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Sand Production Surveillance for Effective Oil Well Production

*Amieibibama Joseph *, Siakae Barile Ziinu*

Department of Petroleum and Gas Engineering, University of Port Harcourt, Nigeria

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Abstract

The problem of sanding is as old as the oil and gas industry. It entails the movement of loosed sand particles from the reservoir, through the wellbore up to the surface equipment. The production of sand pose detrimental challenges to production facilities through erosion and blockages. Sand production from petroleum reservoirs is inevitable howbeit can be managed as there is no absolute remedy to the problem upon its commencement. Management can be achieved through mechanical and chemical means. Since the problem of sanding can be mitigated but not stopped, there is need for an elaborate monitoring process that could be used to determine when sanding commences. This research employs the mechanical method of sand detection by using clampOn device to determine the optimal flow rate without sanding during production. During the monitoring process with the clampOn device, samples of the crude were taken simultaneously at the different flow rates to obtain the volume of sand produced. The results shows that the clampOn sand detector was able to detect the production rates at which the six wells used as case study produced sand and the volume of sand that was detected. These sand volumes detected by the clampOn, when compared to the results obtained from the analysis showed good agreement, with minimal percentage error. This shows that the clampOn sand detector was efficient enough to monitor the sanding process for the six wells throughout the production period.

Keywords: *Sand-production; Flowrate; ClampOn sand deteCtor; Downhole equipment; Surface facilities.*

1. Introduction

Sand production is a prevalent issue that affects operation in the oil and gas industry. Over 80% of the world's oil and gas fields encounter sanding problems during production. It is a major issue that wells encounter during their productive life [1]. Sand production occurs in both consolidated and unconsolidated (compacted and poorly compacted) formation, though more pronounced in unconsolidated. The tendency of sand grains to be loosened depends on the mineral constituents of the sandstone reservoirs such as quartz, potash feldspar, clay and plagioclase[2]. However, Quartz being the major constituent of sandstone reservoirs dictates the mechanical strength of sandstone reservoirs. The higher the quartz content, the higher the rock mechanical strength and vice versa [2-3]. Some studies have also shown that high contents of both feldspar and clay generally weakens the mechanical strength of sandstone reservoirs and thus could trigger sand production [3-8]. There are also reports that investigation of the effects of minerals on the geomechanical properties of sandstone reservoirs which could lead to sand production are inconclusive following inconsistent results from different investigators [9-12].

Thus, when identified that a sandstone reservoir rock is unconsolidated, the major questions that needs to be addressed when sand production is observed are: what is the cause of the sand production? At what rate is the sand being produced? What is the volume of sand being produced? And what volume of sand production is capable of posing a threat to the life of the well? Providing suitable answers to these questions will provide a good surveillance strategy for monitoring the sanding rate and measures to be taken to avert detrimental effects on facilities and productivity.

Beside the in-situ natural prevailing conditions and the constituent minerals of reservoir rocks, many a times, the cause of sand detachment and production could be attributed to bad production practices, high flow rates, high drawdown, high BS&W. Several investigations have studied the effects of these parameters on sand production. It is very important to investigate the impact of production operations on well productivity and reliability such as maximum drawdown and maximum rate that would not compromise downhole sand control completions [13].

Producing an oil well above the well allowable or technical potential could lead to early sand production following the undue stress imposed on the formation [9]. It has been shown that beyond a certain production rate, called the critical rate, sand production would be eminent and initiated in unconsolidated formations [14-15]. Flow rate play a major role in causing instability that results in the detachment of sand grains in unconsolidated layers of reservoir rocks [15]. High drawdown has also been investigated as a root cause of sand production. High drawdown creates higher effective loop stress around the wellbore or in perforation tunnels, which results to the in situ shear stress being exceeded, and thus the manifestation of sand failure [16-17].

An increasing BS&W during production could also portend to sand production. It has been shown that increasing water cut increases the water inflow which changes the relative permeability and capillary pressure, and thus could lead to onset of sand production[18-20]. Water usually being ascribed as a universal solvent have the tendency to dissolve the cement bond and the minerals that binds the sand grains, thus weakening the mechanical strength of the rock and cohesion, which results to sand detachment [20-21].

