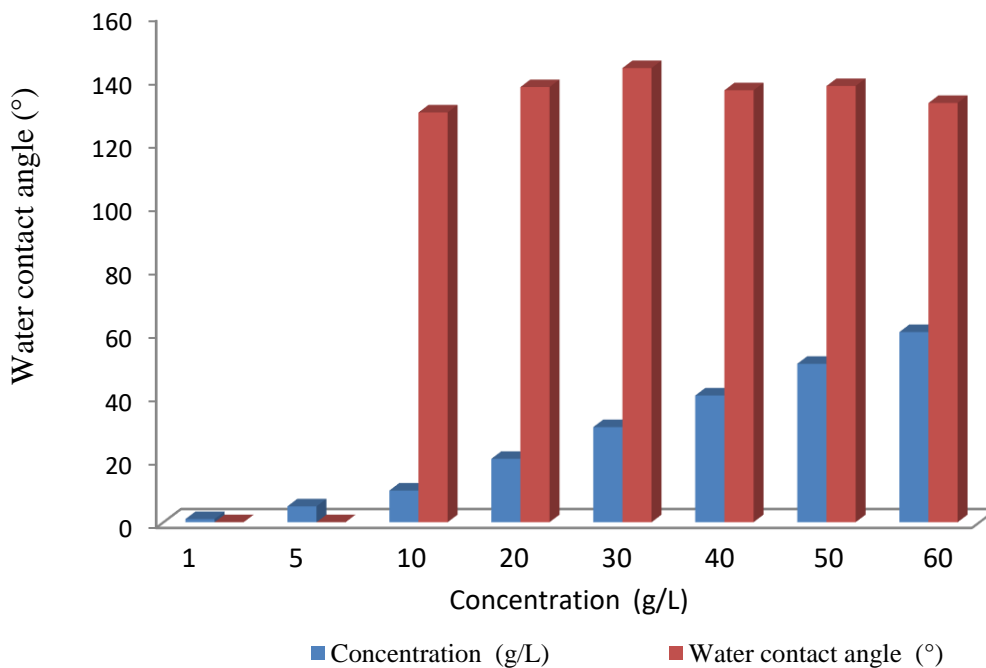
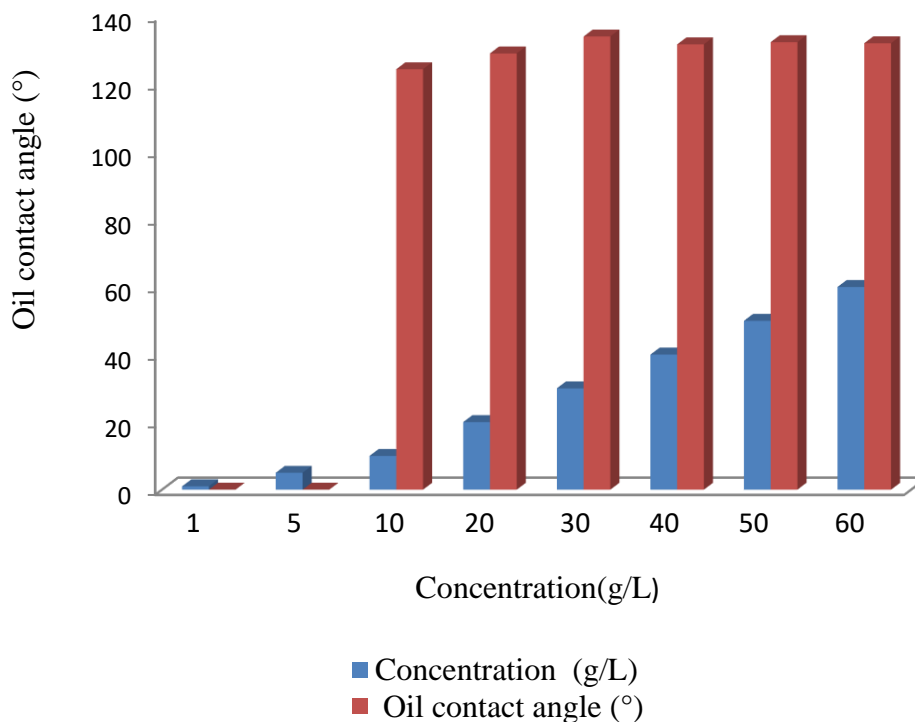


Table 15. Effect of finishing agent concentration on oil repellency of fabric

Concentration (g/L)	Oil contact angle (°)
1	0
5	0
10	124.33
20	129.00
30	134.00
40	131.67
50	132.33
60	132.00

Table 16. A graphical demonstration of the effect of finishing agent concentration on oil repellency of fabric



