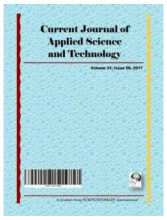

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Impact of Drilling Parameters on Depth of Oil Well in Monitoring and Control System

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Authors' contributions

This work was carried out in collaboration between the both authors. Both authors designed the study, wrote the protocol and the first draft of the manuscript. Author EJA performed the statistical analysis. Author OCA managed the literature searches and supervised the research. Both authors read and approved the final manuscript.

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ABSTRACT

Over the past decades, various methods have been proposed to evaluate drilling depth and complexity because of the large number of factors and events that affect drilling performance, which makes it difficult to construct predictive models. Quantifying drilling oil well depth and complexity is challenging due to restrictions on data collection and availability, constraints associated with modeling or combinations of these factors. Drill rates are often not documented and constrained by factors that the driller does not control. In large investments, the requirements to drill for oil and gas are made primary by oil companies. Many specialized talents are required to drill an oil well safely and economically. Estimation of the depth of oil well is one of the major concerns of oil companies today. The aim of this paper is to study and analyze the associated depth drilling parameters, and to run a comparative analysis of simulated events and regression model software values by adopting mathematical model of multiple regression that transform into programming technique for predicting total depth of drilling oil well. Visual Basic Net programming language (front-end) and Microsoft Access Database relational database management (back-end) were used in the research work for the experimental study. The implemented software has a performance accuracy of 93.94%. The data series explained that higher the drill depth more is the total cost.

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Keywords: Impact; drilling; parameter; oil well depth; predictive model.

1. INTRODUCTION

Oil well control is the management of the dangerous effects caused by the unexpected release of formation fluid, such as natural gas and /or crude oil, upon surface equipment of oil or gas drilling rigs and escaping into the atmosphere. Technically, oil well control involves preventing the formation fluid, usually referred to as kick, from entering into the wellbore during drilling [1]. By extension, depth can be referred to as locations below or distances from a reference point or elevation even when there is no well. In that sense, depth is a concept related to elevation, albeit in the opposite direction. Depth in a well is not necessarily measured vertically or along a straight line. The need to keep drilling pressure under control and avert blowout as well as sporadic oil spillage which often precipitates into conflagration of inclination has motivated the development of several oil well control systems. Iversen et al. [2] developed a monitoring and optimization system for drilling operations based on real time data measurements. The system observed Weight on Bit (WOB), Rotary per Minute (RPM) modulation and Rate of Penetration (ROP) within critical limits with a view to increasing safety and reducing operational downtime. The work of Michael and Collin [3] was focused on oil well drilling control practices and equipment consideration for deep water operation plan.

The prediction of depth and cost of drilling an oil well in a preliminary stage, estimates the cost and depth with minimum project information. The sensor of Mud weight, Hookload, Standard Pipe Pressure, Torque and Rotary per Minute) are used to acquire accurate data for depth and drilling process while cost of rig, bit, mud and auxiliary equipment are used to acquire the cost of materials and parameters like host communities, combination of true depth of drilling, cost of drilling and host communities consideration, which provides a close cost estimate of drilling an oil well. It has been observed that there is a problem of depth estimation in oil and gas industries and the oil and gas industries needs urgent attention to solve this issue. In this paper, the impacts of drilling parameters such as WOB, ROP, TOQUE, MD and HOOKLOAD on the depth of oil well during drilling were carried out. Torque is the turning force that is applied to a rotary mechanism to cause a rotation of the rotary in the oil well in the rig during drilling and it is measured in foot-pounds (klbs). An architectural model for oil well drilling and flow monitoring is proposed. A mathematical regression model for predicting depth of drilling an oil well evaluation and drilling indicator performance parameters are developed.

2. DEPTH OF OIL WELL

Depth in an oil well is the distance between the reference points of elevation and a target point. Oil wells are not always drilled vertically; there may be two depths for every given point in a well bore; namely, the measured depth (MD) which is measured along the path of the borehole and the true vertical depth (TVD), which is the absolute vertical distance between the datum and the point in the well bore. In perfectly vertical oil wells, the TVD is equal with the MD, otherwise, the TVD is less than the MD if measured from the same datum. Commonly used data are Ground Level (GL), Drilling Rig Floor (DF), Rotary Table (RT), Kelly Bushing (KB) and Mean Sea Level (MSL).

