Susceptibility of Flexible Flowlines to Sand Erosion

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Abstract

Sand entrained in produced well fluids has the potential to cause both expensive and dangerous equipment failure. Accordingly, the ability to directly measure the consequences of sand production remains a major business opportunity. However, predicting and measuring sand production rates is difficult, and it has been suspected that the Roxar acoustic sand detection monitors which are installed on the Cossack Pioneer Floating Production, Storage and Offtake (FPSO) vessel are currently over-estimating sand production. The ability to monitor sand production quantitatively is essential in generating an important input parameter for erosion predictions and sand alarm level settings. As such Woodside Energy Limited (WEL) are interested in evaluating the over estimation in the current sand monitoring system. This is being performed in the laboratory via experiments utilising produced sand entrained in water flowing past a Roxar SAM400 acoustic sand monitor placed on a re-circulating test rig. The results of this study will determine if the current sand alarm levels can be increased, if the produced sand rate is found to be less than is currently detected by the monitors. Hence, this study will aim to assess the accuracy in the calibration of the current monitoring system and endeavour to determine appropriate sand alarm levels to ensure safe operation and maximum production.

1.0 Introduction

During the production of hydrocarbons, it is not uncommon for small amounts of sand to be entrained in the reservoir fluids and carried through the production system back to the host facility. This sand can have significant undesirable effects on elements of the production system leading to damage, or in some cases, failure of critical elements. Quantitative sand monitoring provides useful input parameters for erosion predictions and sand alarm level settings. Hence, if the sand detection monitors are over estimating sand production, as is assumed to be the current situation on the Cossack Pioneer FPSO, then the alarm levels may be set too conservatively. This could result in restriction of production as the wells may be choked back in the event that sand alarm levels are exceeded. Woodside Energy Limited are thus interested in evaluating the re-calibration of the sand detection monitors. This information will also aid in gaining a greater understanding of the effects sand erosion will have on the susbsea production system currently in use within the Wanaea, Cossack, Lambert and Hermes (WCLH) oil fields, as well as on the topside equipment located on the Cossack Pioneer FPSO. The method employed to evaluate the over estimation is via laboratory experiments utilising a re-circulating test rig to assess the accuracy of the current sand monitor calibration against known quantities of sand.

2.0 Field Background

The WCLH oil fields are located in 75-120 metres of water, 125 km offshore north-west of Dampier and 35 km East of the North Rankin Alpha platform. Sand production to the Cossack Pioneer has only been considered as a very small possibility in the past. Initial results of core testing and petrophysical log analysis indicated that ongoing sand production was unlikely, and the majority of sand production was expected to occur during initial clean-up of the wells [1, 2]. However, since September 2002, the acoustic sand detectors, which are installed upstream of the test and production separators, have detected small amounts of persistent sand production, especially during transient flow conditions. According to the monitors, approximately 0.47m^3 (1250 kg) of sand has been produced during the period September 2002 to May 2003. However, the test separator was opportunistically opened in January this year, and only a fraction of the amount indicated by the monitors has actually been found in the process system (0.07 m^3, 186.17 kg) [3].

Past studies conducted by WEL [4] have evaluated the erosion impact of the sand production rates suggested by the monitors. Based on this information, in conjunction with the fact that only a very small amount of sand has been found in the test separator, there is no reason to suggest an integrity issue exists with current sand production rates. As such, it is widely accepted that there is 'no sand situation' on the Cossack Pioneer. However, sand production often increases over time as the field depletes and water production increases. When sand production increases, accurate measurement of sand rate will become more important to safely manage the production system and ensure maximum production.

3.0 Acoustic Sand Monitors

Acoustic sand detectors, as produced by such companies as Roxar and ClampOn, are a non-intrusive, strap-on instrument fitted to the outside of production piping. They are capable of detecting the presence of entrained sand through the noise generated by particles impinging on the inner surface of the production piping. The noise generated by flow and other external conditions is removed by digital filtering and an algorithm is used to convert the raw noise signal to a measure of quantity of sand particles flowing in the production pipe (gm/s) [5]. These values are then displayed on the system computer monitor in a graphical interface. A Roxar SAM400 sand monitoring system is being used in the experimental procedure, as this is the system currently in use on the Cossack Pioneer FPSO. An example of this monitor can be seen in Figure 1 on the right.

