Numerical Simulation Of Natural Gas Leakage From Pipelines

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Abstract: **-** Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane. It is a flammable, explosive, poisonous and harmful gas. One easy method to import gas from a faraway location is to transfer it through gas pipe lines. These pipe lines may run underground as well as under water. There are cases where the pipe lines are exposed to ambient also. Due to severe atmospheric conditions, high gas pressure and accidents, there are instances of pipe line explosion resulting in gas leakage. This may cause poison death of human beings as well as other living creatures and environmental pollution. This work involves the model and analysis of a small segment of natural gas pipe line and to find out the range of diffusion of natural gas in vertical direction subjected to different pipeline outside conditions such as 1)when surrounded by air 2) when surrounded by sea water. ANSYS Design Modeler is used for modeling and ANSYS FLUENT is used to analyze the problem. The species transport and chemical reaction processes are considered in the analysis. Various graphs and contours are plotted to study the effect of changes in values of variables like wind velocity and leakage hole diameter.

Keywords: natural gas, Pipeline leakage, , CFD analysis

I. INTRODUCTION

Natural gas is a fossil fuel formed when layers of buried plants, gases, and animals are exposed to intense heat and pressure over thousands of years. Natural gas is a hydrocarbon gas mixture consisting primarily of methane, but commonly includes varying amounts of other higher alkanes and even a lesser percentage of carbon dioxide, nitrogen, and hydrogen sulfide. Natural gas is an energy source often used for heating, cooking, and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

Because of its low density, it is not easy to store natural gas or to transport it by vehicle. Pipelines are usually the only feasible way to transport significant volumes by land over long distances. Pipelines are generally the most economical way to transport large quantities of oil, refined oil products or natural gas over land. Since oil and gas pipelines are an important asset of the economic development of almost any country, it has been required either by government regulations or internal policies to ensure the safety of the assets, and the population and environment where these pipelines run. Pipeline companies take their responsibility seriously to ensure safe and reliable operations.

However, cases involving failure of pipes carrying highly combustible fuel such as natural gas are occasionally reported. High pressure natural gas transmission pipeline (API 5L X60) in northern part Pakistan and a T-shape natural gas pipeline network (API 5L X52) near gas extraction plant in northern Mexico are two examples of such cases. In both cases the material degradation causes by corrosion is the main factor that contribute to the failure of the pipes.

II. EAST WEST GAS PIPELINE INDIA

For this project, East West Natural gas pipeline in India is selected for analysis. East West Gas Pipeline abbreviated as EWPL is a project implemented to transport gas from Kakinada (Andhra Pradesh) to Bharuch (Gujarat) including various spurs and interconnects on the way. EWPL traverses through the Indian states of Andhra Pradesh, Karnataka, Maharashtra and Gujarat. The pipeline system features multiple compressor stations, numerous metering facilities at branch take-offs and an advanced control and communications network. The project is the first and largest privately owned cross-country pipeline in India and the backbone of India's burgeoning natural gas grid.

The current gas source for EWPL is KG-D6 gas block located in Krishna Godavari Basin, 30 to 50 km offshore of the east coast of India. RIL has set up an Onshore Terminal at Gadimoga near Kakinada. EWPL is a **48** inch uniform diameter (API 5L Grade X-70) pipeline across the entire trunk length of around **1375** km with wall thicknesses 17.2, 20.7 and 25.4 mm depending on the code requirement. Maximum Allowable Operating Pressure (MAOP) of the pipeline is 98.0 bar(g).

Eleven compressor stations (CS) have been installed along the length of pipeline for transporting design capacity of **80 MMSCMD** of natural gas. Main facilities provided at a CS comprise of gas turbine driven compressors (GTCs), gas after-coolers, scrubber, fuel gas conditioning system, scraper traps, gas blow-down system, fire alarm and firefighting system, instrumentation and control system, gas engine generators (GEGs), emergency diesel engine generator (DG), buildings and other utilities. The trunk pipeline route of EWPL crosses **18** National Highways, **66** State Highways, **708** roads, **17** railway lines, and **372** rivers and canals. The route of East West gas pipeline in India is shown in the figure below.