The mathematical expressions presented in equation 1 and 2 provide the approximate TVD interval corresponding to the measured interval which is generally accurate enough for pressure calculation in oil wells.

$$TVD_{n+1} = M_1 + (n+1)(M_2 - M_1)\, Cos\Theta,\ n = 0 \qquad (1)$$

$$TVD_1 = M_1 + (M_2 - M_1)\, Cos\Theta \qquad (2)$$

Where, M_1 is first measured depth of the bits in feet.

M_2 is second measured depth of the bits in feet.
C is first depth of bits – second depth of bits

$$C = (M_2 - M_1) \qquad (3)$$

Where, C is change in length of depth of survey of oil well

Θ is angle of inclination of the oil well during drilling.

$$TVD_{n+1} = \text{Initial depth} + (n + 1)\, CCos\Theta \qquad (4)$$

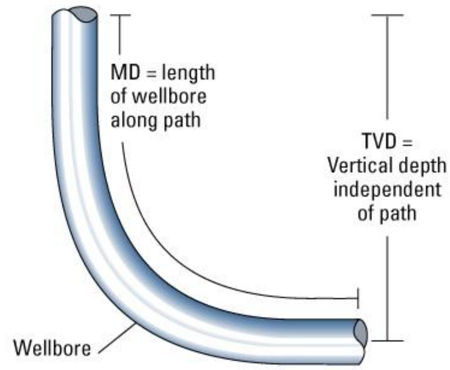

Fig. 1. Oil well depth

2.1 Drilling Rate/Rate of Penetration (ROP)

Rate of Penetration (ROP) in oil well drilling is the speed at which a drill bit breaks the rock under it to deepen the borehole. ROP is also known as penetration rate or drill rate. It is normally measured in feet per minute or meters per hour. Generally, ROP increases in fast drilling formation such as sand stone (positive drill break) and decreases in slow drilling formations such as shale (reverse break). ROP decreases in shale due to diagnosis and overburden stress. Over-pressured zones can give twice of ROP as expected which is an indication of well kick. Rate of penetration can be quantified in two ways:

a. Distance per unit of time, for example 33ft per hour or 10 meters per hour.
b. Time per unit of distance, for example, 2 minutes per feet or 6 minutes per meter. For computation of ROP, individual distance per time intervals must be converted to relative percentages of the total time being averaged. Similarly, each time per distance segment must be observed as a relative percentage of the distance being averaged. If ROP is not calculated correctly, the disputed result can affect drilling decisions. Standard drilling time/ROP values are presented in Table 1.

Table 1. Drilling rate of penetration

Drilling time	ROP
3 hours	10 ft/hr
2 hours	5 ft/hr
2 hours	15 ft/hr
2.5 hours	4 ft/hr
0.5 hours	20 ft/hr

**ROP: Rate of penetration*

Based on the figure in Table 3 and Table 4, it can be written

Depth drill = drilling time * ROP (5)

Where, the Average Drilling Rate (ADR) is obtained from:

ADR = Total ROP (ft/hr)/Numbers ROP (6)

2.2 Weight on Bit (WOB)

WOB as expressed in oil well drilling system is the amount of downward force exerted on the drill bit and is normally measured in thousands of pounds. Weights on bit is provided by drill collars, which are thick walled tubular pieces machined from solid bars of steel, usually plain carbon steel but sometimes made up of non-magnetic Nickel copper alloy or other non-magnetic premium alloys. Gravity acts on the large mass of the collars to provide the downward force needed by the bits to efficiently break the rock. To accurately control the amount of force applied to the bit, the driller carefully monitors the surface weight measured while the bit is just off the bottom of the well bore. Next, the drill string (and the drill bit), is slowly and carefully lowered until it touches the bottom. After that point, as the driller continues to lower the top of the drill string, more and more weight is applied to the bit, and correspondingly less weight is measured as hanging to the surface. WOB is measured in thousands of pounds as the amount of downward force exerted on the drill bit provided by drill collars, which are thick-walled tubular pieces machine of solid bars of nonmagnetic nickel-copper alloy or carbon still. It acts on the large bars of the collars to provide the downward force needed for the bits to efficiently break the rock [4,5,6]. If the surface measurement shows 20,000 pounds (9080kg) less weight than with the bit off bottom, then there should be 20,000 pounds force on the bit (in a vertical hole). Downhole MWD sensors measure weight-on-bit more accurately and transmit the data to the surface.

