

## Chapter Four

### Results and Discussion

Hamra field have been selected as case study to design and analysis slim hole sidetrack from abandon well to hit new target close to abandon well, which contain the following data:

**Abandon well data showed in table below .4.1:**

**Table (4.1):** Abandon well data.

Well Name	Hamra A
Well Type	Development
Block	Block 2B
Basin	Muglad Basin
Latitude	09° 55' 07.16" N
Longitude	29° 26' 22.17" E
Easting(X)	767500.00m
Northing(Y)	1097400.00m
Objective	Aradieba Sand and Bentiu Sand
Ground Elevation	397.000m
RT Elevation	403.024m
Spud In Date	February, 2013
TD Date	February, 2013
Surface Casing	9 5/8" at 962m
Production Casing	7 " at 1887m
Final TD	1888m
Well Status	Completed

Target data showed below in table.4.2:

Table (4.2): Target data.

Easting(X)	767108.996m
Northing(Y)	1097170.043m
Target depth	1900m

## 4.1 Well Trajectory:

### 4.1.1 Azimuth Calculation:

Calculate Azimuth from equation (3.1):

$$azimuth = \tan^{-1}\left(\frac{767108.996 - 767500}{1097170.043 - 1097400}\right) = \tan^{-1}\left(\frac{-391}{-229.96}\right) = 59.5^\circ + 180 = 239.5^\circ$$

### 4.1.2 Trajectory Calculation:

#### 1- Build Section:

- **Data:**

Total horizontal departure = 455 m

$BUR = 3 \text{ deg/ } 30m$

True vertical depth (TVD) = 1900 m

Depth to kick of point (KOP) = 1200 m

- **Radius of curvature  $R_1$ :**

Calculate radius of curvature from equation (3.2):

$$R_1 = \frac{180 \times 30}{\pi \times BUR} = \frac{5400}{\pi \times 3} = 572.96m$$

$$R_2 = 0$$

- **Maximum inclination angle  $I_{max}$**

Calculate The Maximum inclination angle  $I_{max}$  from equation (3.3):

$$I_{max} = 2 \tan^{-1}\left(\frac{1900 - 1200 - \sqrt{455^2 + (1900 - 1200)^2} - 2(572.96 + 0) \times 455}{2(572.96 + 0) - 455}\right) = 44.25^\circ$$

- **Measure depth for build section**

Calculate measure depth for build section from equation (3.4):

$$\Delta L = \left( \frac{\pi}{180} \right) \times 572.96 \times 44.25^\circ = 442.5m$$

- **TVD for build section**

Calculate TVD for build section from equation (3.5):

$$\Delta y = 572.96 \sin 44.25 = 399.81m$$

- **Total horizontal departure of build section**

Calculate total horizontal departure of build section from equation (3.6):

$$X_{build} = 572.96 \times (1 - \cos(44.25^\circ)) = 162.55m$$

**2- Hold Section:**

- **Calculate total horizontal departure of hold section from triangles calculation:**

$$X_{hold} = 455 - 162.55 = 292.45m$$

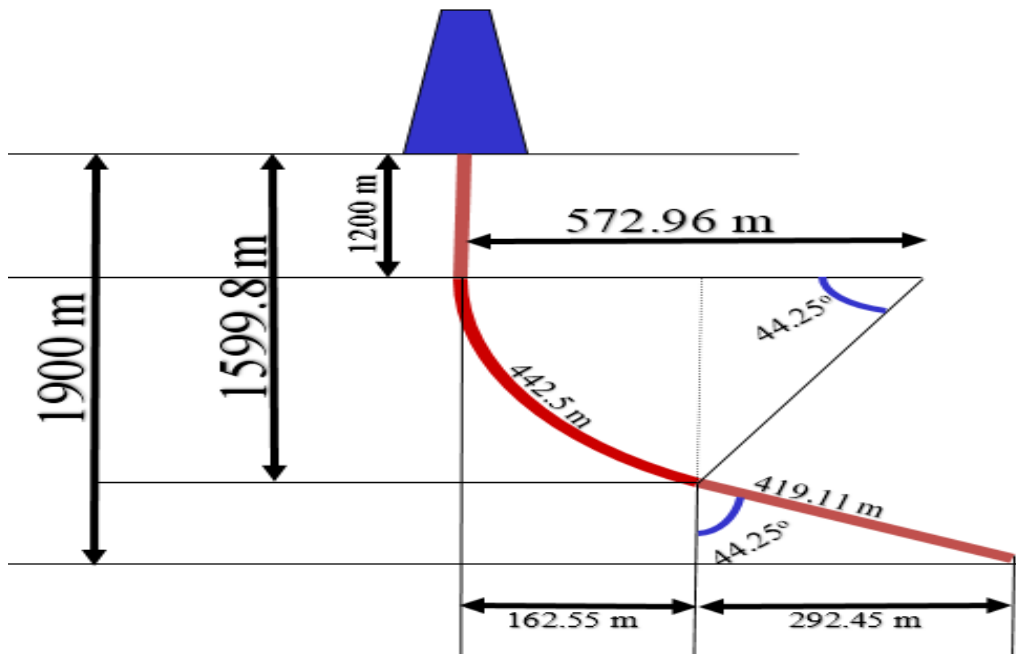
- **Calculate total measure depth of hold section from triangles calculation:**

$$L_{hold} = \frac{292.45}{\sin \theta} = \frac{292.45}{\sin(44.25)} = 419.11m$$

**3- Measure Depth of Target:**

Calculate measure depth from equation (3.7):

$$MD = 1200 + 442.5 + 419.11 = 2061.61m$$



**Fig (4.1):** Explain Build Hold Profile.

### 4.1.3 Input Data in Compass and Landmark:

In put the abandon well basic data in compass the Fig.4.2 below show it:

Fig (4.2): General Data.

#### •Input survey data

Fig.4.3 below explain data needed to create well profile to reach a target. This can be done by input data into compass such as measure depth, inclination, azimuth, the program automatically calculate true vertical depth, North/south, East/West, Vertical Section and Dog leg severity. The survey data can be used in both compass and well plan.

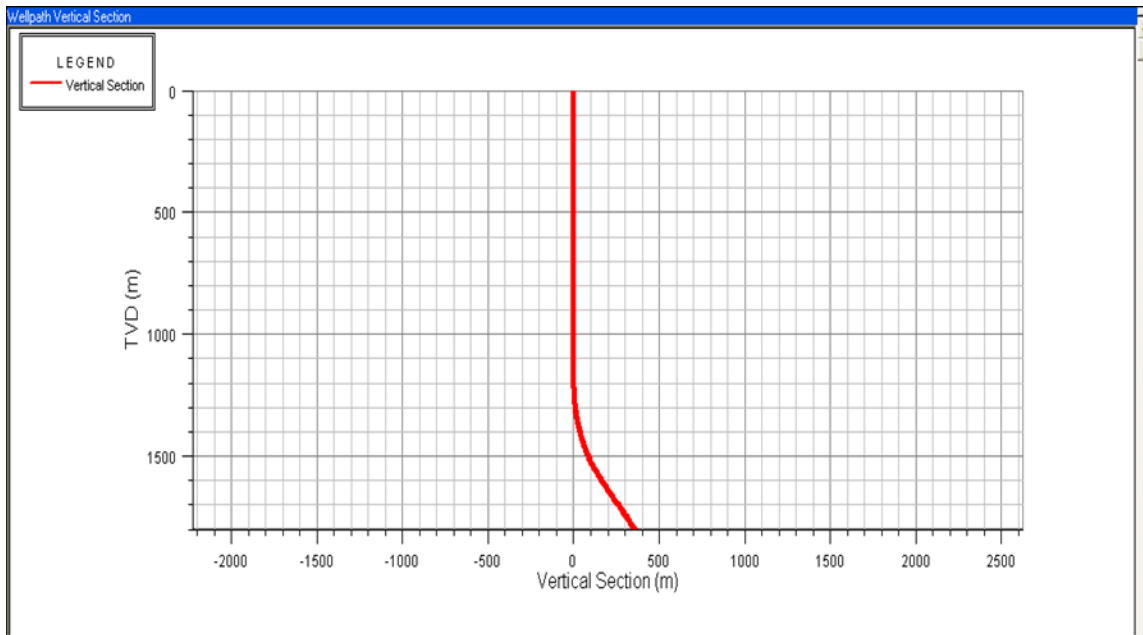
	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target	
1	0.00		0.00	0.00	0.00	1097400.00	767500.00	1339157.56	0.000	0.00	0.000	0.000	0.000	Tie Line	
2	1200.00	1200.00	0.00	239.50	1200.00	1097400.00	767500.00	1339157.56	0.000	239.50	0.000	0.000	0.000	Inc Azi TVD	
3	1230.00	30.00	3.00	239.50	1229.99	1097399.60	767499.32	1339156.85	3.000	239.50	3.000	0.000	0.000	Inc Azi MD	
4	1260.00	30.00	6.00	239.50	1259.89	1097398.41	767497.30	1339154.71	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
5	1290.00	30.00	9.00	239.50	1289.63	1097396.42	767493.92	1339151.14	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
6	1320.00	30.00	12.00	239.50	1319.12	1097393.65	767489.21	1339146.17	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
7	1350.00	30.00	15.00	239.50	1348.29	1097390.09	767483.18	1339139.80	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
8	1380.00	30.00	18.00	239.50	1377.05	1097385.77	767475.84	1339132.05	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
9	1410.00	30.00	21.00	239.50	1405.33	1097380.69	767467.21	1339122.94	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
10	1440.00	30.00	24.00	239.50	1433.04	1097374.86	767457.32	1339112.50	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
11	1470.00	30.00	27.00	239.50	1460.12	1097368.30	767446.19	1339100.75	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
12	1500.00	30.00	30.00	239.50	1486.48	1097361.04	767433.86	1339087.73	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
13	1530.00	30.00	33.00	239.50	1512.06	1097353.09	767420.36	1339073.48	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
14	1560.00	30.00	36.00	239.50	1536.78	1097344.46	767405.72	1339058.02	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
15	1590.00	30.00	39.00	239.50	1560.57	1097335.19	767389.98	1339041.41	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
16	1620.00	30.00	42.00	239.50	1583.38	1097325.31	767373.20	1339023.69	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
17	1642.50	22.50	44.25	239.50	1599.80	1097317.50	767359.94	1339009.70	3.000	0.00	3.000	0.000	0.000	Inc Azi MD	
18	1672.50	30.00	44.25	239.50	1621.29	1097306.88	767341.91	1338990.65	0.000	0.00	0.000	0.000	0.000	Inc Azi MD	
19	1702.50	30.00	44.25	239.50	1642.78	1097296.25	767323.87	1338971.61	0.000	0.00	0.000	0.000	0.000	Inc Azi MD	

Fig (4.3): Survey Data.

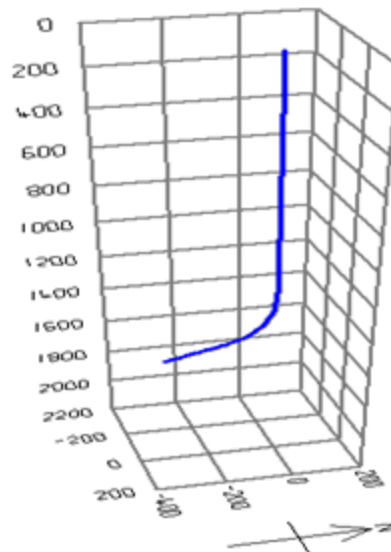
## 4.1.4 Compass and Landmark Result:

### 4.1.4.1 Well Profile:

Well profile structure from abandon well at coordinate (N (1097400), E (767500)) to reach a new target closed to abandon well at coordinate (N (1097207), E (767180)), measure depth 2061.61m and departure 455m, as it is shown in Fig.4.4 from compass in 3D and Fig.4.5 from well plan in 2D.



**Fig (4.4):** Well Profile 2D from Landmark.



**Fig (4.5):** Well Profile 3D from Compass.

#### 4.1.4.2 Dogleg Severity:

The maximum dogleg severity is not consider a great value (only 3.0 deg.) at vertical and build sections, and this value allowed to drill without problems such as key seat...etc. shown in Fig.4.6.