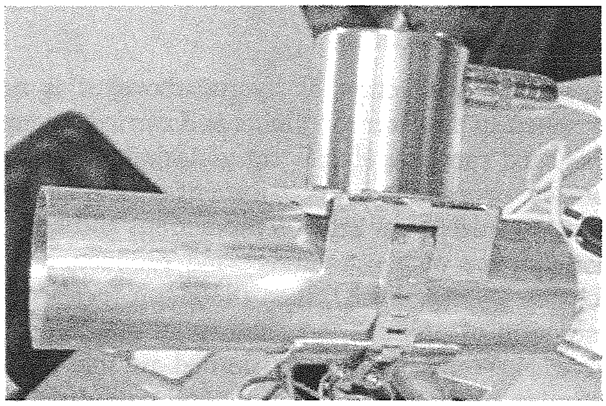

Figure 1: Photo of Roxar SAM400 dry service acoustic sand detector strapped to 3" section of test pipe.

The main advantage in using sand detectors is to safely aid in maximising production by determining maximum sand free production rates. They also provide an early warning of sand production so that quick remedial action can be taken before excessive erosion can pose a risk to safety or the environment. Quantitative sand monitoring gives engineers confidence that their sand control/management methods are working, and as a result, production from wells can be safely maximised.

4.0 Experimental Procedure

The sand monitor calibration is currently being evaluated in the laboratory via the use of a re-circulating test rig, as can be seen in the schematic in Figure 2. A Roxar SAM400 acoustic sand monitor will be calibrated as on the asset (basic field calibration) and strapped onto the test rig at various positions downstream of a 90 degree elbow. According to Roxar [5], best sensitivity is achieved very close to the bend as this is where impinging particles have maximum velocity. However, because the pipe itself is an excelent acoustic wave-guide the exact location of the detector relative to the bend is not critical, and hence several locations will be investigated. The experiment will utilse a sand sample representative of produced sand found in the test separator aboard the Cossack Pioneer. This sand will then be entrained in water and circulated past the sand monitor across water flowrates and sand concentrations of 1-5 m/sec, and 0-2 gm/sec respectively. These sand values are typical of operating envelopes experienced on the asset [4, 3], whereas the velocity range is restricted due to available pump size and capacity.

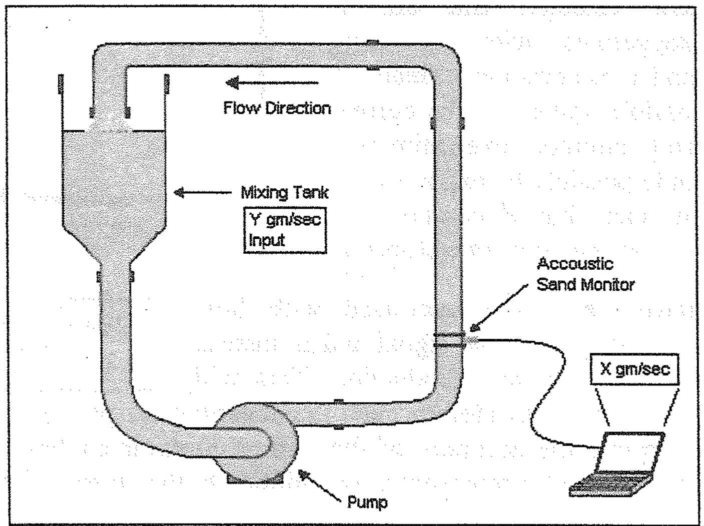

Figure 2: Schematic of re-circulating test rig setup.

