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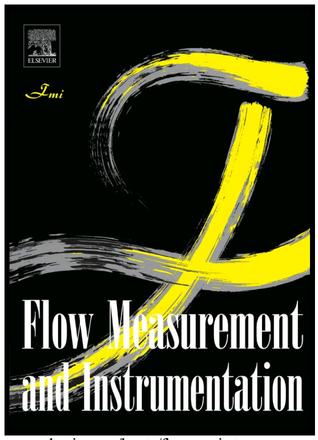

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Measurement Of Velocity Profiles In Transient Single And Multiphase Flows Using Inductive Flow Tomography

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ABSTRACT

This paper reports on the use of inductive flow tomography (IFT) to study the dynamic flow behaviour that occurs when a control valve on a pipeline is suddenly opened or closed with the flow initially at steady state. Single phase (water) and two phase (oil-in-water) vertical flow conditions were investigated. An electromagnetic flow meter (EMFM) having a 16 electrode array was installed downstream of a control valve. The EMFM generated, sequentially, both uniform and anti-Helmholtz magnetic fields and flow induced potentials proportional to the flow rates of water were measured at the electrode array. A novel IFT image reconstruction algorithm was used to reconstruct the water velocity profile in the pipe cross-section at 2-second time intervals.

Velocity profile reconstructions from the EMFM device, both in single phase and multiphase flow, show that when the valve is suddenly opened or closed, the flow downstream of the valve oscillates - with the velocity profile successively changing between a very peaky profile with a much higher than expected velocity at the pipe centre to a velocity profile where the velocity at the pipe centre is much lower than expected. This oscillation occurs until steady state conditions are again reached. It is believed that these novel measurements of transient velocity profiles demonstrate hitherto unseen flow behaviour which may explain some of the damaging effects associated with the phenomenon of 'water hammer'.

Keywords: Transient flow, inductive flow tomography, image reconstruction, electromagnetic flow meter.

1 Introduction

Flow variables such as local pressure and velocity remain constant under steady state conditions in a pipeline system. However, events such as starting or stopping a pump, or opening or closing a valve cause the local velocity and pressure to vary with time. When a valve is suddenly closed, the kinetic energy in the fluid can give rise to 'hydraulic transients' such as 'water hammer' [1] which is often accompanied by a loud banging or hammering noise in the pipeline. Resultant pressure variations accompanying the transient flow can exceed design limits of pipes and fittings and result in noise, vibration and collapse of the pipe and its fittings or even total system failure [1, 2]. The pressure can also drop below the vapour pressure of the liquid and can cause cavitation which is detrimental to the pipe system. A comprehensive understanding of flow velocity profiles under transient conditions can give insight into flow behaviour in transient flows. This can help in the development of transient flow mathematical models which are critical for commercial design and safety of fluid distribution systems in various industrial applications.

In [3] and [4] details were published of velocity profiles of fluids in transient horizontal flows which were observed by means of particle image velocimetry (PIV) and ultrasonic velocimetry systems respectively. Important differences in the velocity distributions between the steady state and the transient (unsteady) flow conditions were reported and it was shown that the process of deceleration of flowing fluid when a valve is suddenly closed is highly non-uniform. One of the observations in transient flow conditions was the reversal of velocity within a single profile, with the flow near the pipe wall moving in the opposite direction to the flow around the pipe centre.