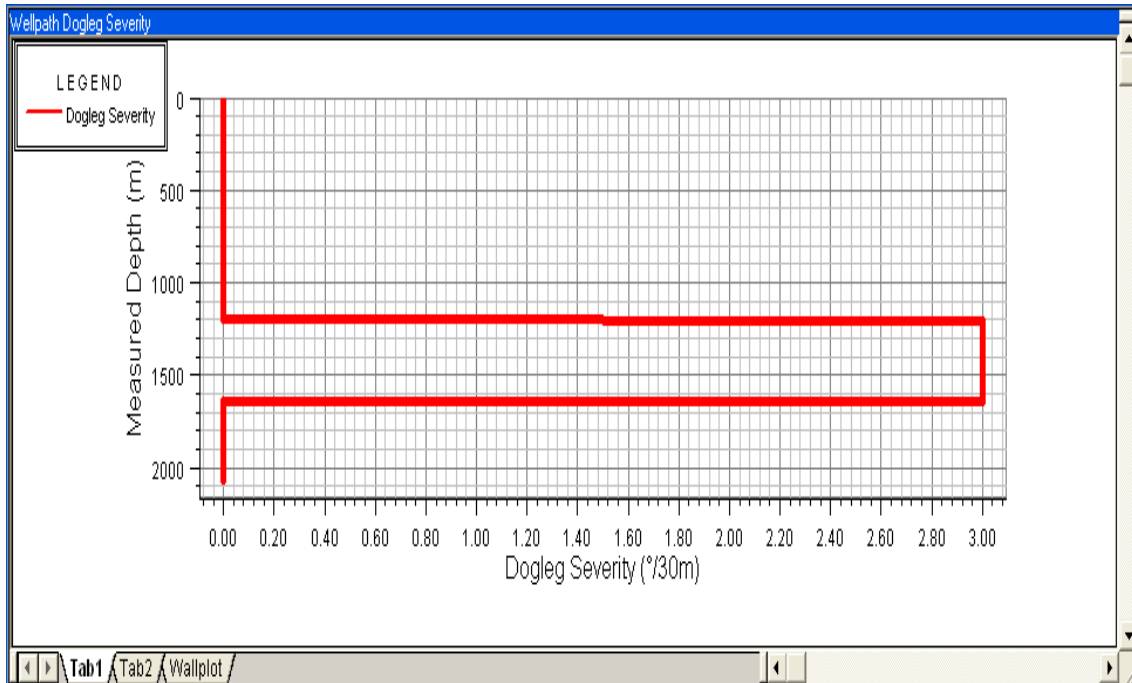


Fig (4.6): Dogleg Severity.

#### 4.1.4.3 Well Path Inclination:

Division angle have been built from KOP at 1200m by BUR 3°/30m and continues build until depth 1642.5m and the total angle at this depth became 44.25 and then keep angle until reach a new target at 2061.61m, as shown in Fig.4.7.

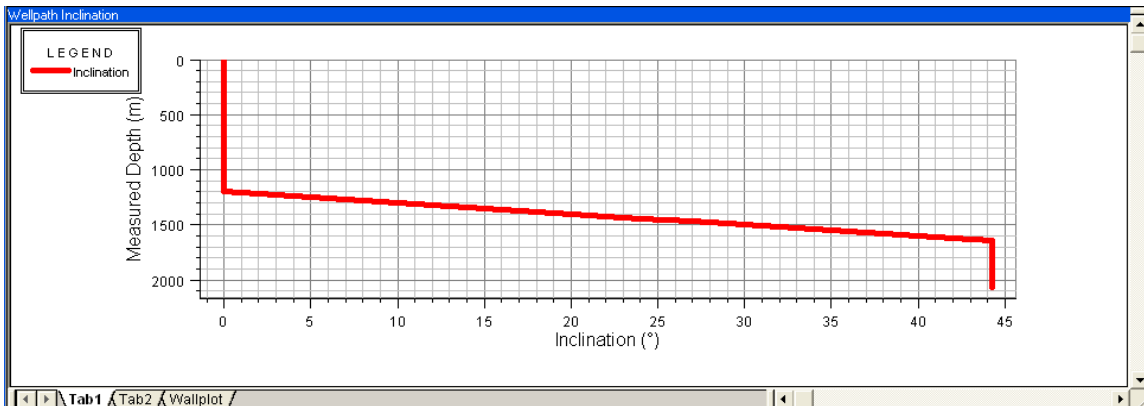


Fig (4.7): Inclination with Measure Depth.

#### 4.1.4.4 Well Path Azimuth:

Directional section have been determined by calculated azimuth  $239.5^\circ$  from north as shown in Fig.4.8:

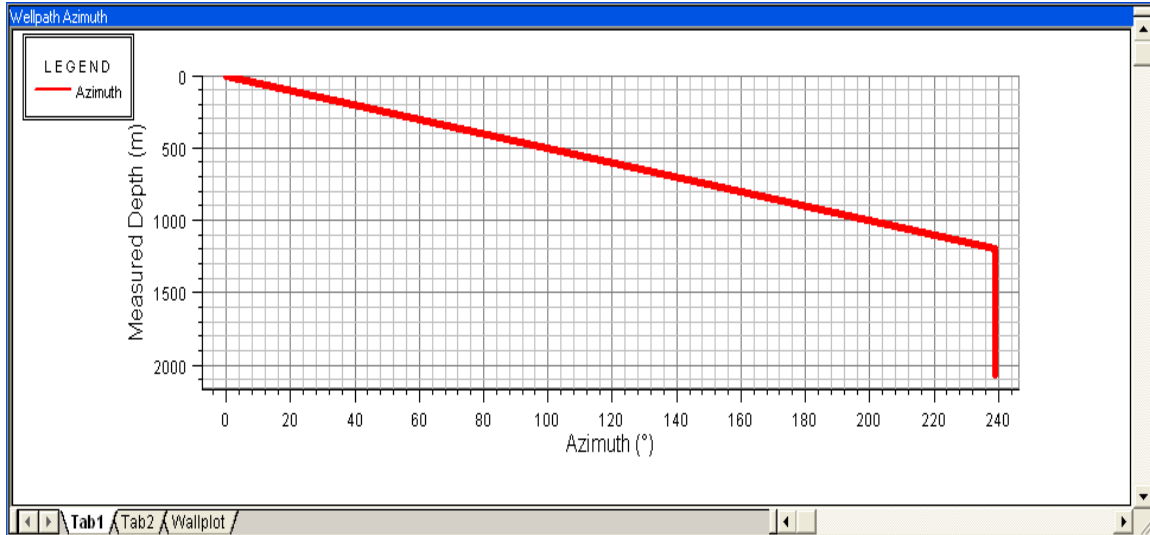


Fig (4.8): Azimuth with Measure Depth

## 4.2 Casing Milling Window (using abaqus (FE) software):

### 4.2.1 Construction Slim Hole Sidetrack Model:

The first step in simulator is construction all geometrical shape and the Fig.4.9, 4.10 and 4.11 below present each geometrical shape individual. Then input the material mechanic data for casing and milling bit but whipstock do not has any properties data because it is considered rigid shape.

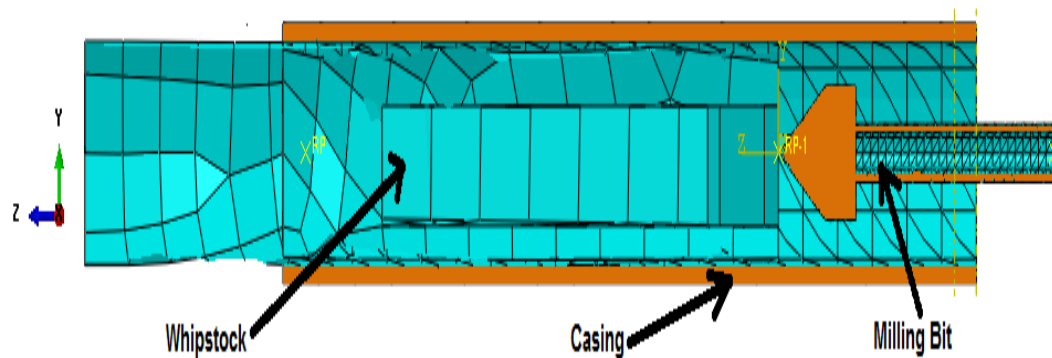
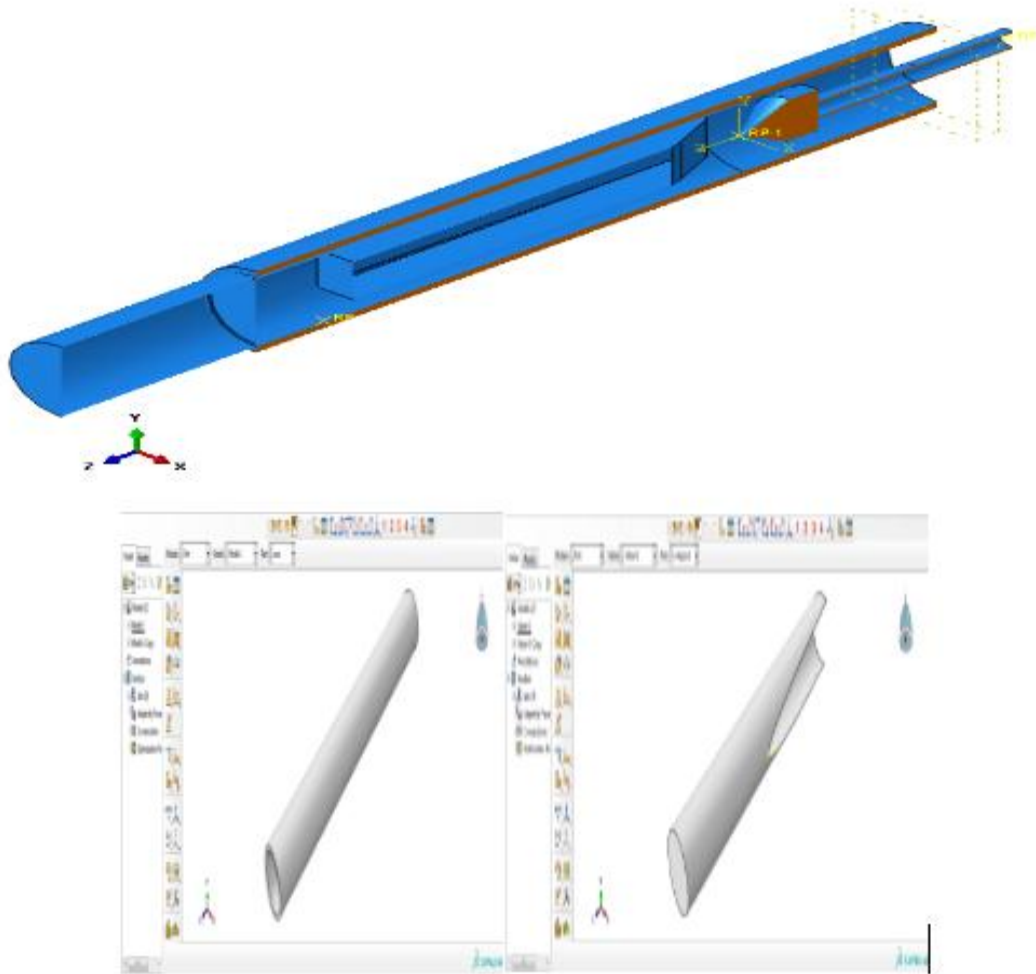


Fig (4.9): Casing, Whipstock.



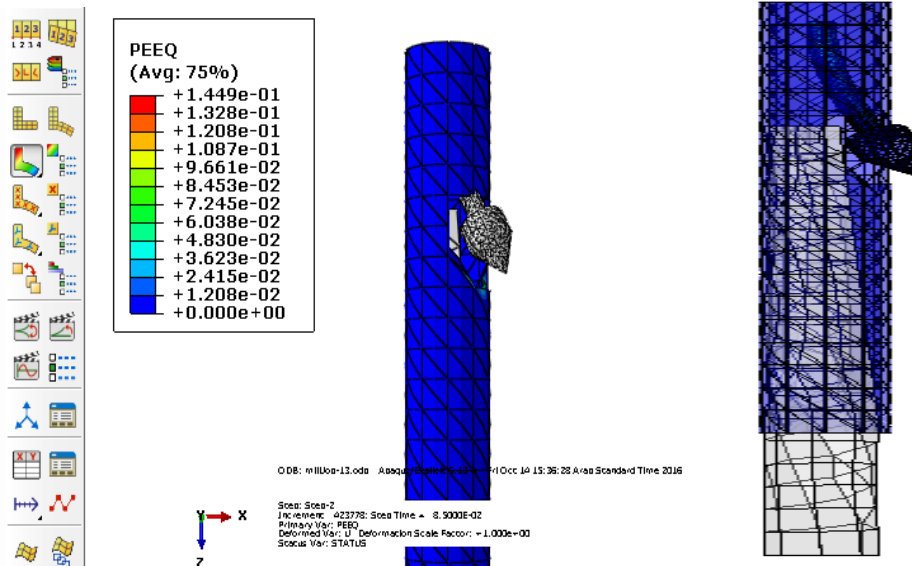
**Fig (4.10):** Casing, Milling Bit, and Whipstock Model Parts.

