CHAPTER IV
RESULTS AND DISCUSSION

4.1 User-Friendly Software Development

4.1.1 Software Introduction

This software uses actual field data to calculate real-time T&D. Data consists of 2 types which are definitive survey data as shown in Table B1 and Ascii data as shown in Table B2. Survey data shows positions of drillstring every stand and Ascii data shows wellbore property every 0.25 m.

In an operation, there are four modes, rotating off the bottom (RoffB), pulling out of the hole (POOH), running into the hole (RIH), and rotating on the bottom (RonB). Calculating Results of these four operations are calculated using GUI in MATLAB which each operation mode has different equation for calculating and equations are based on a soft string model in three-dimensional wellbore presented by Prurapark (2009) and real-time well trajectory is calculated by balanced tangential method due to accurate result and fast calculation.

4.1.2 Software Input

The software imports variables as shown in Table A1 from a file named as survey.xls in the MATLAB destination folder for the software calculation. In each operation users have to fill data needed as shown in Table B3 by inputting

Well section:

- Measured depth, MD (meter)
- Inclination, Inc (degree)
- Azimuth, Az (degree)
- Dogleg Severity, DLS (°/30m)

Drillpipe and BHA:

- Weight On Bit, WOB (lbf)
- Bit Diameter (inches)
- Density of Drilling Fluids, DF (lbm/gal)
- Nominal Weight (lbf/ft)

and four modes which are

Mode 1 Rotating Off Bottom (ROffB)

Mode 2 Pulling out of the hole (POH)

Mode 3 Running into the hold (RIH)

Mode 4 Rotating on bottom (RonB)

When the software is run the data will be transferred and calculated.

4.1.3 Software Calculation Sequence

The calculation of the software can be done both from well trajectory and T&D analysis. The well trajectory shows the consistency between the well planning path and the real-time path, so users can monitor not only to keep the well path but also the discrepancy between two of these. The situation while drilling can be changed by the company man who is the representative of the company to make a decision of any situation properly based on the aspect of operational optimization and economic optimization. Consequently, the well trajectory can also be changed to encounter with an unexpected formation or manipulate equipment. The calculation of T&D is occurring together with feed of input drilling parameters, especially the well trajectory (Inc, Az, MD) that affected directly to the T&D values. The T&D values is the results of overall processing of the software that help the company man to make the decision of the operation whether within the plan or move to another plan that suitable for the current situation.

After users input data into specific file and simulate software, the software will import the well-planned trajectory to be the based case of the real-time well trajectory as shown in Figure 4.1. The real-time information from the well site consisting of survey point, weight on bit, wellbore diameter (this software assume to be equal to bit diameter), drillpipe nominal weight and density, density of the drilling fluid, and different torque (between previous point and the current point) are fed and prepared for T&D calculation.

The well trajectory of the real-time operation is different from the well planning since the well type in real-time situation or short interval section cannot be kept the well type as well planning.