2.3 Data Acquisition

Data acquisition is a tool for data gathering, analysis and real-time decision making for quick effective service in oil well drilling cost estimate system. The type utilized in the architecture of oil well drilling cost estimate system is called Data Acquisition Centre (DAC) (Fig. 1). It has rugged enclosure that contains the Central Processing Unit (CPU), power supplies and hardware that monitors data sensors. This acts as interface between the sensor capture parameter such as mud weight, hook-load, stand pipe pressure, torque and rotary per minute, and the depth, drilling, flow monitor and kick control. This portion of the acquisition aims to ensure reliability, accuracy and easy access to information as it is being measured. The DAC system does not require complicated equipment or procedures to deploy once the work string is in place. The system uses acoustic energy to transmit real time data to the surface where non-intrusive receiver forwards the data to the computer for decoding, display and evaluation purpose. A typical picture of DAC for this instance used in [1, 7] is shown in Fig. 2.

In order to accomplish the objectives of this research work, a mathematical regression model was developed. The model used MD as the dependent variable with functional independent variables that were associated with data from monitoring and controlling of depth and drilling. The Model was based on the data presented in Table 2.

$$\text{MD}=\alpha_0+\alpha_1\beta_1+\alpha_2\beta_2+\alpha_3\beta_3+\alpha_4\beta_4+\alpha_5\beta_5+\alpha_6\beta_6 \quad (7)$$

α_0 is the intercept of the dependent variable, the coefficient variables α_1, α_2, α_3, α_4, α_5 and α_6 are coefficient of independent variables while β_1, β_2, β_3, β_4, β_5, $and\ \beta_6$ are the TVD, ROP, hook load, torque, total cost and mud weight, respectively.

