Inverse transient analysis for detecting multiple branched pipeline segments in a reservoir pipeline valve system

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Introduction

● **Key points**

✓ This study developed a systematic analysis method for detecting multiple side branches in a simple reservoir pipeline valve (RPV) system.

✓ We introduce a polynomial simulation scheme to represent the impact of nonlinear valve action maneuver and a signal processing procedure was developed for detecting multiple branched elements.

● **Method of Characteristic (MOC)**

(Wylie & Streeter 1993)

$$\frac{c^2}{ga}\frac{\partial q}{\partial x}+\frac{\partial h}{\partial t}=0$$

c = wave speed (m/s)
f = Darcy-Weisbach friction factor
a = cross sectional area (m/s)
d = diameter of a pipe (m)

$$\frac{\partial q}{\partial t}+ga\frac{\partial h}{\partial x}+\frac{fq|q|}{2ad}=0 \qquad \text{PDE}$$

⇩

$$\frac{dq}{dt}\pm\frac{ga}{c}\frac{dh}{dt}+\frac{fq|q|}{2ad}=0 \qquad \text{ODE}$$

● **Unsteady friction model**

(Brunone et al. 1991)

$$\frac{\partial q}{\partial t}+ga\frac{\partial h}{\partial x}+\frac{fq|q|}{2ad}+k\left(\frac{\partial q}{\partial t}-c\frac{\partial q}{\partial x}\right)=0$$

k = Brunone's friction coefficient

✓ Determination of the k (Vardy & Brown 1996)

$$k=\sqrt{v^*}/2$$

v^* = Vardy's shear decay coefficient

In laminal flow, v^* = 0.00467

Method and Materials

● **Polynomial Based Transient Characterization Scheme (PBTCS)**

✓ High order polynomial approximation of valve opening dimensionless coefficient (τ)

$$\tau=n_1t^3+n_2t^2+n_3t+n_4$$

n_1, n_2, n_3 and n_4 = nonlinear constants

● **Signal processing procedure for detection**

STEP 1 • Normalizing pressure variations and superimposing between original signals with and without branches

STEP 2 • Obtaining interference signal through the manipulation between superimposed signals

STEP 3 • Isolating the interference impact from superimposed signal and presenting pressure signals of each branch

● **Pilot-scale reservoir pipeline valve system**

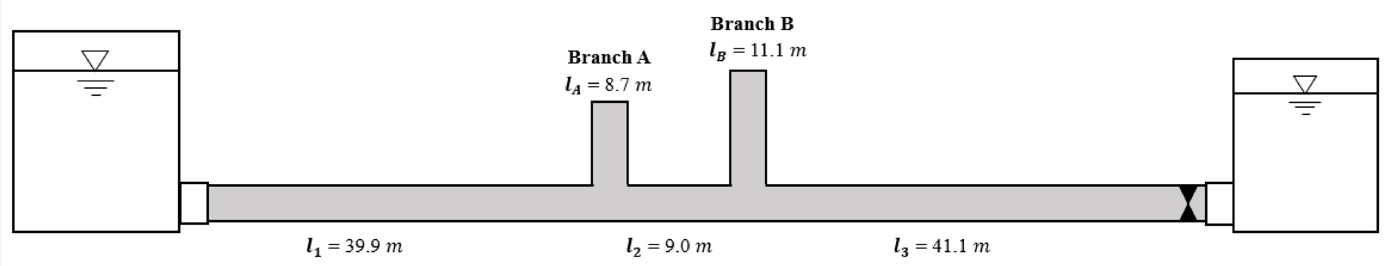

Figure 1 Simple RPV system with two side branches

diameter (m)	Thickness (m)	Darcy-Weisbach friction factor
0.02	0.0021	0.0697
Head loss (m)	Flowrate (m^3/s)	Wave speed (m/s)
0.25	3.93×10^{-5}	1413.43

Table 1 Initial boundary condition in a RPV system

➢ Data acquisition of pressure variations recorded at a point 0.3 m from downstream valve in a RPV system