As suggested above, it will be necessary to adjust and monitor several parameters during the experiment in order to obtain conclusive results. The water flowrate will be determined by the pump specification at various rpm's, and this flowrate value will be converted to a velocity of fluid flow past the sensor. Typical field injection calibration involves injecting a known quantity of sand (1 kg) upstream of the sand detection monitor and assessing the reading, while taking into account noise created by the flow conditions. This injected volume is incrementally reduced until the minimum detectable level is determined. The experiment in this paper will, however, use a novel variation of this procedure. Sand concentration will instead be gradually increased in steps of 0.2 gm/s. This is largely due to the fact that the test rig is recirculating and it is easier to increase, rather than reduce, the sand concentration, which would require flushing the entire system. The sand concentration will be calculated to a measure of gm/s flowing past the sensor considering the volume of water in the system as well as the flow velocity at that particular time. It will be assumed that the sand velocity is equal to the water velocity.

The results expected from this experimental study involve identifying the amount by which the current sand monitor calibration is over estimating sand production onto the Cossack Pioneer. This will be done by observing the trends in signal strength as a function of flow velocity and sand concentration compared to the actual volume of sand injected into the system. Graphical representation of similar results obtained on Roxar's test rig in Norway [5] can be seen in Figure 3 below. Since the sand detection system currently installed on the Cossack Pioneer lacks a flow velocity input, the system runs on a number of constant flow velocities. As can be seen from Figure 3, the monitor signal does not exhibit a linear relationship with respect to flow velocity, and this is exaggerated with increasing sand concentrations. Hence, a possible source of the current sand monitor overestimation could possibly be explained by the fact that fluctuations in flowrate can generate eroneous signals, as noise associated with flow dominates the noise signal and is instead mistaken for sand production. This will need to be confirmed through the experimental procedure. In addition to this, it will be possible to determine the accuracy of the current monitor calibration for known quantities of injected sand, which may also represent a contribution to the current over estimation in sand production.

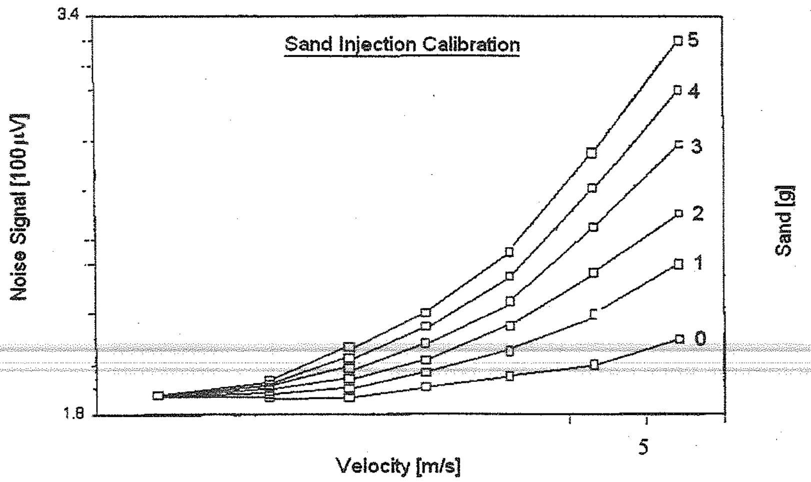

Figure 3: Noise signal as a function of flow velocity and sand concentration on Roxar's test rig.

5.0 Erosion Calculations

This section describes the methodology used in a past study by WEL [4] to determine sand alarm settings, and indicates where the results of this project can be of benefit in updating this information.

The past study involved determining which flowline locations to investigate by ranking them according to susceptibiltiy to erosion based on mixture velocites. Once the areas of likely erosion were determined, the instantaneous and cumulative allowable erosion rates for these sections were calculated based on allowable erosion rates for the particular sections. The instantaneous and cumulative rates used in this study refer to one years allowable metal loss to occur in five days, and one month respectively [6, 7]. This was based on the method used on the Goodwyn platform, which used the minimum measurable metal loss to occur in five days and one month.

The next step in determining the sand production alarm levels was to calculate the expected erosion in the the flowline system for current sand production rates. The study utilised the SEPCo (Shell Exploration and Production Company) erosion prediction spreadsheet to gain an approximation of expected erosion rates using simple well test type data as inputs to existing industy erosion prediction models. These models, including the University of Tulsa (UoT), Harwell and Det Norske Veritas (DNV RP 0501) sand erosion prediction models have been correlated with such factors as impact velocity, impact frequency (solids concentration), fluid density, impingement angle, liquid film thickness, type of material, solids flow distribution (homogeneity), and solids characteristics (weight, hardness, size, shape) [8].