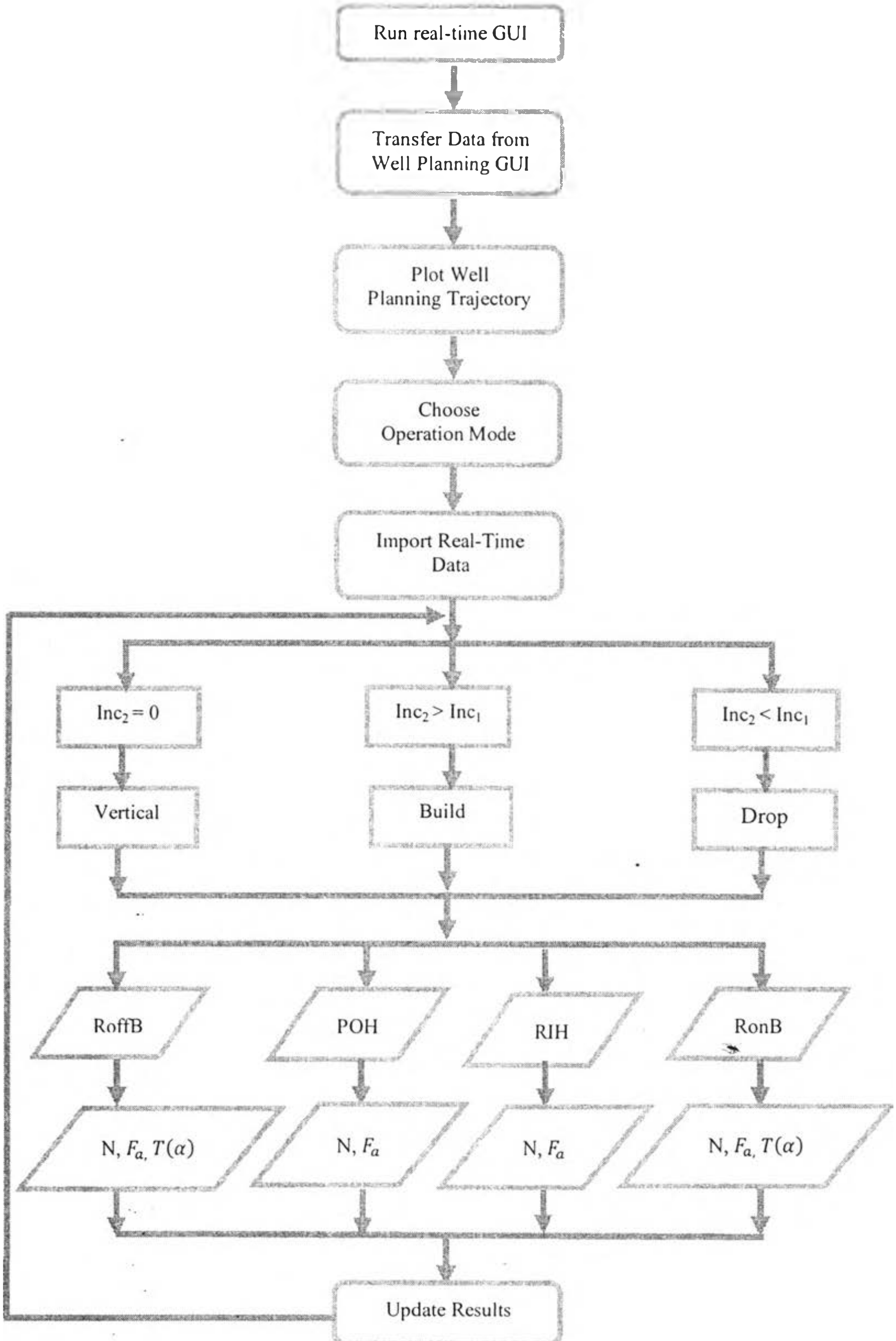


Figure 4.1 Flow chart of the GUI process.

The well type can be classified by the inclination degree. The inclination degree is equal to zero that means the vertical type. For the build type, the inclination degree is higher than the previous one, on the contrary of drop type which the current inclination degree is less than the previous.

Firstly, the well trajectory was calculated presented on the two graphical forms. The first well trajectory aims to compare with the well-planned trajectory and another one marks to present the deeply information as bit goes, in addition to make user-friendly understanding. The well trajectory can be calculated based on the balanced tangential method by using the survey information. The survey data reports every 20 meters (or every stand depending on the drilling rig equipment capacity: 20 or 30 meters length).

Secondly, T&D calculation was performed in different well type and operation mode that users can select and start calculating. The normal contact force (N), which is the ordinary physical parameter represented the contact load between the drillstring and the well bore, is the first value obtained from the calculation procedure to use for others parameter calculation. The axial force (F_a) is the second parameter followed by torque (T) value which is present only rotating operation (RoffB and RonB).

All the values calculated from the software are the surface value. The inputs are updated in real-time beginning from the survey data and all drilling parameters, and then T&D calculation is performed to present the results in graphical form and present value on each panel.

4.1.4 Software Output

Real-time interface as shown in Figure 4.2 consists of 4 output parts:

- Well planning and real-time well trajectory.
- Compass.
- 3D real-time trajectory with normal contact force.
- Real-time calculated data.

