Frederik Scheid, Edith Lambert, Writi Maitra, Marina Niestrath, Daniel Fäh, Christian Portmann, Susanne Gorny and Rainer Stamminger

Textile Quality Depletion due to Household Machine Wash – Ways to Measure and Impacts of Wash Duration and Temperature on Textiles

Washing machines should not only deliver good removal of stains, but also take care of the garments. Mechanical action produced by the washing machine has a twofold impact: It supports the removal of stains, but it also influences the structure of the textiles negatively and is, therefore, critical to textile care. Most washing machines are currently assessed by consumer organisations and political regulations, such as energy labelling, just for their washing properties. However, a long programme may provide a good washing performance, but might also damage the textiles more than a shorter programme. Test specimens assessing the mechanical impact are well known and published, for example, IEC PAS 62473:2007, however, they are rarely used. Reasons may be poor knowledge about their effectiveness in assessing the mechanical action and their reaction to different washing conditions, for example, load size, temperature and duration of the washing programme. It was the task of this study to verify this relationship and confirm that the thread removal fabric, as specified in IEC PAS 62473:2007, adds additional information to the assessment of a washing process. As a result of a wide variation of washing parameters, it could be shown that this test fabric is almost independent of the washing temperature, but shows a clear correlation with the load size and the length of the washing process. The thread removal specimens add valuable additional information concerning a relevant parameter of the washing process.

Key words: Textile damage, IEC PAS 62473:2007, washing parameters, test fabric, household machine wash

Abnahme der Textilqualität durch Waschen im Haushaltsmaschinen – Möglichkeiten, den Einfluss von Waschdauer und Temperatur auf die Textilien zu messen. Die Schonung der gewaschenen Wäsche ist ein wichtiges Merkmal zur Beurteilung eines Waschprozesses. Durch die Bewegung der Wäsche in der Waschtrommel wird nicht nur die zur Reinigung notwendige mechanische Bewegung erzeugt, sondern auch eine Beeinflussung der Struktur der Gewebe und damit eine mögliche Wäscheschädigung. Diese wird bei den üblichen Untersuchungen der Verbraucherschutzorganisationen, als auch bei der Bewertung von Waschmaschinen nach der Energieverbrauchskennzeichnung außer acht gelassen. Energieeffiziente lange Waschprogramme könnten durchaus eine relevant stärkere Schädigung der Wäsche erzeugen als Kurzprogramme. Möglichkeiten zur Untersuchung der Wäscheschädigung sind spätestens seit Veröffentlichung der IEC PAS 62473:2007 international bekannt, werden aber nur selten eingesetzt. Der Grund dafür könnte in mangelnder Erfahrung im Einsatz dieser Spezifikation oder auch in der Sensitivität der darin spezifizierten Testmaterialien auf die verschiedenen Waschparameter wie Zeit, Temperatur, Beladung, etc. liegen. Es war daher Aufgabe, dieses Informationsdefizit zu beheben und zu überprüfen, ob der Einsatz der in IEC PAS 62473:2007 definierten Testgewebe eine zusätzliche wichtige Information zur Bewertung eines Waschprogrammes liefert. Als Ergebnis konnte gezeigt werden, dass das eingesetzte Testmaterial praktisch unabhängig von der Waschtemperatur eine gute Differenzierung von Ergebnissen hinsichtlich Waschdauer und Wäschebeladungsmenge erlaubt und dass die damit erhobenen Informationen weitgehend unabhängig sind von Ergebnissen der Schmutzentfernung.

Stichwörter: Textilschädigung, IEC PAS 62473:2007, Waschparameter, Testgewebe, Haushaltswaschmaschinenwäsche

1 Introduction

According to Sinner [1], the final result in cleaning laundry is influenced by four interdependent factors, represented in the Sinner Circle. If one factor is reduced, the loss must be compensated for by increasing one or more of the other factors to maintain the same level of washing performance. The four factors are:

- Chemical action: represents the action of an acid or alkaline detergent solution. The action is increased or decreased by the concentration of pure product in the solution (water + product)
- Mechanical action: This is the action of the washing machine, which generates friction and pressure. If no equipment is used, the person doing the cleaning is considered to provide mechanical action by rubbing
- Temperature: Heat is often used in cleaning activities. The elevated temperature supports the reaction process and weakens the binding forces of the soil to the fabric
- Time: Duration of the cleaning operations respectively the time that the mechanical and the chemical action is allowed to work on the textiles for stain removal

Water has been introduced by Stamminger [2] as a fifth factor to show its importance as an essential element in wet cleaning processes. Water acts as the agent to form the solution for the detergent, to transport the detergent and heat to the laundry, to provide mechanical forces on the soil particles via hydrodynamic flow resistance, to transport the released soils away from the fibres and to dilute the detergent solution during the rinsing process.

