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Simulation of transient gas flow using the orthogonal collocation method

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ABSTRACT

Proper evaluation of the dynamics of the transmission system is the key element in the design and operation of natural gas pipelines. Basic equations describing the transient flow of gas in pipes are derived from the Euler equations. The orthogonal collocation technique is employed as the mathematical method for the numerical solution of the governing equations. This method leads to a set of non-linear ordinary differential equations which can be solved by the Runge–Kutta–Fehlberg method. The performance of the proposed method is tested using two practical examples. The predicted results clearly demonstrate that the proposed method can successfully simulate the isothermal and non-isothermal unsteady flow in gas transmission systems.

Keywords: Mathematical modeling; Simulation; Transient gas flow; Orthogonal collocation method

1. Introduction

The simulation of natural gas transmission pipelines has been studied by many workers. To keep this analysis simple, most of them assumed that flow is steady in the pipeline. Although, under certain circumstances, the consideration of steady state conditions produces satisfactory engineering results, there are many situations in which this assumption leads to unacceptable results. The fluctuations in demand as well as the operation of system controlling devices such as valves, compressors and pressure regulators bring about disturbance in the pipeline.

Evidently, the analysis of unsteady state conditions owing to dependence of variables to time and space is much more difficult than that of steady state where its parameter is only depended to space. The investigation of such transient phenomena enables the gas transmission operators to control and monitor any changes in the gas pressure, temperature and flow rate.

To simulate one-dimensional transient flow in natural gas pipeline, the continuity, momentum, and energy equations must be solved simultaneously. This creates a set of non-linear partial differential equations, which are complex and cumbersome. There are various traditional numerical methods to simulate one-dimensional transient flow such as the method of characteristic, several finite difference schemes such as such as explicit finite differences and implicit schemes, finite volume, finite element and finite volume with total variation diminishing (TDV) (Dorao and Fernandino, 2011).

Tentis et al. (2003) developed an adaptive method of lines algorithm for the simulation of unsteady flow in gas transmission systems. Two numerical experiments were used to assess the validity of the proposed method. They concluded that the suggested numerical procedure is computationally efficient and is appropriate for the simulation of slow and fast transients.

Osiadacz and Chaczykowski (2001) aimed at investigating the differences between the isothermal and non-isothermal transient gas flow models. It was concluded that there exists a significant difference in the pressure profile through the pipeline between the two processes. This means that, in the case when the transmitted gas does not have sufficient time to reach the thermal equilibrium with its surroundings, the use of an isothermal model leads to significant errors.

Chaczykowski (2009) evaluated the impact of the type of the equations of state on the hydraulics of natural gas transmission pipelines. Soave Redlich–Kwong (SRK), Benedict–Webb–Rubin (BWR), AGA-8 and SGERG-88 equations

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