A novel fabric softener system to make the softness and water wiping effect compatible.

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ABSTRACT

It is well known that the softness of fabrics is realized when fabric softener is used after washing, and it is also well known that the water-absorbency of the fabrics is decreased as an unfavorable side-effect. In order to overcome this trade-off relationship, we found it effective to introduce "additional hydrophilic surfaces" onto the surface of cotton fibers using highly hydrophilic small particles. This phenomenon is to be explained by a new wetting theory explained by modification of Cassie-Baxter equation.

Keywords: fabric, softener, softness, water-absorbency, particle, wetting theory, Cassie-Baxter

Proper amount of fabric softener usage (hereafter referred to as "softener") can give apparent softness to cloths and especially to cotton towels, and we can easily recognize improved comfortable good feel. In our previous two studies [1][2], we proposed new theories regarding the softening mechanism of softener, that is, softening phenomenon of cotton is caused by the inhibition of the formation of cross-linkage of hydrogen bonding network mainly including "non-frozen type of water".

With this mechanism, softener can certainly give texture abundant soft feel. On the other hand, water absorbency that is commonly regarded as the good property of cotton apparently decreases when softener is used.

Current widely distributed softening agents in the market have a particular structure having two long hydrophobic alkyl chains, and the surface of the softener-treated yarns and cloths turned easily to be hydrophobic. This is also the reason why water absorbency of cotton cloths is lost when softener is used.

In our daily life, we recognize the loss of water absorbency of cotton-related products such as towel when softener is used on the occasions that we try to wipe off the water or sweat from our skin. In these activities, we can visually recognize the residue of water on the surface and/or perceive tactile feel of coldness on the skin. As the result, we clearly recognize the lack of water absorbency.

When we apply towels for the purpose of wiping off the water, hydrophobic cotton towels treated with softeners show the following tendencies; it is difficult for the water droplets to move from the surface of the towel to deeper inside part of it and they stay relatively long time around the surface of cotton cloth. As the result, the phenomenon called "tacking" caused by the liquid-film effect also occurs between the surface of the cloth and human skin. These phenomena are thought to be the main causes of the unpleasant sensation we get when softener is used.

Since softener was introduced to the US market in 1955, DODAC (di-octadecyl ammonium chloride) had been commonly used as the softening agent, but the problems such as low water-absorbency, low biodegradability and environmental safety issues turned to be discussed as social issues. In order to overcome these issues, various efforts regarding development of new compounds have been carried out. Through these efforts, some high-water-absorbing types of softening agents have been proposed to the market. One of the good examples is DOE (di-oleyl ammonium chloride) which is a cationic surfactant having unsaturated long alkyl chains. Ohbu reported that DOE has excellent properties to improve not only water-absorbency but also quick drying [3]. Ion-complex type of softener composition made of anionic surfactant with branched alkyl chain and cationic surfactant is also known to be effective to improve water-absorbency [4]. Furthermore, Imidazole salt type synthesized from low-cost materials such as fatty acid and diethlenetriamine are very famous [5] which can give not only good soft feel but also better water-absorbency than DODAC.

The reason why these types of softening agents improve water-absorbency is explained based on the molecule mobility. Yamamura reported that the flexibility of the DODAC type molecules having different length of alkyl groups can dynamically change its molecular mobility around the gel transition temperature (Tc) as the critical point which accompanies the change of the mobility /migration ability of water, resulting in the improvement of water-absorbency and wettability. Ohbu also gave a similar interpretation based on molecular mobility focusing on the fact that DOE forms lamellar liquid crystal structure at room temperature. Good characteristic of Ion-complex type of softener is understood with the same point of view.

As mentioned in the former part, when we tried to evaluate the performance of these softeners with the points of use-feeling, that is to say, easiness to wipe off water from our skin, water adsorbing feeling became less with the increase of the softener concentration. In order to understand the relationship between physical property of water absorbency and the feeling of easiness to wipe off water, we tried to evaluate the water absorbency of cloths with the well-known JIS method (JIS L 1907) such as dropping method, Virek method and sedimentation method, but it was not successful to find the clear correlation between these physical property values and water wiping-off performance nor sensation. Our research results suggested that we had better think that the so-called "water wiping performance" is a multivariate phenomenon or feeling composed of complex elements. This complexity is to be the reason of difficulty to measure the "water wiping performance" by any only one particular water absorbency performance measurement.

For a long time, it has been regarded to be a trade-off to get high level of softness and to get high level of water absorbency for cotton when fabric softener is used. In our research, we introduced a new sensory evaluation indicator called "water wiping-off feeling ratio" and also created a new method/model to overcome above-mentioned trade-off by the use of small particles having hydrophilic surface in the course of using a softener.

As we tried to compare the performance of water absorbency of towel cloth without and with softener treatment, when softener was not used, water droplets were immediately widespread inside the cloth, but in the case of using softener treated towel, the speed of diffusion of water was low and it is difficult for water to penetrate and move into the inside of the cloth. As we tried to wipe water off from the skin with such a low-water absorbency towel (softener concentration was set to 0, 0.1, 0.3%o.w.f.) and investigate the ratio of residue of water that was hard to wipe perfectly, the weight ratio of water was 7.5% in the case of using untreated towel. But softener concentration was set to higher from standard to 3 times of softener, water content ratio turned to be higher from 21.2% to 36.4%.These results showed that it was difficult to remove water effectively from the skin using softener treated towels On the other hand, much complex movement frequently occurred and total labor load was increased when we observed the motion of hands of the panelists during wiping off the water when the softener-treated towels were used. This observation indicates that useless movements of hands surely increased during wiping activity, and tendency of increase of remaining water increased. As the result not only lowering of wiping performance but also psychological and physical burden to user was certainly added.

In this research, we defined this performance as "wiping performance" and tried to evaluate it with 5 sensory evaluation axis method. As we tried to investigate the influence of wiping performance according to the volume of softener concentrations and tried to do calibration with this new functional axis, we understood with certainty that wiping performance decreased with the increasing of EA- the standard agent for us: KAO's product softener concentration, and level was down to 1 at the concentration of around 0.075%o.w.f.

When we tried to evaluate wiping performance of so called water-absorbency-type products such as DOE type softener (used for "Touch", Kao corporation,Japan,1984-1994) and ion-complex type of softener (use for "Hamming Flair", Kao corporation, Japan, 2002-2011), higher water-absorbing performance than that of EA softener was found, but softening performance decreased with the increasing of softener concentration. As a result, it was found quite difficult to obtain high water-absorbency feel like non-treated cotton towels with these existing fabric softeners.

In order to overcome this trade off of the wiping-off efficiency of water of softener-treated cotton clothes and softness, we introduced a new hydrophobic surface by using hydrophilic small particles together with the fabric softener in use. Inspired by the theory of fractal geometry, onto the combination of models / equations of Cassie, Baxter and Wenzel, the idea of adding new convex hydrophilic domains onto the surface of the cotton fibers where the softener molecules co-exist. Finally, we found we could improve the wiping-off feel without decreasing the soft feel, i.e. we could find a way to overcome ever impossible above-mentioned trade-off haunted for fabric softening agents.

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