The presence of sand in the flowing fluid could make the fluid denser, allowing most produced sands to deposit at the wellbore or flow lines when the transport velocity decreases. This may pose serious threat to downhole and surface equipment if the rate at which the fluid flows is not high enough to transport the sand. Moreover, decline in reservoir pressure increases fluid viscosity which in turn decreases the sand mobility; leading to sand accumulation in the perforation tunnels, the wellbore and at surface facilities [19, 22-23]. This can lead to the blocking of the production equipment and imposition of a back-pressure on the adjacent formation. It could also affect the productivity of the well through erosion, formation collapse, damage to casing, production liners and increase downtime [24]. The effect of the sand produced are always detrimental to short and long term productivity of a well. Such effects can lead to constant well intervention and workover operations which could compromise the integrity of well and surface equipment. Therefore, sand surveillance to detect sanding at early stages of production is critical to mitigate prolong detrimental challenges it could pose.

Figure 1. Acoustic sand detector.

In order for an oil well to produce efficiently without threats from sand production, the field operators should be able to account for the type of sand being produced, volume of sand produced and the rate at which the sand is being produced to adduce the severity of the problem. Thus, the ability to predict sand production from the wellbore forms the basis upon which a good surveillance method can be developed to help monitor oil and gas wells producing sand. Sand surveillance was carried out in a field in Niger Delta Nigeria using the ClampOn sand detector as shown in Figure 1.

The ClampOn is an acoustic digital signal processing system that is clamped non-intrusively on bends of flowlines to detect and monitor sand production using ultrasonic techniques [25]. The ClampOn has been proven to be reliable and thus greatly acceptable in the oil and gas industry for sand surveillance [25]. The field under study has many reservoirs that are unconsolidated, an thus prone to high sand production. Thus, in this work, a comparative sand surveillance was done using the ClampOn sand detector and experimental sampling method. in determining the quantity of sand produced from six wells in the same field.

2. Methodology

Basically, two methods were deployed to detect and monitor the sand production- the clampOn sand detector and the experimental sampling method.

2.1. ClampOn monitoring approach

A typical flow chart illustrating the process of detecting and monitoring sand production using the clampOn system is shown in Figure 2. The clampOn detector is usually installed within the insulating layers of the pipeline wall at the downstream bend. The clampOn detector collects impact vibration signals from the oil flow carrying sand. A digital signal processor (DSP) in the clampOn analyzes the vibration signals from the impact and converts them into a 2-D time-frequency domain for all frequencies contained in the vibration signal, and also provides an estimated percentage volume of sands being produced. The signal is also filtered by the DSP before being amplified by the amplifier, converting from AC to DC, displayed and recorded on a strip chart.

