An Evaluation of Acoustic Sand Monitoring and its Application to the Cossack Pioneer

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Abstract

As the petroleum industry continues to look for ways to maximise production, sand management and sand monitoring are becoming increasingly important in the operation of unconsolidated and maturing fields.

Sand management describes the strategies for producing sand in a safe and controlled manner in order to maximise field productivity and revenue. And a critical part of safe sand management is the continuous and accurate monitoring of sand production rates. Non-intrusive acoustic sand monitors often present the best option in sand detection for their flexibility in installation and sensitivity to low sand rates.

Although the Cossack Pioneer development has shown no evidence of significant sand production thus far, Woodside Energy Limited are looking to ensure the asset is prepared for the possibility of sand production as the field declines. The project aims to assess the Cossack Pioneer's current sand monitoring system, and make recommendations for future hardware upgrades and sand management processes.

This paper will introduce the sand management concept, and the theory critical to understanding the nature of sand production and interpreting monitoring data. It will also discuss the challenges of retrofitting a topside sand monitoring system in a subsea development, preview a performance assessment of acoustic sand monitors on this particular asset, and overview the field testing of the ClampOn DSP particle monitors on the Cossack Pioneer.

1.0 Introduction

Through erosion and settlement processes, sand production can pose a significant threat to asset integrity, hydrocarbon control and the availability of production. Sand management is thus a vital element of the design and operation of any field development. As established fields decline, and as the industry looks to develop more marginal fields, sand management and accurate sand monitoring technologies are becoming increasingly important.

Sand production is not uncommon in the petroleum industry; BP recently estimated that about 60% of its worldwide production comes from fields where sand management is necessary (Allahar, 2003). And as some of the fields of north-western Australia mature, they too are beginning to produce sand.

It is well known that sand management (and thus sand monitoring) is a major issue for high rate gas wells, however it is also an important consideration in subsea developments such as Cossack Pioneer due to:

- the high rig costs incurred for the repair of sand related damage to subsea and subsurface equipment,
- the potential for significant deferred revenue from equipment failure due to high production rates,
- the particularly low metal loss allowances of subsea flexible flowlines,
- and the long service life required for subsea equipment.

2.0 Background

2.1 Consequences of Sand Production

Sand production can lead to numerous problems and affect the functionality of hydrocarbon producing assets.

The erosive nature of sand production can lead to the erosion of downhole tubulars, valves and fittings, surface flow lines and surface processing equipment. Uncontrolled erosion can lead to a loss of integrity and hazardous situations.

The settlement of sand can clog perforations and fill wellbores, and collapsed casing is a risk if a lack of formation support occurs. Remedial workovers are costly and defer production. Sand fill in separators or other vessels can cause process problems and ultimately lead to costly shut downs and removal operations (Andrews, Kjorholt & Joranson, 2005).

2.2 The Nature and Causes of Sand Production

Understanding the causes of sand production is not only an important element of sand management, but also essential knowledge for interpreting sand monitoring data.

Sand production is caused by the failure of formation rock due to excessive local stresses at the free surface near the wellbore. The resulting detached sand particles are then entrained in the flowing reservoir fluid and produced up the well (Tronvoll et al., 2001).

Sand production can arise due to excessive drawdown, reservoir pressure depletion, or formation weakening (perhaps due to fatigue from repeated well shut-ins); aggressive shut-in or bean-up rates; or water breakthrough and associated capillary or chemical cohesion loss. (Tronvoll et al., 2001). The likelihood of sanding is a function of the in-situ rock strength (which is in-turn a function of degree of cementation, particles size and shape, reservoir pressure and formation depth) and the completion type (Balgobin, 2005).

Sand will generally be produced in random, discrete bursts. After each sand burst, the affected sand face stabilises due to the general increase in porosity and subsequent reduction in pressure gradient in the sand impacted region (Vaziri et al., 2004). After the localised failure the sand grains move into a new stabilised configuration, and the friction between grains must be overcome to result in further sand production.

Sanding patterns during well bean-up or increased water cut are in many cases related to the improved transport capacity of the fluid, and subsequent transport of sand accumulated in the wellbore or in cavities behind the casing rather than to formation failure (Andrews, Kjorholt & Joranson, 2005). The ability of the fluid to transport the sand through subsea flowlines and risers also affects the likelihood of sand being produced to the surface.

2.3 Sand Management

Traditionally sand production has been considered an unacceptable risk, and operators have typically acted conservatively by restricting production rates (and thus revenue) to prevent sand production.

Sand management involves the relatively new strategies of producing sand in a safe and controlled manner, where the negative impacts of sand production are manageable and predictable. Effectively a risk management approach, sand management aims to increase production rates, reserves and productivity; and reduce completion costs.