The water and oil repellency of the fabric is achieved by a layer of material with low external energy adsorbed on the surface of the fabric. The effective component in the finishing liquid is an organic fluorine compound, and the alignment of the organic fluorine molecules on the surface of the fiber reduces the surface tension of the fiber, thereby imparting a water and oil repellency effect to the fabric. Therefore, the content of organic fluorine in the finishing liquid determines whether the organic fluorine molecules on the surface of the fiber can be closely aligned, that is, the concentration of the finishing liquid can affect the water and oil repellency of the fabric after finishing. It can be realized from Table 14 & 16 that, when the finishing agent concentration is 1 g/L and 5 g/L, the water-oil contact angle of the cloth is zero. When measuring, the water precipitations and oil droplets will be on the external of the finished cotton cloth in a short time. Completely spread. With the rise of the concentration of the finishing liquid, the water-oil contact position (angle) of the cotton fabric

after finishing has a tendency to increase first and then decrease. According to the Cassie-Wenzel transition state mode, the state of the droplet in contact with the solid depends on the relative size of the critical contact angle between the Wenzel state and the Cassie-Baxter mode[6].

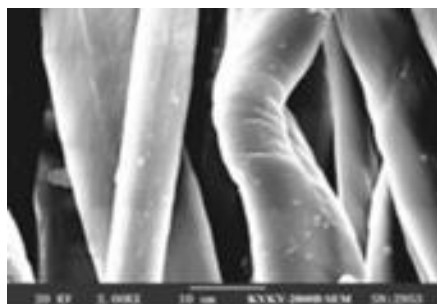


Figure 1. Unfinished cotton fabric SEM image

The surface should have a certain rough structure, and when the concentration of the finishing agent is too high, the film is uniformly designed on the surface of the cloth, and the surface is too smooth, thereby reducing the water and oil repellency[7]. When the concentration of the finishing liquid is 30 g/L, the water-oil contact position (angle) of the cotton fabric after finishing is the largest, so the optimum finishing liquid concentration is 30 g/L.

5. Water and oil repellency test of cotton cloth after finishing

The concentration of water and oil repellent agent is 30 g/L, the pick-up rate is 80% (two dip two pad), pre-bake at 80 °C for 5 min, and baking at 140 °C. The finishing process of min is used for water and oil repellent treatment of cotton fabrics. The water and oil contact angles of cotton fabrics after finishing are shown in Figure 2 & 3.



Figure 2. Water contact angle of cotton fabric after finishing



Figure 3. Oil contact angle of cotton fabric after finishing

It can be perceived from Figure2 & 3 that, the cotton fabric has good water and oil repellency after finishing, and the best water-oil contact angle reaches 143.33° and 134°. From the above results, it is known that the measured oil contact angle is always smaller than the water contact angle. According to Young's equation , $\gamma_{SL} - \gamma_S + \gamma_L \cos\theta = 0$, where γ_{SL} is the interface tension between solid and gas, γ_S is the interfacial tension between liquid and gas, and γ_L is the interfacial tension between liquid and solid. When γ_S is constant, the

smaller γ_L is, the smaller θ is, and the liquid is more likely to wet the solid[8]. The surface tension of oil is 32.95 (mN·m⁻¹), while the surface tension of water is 71.79 (mN·m⁻¹). The surface tension of oil is much smaller than the surface tension of water, so water contact angle is also larger than the contact angle of the oil, but both water repellent and oil repellent can achieve better results.

6. Observation of surface morphology before and after finishing

Observing the scanning electron micrographs Figure 1 and Figure 4 before and after finishing the cotton fabric, it can be seen that after the water and oil repellent finishing, the surface of the cotton fiber is smooth, the film forming property of the finishing agent is good, and a uniform organic fluoride film can be formed on the external of the fiber[9]. Has good water and oil repellency which is shown below in Figure 4.

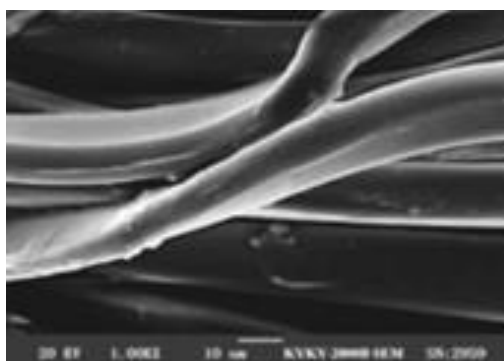


Figure 4. SEM image of cotton cloth after water and oil repellent finishing

Conclusion

Water and oil repellent treatment of plain weave bleached cotton fabric was treated with Swiss Clariant three anti-finishing agent. Fluorocarbon-free finishing which are applied on cotton fabrics by two dip-two pad process. Applying water and oil repellent chemicals, the surface of the hydrophobicity of cloth was investigated. When a water and oil finishing chemical was used, then the best water and oil finishing is obtained by evaluating especially contact angle test and the optimized condition was concentration 30g/L, backing temperature 140°C, backing time 8 min and pick up-rate 80%. The finishing agent has the function of changing the surface belongings of the fiber, so that the external of the fiber variations from hydrophilic to hydrophobic.

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