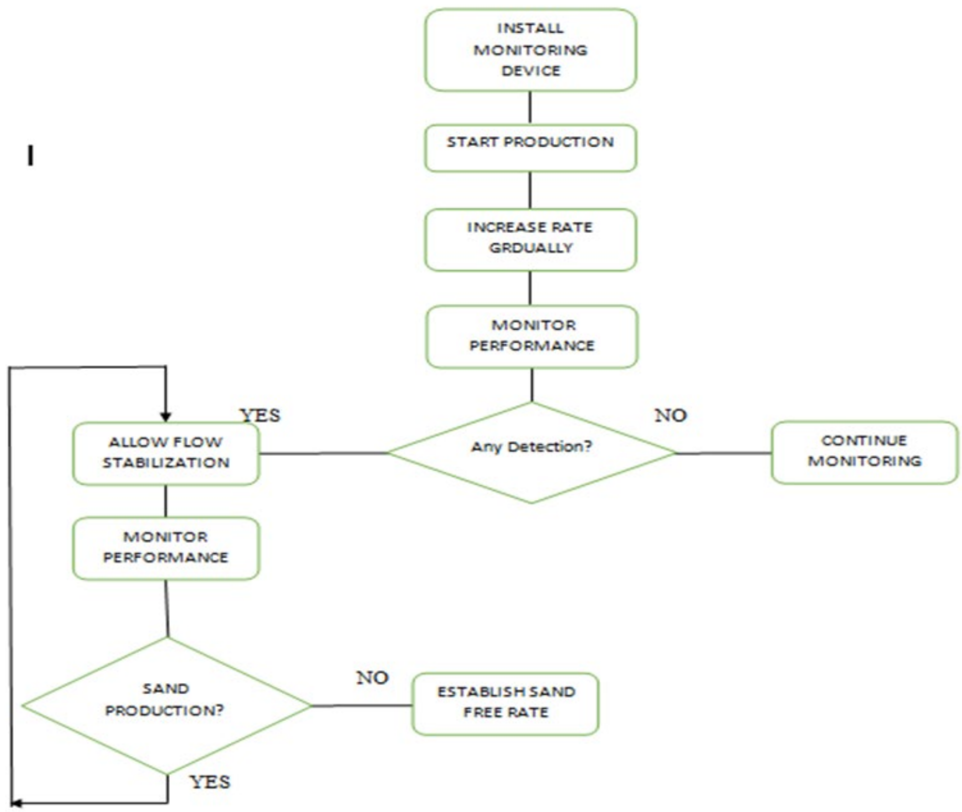

Figure 2. Flow chart for monitoring sand production.

The monitoring of sand production using ClampOn is a real-time process of detecting sand production during fluid flow through pipelines. On approaching a bend, where pressure drop would be experienced due to change in the flow direction, sand inertia causes it to deviate from the streamlines of the carrying fluid, generating a vibration signal as the particles strikes the walls of the pipe. Sand does work on the bend walls and the impact of kinetic energy will be converted into the strength of the vibration. Figure 3 depicts a block diagram of the entire clampOn sand detector process.

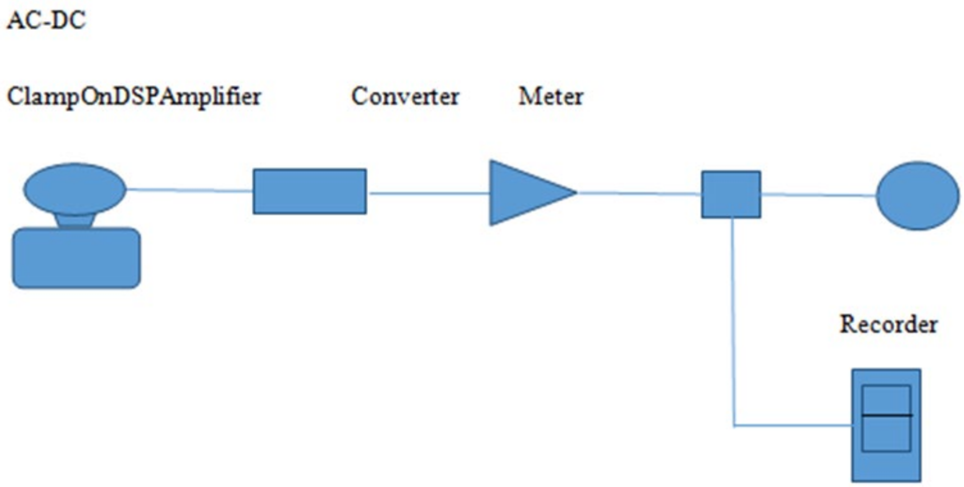

Figure 3. Block diagram showing signal analyzing process of clampOn sand detector.

2.2. Experimental sampling approach

The sampling approach involves determination of basic sediments and water (BS&W) of samples collected from different wells using centrifuges. Samples from six wells were collected at different flowrates at which the wells were flowed and taken to the laboratory for basic sediments and water |(BS&W) analysis. Centrifuge method was used to determine the percent sediments. All apparatus used was cleaned thoroughly using acetone to prevent contamination during the analysis. A 100ml of the representative crude oil sample was mixed with 100ml of xylene and a demulsifier in a graduated centrifugal tube to help breakdown the emulsion. The mixture was then placed in a water bath at 60°C for about 2 to 5 minutes to further breakdown any emulsion not resolved by the demulsifier to aid separation. Afterwards, the sample was spun for about 10 to 15 minutes in the centrifuge. The spinning process helps to separate the fluid from the sand contained in it through gravity settling principle where heavier particles settles at the bottom. Thereafter, the sample volume of the sediment obtained was used to determine the sand content produced at that particular flow rate under which the sample was collected. This method was used for varying rates the wells were flowed.

3. Results and discussion

The time-frequency domain data analysis approach was utilized to analyze the signals obtained from the clampOn sand detector. The rates from the wells were varied by changing the choke sizes. The smallest choke size used was 18/64in while the biggest was 38/64in. At each choke size, the respective flow rate, sand-cut and frequency signals from the clampOn are measured and compared with the results from the sampling method. The sand content obtained was used to develop plots showing the different production rate at which the sand was detected. A 2KHz high pass filter was set to eliminate most of the mechanical system background noise.

