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A Model for Predicting the Volume of Sand during Production

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Abstract
Due to the current global oil price, the sand production is considered undesirable product and the control of sand production is considered as one of the main concerns of production engineers. It can damage downhole, subsea equipments and surface production facilities, also increasing the risk of catastrophic failure. As a result of that it costs the producers multiple millions of dollars each year. Therefore, there are many different approaches of sand control designed for different reservoir conditions. Selecting an appropriate technique for preventing formation sand production depends on different reservoir parameters. Therefore, choosing the best sand control method is the result of systematic study. In this paper the sand production factors and their effects are presented where the emphasis is given towards the sand prediction to determine the probability of producing sand from the reservoir, followed by the correct prevention implementation of sand control method. The combination of these two is presented as a smart control framework that can be applied for sand production management.
Keywords: *Sand Production, Sand Prediction Model, Sand Control.*

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I. INTRODUCTION

Sand production is a significant challenge in the oil and gas industry, as it can have detrimental effects on well productivity, equipment integrity, and overall production efficiency. When reservoir conditions and fluid flow dynamics result in the loosening and migration of formation sand into the wellbore, it can lead to wellbore instability, formation damage, and the impairment of production rates. Therefore, accurately predicting the volume of sand produced during the extraction process is crucial for optimizing production strategies, designing effective sand control measures, and ensuring the longevity and profitability of oil and gas reservoirs.

The conventional approach to managing sand production involves using empirical rules or guidelines based on historical data and field experience. However, these methods often lack precision and may not account for the specific characteristics of a reservoir or the influence of various production parameters. To overcome these limitations, the development of analytical models that can provide quantitative predictions of sand volume during production has gained significant attention in recent years.

The objective of this project is to develop an analytical model that can accurately predict the volume of sand produced during oil and gas extraction. The model aims to incorporate key reservoir properties, production parameters, fluid properties, wellbore geometry, completion design, and other relevant factors to provide a more comprehensive understanding of sand production mechanisms.

By utilizing advanced mathematical equations and empirical correlations, this analytical model will seek to establish a robust framework for sand volume prediction. The model's accuracy will be validated through comparison with field data and measurements, allowing for the assessment of its reliability and effectiveness in practical applications.

The importance of this study lies in its capacity to improve production optimization techniques and sand control practices within the oil and gas sector. With a reliable analytical model, operators and engineers can make informed decisions regarding production rates, wellbore design, completion techniques, and the implementation of sand control methods. By proactively managing sand production, the industry can minimize the associated risks and costs, increase well productivity, and extend the economic life of reservoirs.

The study will further delve into the development of the analytical model, including the selection and formulation of relevant equations, the calibration and validation process, and a comprehensive analysis of the model's sensitivity to various parameters. Additionally, practical implications and recommendations for implementing the model in real-world scenarios will be discussed.

To conclude, the creation of an analytical model for predicting sand volume during production marks a crucial advancement in optimizing oil and gas operations and mitigating the challenges posed by sand production. By providing a quantitative understanding of sand behavior and its interaction with production parameters, this model can contribute to improved decision-making, enhanced sand control strategies, and ultimately, increased efficiency and profitability in the industry.

II. Literature Review

Studies have been conducted on predicting sanding and its impact on oil and gas production. Authors' perspectives mainly revolve around well instability, rock properties, and influencing factors. Terzaghi, K., Peck, R. B., &Mesri, G. (1948), Hall &Harrisberger (1970), and Stein (1972) argue that sand production prediction relies on sand arch instability. On the other hand, Antheunis, J. W., Van Laer, F., &Huijsmans, J. (1976);Morita, N., Nguyen, V. D., &Miska, S. Z. (1987), and Tronvoll, J., Brouwer, G., & Van Den Berg, P. (1992) focused on perforation tunnel stability, while Paslay and Cheatham (1963) and Valko& Economides (1995) studied open-hole stability. Experimental studies focus on key factors like tensile strength, wellbore and perforation geometry, pressure drawdown, pressure depletion, stress state, and rock mechanical properties, which are analyzed to predict sand production during oil and gas operations. Understanding these parameters helps in developing effective strategies for sand control and management, ensuring efficient and safe production processes. The review will explore the effects of these parameters on sand production and estimate when and how much sand will be produced.