Results

● **Signal processing using instant valve closure**

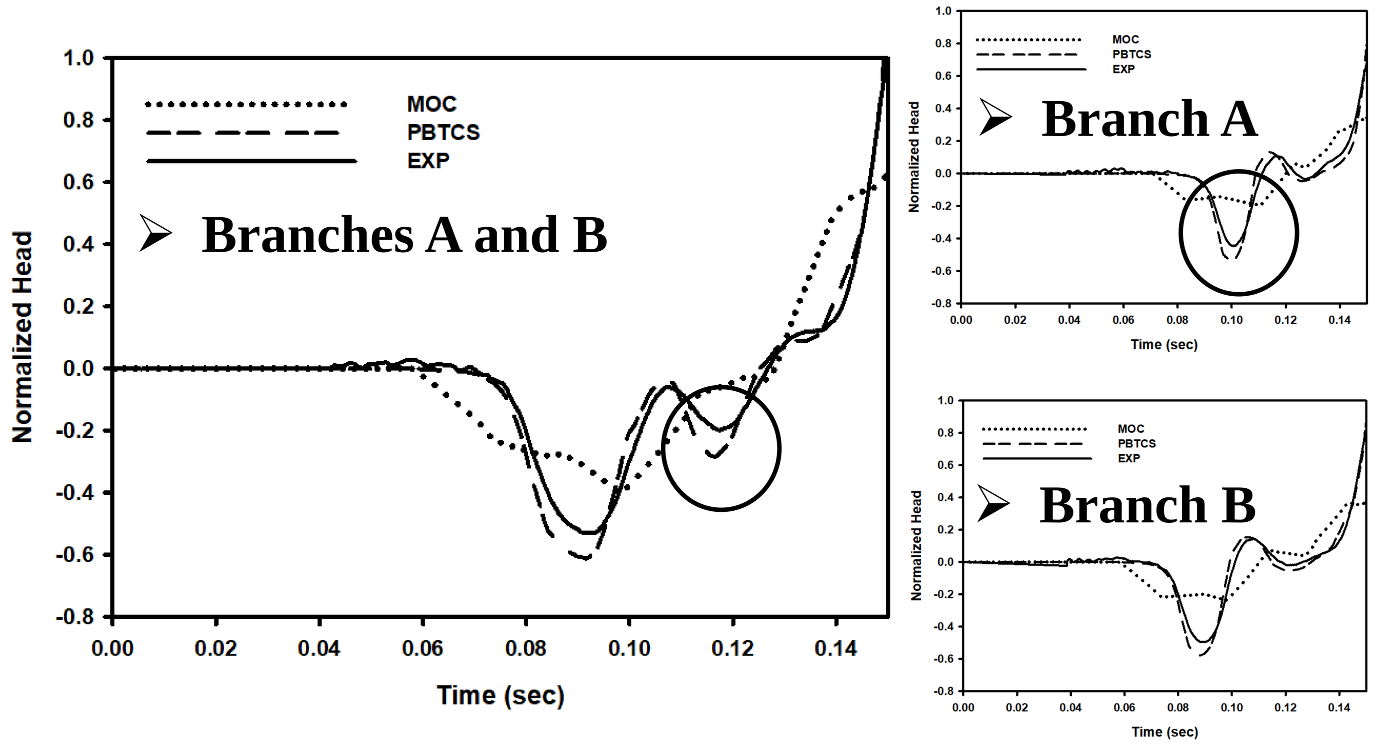

Figure 2 Superimposed pressure signal in three layouts of pipelines

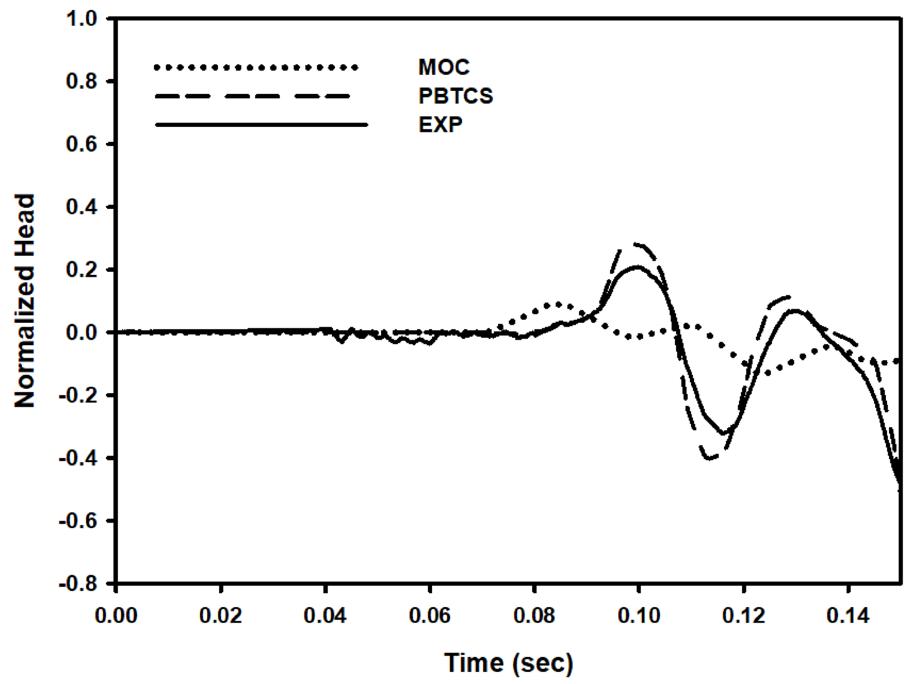

Figure 3 Interference signal between branches