The Sinner Circle is represented graphically (Fig. 1) by a circle divided into four sections, each representing one of the four factors. The size of the sections may be different, depending on the contribution of the individual factor to the total cleaning result. Mechanical action is, therefore, one of the important factors needed to maintain a good washing performance. Mechanical action is different for different washing systems, like horizontal or vertical axis washing machines. Also within a particular washing system, relevant differences can be observed, depending on the mechanical structure of the drum, the paddles, the door of the machine and also the washing parameters. In this study, we concentrate only on one horizontal axis washing system.

However, the cleaning result is not the only parameter which is relevant for assessing the performance of a washing process for household and professional purposes [3–6]. Consumers also rate textile care as a top priority when asked about factors relevant for an automatic washing process [7, 8]. Quality depletion to the garments may also occur during the washing process in various way. This may be especially relevant for new washing machines, where the washing cycles are sometimes programmes which can take up to six and more hours [9, 10]. Specialised test protocols have been developed to assess the influence of the chemistry on the garments' mechanical strength [11, 12]. Mechanical action is a process which will also damage the garments. The effect of the mechanical action on the garments was tested over decades by the pigment removal of soiled fabric, e.g. carbon black, however, this value is not independent from the detergent dosage and the latter's management in a washing system. Therefore, there was a need to develop a test procedure which only shows the influence of the mechanical action. This is because mechanical action is one of the main factors effecting both washing performance and textile depletion.

The result was the development of so-called "thread removal fabric", which is specified in IEC/PAS 62473:2007 [13] (see also clause on "Gentleness of action evaluation" in chapter Materials and Methods") and was tested in some round robin tests by the International Electrotechnical Commission (IEC), Technical committee SC59D 'Performance of household and similar electrical laundry appliances' . A clear correlation between the damage of real washed garments and the results of the thread removal fabric was shown in a diploma thesis [14]. The Pareto Chart (Fig. 2) shows the standardised effect of the thread removal fabric.

However, those data are not fully disclosed and not performed under washing conditions of today. There are no systematic data of the gentleness of action of a washing machine as measured with a thread removal fabric compared with the washing factors time, temperature, detergent and load as relevant for the washing performance according to

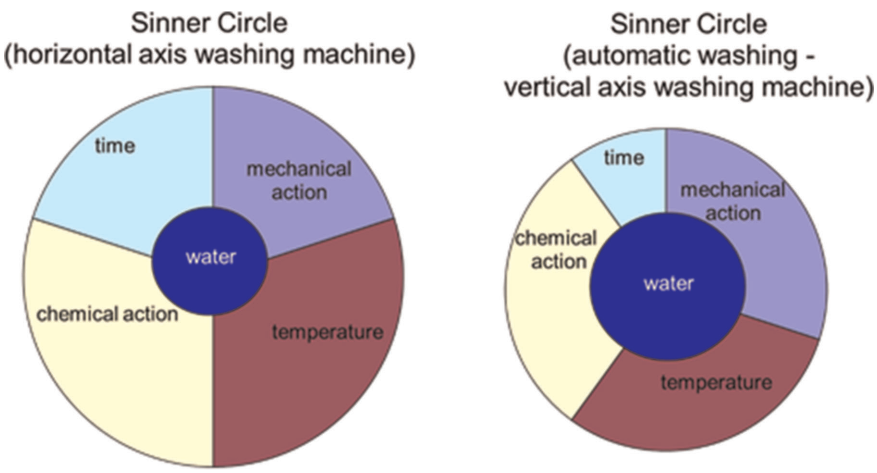

Figure 1 Sinner Circle depicting the relative influence of time, temperature, chemistry, detergent and water on the washing result; here for comparison of horizontal and vertical axis washing machines [2]

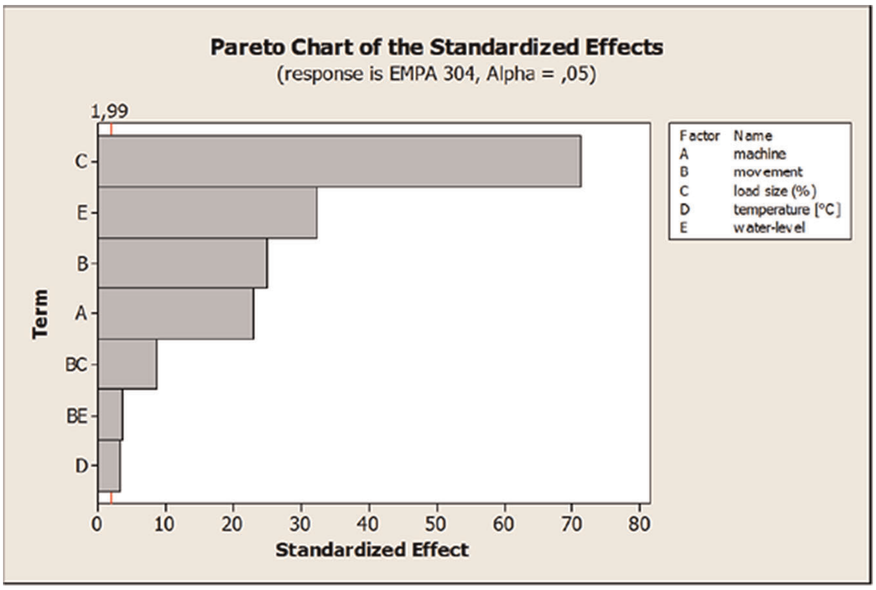

Figure 2 Pareto Chart of the standardised effects [14] (EMPA 304 is the old name of the thread removal fabric)

Sinner. It was, therefore, the task of this study to verify the relationship of the gentleness of action of a washing machine as measured with a thread removal fabric compared with the washing factors time, temperature, detergent and load and to confirm that the thread removal fabric adds additional information to the assessment of a washing process.

