Investigation into Sand Deposition and Transportation in Multiphase Pipelines

Ciaran Spillane

Jeremy Leggoe
School of Mechanical and Chemical Engineering

CEED Client: Woodside Energy Ltd.

Abstract

The transportation of sand within multiphase pipelines can pose significant problems in the oil and gas industry. Sand particles tend to settle out of suspension leading to the formation of stationary or mobile beds along the bottom of pipelines. Such beds provide an environment susceptible to increased corrosion rates and can also pose flow assurance problems. Woodside has recognised this issue as an area where further research could help to improve pipeline design in industry. This project aims to investigate the behaviour of sand in various flow scenarios. An experimental apparatus has been designed and will be used to generate a comprehensive database which will be used to improve currently available sand transportation preditction models.

Upon completion of the experimental apparatus, testing will cover a range of flow rates, pipe angles and sand particle sizes. Possible future work branching from this project will introduce the testing of varying pipe sizes and internal coatings to provide data over a wider range of flow conditions.

1. Introduction

The presence of sand in multiphase oil and gas pipelines can pose a significant design issue in the oil and gas industry. The majority of oil and gas production worldwide is from sand formations, where there is always a risk of sand being produced out of the well. Even where downhole sand exclusion systems have been implemented to prevent sand production, the pipeline design should consider the potential failure of such systems. One such design consideration is to ensure that sand particles in the pipeline remain in suspension, and do not settle out as a moving or stationary bed along the bottom of the pipe, as shown in Figure 1.

A build-up of sand along the bottom of the pipeline as either a stationary or mobile bed creates an area susceptible to accelerated corrosion, either microbial due to oxygen depletion, or erosion based (Danielson 2007). Over time the build-up can also lead to significant frictional losses as well as flow assurance problems. The increased risk of corrosion warrants the use of additional corrosion protection methods, which can result in significantly increased capital expenditure and operational costs for projects. Without careful monitoring and maintenance, build-up of sand also has the potential to affect production rates.

This project aims to investigate the transportation of sand in multiphase pipelines, by creating a range of experimental data for use in pipeline design. Testing in a flow loop experimental apparatus over a range of conditions will be used to generate a comprehensive database to enable better models in predicting the onset of sand bed formation.

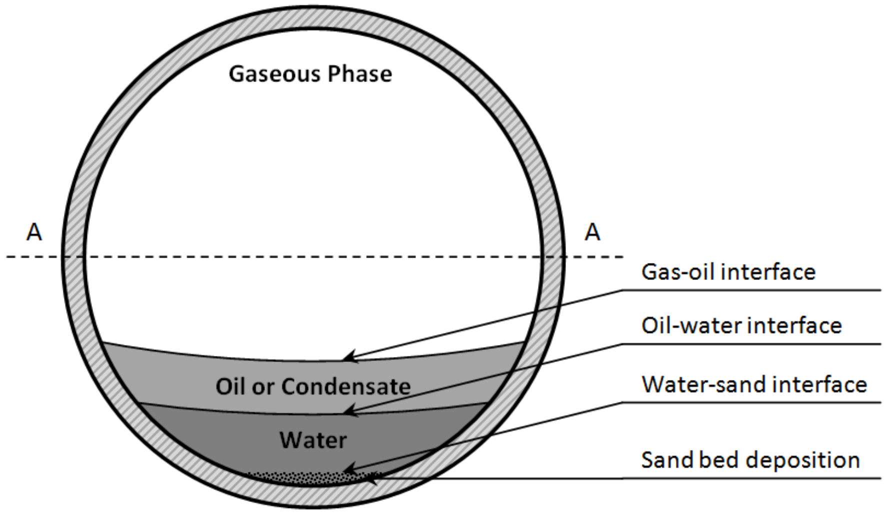

Figure 1 Section view of a pipeline showing sand bed deposition in a stratified multiphase flow scenario. Not to scale.

