Characterization of flow and mixing of complex fluids in continuous processing equipment

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Fluid flow and mixing is an integral part of most industrial processes. Flow of fluids that differ in rheology, e.g. a Newtonian and a Herschel-Bulkley fluid, or cases involving flow of complex fluids (e.g. time dependent properties) through complex geometries, such as static mixers, are not as well understood despite the industrial benefit.

Typical cleaning formulations are a combination of either water or oil base with a range of additives, which are mixed into the product at different stages of the process, often using static mixers. In order to achieve the highest quality product a high degree of mixing is desired. However, as the fluids undergoing mixing rarely have the same rheological properties it is often hard to predict the degree of mixing achieved and the number of static mixer elements required to attain desired results

Therefore, the aim of the current work is to develop an approach that would allow characterising the flow of complex fluids in complex geometries to understand and predict the conditions of flow better. It is proposed that this can be achieved using a number of complementary techniques which are described below.

- Experimental characterisation of the flow using PEPT (Positron Emission Particle Tracking). This technique allows tracking the flow in opaque and obstructed systems, such as pipes and mixers.
- Development of mathematical models using commercially available software packages, such as COMSOL and Matlab.
- Optical changeover experiments using high speed cameras and stained fluids.

To investigate mixing, PEPT experiments have been carried out in a 1" pipe containing a 9 element 1" SMX static mixer. The experiments were run at various flowrates (200 and 300 l/h) and using a range of fluids with varying rheological properties, such as Guar gum (0.8% solution), CMC (carboxymethyl cellulose) (0.8% solution) and Glycerol. The concentrations were selected so that under the conditions of the flow the viscosity of all three fluids would be comparable. The data acquired through PEPT allows estimating a range of properties of the flow, such as local velocities, shear rates and time based occupancies [1]. Furthermore, it allows characterizing the mixing process by observing the path of the tracer particle. For example, Figure 1 shows a number of particle paths that originate at the same position at the mixer entrance and illustrates that regardless of the entry location towards the end of the static mixer the fluid gets dispersed across most of the pipe. This information can be useful when designing static mixer systems, allowing to pinpoint the minimum number of mixer elements required to achieve the desired levels of mixing.

Another issue that arises when processing fast moving consumer goods is the fact that a large number of products is manufactured from the same processing lines. Such processes commonly result in issues of changeover, where it is desirable to reduce the levels of mixing between the incoming fluid and the fluid that is being displaced, in order to reduce waste.

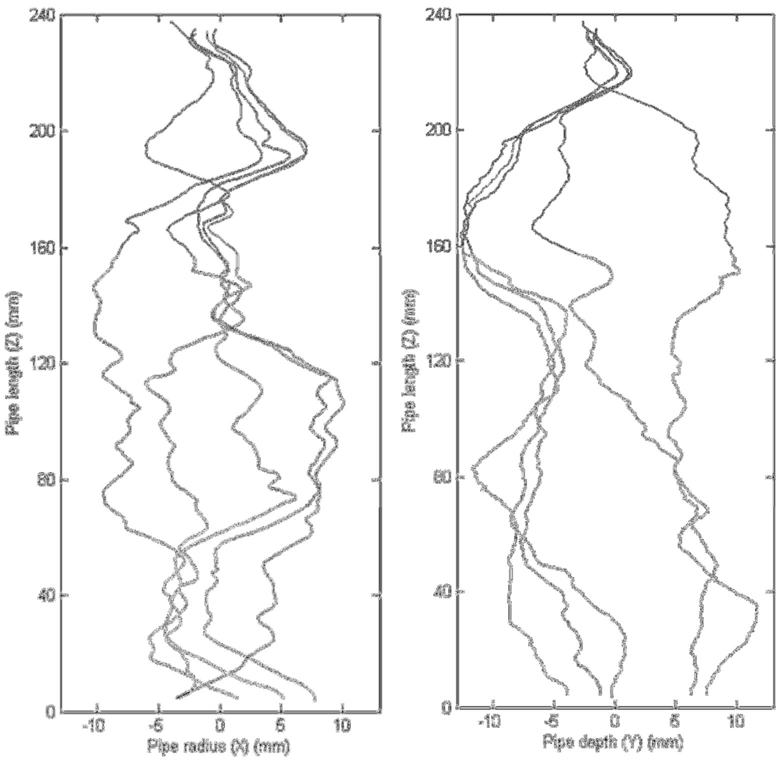

Figure 1. Particle paths as seen for the events that originate at the same entry locations

Mathematical models using both COMSOL and Matlab were developed for the Herschel-Bulkley type fluid. The models were developed using different approaches in order to compare the results between the models, thus verify them. Figure 2 shows how the results compare. It can be clearly seen that the two models match well, with the fluid reaching the same position in both case and with the flow profiles appearing very similar.

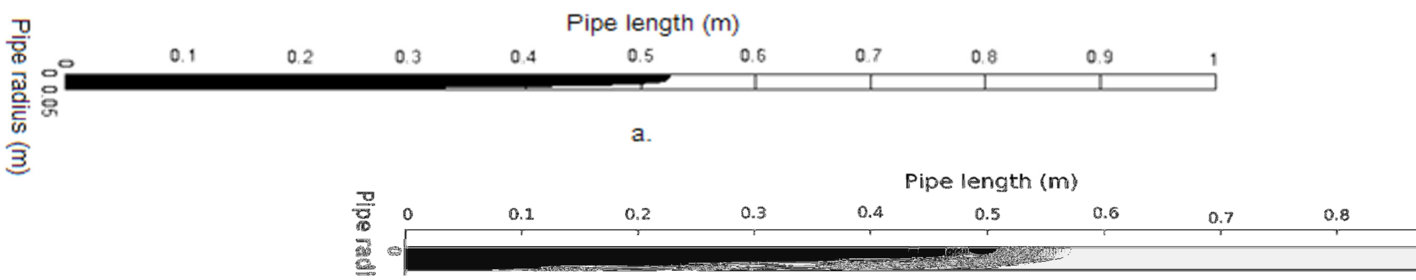

Figure 2. Estimated position of the fluid during changeover after 50 seconds. a. Using the Matlab model. b. Using the COMSOL model. The fluid is a Power Law fluid with the following parameters: Power Law Number = 0.2, Consistency Coefficient = 10 Pa.s. Flowrate = 20 l/h.

It is expected that the results obtained from the optical flow experiments can be compared to these models in order to improve and develop them further.

[1] C. Mac Namara, a. Gabriele, C. Amador, and S. Bakalis, "Dynamics of textile motion in a front-loading domestic washing machine," *Chemical Engineering Science*, vol. 75, pp. 14–27