2 Materials and Methods

2.1 Experimental design

The tested parameters were: water temperature, washing time and load size (half = 4 kg, full = 8 kg load; tolerance: ± 60 g). Overall, the test design consisted out of 40 test series, where all parameter variations were conducted. The test series were conducted in a randomly defined order, three times in consecutive.

2.2 Materials and test conditions

The reference detergent A* and a cotton base load were used, following the IEC 60456:2010 methodology. The reference and neutralization washing were carried out in a defined programme (IEC 60456, cotton 60 °C) and in a reference machine (Wascator FOM71 CLS, Electrolux). Reference washing was performed five times. Normalisation washing was carried out prior to and after every five cycles. Prior to each test series, the cotton base load was conditioned at 20 ± 2 °C and a relative humidity of 65 ± 5 %, following IEC 60456: 2010 [15].

Testing conditions, such as ambient and water temperatures, water pressure, water hardness, power supply voltage and frequency were also in accordance with IEC 60456: 2010. Four pieces of thread removal material, as defined in the PAS 62473:2007, were added to the base load to measure the gentleness of action. Two different test strips were used as an indicator of the washing performance (see [16]). Two of each strip type were used for half-load experiments and four of each strip type were used for full load experiments. While the test strips had additional stains, the test strips' attaching to and removing from the test load and the subsequent drying and ironing were in accordance with IEC 60456:2010.

The experiments were carried out in two identical washing machines (Miele W 5000 Supertronic, maximum capacity of 8 kg cotton) using a specially designed wash cycle. The wash cycle consisted of four steps. First step: heating up to the targeted nominal washing temperature (variable duration, depending on the temperature: 3 – 20 min); second step: washing at the targeted nominal washing temperature (25, 35, 45 or 55 °C) for specified washing times (60, 120, 180, 240 or 300 min) where the temperature is kept (almost) constant by allowing a reheating of the suds; third step: two rinsing cycles and fourth step: spinning for all experiments (third and fourth steps are considered to be not temperature-dependent). All wash cycle steps had equally defined drum movements as normally used for cotton wash. The actual washing temperatures that are reached inside the cotton load were tracked by four (for half load) or five (full load) temperature loggers (TELID 311, microsensys GmbH), which were sewn into different cotton towels. The maximum average temperatures measured inside the load were found to be about 2 K lower than the nominal washing temperatures.

2.3 Evaluation of washing performance

Washing performance was assessed according to IEC 60456: 2010 via tristimulus Y reflectance measurements performed twice on both sides of every stained piece of all the test strips. Only the front side of the stain pieces with lipstick was measured. The average of the four readings per stain was calculated. Subsequently, the average value for each stain type of all repetitions and the related standard deviation was calculated. More details can be found in [16].

2.4 Gentleness of action evaluation

Gentleness of action was measured as thread removal of a special thread removal specimen of 499 × 499 threads, as defined in PAS 62473:2007. The thread removal material is a plain woven fabric with an open structure on all sides allowing loosening of threads by mechanical impact (Fig. 3). This material is available as article 304 from Swissatest Testmaterialien AG. Depending on the strength of mechanical agitation, a certain number of threads will be lost during the wash cycle on each of the four thread removal specimens added to the wash load. After washing, the thread removal material is carefully removed from the load, taking care not to pull, stretch or distort the test specimens. The mechanical action test specimens are dried by laying them out flat, and care is taken not to apply any further mechanical action. The evaluation of the thread removal specimen is carried out by counting the threads removed (considered as "not remain-

