VALIDATION OF UNSTEADY FRICTION MODEL IN FLOWMASTER 1D THERMO-FLUID SIMULATION

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Introduction

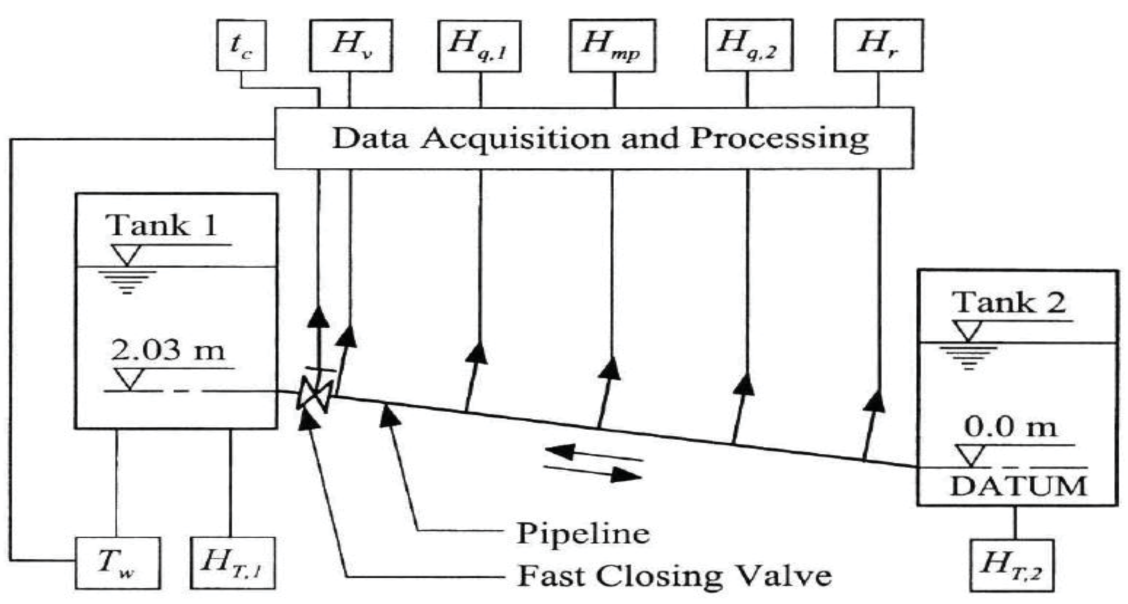
Rapid transient events - where fluid is brought to rest suddenly by (for example) a tripped pump or closing valve, can occur in many fluid systems and can result in component damage or even system failure. Systems where such events can arise include hydro-electric power generation, fuel injection and water deluge.
In extreme case events the traditional quasi-steady models may not be appropriate the model the resulting pressure surges, with larger discrepancies occurring as the rapid transient event develops.
It is therefore necessary to use an unsteady friction model to correctly model the dissipation of the pressure wave as the event progresses.

Aim

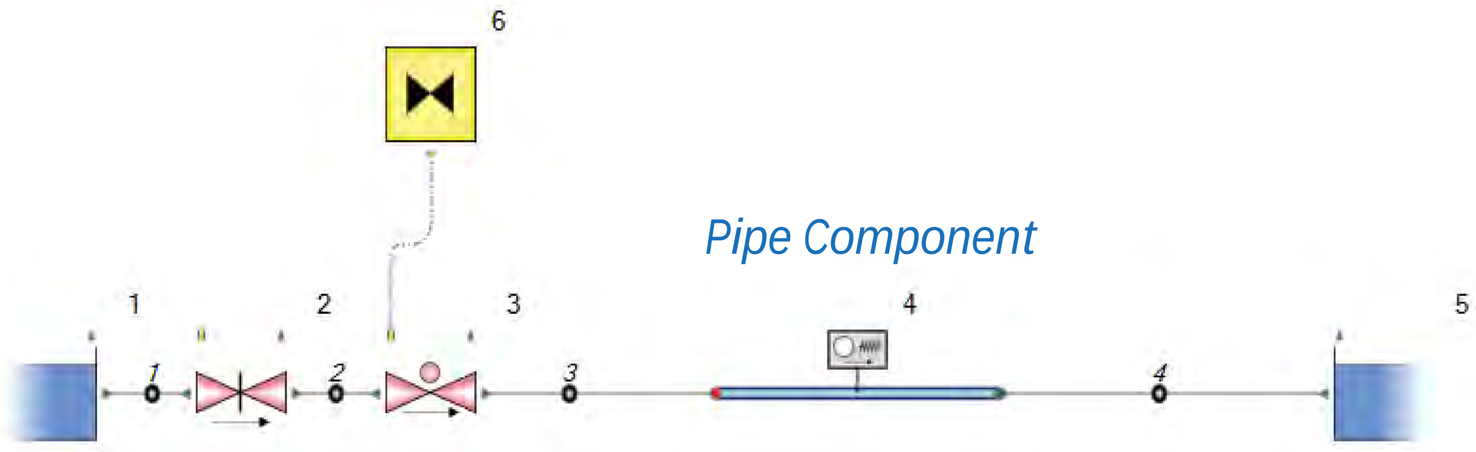
The study demonstrates the accuracy of the Flowmaster unsteady friction model, comparing it against experimental results presented in “Developments in unsteady pipe flow friction modelling” by A. Bergant et. Al.
Additionally the Colebrook-White quasi steady model is measured against these.

Modelling Approach

The system diagram presented in “unsteady pipe flow friction modelling” is shown below.



