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Design of Horizontal Well Program for Ajeel Field

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Abstract

Horizontal wells are of great interest to the petroleum industry today because they provide an attractive means for improving both production rate and recovery efficiency. The great improvements in drilling technology make it possible to drill horizontal wells with complex trajectories and extended for significant depths.

The aim of this paper is to present the design aspects of horizontal well. Well design aspects include selection of bit and casing sizes, detection of setting depths and drilling fluid density, casing, hydraulics, well profile, and construction of drillstring simulator. An Iraqi oil field (Ajeel field) is selected for designing horizontal well to increase the productivity. Short radius horizontal well is suggested for the developing the field since many drilled vertical wells are exists

A soft string model was programmed to predict the imposed loads on suggested drillstring. Six operating conditions of drillstring includes rotating off bottom, pick up without rotation, slack off without rotation, pick up with rotation, slack off with rotation, and sliding ,were considered. Also, two buckling modes of drill string were estimated. According to drillstring simulator results, short radius well of build rate 90 deg/100 ft could be implemented without exceeding the strength limits of the suggested drillstring.

Keywords: Petroleum; Horizontal drilling; Design well

Introduction

To meet the increasing demand of petroleum resources, since 1970's the horizontal well drilling technology has been improved festally. Now this technology has become the important technical way to enhance oil recovery of old wells [1].

Ajeel field is located about 30 km to the North East of Tikrit city, North Iraq. The average elevation of the field area is 150-170 m above Mean Sea Level. The reservoir structure consists of the main (southern) dome and North West dome. The main structure contains an oil accumulation mainly in the Jeribe, Dhiban, Euphrates, Serikagni, and Favreina formations, and a gas cap mainly in transition beds. All these units contain carbonated rocks with quite poor permeability [2].

In 1996 HORWELL Company examined for N.O.C the possibility to apply horizontal well technology on the field to increase its productivity. Five main formations were selected to perform the study, which are T12-T15, Jeribe, Dhiban, Euphrates, and Favreina. Due to the proximity of gas and/or water contacts in some critical areas and low permeability in other, the company suggested three locations for horizontal drilling which are Jeribe, Euphrates, and Favreina. With aid of analytical calculation and correlation issued from basic numerical simulation, high horizontal well productivity indexes were obtained ranged from 6 up to 14 for replacement ratio from 2.75 to 6.5 [3].

Steps of Design

1- Bit and Casing Sizes

HORWELL [3] study suggested hole size of about 8.5 in for horizontal well. If the production casing or liner size was chooses as 6 5/8in, the sizes of bits to drill the whole well and casing sizes for casing the well could be determined with API tables. Table 1 provides the final sizes of bits and casing strings.

2- Setting Depths and Drilling Fluid Densities

Pore and fracture pressures data of the Ajeel field were gathered from offset well reports (geologic reports). Table 2 shows these values of pressures at different depths. With these data, casing setting depths and drilling fluid densities were determined with liner interpolation method. Since the depth of Euphrates formation is nearly 2975 ft (setting depth of the production casing), table 3 provides setting depths of other casing strings and required density for drilling these sections.

3- Casing Grads

Casing Grads and weights were determined for each section based on the density of drilling mud and formation pressures of the field. A worst conditions design were considered in computing of tension, burst, collapse, and bending loads imposed on casing string [4]. Also safety factors with high values for each type of load were assumed. For tension (SF=2), for burst (SF=1.2), and for collapse (SF=1.2) .With the aid of computer program, the detailed information about the casing program was provided in table 4.

4- Well Profile

Ajeel oil field has many vertical wells with known depths. These vertical wells could be converted to short radius wells (reentry wells) by drilling building section with a high build rate of angle. Usually, this type of horizontal well could be completed as open hole, since the formation is limestone. Well profile was constructed with radius of curvature method (most common method for profile design) as single curve with the following equations [5].

$$R = 5727.27/BUR \quad \ldots(1)$$

$$V1 = R.(\sin I_2 - \sin I_1) \quad \ldots(2)$$

$$H1 = R.(\cos I_1 - \cos I_2) \quad \ldots(3)$$

$$L1 = 100.(I_2 - I_1)/BUR \quad \ldots(4)$$

Figure 1 depicts single build (constant build) horizontal well profile suggested for this field when the rate of build is 90 deg/100ft. Table 5 presents the dimensions of this profile (Short radius well profile). A 63.66 ft vertical distance is required to convert the well from vertical to horizontal. While vertical depth of about 2934 ft is required to start the deflection process.