➢ Need for isolation of the interference between branches A and B by manipulating of Figs 2 and 3

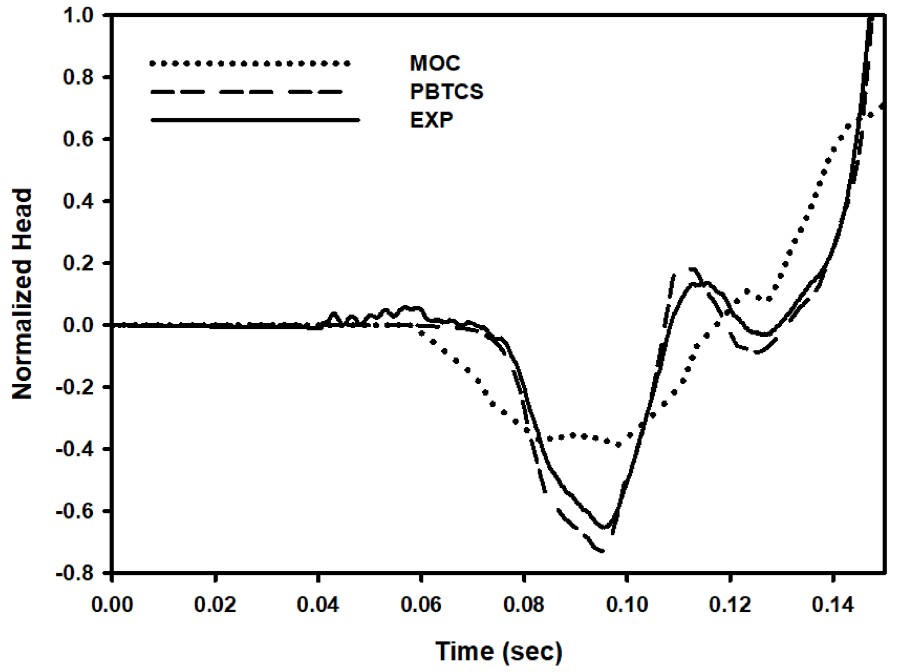

Figure 4 Pressure signals of each branch A and B

➢ Disturbance between wave reflections from the dead end branch B and the entrance of branch A