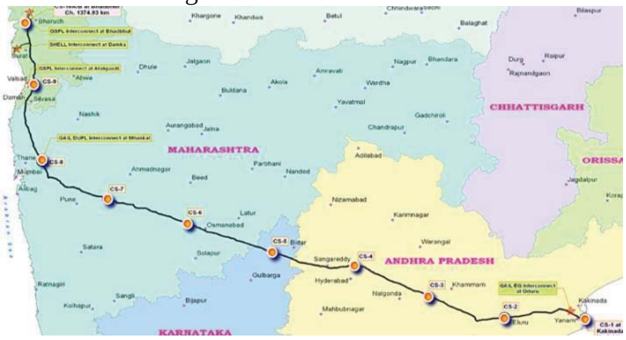

Fig. 1 Route of East West Natural Gas Pipeline (India)

III. MODELLING AND ANALYSIS

1. Geometric Model

The domain and the meshes were created using ANSYS 14.5 software. The domain is created with dimensions taken from the real gas pipeline (East west gas pipeline). The outer diameter of the pipe is 1219.2mm and the thickness is 17.2mm. We have taken a small section of the pipe for our analysis that is 4m in length. At 2 m from one end a leakage hole is created. The diffusion volume is created around the pipeline as a cube of 3*3*3m^3 volume.

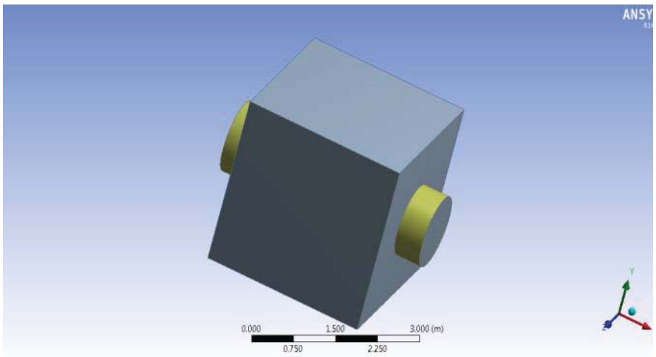

Fig.2 Computational domain

All the surfaces are named. A tetrahedron meshing approach was used to create the mesh. Refinements were made in the vicinity of the junction to resolve the rapid changes in the flow occurring there. Controlled meshing is done with edge sizing of .05m and face sizing of .5m is given. In mesh 24702 nodes and 134130 elements are there.

2. Boundary conditions

The maximum allowable operating pressure of the pipeline is 98 bar. In this analysis the inlet pressure is taken as 93bar by giving a factor of safety. At inlet species concentration is taken as 1 which indicates that only methane gas is present in the inlet. At exit pressure outlet is taken as the boundary condition. For the first condition one face of the cube is taken as the wind inlet and all other faces are taken as pressure outlets. This is done to study the variation of natural gas diffusion in vertical direction by changing the velocities of the wind. For the second condition one face of cube is taken as the mass flow inlet and all other faces are taken as pressure outlets. This is done to study the variation of natural gas diffusion in vertical direction by changing the mass flow rate of seawater. The pipe surface is given as wall and heat transfer conditions are not given as there is no heat transfer for the pipe to the atmosphere or vice versa. A summary of the boundary conditions can be found in figure below. Leakage hole diameter is also changed for the analysis of influence of hole diameter in diffusion range.

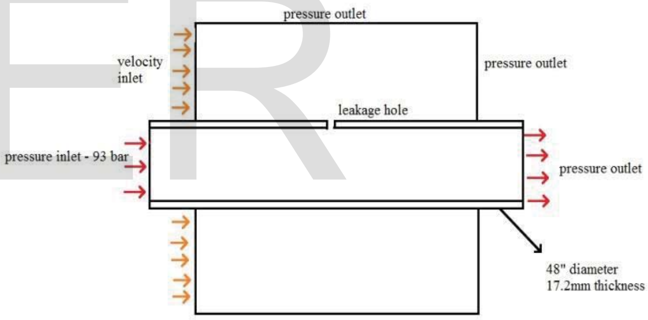

Figure 3: Boundary Conditions

3. Results and post-processing

The contours of mass fraction of methane under different wind velocity and the concentration of methane in the upward direction from pipe hole is also shown in graph. The area with more than 5% methane is considered as the risky area for explosion. The mass flow rate varying with different wind velocity is also shown in graph. The contours of mass fraction of methane by changing hole diameter is also shown below.

3.1 When pipeline is exposed to ambient

In the first condition the medium surrounding the pipeline is air. The diffusion of natural gas through air at different wind velocities such as 0m/s, 1.5m/s and 3m/s is determined. When the gas leaks from the pipe through a hole we obtain a contour of species showing concentration of mass fraction of CH_4. It can be seen that for different wind velocities the contours obtained are different.

Figure 4: contours of mass fraction of methane at wind velocity 0m/s

The simulation is again repeated by changing the hole diameter to 0.05m to find out the effect of hole diameter in natural gas diffusion range.The contours obtained by changing the hole diameter is shown below.