Assembly geometrical shape to take the right place in the model and Input boundary condition for it and also meshing slim hole side track model to fine element to five good approximate model.

#### **4.2.2 Model Result and Analysis:**

Abaqus (FE) software provided good simulator for slim hole wellbore by milling the production casing. In this model the selected shape of milling bit used by Baker Huge Company and this provided successful open window in production casing and then allow making sidetrack to reach a new target. Fig.4.11 below present simulation results of milling casing and opening window.





**Fig (4.11):** Casing Milling with Baker Milling Bit Shape

## 4.3 Bottom Hole Assemble:

### 4.3.1 Selection BHA:

The Table (4.3) below showed BHA selection:

**Table (4.3):** BHA

Section type	OD/ID (in )	From table
HWDP	3.5/2.06	(3.3)
Jar	4.75/2.25	(3.4)
Drill collar	4.75/2.25	(3.1)&(3.2)
Non-Mag Drill collar	4.75/2.25	(3.5)
MWD	4.75/1.6	-
Sub	4.5/1.5	-
Mud Motor	4.75/1.75	-
Bit	6/-	(3.6)

### 4.3.2 Drill Collar and HWDP Calculation:

- Data:**

Hole Size: 6 inch

Well Inclination: 44.25°

Mud Density: 10.4ppg

Required WOB: 7.7 ton = 16975.59 lb.

Drill collar OD/ID: 4.75/2.25 in

HWDP OD/ID:3.5/2.06 in

• **Calculation:**

1- Determine the buoyancy factor for the mud weight in using the formula (3.8):

$$BF = 1 - \frac{10.4}{65.5} = 0.84$$

2- Calculate the required collar number to achieve the desired weight on bit from equation (3.9):

$$DC_{length} = \frac{16975.59}{0.84 \times \cos 44.25} = 28213.01 Ibf$$

Safety factor 15%

$$DC_{length} = \frac{28213.01}{0.85} = 33191.8 Ibf$$

Nominal weight:  $DC(4.75OD/2.25ID) = 46.77 Ibf/ft$

One drill collar weight = 46.77 x 30 = 1403.1 Ibf

Number of drill collars  $DC_{number} = \frac{33191.8}{1403.1} = 24$  drill collars

3- Calculate the required collar and HWDP length to achieve the desired weight on bit:

We used 10 drill collar and replaced 14 drill collar to HWDP:

HWDP (3.5OD / 2.06 ID) = 23.2 Ibf/ft

One HWDP weight = 23.2 x 31 = 719.2 Ibf

10 x DC = 14031 Ibf

Number of HWDP = (33191.8 - 14031) / 719.2 = 26.6 = 27 hwdp

**Length of drill collars = One drill collar length x DC number**

$L_{DC} = 30 \times 10 = 300$  ft

**Length of HWDP = One HWDP length x DC number**

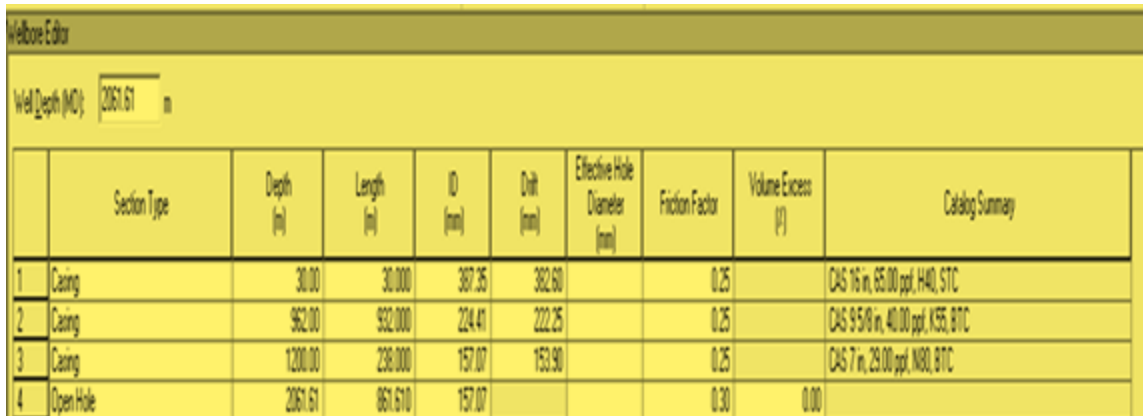
$L_{HWDP} = 31 \times 27 = 837$  ft

### 4.3.3 Input BHA Data in landmark:

The Bottom Hole Assembly module was designed to predict the directional drilling performance of a bottom hole assembly. The module can provide an accurate representation of the forces acting on the assembly as it exists in the wellbore. This type of analysis can be useful for explaining unexpected performance or for determining the causes of tool failures.

#### 4.3.3.1 Wellbore Editor:

Wellbore editor enables the user to input the wellbore information for casing and open hole such as Length, internal diameter (ID), and friction factor. The friction factor is assumed or could be matched later with the actual data. The Fig.4.12 showed wellbore editor.



	Section Type	Depth (m)	Length (m)	ID (mm)	Odt (mm)	Effective Hole Diameter (mm)	Friction Factor	Volume Excess (l)	Catalog Summary
1	Casing	30.00	30.000	387.35	382.60		0.25		CAS 16 in, 65.00 ppi, H40, STC
2	Casing	962.00	932.000	224.41	222.25		0.25		CAS 9 5/8 in, 40.00 ppi, K35, BTC
3	Casing	1200.00	238.000	157.07	153.90		0.25		CAS 7 in, 29.00 ppi, N80, BTC
4	Open Hole	2067.61	867.610	157.07			0.30	0.00	

Fig (4.12): Wellbore Editor.

#### 4.3.3.2 String Editor:

String and BHA data can be inputted in the string editor. It includes the outer diameter, yield strength, torsional strength, weight, etc. Fig.4.13 below show string editor.

String Editor

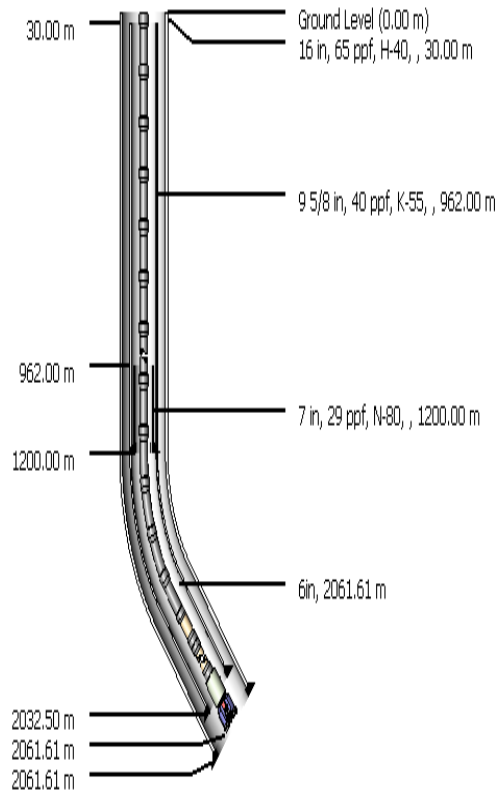
- String Initialization

String Type:  String Depth:  m Specify:

	Section Type	Length (m)	Depth (m)	OD (mm)	ID (mm)	Weight (kg/m)	Catalog Description
1	Drill Pipe	1684.871	1684.87	88.90	70.21	21.86	DP 3 1/2 in, 13.30 ppf, S, NC38(F), P
2	Heavy Weight	246.888	1931.76	88.90	57.15	34.53	HW Grant Pntoco, 3 1/2 in, 23.20 ppf
3	Jar	9.754	1941.51	120.65	57.15	69.62	JRH Daley Hyd, 4 3/4 in
4	Drill Collar	91.440	2032.95	120.65	57.15	69.60	DC 4 3/4 in, 2 1/4 in
5	Drill Collar	9.150	2042.10	120.65	57.15	69.60	DC 4 3/4 in, 2 1/4 in
6	MWD	9.144	2051.25	120.65	40.64	85.07	MWD 6 3/4, 6 3/4 x 2 1/2 in
7	Sub	0.914	2052.16	112.78	36.58	71.60	FS 4 1/2, 4 1/2 x 1 1/2 in
8	Mud Motor	9.144	2061.31	120.65	44.45	77.56	BHM 4 3/4, 4 3/4 x 3/4 in
9	Bit	0.305	2061.61	152.40		52.09	

**Fig (4.13):** String Editor.

Fig.4.14 and 4.13 below presents BHA components with inside, outside diameter and length of each component.



**Fig (4.14):** BHA Model.

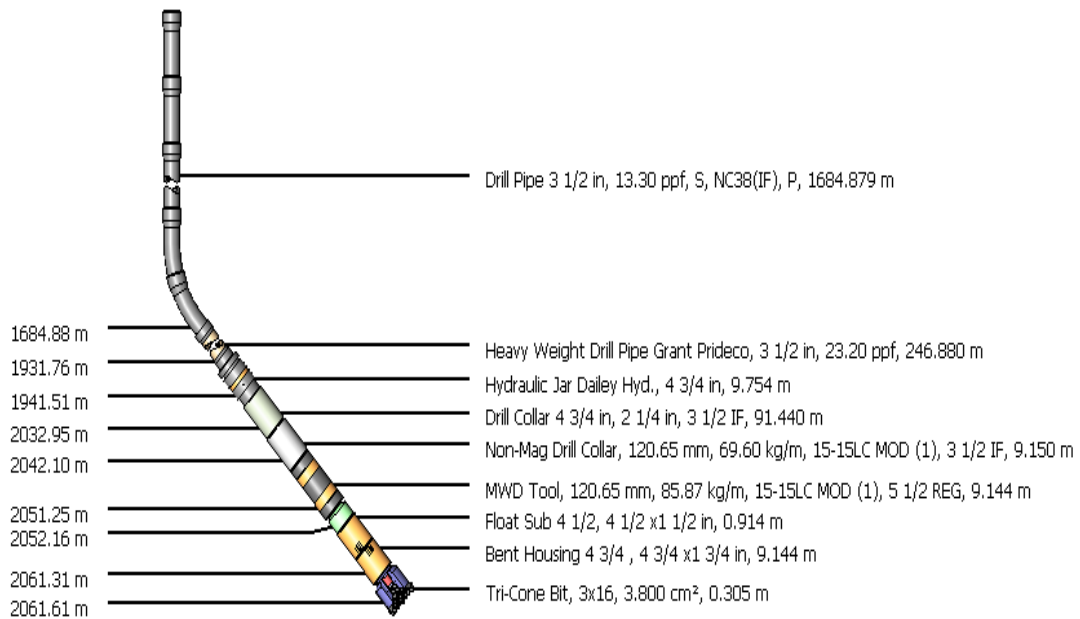


Fig (4.15): Describe BHA.

#### 4.3.3.3 BHA Analysis Data:

Input parameters needed to perform the calculations include torque at bit, weight at bit, and rotary speed. Do not mark the Enable Drill ahead check box at this time. Fig.4.16 apparent BHA analysis data.

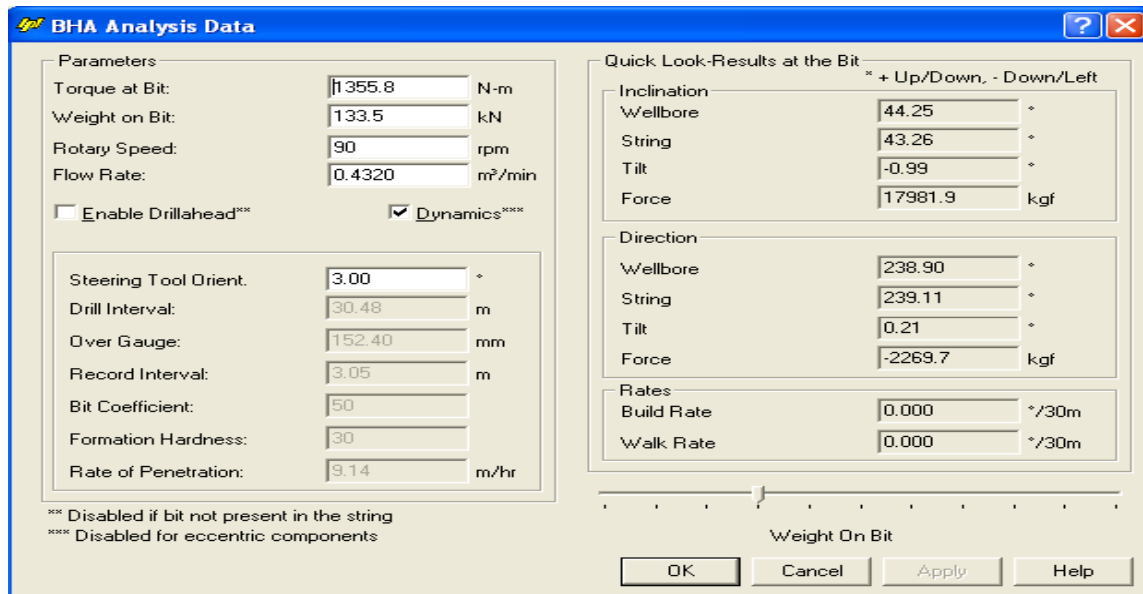


Fig (4.16): Apparent BHA Analysis Data.