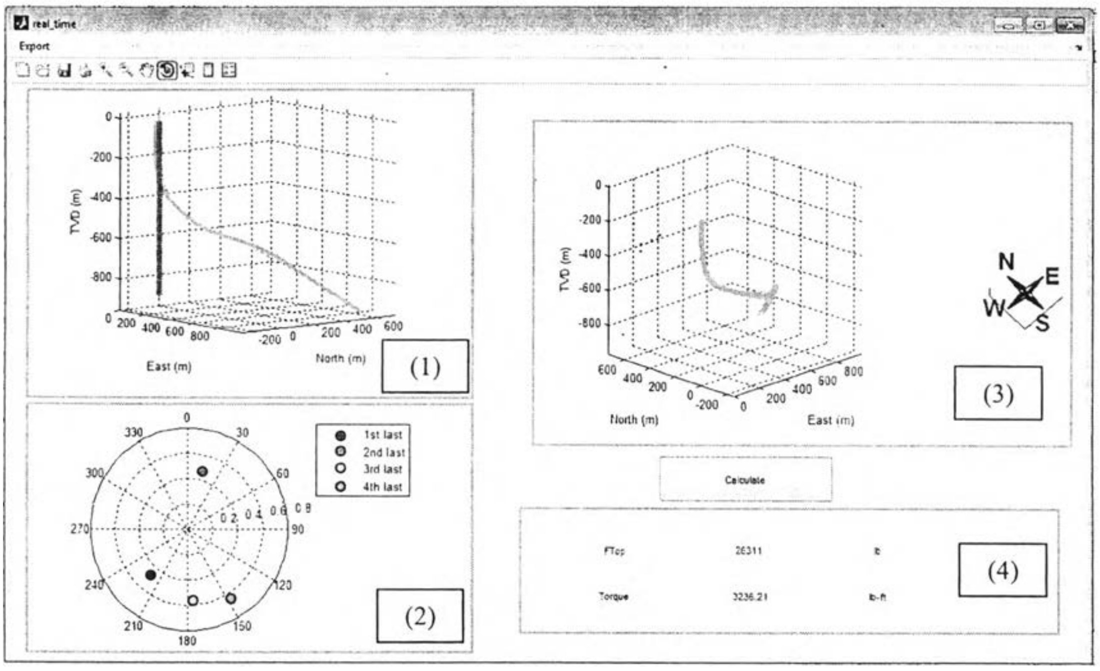


Figure 4.2 Real-time interface.

First section shows well trajectory of well planning and real-time well trajectory, so users can compare real-time well trajectory with what has been planned. Well trajectory of well planning and real-time were plotted in blue and green color, respectively which x axis is east-west, y axis is north-south, and z axis is TVD. Real-time well trajectory was updated after data being transferred as shown in Figure 4.3.

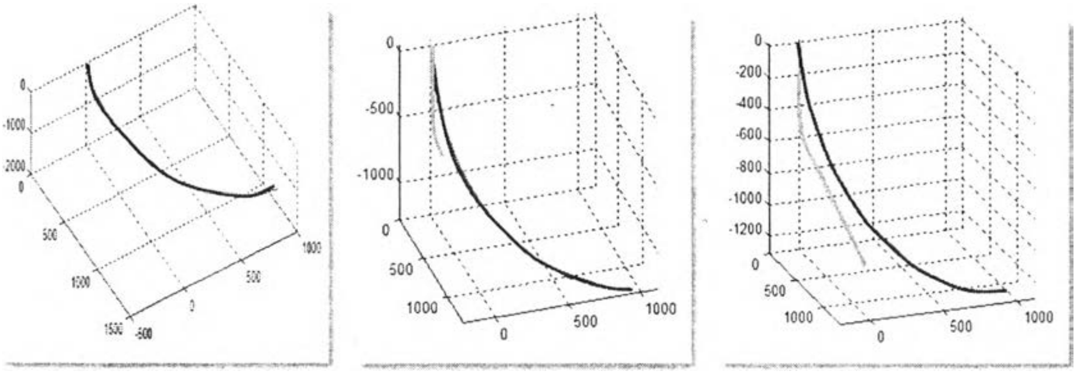


Figure 4.3 Well trajectory of well planning and real-time.

Second section is a compass that displays tool face of last 4 positions in order to show direction of bit to users as shown in Figure 4.4 (a). in Figure 4.4 (a) shows first position (1^{st} last) and then after new data were transferred and calculated that first position became second position (2^{nd} last) as shown in Figure 4.4 (b) and new position became first position in Figure 4.4 (b).

