IMPULSE RESPONSE METHOD FOR SOLVING HYDRAULIC TRANSIENTS IN VISCOELASTIC PIPES

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The current paper presented the calculation of waterhammer in polyethylene pipes taking into account unsteady friction effects and the viscoelastic behaviour of pipe-walls by means of the Impulse Response Method (IRM). Basic fluid equations are linearised and described in the frequency domain by transfer functions, as for steady oscillatory flows, and are used for the evaluation of response functions by the inverse Fast Fourier Transform (invFFT) technique. Non-periodic pressure perturbations are obtained by the direct convolution of response with the function the discharge change (or pressure pulse). This method is a particularly useful procedure to take into account frequency-dependent factors, such as unsteady skin friction and pipe-wall viscoelasticity, which considerably influence the dynamic behaviour of the fluid system in transient or steady oscillatory conditions. These two phenomena were incorporated into the transfer functions by a complex-valued wave speed and complex-valued propagation operators.

The numerical results obtained considering the pipe linear elastic and linear viscoelastic models were compared with experimental data, neglecting and taking into account unsteady friction. Transient data collected from a 270 m polyethylene (PE) pipeline, with 50 mm diameter, at Imperial College (London, UK) are used for validating the developed method. The IRM consists of three-step procedure: (i) evaluation of the system transfer function (Fig. 1a); (ii) calculation of the response function by the Inverse Fast Fourier Transform of the discrete transfer function (Fig. 1b); and (iii) the transient pressure response calculation by the discrete convolution of the response function with the flow variation at the valve (Fig. 2). Two formulations for the friction calculation are presented: the first refers to the linearised constant friction and the second the frequency-dependent friction developed by Brown (1962) for laminar conditions. The viscoelastic behaviour is described by a complex-valued creep function J^* in the wave speed calculation. A Prony series representation of the Generalised Viscoelastic solid is used to describe the creep function as presented in (Covas *et al.*, 2005).

Numerical results obtained for the initial flow of 1.008 l/s are compared with the collected piezometric-head data at the downstram end of the pipe (Fig. 2). Transient head obtained for the viscoelastic case (complex-valued wave speed) showed a very good agreement with the experimental data. Conversely, the pressure obtained for the elastic case with no unsteady friction showed a large discrepancy with the observed data. The major challenge of the current and the future work is the distinction between frictional and mechanical dampening, as the viscoelastic behaviour of pipe-walls has a dissipative and dispersive effect on the pressure wave, similar to unsteady friction losses.

The use of this method (i.e. IRM) is much faster than the typical method of characteristics and can straightforwardly include frequency-dependent factors; however, it has the disadvantage of the loss of accuracy due to the linearization of the friction term and the valve equation, and the complex application to multi-pipe systems.

Keywords: frequency domain, impulse response, transients, viscoelastic, Fourier analysis.

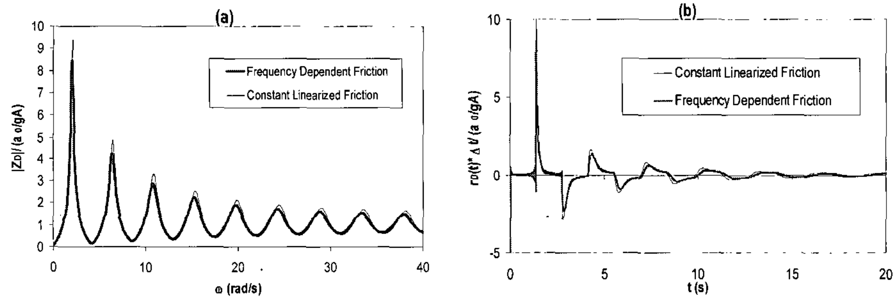

Fig. 1 (a) Transfer function $Z_D(\omega)$ and Impulse response function $r_{H_D}(t)$ at the downstream end for the linear viscoelastic reservoir-pipe-valve system with constant friction and frequency-dependent friction

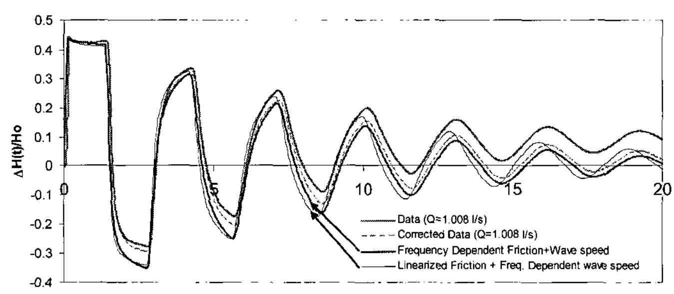

Fig. 2 Piezometric head H_D at the downstream end for the linear viscoelastic reservoir-pipe-valve system versus collected transient data.

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