Computational Tool for Surface Back Pressure Prediction in Constant Bottom Hole Pressure Variant of Managed Pressure Drilling

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ABSTRACT

Managed Pressure Drilling (MPD) as a drilling method is the outcome of high cost of Non Productive Time (NPT) caused by the closeness of formation pore pressure and fracture pressure which is regular in deep off shore, off shore, high pressure and high temperature and depleted reservoirs as well as some onshore drilling operation. The study was performed with a goal to develop a high prediction precision surface backpressure computation tool amenable to CBHP MPD field practice, used for computation and simulation of down-hole pressures during static and dynamic down-hole conditions. The developed software works on the principle of a generated multiple linear regression annular friction loss (AFL) correlation developed on the basis of surface response methodology (SRM) with AFL as the response variable, the predictor variables were well depth, flow rate, mud weight and hydraulic diameter. The designed software program was used to estimate the back pressure requirement at every given depth for the fields under consideration to test its level of accuracy and robustness. The economic effect of the study was also analysed in view of reduction of the production cost involved in NPT during drilling operations in the field under consideration.

Index Terms – Managed Pressure Drilling, Non Productive Time, Surface Response Methodology, Annular Friction Loss.

1. INTRODUCTION

Drilling a hole from the surface to the target deep in the subsurface poses several challenges. In a bid to surpass these challenges, drilling operations have witnessed a lot of evolutionary phases and several methods have been explored by practicing drilling engineers. In order to profitably drill formations of different pressures. Again for several years now, underbalanced, overbalanced and balanced drilling methods have be discussed and the resolve was suitable aid for which situation depended on many factors, some of which were expertise (or technical know how) down hole pressure limits, health safety and environment constraints, formation damage possibilities, etc, Elliot *et al.*,2011).

Furthermore, managed pressure drilling (MPD) is a drilling technology used to drill wells that are neither method in line with overbalanced nor underbalanced drilling method Hamegan (2005). The primary objective of MPD is to alleviate drilling related problems, to optimize drilling and to optimize drilling by decreasing non – productive time (NPT) Malloy et al (2009).

Again, the main concept behind MPD is that it disobeys the fundamental assumption of zero surface pressure and an open mind circulation system, yet the MPD concept has been explored and landable efficiency, depending on the nature of the formation, the down – hole condition and the reservation. For health and safety Hamegan (2015) stated the different variations of MPD as follows:

1. Constant Bottom-hole Pressure (CBHP)
2. Pressurised Mud Cap Drilling (PMCD)
3. Dual Gradient (DG)
4. Returns Flow Control (HSE) Variation.

The above MPD variations may be applied alone or in combination. However in this work priority will be given to the constant Bottom-hole Pressure (CBHP) variation in this work.

1.1. Constant Bottom-Hole Pressure (CBHP) MPD

CBHP describes all the actions taken to correct or lessen the effect of circulating friction loss or Equivalent Circulating Density (ECD) in an attempt to stay in the limits imposed by the formation pressure and fracture pressure and maintaining an annular pressure profile within this window is the goal of the managed pressure drilling technology.

In CBHP MPD systems, the Bottom-hole Pressure during circulation is represented as:

$$BHP = HP + AFL + SBP \qquad (1)$$

Where; BHP =Bottom hole pressure psi, HP =Hydrostatic pressure psi, SBP = Surface Back pressure psi. $AFL = Annular\ friction\ Loss\ (psi)$

The AFL term becomes zero when the mud pump is off for any reason thereby reducing equation 1 to:

$$BHP = HP + SBP \qquad (2)$$

The BHP is hence controlled by back pressure manipulation to balance the diminished Annular Friction Losses ensuring a Constant Bottom-hole Pressure at all time at any given depth during circulation or connection.

2. METHODOLOGY

2.1. Data Acquisition

Primary data acquisition across three drilled hole sections was accomplished by an automatic measurement and recording of the drilling operations parameters via mud pulse telemetry as the signals return to the drillers console. Secondarily, signals from down-hole measurement sensors are stored in a memory card installed in the bottom-hole assembly. This second source of data is a back up to the data gathered in the driller's console.

A summary of the data collected by the surface and down-hole tools are tabulated in table 1.