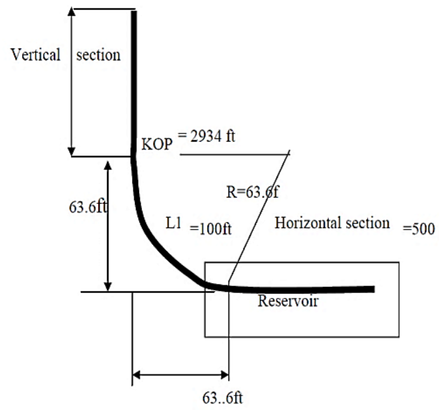

Fig. 1, Horizontal Well Profile

5- Drillstring Loads

Drill string Loads (drag & torque) were calculated with soft-string model [6]. The equations of this model are:

$$F_N=[(T\ \Delta\varphi\ \sin\theta_{AVG})^2+(T\ \Delta\theta + W\ \sin\theta_{AVG})^2] \quad \ldots(5)$$

$$\Delta T=W\cos\theta_{AVG}\pm f F_N \quad \ldots(6)$$

$$\Delta M= f\, F_N r \quad \ldots(7)$$

$$F_f= f\, F_N \quad \ldots(8)$$

Six operating parameters (pick-up without rotation, slack-off without rotation, sliding, pick with rotation, slack-off with rotation, drilling with rotation) are considered in the computation [7]. Friction coefficients between drillstring and wall of the hole are derived from the type of mud [8].Also; buckling tendencies (sinusoidal and helical buckling) of drillstring are calculated from the following equations [9]:

$$F_{cir} = 2\left(\frac{EI\rho A_s g\sin\phi}{r}\right)^{0.5} \quad \ldots(9)$$

$$F^* = 2.83\sqrt{\frac{EIW}{r}} \quad \ldots(10)$$

Figure 2 shows the loads analysis of inverted drillstring using drillpipe type(S-135) and drillcollar without rotation. While Figure 3 shows the string loads for rotating case.

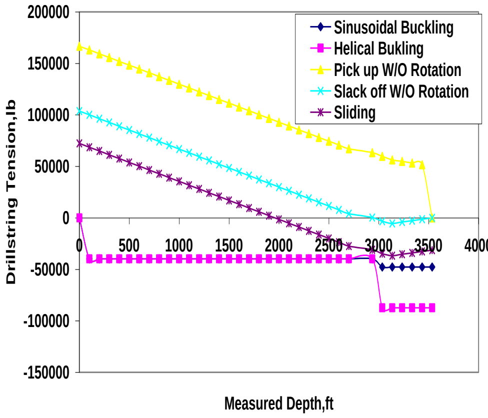

Fig. 2, Drillstring Loads without Rotation

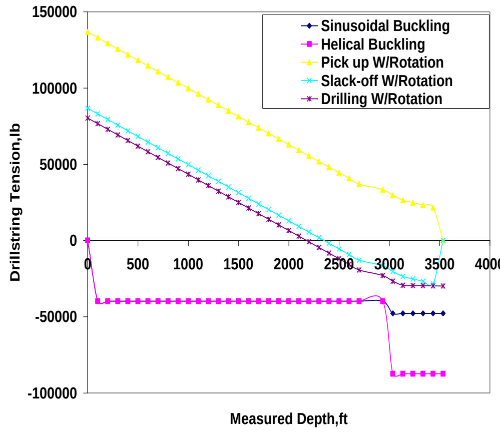

Fig. 3, Drillstring Loads with Rotation

In both cases, a maximum surface tension of the string was recorded in pick-up condition. These values are smaller than the tensile strength of drillpipe (388000 lb), which provided reasonable safety margin. Also, maximum compressive load has been achieved when using steerable bottom hole assembly (sliding mode). This mode of drilling could be used safely since the sinusoidal critical buckling of drillpipe (40000 lb) is larger than the compressive load in the string. In addition, a sufficient surface slack-off load is noticed which provided adequate string weight to offset the axial friction effects while tripping in the hole.

