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Research project *Simulation Wäschepflege* – Recommendations for improving resource efficiency in the laundry process in households in Germany

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ABSTRACT

The consumption of energy, water and detergents during the washing process of laundry in private households in Germany is remarkably high, with over 5.5 billion kWh of electricity and 380 million m^3 of water used every year. In this paper, the work of the research team *Simulation Wäschepflege ("Laundry care simulation")* is presented. This includes insights into the research steps simulation, experimental work and physical textile testing. The main focus is on results from a consumer survey conducted to gain a better understanding of the education level of consumers with respect to laundry care. The washing behavior of 840 consumers in Germany was analyzed in 2012. Consumers were asked questions about themselves and their households, washing machines and practices, laundry sorting and ideas for future washing technologies.

1. Introduction

Washing clothes is a frequent process in each household. In Germany 4 kg of laundry per person and week are washed and 20 million t of laundry are processed yearly (Forum Waschen, 2011). The resource consumption of energy, water and detergents during the washing process of laundry in private households is remarkably high. In private households in Germany, 5.5 billion kWh of electricity and 380 million m^3 of water as well as 600,000 t of detergent are used for washing laundry (Pakula and Stamminger, 2010). In most industrialized countries, washing machines and tumble dryers are the two highest energy-using appliances in the average home, after refrigerators (ACEEE, 2011). Clotheswashing makes up 12% of the total water consumption of drinking water in private households in Germany and is therefore the third largest consumer. For comparison, dishwashing requires 6% of the water consumption (BDEW, 2014). In light of these data and the high impact laundry has on sustainability, research into the washing process, the behavior of the consumer, and their role in the process is needed.

The main influences on resource consumption and on good cleaning performance are described in the *Sinner's Circle for Laundry and Cleaning* (Fig. 1) and listed below: mechanical action, time, chemistry and temperature. The segments of the circle can be changed in their size, but not the circle's total area: reducing the size of one segment increases the size of one or more of the others. For example, if temperature is reduced in order to save energy the amount of time required to complete the washing process will be increased, or more chemistry has to be used.

However, two important aspects are missing in this view: textiles and consumer behavior in laundry care. Both have a great influence on the results of the washing process.

In general, laundry items can be divided in household and clothing items. Properties of both are mainly influenced by the construction of the garment itself, construction of the fabric (woven or knitted) and the used yarns, dyeing and finishing processes as well as by fiber type and fiber composition. Innovations and new products influence the properties. Clothing items are also

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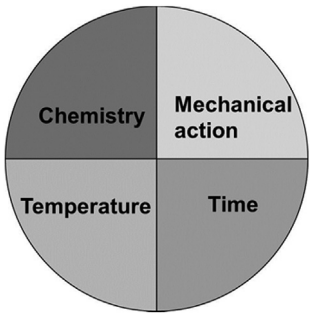

Fig. 1. Sinner's circle for laundry and cleaning.

influenced by fashion trends. Not only the textiles themselves, but also the number of textiles influence the results of the washing process. The quantity of laundry that is washed in the washing machine always depends on the consumer sorting habits. Consumers not only decide on the amount of laundry that is washed but also on other washing process specific parameters such as the washing program used, washing temperature, detergent and dosing of detergent. Textiles and consumers do have an important influence on energy, water and detergent consumption, stain removal and hygiene as well as on the gentle care of laundry.

Current consumer behavior research (Berkholz et al., 2007; Conrady et al., 2013; Laitala et al., 2012) focus on the evaluation of detergent dosing, amount of laundry in the washing machine or resource consumption. A specific investigation of consumer handling of textiles such as the composition of laundry loads and preparing tasks is missing.

Ideals in laundry care are a reduction of resource consumption, better stain removal, better hygiene and gentle care. These objectives are a focus of research of our interdisciplinary research program, *Simulation Wäschepflege* ("Laundry care simulation") where researchers from three different universities and an industrial partner cooperate.

In this paper, the research program *Simulation Wäschepflege* and results from an online survey (conducted as part of the program) with special focus on textiles are presented. The research program and its main activities are presented for a better understanding of the position of the consumer survey within the general context of the research program.