Figure 4 shows the time-frequency data for Well XH. The characteristic sand vibration frequency band was a bit higher during production from this well. The frequency created by the impacts recorded by the clampOn ranges between 2.5KHZ and 11KHZ as shown in Figure 4. At frequencies below 2.5Hz, no sands were detected nor produced; and the higher the volume of sand produced, the higher the frequency. For well XH, the highest frequency of 11Hz was recorded when the sand content in the crude rose to 143 lb/1000bbl.. This is also depicted in the comparative plot of sand detected and measured using the ClampOn and sampling method as production increases as shown in Figure 5. As can be seen in Figure 5, at early stages of production, no sand was produced nor detected until the critical rate of 550bbl/day was exceeded. This rate is what is termed the critical sand free rate or the maximum sand free rate. Beyond this rate, the incidence of sand becomes pronounced and progresses as the production rate increases [14].

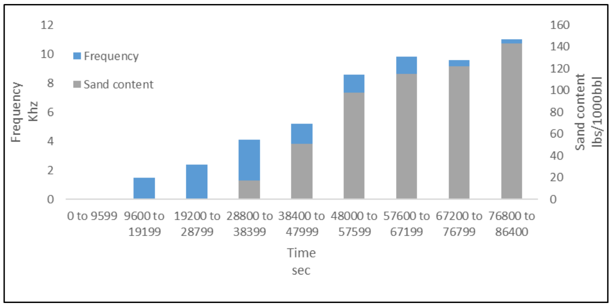

Figure 4. Frequencies to show the corresponding sand detected for well XH.

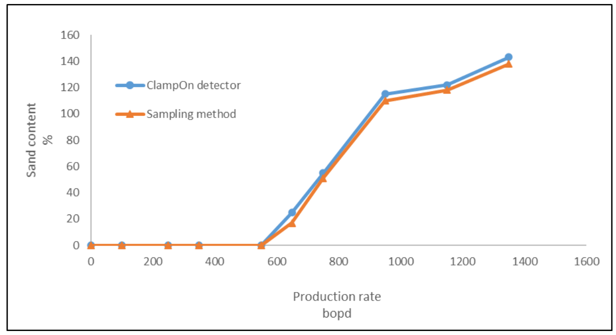

Figure 5. Plot to show results from clampOn sand detector and sampling method for well XH.

Figure 6 shows the time-frequency and sand content data for Well XD. The results shows that the energy intensity level for the characteristic sand frequency is higher than that of well XH as shown in Figure 4. The frequency created by the impact ranged between 2.8KHz to 15KHzZ. From Figure 6, it can be seen that the vibration signal created was high, indicating that well XD produced sand. The sand cut as production rate increases for the clampOn and sampling methods is shown in Figure 7. Unlike well XH, the critical production rate to initiate sand detachment is 380bbl/day for well XD, an indication that well XD may be highly unconsolidated. Moreover, as can be seen in Figure 7, the sand cut continue to increase until it attains stabilization between 1200 and 1500bbls/day .

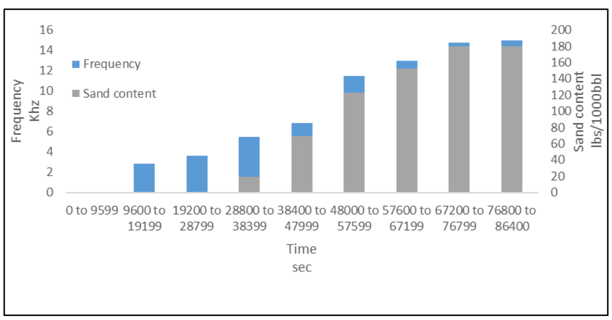

Figure 6. Frequencies to show the corresponding sand detected for well XD.