Sand management includes all the technologies, processes, and practises in maximising safe production from unconsolidated formations (Stephen, 2003). It is a multidiscipline field that includes:

- the modelling of formation rock failure and the transport of sand from the formation through to the production facility,
- the modelling of potential erosion rates across the entire asset,
- sand control and completion techniques,
- sand production monitoring,
- surface equipment for handling produced sand,
- and well operation procedures for safe and optimised production.

2.4 Non-intrusive Acoustic Sand Monitoring Technology

Non-intrusive acoustic sand monitors are strapped to the outer wall of a flowline downstream of a bend. The device detects the sound created by sand particles impacting the interior wall of the flowline and converts it to an electrical signal. During calibration the background noise at different velocities is recorded, and a relationship between known sand injection quantities and the corresponding signal is determined.

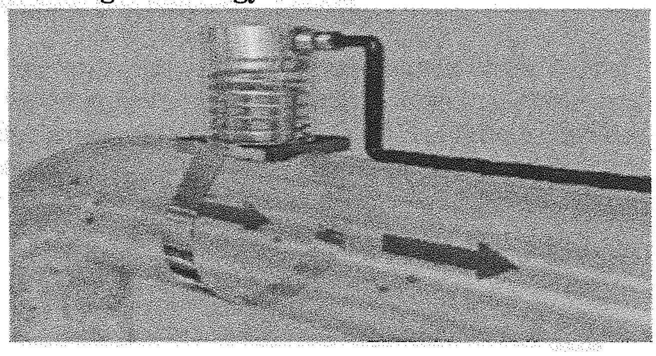

Figure 1 - Passive acoustic sand monitor (Allahar, 2003)

The advantages of the acoustic technology are the greater sensitivity (Allahar, 2003), the early detection of a sand production, and the simple non-intrusive installation (a particular advantage when retrofitting). However, the detector cannot be installed close to the choke due to unacceptably high background noise levels and is highly influenced by multiphase production such as that at Cossack Pioneer.

3.0 Field Testing of Acoustic Sand Monitors

In order to evaluate the latest acoustic monitoring technology in its application to the Cossack Pioneer, the ClampOn DSP Particle Monitor was tested in the field. Three ClampOn particle monitors and a Clampon Spectrum Analyser where taken offshore to the Cossack Pioneer FPSO to collect four days of sand monitoring data.

Firstly, the sensors were configured to monitor normal production. In normal operation, the wells are manifolded subsea and the resulting commingled fluid is all that can be monitored on the topsides. After this stage of data acquisition the well testing procedure was monitored, where each well is produced in isolation to the test separator. This created the opportunity to assess any sand production from each individual well.

During normal production and each stage of well testing, sand injections were performed upstream of the sensors. The response of the sand monitors to the injections can be used to calibrate the monitors, and estimate the natural sand rates of the wells.

3.0 Early Results and Discussion

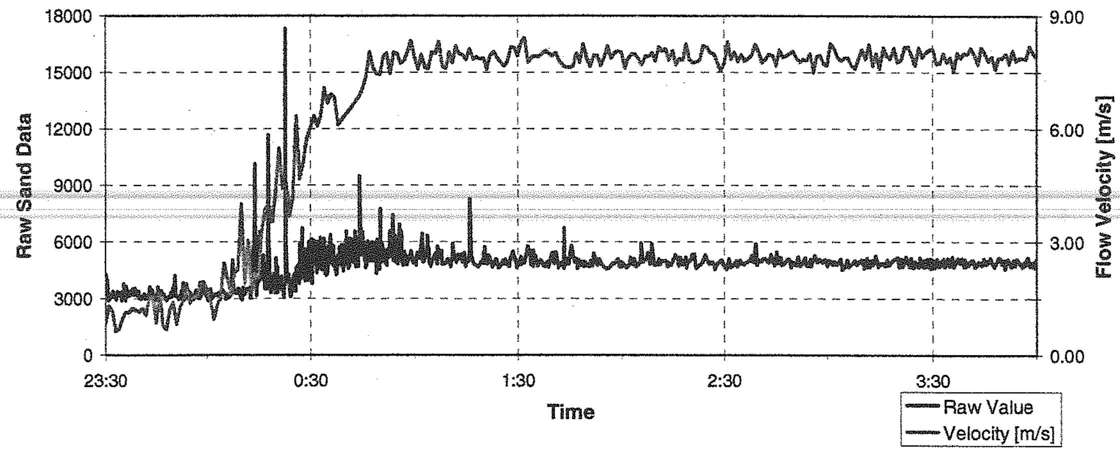

Figure 2 - Transient sand production after bean-up.

Figure 2 shows the raw (not calibrated) sand data and flow velocity at the beginning of a well test. Notably, discrete spikes in the raw data exist after the well velocity has stabilised and then gradually diminish. This can be explained by the reduction in cementation caused by shut-in and rock failure at the sandface during the sudden bean-up. As the flow velocity plateaus, post failure stabilisation causes the gradual reduction in sand rate.

