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Exposure Zone Determination from gas pipeline lekage using CFD

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Abstract: The transportation of gas through pipelines is complex process and possess risks of leakage. The design and supply chain of gas pipelines should be properly done in order to meet demands and reduce risks. The objective of current research is to investigate the effect of external air velocity on exposure zone of methane air from gas pipeline leakage. The CAD modelling of exposure zone as computational domain is developed in Creo parametric software and CFD analysis is conducted using ANSYS v21 software. The results have an increase in exposure zone with increase in external air velocity. The methane exposure zone for 5m/s is found to be .14m whereas for external air velocity of 10m/s the exposure zone of .17m is found.

Key Words: Pipeline distribution, safety, gas leakage

1. INTRODUCTION

Pipeline systems are divided in three major categories based on the type of fluid transported: oil pipelines (both crude and refined petroleum), natural gas pipelines and others (water, chemical, slurry, etc.) [1]. When compared with other methods of transportation, such as tankers, railroad, trucks, etc., it has been stated that the transportation of oil, gas and their products through pipelines is still safe and economically efficient [2]. Although most pipes are made from steel, some oil pipelines and distribution lines can be also made from plastic materials. Pipe diameters vary from 4 to 48 inches (102-1219 mm) for oil pipelines and 2 to 60 inches (51-1524 mm) for gas pipelines, where small diameters are used for gathering and distribution lines Several standards, issued jointly by the American National Standards Institute (ANSI) and American Society of Mechanical Engineers (ASME), are used to design pipelines in the United States.

The standards are:

- ANSI/ASME Standard B31.1, Power Piping [4]
- ANSI/ASME Standard B31.3, Chemical Plant and Petroleum Refinery Piping [5], which is applied to main onshore and offshore facilities worldwide.
-ANSI/ASME Standard B31.4, Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols [6].
-ANSI/ASME Standard B31.8, Gas Transmission and Distribution Piping Systems [7].

The first step in the design of a new pipeline is projecting the route based on the original and destination points, so that topography of the pipeline route can be determined. Subsequent major steps in piping design require input parameters, such as [8]:
- Volumetric flow rate of the fluid carried by pipe
- Fluid type, temperature and quality
- Maximum operating pressure for the pipeline
- Minimum pressure required at the destination points
- Ambient temperature

2. LITERATURE REVIEW

Welch et al. [9], for example, proposed to deal with this problem by using other fuels and optimizing a number of scheduled interruptions whenever the gas flow broke down. In addition, they showed that the availability of large industrial contracts was an important factor in containing the peak demand.

More recently, Contesse, Ferrer, and Maturana [10] conduct a study on the natural gas supply chain, in which they infer that the changes in the gas industry regulatory system have lead to several alternatives for absorbing demand fluctuations based on contractual strategies of, for example, the use of storage facilities. They mainly refer to two types of contracts: (a) a sale customer contract on a supply interruptible basis in which customers have their gas supply shortened during periods of peak demands in exchange for a lower price; and (b) the firm transportation contract, which allows shippers to reserve a portion of the pipeline's total delivery capacity for their own use.

From the mathematical programming perspective, some attempts, although few, have been made in the direction of mathematical planning models for the line-packing problem [11, 12, 13, 14, 15]. For instance, de Nevers and Day [11] examine the natural gas pipeline inventory from a mathematical perspective to match time-varying demands with supplies in an unsteady-state pipeline network system. Their study is based on two dimensionless parameters for the packing and drafting behavior. As a result, their model is capable of showing the limits of the line-pack line-drafting for a single pipeline segment.

Carter and Rachford [12] discuss several control strategies to operate pipeline network systems through periods of fluctuating loads. Their study aims at finding an optimal schedule for the line-pack under uncertain demand assumptions. As a result, they provide a number of possible scenarios with specific schedules for modifying the set-point values of compressor stations.

Krishnaswami, Chapman, and Abbaspour [13] present a simulation approach for optimizing pressure units of compressor stations to meet a specific line-packing along transient, non-isothermal pipeline network systems. They first formulate an implicit finite difference model to provide a flow capacity analysis, and then propose a nonlinear programming model to minimize the average fuel consumption rate of each compressor station over a given planning horizon. The model is solved by applying a sequential unconstrained minimization technique based on a directed grid search method that solves the unconstrained subproblems. Due to the complexity of problem, their study is, however, limited to a linear (gun-barrel) pipeline network system with two compressor stations composed of three compressor units each.

Frimannslund and Haugland [14] follow the ideas presented in the work of Carter and Rachford [12], and propose a mathematical formulation to cope with line-packing levels for a pipeline network system in steady-state conditions. Their study is based on homogeneous gas batches, a concept introduced in [28]. The concept refers to the creation of a number of batches (gas packages) inside the pipelines for their future scheduled withdrawal. The "homogeneous" term in turn establishes that all gas batches are made of the same gas composition no matter when they are constructed, thus implying the assumption that all gas sources in the network provide gas of the same quality. Due to this assumption, no quality constraints on the transported and delivered gas was required. According to [14], a blending process between the batches inside the pipeline seems to be unrealistic unless a long lasting shortfall in downstream capacity takes place.

3. OBJECTIVES

The objective of current research is to investigate the effect of external air velocity on exposure zone of methane air from gas pipeline leakage. The CAD modelling of exposure zone as computational domain is developed in Creo parametric software and CFD analysis is conducted using ANSYS v21 software.

4. METHODOLOGY

The CAD model of gas leakage computational domain is developed using Creo design software. The developed CAD model is then imported in ANSYS design modeler (.iges file). The imported CAD model of gas leakage computational domain is shown in figure 1 below.

