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Combination effect of ultrasound and shake as a mechanical action for textile cleaning

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ABSTRACT

The ultrasonic cleaning of artificially soiled fabrics with and without shake was carried out in an aqueous anionic surfactant solution. The polyester, cotton and polyester/cotton (65/35) fabrics were soiled with oleic acid or carbon black as a model soil, and cleaned together with their original fabrics with applying ultrasound for 5 min. The detergency and the soil redeposition were determined from the change in the Kubelka–Munk function of the soiled and original fabric surfaces due to the cleaning. For any fabric, the removal of oleic acid and carbon black from the soiled fabric and their redeposition onto the original fabric increased with increasing electric power consumption of ultrasound. When ultrasound and shake were applied at the same time, the detergency further increased for any electric power consumption. The maximum detergency obtained with combination of ultrasound 340 W and shake 160 spm was compared with detergency obtained with Wascator, a horizontal axis drum type washer. It was found that the ultrasound/shake combination cleaning enabled efficient removal of both soils from any fabric and the detergency of the polyester fabrics was comparable to that with Wascator. The mechanical action during the washing was evaluated by two mechanical action test pieces commercially available, which indicated that the ultrasound/shake combination cleaning provided gentle mechanical action to the fabric in comparison with the drum type washer. The SEM observations showed the damage of the fabric and fiber surfaces was negligibly small after the ultrasound/shake combination washing.

1. Introduction

Domestic or commercial laundry of textiles has been carried out using conventional front-loading tumbler washers or top-loading design washers. Such textile washing machines often cause heavy damage to clothes because of the deformation and friction of fabrics. Especially for low-water laundering in recent years, external fibrillation of fibers and migration of dye between clothes can be promoted. Commercial dry-cleaning with organic detergent solvents has been utilized for delicate garments. However, the solvents cannot remove water-soluble contaminants sufficiently as well as have human toxicity and environmental impacts [1,2]. Moreover, many dry cleaning accidents have been recently reported, especially for the textiles coated and laminated with other materials. With the above points as background, aqueous textile cleaning systems with less fabric damage as well as high detergency performance has been desired.

As another type of cleansing action differ from the tumbling or stirring actions of general washing machines, ultrasound has been used for material surface cleaning in many industries [3–6]. Ultrasound acts on contaminants adhering to relatively hard substrates like metals, plastics, glass, rubber and ceramics due to growth and collapse of a cavitation vacuum bubble in a cleaning bath. The cavitation bubble size, which determines the amount of energy released at implosion, is governed by the frequency of the ultrasonic generator [7]. An ultrasound generator and transducer create alternating waves of compression and expansion in the liquid at extremely high speeds, usually between 25 and 100 kHz [8]. Although ultrasound is not generally applicable for cleaning of soft and flexible fibrous assemblies [9], it has been reported that energy efficiency and processing time of the wet textile processes can be improved in the presence of ultrasound [10,11].

In the previous paper [12], we found that ultrasound can remove particulate and oily soils from the polyester fabric in a short time and at low bath ratio in aqueous detergent solutions. Moreover, it was confirmed that the ultrasound caused little damage to the fabric during the washing.

For the practical use of ultrasound in wet cleaning process of textiles, we attempt here the ultrasonic washing in combination with shake in expectation of improving soil removal and preventing the soil redeposition. Three fabrics, polyester, cotton and

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polyester/cotton, and two model soils, oleic acid and carbon black were chosen. The self-developed artificially soiled fabrics and their original fabrics were cleaned together in an aqueous anionic surfactant solution by applying ultrasound with and without shake. The soil removal and the soil redeposition were determined by the surface reflectance method. Effects of ultrasound electric power consumption and on the soil removal and redeposition were discussed. Furthermore, the detergency and the fabric damage after the ultrasonic washing were compared with those after washing with Wascator, a horizontal axis drum type washer in accordance with ISO 6330 [13].

2. Materials and methods

2.1. Materials

As model soils, oleic acid and carbon black (Sentaku Kagaku Kyokai, Japan) were used. Sudan III (oily-soluble dye, CI 26100, Wako Pure Chemical Industries, Ltd., Japan) was chosen as an indicator of oleic acid. Plain-woven fabrics of polyester 100% (30A, wfk Testgewebe GmbH, Germany), cotton 100% (10A, wfk Testgewebe GmbH, Germany) and polyester65%/cotton 35% (20A, wfk Testgewebe GmbH, Germany) were used as original fabrics. Each fabric has the same weaving structure, 170 g/m^2 in area weight, 270/270 (warp/weft) per dm in pick count and 295/295 (warp/weft) dtex in yarn count. The fabrics were purified in boiled water twice and were cut into swatches 50 $\times$ 50 mm^2.