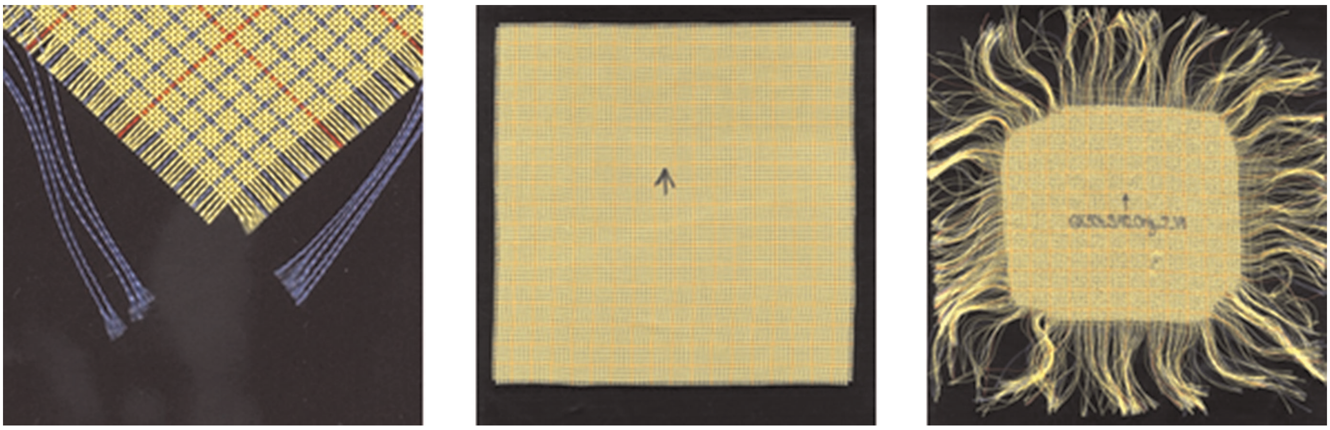

Figure 3 Thread removal fabric (article 304 Swissatest Testmaterialien AG) shown in detail (left) and as a whole test swatch before (middle) and after (right washing)

ing") and is expressed as total lost area in %, according to PAS 62473:2007.

3 Results and Discussion

The total lost area in % for each of the three cycles of one test series was calculated as the arithmetic mean value of the total lost area in % for the four test specimens used in each test cycle. The total lost area in % for each test series of the 40 different test series with varied load size, washing temperature and washing time was calculated out of those single arithmetic mean values of the three consecutive cycles. Results of the total lost area in % for each test series are shown in Fig. 4 for the load size of 4 kg (half load) and in Fig. 5 for the load size of 8 kg (full load conditions). Error bars show the standard deviation calculated from those three repetitions. Some results, which have not followed the trend, may be regarded as statistical outliers.

For both load sizes, there is a clear and visible trend of the increase of the total lost area in % with increasing washing times. Also, a relevant influence of the load size on the absolute value of the total lost area in % can be observed: For the half load the highest value of the total lost area in % goes up to 35 and for the full load the highest value of the total lost area in % stays closely to 20. This clearly shows that with a reduced load the mechanical action in a washing machine on the load is considerably increasing. This is best illustrated by comparing the total lost area for a full load at the maximum washing time of 300 min (equals 5 h!) and 55 °C wash temperature with the total lost area for a half-load and only 60 min washing time at 25 °C: both are equal (approximately 17,5 %). This means that the size of the textile load has much higher influence on the gentleness of action inside the load than the washing and programme duration. The total lost area measured in the reference machine with a large drum (about 80 litres) with 5 kg of load produces 24.96 % total lost area with a standard deviation of 0.74 %.

Data in Fig. 4 and Fig. 5 also show some tendency of higher total lost areas with increasing temperature. To verify if this is actually an effect of the increased temperature, one has to consider that there are additional times during the execution of a programme when the load is tumbled in the

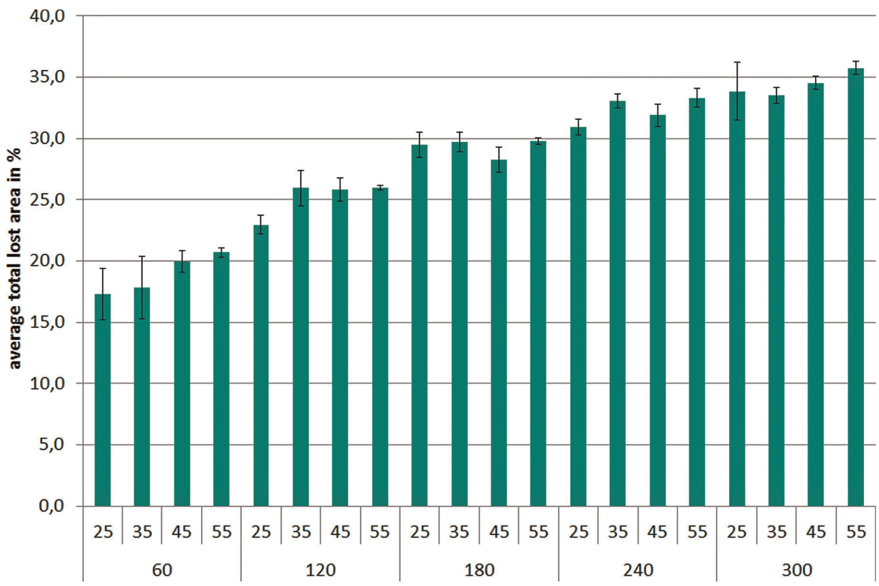

Figure 4 Average total lost area for washing with half-load. On x-axes: upper figure: nominal temperature; lower figure: active washing time at temperature