During the course of the project only the water-sand interface will be considered, with experiments to be conducted in a half-pipe open channel flow path (the pipe will be cut at its mid-plane AA in Figure 1). This approach is justified as prior research has shown that sand is directly affected by the aqueous phase in a pipeline, and the gaseous phase in a multiphase flow does not directly affect the water-sand interaction (Danielson 2007). Furthermore, multiphase flow at low velocities tends to be stratified as in Figure 1, so that the presence of an oil phase does not directly affect the water-sand interaction. The use of water also minimises potential HSE risks involved with the project and the open channel setup of the flow loop enables direct observation of sand transportation behaviour during testing.

With extensive operations and planned developments in Western Australia, Woodside's interest in improving pipeline design and performance is increasing. Addttionally, more oil and gas developments are in deeper waters where the design of subsea pipelines becomes increasingly critical. Data obtained through this research can be used to improve pipeline design in terms of economic efficiency as well as environmental sustainability, and to provide better solutions for the future of the oil and gas industry.

1.1 Background Information

Various sand transportation models for the design of pipelines are currently in use throughout the oil and gas industry, with constant development occurring. These models predict the critical velocity at which the onset of particle settling begins. Two well known models are the Wicks and Oroskar & Turian models (Wicks 1971; Oroskar et al. 1980).

The Wicks model was developed through analysis of the four fundamental forces acting on a submerged solid particle (drag, lift, gravitational and buoyant forces) with supporting experimental data. However, this method did not account for particle diameter (Danielson 2007), and the sand concentrations tested were significantly greater than those of interest for this project (Wicks 1971, p. 107). For this project sand concentrations of 1% or less by volume will be considered. The Oroskar & Turian model was also developed using relatively high sand concentrations.

A more recent model created by Danielson was based on extensive data collected by an independent research organisation, SINTEF, and took into account particle size and lower solids loading (Danielson 2007). This model also accounted for varying degrees of pipe inclination, but only tested one pipe diameter.

These existing models, and others not mentioned here, provide a strong basis for further research into the transport of sand in pipelines. This project aims to improve the range of flow conditions covered; flow rate, fluid level, particle size and pipe inclination will all be varied to build a comprehensive database. Possible further research branching from this project will introduce the variables of pipe diameter and internal pipe coating, which could yield a viable design alternative for pipelines to lower the critical velocity required to avoid sand deposition.

2. Experimental Setup

In order to achieve the project objectives outlined above an experimental test apparatus was required. The design of this test rig has accounted for much of the project timeline so far and its construction marks the transition from a design based project to an experimental one. Extensive calculations have been carried out to ensure the test rig meets the requirements for the desired range of flow conditions to be tested.

A simplified schematic is given in Figure 2, showing the major components of the test rig. An upstream reservoir tank supplies water to the half-pipe water channel. The tank is designed with a number of baffles to aid in calming the water before it enters the channel. This channel is hinged at one end to allow small inclinations to be made, and will also incorporate a sand delivery system. In this channel the water and sand will flow freely for 4.25m, inclusive of a 2m section for observation of any sand deposition. The length of the channel was heavily dependent on the length of the entrance region of flow from the reservoir tank. This entrance length was taken to be roughly 10 times the pipe diameter based on research by Rajaratnam et al in 1991. The test rig is designed to allow various channel sizes to be tested; from 100 to 225 mm diameters. The largest channel size will be used initially.

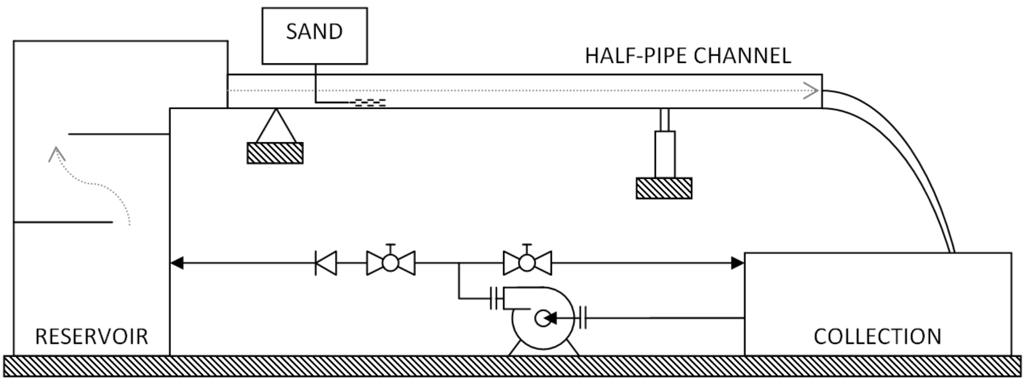

Figure 2 Simplified schematic showing major components of the test rig design. Not to scale.