Discussion and Conclusion

● **Impact of unsteady friction in processing**

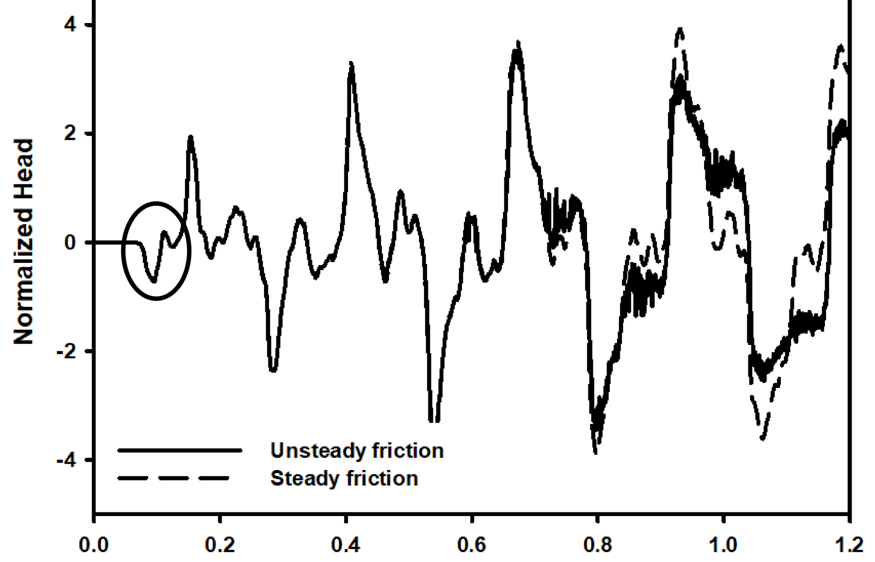

Figure 5 Comparison in steady and unsteady conditions

➢ Almost identical signals for branch detection between steady unsteady friction for the first reflection of pressure signals

● **Signal processing using pressure injection**

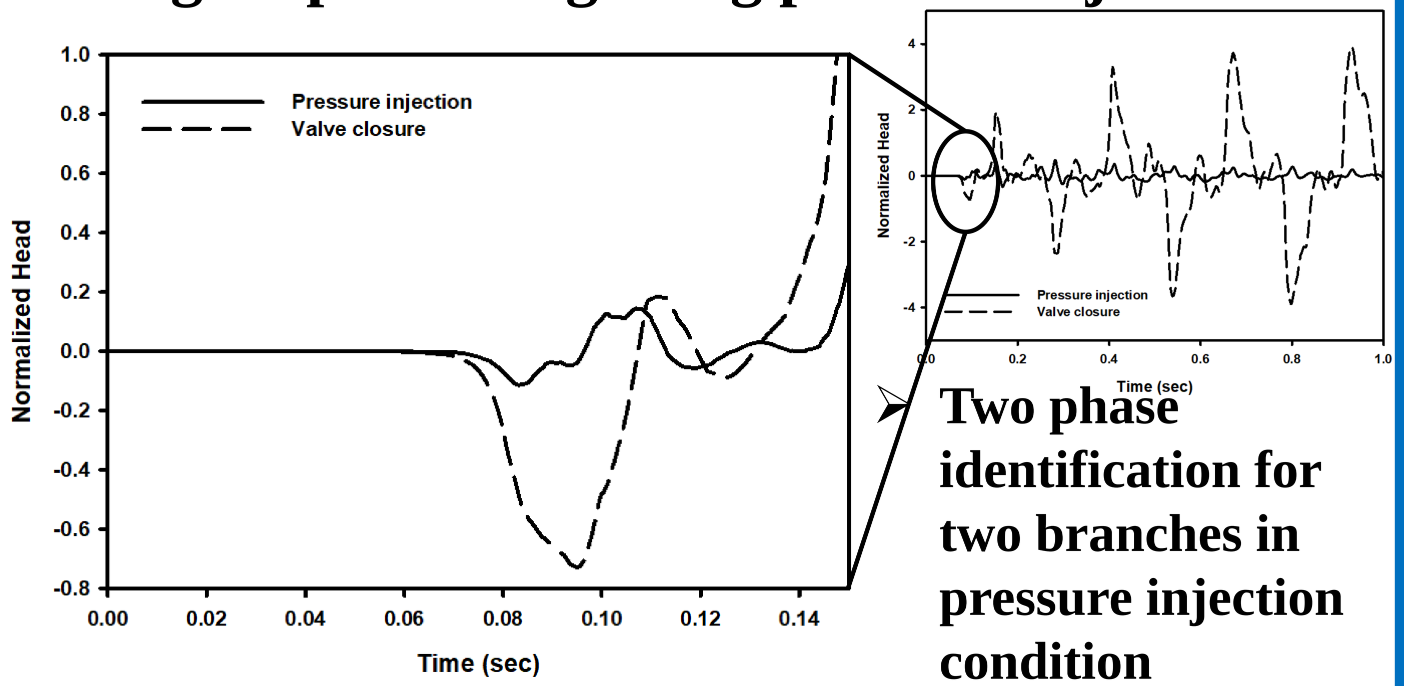

Figure 6 Comparison in pressure injection and valve closure

➢ Two phase identification for two branches in pressure injection condition

● **Conclusion**

✓ The proposed method, PBTCS, considering nonlinear valve maneuver well capture the overall pressure responses in a RPV system.

✓ Future studies are required to detect multiple branches by adjusting distances between each branch or applying the other methods of transient events.

References

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