To ensure a conservative first pass analysis, several 'worst case' assumptions were made regarding variables such as sand particle size (350 μm), a minimum bend radius (MBR) of 1.5x minimum storage radius and worst case downstream pressures [9]. The sand production rates in the prediction spreadsheet were then adjusted until the instantaneous and cumulative erosion rates were reached for each section of concern. The resulting sand production rates are shown below in Table 1 and 1a. [3].

	Jumpers			Risers				
	Production	Test	Test (WA-2 only)	W1M 6"	W1M 10"	W3M 6"	W3M 10"	W1M 6" (WA-2 only)
Mix Vel.	18.7	13.6	7.3	12.1	16.8	21.3	11	6.9
Allowable erosion rate (mm/yr)	0.018	0.018	0.018	0.015	0.02	0.015	0.02	0.015
Instant. allow. erosion rates (mm/yr)	1.314	1.314	1.314	1.095	1.46	1.095	1.46	1.095
Cum. allow. erosion rates (mm/yr)	0.216	0.216	0.216	0.18	0.24	0.18	0.24	0.180
Instantaneous sand rate (gm/s)	3.4	9.2	>50	4	9.8	0.75	2.85	14.4
Cumulative sand rate (gm/s)	0.55	1.5	32	0.65	1.6	0.125	0.5	2.35

Table 1 (above) and 1a (below): Predicted mixture velocities and subsequent sand rates.

	Manifold to RBM flowline				Wellhead to Manifold jumpers
	W1M 6"	W1M 10"	W3M 6"	W3M 10"	WA-1
Mix Vel. (m/s)	9.8	13.5	13.2	8.8	18.1
Allowable erosion rate (mm/yr)	0.009	0.018	0.009	0.018	0.009
Instant. allow. erosion rates (mm/yr)	0.657	1.314	0.657	1.314	0.657
Cum. allow. erosion rates (mm/yr)	0.108	0.216	0.108	0.216	0.108
Instantaneous sand rate (gm/s)	3.2	11.8	0.9	30	1
Cumulative sand rate (gm/s)	0.5	1.9	0.15	5.3	0.17

Based on the above allowable sand production rates, the resulting sand alarm levels were determined based on the smallest values for instantaneous and cumulative sand rates for the typical production and test separator configurations. These values are shown below in Table 2.

	Instantaneous sand production rate (gm/s)	Cumulative sand production rate (gm/s)
Production header monitor	1	0.1
Test header monitor	0.7	0.1

Table 2: Allowable sand production rates during normal system configuration.

If it is determined through the experimental evaluation of the sand detector calibration that the monitors are over estimating sand production, and hence the current alarm settings are too conservative, it will be advisable to increase the alarm levels by the value of the determined over estimation.

6.0 Conclusions and Future Work

Even though current ***over predicted*** sand production rates have been used to determine the instantaneous and cumulative sand alarm levels, it is evident that erosion has ***not*** occurred on a scale which threatens flowline integrity. However, it is clear that there is a discrepancy regarding the sand monitor readings and the sand volumes which have been observed in the Cossack Pioneer process system (1250 kg and 186.17 kg respectively). As such, further work is currently underway to evaluate the accuracy of the current sand detection system on a re-circulating test rig. This involves identifying if there exists an inability for the sand detection system in its current calibration to quantifiably detect sand production, as well as determine the extent to which the lack of a flow velocity input can alter the monitor noise signal. Hence, the findings of this study are expected to determine the relationship between noise signal and flow velocity for various sand concentrations, as well as the amount by which the current sand monitors are over predicting sand production rates. This data would be an important input to safely manage the production system from an integrity point of view. As a result of this, it is foreseen that current sand alarm levels could be raised, which subsequently would mean less choking back of wells, resulting in maximum sand free production rates, safety and revenues.

7.0 References

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