Fig. 5 Contours of mass fraction of CH_4 with wind velocity 0m/s and hole diameter 5cm

From the above contour it is found that the diffusion of natural gas in vertical direction increases with increase in hole diameter. Therefore, it can be concluded that both wind velocity and leakage hole diameter are significant factors in determing the diffusion range of natural gas in vertical direction.

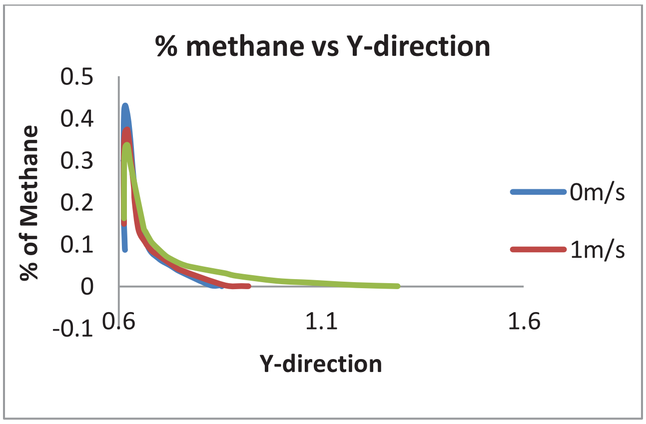

Fig. 6 variation of % of methane along vertical direction for different wind velocities.

From the above graph it is found that the diffusion range of natural gas is found to be increasing with increase in wind velocity. The diffusion in vertical direction changes from 0.85m to 1.3m when the wind velocity increases from 0m/s to 1.5m/s.

3.2 **When pipeline is surrounded by sea water**

In this condition the medium surrounding the pipeline is sea water. The diffusion of natural gas through sea water at different mass flow rates of sea water such as 0kg/s,1.5kg/s and 3kg/s are found out. It can be seen that for different mass flow rate of sea water the contours obtained are different.

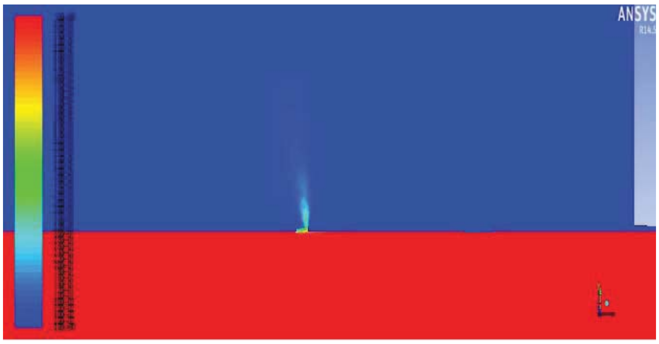

Fig. 6 Contours of mass fraction of CH_4 with mass flow rate 0kg/s and hole diameter 5cm

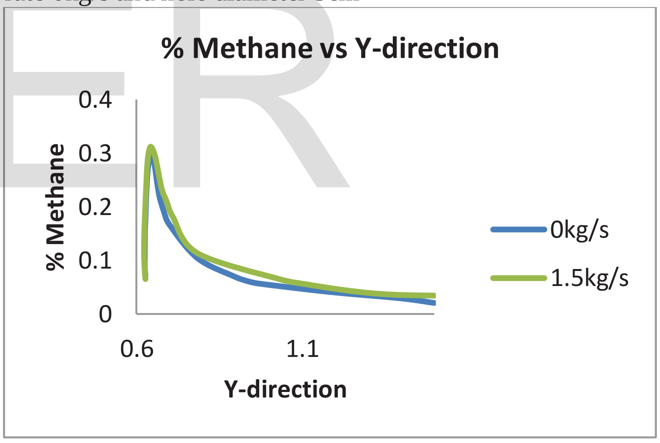

Fig. 7 variation of % of methane along vertical direction for different sea water mass flow rate

From the above graph, Natural gas is found to be diffusing in the upward direction and reaches the topmost level in all cases.But the concentration of methane at a particular point is found to be increasing with increase in mass flow rate of sea water.

IV. CONCLUSION

The results obtained from the modelling and simulation analysis suggest that Numerical Simulation with softwares like ANSYS and FLUENT can be used to analyze the extent of natural gas leakage in vertical direction. It can also be understood that wind velocity and leakage hole diameter has significant influence on the diffusion range of natural gas in vertical direction and the various graphs plotted quantify the relation between the wind velocity and height of spread of natural gas leakage. By specific test, the use of different wind speed and different concentration of natural gas simulation, can give more scientific understanding of gas leakage process.

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