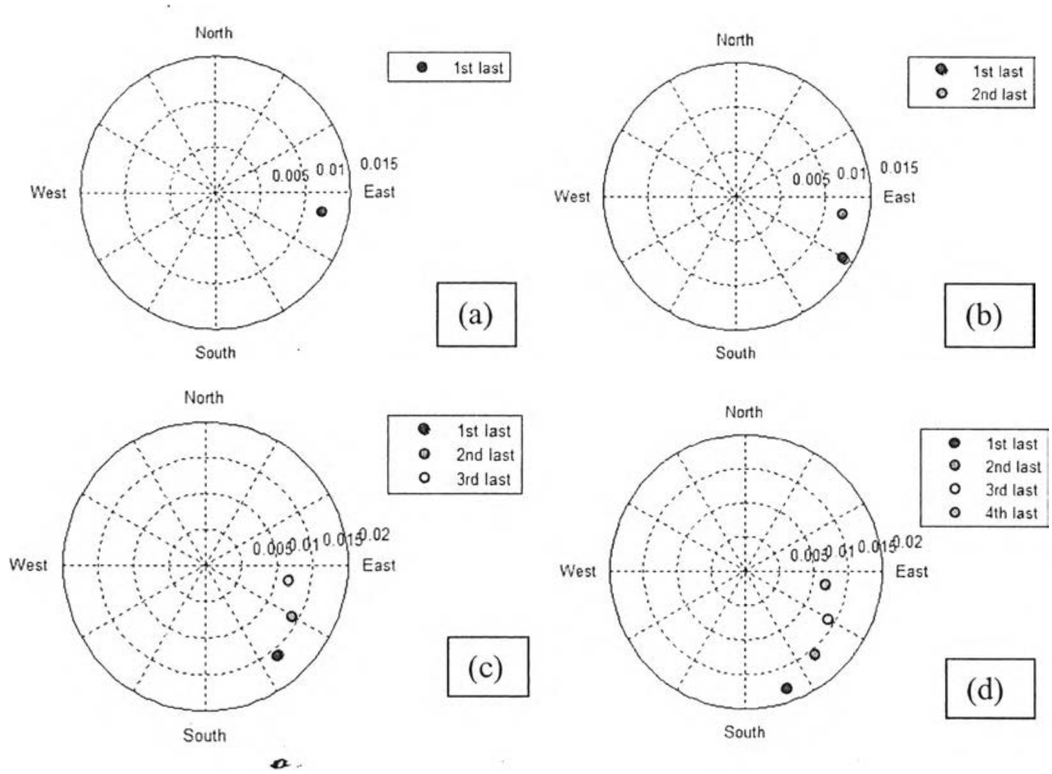


Figure 4.4 Magnetic compass.

Tool face consists of two types:

➢ Magnetic tool face: This kind of tool face shows vertical view of well as shown in Figure 4.3 which is used when inclination is lower than 5^o because magnetic tool face is easier to read and more useful when inclination is low.

➢ Gravity tool face: This tool shows azimuth and inclination change of bit from last position as shown in Figure 4.5 and 4.6. This tool face was used when inclination is higher than 5^o because it starts building then it's better to observe it in tool-face view than vertical view.

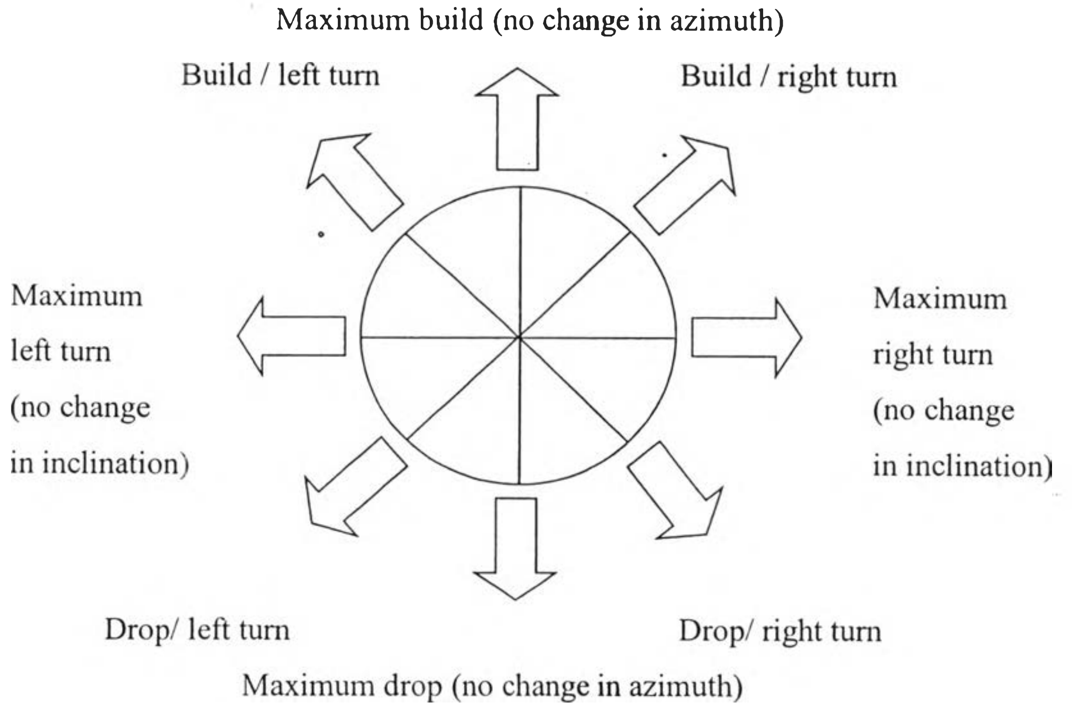


Figure 4.5 Gravity tool face.