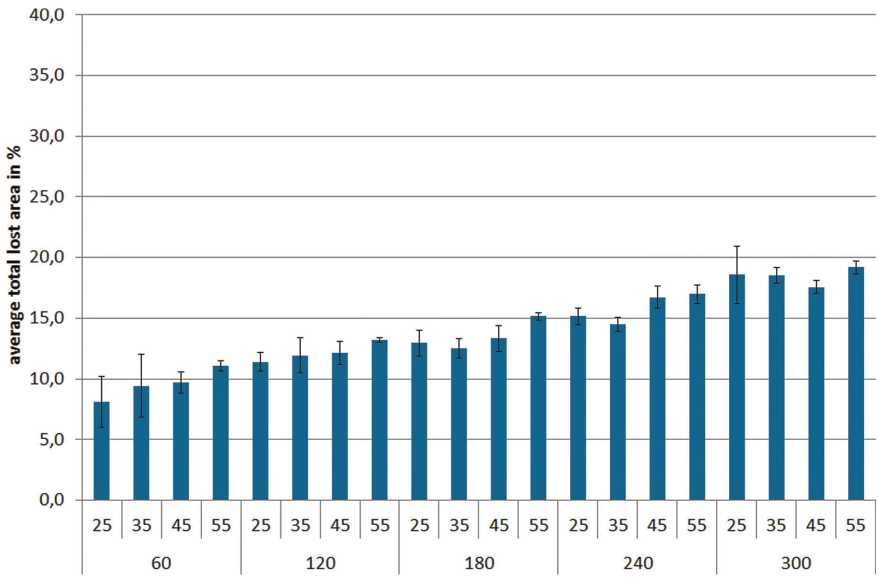

Figure 5 Average total lost area for washing with full load. On x-axes: upper figure: nominal temperature; lower figure: active washing time at temperature

suds, for example, during the first (heating-up) and during the third phase (rinsing). While the third phase is considered to be independent of temperature, the first one is longer the higher the washing temperature is. Table 1 summarises the average time it takes to reach the washing temperature depending on the temperature and the load size. The rinsing cycles were measured to last for 1 306 s for a full load and for 1 403 s for a half-load. Therefore, besides the tumbling of the load during the washing step (second step) there is an additional time of approximately one hour where the load is tumbled in the suds and thus mechanical action is working on the garments. Considering these additional tumbling times, it is obvious that the total lost area for higher temperatures is higher than for lower temperatures with the same washing time. Figure 6 shows the correlation of the total lost area versus the total tumbling time in the suds for all possible variations of water temperature and load size and also includes the trend-lines for full and half load. Both reflect all the individually measured data well considering the goodness of the fit ($R^2 = 0.94$ for full load and $R^2 = 0.93$ for half-load) and the average standard deviation of 1.4% total lost area of the data. The visible increase of the total lost area with increasing temperature may thus be explained by the prolongation of the washing time at a higher temperature.

The steepness of the trend lines also allows one to calculate a general statement about the effect of tumbling the load in the washing machine: for a fully loaded machine, the total lost area increases by a factor of 0.036% per minute of tumbling in the suds, while for a half-load, this factor is 0.064% per minute. Assuming a linear relationship between the total lost area factor and the load size, one may speculate that for a (almost) zero load, this factor would be (0.064 + 0.028) 0.092% total lost area per minute tumbling.

T/°C	Half-load/s	Full load/s
25	257	164
35	357	318
45	624	614
55	972	1172

Table 1 Heating-up times for full and half-load at various nominal temperatures

Another interesting aspect is, if the total lost area as measured with the thread removal specimens, is replicating information, which is already assessed by any of the test strips used for measuring the soil removal. To verify this aspect the correlation of the total lost area of the thread removal specimen to cleaning parameters of the test strips has been analysed (Fig. 7).

The highest correlation of the reflectance values to the total lost area is achieved for the cacao stain (Fig. 7) with a coefficient of correlation (R^2) of 0.5628, showing that cacao stain has some sensitivity to mechanical action. The correlation is smaller for sebum and carbon black stains, which are also supposed to be sensitive to mechanical action, with $R^2 = 0.3953$ and 0.4288, respectively. The correlation coefficients for all other stains are even smaller.

Thus, in conclusion, the thread removal specimens add valuable additional information about the gentleness of action as a relevant parameter of the washing process.

4 Conclusion and Outlook

The test series performed intended to verify that thread removal specimens are sensitive to differentiate between relevant conditions in a washing machine and that their usage gains important additional information on the washing performance of a test program or test machine.

The results observed verified the initial expectations and former experiences of longer program durations and smaller load sizes increasing the mechanical damage on the wash load and deliver absolute numbers for these effects. This is best illustrated by the observation that the total lost area in case of a full load wash at the maximum washing time of 5 h is almost the same as that in case of a half-load wash with only 1 hour washing time.

