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A New Mathematical Model Gas Flows in Pipeline with Leak

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1. Introduction

One of the most important issues in the gas industry is the calculation of wasted gas, which has always been a concern.

Mathematical modeling of flow in a leakage of gas can be considered by considering changes in parameter of flow such as pressure and flow velocity in ducts after a leak, so it can be used to evaluate leakage losses. Equations governing the flow behavior in a pipeline are a set of partial differential equations and are difficult to solve by analytical and even numerical methods such as characteristic (MOC). In all of these numerical methods, we need information on the pipeline boundary conditions, which depend on the upstream and downstream features. In this study, the leakage pipeline is simulated by an equivalent electrical circuit and the outlet end of the pipeline can be considered with an approximation of one type of circuit. The main idea of this work is taken from the papers and researches of Zabih et al. and Taherinejad et al. The details of this approach are then tested and compared with the proposed model with real data.

2. Modeling the flow in a pipeline with leak

To simplify mathematical expressions, the following two hypotheses are considered: 1. The synchronous current in a pipeline is assumed and therefore the energy equation can be ignored; 2. Since the given the high ratio of tube length to diameter, one-dimensional flow is assumed. Assuming sudden leakage, rapid changes in pressure and flow velocity cause the waves to propagate from the leakage point to the two ends of the pipeline. We restricted our study to a mild transient process that can be described by steady-state equations.

3. Solving the model equations based on the equivalent circuit

The main objective is to simulate the gas transition pipeline as the most effective natural gas transition and distribution networks, the resolution and prediction of flow velocity and pressure distribution along the pipe. Pressure as the driving factor of gas flow is considered as the electric potential in the electric analogy method, which is the factor of electrical conversion. It is clear that the gas flow is similar to the electricity flow. A simple tube element is an electric element that stores the flow rate and pressure at its beginning and end. The difference between electric potential (pressure drop) and electric current (current velocity) is taken into account, so a model should be presented that illustrates the physics of gas transition through the pipeline. Figure 1 shows the gas leakage pipeline and its equivalent circuit.

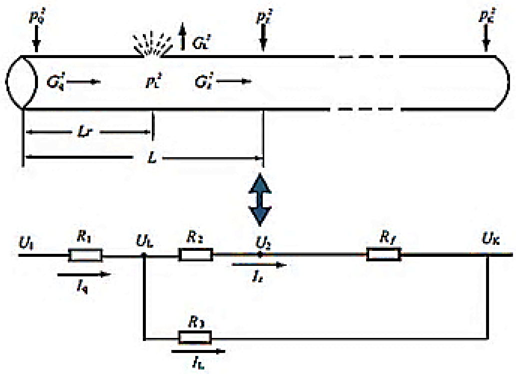

Figure 1. Leakage pipeline and equivalent circuit

4. Numerical results and comparison with experimental sample

Experimental measures were performed by manipulating the manual valves at three leak points different leakage sizes occur and pressure and flow changes were recorded at both ends of the pipeline. Figures 2 and 3 show the comparison between simulation and measurement results as a leak in L_2. Figure 4 shows the changes in the total resistance of the pipeline and the end of pipeline output during leakage. R_f is the end resistance of the pipeline and the total resistance of the pipeline is R_T.

5. Conclusion

A simple and efficient way to develop leak pipeline models was presented in this study. The models developed in this method can be used to estimate pressure and flow changes in a conduit after a leak. To solve the model equations, a new approach based on the similarity between the pipeline and the electrical circuit is proposed. As such, an equivalent circuit with a specific structure is used to simulate a pipeline leakage and a specific approximation is made to express the endpoint of the pipeline from the point of view of the circuit. The model's success in leaking pipeline simulations also confirms the validity of the method.

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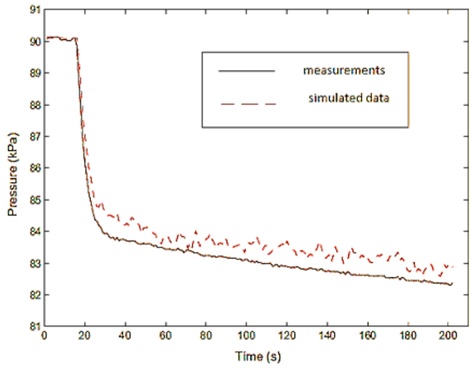

Figure 2. Comparison of pressure at gas pipeline outlet

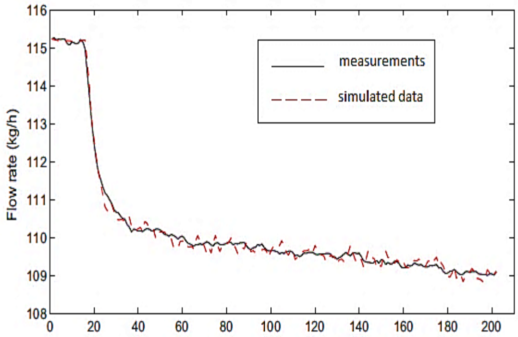

Figure 3. Comparison of gas pipeline outlet flow

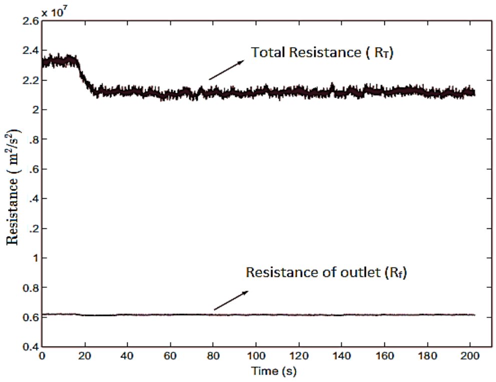

Figure 4. Change in resistance of a pipeline to a leak