Research Proposal: Predictive Design, Measurement, and Control for Complex Materials Transport in Chemical Processes Christopher Boyle ∗ May 19, 2017

Abstract

Fluid transport in industry is only well understood in terms of simple fluid flow in a single pipe. Real industrial processes have complex fluids in networks of geometries, complete with phase changes and multiple phase flow (solids, liquids, and gases) – a flow system that is difficult to predict and design for. Also, in most industrial processes solids must be dealt with at some stage which presents a problem for transport and mixing. Unlike fluids, solids cannot be pumped down a pipe, but must be carried by some mechanism (e.g. a fluid pumped along a pipe carrying the solid). In addition, solids (and multiphase mixtures involving solids and complex non-newtonian fluids) are susceptible to extreme increases of apparent viscosity - jamming. This must be dealt with by reducing the flow in the process andslowing production, or decreasing the concentration of the solids (increasing costs). Neither solution is ideal, and the latter may not apply if a certain concentration is required for a reaction to take place. Proposed here is a system for predicting and designing chemical processes; simulating flows through piping networks and making use of powerful ‘Rules of Thumb’ (derived from years of engineering experience) into the design. By improving the design, measurement, and control of the complex flow for industrial processes the process will be better off (less weak assumptions) -> (doesn’t really make sense?) and will require less maintenance (better understanding of the flow patterns and phenomena). All this would be done faster and at a lower cost than a manual design process.

Objectives

The objectives of this proposal are:

• To produce both theoretical and empirical models to explain flow behaviour of multiphase fluids in complex pipe networks.

• To apply this understanding in order to reduce the barriers to effective design of processes involving such fluids.

• To create a prototype CAPE/CAPD package to predict the flow patterns in a pipe network and produce recommendations for change and optimization.

Methodology

The research will take the form of three main sections: Experimental fact finding; transforming experimental results into empirical models able to be applied to full scale industrial system design; finally, creating an implementation of the methods developed in the form of a CAPP program. A lab-scale environment will be set up using simple and versatile hardware (such as Raspberry Pi aided interfaces). Sensors will be developed to read information about the flow in the geometry — a pipe network emulating that which may be found in an industrial process. Varying flow of complex (non-newtonian, multiphase) fluids through these geometries will allow the examination and modelling of the flow properties. This experimental case study will use shear-thickening particle suspensions which are currently under study for their thickening, jamming, and unstable flow behaviours. Practical methods of precise measurement of flow fluctuations will be used alongside statistical data (on the fluctuations in stress of the flowing fluid, for example) to form a method of dynamic control. Using information gained from the experimental stage, theoretical and computational models will be formed. These models will be used to simulate the flow of a desired material through a desired pipe network (geometry). ‘Circuit analysis’ (as used in electrical engineering to solve for the properties of a circuit) will be used to solve across the pipe network to complete the behaviour profile for the fluid in the geometry. The models developed will then be packaged as a Computer Aided Process Engineering (CAPE) package. This will incorporate theoretical and empirical models developed in the 2nd stage, as well as Rules of Thumb used by design engineers. The package can then be used to aid and inform the design process: where the process is faulty, where the pipe-network will fail, how often maintenance can be expected, and where the design violates a Rule of Thumb.

Rules of Thumb (RoTs) are the result of years of trial and error experience in process design, and are normally passed down by word of mouth and rarely formally taught. RoTs are only guidelines rather than hard-and-fast rules. A design which violates an RoT may not be invalid, but may require extra maintenance or could be difficult to replace or operate. Thus, a warning system will be in place to check the design in question for compliance with RoTs. 2