#### 4.3.4 BHA Result and Analysis in Landmark Software:

Two plots are available for analysis. The Displacement plot allows you to determine how the bottom hole assembly is lying in the wellbore. The Side Force plot indicate that side force acting on the bottom hole assembly as it lies in the wellbore.

##### 4.3.4.1 Displacement Analysis:

Plot displays the displacement from the versus centerline distance from bit, Value of inclination and direction away ( $\pm 18$  mm) from centerline of well bore clearance indicates Zero the string is lying along the well bore. The Fig.4.17 below present displacement and distance from bit.

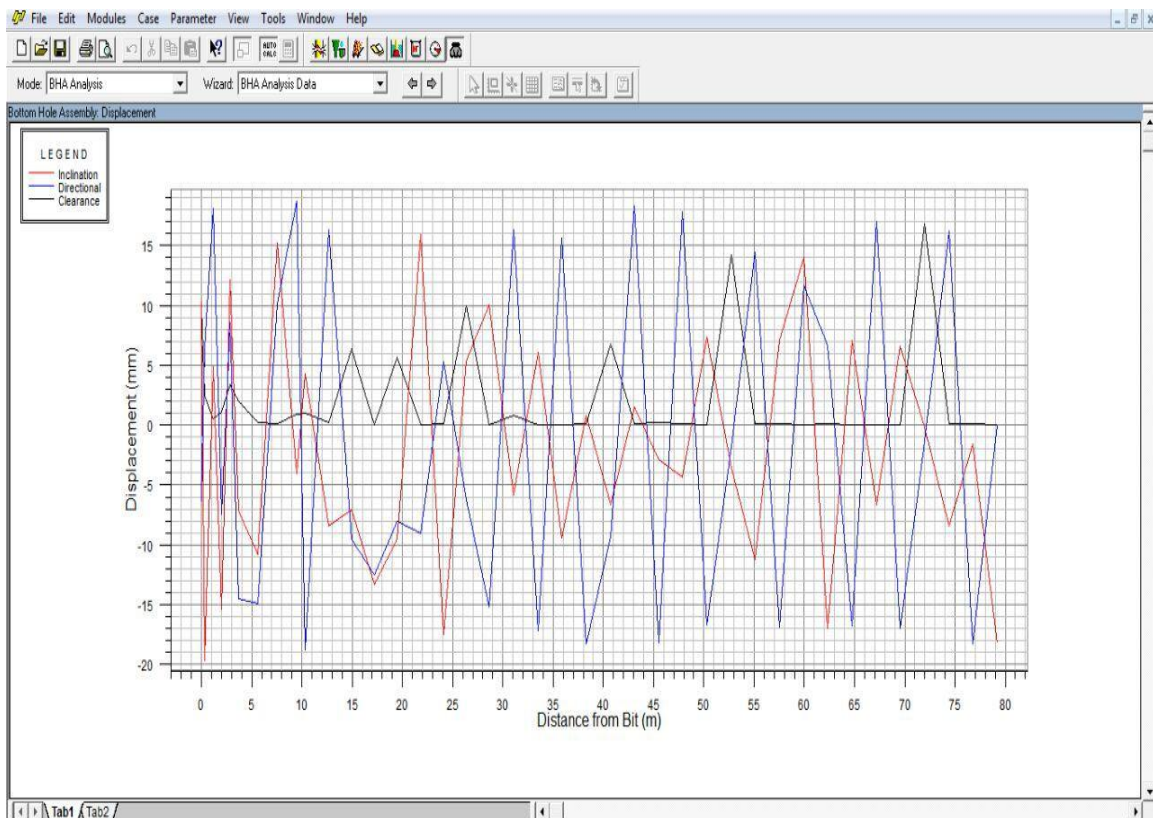
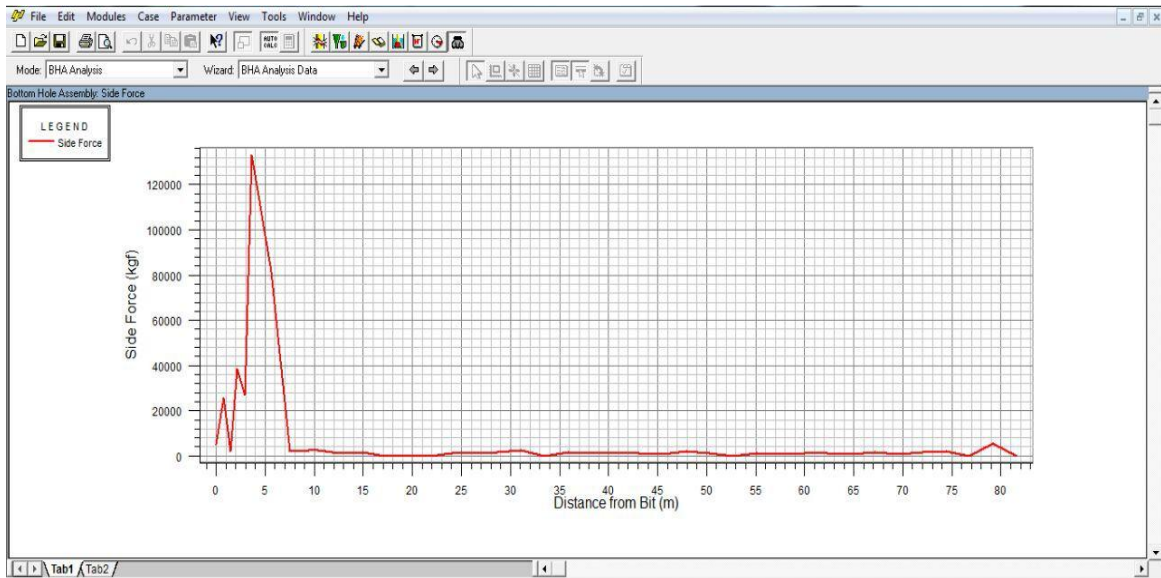


Fig (4.17): Displacement Along Distance from Bit.

##### 4.3.4.2 Side Force Analysis:

Maximum side force at bit is 135000kgf at 4.5 m from bit. At 2m distance from bit side force is 40000kgf, UN like that side force equal zero. Fig.4.18 presents side force near bit which mean a build tendency had been achieved.



**Fig (4.18):** Side Force Vs Distance from bit

## 4.4 Hydraulic:

Formation Mud program data present below in Table (4.4):

**Table (4.4):** Mud Program Data.

Formation	Depth (m)		Thickness (m)	Mud weight (ppg)
	From	To		
Baraka sand	1200	1216	16	10.2
Gazal shale	1216	1243	27	10.2
Gazal sand	1243	1314	71	10.4
Zarqa shale	1314	1370	56	10.5
Aradeiba upper shale	1370	1519	149	10.8
Aradeiba main sand	1519	1537	18	10.8
Aradriba lower shale	1537	1573	36	10.8
Aradeiba D sand	1573	1677	104	10.8
Aradeiba F sand	1677	1712	35	10.8
Bentue 1 sand stone	1712	1774	62	10.9
Bentue 2 sand stone	1774	1820	46	10
Bentue 3 sand stone	1820	1900	80	10.9

#### 4.4.1 Surge and Swab Calculation:

- **Data:**

$$\theta_{600} = 40.69$$

$$\theta_{300} = 27.789$$

$$V_p = 0.32 \text{ m/s} = 62.95 \text{ ft/min}$$

$$D_p = 3.5 \text{ in}$$

$$D_h = 6 \text{ in}$$

$$D_c = 4.75 \text{ in}$$

$$L_{dp} = 5527.79 \text{ ft}$$

$$L_{dc} = 300 \text{ ft}$$

$$V_{pc} = 46.8 \text{ ft/min}$$

- **Calculation:**

1. Determine pressure around drill pipe:

i. Determine,  $n$  from equation (3.10).

$$n = 3.32 \log\left(\frac{40.69}{27.789}\right) = 0.55$$

ii. Determine,  $k$  from equation (3.11).

$$K = \frac{27.789}{(511) \times 0.55} = 0.9$$

iii. Determine fluid velocity around drill pipe,  $V_{dp}$  from equation (3.12).

- For closed ended pipe (plugged flow):

$$V_{dp} = \left(0.45 + \frac{3.5^2}{6^2 - 3.5^2}\right) \times 62.95 = 60.796 \text{ ft/min}$$

iv. Maximum pipe velocity,  $V_m$  from equation (3.13).

$$V_m = 60.796 \times 1.5 = 91.194 \text{ ft/min}$$

v. Pressure loss around drill pipe,  $P_{dp}$  from equation (3.14).

$$P_{dp} = \left(\frac{2.4 \times 91.194}{6 - 3.5} \times \frac{2 \times 0.55 + 1}{3 \times 0.55}\right)^{0.55} \times \frac{0.9 \times 5527.79}{300 \times (6 - 3.5)} = 88.949 \text{ psi}$$

2. Determine pressure loss around drill collar:

-for close ended pipe (plugged flow):

i. Determine fluid velocity around drill collar,  $V_{dc}$  from equation (3.15).

$$V_{dc} = \left(0.45 + \frac{4.75^2}{6^2 - 4.75^2}\right) \times 46.8 = 99.64 \text{ ft/min}$$



ii. Maximum pipe velocity,  $V_m$  from equation (3.16).

$$V_m = 99.64 \times 1.5 = 149.46 \text{ ft / min}$$

iii. Pressure loss around drill collar,  $P_{dc}$  from equation (3.17).

$$P_{dc} = \left( \frac{2.4 \times 149.46}{6 - 4.75} \times \frac{2 \times 0.55 + 1}{3 \times 0.55} \right)^{0.55} \times \frac{0.9 \times 300}{300(6 - 4.75)} = 18.5 \text{ psi}$$

3. Determine total pressure loss from equation (3.18).

$$\text{Total pressure loss} = 88.949 + 18.5 = 107.45 \text{ psi}$$

4. Determine surge and swab pressure:

-For surge pressure from equations (3.19),(3.20) and (3.21):

$$P_{hydraulic} = 0.052 \times 10.4 \times 1900 = 3371.13 \text{ psi}$$

Bottom hole pressure from equation (3.19) = 3371.13 + 107.45 = 3478.58 psi

$$\text{Surge} = \frac{3478.58}{0.052 \times 6233.59} = 10.73 \text{ ppg}$$

-For swab pressure from equation (3.22) and (3.23):

Bottom hole pressure = 3371.13 – 107.45 = 3263.68 psi

$$\text{Swab} = \frac{3263.68}{0.052 \times 6233.59} = 10.1 \text{ ppg}$$

#### 4.4.2 Input Hydraulic Data in landmark:

Fluid editor options enable the user to input the fluid used in the drilling such as: rheology properties, mud base and other mud properties. Fig.4.19 present fluid editor.