For the evaluation of fabric damage during washing, two standard mechanical action test pieces, WAT cloth (Japan Textile Evaluation Technology Council, Japan) and mechanical action (MA) test piece (Danish Textile Institute, Denmark) were used. These test pieces were cut into swatches 50 $\times$ 50 mm^2 (35 mm circular hole was centrically positioned for MA test piece) prior to washing. The polyester (200 $\times$ 200 mm^2, 50 g) and cotton (920 $\times$ 920 mm^2, 130 g) ballasts purchased from SDC Enterprises Ltd., UK were used for the test load for the washing test with Wascator.

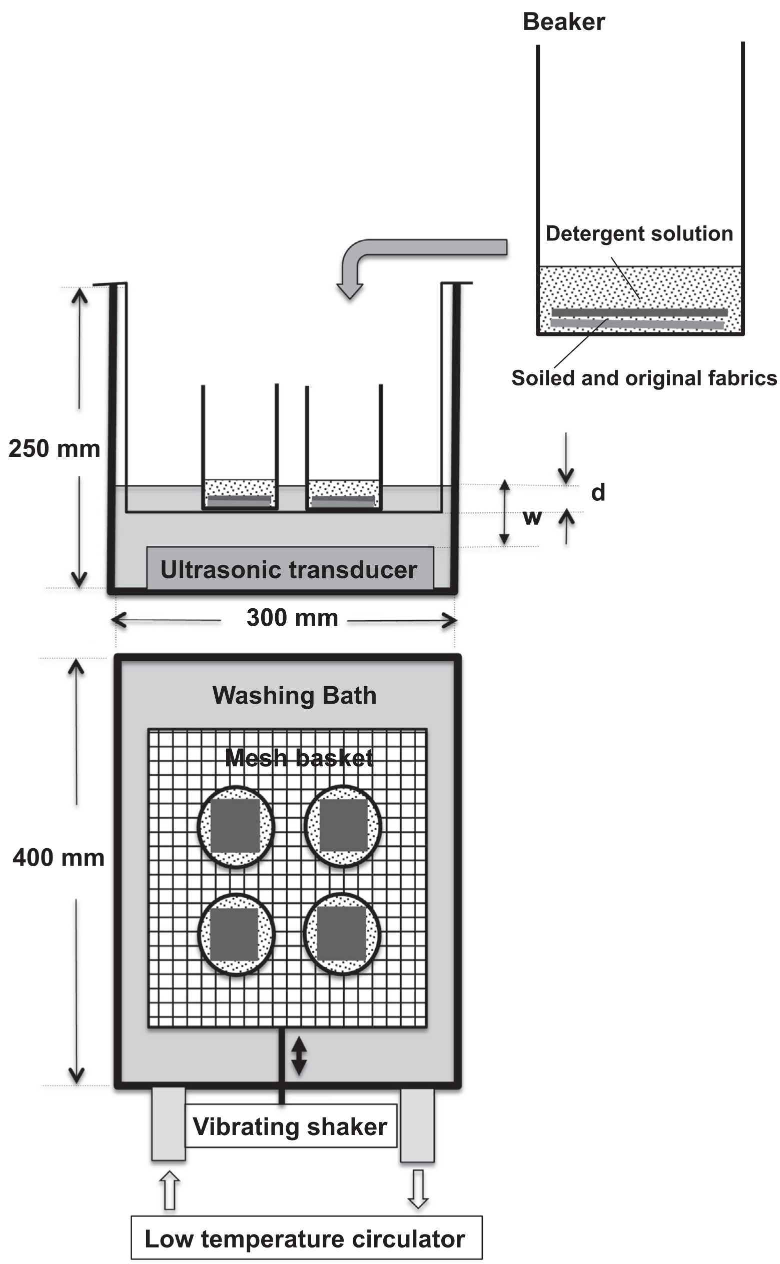

Fig. 1. Experimental setup for washing test.