	Surface Data	Down-hole Data
Mud Data	I. Pit volume II. Mud temperature III. Mud weight IV. Flow rate	N/A
Geologic Data	Cuttings analysis	i. Density ii. Porosity iii. Resistivity iv. Gamma
Well Data	i. Temperature ii. pressure iii. Gas measurement	Temperature Pressure
Drilling Mechanics	i. RPM ii. Weight on bit iii. Torque	RPM Weight on bit Torque on bit

	iv. Bending Moment v. Rotary torque vi. Hook load vii. ROP	Bending moment Down-hole vibration

Table 1 Summary of Types of Drilling Operation Data during MPD

2.2. Calculation of Back Pressure

The drilling margin as imposed by nature has an upper boundary as the fracture gradient and a lower boundary as the pore pressure. Maintaining an annular pressure profile within this window is the goal of the managed pressure drilling technology. This is mathematically expressed thus:

$$PP \leq BHP < FP \quad (3)$$

Where; PP =Pore pressure (psi0, BHP -=Bottom hole pressure (psi) FP = Fracture Pressure (psi0

However, the conventional expression of bottom-hole pressure (BHP) during circulation is thus;

$$BHP = MW + AFL \quad (4)$$

Where; BHP = Bottom hole pressure (psi) MW =Hydrostatic pressure (psi) AFL =Annular friction loss (psi)

When circulation is halted for any reason, the AFL becomes zero and equation (4) becomes:

$$BHP = MW \quad (5)$$

In a CBHP MPD system, the bottom-hole pressure during circulation is represented as:

$$BHP = MW + AFL + BP \quad (6)$$

Where; BHP = Bottom hole pressure (psi), MW =hydrostatic pressure (psi) BP= Back pressure (psi) the AFL term becomes zero when the mud pump is off for any reason thereby reducing equation (6) to:

$$BHP = MW + BP \quad (7)$$

The BHP is hence controlled by back pressure manipulation to compensate the diminished annular friction losses, ensuring a constant bottom-hole pressure all the time at any given depth during circulation or connection.

2.3. Back Pressure Calculation

$$PP \leq MW + AFL + BP < FP \quad (8)$$

$$(MW + AFL) - PP \leq BP < FP - (MW + AFL) \quad (9)$$

For a given hole section, the designed mud weight is relatively fixed while the annular friction losses are dynamic, increasing as the hole section elongates. However, it is safe to say that the back pressure applied is a direct consequence of the annular friction loss incurred within the annulus. Therefore inaccurate annular friction loss estimation will lead to an incorrect back pressure calculation and application.

2.4. Software Application

A software for computing SBP was developed and its application is as follows

1. First you need to install the software by inserting the disc into your disk drive and following the instruction of the setup that comes up.
2. Launch the application by double clicking on the application Icon in the desktop or from the start menu.
3. Import your input data from an excel file by clicking on the excel icon shown in the UI, it will bring up a prompt for you to select the excel file that houses your data.
4. Select the Excel sheet in the file that contains the data by clicking on the dropdown that shows all the excel sheets in your excel file.
5. Once, you select a sheet, another prompt will come up for you to map the headers in your Excel sheet to the appropriate

variable in the software. Once mapping is complete click the “Ok” button.

6. The application will automatically display all your data in a table.

7. On the adjacent table enter each section depth with their corresponding BHP.

8. Now Click on the “Validate” button.

9. On the Home Tab, click on “Calculate”, this will use your input data to run the calculations for each section depth you entered. Click on “Plot” to visualize the result in different chart types.

2.5. Back Pressure Calculator

Based on the proposed model, a software was developed to estimate the required back pressure that is needed to ensure constant bottom-hole pressure.

