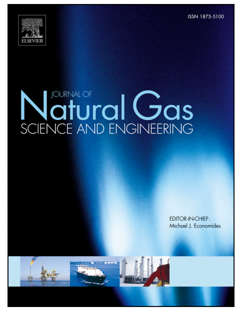
Accepted Manuscript



Simulation of steady flow of natural gas in a subsea flexible riser with heat exchange

Navid Pouladi, Helge Heitmann

PII: S1875-5100(17)30345-1

DOI: 10.1016/j.jngse.2017.08.012

Reference: JNGSE 2275

To appear in: *Journal of Natural Gas Science and Engineering*

Received Date: 26 February 2017

Revised Date: 15 July 2017

Accepted Date: 15 August 2017

Simulation of steady flow of natural gas in a subsea flexible riser with heat exchange

Navid Pouladi*, Helge Heitmann*

* National Oilwell Varco-APL, Arendal, Norway

Abstract

Flexible riser technology is widely used in today's offshore industry. Evaluating pressure, temperature and velocity profiles in a subsea riser or a flexible pipe is essential in the design of a gas transfer system. Conventional pipeline correlations fail to give an acceptable accuracy for sizing, design and flow assurance applications of flexibles. Hence, availability of a rather simple computational model, which can give results with acceptable accuracy is highly advantageous. The aim of this article is to present a simple numerical method which can be used efficiently to accomplish this goal. A one dimensional finite difference method is used where the riser length is discretized into small segments. Natural gas physical and transport properties are calculated in each segment and flow equations in addition to a state equation are solved simultaneously to find the velocity, pressure and temperature profiles in the flexible riser. The Lee-Kesler corresponding states EOS has been used as the state equation. Mathcad™ has been applied for solving equations. The ability of the model to predict thermodynamic properties of natural gas has been compared with experimental data. Further, friction and heat transfer models for a smooth and rough bore riser have been analyzed. For a rough bore riser with carcass corrugations, selecting a reasonable value for the equivalent sand grain roughness has been found to be crucial. The authors has also found the Joule-Thomson effect to be decisive in temperature change for a high pressure rough bore flexible gas riser subject to high pressure drop

Keywords: Flexible riser, Natural gas, Lee Kesler equation of state, Friction factor, Numerical model, Pressure drop

1. Introduction

The task of gas flow in a subsea flexible pipe or riser is a subcategory of the major task of gas flow in a subsea pipeline; although there are some basic differences regarding the configuration and nature of flow path of a subsea riser compared to a subsea pipeline, which will be discussed here.

Finding pressure, temperature and velocity profiles for a gas pipeline has been an issue for engineers in the past decades as natural gas has got a larger portion in the world energy supply. During the past century, engineers have developed analytical methods with simplifying assumptions for ease of use, e.g. AGA, Weymouth, Panhandle etc. Many of these correlations are overgeneralized by assumptions and approximations, beside the use of inaccurate friction factor correlations (Ouyang & Aziz, 1996). Ouyang and Aziz reviewed conventional equations and suggested new equations which takes into account the effect of kinetic and potential energy changes as well as a more accurate correlation for friction factor. More recently Abdolahi et al. (2007) reviewed existing correlations and evaluated the effect of different model parameters such as pipe roughness and velocity profile correction factor and suggested and verified a numerical model to predict gas flow in buried gas pipelines. Nouri-Borujerdi and Ziaei-Rad (2009) investigated heat transfer from high pressure buried gas pipelines and suggested a numerical model for solution of the gas flow. Chaczykowski and Osiadacz (2012) examined analytical and numerical gas flow models and compared the results with measured data from the pipeline. Recently Lopez-Benito et al (2016) used a numerical method to predict pressure, temperature and velocity profiles in a natural gas pipeline and compared the results with field data and previous works.

There is a good number of publications available for calculations of pipeline gas flow, some mentioned above. However, for a flexible riser as a relatively novel technology this is not the case. Flow calculation methods used for pipeline cannot directly be used for a flexible riser. A subsea riser used to transfer gas between the seabed and a floating vessel is exposed to the sea current and this