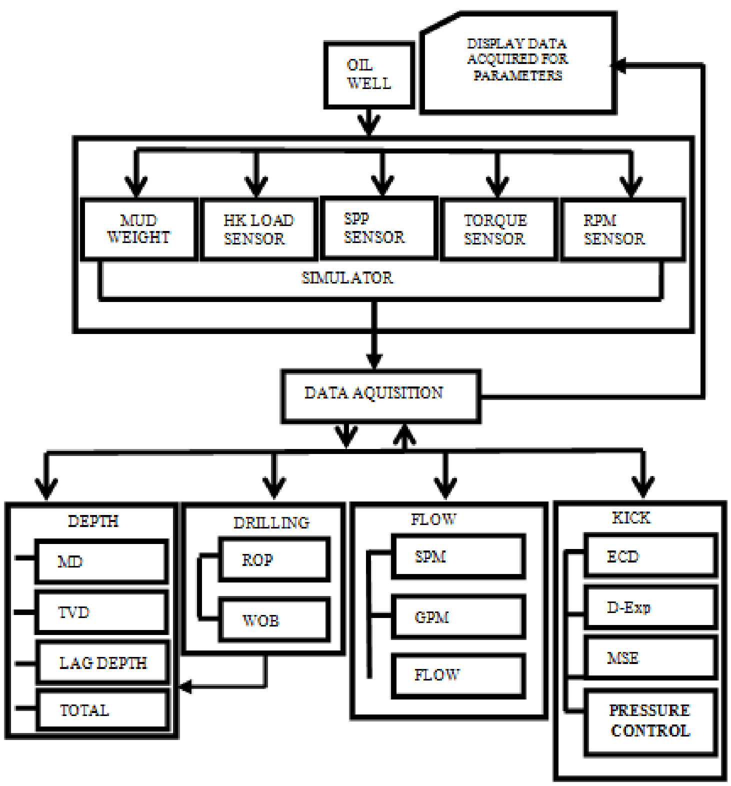

Fig. 2. Architecture for oil well control system

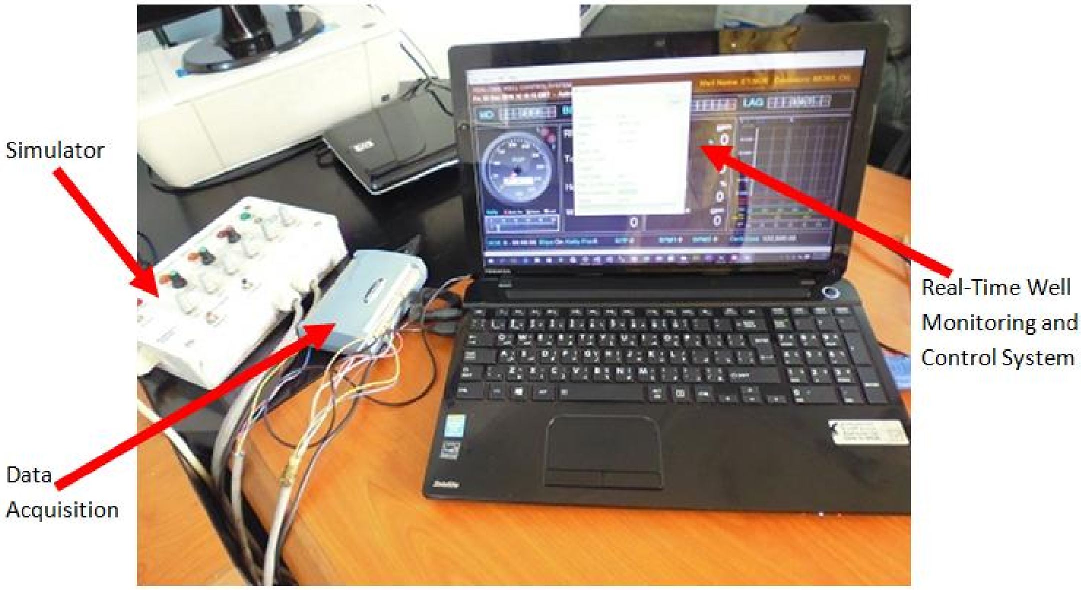

Fig. 3. Data acquisition centre

Table 2. Stimulated data generated from oil well A

MD in ft	TVD in ft	ROP in ft/hr	HooKload in klbs	Torque in klbs	Total Cost in $	Mudweight in ppg
63.77	341	00	299.63	9.55	130000	6.40
364.83	348	10	298.73	9.54	132000	6.39
365.16	356	20	299.79	9.51	134000	6.38
368.63	364	30	296.62	9.52	136000	6.38
369.52	364	40	297.68	9.52	138000	6.38
371.89	364	50	296.47	9.52	140000	6.38
374.26	364	60	300.09	9.52	142000	6.38
375.70	364	60	300.84	9.47	144000	6.35
376.71	364	60	291.35	9.35	146000	6.27
376.71	364	60	302.95	9.46	148000	6.34
389.66	387	45	299.90	9.54	150000	6.43
402.60	399	45	300.73	9.56	152000	6.39
415.55	411	40	300.79	9.58	154000	6.38
428.49	424	35	296.62	9.6	208000	6.41
441.44	437	35	297.68	9.64	224000	6.43
454.39	450	35	296.47	9.5	240000	6.44
467.33	463	32	300.09	9.53	256000	6.39
570.89	540	32	300.84	9.56	382000	4.41
674.45	644	30	291.35	9.59	508000	6.45
778.02	747	30	304.95	9.54	634000	6.39
881.58	851	30	299.63	9.52	760000	6.31
985.14	954	30	298.73	9.56	886000	6.38
998.09	994	30	299.79	9.56	900000	6.45
999.15	998	30	296.62	9.59	902000	6.36
1000.21	999	29	297.68	9.55	904000	6.43