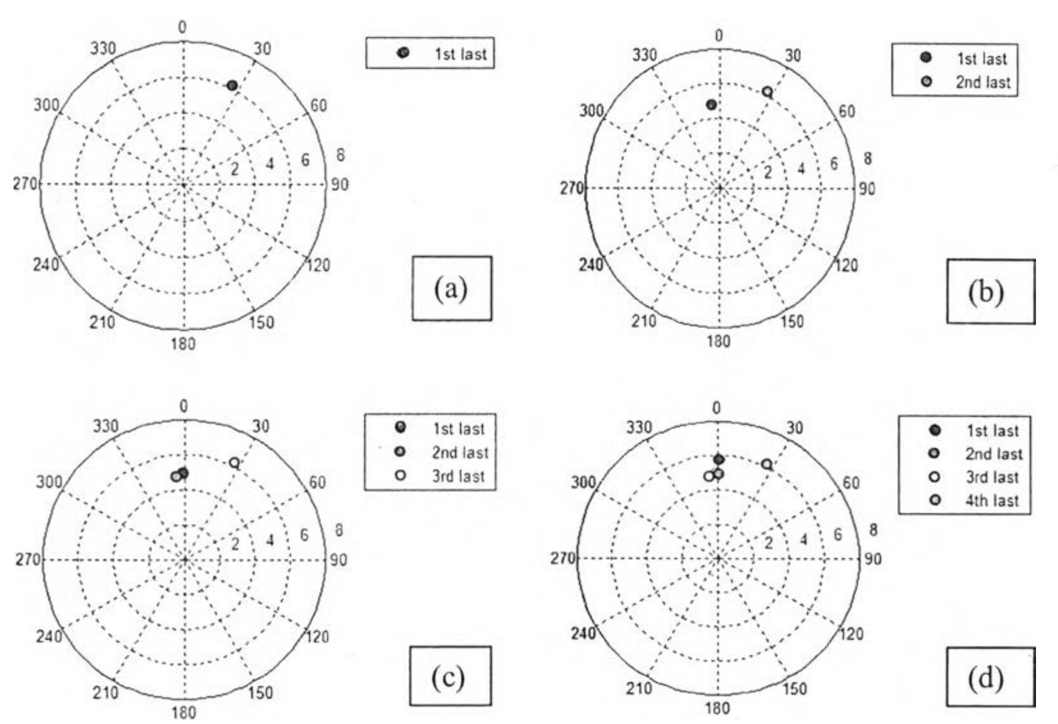
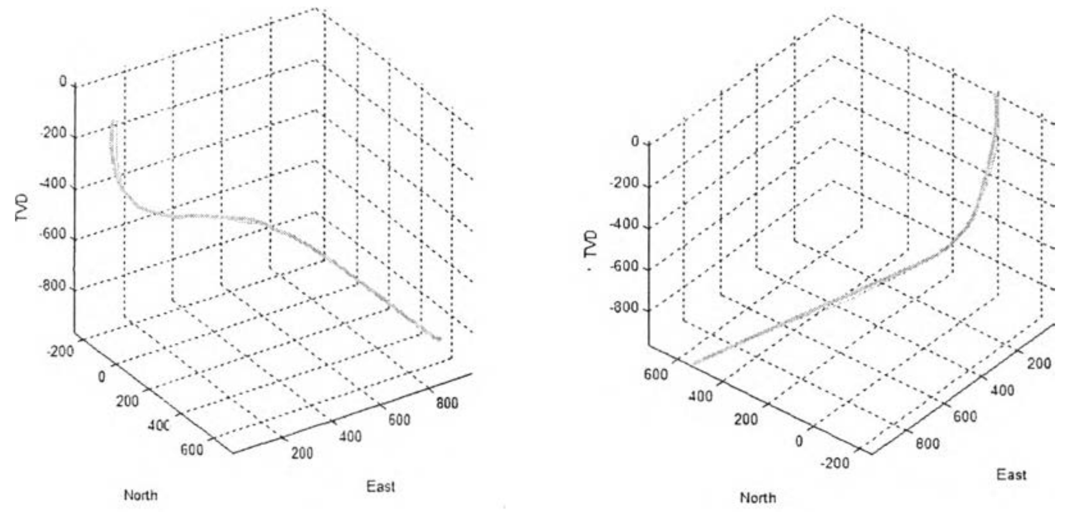


Figure 4.6 Gravity compass.