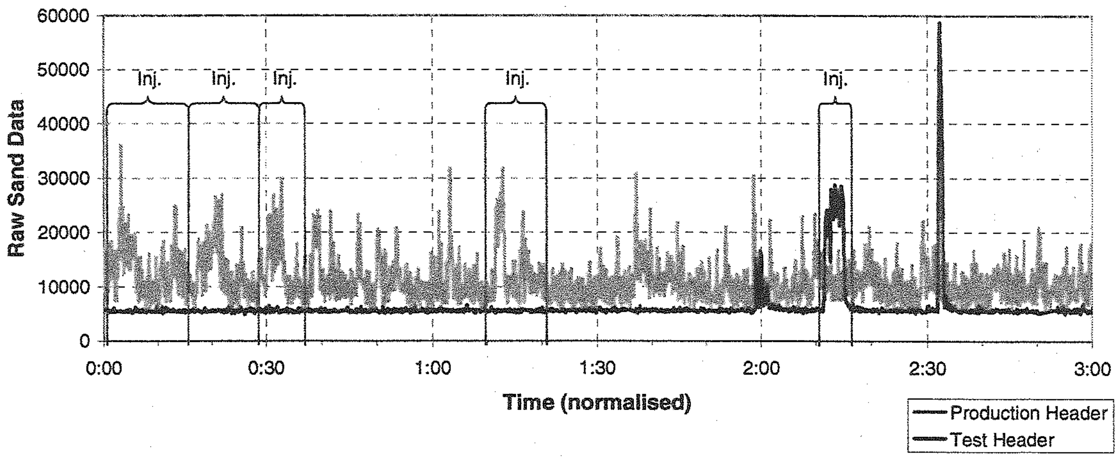

Figure 3 - Raw signal comparison of production and test headers (400g sand injections labelled).

Figure 3 plots the monitor response to a series of injections in the commingled production header fluid alongside the response to injections in an individual well fluid during well testing. The plot reveals the poor signal to noise ratio while monitoring the commingled fluid. This is likely to be due to the complex flow pattern of the fluid. Annular mist, slug or froth flow is possible, and could possibly explain the 'wandering' baseline and excess noise. Many discrete spikes that could indicate sand bursts are also monitored. On the other hand, the response to injections in the test header produce well defined humps' with a much better SNR.

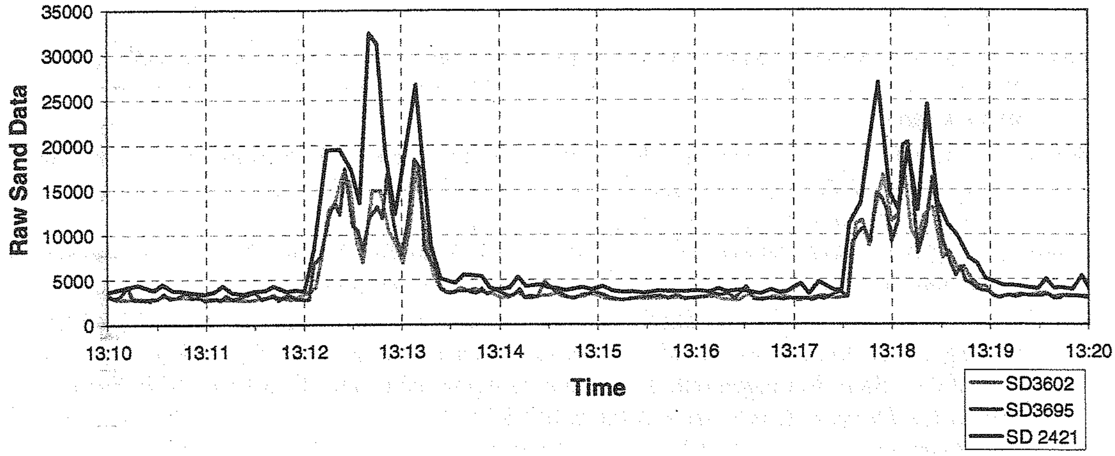

Figure 4 - Simultaneous response from three sensor locations around the elbow (two 400g injections).

Figure 4 plots the injection response of sensors located at three different points of the elbow. The baseline of all locations is similar, yet the signal response to the injection varies. This indicates that the SNR varies depending on the location of the sensor around the elbow.

4.0 Preliminary Conclusions & Remaining Work

The early quantitative data that has been processed has proved quite useful:

- The poor SNR evident in the monitoring data of the commingled fluid during normal operation means only a poor sand rate sensitivity can be achieved.
- The raw signal response during well testing has proved a well test is long enough to show the transition from transient sand production to steady-state production. The well testing period is thus sufficient to monitor sand production on a periodic basis.
- SNR varies depening on the location of the sensor around an elbow. This suggests time spent finding the 'sweetspot' during installation would be well spent.

In remaining work, the injections will be used to quantify any sand production from the individual wells. The offshore field data has given a good indication of the quality of data attainable, and will be used to form suggestions to future sand monitoring hardware and sand management practices.

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