III. Methodology

The materials used for this study include;

I. Dataset pertaining to sand production from different wells in the Niger-delta region of Nigeria.
II. Experimental design software.

In order to develop the analytical model, datasets pertaining to sand production was obtained from literature and statistical modelling software was used to fit the data to the model. The data are shown in Table 1 and consists of data from different wells in the Niger Delta known to produce sand. The independent variables include sand concentration, oil rate, Reynolds number, water rate, water cut, gas rate, and gas liquid ratio (GLR). For each dataset, the sand production rate observed is presented.

Table 1: Sand production rate dataset (Okereke, N., Ogbuka, V., Izuwa, N., Kara, F., Nwogu, N., Nwanwe, O., Baba, Y. &Oguama, I., 2020)

	Sand concentration	**Oil rate**	**Reynolds number**	**Water rate**	**Water cut**	**Gas rate**	**GLR**	**Observed SPR**
S/N	PPTB	bbl./m		bbl./m	%	Mscf/m	scf/bbl.	**Ib/m**
1	40	13081	1.66E-02	36322	74	5919	120	**523.2**
2	34	17137	2.18E-02	14032	45	82393	2643	**582.7**
3	33	15323	1.95E-02	11686	43	2899	107	**505.7**
4	33	14850	1.89E-02	10520	41	19075	752	**490.1**
5	33	19788	2.51E-02	14790	43	14550	421	**653**
6	33	18150	2.30E-02	13607	43	15624	492	**598.9**
7	33	18615	2.36E-02	13327	42	5813	182	**614.3**
8	3	8688	1.10E-02	4313	33	8193	630	**26.1**
9	*2*	6184	7.85E-03	4598	43	12934	1200	**12.4**
10	*2*	3930	4.99E-03	2947	43	23332	3393	**7.9**
11	8	1436	1.82E-03	1115	44	38364	15043	**11.5**
12	*2*	7275	9.24E-03	10625	59	2920	163	**14.6**
13	3	9242	1.17E-02	8133	47	35	2	**27.7**
14	4	15047	1.91E-02	14277	49	3557	121	**60.2**
15	5	5453	6.92E-03	7029	56	9372	751	**27.3**
16	2	54279	6.89E-02	31	0	11063	204	**108.6**
17	0	21540	2.74E-02	8	0	9525	442	**0**
18	1	13506	1.72E-02	5814	30	5550	287	**13.5**

19	1	3646	4.63E-03	1497	29	1024	199	**3.6**
20	2	39280	4.99E-02	16440	30	7541	135	**78.6**
21	2	38743	4.92E-02	7399	16	6933	150	**77.5**
22	2	23049	2.93E-02	4228	15	4778	175	**46.1**

The data were entered into the blank spreadsheet section of design expert software for analysis and model development to be conducted. The procedure for developing the model is as described in the work by Chikwe et al. (2022). Analysis of Variance (ANOVA) was conducted to determine the variables that were significant to the model. Also, a comparison was conducted between R2, predicted R2, and adjusted R2 and when they were found to be in close agreement with each other, the model was outputted. The model developed calculates sand production rate and in other to determine the volume of sand, the following equation is used

$$V_{sand} = \frac{SPR * time}{\rho_{sand}} \quad (1)$$

IV. RESULTS AND DISCUSSION

Tables 2 and 3 shows ANOVA and fit statistics results for the SPR model developed in this study.

Table 1: ANOVA for Sand Production Rate Model

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	1.391E+06	7	1.987E+05	3.942E+08	< 0.0001	significant
A-A	1.747E+05	1	1.747E+05	3.465E+08	< 0.0001	
C-C	24886.96	1	24886.96	4.938E+07	< 0.0001	
E-E	0.0003	1	0.0003	0.5359	0.4762	
G-G	0.0001	1	0.0001	0.1618	0.6936	
AC	19929.38	1	19929.38	3.954E+07	< 0.0001	
AE	0.0045	1	0.0045	8.91	0.0098	
G^2	0.0026	1	0.0026	5.06	0.0410	
Residual	0.0071	14	0.0005			
Cor Total	1.391E+06	21				