The developed software is a robust and highly interactive surface backpressure (SBP) estimator that is capable to precisely predict the requisite SBP needed to maintain a desired bottom-hole pressure (BHP) during both static and dynamic down-hole conditions, considering any pre-determined drilling window

The developed tool software has the following capabilities:

i. Read data directly in Excel file format

ii. Sort desired columns from a multiple column data set

iii. Output and save its estimations in Excel format

iv. Display output as graphical plots

3. RESULTS AND DISCUSSION

Extracts from the developed software are provided subsequently:

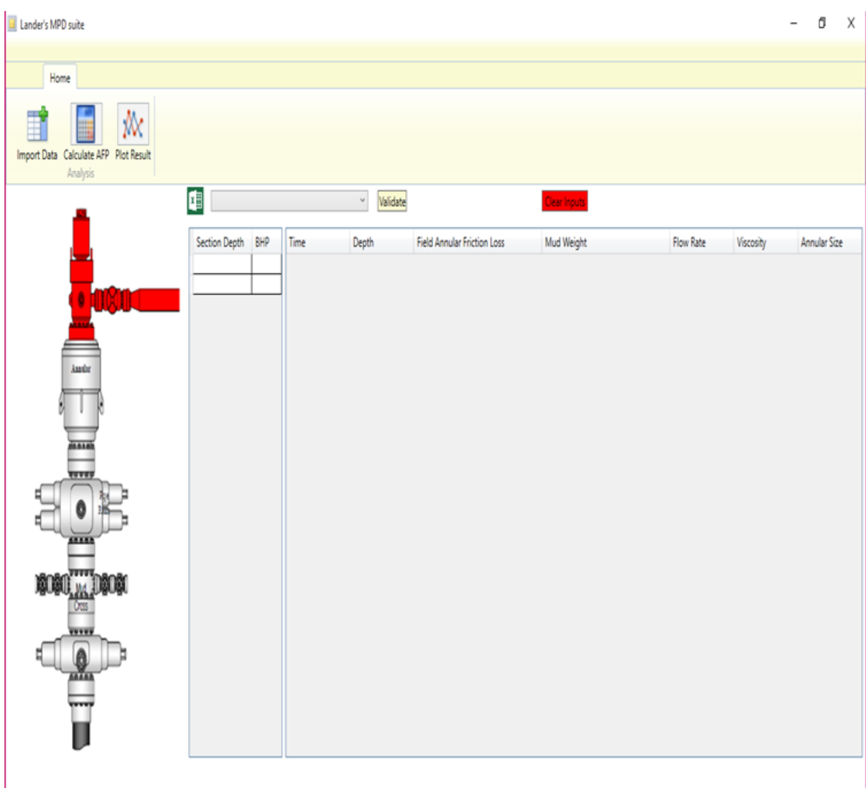


Figure 2 Home Page of Developed Software

3.1. SBP Computation Using Developed Software

The developed software reads data from an excel file and provides an interactive interface for selecting variable and specifying the desired BHP expected to be kept constant during drilling operation.