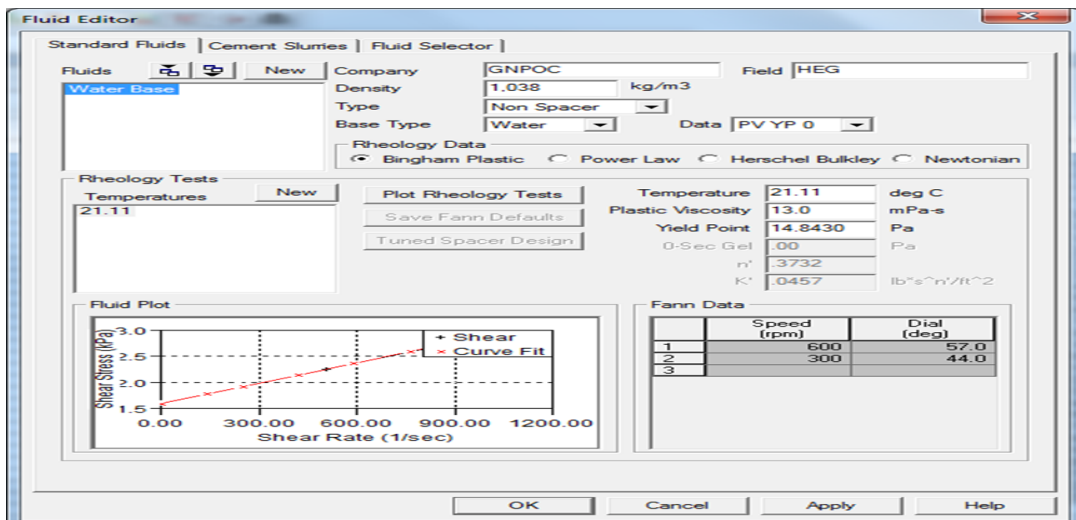


Fig (4.19): Present Fluid Editor.

#### 4.4.2.1 Surge and Swab Input Data:

All surge and swab data inputted in landmark apparent in Fig.4.20, 4.21 and 4.22 below:

**Circulating System**

Surface Equipment | Mud Pumps

Surface Equipment Rated Working Pressure:  kPa

Specify Pressure Loss  kPa

Calculate Pressure Loss

Surface Equipment Type:

Surface Equipment Data

- 40'x3" StdPipe + 45'x2" Hose + 4'x2" Swivel + 40'x2.25" Kelly
- 40'x3.5" StdPipe + 55'x2.5" Hose + 5'x2.5" Swivel + 40'x3.25" Kelly
- 45'x3.5" StdPipe + 55'x3" Hose + 5'x2.5" Swivel + 40'x3.25" Kelly
- 45'x4" StdPipe + 55'x3" Hose + 6'x3" Swivel + 40'x4" Kelly

OK Cancel Apply Help

**Fig (4.20):** Circulating System Data-Surface Equipment.

**Circulating System**

Surface Equipment | Mud Pumps

	Active	Pump Name	Vol/Stk (m3/stk)	Maximum Speed (spm)	Maximum Discharge Pressure (kPa)	Horsepower Rating (kW)
1	<input checked="" type="checkbox"/>	Triplex	0.022701	40.00	23649.0	397.62
2	<input type="checkbox"/>					

**Fig (4.21):** Circulating System- Mud Pumps.

**Operations Data**

Swab

Open End Flow:  m<sup>3</sup>/min

Closed End

Maximum Delta-P (swab):  kg/m<sup>3</sup>

Surge

Open End Flow:  m<sup>3</sup>/min

Closed End

Maximum Delta-P (surge):  kg/m<sup>3</sup>

Common

Stand Length:  m

Use String Editor Bit Nozzles

OK Cancel Apply Help

**Fig (4.22):** Operation Data.

#### 4.4.2.2 Surge & Swab Result and Analysis:

These plots will display the pressure and ECD at the bit, at the casing shoe (as the bit passes the shoe) and at total depth (TD). If the bit is at total depth (TD), the curves will overlay, and it may appear that the curves are missing from the plot. The bit depth is obtained from the String Editor, and the stand length is specified on the Operations Data Dialog. The casing shoe depth is retrieved from the Wellbore Editor. These plots also indicate the minimum allowable trip time per stand of pipe. Depending on the situation, there could be one value for all stands or there could be a number of values for different sets of stands.

If you specify a high value for the allowable trip margin, it is possible that the minimum time per stand (10 seconds) will not reach the allowable trip margin. In that case, the trip schedule produced will indicate that all stands can be tripped at the minimum time per stand. Conversely, if you specify a very small value for the allowable trip margin, it is possible that even at the maximum time per stand (200 seconds), the allowable trip margin will still be exceeded. In that case, the trip schedule will show that all stands should be tripped at the maximum time per stand (200 seconds). The Fig.4.23 and 4.24 below present surge closed end and swab closed end.

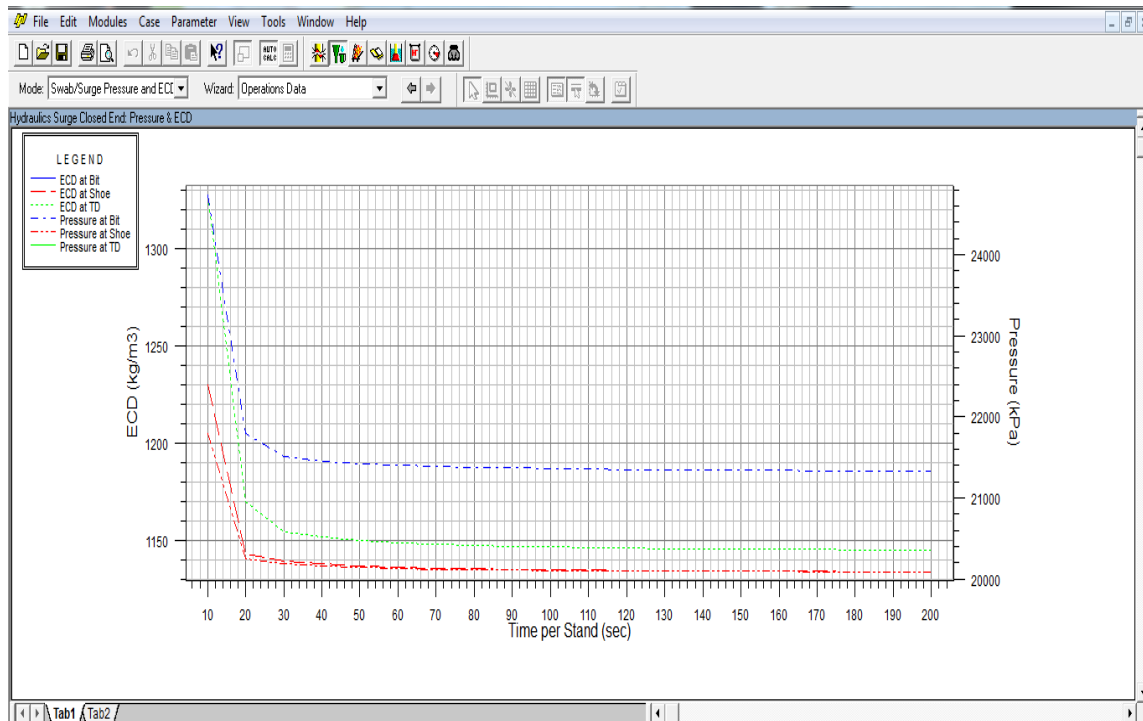
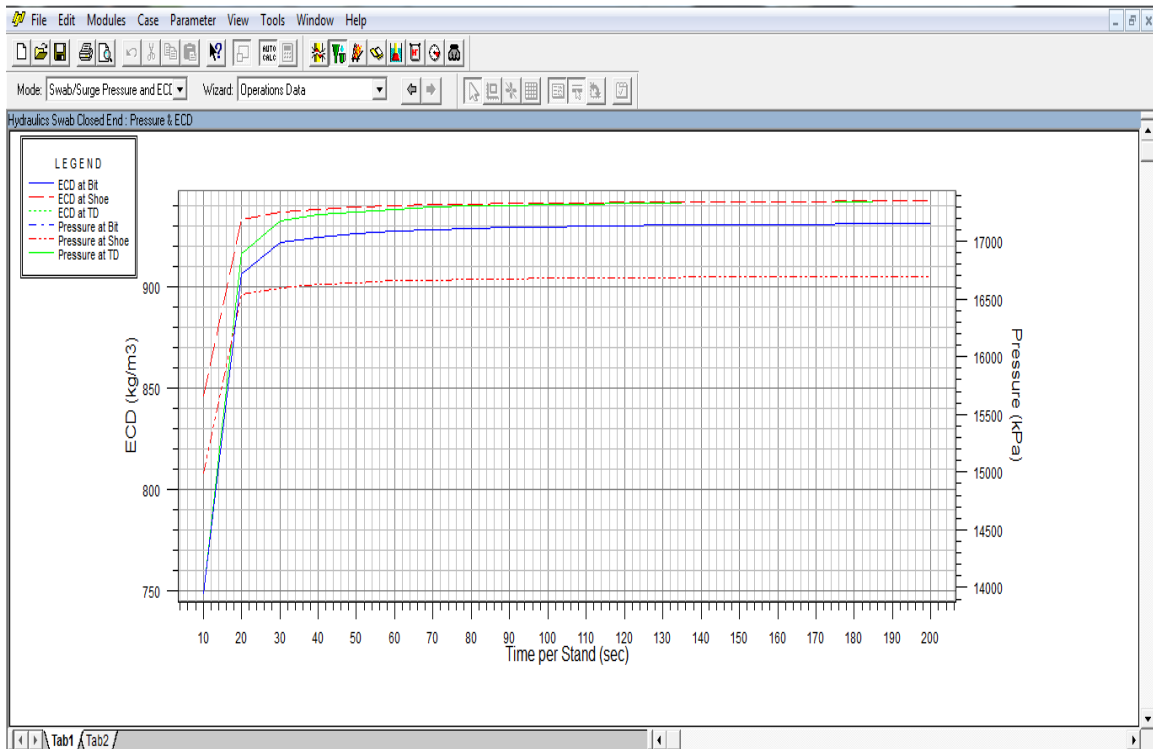


Fig (4.23): Surge Closed End (1).



**Fig (4.24):** Swab Closed End (2).

#### 4.4.2.3 Input hole cleaning data in landmark:

Input cutting transport data in landmark software including rotary speed, rate of penetration and flow rate. The flow rate here has major effect to make the hole cleaning and stable so choice two flow rate ( $0.4732 \text{ m}^3/\text{min}$  and  $0.9085 \text{ m}^3/\text{min}$ ) to make analysis for cutting transport. Fig.4.25 and 4.26 below the data required.

**Fig (4.25):** Cutting Transport Data with Flow Rate ( $0.4732 \text{ m}^3/\text{min}$ ).

Input		
Rate of Penetration:	9.14	m/hr
Rotary Speed:	90	rpm
Pump Rate:	0.9085	m <sup>3</sup> /min

Additional Input		
Cuttings Diameter:	3.18	mm
Cuttings Density:	2.500	sg
Bed Porosity:	36.00	%
MD Calculation Interval:	30.48	m

Buttons: OK, Cancel, Apply, Help

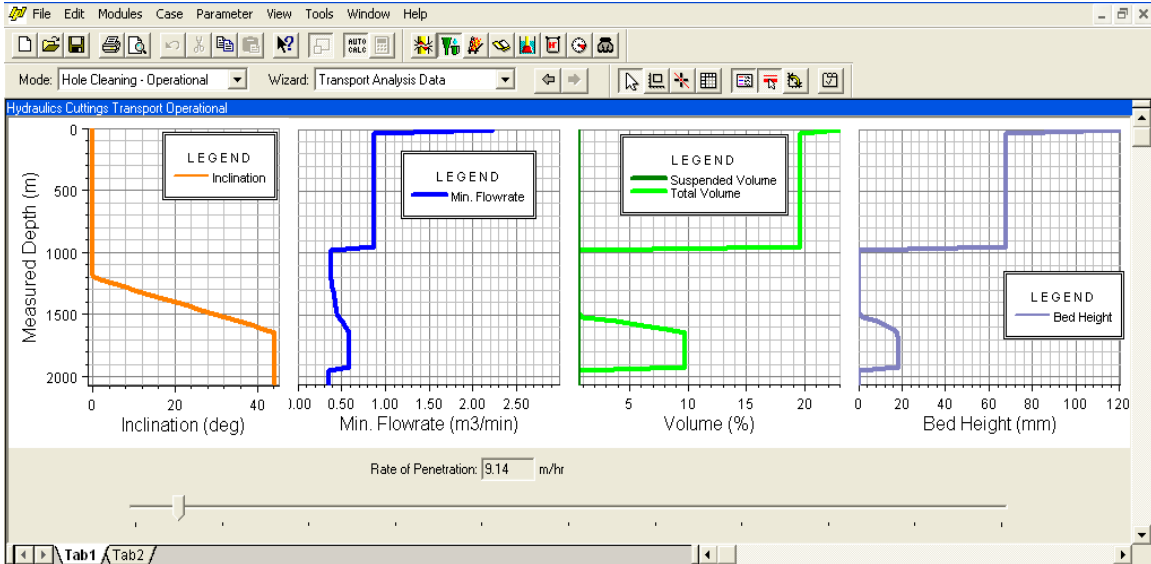
**Fig (4.26):** Cutting Transport Data with Flow Rate (0.9085 m<sup>3</sup>/min).