6- Hydrulic Requirements

A computer program was constructed to calculate the pressure losses in the circulation system for Bingham plastic fluid (since the offset wells are drilled with Bingham plastic mud). Also nozzles size, jet velocity, hydraulic power at the bit (BHHP), and impact force of the bit (BIF) were calculated. Table 6 provides the results of calculations.

Conclusions

This paper is concerned with the design of horizontal well aspects. These included selection of bit and casing size, setting depths and drilling fluid densities, well profile, drillstring loads and casing. An Iraqi oil field which is (Ajeel field) is selected for application this design. From the obtained results, a vertical well could be converted to short radius well with 64 ft vertical distance needed. Also, a single build profile with rate of build of about 90 deg/100ft could be implemented without exceeding the strength limits of the inverted drillstring.

Nomenclature

Θ: inclination angle at the lower end of element, degree.
Φ: azimuth angle at lower end of element, degree.
θ: hole angle, measured from vertical, deg
ρ: weight per cubic inch, lb_m.
f: coefficient of friction.
ΔT: change of axial tension over the length of element, lb_f.
ΔM: change of torsion over the length of element, ft-lb_f.
Δθ: change of inclination angle over the length of element, degree.
ΔΦ: change of azimuth angle over the length of element, degree
A_s: cross- sectional area of pipe,in^2
BUR:build up rate of angle ,deg/100ft
E: Young's modulus, psi
F_{crit}: critical buckling force ,lbf
F_N: the net normal force, lb_f
F_f: sliding friction force acting on the element, lb_f.
F^*: helical buckling force, lb
g: gravitational force, lb_f .
H1: horizontal displacement of build section, ft
I_1, I_2: inclination at station 1and 2, degree
I: moment of inertia of pipe, in^4
L1: length of build section, ft
M: torsion at the lower end of element, ft-lb_f.
R: radius of curvature, ft
r: characteristic radius of element, ft.
T: axial tension at the lower end of the element, lb_f.
V1: vertical height of upper build section, ft
W: buoyed weight of drillstring element, lb_f.

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Table 1, Bit and Casing Sizes for 6 5/8 in Production Casing

Bit Size, in	Casing Size ,in
17 1/2	13 3/8
12 1/4	9 5/8
8 1/2	6 5/8

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Table 2, Pore and Fracture Pressure Data

Depth(RTKB) ft	Pore pressure psi	Fracture pressure psi
2261	1518	2057
2404	1572	2212
2562	1487	2383
2747	1492	2637

Table 3, Setting Depths and Drilling Mud Densities

Setting Depth ,ft	Mud Density, ppg
1445	8.92
2520	12.63
2975	11.77

Table 4, Casing Grads and Weights

Hole Size in	Casing Size in	Grade	Weight Lb/ft	Length ft
17.5	13 3/8	k-55	54.5	1445
12.25	9 5/8	K-55	36	2520
8.5	6 5/8	N-80	26	2975

Table 5, Dimensions of Horizontal Well Profile

Radius of Curvature, ft	63.66
Vertical Depth of Build Section, ft	63.66
Horizontal Length of Build Section, ft	63.66
Length of build Section, ft	100
Kick-off Point(KOP),ft	2934
Total Measured depth, ft	3534

Table 6, Hydraulic Calculation of Circulation System

Dh in	Q gpm	Ps psi	P_{string} psi	$P_{annulus}$ psi	P_{bit} psi	A_n In^2	V_n Ft/sec	$D_{n,}$ 1/32in	BHHB hp	BIF Lb_f
17.5	692	50	412	42	2525	0.39	561	13.1	1018	1789
12.25	510	38	403	73	2555	0.34	474	12.2	758	1577
8.5	310	22	250	94	2703	0.24	505	10.29	602	1179