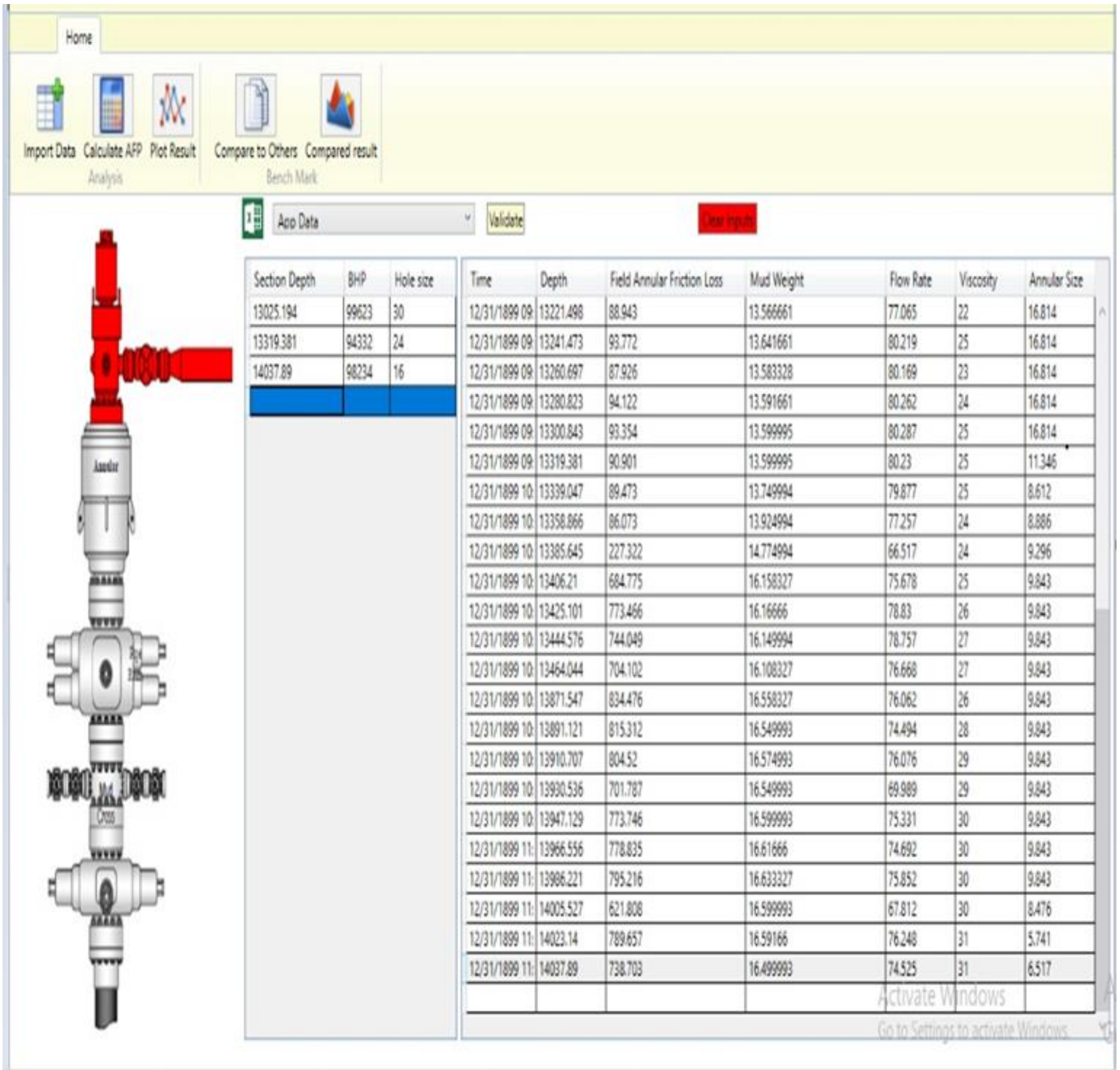