Table 2: Fit statistics results for SPR model

Std. Dev.	0.0207		**R^2**	1.0000
Mean	203.80		**Adjusted R^2**	1.0000
C.V. %	0.0102		**Predicted R^2**	1.0000
			Adeq Precision	48235.208

Based on the ANOVA and fit statistics results, it can be inferred that the resultant model is accurate and is shown in equation (2).

$$SPR = -0.0695832 + 0.00969054 * A + 1.77452 * C + 0.0011509 * E + 1.65753e-05 * G + 787.184 * AC + -9.20236e-05 * AE + -1.15208e-09 * G^2 \quad (2)$$

Where A is sand concentration, B is oil rate, C is Reynolds number, D is water rate, E is water cut, F is gas rate, and G is gas liquid ratio (GLR).

4.1.1 Validation of SPR model

The model was validated using cross plots, trend analysis, and statistical error analysis. Figures 1 and 2 shows cross plots and trend analysis results while Table (4) shows statistical error analysis results

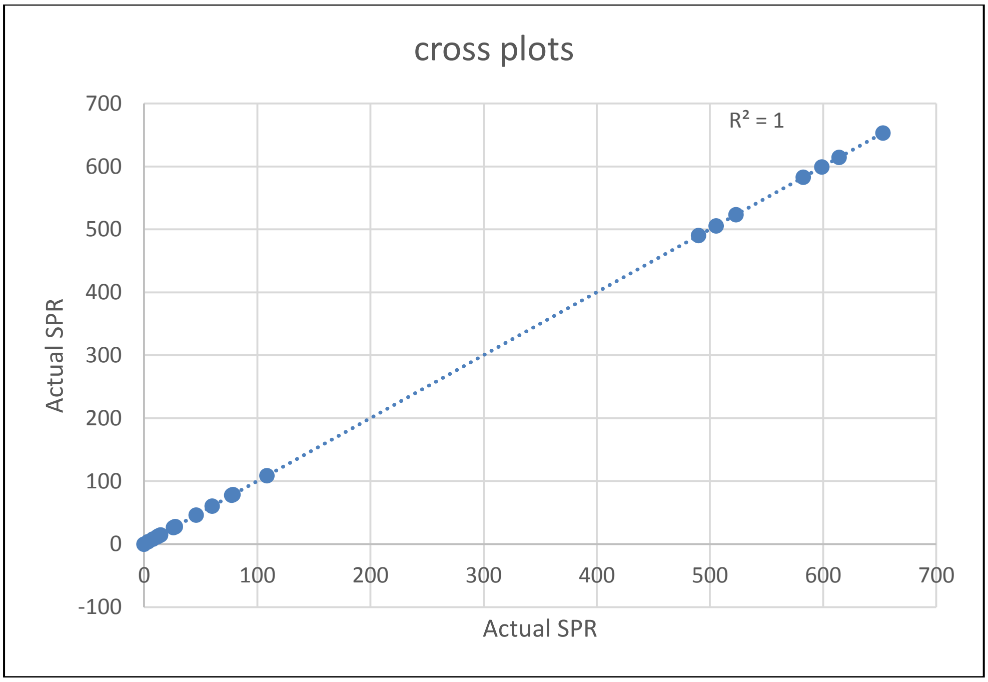

Figure 1: Cross Plots of actual versus predicted SPR

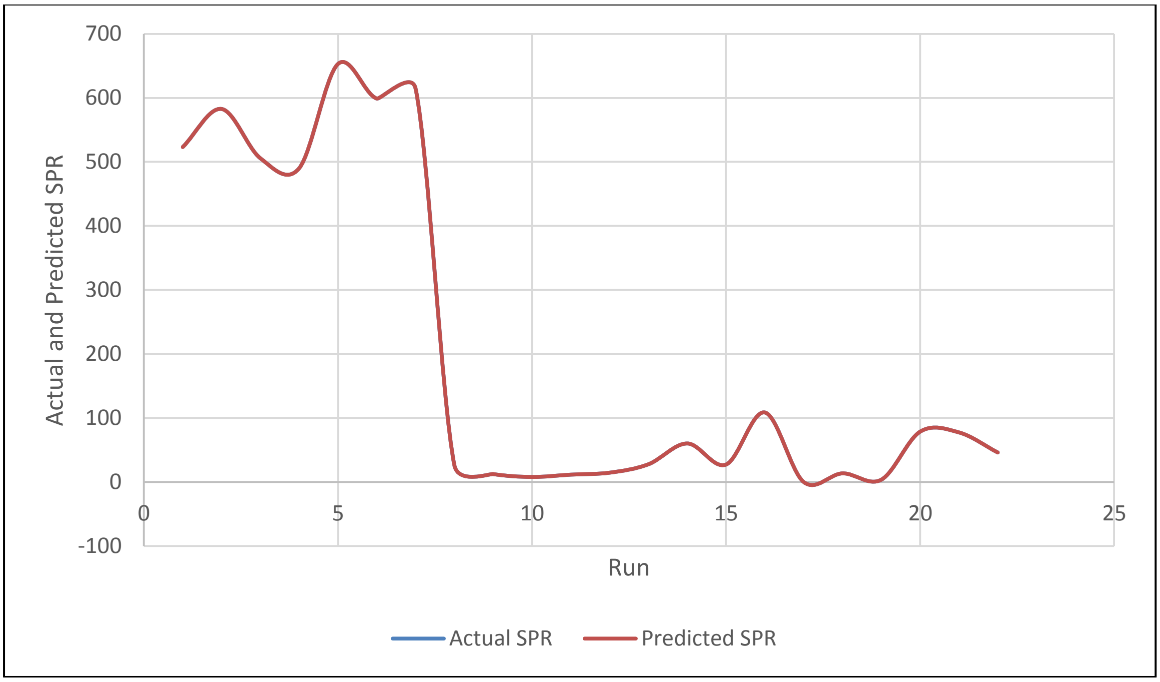

Figure 2: Trend Analysis results for actual and predicted SPR

Table 3: Error analysis results

Sum of Square Errors (SSE)	0.008292
R-square	1
Adjusted R-square	1
Root mean squared Error (RMSE)	0.02036

The model developed in this study was also compared with the model developed in previous research work(Okereke et al. *2020)*. Results from this current model and the previous are presented in Table 5.

Table 4: Comparison between observed SPR and predicted SPR from two model types

Observed SPR	Predicted SPR (Okereke et al., 2020)	Predicted SPR (Current study)
523.2	521.8	523.2
582.7	583.3	582.72
505.7	506.6	505.69
490.1	491.4	490.09
653	637.6	652.97
598.9	590.9	598.94
614.3	598.3	614.29
26.1	27	26.07