Table 3.1. Regression statistics

Multiple R	0.984
R Square	0.967
Adjusted R Square	0.956
Standard Error	53.831
Observations	25

Table 3.2. ANOVA

	Df	SS	MS	F	Significance F
Regression	6	1543367.469	257227.912	88.768	2.210E-12
	18	52159.637	2897.757605		
	24	1595527.106			

Table 3.3. Depth of drilling oil well A

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-1137.72	2530.94	-0.45	0.66	-6455.02	4179.59
TVD	0.88	0.92	0.95	0.35	-1.05	2.81
ROP	2.52	0.92	2.73	0.01	0.58	4.46
HooKload	-1.45	3.72	-0.39	0.70	-9.27	6.37
Torque	168.31	254.36	0.66	0.52	-366.07	702.70
Total Cost/ ($)	0.00	0.00	0.22	0.83	-0.00	0.00
Mudweight	-18.23	30.04	-0.61	0.55	-81.34	44.87

$$MD = -1137.72 + 0.88\beta_1 + 2.52\,\beta_2 - 1.45\beta_3 + 168.34\beta_4 - 0.0002\beta_5 - 18.23\beta_6 \quad (8)$$

It is clear from the above result that the model is fit to predict the Depth of drilling oil well A. It also revealed that about 97% of variation was being accounted for by the variable considered in the analysis. The values showed that the variables considered are all significant contributors.

3. IMPLEMENTATION AND RESULT

There were three modules in this phase, namely: input module, output module and viewing module. The functionality of each module was as follows:

a. Input module: This module provided a way for the Drilling Engineer and the Surveyors to log in to the system software and input data, reports and observations.
b. Output module: This module provided the cost estimate of drilling an oil well output for the project obtained from the input data.
c. Viewing module: This module displayed the output for the management to see, discuss and make decision on.

The proposed system was implemented in the system specified in Table 4.

Table 4. System requirements

System components	Specification
Processor	Pentium 4 board with IGHZ speed
Ram	128MB
Hard Disk	40GB
Display Unit	14″ Monitor (VGA)
CD ROM	Writer X54
Keyboard	Window enhanced
Mouse	Optical
Printer	LaserJet
Operating System	Windows 7
Programming Language (Front end)	Visual BASIC 6.0
Database (Back end)	Access

4. OBSERVATIONS AND FINDINGS

Comparative Analysis: Comparison between the generated simulation values and regression model based software was carried out and it is shown in Table 5.

From the table above, it is observed that there were changes in values and these changes were due to the impacts of TVD, Torque, Hookload, ROP and Mudweight on the depth during drilling operation. Percentage error is calculated as:

$$\text{Percentage Error} = \frac{Experimental\ Value - Theoritical\ Value}{Theoritical\ value} * 100$$

Table 5. Comparison of simulation values and regression model based depth software values

S/N	Total cost in $	Event simulation for depth (ESD) in ft.	Software depth from regression (SDR) in ft.	Δ = |SDR – ESD| in ft.
	130000	63.768	242.828	179.060
	132000	364.831	274.416	90.415
	134000	365.158	300.670	64.488
	136000	368.626	339.620	29.006
	138000	369.525	363.707	5.818
	140000	371.891	391.098	19.207
	142000	374.258	411.467	37.209
	144000	375.701	402.907	27.206
	146000	376.713	398.367	21.653
.	148000	376.714	399.139	22.425
.	150000	389.658	398.150	8.492
.	152000	402.604	411.979	9.375
.	154000	415.549	413.764	1.785
.	208000	428.494	331.260	97.234
.	224000	441.440	451.693	10.253
.	240000	454.385	444.324	10.061
.	256000	467.330	452.070	15.260
.	382000	570.892	584.961	14.0690
.	508000	674.454	678.110	3.6544
.	634000	778.016	766.700	11.316
.	760000	881.578	889.045	7.467
.	886000	985.140	1011.500	26.36
.	900000	998.086	1046.592	48.506
.	902000	999.148	1061.805	62.657
.	904000	1000.211	1051.010	50.799

The experimental value in this research was the regression based software value obtained after calculation (**SDR**) while the theoretical value was the known simulated values from the simulator (**ESD)**. Hence,