By using MATLAB plotting real-time well trajectory by balance tangential method which it is simple and accurate as shown in Figure 4.7. So users can view it 360° which is convenient to look around.



(a) (b)

Figure 4.7 Well trajectory in 3D views.

Fourth section displays real-time calculated hookload and torque which it's automatically updated after data are calculated as shown in Figure 4.8.

FTop	75084.7	lb
Torque	816.314	lb-ft

Figure 4.8 Calculated rigfloor hookload and torque display.

Software can run automatically after program started and users can easily read the results and view the graphs so this is why software is user-friendly software.

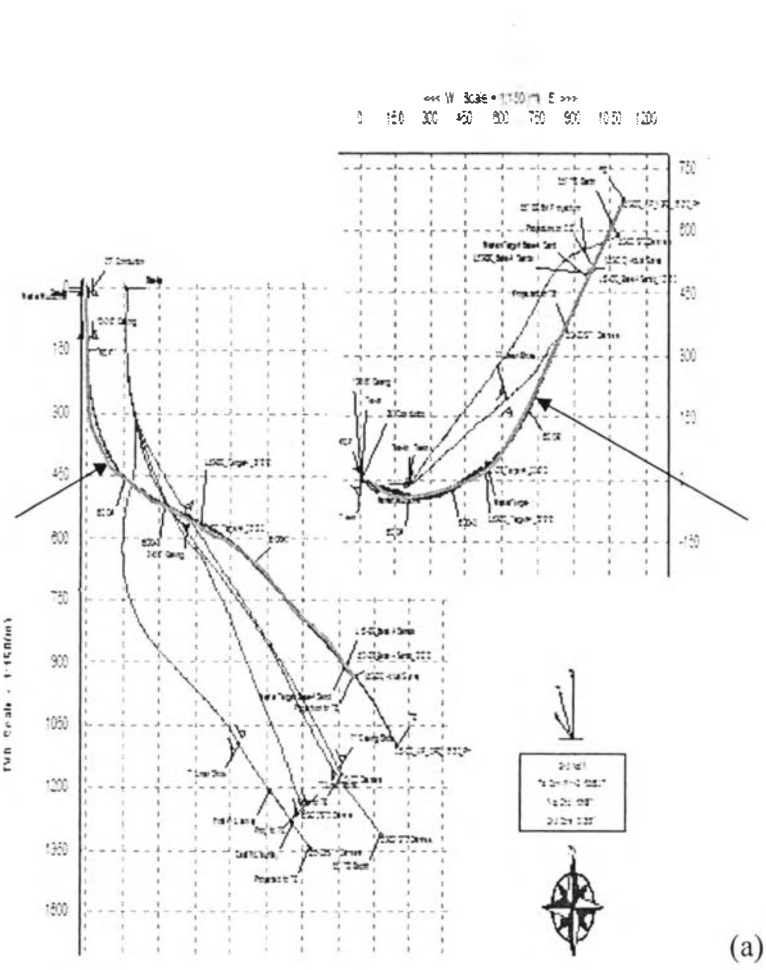
4.2 Actual Field Data

Well A was brought to verify software which is a complex on-shored oilfield well in Thailand that has target depth of 5,450 ft, and the drillstring consists of six bit runs. The first bit run is from 0 ft to 66 ft, second bit run is from 66 ft to 341 ft, third bit run is from 341 ft to 2630 ft, forth bit run is from 2630 ft to 3697 ft fifth bit run is from 3697 ft to 4818 ft and last bit run is from 4818 ft to5450 ft. For Bottom Hole Assembly (BHA) of each bit run shown in Appendix B (Table B5). Top drive and traveling block weight are 25,000 lb.