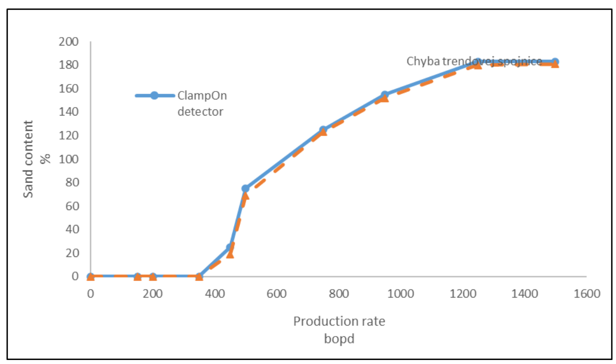

Figure 7. Plot to show results from clampOn sand detector and sampling method for well XD.

The time-frequency data for Well XA is shown in Figure 8. From the analysis, the energy intensity level for the typical sand frequency is noticed to be at the range at which sand is usually detected. The frequency of the impacts was between 4.8KHZ to 12.9 KHZ and thus, sand was detected by the clampOn device. However, as shown in Figure 9, sand production was not initiated until the production exceeds 500bbl/day after which sand production increased as the choke size was increased for higher production rates.

For well XX, the sand frequency signal produced by the clampOn sand detector ranged from 3.4KHz to 13 KHz as shown in Figure 10. Sand production and detection was lately observed in well XX when the production from the well exceeds 1000bbl/day as against wells XH, XD and XA whose sand initiation commenced at lower production rate as shown in Figure 11.

The time-frequency data for well XS is shown in Figure 12. The sand frequency signal produced by the clampOn sand detector ranged from 3.8KHz to 18.0KHz, a much higher frequency than other wells. This is also an indication that a higher sanding is experienced by well

XS as the sand cut was over 200% when compared to wells XH, XD, XA and XX as shown in Figures 12 and 13. However, for well XS, sand production was initiated when the production exceeded 700 bbls/day and progressed as the choke size increases as shown in Figure 13.

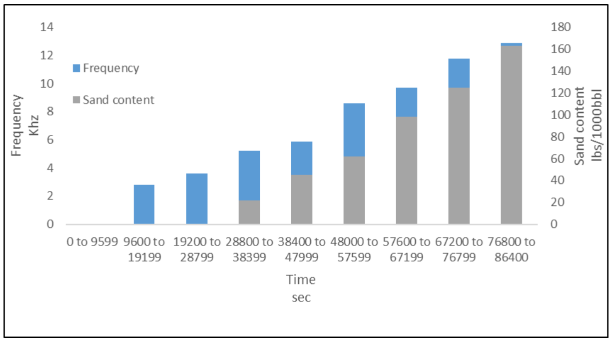

Figure 8. Frequencies to show the corresponding sand detected for well XA.

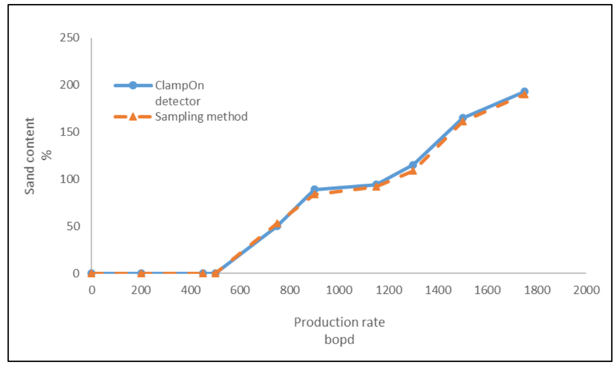

Figure 9. Plot to show results from clampOn sand detector and sampling method for well XA.

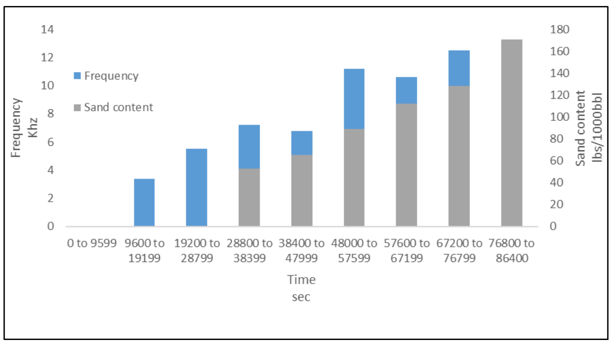

Figure 10. Frequencies to show the corresponding sand detected for well XX.