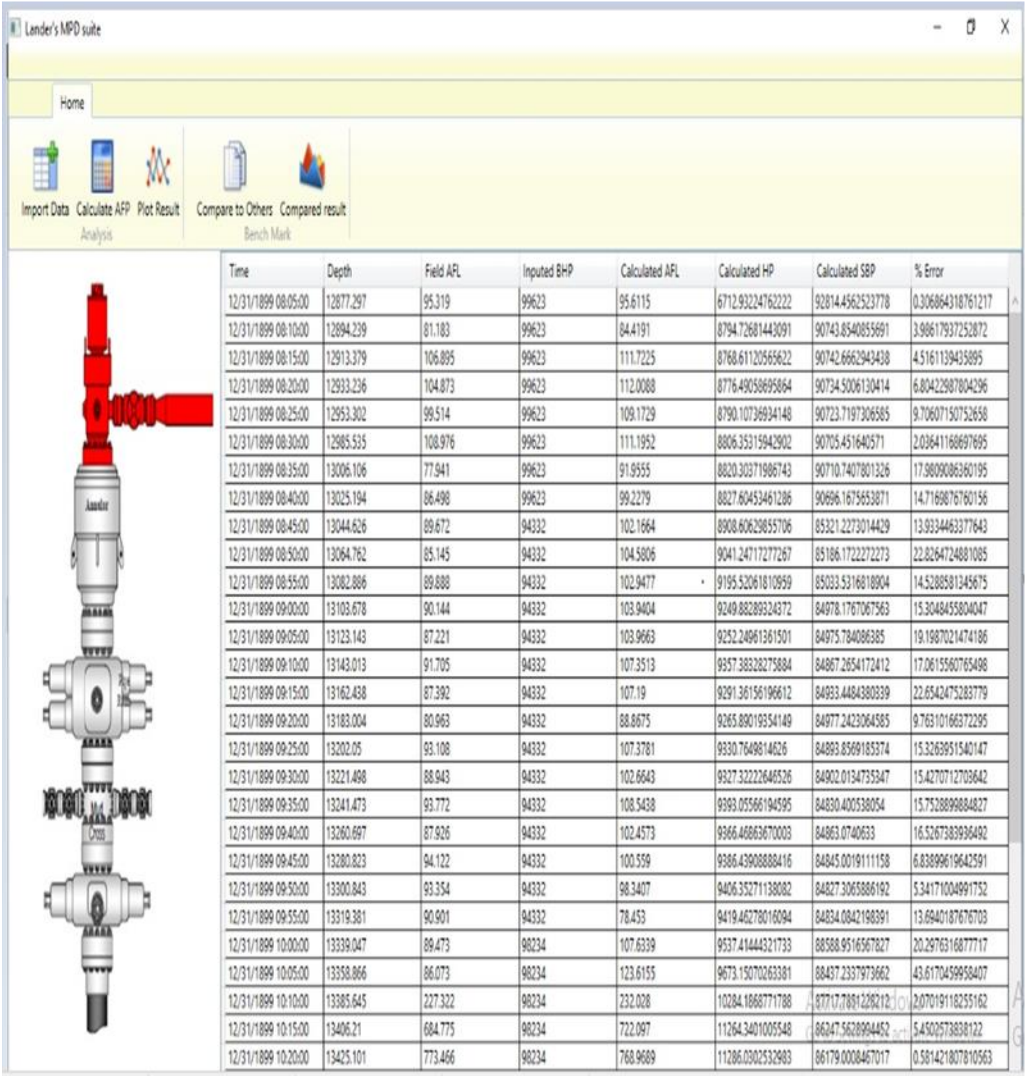


