ABSTRACT

Reliable operation and monitoring of subsea pipelines rely on accurate modelling of the flow as well as good measurements. While one-dimensional pipeline models have been made highly accurate they make use of simplifications and are dependent on an accurate description of the surroundings. For a subsea pipeline the degree of burial can vary, the exact properties of the soil may be lacking for parts of the pipeline, and one typically has to rely on an oceanographic model for the ambient temperature. Uncertainties in the input reduce the accuracy of the modelling, however information of the inaccuracies of the model can be obtained by analyzing the historical differences between modelled and measured parameters. This paper makes use of multivariate analysis to analyze the inaccuracies of a one-dimensional flow model and shows how it can be used to improve the predictive power of the flow model.

KEY WORDS: Pipeline modelling, subsea pipeline, multivariate analysis.

INTRODUCTION

One-dimensional pipeline models offer an accurate description of flow in the system. The level of accuracy desired may lead to need for improved metering or a more detailed description of the pipeline profile, as well as increasing the complexity of the flow models (Ytrehus and Helgaker (2013)), or the modeling of heat transfer between gas and ambient (Chaczykowski (2010)). In addition one may benefit from more accurate real-time data for the temperature of the ambient (Hendriks et al. (2006) & Sund et al. (2015).

Pushing the boundaries may be expensive compared to the increased accuracy, and may depend on the involvement from third-parties, such as developers of oceanographic models. However, pipeline operators themselves have information on how their models compare to measurement data, and can make use of this information to improve the simulation system.

Multivariate data analysis (MVA) refers to any statistical technique used to analyze data that arises from more than one variable. Multivariate methods can be used to reveal hidden structures in data and find new relations between existing parameters. This paper shows how to use MVA to improve the predictive power of one-dimensional pipeline models. The deviations between modelled and measured data are monitored and an ordinary least squares (OLS) method is used to make an improved model of inlet pressure and outlet flow and temperate. This model is then used to generate new and improved predictions.

PIECELINE MODEL

Governing equations

An overview of the governing equations for one-dimensional pipe flow can be found for instance in Thorley and Tiley (1987). The governing equations for one-dimensional compressible viscous heat conducting flow are found by averaging the three-dimensional equations over the pipe cross-section. The result is

Continuity

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} = 0$$  \hspace{1cm} (1)

Momentum

$$\frac{\partial (\rho u)}{\partial t} + \frac{\partial (\rho u^2 + p)}{\partial x} = -\frac{f \rho u |u|}{2D} - \rho g \sin \theta$$  \hspace{1cm} (2)