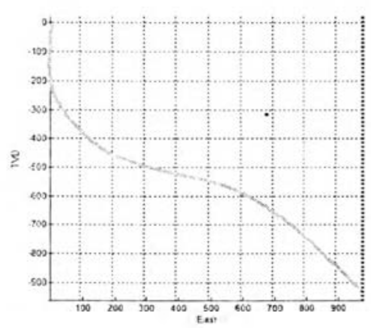
4.2.1 Well Trajectory of Well A

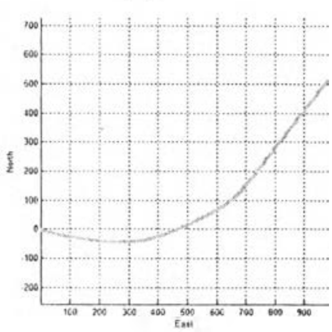
The well trajectory of well A was plotted with axis ratio of x : y : z axis is 1 : 1 : 1 because it will suitable for the users to understand the real dimension in the real-time graphical form. This trajectory was brought to compare with actual well trajectory as shown in Figure 4.8. Figure 4.9 (a) is actual well trajectory of well A obtaining from the definitive survey from service company which lines that are being pointed is brought to compare with well trajectory from software Figure 4.9 (b) and Figure 4.9 (c). The result shows that well trajectory from software is the same shape as s-shape well. The horizontal departure and vertical section of the well are shown in Figure 4.9. This example will demonstrate the application of the model for tripping the drill string in and out, including rotating on and off bottom. In this horizontal well, the drill string must be forced into the wellbore. Here, the 5 inch heavy weight drill pipes were placed in the vertical section to provide sufficient weight to push the drill string into the horizontal section.

The entire drill string in the horizontal section is compressed during drilling. The adjusted weight for the 5 inch drill pipe and 5 inch heavy weight drill pipe are 19.5 lb/ft and 50 lb/ft, respectively. The adjusted diameter for the drillpipe and heavy weight drillpipe is 5 inch. The well is filled with a drilling fluid with a various weight about 9 to 10 lb/gallon. For this well, there is a change in the well azimuth turn to the north-east compared with the rig floor. Also, the dogleg change of this well is the change of the inclination.



(a)





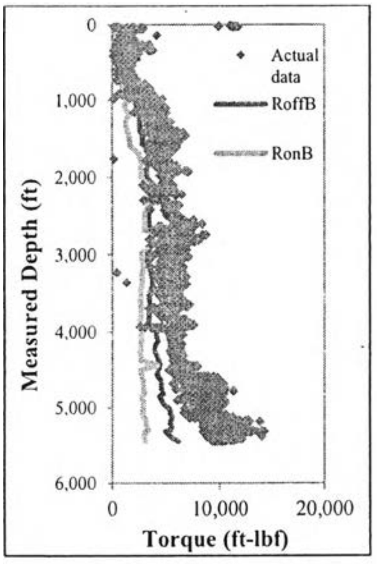
(b) (c)

Figure 4.9 Well Trajectory of well A (a) actual (b) side view and (c) top view

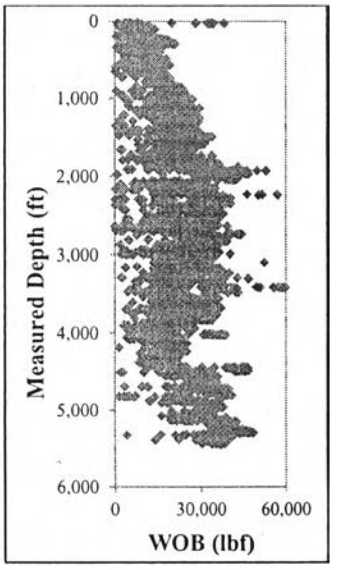
T&D analysis of well A was performed by various the coefficient of friction since this factor is extremely involved in T&D equations, but it is rarely indicated the actual values along the well path as a single value. The friction factor can express the fact that a problem is existing in the wellbore (Brett *et al.*, 1989) which could be either to hole geometry (inclination and azimuth changes) or to some other factors (problems with cuttings accumulations, tight hole, and type of rock formation). Moreover, the coefficient of friction can be separated into two types: the rotating friction factor for conventional drilling (RoffB and RonB) or wiper trips and sliding friction factor for turbine/downhole motor drilling or POOH/RIH (Lesage ét al., 1988). Thus, this T&D well-planning software used a single average friction factor for the entire wellbore interval, which is very common in available torque and drag simulators, for both rotational and axial motion.

4.2.2 Torque

The equations used for calculating torque in software consists of two operation modes, RoffB and RonB because in RIH and POOH modes, there is no torque present due to no rotating bit. The torque was calculated starting bottom-up at the bit with the bottom-end boundary conditions to set torque equal zero at the bit, for RoffB assumed that there is no-loss of frictional torque. Even if RonB present the weight on bit, there is no torque at bit The different well geometry will show the different torque behavior due to the different friction drag acting on the drillstring.