12.4	13	12.39
7.9	7.9	7.9
11.5	10.9	11.5
14.6	15.3	14.57
27.7	27.6	27.74
60.2	58.8	60.21
27.3	27.6	27.29
108.6	109	108.59
0	48.4	-0.0139
13.5	14.5	13.51
3.6	4.1	3.63
78.6	78.9	78.6
77.5	77	77.51
46.1	46	46.1

Results from Table 5 show that sand production rate results obtained from the model developed in this study outperformed that developed in previous research depicted by SPR values of this current study being very close to the observed SPR values.

4.1.2 Model for determining volume of sand

The volume of sand produced can be calculated by substituting the model developed in this study into the following equation

$$V_{sand} = \frac{SPR * time}{\rho_{sand}} \tag{1}$$

The resultant equation for calculating volume of produced sand is developed and is presented in equation (3)

$$V_{sand} = \left(\begin{array}{c} -0.0695832 + 0.00969054 * A + 1.77452 * C + \\ 0.0011509 * E + 1.65753e-05 * G + \\ 787.184 * AC + -9.20236e-05 * AE + \\ -1.15208e-09 * G^2 \end{array} \right) * time \Big/ \rho_{sand} \tag{3}$$

Where A is sand concentration, B is oil rate, C is Reynolds number, D is water rate, E is water cut, F is gas rate, and G is gas liquid ratio (GLR), time is the production time, ρ_{sand} is the density of sand

4.2 Discussion of results

In this study, field data from different wells in the Niger delta were collected and used in model development. In the Niger delta, sand production is a norm and the wells used for this study were producing sand. The datasets consists of 7 independent variables namely sand concentration, oil rate, Reynolds number, water rate, water cut, gas rate, and gas liquid ratio (GLR), and one dependent variable referred to as sand production rate.