Percentage error=

$$\frac{Software\ Value - Simulated\ Value}{Simulated\ Value} * 100$$

$$= \frac{SDR - ESD}{ESD} * 100 \ = \frac{\boldsymbol{\Delta}}{ESD} * 100$$

A percentage very close to zero means we are approaching to the targeted value which is good. It is always necessary to understand the causes of the error, such as whether it is due to the imprecision of the simulator or the estimations from the software due to the impact of some parameters like the Rate of Penetration (ROP). Average percentage error (% error) is the summation of percentage error, divided by the total number n where n = 25

Average $Percentage\ error = \frac{426.35}{25} = 12.08\%$

In the above calculation, the average percentage error is a little bit high due to no impact of the ROP. The rate of penetration for the above calculation is ‘**0’.** Therefore, the real average percentage error

$$= \frac{426.35-280.80}{25-1} = \frac{145.564}{24} = 6.065\ \%$$

Hence, the implemented software has a performance accuracy of 93.935% which is very satisfactory. The plot below depicts a graph of software simulated values against the total cost (Fig. 4). The data series explained that higher drill depth caused higher total cost.

Table 6. Calculation of the percentage error

S/N	ROP in ft/hr	Δ = |SDR – ESD| in ft	$Percentage\ error = \frac{\Delta}{ESD} * 100$
1.	00	179.060	280.80%
2.	10	90.415	24.78%
3.	20	64.488	17.66%
4.	30	29.006	7.87%
5.	40	5.818	1.57%
6.	50	19.207	5.17%
7.	60	37.209	9.94%
8.	60	27.206	7.24%
9.	60	21.653	5.75%
10.	60	22.425	5.95%
11.	45	8.492	2.18%
12.	45	9.375	2.33%
13.	40	1.785	0.43%
14.	35	97.234	22.69%
15.	35	10.253	2.32%
16.	35	10.061	2.21%
17.	32	15.260	3.27%
18.	32	14.069	2.46%
19.	30	3.654	0.54%
20.	30	11.316	1.46%
21.	30	7.467	0.85%
22.	30	26.36	2.67%
23.	30	48.506	4.86%
24.	30	62.657	6.27%
25.	29	50.799	5.08%