The tests also verified that the thread removal test specimen is a useful method for differentiating the gentleness of action of different wash programs or washing machines. Considering the range of measured values for the total lost area in % (between 8 and 36) and comparing this to the average standard deviation of the measurement of 1.4% total lost area shows that the thread removal test specimen is able to differentiate 20 ((36-8)/1.4 = 20) classes separated by one

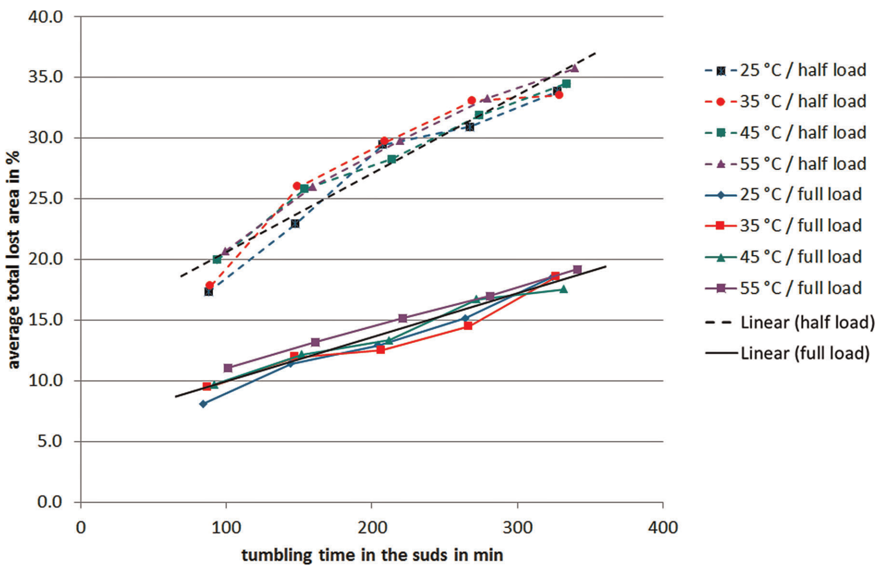

Figure 6 Average total lost area in % for all conditions versus the real tumbling time in the suds (lines are for visualisation only). Linear trend lines included for full and half-load conditions