(a)



(b)

Figure 4.10 Comparison between (a) Torque and (b) WOB with measured depth.

Torque from the software is considered only the frictional torque, but the surface torque consists of the frictional torque, dynamic torque, mechanical torque, and bit torque. Therefore, the bit torque, which is generated by the impact of the bit and the formation of the RonB operation, is not considered. From Figure 4.9 it shows that when WOB increases actual torque also increases, in contrast, calculated torque in RonB mode decreases. This is because higher WOB makes higher bit torque but software doesn't count bit torque effect thus RonB mode has lower torque than usual.

4.2.3 Axial Force and Hookload

The axial force cannot be presented directly by itself, but it is included in form of the measured Hookload as Equation 4.1:

$$\text{Hookload} = Axial\ force + W_{top} - WOB \tag{4.1}$$

Where W_{top} is weight of hoisting system including travelling block and top drive, and WOB is accounted only in RonB operation. The W_{top} parameter of the software is set to be 25,000 lb as a default.

In real time, the Hookload and WOB are inverse direction of eachother because Hookload is measured by the hoisting tension weight of the drill string as shown in Figure 4.11, while the WOB is the compressive force in the drill string. The higher WOB can be observed by the lower measured Hookload from time to time. The calculated Hookload of RonB is less than others operation since this operation mode uses WOB to calculate as shown in Figure 4.12. Consequently, the calculated Hookload of RonB is very close to the actual field data. The actual field data of Hookload obtained from the drilling operations (RonB and sliding operation), is compared with the calculated Hookload from RonB and RIH operations. The discrepancy between the actual and the calculated could be the friction coefficient. The friction factor is affected by the other parameters such as cuttings bed, drilling fluid density, formation etc.

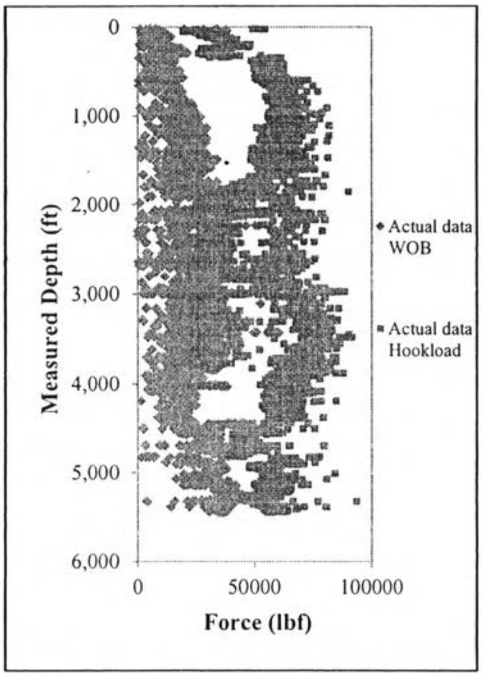


Figure 4.11 Well A actual data between WOB and hook load with measured depth.

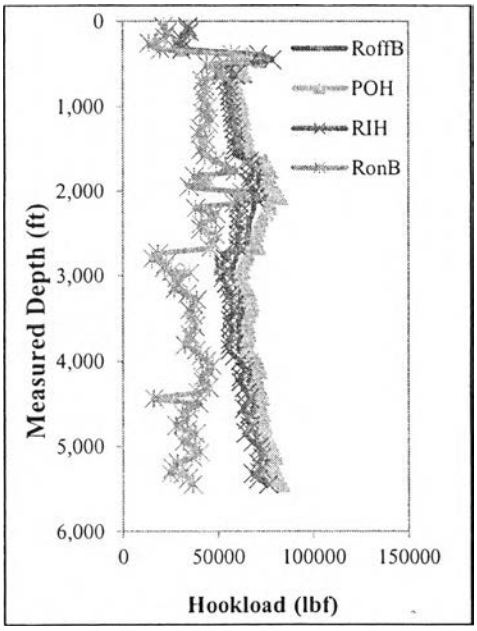


Figure 4.12 Calculated hookload with different operation modes from software.

Figure 4.12 (green) shows the measured hook loads while tripping out. The measured hook load values are a function of drill string length, well geometry, drill string configuration and wellbore conditions. Different wellbore geometries and drill string configurations in the vertical sections show different measured hook load trends. Also, Figure 4.11 shows the hook load measurements when the entire drill string weight is on the slips during connection times. Hook load measurements during connection time represent the weight of the hoisting assembly at surface without a precise calibration.