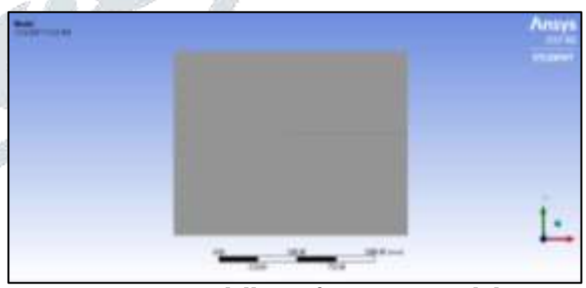

Figure 1: CAD modelling of computational domain

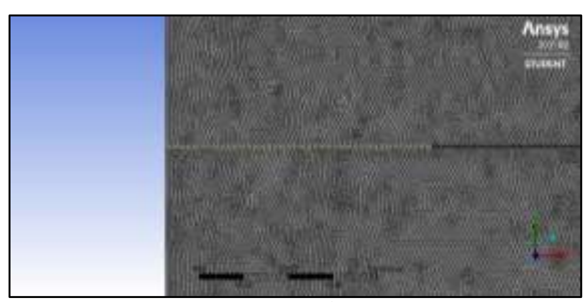

Figure 2: Discretized model of computational domain

The computational domain of gas leakage domain is discretized using tetrahedral elements. The number of elements generated is 199445 and number of nodes generated is 51547.

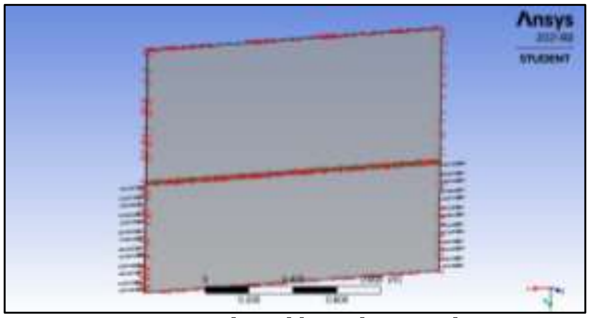

Figure 3: Loads and boundary condition

The fluid domain of gas leakage computational domain is defined. The domain definition includes reference pressure definition of 1atm, the turbulence model used in the analysis is k-omega. The external air velocity of 5m/s is defined and gas leakage velocity of 213.4m/s is defined.

5. RESULTS AND DISCUSSION

The CFD simulation is conducted to determine thermal and fluid flow characteristics of exhaust gases. The temperature plot at 5m/s external air velocity is obtained as shown in figure 4 below.

Figure 4: Temperature plot for 5m/s

The mass fraction plot is obtained for N_2 gas and CH_4 gas. The exposure zone of these 2 gases are determining from CFD results. The contour plots are shown in figure 5 and figure 6 below.

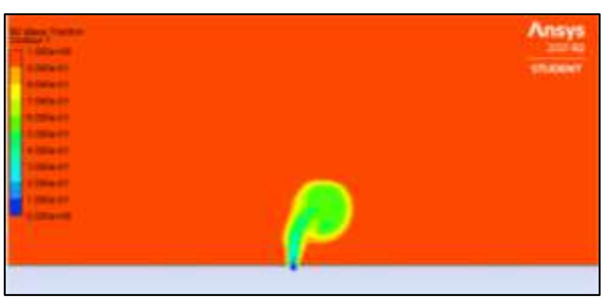

Figure 5: N_2 mass fraction plot for 5 m/s

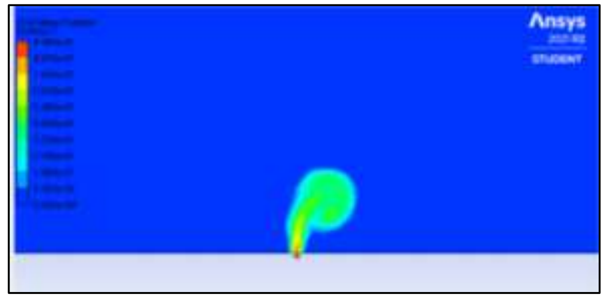

Figure 6: CH_4 mass fraction plot for 5m/s

The exposure zone of methane gas is hazardous and its found to be 0.14m. The similar analysis is conducted at 10m/s external air velocity.

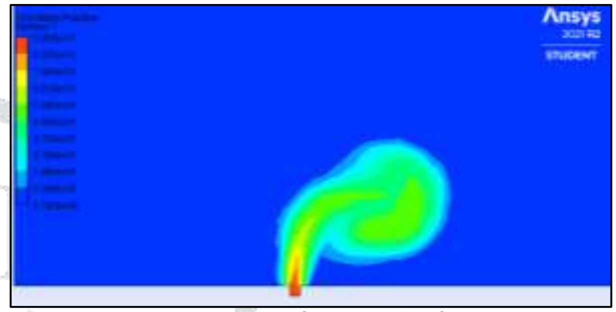

Figure 7: CH_4 mass fraction plot for 10m/s

The CFD results are obtained for external air velocity of 10m/s as shown in figure 7 above. The plot shows exposure zone of .17m. The similar analysis was conducted for 20m/s external air velocity to determine mass fraction and exposure zone.

6. CONCLUSION

The CFD is a viable tool in determining fluid flow characteristics of exposure zone from gas pipeline. The temperature and mass fraction of methane gas is determined for different external air velocity. The results have an increase in exposure zone with increase in external air velocity. The methane exposure zone for 5m/s is found to be .14m whereas for external air velocity of 10m/s the exposure zone of .17m is found.

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