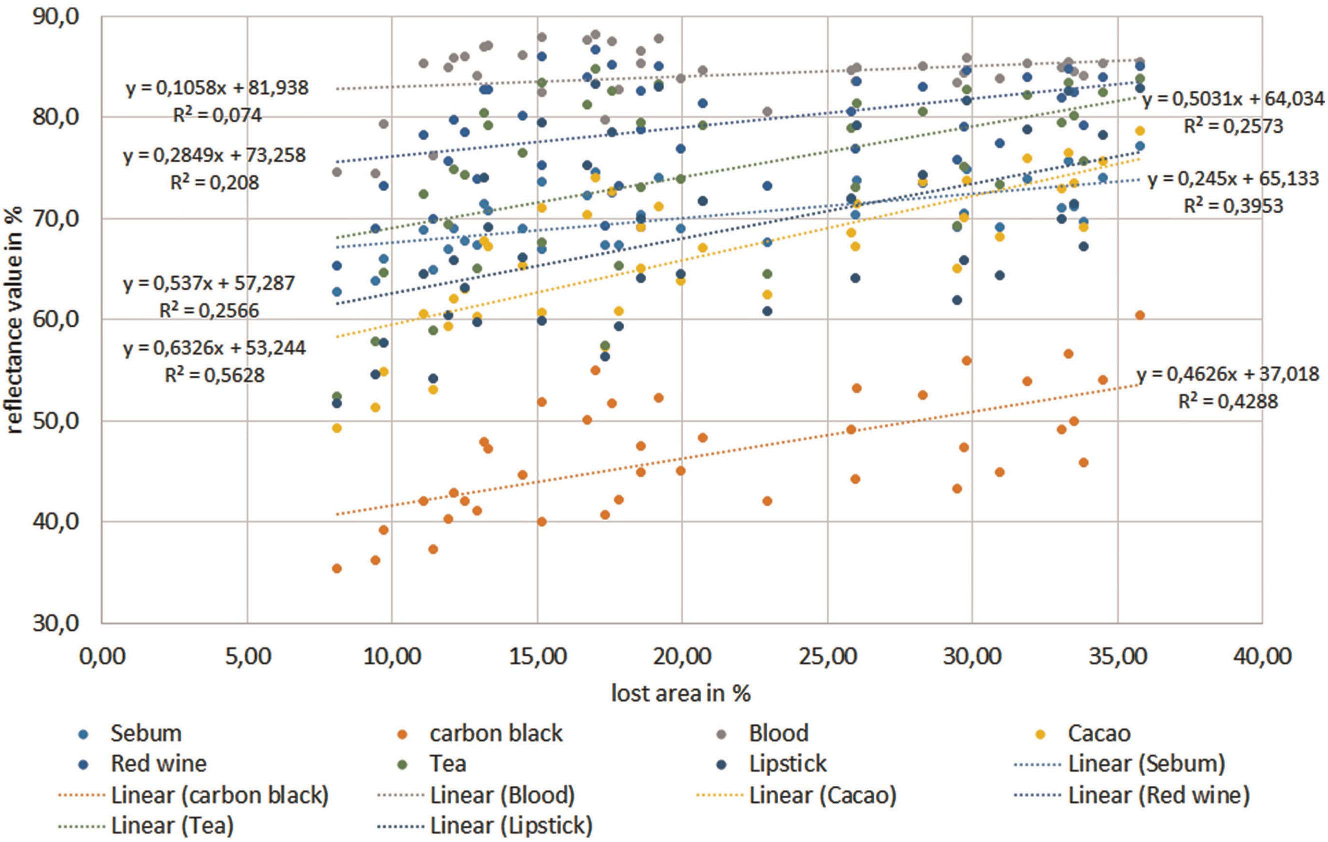

Figure 7 Correlation of reflectance values for washing performance of various stains versus total lost area of the thread removal specimens

standard deviation. This differentiation allows a better comparison of the gentleness of action than what is known so far for differentiating power of stained test swatches ([16]). The test results also revealed that the water temperature of the wash cycle has only minor influence on the total lost area in % and consequently on the quality depletion of textile during automatic laundry washing.

Analysing the correlation of the total lost area in % of the thread removal specimen to the reflectance values in % of the stained test swatches indicating the washing performance showed that none of the test stains delivers similar results. Thus, the thread removal specimens add valuable additional information for assessing and comparing a washing process.

However, it must be noted that the results achieved are only relevant for this particular type of washing machine used for the tests. In case of other washing machines, which may have different ways of tumbling or different load to volume ratios, such results may vary. Also, the material and the surface design of the machine drum might have some influence on the quality depletion of the textile. However, it is believed that the results of the impact of washing conditions on the gentleness of action could be somehow generalised for all kind of horizontal axis washing machines. This would allow conclusions to be drawn for the general usage of the washing machine: It is of major importance to wash with a fully loaded drum to avoid quality depletion to the textiles. Long washing times do not harm the textiles in a similar way to washing with small loads.

This conclusion may provide an argument to a very different assessment of the washing performance of washing machines: Garments are resource intensive goods during their production phase [17]. A life cycle analysis considering the production and lifetime of the garments, together with resources needed for washing may perhaps find that short washing times at high temperatures are overall more sustainable as what is considered today as the best environmental washing process (long washing times at low temperatures a la Sinner).

However, the results presented must be seen as a first step. They need to be replicated with other washing machines. In addition, other parameters which assess the mechanical effects on the garments may need to be investigated to ascertain whether they delivery similar or complementary information.

Acknowledgements

The authors want to thank Swissatest Testmaterialien AG, wfk Testgewebe GmbH and Miele & Cie. KG for providing test materials and machines for this test.

References

1. *Sinner, H*: Über das Waschen mit Haushaltwaschmaschinen: in welchem Umfange erleichtern Haushaltwaschmaschinen und -geraete das Waeschehaben im Haushalt? In.: Haus und Heim-Verlag, Hamburg; 1960.
2. *Stamminger, R*: Reinigen. In: Lebensmittelverarbeitung im Haushalt. Edited by Gomm U. LW, vol. 1. Bonn: aid infodienst; (2010) 28.
3. *Schambil, F., Buchmeier, W., Glüsen, B., Bohnen, J., Hloch, H. G.* and *Ophüls A.*: Will Detergents Disappear ? An Evaluation of Alternative Wash Technologies. SOFW Journal 2009, 6.
4. *Lodewick, R., Krijnen, E. S., Chevalier, O., Schambil, F., Nickel, D., Crestana, A.* and *Spadoni, L*: Minimum Protocol for Comparative Detergent Performance Testing "Detergent Testing" AISE Working Group. Tenside Surfactants Detergents *49(1)* (2012) 57–60. DOI:10.3139/113.110167
5. *Fijan, S., Turk, S. S., Neral, B.* and *Pusic, T.*: The influence of industrial laundering of hospital textiles on the properties of cotton fabrics. Textile Research Journal *77(4)* (2007) 247–255. DOI:10.1177/0040517507077476

