How Well Do You Know Your Washing Machine?

Swapan Kumar Dutta

The influence of science in daily life is undeniable. Science has made all our daily activities much easier, safer, faster, and wherever applicable, energy and water efficient too. However, often we are not aware enough to apply the science for our full benefit.

For instance, “effective” washing of clothes, where “effective” has been used to mean efficient and economic cleaning with high detergent, water & energy efficiency; complete removal of dirt and alkaline water from the clothes, and minimum damage to the fabric.

The washing machine is an important modern household appliance. However, the right application of knowledge in science is necessary for selection of a good machine at the buying stage, and the choice of a suitable program for operation. Understanding the principles involved will assist us in making a wiser choice.

Let us take a look at the general procedure followed in washing. First, the laundry items are sorted out according to the type of clothes, the level of dirt and other factors for increasing the washing efficiency. Depending on the batch under process, detergent type & quantity are determined; the choice of which are important for general health of the fabric. The clothes are now soaked in an optimum quantity of warm/cold water-detergent solution for an optimum amount of time. Time is required for the detergent solution to wet the surface completely, to penetrate into the interior surface of the fibres, and then to surround the oily and or dirty particles which are to be separated.

Now dirt, loosened from the fabric surface, is to be removed in the successive steps of washing. They need to be de-touched and separated from the surface of clothes slowly by splashing, scrubbing and or agitation. This is the ‘First Phase’ of washing.

The next steps of removing the adsorbed detergent or de-touched and separated dirt, and alkaline water completely from the direct contact of the fabric by rinsing constitute the ‘Second Phase’ of washing – here the clothes are treated with an optimum quantity of clean water and the whole mass is well agitated for an optimum amount of time. The dirty & alkaline water separated, is then drained out before a fresh optimum quantity of water is added again to the same batch to repeat the operation.

Drawing analogy and using the same concept of extraction, the effect of the variables are further discussed below. At every step instinctive judgements (though difficult) can be made while hand-washing the garments; always taking care to use the right quantity of water during the whole procedure. For machine wash, however, we need to select variables and a suitable program, provided on the machine as a best guess by the design engineer.

To understand better the scientific principle of detergent action and rinsing, let us familiarise ourselves with a few scientific terms, namely, surface tension, interfacial tension,
Surfactants, colloids, suspensions, emulsions, etc.

Surface tension, the contractive tendency of the surface of a liquid, is measured as the energy needed to increase the surface area of a liquid by unit area. This property resists distortion at its surfaces between the liquid and air or the liquid and its vapour.

Instead of the saturated vapour or air, when both the phases constitute liquids, then their boundary of separation is known as interface, and the tension at the interface is known as interfacial tension. Addition of a detergent or surfactant in water or water solution reduces both the surface tension and the interfacial tension, facilitating washing action, by enabling them to permeate the surface at all possible locations of the fabric.

Surfactants or surface active agents have the capacity to allow easier spreading, and to lower the interfacial tension between two liquids. Synthetic detergents are defined as a group of synthetic organic chemicals (not prepared from fats & oils), having cleaning power similar to or better than that of soap, and having properties of wetting agents and emulsifying agents. Synthetic detergents, unlike soaps forming insoluble compounds or “curds” complicating the cleaning process, form products which are either soluble or remain dispersed in colloidal form in hard water. So, they are very easily washed out of the fabrics.

Particles, in the size range of $10^4$ to $10^7$ cm, form colloidal dispersion. Colloids may be classified as suspensions and emulsions. When a solid is dispersed in a liquid medium, it is called suspension. But when a liquid is dispersed in another liquid, it is called emulsion.

Each molecule of a cleaning solution (soap or detergent) may be considered as a long chain compound having two ends named as hydrophilic or water loving end, and hydrophobic or water hating or soil loving end. The hydrophobic ends of some of these molecules of the long chain compound are attracted to soil particles, and surround them. At the same time the hydrophilic ends of the detergent pull the molecules and soil particles away from the fabric, and transfer them into the wash water.

This action when combined with the agitating action of the whole mass, applied manually or mechanically through a washing machine, results in removal of the soil particles from the fabric surface. The detergent thus removes soil particles, suspends and keeps them away from re-deposition on the surface of the clothes. Agitation/mechanical action additionally helps in keeping them in suspension. This is the basic scientific principle of detergent action on the surface. The surface of clothes is then cleaned by rinse water in the “second phase” of washing.

Leaching or solid extraction may be defined as the preferential solution of one or more constituents of a solid mixture by contact with a liquid solvent. The term extraction is also widely used to describe this type of operation. Cleaning of dirty clothes during the “second phase” of washing has been assumed here to be similar in some respects to this unit operation of chemical engineering, with some differences too.

Temperature, another very important parameter of washing & cleaning, depends on the type of clothes under the process. Hot water itself acts as a detergent, as it has the power to dissolve dirt, grease, etc. Temperature helps in better cleaning because surface tension is reduced with increase in temperature. But temperature should not be too high to cause any harmful effect on the fabric.

In all naturally occurring processes, the rate of transfer is directly proportional to the driving force, and inversely proportional to the resistance. The driving force here is the difference in concentration or gradient. So, a higher concentration of detergent can increase the transfer rate of dirt from the surface of the fabric to the bulk solution, and hence can increase the cleaning effectiveness.

For selection of a washing machine, capacity vs. cost of the clothes washer, against the size of the family are the primary factors. Running a large machine with small load is not economical. A machine run in overloaded condition also cannot give the desired result, and hence should always be avoided.

Assuming analogous behaviour with extraction, washing efficiency is increased with optimum amount of water used in more number of stages, than more water in fewer stages. As many stages as desired may be used while balancing the time of operation in each stage and the differential amount of gain obtained at later stages. Better rinsing will preserve the new look of the fibre. Subject to fulfilment of the above conditions, detergent, water & energy efficiency will be higher.

Cleaning effectiveness is enhanced by use of multiple contacts because the clothes in each stage with already separated and drained-out dirty & alkaline water from the earlier stage can come in direct contact with fresh water. This results in increased driving force in each stage.

For machine washing, optimum quantity of water has been defined as the amount of water which will be just sufficient to immerse the laundry items in detergent-water solution inside the vessel, yet there will remain space for movement of the clothes for continuous exposure of newer surfaces. Conservation of water, saving water leads to saving more energy. A well designed machine may take care of all the important parameters. If the machine can be run under full-load condition, lesser number of runs of a larger machine will be more economic than more number of runs of a smaller machine.

Prof. Swapan Kr Dutta is former professor and head, Dept. of Chemical Engineering, National Institute of Technology, Durgapur. Address: Flat C-3, Akashdeep Co-Opt., Armstrong Avenue, Sector 2A, Bidhan Nagar, Durgapur-713212; Email: swapankrdutta@yahoo.com