This plot below presents the following for each measured depth in the wellbore:

- Inclination.
- Minimum flowrate to avoid cuttings formation.
- Suspended cuttings volume.
- Bed height.

The bed height and cuttings volume portions of the plot are calculated using the flow rate specified on the Transport Analysis Data Dialog (Operational). The minimum flow rate, and inclinations portions of the plot are independent of the specified flow rate.

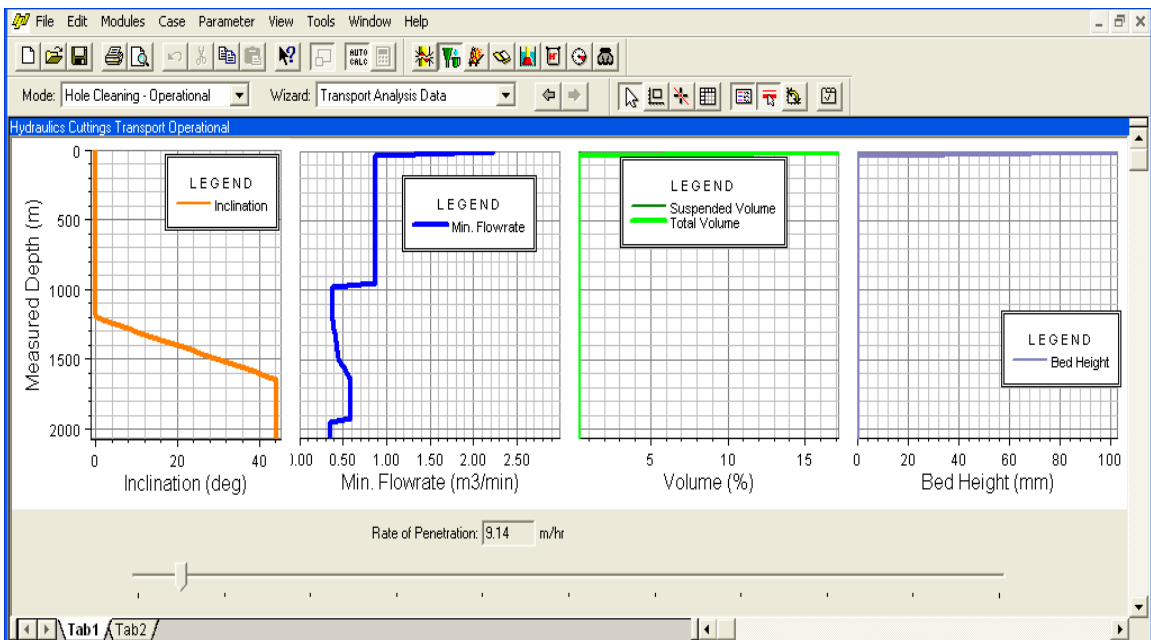
If there is a bed height forming, the total cuttings volume will begin to become greater than the suspended cuttings volume in that portion of the wellbore. Also, you will notice that the bed height begins to form when the minimum flow rate to avoid bed formation for a section of the well is greater than the flow rate specified on the Transport Analysis Data Dialog (Operational). In order to avoid the formation of a cuttings bed in that portion of the well, you must increase the specified flow rate to a rate greater than the minimum flow rate to avoid bed formation. This analysis uses the data input on the Fluid Editor, String Editor, Survey Editor, Wellbore Editor and the Transport Analysis (Operational) Data Dialog, (from chapter three). Fig.4.27, 4.28 and Table.4.5, 4.6 below apparent minimum flow rate (0.4732m<sup>3</sup>/min and 0.9085m<sup>3</sup>/min) volume of cutting and bed height.



**Fig (4.27):** Cutting Transport Result for Flow Rate (0.4732 m³/min).

**Table (4.5):** Cutting Transport Result for Flow Rate (0.4732 m³/min).

Sections	Measured Depth (m)	Minimum flow rate (m³/min)	Volume (%)	Bed Height (mm)
Hold	2061.6-1642.5	0.6	9.8	19.8
Build	1642.5-1200	0.4	0	0
Vertical	1200-0	0.9	19.5	68



**Fig (4.28):** Cutting Transport Result for Flow Rate (0.9085m³/min)

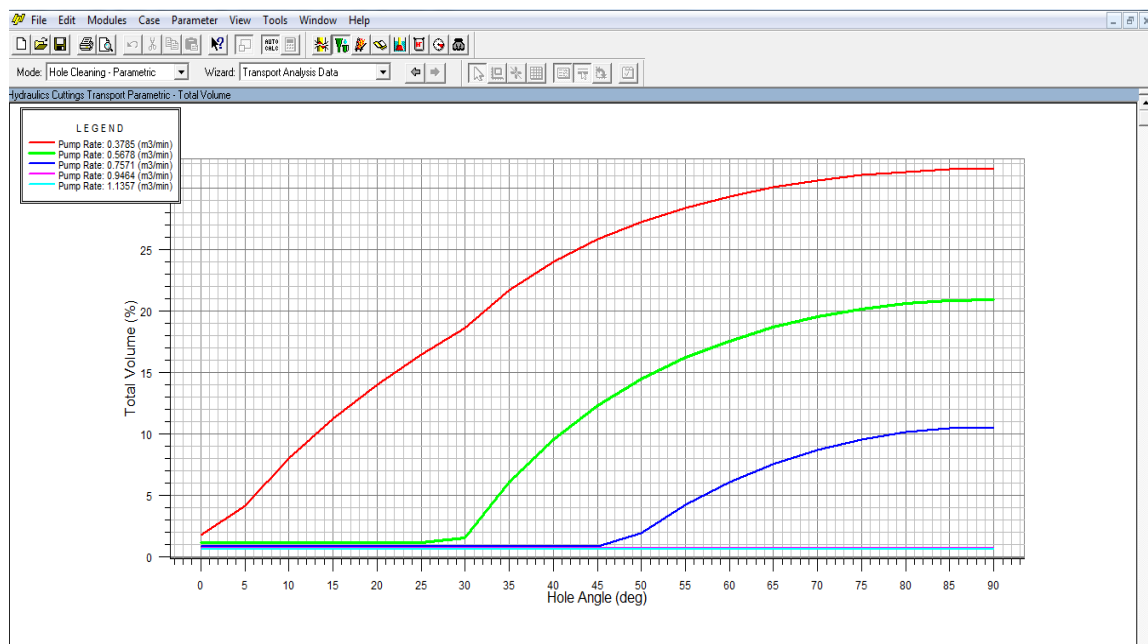
**Table (4.6):** Cutting Transport Result for Flow Rate (0.9085m<sup>3</sup>/min)

Sections	Measured Depth (m)	Minimum flow rate (m <sup>3</sup> /min)	Volume (%)	Bed Height (mm)
Hold	2061.6-1642.5	0.6	0	0
Build	1642.5-1200	0.4	0	0
Vertical	1200-0	0.9	0	0

when used flow rate 125gpm (0.4732 m<sup>3</sup>/min), volume and bed height increase in hold and vertical sections but equal zero in build section because it is small, while minimum flow rate has different values at three sections more than zero.

In the other hand, when used flow rate 240gpm (0.9085m<sup>3</sup>/min) volume and bed height constant zero at three sections because flow rate suitable to transport all cutting to surface, while minimum flow rate still constant in flow rate125gpm (0.4732 m<sup>3</sup>/min) because it is not affected by the change of flow rate.

The plot below in Fig.4.29 explain total volume of cutting in hole with different pump rate (100, 150,200,250,300gpm), as pump rate increase volume of cutting reduce until arrive to clean hole at 250gpm.



**Fig (4.29):** Cutting Transport Volume VS Hole Angle Result with Different Pump Rate (100, 150,200,250,300gpm)

## 4.5 Wellbore Stability:

It has been analyzed the wellbore stability by using program was design in matlab software (GUI), The program contains two model, fraction pressure model and mohr-coulomb collapse model.

### 4.5.1 Data Required:

The data required to run the program showing in below:

- Insitu Stresses:

TVD = 6233.596 ft.

pf = 3242 psi.

$\sigma_V = 6795$  psi.

$\sigma_H = 3590$  psi.

$\sigma_h = 3590$  psi.

- Rock Properties:

$S_o = 2401$  for fraction pressure model & 1402 for mohr-coulomb collapse model.

$\phi = 39$  degree.

$\nu = 0.28$ .

$\alpha_p = 0.72$ .

- Drilling Data:

$\beta = 90$ .

$\theta = 90$  for fraction pressure model & 0 for mohr-coulomb collapse model.

### 4.5.2 Input Data in Program:

Input data in, the Fig.4.30, 4.31 and 4.32 present the entering process in program:

**Well bore stability**

**Borehole Stability Analysis:**

**About the program:**  
This program takes into account both the rock properties and Insitu Stresses and drilling data to analyze the stability of the well and how likely the well failed. Where drilling can be done safely, with a low probability of suffering as well as wall collapse or disintegration of the formation of the rock.

**The Process:**  
\*Obtain insitu stresses and rock properties.  
\*Transform insitu stresses to a borehole oriented coordinate system.  
\*Determine resultant stresses.

**Analyst Name:** slimhole sidtrack

**Company:** GNPOC

**Well:** Abandon well-H

**Field:** Hamra

**Date:** 2016

Next >>

Fig (4.30): Program Face.



## Fracturing Gradient Model

### Input Data & Calculate

**Insitu Stresses :**

True Vertical Depth ( D )  ft

Pore Pressure ( Pf )  psi

Vertical Insitu Stress  psi

Maximum Horizontal Stress  psi

Minimum Horizontal Stress  psi

**Rock Properties :**

Cohesive Strength ( So )  psi

Friction Angle ( Fa )  degrees

Poisson's Ratio

Poroelastic Constant

	Mud Weight (ppg)	Inclination Angle (Degree)
3	12.7	20
4	12.4	30
5	12.2	44.25
6		

**Calculate**

	Fracturing Pressure (psi)
1	5.3029e+03
2	5.0571e+03
3	4.6632e+03
4	4.0012e+03

Fig (4.31): Input Data in Fraction Pressure Model.

## Mohr-Coulomb Collapse Gradient Model

### Input Data & Calculate

**Insitu Stresses :**

True Vertical Depth ( D )  ft

Pore Pressure ( Pf )  psi

Vertical Insitu Stress  psi

Maximum Horizontal Stress  psi

Minimum Horizontal Stress  psi

**Rock Properties :**

Cohesive Strength ( So )  psi

Friction Angle ( Fa )  degrees

Poisson's Ratio

Poroelastic Constant

	Mud Weight (ppg)	Inclination Angle (Degree)
3	8.7	20
4	8.8	30
5	8.9	44.25
6		

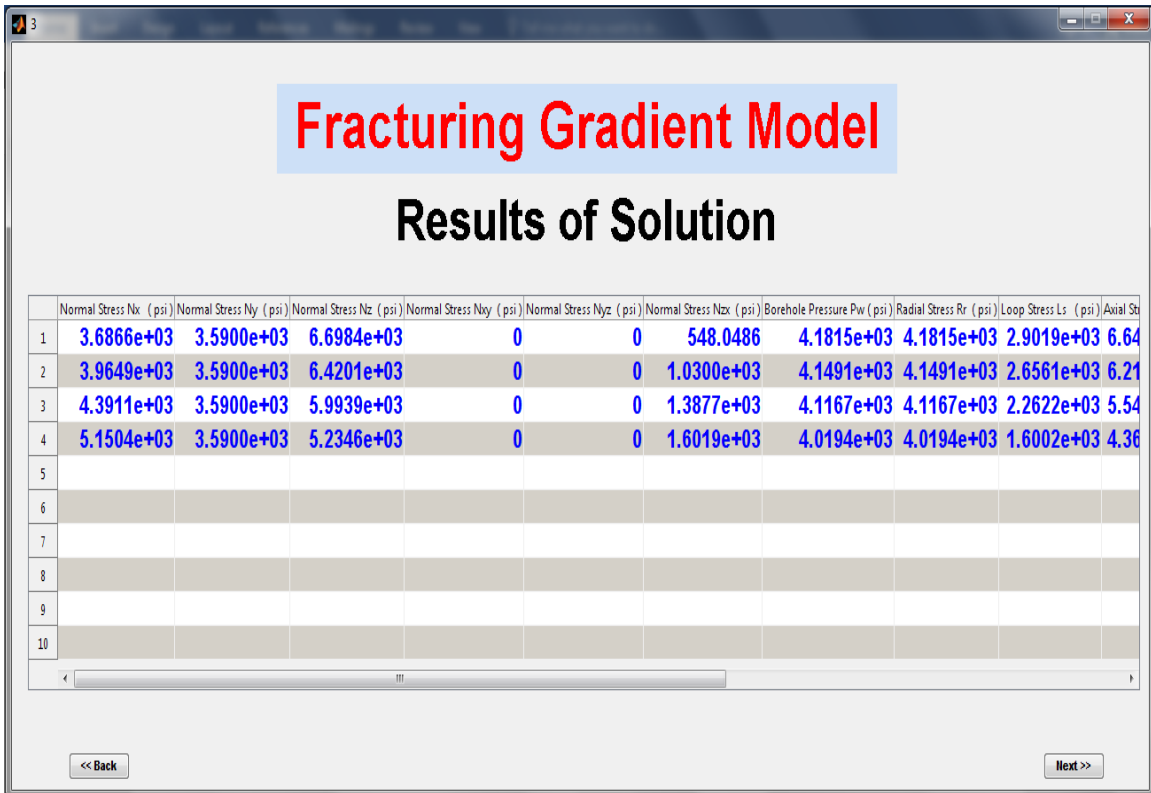
**Calculate**

	Mohr-Coulomb failure stress (psi)
1	1.0806e+03
2	1.0894e+03
3	1.1027e+03
4	1.1071e+03