6. *Hloch, H. G.* and *Bohnen, J.*: Sustainability in Industrial Laundering. Tenside Surfactants Detergents *46(1)* (2009) 48 – 52. DOI:10.3139/113.110007
7. *Laitala, K.* and *Jensen, H. M.*: Cleaning Effect of Household Laundry Detergents at Low Temperatures. Tenside Surfactants Detergents *47(6)* (2010) 413 – 420. DOI:10.3139/113.110096
8. *Kruschwitz, A., Karle, A., Schmitz, A.* and *Stamminger, R.*: Consumer laundry practices in Germany. International Journal of Consumer Studies *38(3)* (2014) 65 – 277. DOI:10.1111/ijcs.12091
9. *Schmitz, A.* and *Stamminger, R.*: Washing Machines in Europe – Detailed Assessment of Consumption and Performance. Tenside Surfactants Detergents – Journal *53(1)* (2016) 16.
10. *Schmitz, A., Alborzi, F.* and *Stamminger, R.*: Large Washing Machines are not used Efficiently in Europe, Tenside Surfactants Detergents *3* (2016) 227 – 234. DOI:10.3139/113.110427
11. *Luijkx, G. C. A., Hild, R., Krijnen, E. S., Lodewick, R., Rechenbach, T., Reinhardt, G.* and *Phillips, D. A. S*: A protocol to examine the colour damage profile of bleach containing detergents. Tenside Surfactants Detergents *41(4)* (2004) 156 – 162. DOI:10.3139/113.100218
12. *Luijkx, G. C. A., Hild, R., Krijnen, E. S., Lodewick, R., Rechenbach, T.* and *Reinhardt, G.*: Testing of the fabric damage properties of bleach containing detergents. Tenside Surfactants Detergents *41(4)* (2004) 164 – 168. DOI:10.3139/113.100219
13. IEC PAS 62473:2007 – Clothes washing machines for household use – Methods for measuring the mechanical action in household washing.
14. *Lovrek, L.*: Vergleichende Untersuchung bestehender und neuer Prüfmethoden zur Ermittlung der mechanischen Beanspruchung von Textilien während des Waschprozesses in Haushaltswaschmaschinen, Diplomarbeit Bauknecht Hausgeräte GmbH, Schorndorf, 2009.
15. IEC 60456:2010, Edition 5.0 (2010), Clothes washing machines for household use – Methods for measuring the performance.
16. *Lambert, E., Writi, M., Scheid, F., Niestrath, M., Gorny, S.* and *Stamminger, R.*: Differentiated evaluation of washing performance in washing machines of test stain strips as a function of temperature, washing duration and load size. Tenside Surfactants Detergents *5* (2016).
17. *Sandin, G., Peters, G. M.* and *Svanstrom, M.*: Moving down the cause-effect chain of water and land use impacts: An LCA case study of textile fibres. Resources Conservation and Recycling *73* (2013) 104 – 113. DOI:10.1016/j.resconrec.2013.01.020

Received: 09. 04. 2016
Revised: 30. 05. 2016

Bibliography

DOI 10.3139/113.110462
Tenside Surf. Det.
53 (2016) 5; page 438 – 444

ISSN 0932-3414

Correspondence address

Prof. Dr. Rainer Stamminger
University of Bonn
Institute of Agricultural Engineering
Household and Appliance Technology Section
Nussallee 5
53115 Bonn
Germany
Tel.: 0049-228-735955
Fax: 0049-228-732596
E-Mail: haushaltstechnik@uni-bonn.de

The authors of this paper

Frederik Scheid has studied nutrition and food science at the University Bonn, Germany and has made his bachelor degree thesis on the subject of this paper.

Edith Lambert, University of Bonn, has a diploma in nutrition and household science. She works as research assistant at the university of Bonn in the household and Appliance TechnologySection in different research areas with focus on laundry washing and the applicability of NIRS in household technology.

Writi Maitra, Research Assistant, Household and Appliance Technology Section, University of Bonn. She completed Masters in Food Business and Consumer Studies at University of Kassel, Germany. Since 2013, she has worked in research study on consumer behavior of dishwashing practices in different international economies in collaboration with one of the leading European FMCG companies.

Marina Niestrath, University of Bonn, has an apprenticeship as a technical assistant for laboratory. Since 2004 she works as technical assistant at the University of Bonn in the Household and Appliance Technology Section. She is experienced in testing behaviour of household appliances in different research areas, mainly in testing washing machines.

Daniel Fäh, Swissatest Testmaterialien AG, holds a master degree in textile engineering (1984) and a master degree in chemical engineering (1990). He is founder and CEO of Swissatest Testmaterialien AG, a "spin-off" of EMPA (Eidgenössische Material und Prüfanstalt, Swizzerland). He has published several articles in the field of "biofilms" and "hygiene". He is member of international standardisation bodies as: IS0, CEN, IEC, AHAM, VDA.

Christian Portmann, Swissatest Testmaterialien AG, holds a master degree in textile engineering (1987). After several years in the textile business in different functions. He works since 2011 at Swissatest Testmaterialien AG and is responsible for quality and technical questions. He is a member of ISO and VDA.

Susanne Gorny finished her doctorate at the Household and Appliance Technology Section at the University of Bonn in 2014. In her doctoral thesis, she modelled the cleaning performance and energy consumption of an electric household dishwashing system and describes the potentials and impacts of low-temperature electric household dishwashing. Currently, Susanne Gorny is working as manager of the quality testing laboratory for electric household appliances and personal care products at TÜV Rheinland LGA Products GmbH.

Rainer Stamminger, University of Bonn.After 17 years of practical experience in the development of washing machines and dishwasher with AEG Hausgeräte, Germany Rainer Stamminger was promoted in 2002 as professor for appliance and process engineering at University of Bonn. Main areas of research at University are consumer behaviour of homework with and without using appliances, new products or features, smart appliances, robots for household application and questions of sustainability of housekeeping.