The water and sand mixture will flow from the test channel into a collection tank where it will be filtered. A pump system has been designed to return the water to the reservoir tank in order to maintain a closed loop system. The system curve and chosen pump curve are illustrated in Figure 3. The pump is to be controlled by a variable speed drive, with a split path throttling setup used as a backup control measure.

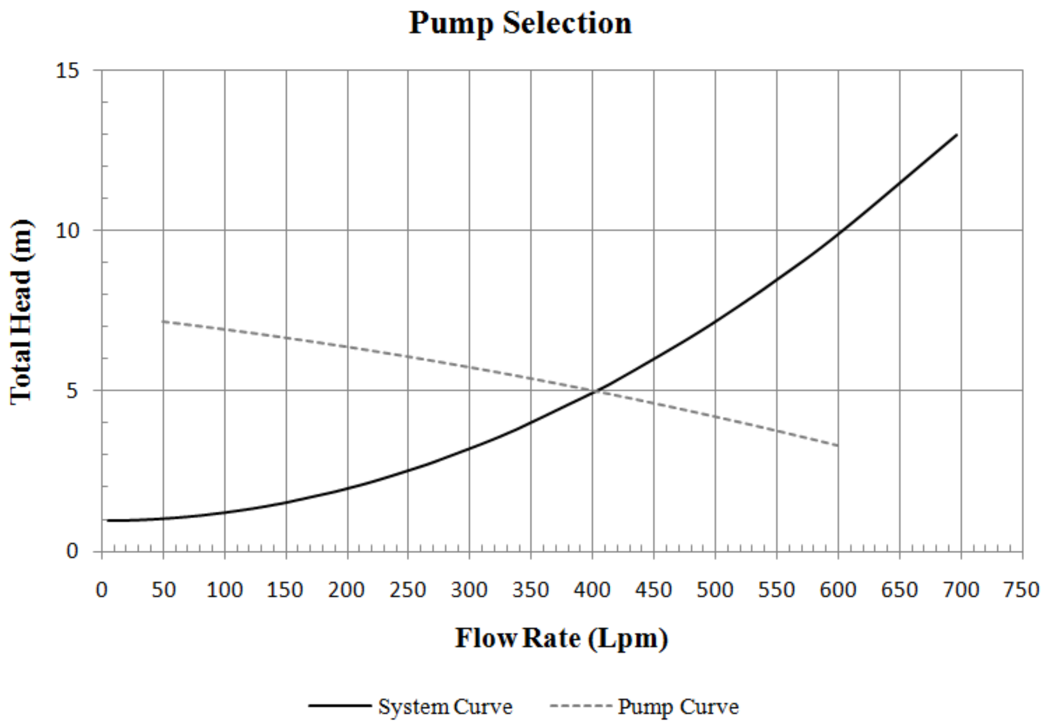

Figure 3 **Pump selection curves showing a maximum operating point of 400 Lpm. A variable speed drive will be used to run tests at lower rates.**

Once the water has returned to the reservoir tank, it will rise to the desired level courtesy of the pump. An overflow system has been utilised to ensure the tank or channel will not overflow if the pump is run too fast.

From the design specifications a 3D model of the test rig was developed using SolidWorks. The final design model is given in Figure 4. This model was then used to produce detailed engineering drawings to be used to construct the test rig.