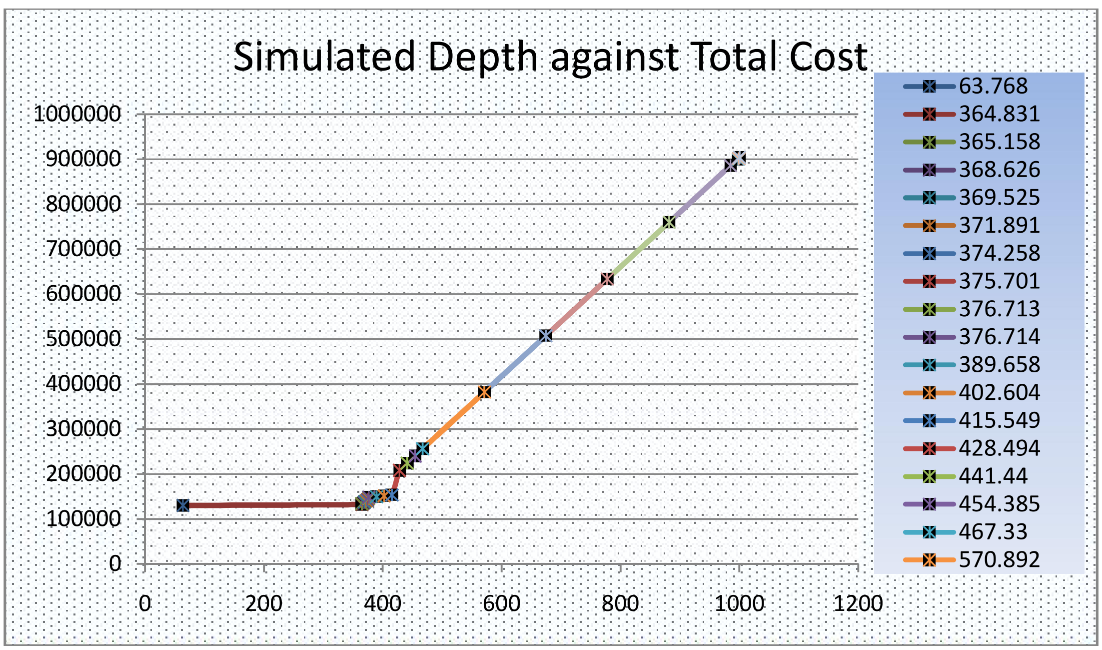

Fig. 4. A plot of simulated values against total cost

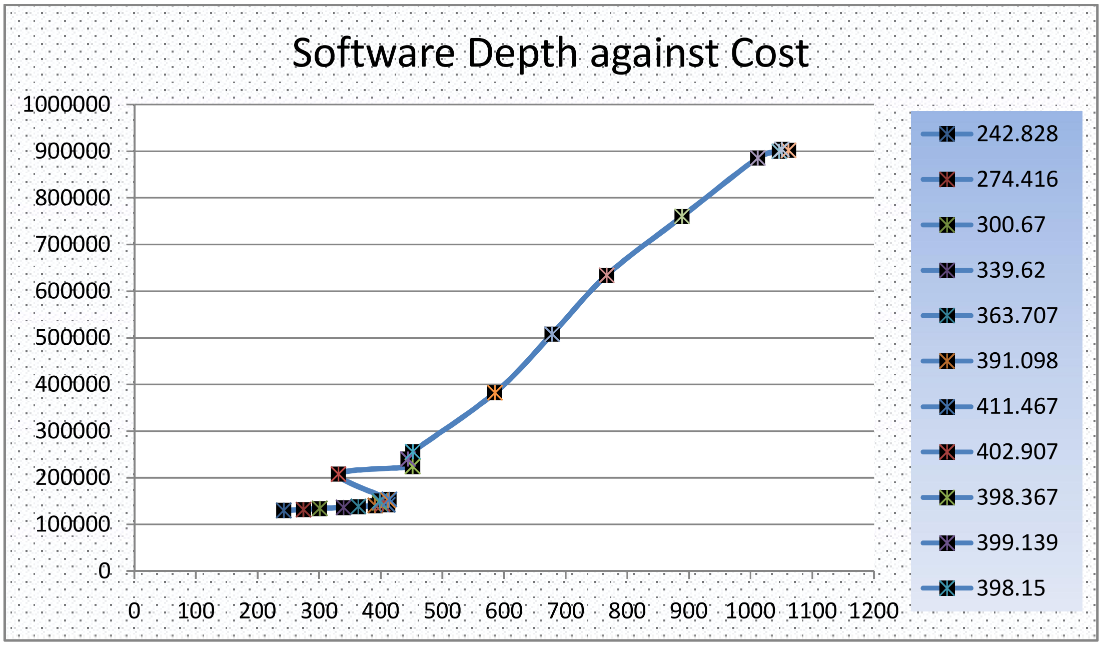

Fig. 5. A plot of software values against the total cost

5. CONCLUSION

This paper focuses on architectural model for oil well drilling and flow monitoring. A mathematical regression model for predicting depth of drilling an oil well evaluation and drilling indicator performance parameters was developed. The impacts of drilling parameters such as WOB, ROP, Torque, HooK Load and total cost on depth of oil well during drilling had been carried out. This study resulted to a mathematical regression model for MD. A mathematical regression model for predicting depth of drilling an oil well evaluation and also drilling indicator performance parameters were developed. It is clear from the study that the model is fit to predict depth of drilling oil well as it shows that about 97% of variation is being accounted for by the variable considered as indicator parameter in the analysis. The values also revealed that the considered variables are all significant contributors. The event stimulated depth of oil well and the mathematical regression based model software developed were compared and showed a performance accuracy of 93.94%. Therefore the mathematical regression model can be adopted for an oil well of 1000ft with almost the same geological history. Hence, this mathematical regression model can be adopted by oil well site engineers and geologists for drilling purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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