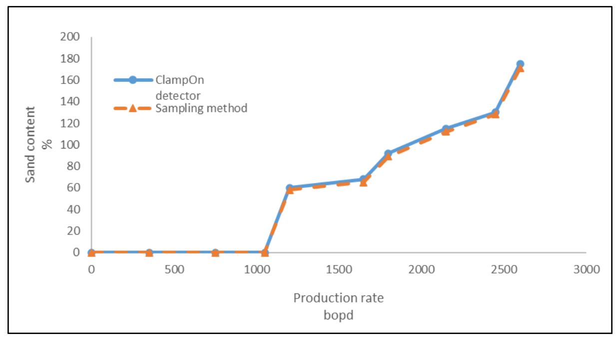

Figure 11. Plot to show results from clampOn sand detector and sampling method for well XX.

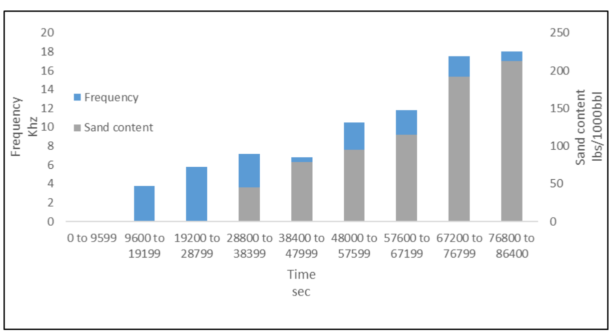

Figure 12. Frequencies to show the corresponding sand detected for well XS.

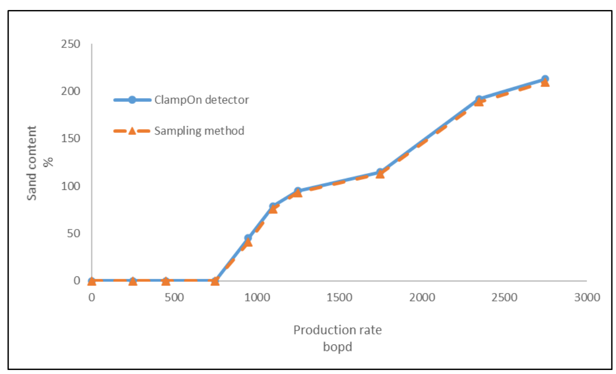

Figure 13. Plot to show results from clampOn sand detector and sampling method for well XS.

The highest sand cut and frequency was experienced in well XI as shown in Figure 14. It can be seen that the sand frequency for this well ranged from 5.5KHz to 20KHz, with a concentration on 11KHZ to 20KHz. This shows that the frequency created was high, an indication that the sand impacts alongside the crude oil flow was high. Sand production in well XI was not initiated until production exceeded 750bbl/day and the maximum sand-cut was about 300% corresponding to a production rate of 3250bbl/day as shown in Figure 15.

To ensure adequate facilities sand management, it is required that there is sustained hydrocarbon production in the presence of solid particles with minimal impact that will not compromise the integrity of surface equipment [26]. One way of minimizing sand production impact is through the management of drawdown by controlling the production rates with the surface choke [13,16]. However, this comes with a cost for very unconsolidated formations as production rates might be drastically reduced to achieve this.

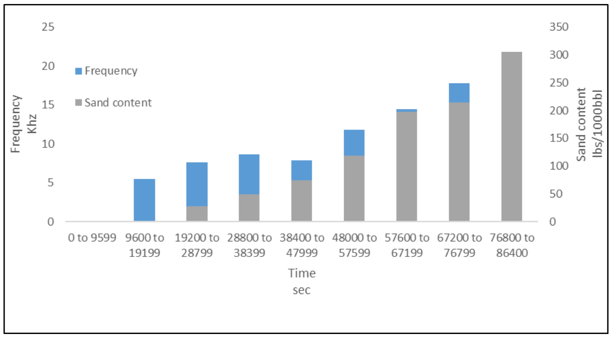

Figure 14. Frequencies to show the corresponding sand detected for well XI.