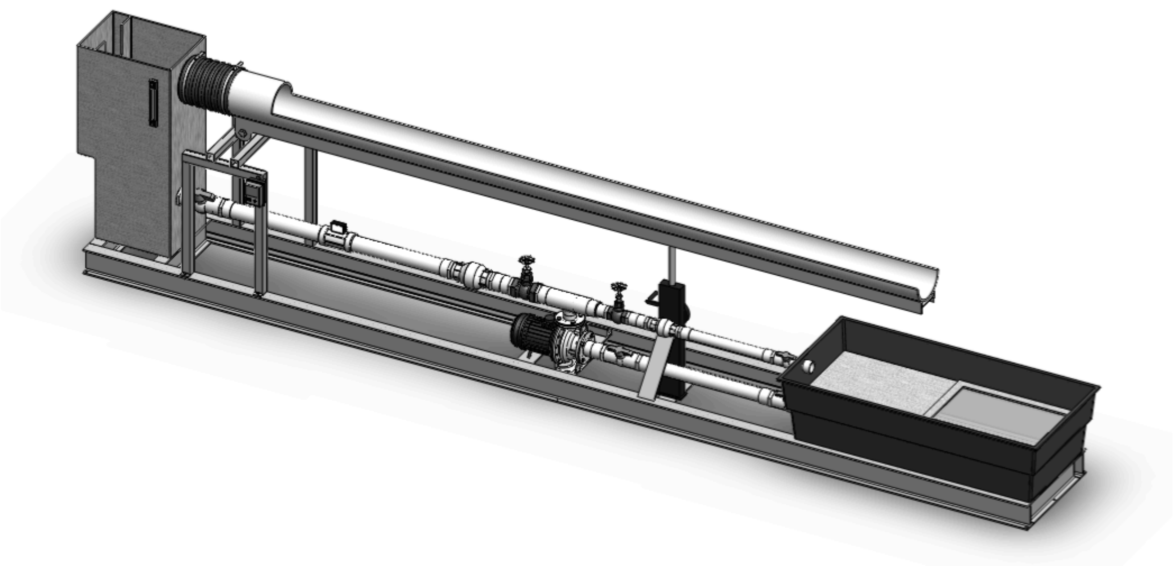

Figure 4 **Final SolidWorks 3D model of the test rig. Detailed engineering drawings were produced from this model and supplied to the UWA Mechanical workshop technicians.**

At the current stage of the project the test rig is being constructed by the UWA workshop technicians. Figure 5 depicts the progress thus far.

Figure 5 Test rig under construction in the mechanical workshop. All major components have been delivered and construction is scheduled to finish at the end of September.

3. Discussion

As much of the project timeline to date has been required for design and fabrication of the test rig no tests have yet been run. The successful design of the test rig, within the allocated budget has been identified as a significant sub-objective of the project and its completion represents a major milestone.

One important aspect of the project has also been coordinating materials procurement with multiple suppliers through the UWA Mechanical and Electrical workshops. This side of the project has been a difficult yet valuable experience, and has progressed relatively smoothly so far.

The completion of the test rig will represent the next major milestone for the project, and will allow the experimental stage to begin. The completion of the test rig also offers new opportunities for future work in the field of particle transport in multiphase flows.

4. Conclusions and Future Work

With the construction and set up of the experimental apparatus still under way no results have been collected to date. During the remainder of the construction stage, work will focus on clearly defining the range of tests required to meet the project objectives. An experimental matrix will result from this and testing will begin as soon as the test rig has been completed, and its pumping system calibrated.

Introduction of sand particles and measurement of key variables will be explicitly defined before testing begins to ensure consistent and reliable sand injection is obtained, leading to reproducible results.

The availability of the test rig will lead to future work opportunities upon the conclusion of the project. Likely work may introduce the testing of various internal pipe coatings and may be carried out in different pipe sizes. Such work would further aid in the design of multiphase pipelines to avoid sand particle deposition.

Further work could also be carried out to investigate the dynamic similarities between the simplified water and sand used in this project and more realistic oil and gas mixtures.

5. Acknowledgements

In addition to his academic supervisor and client mentor, the author would like to thank the UWA workshop and finance staff for their assistance throughout the project. In particular Michael Armstrong, Gerald Wright, Derek Goad and Shae Harris whose input on the project made its progression possible. Finally, the author would like to thank the CEED Office and Woodside Energy Ltd. for awarding and supporting the project.

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