Figure 3 Interactive Mode during SBP Estimation

3.2. Down-Hole Simulation Using Developed Software

The software was able to simulate down-hole pressures, showing the system's ability to maintain the bottom-hole pressure(BHP) within the given drilling margin specified by pore and fracture pressures and produce a visual output of the simulation as shown in figure 4.9. The software also shows the likely down-hole situation assuming a conventional BHP.

The output from the software computations is shown in figure 4 below. The AFL, HP and required SBP were calculated for every depth from top to bottom of the hole section and results were displayed and saved on a Microsoft Excel readable worksheet.



Time	Depth	Field AFL	Inputed BHP	Calculated AFL	Calculated HP	Calculated SBP	% Error
12/31/1899 08:05:00	12877.297	95.319	99623	95.6115	6712.93224762222	92814.4562523778	0.306864318761217
12/31/1899 08:10:00	12894.239	81.183	99623	84.4191	8794.72681443091	90743.8540855691	3.98617937252872
12/31/1899 08:15:00	12913.379	106.895	99623	111.7225	8768.61120565622	90742.6662943438	4.5161139435895
12/31/1899 08:20:00	12933.236	104.873	99623	112.0088	8776.49058695864	90734.5006130414	6.80422987804296
12/31/1899 08:25:00	12953.302	99.514	99623	109.1729	8790.10736934148	90723.7197306585	9.70607150752658
12/31/1899 08:30:00	12985.535	108.976	99623	111.1952	8806.35315942902	90705.451640571	2.03641168697695
12/31/1899 08:35:00	13006.106	77.941	99623	91.9555	8820.30371986743	90710.7407801326	17.9809086360195
12/31/1899 08:40:00	13025.194	86.498	99623	99.2279	8827.60453461286	90696.1675653871	14.7169876760156
12/31/1899 08:45:00	13044.626	89.672	94332	102.1664	8908.60629855706	85321.2273014429	13.9334463377643
12/31/1899 08:50:00	13064.762	85.145	94332	104.5806	9041.24717277267	85186.1722272273	22.8264724881085
12/31/1899 08:55:00	13082.886	89.888	94332	102.9477	9195.52061810959	85033.5316818904	14.5288581345675
12/31/1899 09:00:00	13103.678	90.144	94332	103.9404	9249.88289324372	84978.1767067563	15.3048455804047
12/31/1899 09:05:00	13123.143	87.221	94332	103.9663	9252.24961361501	84975.784086385	19.1987021474186
12/31/1899 09:10:00	13143.013	91.705	94332	107.3513	9357.38328275884	84867.2654172412	17.0615560765498
12/31/1899 09:15:00	13162.438	87.392	94332	107.19	9291.36156196612	84933.4484380839	22.6542475283779
12/31/1899 09:20:00	13183.004	80.963	94332	88.8675	9265.89019354149	84977.2423064585	9.76310166372295
12/31/1899 09:25:00	13202.05	93.108	94332	107.3781	9330.7649814626	84893.8569185374	15.3263951540147
12/31/1899 09:30:00	13221.498	88.943	94332	102.6643	9327.32222646526	84902.0134735347	15.4270712703642
12/31/1899 09:35:00	13241.473	93.772	94332	108.5438	9393.05566194595	84830.400538054	15.7528899884827
12/31/1899 09:40:00	13260.697	87.926	94332	102.4573	9366.46863670003	84863.0740633	16.5267383936492
12/31/1899 09:45:00	13280.823	94.122	94332	100.559	9386.43908888416	84845.0019111158	6.83899619642591
12/31/1899 09:50:00	13300.843	93.354	94332	98.3407	9406.35271138082	84827.3065886192	5.34171004991752
12/31/1899 09:55:00	13319.381	90.901	94332	78.453	9419.46278016094	84834.0842198391	13.6940187676703
12/31/1899 10:00:00	13339.047	89.473	98234	107.6339	9537.41444321733	88588.9516567827	20.2976316877717
12/31/1899 10:05:00	13358.866	86.073	98234	123.6155	9673.15070263381	88437.2337973662	43.6170459958407
12/31/1899 10:10:00	13385.645	227.322	98234	232.028	10284.1868771788	87717.7881228212	2.07019118255162
12/31/1899 10:15:00	13406.21	684.775	98234	722.097	11264.3401005548	86247.5628994452	5.4502573838122
12/31/1899 10:20:00	13425.101	773.466	98234	768.9689	11286.0302532983	86179.0008467017	0.581421807810563

Figure 4 The Developed Software SBP Computation Output

3.3. Down-Hole Simulation Using Developed Software

The developed software was able to simulate down-hole pressures, showing the system's ability to maintain the bottom-hole pressure(BHP) within the given drilling margin specified by pore and fracture pressures and produce a visual output of the simulation as shown in figure 5. The software also shows the likely down-hole situation assuming a conventional BHP.

The plot above is a simulation done by the developed software for this study, the simulation displays what would have happened if conventional mud-weight alone was used and also displays how the software maintains constant BHP.

The Green line indicates the conventional mud-weight, the dotted blue line indicates the CBHP based on the model, the yellow line indicates the Fracture gradient line, and the red line denotes the pore-pressure line. We see that at a depth of 13946 ft, we see that the conventional mud-weight would be equal to the pore-pressure and beyond that point we see that the conventional mud-weight would go below the pore pressure line indicating that the pore pressure would be greater than the hydrostatic pressure of the conventional mud-weight, that is the scenario we call a kick, which if not controlled would lead to the feared blowout. So we would have had a kick possibly blowout with the conventional method, furthermore you notice that with the conventional method, the BHP is unsteady as shown by the plot, but as we can see, the dotted blue line was always between the operating window and unchanging as seen in the plot, so we see that we would maintain a steady BHP and yet walk between the line and stay away from possible kick occurrence which is achieved by using the developed software.

