ABSTRACT

Concern for the environment is a major driver in the present day technological developments. With pressure building globally for consumers, to cut down both on water usage and greenhouse emissions, the time is right to develop sustainable textile cleaning system which will help reduce the environmental impact of washing without compromising the cleaning efficiency. From the consumers point of view these new technologies should be compatible with the existing laundry practices and are both user and fabric friendly. Currently available methods of cleaning highly soiled areas of apparel are labor intensive, harsh on the fabric and not necessarily environment friendly. These involve use of strong chemicals, enhancement in agitation like brushing of soiled areas or washing at high rotor speed for longer durations at higher temperatures. This affects the appearance and serviceable life of the garment, negatively. Use of high frequency sound waves or ultrasonic offers an effective and fiber gentle alternative.

In the present work, an effort was made to use ultrasonic energy as an alternative to mechanical agitation to enhance laundry process effectiveness and thereby efficaciously clean heavily soiled areas of the garment. The cleaning action of ultrasonic energy is mainly due to the phenomenon of cavitation which is the nucleation, growth and collapse of small gas or vapor bubbles inside the cleaning liquid and near the surface to be cleaned. This is responsible for laundry process intensification by enhancement in mass transfer in textiles. The washing process parameters were optimized for ultrasonic washing in terms of type and concentration of detergent, time and temperature. Effect of this optimized ultrasonic washing method on fabric properties as well as appearance was studied and compared to conventional washing method with reference to repeated soiling and washing. To meet the specific requirement of cleaning highly soiled apparel, factors affecting system efficiency were studied. The relationship between the cleaning behavior and the operating parameters was studied, to facilitate conceptualization of design parameters for the ultrasonic garment cleaning prototype. After standardization of running parameters for the fabricated prototype its cleaning efficacy was established. The prototype was field tested at a commercial laundry to assess its commercial and technical feasibility. Further, the efficacy of ultrasonic cleaning mechanism on various kinds of soils and stains as well as on different textile substrates particularly delicate fabrics was studied.
Washing process parameters were optimized for ultrasonic washing and the impact of optimized conditions on textile, environment, economic efficiency and process effectiveness was considered. The final outcome was either comparable or an improvement upon the presently prevalent conventional method. Optimal integration of factors of cleaning in concert with ultrasonic agitation led to enhancement in cleaning efficiency. Ultrasound waves provided the mechanical agitation which expedited the cleaning process; reduced the amount of cleaning chemical required (3g/l) to achieve the same level of cleaning at lower temperature (40°C). Its use in washing apparel in a fabric friendly manner compared to conventional method was affirmed. No additional damage to fabric was observed in terms of appearance or service properties with use of ultrasonic energy after repeated washings. Scanning Electron Micrographs revealed natural fiber structure and no damage to fibers due to phenomenon of cavitation was observed.

Characterization of parameters related to acoustics, machine and wash process helped in integration of operational, structural and design parameter requirements. These findings were collated and this information combined with empirical industry knowledge and equipment available helped in development of ultrasonic garment cleaning prototype. Operational considerations such as suitable frequency (40 kHz) and power (500W) along with structural requirements like configuration and dimensioning of the ultrasonic bath and selection of suitable work fixtures were suitably met. The prototype was assembled using specially fabricated components imported from Penang, Malaysia and indigenously fabricated tank and special work fixtures. Improvement in cleaning efficiency with this ultrasonic garment cleaning prototype over the previous fabrication and conventional method was noted.

Efficacy of this prototype both in laboratory conditions as well as in dynamic commercial set up was established. Economic viability of using the prototype was confirmed by computing cost of operation of this system vis-à-vis prevailing practices in a commercial laundry. Ultrasonic washing was found effective in cleaning various substrates, stains and soils. Cleaning was comparable to conventional methods under milder optimized conditions of ultrasonic washing and better under prescribed conditions of standard methods. Thus, ultrasonic washing was found to be an effective and fiber friendly alternative to existing practice of brushing to clean highly soiled areas in apparel. Its gentler cleaning action under milder washing conditions can be further explored for cleaning fabrics with surface textures, such as embroidered/embossed fabrics, embellishments, accessories etc. Its use as an eco-friendly alternative to dry cleaning can also be investigated.