The Flowmaster network created to model this is shown below. The pipe component is where the unsteady and quasi-steady friction models are implemented in the Flowmaster solver.



Solution Algorithms

Quasi-Steady Friction Model

The quasi-steady friction model used in the investigation is the Colebrook-White approximation. The model is normally appropriate for most simulations, such as steady state and slow transients.

$$f = f_t = \frac{0.25}{\left[\log\left(\frac{k}{3.7D} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

Where f represents the Darcy friction factor.

Unsteady Friction Model

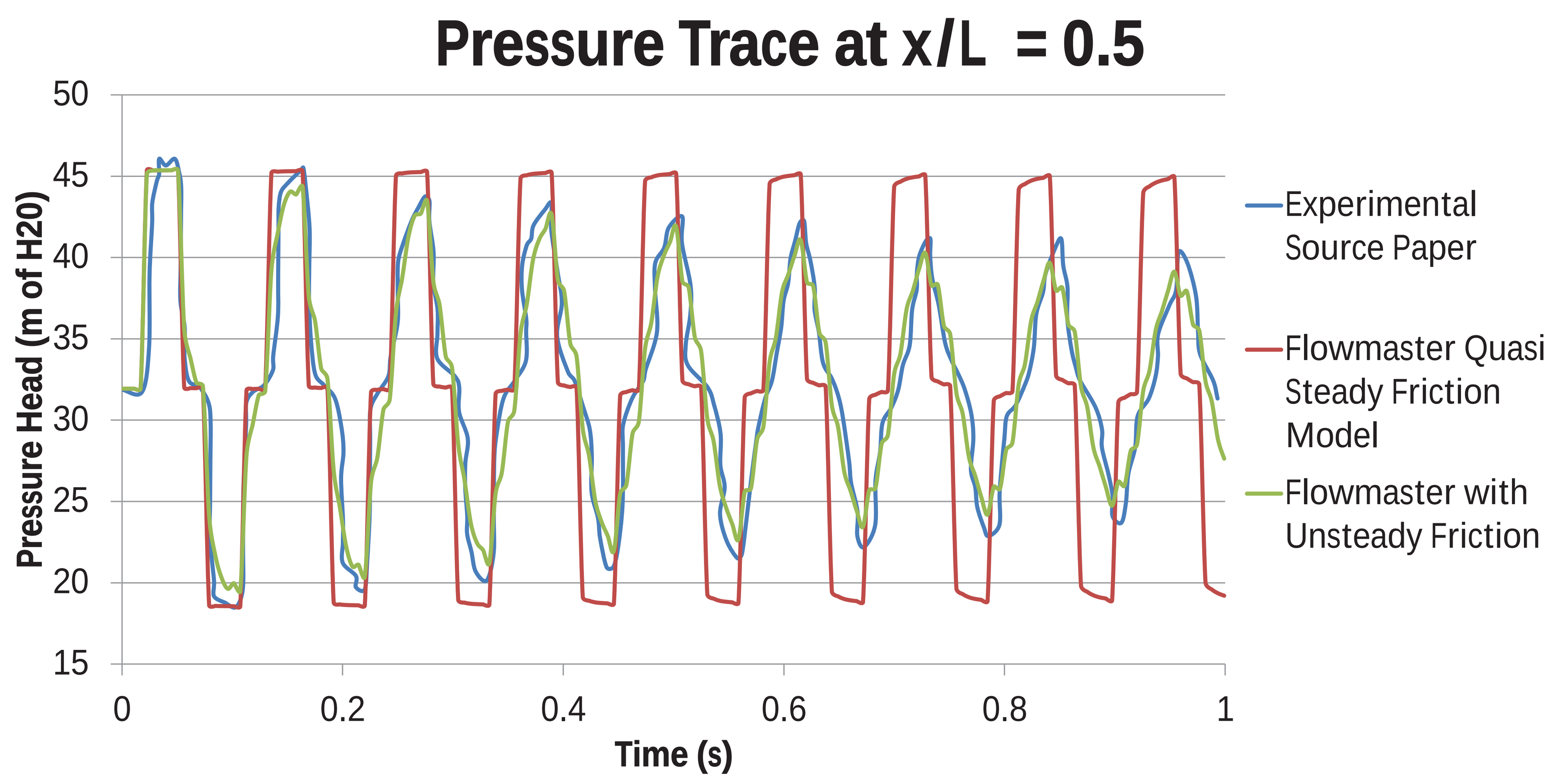
The unsteady friction model uses the Vítkovský formulation of the Bronone unsteady friction model.

$$f = f_q + \frac{kD}{V^2}\left[\frac{\delta V}{\delta t} + aSign(V)\left|\frac{\delta V}{\delta x}\right|\right]$$

This equation relates the unsteady friction to both local and convective instantaneous acceleration. Additionally the “aSign(V)” function corrects the convective acceleration for all possible flows and waterhammer wave directions.

Comparison with Experimental Results

Pressure traces from the unsteady friction model used by Flowmaster, the traditional quasi-steady friction model and the pressure trace recorded from the practical results from the experimental paper are compared below.



It can be seen that for the first two sets of oscillations that the pressure traces from all three results match, however as the rapid transient progress along, the quasi-steady friction model produces discrepancies between the experimental pressure trace. The experimental pressure trace being dampened due to the unsteady fluid flow occurring with in the system. The unsteady friction model accounts for this with the two acceleration terms in the model formulae.

Conclusion

Flowmaster’s unsteady friction model correctly models the pressure trace for a rapid transient water hammer event. The quasi-steady model initially matches the pressure trace from the experiment, however discrepancies increase with time due to the model not accounting for instantaneous acceleration.