Mathematical and Computer Modelling 54 (2011) 3037–3045

Contents lists available at SciVerse ScienceDirect

Mathematical and Computer Modelling

journal homepage: www.elsevier.com/locate/mcm

Transient modeling of gas flow in pipelines following catastrophic failure

A. Nouri-Borujerdi

Islamic Azad University, South Tehran Branch, Tehran, Iran

ARTICLE INFO

Article history:
Received 22 February 2011
Received in revised form 5 June 2011
Accepted 25 July 2011

Keywords:
Transient compressible pipe flow
Gas dynamics
Rupture
Numerical simulation

ABSTRACT

This paper simulates transient compressible adiabatic gas flows in a long pipeline following a catastrophic failure using an implicit high order finite difference scheme as a discretisation technique for convective terms. A rupture is assumed to be occurred accidentally at a distance from the feeding point of a pipeline where the pipeline being divided into two distinct sections, high and low pressure segment.

The results show that at early times after the rupture, considerable pressure loss will occur at the breakpoint with a chocked flow at this point. After expansion waves reach the closed end of the pipe, a reversal flow will constitute in the pipe. In the high pressure segment, the gas feeding continues and flow rate reaches a steady state chocked flow. In the low pressure segment, the flow rate decreases towards zero until the entire gas of the low pressure segment be evacuated.

1. Introduction

Unsteady gas flow in pipelines occurs due to rapid and slow disturbances. In general, pressure and mass-flow fluctuations cause slow disturbances where rapid disturbances are associated with compression wave effects caused by sharp closure of a shut-off valve, the system startup or expansion wave related to the pipeline rupture. The unsteady flow of gas in a long pipeline after an accidental rupture is of considerable interest to the natural gas industry due to the enormous amount of flammable gas release and its potential hazards. The area, which is affected by the escaping gas, could be rather high due to the large amount of gas contained in the pipeline. Therefore it is necessary to know the rate of gas release from the breakpoint to calculate the dispersion range.

A break divides the pipeline into two segments: high and low pressure sections where the line is totally cut and the flows from each segment do not interact. As a result of the rupture, an expansion wave moves into the pipeline and sets the gas in motion towards the breakpoint. The gas flow in the low pressure segment is more complex than that in the high pressure one, since the expansion waves entering the pipeline cause flow reversal in this segment and two directions of flow exist. In one part of this segment the gas still maintains its initial direction, whereas in the other part the gas moves towards the broken end. These unsteady flows are usually studied with simplified computational models, such as adiabatic or isothermal models. Slow transients caused by pressure and mass-flow oscillations have been investigated by many workers. Under adiabatic flow assumption, Gato [1] has investigated the effect of rapid closure of downstream shut-off valves on dynamic behavior of high-pressure natural-gas flow in pipelines using the Runge–Kutta discontinuous Galerkin method. Tentis [2] studied the transient gas flow simulation using an Adaptive Method of Lines. Comparison of isothermal and non-isothermal pipeline gas flow is also modeled by Osiadacz [3]. Ryhming [4] studied early development of the flow in a pipe for which the flow conditions are always critical at the breakpoint. He used the method of matched asymptotic expansions using an isothermal model to predict velocity profile at early times. The method of characteristics is used by Flatt [5]. He assumed the adiabatic model for gas flow after rupture. He substituted a line segment of the pipeline next to the break by a nozzle with a

E-mail address: anouri@sharif.edu.

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doi:10.1016/j.mcm.2011.07.031