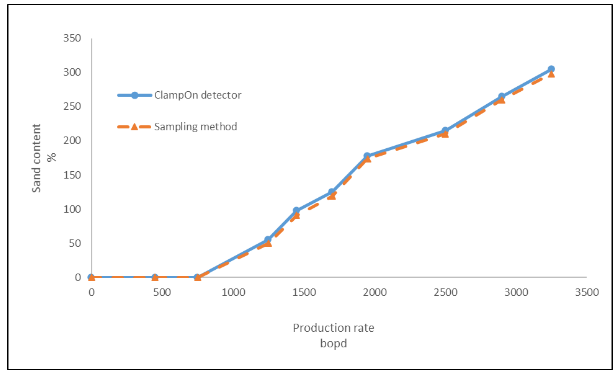

Figure 15. Plot to show results from clampOn sand detector and sampling method for well XI.

From the six wells investigated, it was noticed that as the production rates increased, the sand volume that was detected also increased .This shows that the rate at which sand is produced from a well is dependent on the rate at which the well is being produced at any given period, depending on the choke size used [13]. The higher the choke size, the higher the production rate is increased; and thus the higher the tendencies for sand production from wells producing from unconsolidated formations..

It is also noteworthy that the tendency of a reservoir to detach solids varies from reservoir to reservoir even if they may all be considered unconsolidated following their properties. Hence, all things being equal, no two reservoirs will detach sand grains at the same flowrate and choke size. Considering the six wells, as the choke sizes are varied and flow parameters are measured, the optimum production rate at a given choke size at which the wells can flow with minimal or no sand production was obtained for the six wells. This is shown in Table 1. This rate is what is termed the critical flow rate or maximum sand free rate (MSFR) for each well [15,27-28]. Table1 shows the optimum production rate for each well. As can be seen in Table 1, well XH sand free production rate is 600bopd, Well XD, 420 bopd, Well XA, 710 bopd, Well XX, 1010 bopd, Well XS, 900 bopd and Well XI 1400 bopd respectively.

The values of the mean absolute error between the measured and predicted sand contents is an indication of the reliability of the ClampOn sand detection equipment as shown in Table 2.

Table 1. Maximum sand free rate for each well considered in this study.

WELLs	Wellhead temperature (oF)	Choke size (1/64)in	Oil rate (bopd)
WELL XH	92	18	600
WELL XD	87	22	420
WELL XA	88	26	710
WELL XX	88	32	1010
WELL XS	91	36	900
WELL XI	96	38	1400

Table 2. Mean absolute error of measurement for different wells using the ClampOn and sampling methods of sand production at different flow rates.

WELLs	MAE	WELLs	MAE
WELL XH	2.6	WELL XX	1.7
WELL XD	2.2	WELL XS	1.7
WELL XA	2.3	WELL XI	3.9

4. Conclusion

A special sand detector (clampOn sand detector) was selected to acquire sand production signals. The time frequency analysis, a characteristic sand frequency band digital method was used to successfully extract the sand frequency signals from the crude oil background noise. The clampOn sand detector approach was used to determine the different rates at which sand was produced for the six wells.

Sand production was shown to have a good correlation with production rate for the wells, as it was observed that as the production rate was increased, the tendencies for the wells to produce sand increased until the first sand was produced. The clampOn sand detection approach clearly shows that it can effectively monitor sand production in real-time during oil well production. These non-intrusive clampOn sand detector approach, not only provides a low cost and easy sand production monitoring method compared to the sampling method, but can also lay more foundation for the mathematical model studies of real-time and accurate sand production volume.

The result obtained by the clampOn sand detector was seen to be almost the same to that obtained from the sampling method, showing that the clampOn was able to efficiently detect sand production from the wells at their varying rates. Experience and/or instruction for accurate data interpretation are essential for instilling confidence in the user and allowing the system to be used to its full potential. It is advantageous to install redundant non-intrusive sand detectors where possible.

5. Recommendation

The research conducted in this project is subjected to limitations due to the fact that every mechanical device (non-intrusive devices) has a tendency to fail at some points. Thus further improvements on this real-time non-intrusive devices such as the clampOn sand detector device to:

- Reduce tear and wear during usage. Increase sensitivity for faster detection.
- Obtain a more accurate and better results in order to minimize loss in the industry.

Moreover, the ability of the clampOn detector to closely predict the volume of sand produced with that obtained through the sampling method is an indicator that the clampOn sand detector is a reliable and efficient surveillance tools recommended for detecting and monitoring sand production from oilfields.

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To whom correspondence should be addressed: Amieibibama Joseph, Department of Petroleum and Gas Engineering, University of Port Harcourt, E-mail: Amieibibama.joseph@uniport.edu.ng