Experimental Study on Fabric Surface Wettability based on Contact Angle and Surface Energy

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ABSTRACT

The paper studies on surface wettability characterization of fabric by using contact angle. According to surface tension of liquid, contact angle between liquid and fabric, based on Owens model, the surface energy of nonwoven surface that has water repellent finishing (sample 2) is 29.54 mN/m, and nonwoven surface that hasn’t water repellent finishing (sample 1) is 43.99 mN/m. The essence of water-repellent finishing is to reduce solid surface energy. The surface tension of liquid drop is lower; the contact angle of droplet and fabric surface is smaller.

INTRODUCTION

The surface wettability of fabric is one of important characteristics in surface properties. Including of raincoat fabric, out door clothing, medical protective clothing, surgical drapes, desk clothing and wall clothing, they all need to evaluate their surface wettability.

A droplet drops on fabric surface, droplet contacts fabric surface and reaches to equilibrium state. The intersection angle between gas-liquid interface tangent and solid-liquid boundary line is named contact angle. As shown in Fig. 1, contact angle of liquid and fabric surface is an evaluation index of surface wettability, and it is a quantitative physical quantity, not subjective.

The contact angle reflects the reaction of affinity between liquid and solid surface, the stronger affinity, the smaller contact angle. If contact angle is less than 90°, fabric surface is considered to be hydrophilic solid. If contact angle is higher than 90°, fabric surface is considered to be hygrophilous, so liquid is difficult to wet fabric surface.

![Different shape of droplet on fabric (hydrophobicity).](image)

(a) Poor           (b) Middle            (c) Good

Figure 1. Different shape of droplet on fabric (hydrophobicity).

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The fabric surface energy originates from atoms or molecules that on the surface of solid is different from inner. Surface energy affects the properties of surface wettability. The surface tension of liquid can be measured directly, but so far, we can’t measured solid surface energy by using of instrument, only through calculating based on contact angle to estimate.

EXPERIMENTAL

Test Liquid

Distilling water, ethylene glycol, and their mixed liquid.

Instrument

Optical contact angle measuring instruments, Dataphysics OCA 15EC, Germany.

Fabric

Spunbond nonwoven, including of water-repellent-finishing nonwoven (1) and non-finishing nonwoven (2); knitted fabric; woven fabric.

RESEARCH CONTENTS

Contact Angle

Using different liquids, research on the relationship between surface tension and contact angle.

Surface Energy

Using two different liquids which have different surface tension, two different of contact angle can be measured, and OWRK method is used to calculate fabric surface energy.

EXPERIMENTAL RESULTS

Liquid Surface Tension and Contact Angle

The surface tension of liquid, including of their dispersion component and polar component are as seen from Table 1.

<table>
<thead>
<tr>
<th>TABLE 1. SURFACE TENSION OF MIXED LIQUID.</th>
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<tbody>
<tr>
<td>Mass fraction of ethylene glycol /%</td>
</tr>
<tr>
<td>Surface tension /mN/m</td>
</tr>
<tr>
<td>Disp. component /mN/m</td>
</tr>
<tr>
<td>Polar component /mN/m</td>
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</tbody>
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Seen from Fig. 2, using liquid of Table 1, to water-repellent finishing nonwoven, when surface tension is 72.8mN/m, contact angle is 142°, when surface...
tension is 48.2mN/m, contact angle is 112°. With the liquid surface tension is bigger, contact angle is bigger. The experimental results are in accord with Young’s equation. Compared with two curves, the contact angles of water-repellent finishing nonwoven are all bigger than non-finishing nonwoven; it can show that the effect of water-repellent finishing is good.

**Contact Time and Contact Angle**

When droplet on fabric surface, to reach an equilibrium state, it need some time, the molecular of fabric and liquid will interact until equilibrium. We can see from Fig. 3(a), (b) and (d), with contact time is increasing, contact angle will be smaller, and eventually reaches a staple state, contact angle remains unchanged basically, this contact angle is named static contact angle or equilibrium contact angle. To Fig. 3(a), (b) and (d), after 16 seconds of contact time, contact angles of four different fabric reach to equilibrium state. To Fig. 3(c), it can be seen that non-finishing nonwoven is wetted when droplet contact fabric surface, so its contact angle is 0°. The contact angle of knitted fabric at the time of 24s-28s, contact angle reduced from 100° to 0°, which indicates that the interaction between liquid drop and fabric surface is longer, and finally, fabric is wetted. The woven fabric is wetted at the time of 8s-10s. Seen from four figures, we know that it need some time of contact angle between liquid drop and fabric surface becomes equilibrium, when reach equilibrium, the equilibrium contact angle can be obtained.

