The Physics of Washing Machines

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The cleaning performed in most consumer available front loading washing machines is a complex multi-phase and multi-scale process, involving a range of physical phenomena that affect mass transfer in textiles as they move and tumble during rotation of the drum, as well as the chemical actions of detergent mixtures resulting in soil loosening and suspension in the bulk liquid. Since the washing machines conception, a great deal of attention (Zoller, 2008; Lynn, 2000; Bacon and Smith, 1948) has been dedicated to classical parameters that are known (experimentally) to have a real impact on cleaning performance such as detergent concentration, wash time, water temperature and textile loading with little attention paid to developing an understanding of the nature and effects of the actual physical phenomena taking place. The modern washing machine is essentially treated as a 'black box', and the design and optimization of cleaning products used in these machines can only be realized through full-scale trials which are environmentally unfriendly and labour intensive.

By comparing the washing process to other well-researched chemical engineering unit processes, in which similar dynamic and mass transfer principles are at work, a theoretical framework of the possible mechanical cleaning mechanisms in the wash process was developed. Using this framework as a starting point, the wash process was then investigated using a series of experimental techniques:

1) PEPT (Positron Emission Particle Tracking), from which an understanding of the motion of textiles and its importance for mechanical cleaning was developed (MacNamara, 2012)

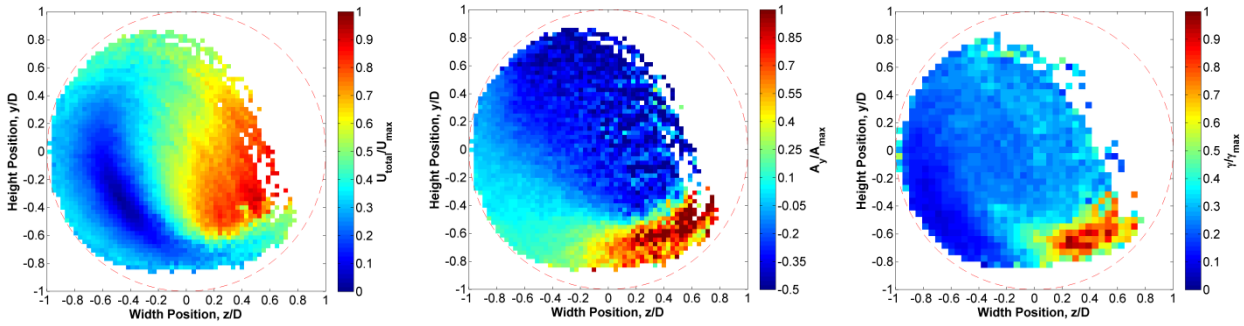

Figure 1 Time Averaged Velocities, Acceleration and Shear Rates of a PEPT particle attached to a textile as it is tumbled by clockwise rotation of the washing machine drum

2) Dimensional Analysis, through which the effect of changing drum geometry, wash conditions or ballast conditions on mechanical cleaning was understood

3) Motor Power Measurements, where the energy input into the wash process has been shown to correlate to the mechanical cleaning experienced by textiles

4) Decoupled Flow and Force Measurements, where several experimental rigs were developed in order to study the key physical mechanisms for mechanical cleaning separately from the wash process

First principles parametric modeling of the motion of textiles has also been carried out, based on the physical mechanisms identified in the PEPT studies, in order to be able to predict the energy available to textiles for mechanical cleaning for different drum geometries, wash conditions, etc.

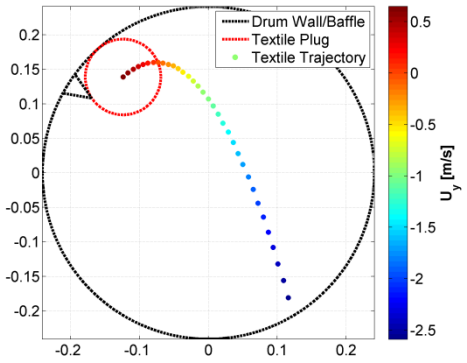

Figure 2 Parametric Modeling of a Tumbling Textile

The overall aim of this project is to develop this understanding of the physical mechanisms by which mass transfer is enhanced in the washing machine so that the future development of both washing machines and formulation of cleaning products can be carried out in tandem, essentially yielding an optimized process in which the interactions between process inputs and the process itself are known.

References

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