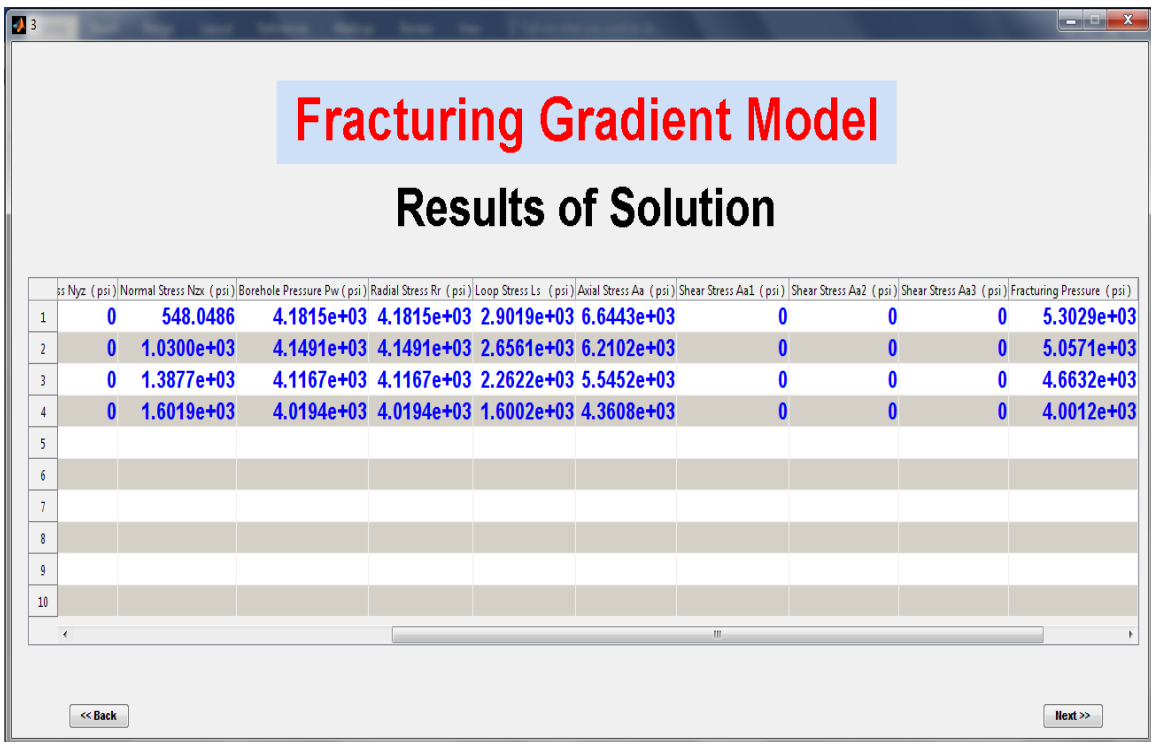
Fig (4.32): Input Data in Mohr-Coulomb Collapse Model.

### 4.5.3 Program Results:

Fig.4.33, 4.34, 4.35, 4.36 and 4.37 present the results of solution model, such as normal stress, shear stress, borehole pressure, radial stress, loop stress, axial stress, fracturing pressure, principal stress, maximum principal stress, minimum principal stress, maximum effective stress, minimum effective stress and mohr-coulomb failure stress.



**Fig (4.33):** Results of Solution for Fracturing Gradient Model (1).



**Fig (4.34):** Results of Solution for Fracturing Gradient Model (2).

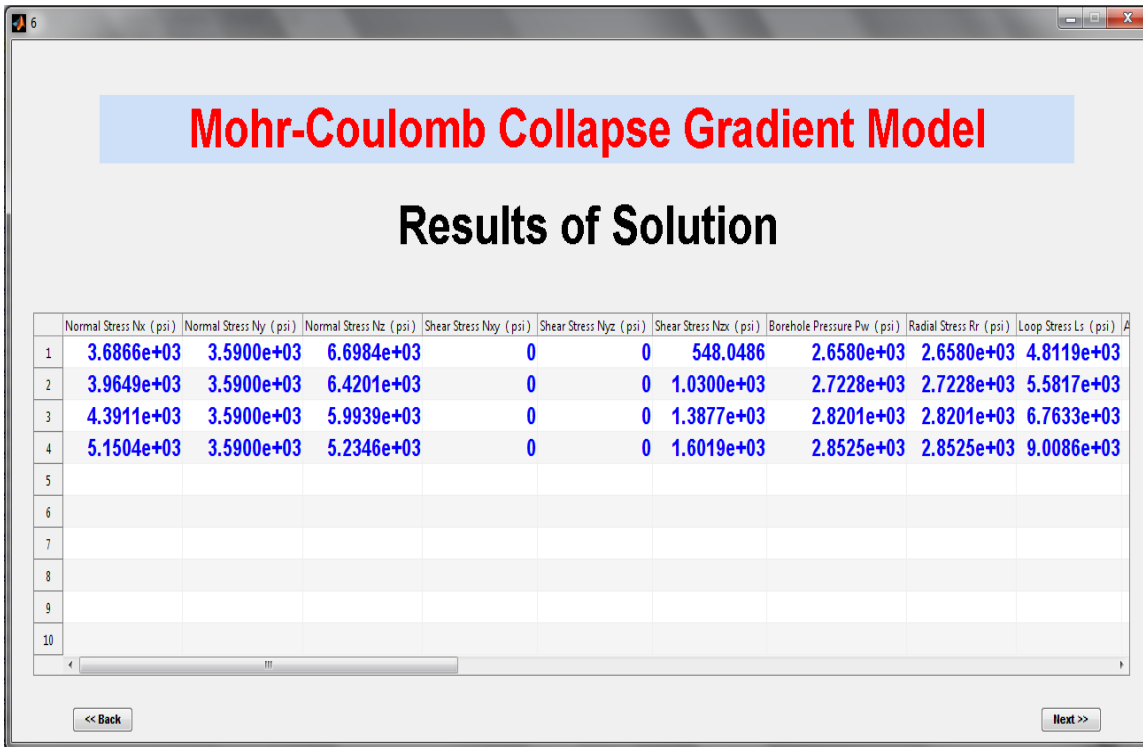


Fig (4.35): Results of Solution for Mohr-Coulomb Collapse Model (1).

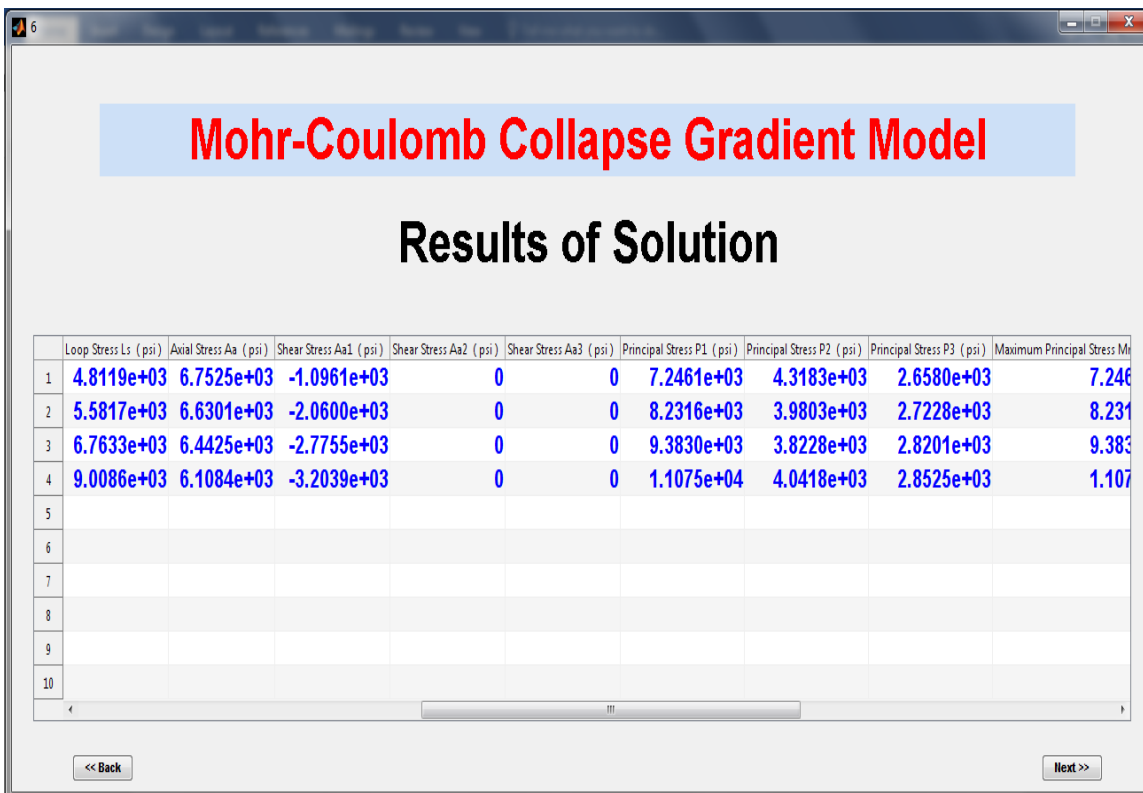
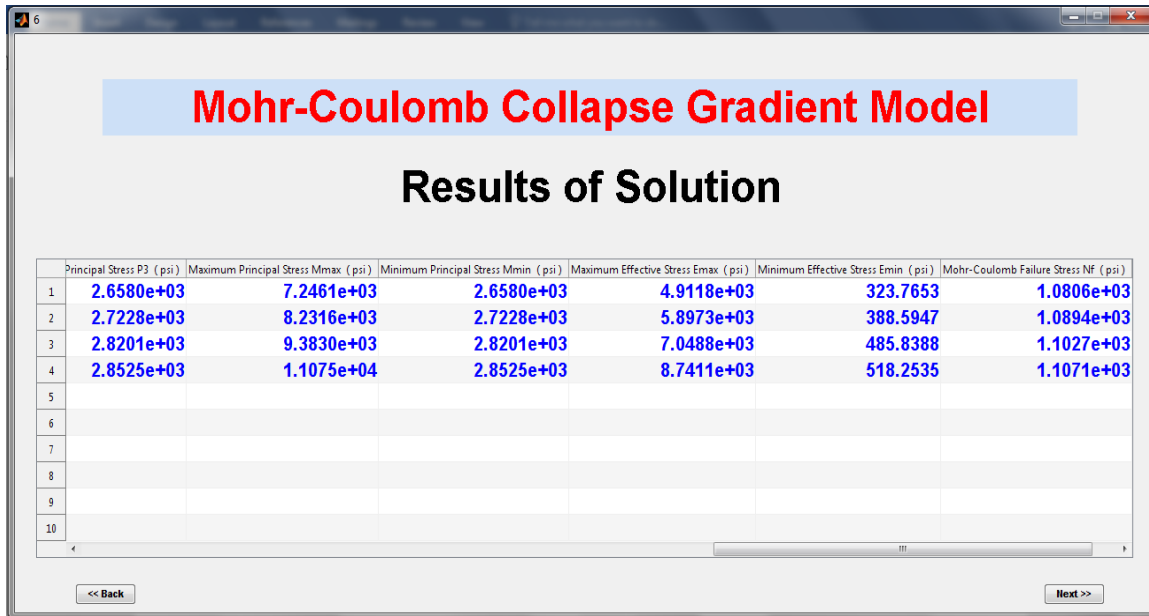


