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Modelling and transient simulation of water flow in pipelines using WANDA Transient software

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Abstract Pressure transients in conduits such as pipelines are unsteady flow conditions caused by a sudden change in the flow velocity. These conditions might cause damage to the pipelines and its fittings if the extreme pressure (high or low) is experienced within the pipeline. In order to avoid this occurrence, engineers usually carry out pressure transient analysis in the hydraulic design phase of pipeline network systems. Modelling and simulation of transients in pipelines is an acceptable and cost effective method of assessing this problem and finding technical solutions. This research predicts the pressure surge for different flow conditions in two different pipeline systems using WANDA Transient simulation software. Computer models were set-up in WANDA Transient for two different systems namely; the Graze experiment (miniature system) and a simple main water riser system based on some initial laboratory data and system parameters. The initial laboratory data and system parameters were used for all the simulations. Results obtained from the computer model simulations compared favourably with the experimental results at Polytropic index of 1.2.

1. Introduction

1.1. Flows in pipeline systems

The use of pipelines in the transportation of fluids is essential as it could be a more convenient means. Pipeline systems could be very simple, large or complex in nature. A very good example of a simple pipeline system is a single pipe transporting water from one reservoir to another. Complex pipeline systems could take the form of an interconnected set of water distribution networks for a major metropolitan area. Also, a complex system may have different sub-networks separated by varying energy lines or pressure levels that serve different locations within the networks [1,2]. Hydraulic components such as

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Nomenclature

Symbol	Definition (Unit)
A	cross sectional flow area of the pipe (m^2)
C_l	total loss co-efficient from reservoir to air pocket for all hydraulic losses except friction (–)
C_1	total loss co-efficient from entrance to exit including fiction losses (–)
d_1	inner diameter of the vertical and section of galvanized steel pipe (m)
d_2	inner diameter of the plastic tube (air vessel) (m)
D	pipeline diameter (m)
e	wall roughness (m)
f_1	friction factor in the pipe (m)
f_2	friction factor in plastic tube (air vessel) (–)
g	acceleration due to gravity (m/s^2)
h_{atm}	local atmospheric head (m)
H	absolute pressure head of the air volume (in metre of water) (m)
H_1	upstream head at point 1 (m)
H_2	downstream head at point 2 (m)
H_A	constant reservoir head (m)
H_{GA}	gauge pressure head at the main supply (m)
H_p	gauge pressure head at the temporary BOUNDH reservoir (m)
H_R	constant head value of the reservoir (m)
H_Y	head in horizontal pipe section at a distance L_Y from the reservoir (m)
H_Z	head in vertical pipe section at a distance L_Z from the horizontal pipe (m)
L	length of the pipe (m)
L_{11}	horizontal section of galvanized steel pipe (m)
L_{12}	vertical section galvanized steel pipe (m)
L_{21}	length of plastic tube (height of air vessel) (m)
L_{TC}	distance between upper end of plastic pipe to location of thermocouple (m)
L_Y	length along L_{11} measured from the reservoir to location Y (m)
L_Z	length along L_{12} measured from pipe L_{11} to location z (m)
n	mean polytropic index (–)
P	absolute pressure of the air volume (Pa)
Re	Reynolds number (–)
t	time (s)
v	flow velocity (m/s)
V	volume of air (m^3)
z	elevation (m)
Greek	
μ	co-efficient of dynamic friction ($N\ s/m^2$)
Subscript	
i	initial condition
1	upstream condition /pipeline
2	downstream condition/air vessel

pump(s) for supplying the pressure required to overcome static head and losses (frictional and minor) and valve(s) used to control the rate, direction and pressure of fluid flow are usually required.

Transient flows in pipeline maybe initiated by systems operator, be imposed by an external event, be caused by a badly selected component or be developed as a result of poor maintenance [2]. Some of the events that cause transient flows include the following: uncontrolled pump trip, valve movement, check valve slam, pump start problem, excitation of resonant vibrations by pumps with an unstable head against discharge curve, and air in lines [1–8].

The study of true transient flows must include fluid inertia and may also include the elasticity or compressibility of the fluid and the conduit. The rigid column theory and water hammer theory are the two approaches adopted in pressure transient analysis [1,2,9]. In both cases, the analysis requires the application of Newton's second law which leads to the Euler equation. In the rigid column analysis approach, the elastic effects of the fluid and conduit material are ignored without compromising the accuracy of the analysis. When the velocities in a pipe system change so rapidly that the elastic properties of the pipe and liquid must be considered in an analysis, then we have an elastic theory of hydraulic transient commonly known as water hammer [10,11]. A water hammer is a pressure surge or wave caused by the kinetic energy of a fluid in motion (especially in conduit systems) when it is forced to stop or change direction suddenly [12].

1.2. WANDA Transient simulation tool

WANDA Transient is manufactured by Deltares in the Netherlands for the hydraulic design and optimization of pipeline systems ranging from small central heaters to hydrocarbon transport pipelines. WANDA has been used for diverse applications related to drinking water systems, oil or liquefied natural gas loading and offloading systems, fire fighting systems, process plant piping, district heating systems, hydropower industry, aircraft hydraulics, etc. WANDA's intelligent components and user-friendly interface enable its user to carry out any hydraulics analysis in the most efficient way [13]. The software is operated in two main modes (the engineering mode and the transient mode). The engineering mode supports most common activities in the hydraulic design of any piping system. In this mode, steady state flow condition (stationary flow) analysis can be carried out. The transient mode allows unsteady flow conditions (water hammer) to be investigated. [13].

The objective of this work was to predict the pressure surge for water flow in two different pipeline systems using WANDA transient simulation software.

2. Methodology

Computer modelling and simulation were done for two systems using the WANDA Transient simulation tool. The