2. Research program and research steps

The research program *Simulation Wäschepflege* was founded in 2011. The research network includes the Technische Universität Berlin – Department of Fluid System Dynamics (Prof. Dr.-Ing. Paul Uwe Thamsen), the HTW Berlin University of Applied Sciences – Clothing Technology/Fabric Processing (Prof. Monika Fuchs, Prof. Ulrich Bauer, Prof. Dr.-Ing. Thomas Schneider), the Beuth Hochschule Berlin University of Applied Sciences – Mechanical Engineering (Prof. Dr.-Ing. Joachim Villwock) and BSH Hausgeräte GmbH Berlin (Dr. Andreas Hanau). Project manager of the research network is Tobias Morgenthal.

The objective is to work in an interdisciplinary team to make improvements to the complex process of washing. The main objective of this program is to improve resource efficiency and stain removal during the washing process while maximizing laundry life. The research focuses on the analysis and the simulation of the washing process. Therefore the behavior of the textiles and garments itself and in the washing process have to be investigated. But there are no studies or statistical data available which can give information on the existence of different typical laundry items, frequencies of fabrics or fiber types used for clothing. The volatile price of raw cotton has lead manufacturers to use different and changing fiber mixtures for new garments. Those new mixtures greatly differ from familiar traditional fiber mixtures, so it has been difficult to develop statistics concerning fiber mixtures and laundry items for usage in physical textile testing in the lab. But there are typical product specific characteristics; for example, jeans are always made of denim with a high percentage of cotton, and socks are always made from knitted fabrics. Provided the product area is limited in this way, textiles and the consumer behavior can be investigated in a consumer study.

The research on consumer behavior with a special focus on textiles and consumer impact on the washing process is primarily performed by Katharina Ellmer. Online surveys are developed, implemented and evaluated by the research team. The surveys focus on consumer behavior and especially on treatment of textile garments during laundry care in private households. In one survey, for example, consumer knowledge and behavior concerning the care of functional wear and outdoor clothing was analyzed.

2.1. Research component: simulation and experimental work

An important part of the interdisciplinary research program focuses on the simulation of the entire washing process by computer to enable the development of environmentally friendly washing machines. Those should need less water while achieving the same hygienic washing results at very low temperatures. So far the development of washing machines has depended primarily on prior physical testing. Process prediction on the basis of validated results from simulations is a new approach. Mathematical modeling and simulation of laundry movement in the rotating drum is a first step in that direction.

A transparent washing machine was designed and developed in 2012. The transparent washing machine is used for observing movement of laundry items and water in the drum in three dimensions, also for the purposes of validating the simulation. Movement is recorded with video cameras and the mode of motion is evaluated by analyzing the videos. As the project proceeds, the transparent machine will be developed further and a sensor-based method for tracking the motion of the laundry items will be added and evaluated.

2.2. Research component: physical textile testing

To develop a mathematical model and a simulation of the laundry movement in the rotating drum the material parameters of the laundry must be clearly described. First, the parameters having an impact on the rheological behavior of two specific textiles were evaluated. The physical textile testing of textiles in the laboratory can deliver material parameters such as the type of fiber and fiber composition, the thread construction, the construction of the fabric, the design of the garment or the type of seams. In accordance with DIN EN 60456, primarily woven cotton towels and bed sheets were tested. Other textiles that represent typical textiles will be defined and tested as the project proceeds. The tests include, for example, mass per unit area (DIN EN 12127:1997), thickness (DIN EN ISO 5084:1996), tensile strength (DIN EN ISO 13934–1:1999), bending rigidity (DIN 53362:2003), fabric drape (DIN EN 54306:1979) and water absorption capacity (DIN 53923:1978).

The tests were made in the physical textile testing labs of HTW Berlin University of Applied Sciences under standardized testing conditions. Depending on the test equipment and the technical execution, tests were made in three clearly defined textile conditions: dry, damp and wet. An individual method for humidification and watering of the textile samples was developed referring to DIN

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