The input and output data were curve fitted to create a relationship between them using response surface methodology. Hence the model shown in equation (3) was developed. The model was validated using cross plots, trend analysis, and statistical error analysis as depicted in Figures 1 and 2, and table 4 respectively. Validation results presented in this study show that the model is accurate and can be used in predictions. The developed model was further validated by comparing it with that developed in previous research *(*Okereke et al. *2020)* as shown in table 5. Results from table 5 show that the model developed outperformed that developed by *(*Okereke et al. *2020)* since SPR values obtained from the current model were in closer to the observed SPR values. Hence, it can be inferred that the developed model is accurate. The volume of sand produced can hence be determined by incorporating the SPR model developed in this study into equation (2) to result into equation (3) which is a function of SPR, time and density of sand.

V. CONCLUSION

The following conclusions can be drawn from this study

a. Sand production during petroleum production is a major challenge facing the oil and gas industry and more research needs to be conducted to mitigate the problem

b. Sand production is inevitable in unconsolidated sandstone formations

c. Using rate exclusion method is a proved approach for preventing flow of sand into the wellbore but has the disadvantage of reducing oil production which might be undesirable for an operator.

d. The use mechanical sand control methods is also a proven approach for preventing flow of sand into the wellbore, however, sand exclusion cannot be 100%. In some cases, the sand flows with oil to the surface

e. It is important to know how much sand gets to the surface, hence the need to develop numerical models which predict the sand volume at the surface.

f. This has been addressed in this study since a model which determines volume of sand as a function of sand production rate, time, and sand density was developed using field data.

REFERENCES

[1]. Terzaghi, K., Peck, R. B., &Mesri, G. (1948). Soil Mechanics in Engineering Practice. John Wiley & Sons.

[2]. Hall, G. F., &Harrisberger, L. N. (1970). Effects of Reservoir Flow on Sand Arching. Journal of Petroleum Technology, 22(11), 1373-1380. doi:10.2118/2728-PA.

[3]. Stein, J. (1972). Sand Control: Review of the State of the Art. Journal of Petroleum Technology, 24(8), 1006-1014. doi:10.2118/3532-PA.

[4]. Antheunis, J. W., Van Laer, F., &Huijsmans, J. (1976). Sand Production Prediction in Petroleum Engineering. Society of Petroleum Engineers. doi:10.2118/5945-MS.

[5]. Morita, N., Nguyen, V. D., &Miska, S. Z. (1987). Sand Production Prediction in Gas Wells. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers. doi:10.2118/16439-MS.

[6]. Tronvoll, J., Brouwer, G., & Van Den Berg, P. (1992). Predicting Sanding in Deviated and Horizontal Wells - A Case Study. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers. doi:10.2118/24633-MS.

[7]. Paslay, P. R., & Cheatham, W. B. (1963). Study of Sand Production in Gas Wells. Journal of Petroleum Technology, 15(11), 1241-1247. doi:10.2118/399-PA.

[8]. Valko, P. P., & Economides, M. J. (1995). Rock Failure Mechanics and Sanding Prediction. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers. doi:10.2118/30815-MS.

[9]. Okereke, N., Ogbuka, V., Izuwa, N., Kara, F., Nwogu, N., Nwanwe, O., Baba, Y. &Oguama, I. (2020). AdvancedMathematical Model for Prediction of Sand Production Rate: A Niger-Delta Case Study. Society of Petroleum Engineers. https//doi.org/10.2118/203692-MS

[10]. Chikwe, A.O, Nwanwe, OI, Onyia, O.S, Okereke, N.U. &Odo, J.E. (2022). Development of Proxy Models for Predicting and Optimizing the Time and Recovery Factor at Breakthrough during Water Injection in Oil Reserves. International Journal of Oil, Gas and Coal Engineering. Vol 10 (1), 17-30. doi:10.11648/j.ogce.20221001.12