It is very important to choose reasonable contact time to measure equilibrium contact angle. If the time is too short, the interaction between droplet and fabric is not balancing, the time is too longer, and the evaporation of the droplets will affect the shape of the droplet. So it will affect the measurement of equilibrium contact angle. From all test, to fabric, in general, 60s contact time is appropriate.

**Surface Energy**

Through contact angles from two kinds of liquids with different surface tension, surface energy can be calculated.

The Young’s thermodynamic equilibrium equation is as follows:
\[ \gamma_{sg} = \gamma_{lg} \cos \theta + \gamma_{sl}. \]

Among them, \( \gamma_{sg} \) represents solid surface energy, \( \gamma_{lg} \) represents liquid surface tension, \( \gamma_{sl} \) interfacial tension between liquid and solid. \( \gamma_{lg} \). And \( \theta \) can be measured by instrument, but \( \gamma_{sg} \) and \( \gamma_{sl} \) can’t. Therefore, we need another equation from some theory model, in this paper, Owens model is used for calculating surface energy, and it assumes that dispersion and polar force of molecular can be added independently.
\[
\gamma_{st} = \gamma_{sg} + \gamma_{lg} - 2\left(\sqrt{\gamma_{lg}^d \cdot \gamma_{sg}^d} + \sqrt{\gamma_{lg}^p \cdot \gamma_{sg}^p}\right);
\]

\[
\gamma_{lg} = \gamma_{lg}^d + \gamma_{lg}^p;
\]

\[
\gamma_{sg} = \gamma_{sg}^d + \gamma_{sg}^p
\]

From above equation, we can get follow equation:

\[
\frac{\cos \theta + 1}{2} \cdot \gamma_{lg} = \sqrt{\frac{\gamma_{lg}^d}{\gamma_{lg}^d}} \cdot \sqrt{\gamma_{sg}^p + \gamma_{sg}^d};
\]

\[
y = \frac{\cos \theta + 1}{2} \cdot \gamma_{lg};
\]

\[
x = \sqrt{\frac{\gamma_{lg}^p}{\gamma_{lg}^d}};
\]

\[
a = \sqrt{\gamma_{sg}^p};
\]

\[
b = \sqrt{\gamma_{sg}^d}
\]

To non-water-repellent finishing nonwoven, when liquid uses water, \(\gamma_{lg} = 72.80\) mN/m, \(\gamma_{lg}^d = 21.80\) mN/m, \(\gamma_{lg}^p = 51.00\) mN/m, \(\theta = 93^\circ\). When uses glycol,
\( \gamma_{lg} = 50.46 \ \text{mN/m}, \ \gamma_{lg}^d = 19.13 \ \text{mN/m}; \ \gamma_{lg}^p = 31.33 \ \text{mN/m}, \ \theta = 75^\circ \). According to above, the surface energy of fabric is: \( \gamma_{sg} = 43.99 \ \text{mN/m} \).

To water-repellent finishing nonwoven, when liquid uses water, \( \gamma_{lg} = 72.80 \ \text{mN/m}, \ \gamma_{lg}^d = 21.80 \ \text{mN/m}; \ \gamma_{lg}^p = 51.00 \ \text{mN/m}, \ \theta = 145^\circ \). When uses glycol, \( \gamma_{lg} = 50.46 \ \text{mN/m}, \ \gamma_{lg}^d = 19.13 \ \text{mN/m}; \ \gamma_{lg}^p = 31.33 \ \text{mN/m}, \ \theta = 131^\circ \). According to above, the surface energy of fabric is: \( \gamma_{sg} = 29.54 \ \text{mN/m} \).

From above calculation result, the surface energy of water-repellent finishing nonwoven is 29.54mN/m, and non-finishing nonwoven is 43.99mN/m. So it explains that essence of water or oil-repellent finishing is to reduce solid surface energy. If only consider surface energy, in theoretically, in order to wet fabric surface, surface tension of liquid should be less than solid surface tension. Through fabric surface energy, so we can estimate surface wettability situation of fabric using a liquid which has known surface tension.

**CONCLUSIONS**

The following conclusions can obtained from above experimental results:

1. With the liquid surface tension is bigger, contact angle between liquid drop and fabric surface is bigger. We can estimate water-repellent finishing effect through contact angle of fabric which has water-repellent finishing.
2. Contact time will affect the measurement of equilibrium contact angle. From all test, to fabric, in general, 60s contact time is appropriate.
3. The surface energy of water-repellent finishing nonwoven is 29.54mN/m, and non-finishing nonwoven is 43.99mN/m. So it explains that essence of water or oil-repellent finishing is to reduce solid surface energy.

**REFERENCES**