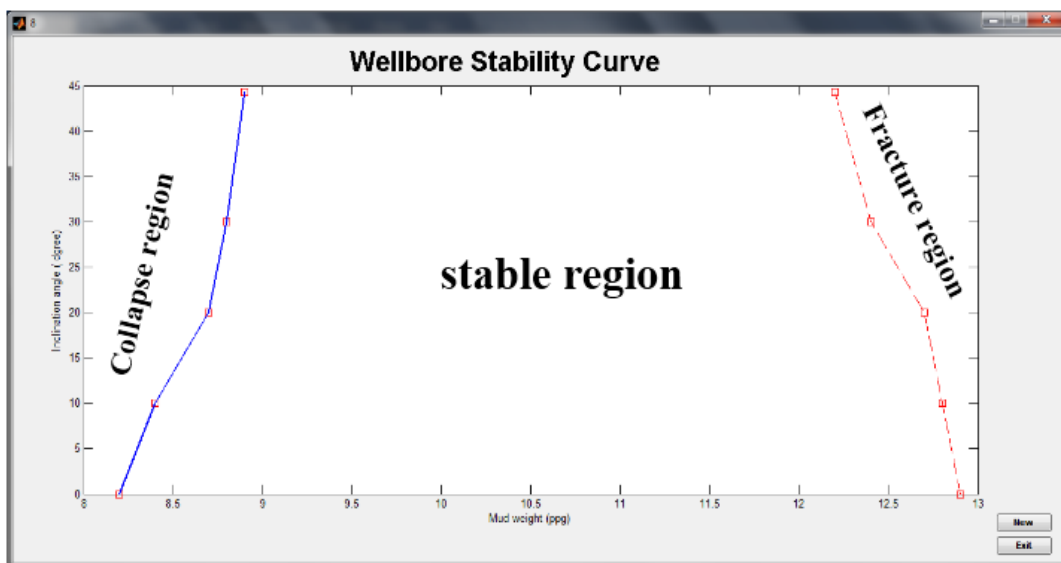
Fig (4.36): Results of Solution for Mohr-Coulomb Collapse Model (2).



**Fig (4.37):** Results of Solution for Mohr-Coulomb Collapse Model (3).

#### 4.5.4 Wellbore Stability Curve:

Finally, the program plots the mud weight vs inclination angle, the Fig.4.38 present the wellbore stability curve, the graph contents three region: Collapse region, stable region and Fracture region. From graph the stable region refers to the extent permitted to choose the mud weight appropriate that lead to the drilling process with the stability of the borehole wall. In other region the mud weight causes collapse or fracture.



**Fig (4.38):** Wellbore Stability Curve.

## 4.6 Torque and Drag:

### 4.6.1 Input Torque and Drag Data in Normal Analysis Model in Landmark Software:

Normal Analysis calculates the torque, drag, normal force, axial force, buckling force, neutral point, stress and other parameters for a work string in a three-dimensional wellbore. With a Normal Analysis, all calculations are performed with the bit at one position in the wellbore, and with one set of operational parameters. May choose to perform the analysis using either the soft or stiff string model. However, for now

Use the soft string model. Normal Analysis mode calculates the forces acting along the string and at the surface for several operating conditions, including:

- Tripping in (with and without rotating).
- Tripping out (with and without rotating).
- Rotating on bottom.
- Rotating off bottom.
- Back reaming.
- Sliding drilling.

The Fig.4.39, 4.40 below present minimum data required to input in landmark software

**Torque Drag Setup Data**

Hook-Load/Weight-Indicator Correction

Traveling Assembly Weight: 498.8 kN

Enable Sheave Friction Correction

Lines Strung:

Mechanical Efficiency (single sheave): 97.00 %

Analytical Methods

Use Bending Stress Magnification

Use Stiff String Model

Use Viscous Torque and Drag

Contact Force Normalization Length: 9.45 m

Mechanical Limitations

Maximum Weight-on-Bit Rotating (no sinusoidal buckling)

Maximum Weight-on-Bit Rotating (no helical buckling)

Maximum Overpull Using % of Yield: 90.00 %

OK Cancel Apply Help

Fig (4.39): Torque Drag Setup Data.

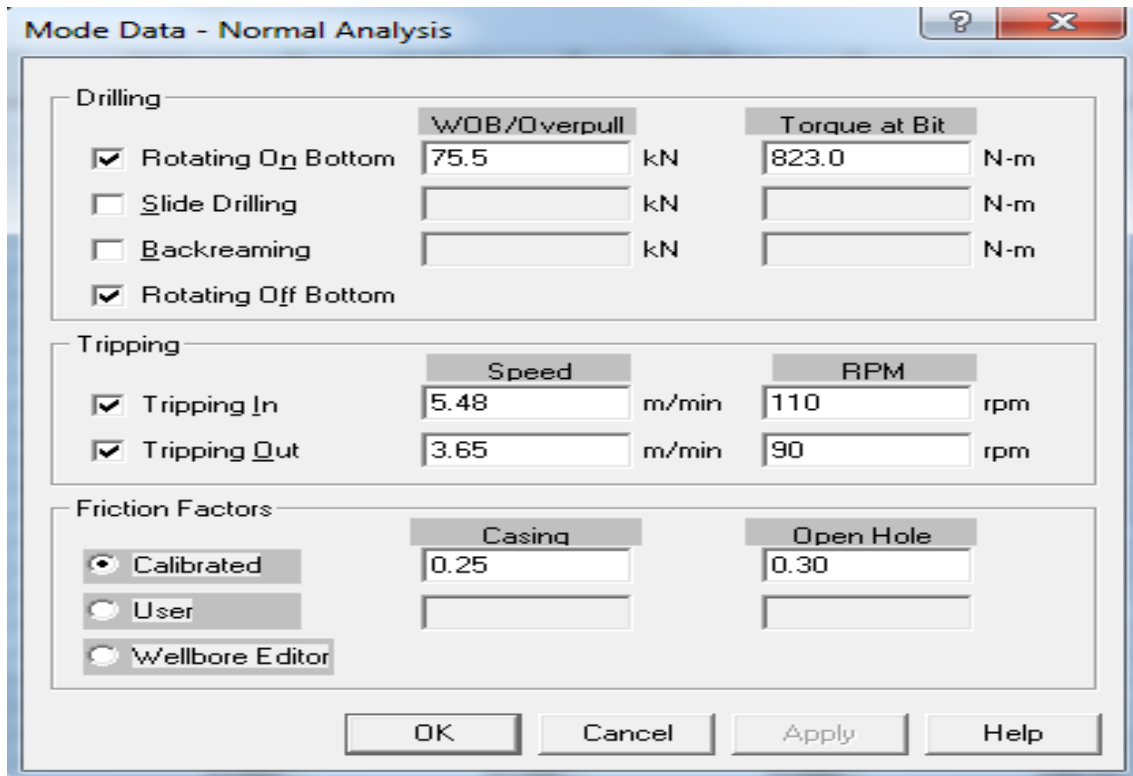


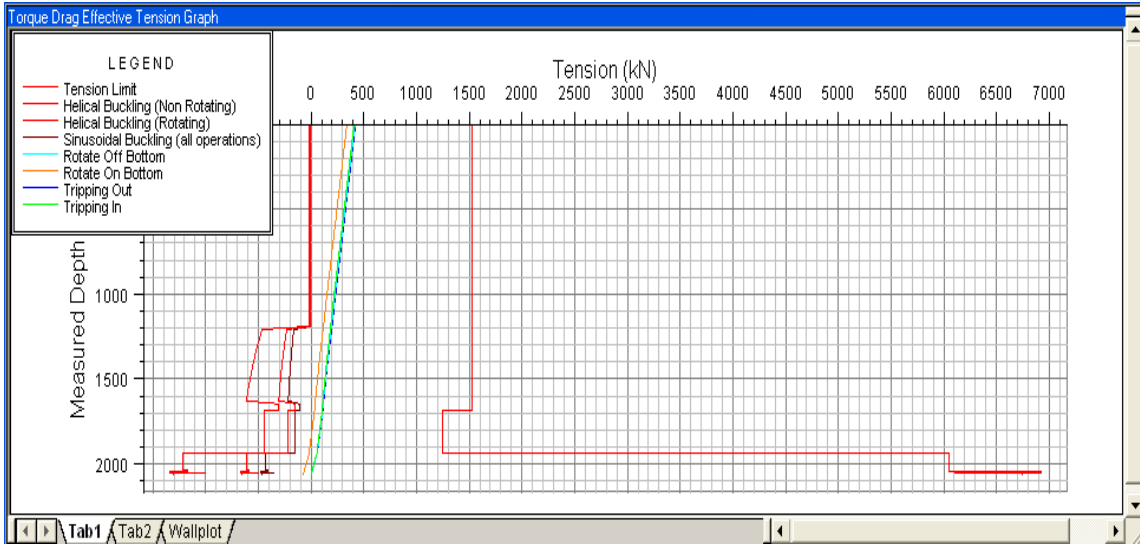
Fig (4.40): Mode Data-Normal Analysis.

## 4.6.2 Torque & Drag Result and Analysis in Landmark Software:

### 4.6.2.1 Effective Tension Plot:

The Effective Tension plot displays the tension in all sections of the work string for the operating modes specified on the Normal Analysis. The graph includes data for measured depths from the surface to the string depth specified on the String Editor. The effective tension can be used to determine when buckling may occur.

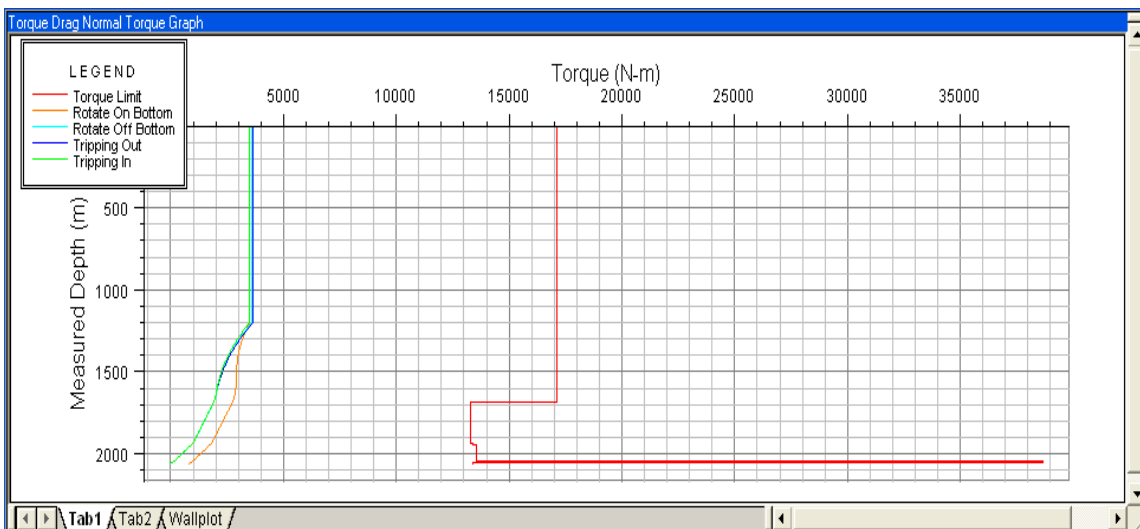
On the plot Fig.4.41 below indicating the loads required to buckle 100kN (helical or sinusoidal) at 1200m and 1650m on the work string. The plot also indicates the tension limit for the work string component at the corresponding measured depth. If the effective tension curve for a particular operating mode exceeds the tension limit curve, the work string is in danger of cutting-off at that point. The compression at these depth ensure that the drill pipe are not exposed to buckling.



**Fig (4.41):** Torque Drag Effective Tension Graph Result.

#### 4.6.2.2 Torque Graph:

Torque is displayed in all section of drill string for the tripping in, tripping out, rotating on bottom and rotating off bottom operations. From Fig.4.42 below torque at surface during rotating on bottom is greater than rotating off bottom operation (at value 4000 KN rotate on bottom and rotate off bottom). Torque at surface start to decline until reach minimum value at the bit which known torque on bit. It should be noted that the torque during tripping in and tripping out equal zero because there is no rotation of the drill string.



**Fig (4.42):** Torque Drag Normal Torque Graph Result.