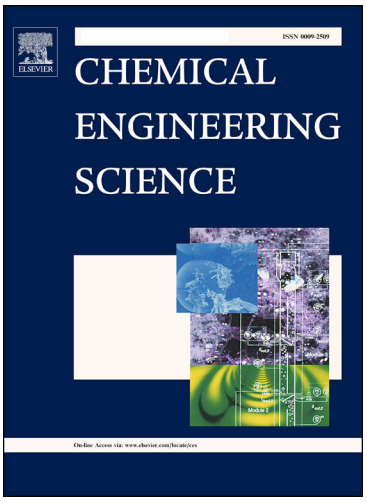


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# In-Pipe Rheology and Mixing Characterisation using Electrical Resistance Sensing

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**Abstract**

This paper presents a novel, in-line Electrical Resistance Rheometry (ERR) technique which is able to obtain rheological information on process fluids, in-situ, based on electrical resistance sensing. By cross-correlating fluctuations of computed conductivity pixels across and along a pipe, using non-invasive microelectrical tomography sensors, rheometric data is obtained through the direct measurement of the radial velocity profile. A range of simple, Newtonian and non-Newtonian fluids, have been examined with the obtained velocity profiles independently validated using Particle Image Velocimetry (PIV); results from both ERR and PIV techniques are in excellent agreement. Comparison of the rheological parameters obtained from ERR with off-line rheology measurements demonstrated that ERR was able to perform with an accuracy of 98 % for both Newtonian and non-Newtonian fluids. The ERR technique presented offers new capabilities of true in-situ analysis of fluids relevant to formulated products and in-pipe spatial and temporal analyses afford the simultaneous interrogation of localised and global mixing behaviour.

**Keywords:** in-line, rheology, non-Newtonian, mixing, Electrical Resistance Tomography

## 1. Introduction

The rheological properties of a fluid system are critical in chemical and physical processing, since they govern both in-process efficiency and final product quality. Conventionally, the measurement of such properties is conducted off-line with careful sampling and removal from the product stream. The fluid rheology obtained from off-line rheometry is often considered, with assumptions, as applicable to flows in real processes. However, this approach is in the majority unsatisfactory since off-line measurements afford a retrospective characterisation of the sample structure which may not be representative of structure as a function of the time-shear history received during processing. In-situ measurements overcome this deficiency as they are inherently conducted within the flow environment and remove the possibility of degradation of the sample. Since in-line rheometer measurements are conducted within the process flow environment, they possess the capability to elevate rheometry from a quality control tool at process end-point to one which is able to control and optimise processes. Rides et al (2011) suggested in-line techniques may also afford opportunities for new product development.

There is thus an ever-increasing demand for the development of in-line rheometers as the majority of industrial complex fluids exhibit non-Newtonian behaviour. Complex fluids may observe wall slip, thixotropy, shear-induced phase migration and shear banding during processing; interpretation via conventional rheology measurements is often demanding and complex (Olmsted, 2008). Such phenomena may be captured with localised rheological measurements, with velocity profiling being a preferred technique (Ovarlez et al, 2011). The low shear rate range of in-line rheometers, 0.05 - 100 $s^{-1}$, is typically relevant for the rheological phenomena observed in complex systems. Despite