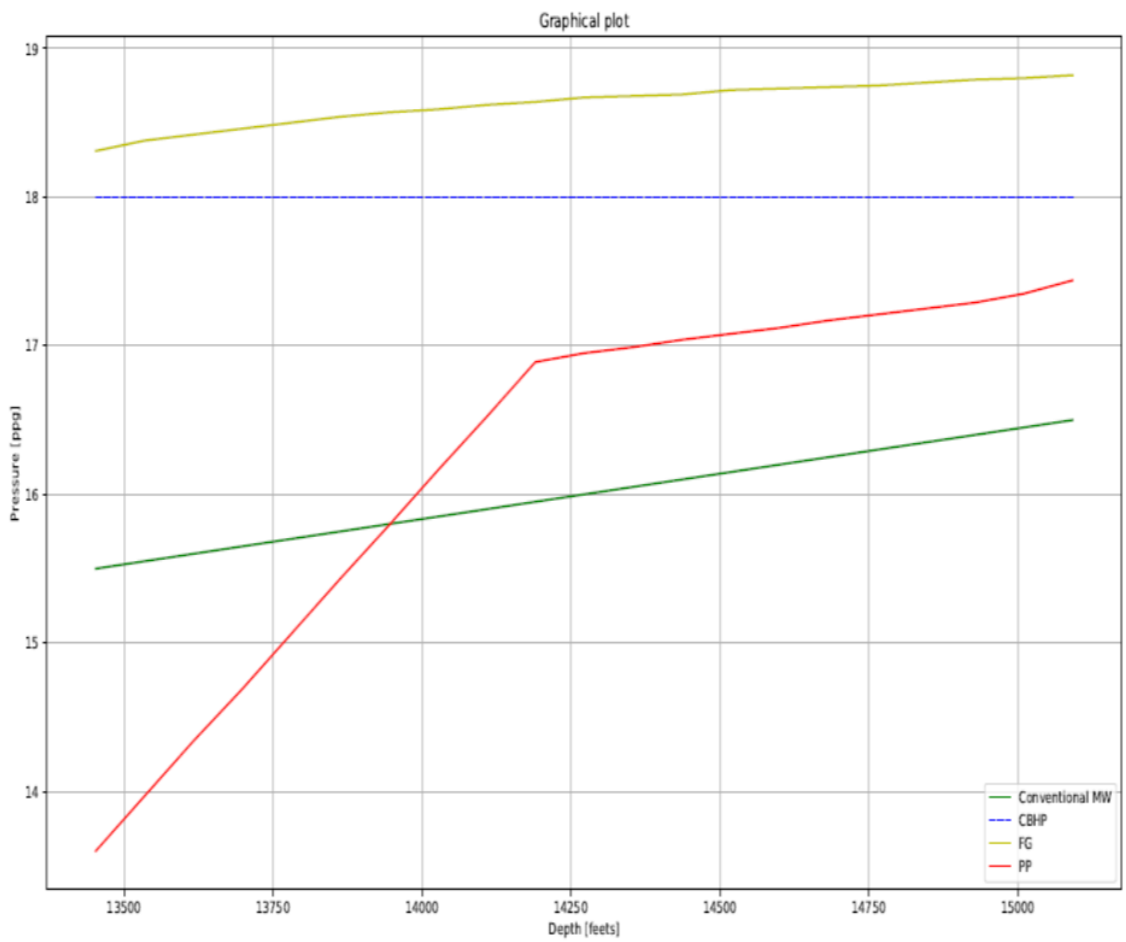


Figure 5 Simulation of Constant BHP using the Developed Software

4. CONCLUSION

A robust and highly interactive backpressure software was developed on the basis of the proposed model to compute with commendable prediction precision for the required SBP needed to maintain CBHP. The study was performed with a goal to develop a SBP computation software amenable to CBHP MPD field practise, used for computation and simulation of down-hole pressures during static and dynamic down-hole conditions. The developed software works on the principle of a generated multiple linear regression annular friction loss (AFL). The predictor variables were well depth, flow rate, mud weight and hydraulic diameter. The generated AFL model was verified to fit satisfactorily with actual data as depicted by a correlation coefficient (R) of 0.998. The success of the developed software depends entirely on open-hole annular friction loss estimation. Real time software applicability – A measure of artificial intelligence upgrade is required to achieve an automatic real time data reading, computation and back pressure manipulation by the surface choke.

The following are the conclusions reached in this research work

1. The developed surface backpressure computation tool is robust, amenable to practice and very user friendly and interactive. It therefore requires minimal training to use.

The contribution of this research is that High precision user friendly backpressure computing software amenable to rig application is developed in this research.

This work has established a springboard upon which further research on the application of optimal SBP prediction technique in Niger Delta region and similar drilling site can be made.

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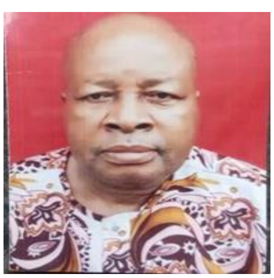

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