GEOMECHANICAL APPROACH FOR CASING DESIGN OF DIRECTIONAL WELLS

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Summary

This paper is based on the design calculations of the casing using combination grade through graphical-manual approach. Here an attempt has been made to model a casing programme for a directional well taking into account pore pressure and fracture gradient data of a particular well. Assumptions and considerations are made based on prevalent drilling conditions in the area and an effort has been made to design a casing programme so that it can successfully be implemented safely in oil-field practices.

Introduction

Design of a casing string for directional well has always been a problem for the oil and gas industry. Various forces are acting downhole due to inclined trajectory which makes the pre-planned wellpath under suspect. This paper is generally based on design considered under uniform safety factor at change-over points and selection of grades is taken. Various material grades are evaluated for safety limits and accordingly using manual approach the selection is done. The basic idea behind using this approach is to make a casing programme so that it can withstand the all possible loading conditions encountered in real drilling practices.

Theory / Method

Using pore pressure plot we identify combination casing program. We design a combination casing string taking into account the economic aspect. The method for designing each of the casing strings are presented based on the unfavorable conditions like gas kick, invading fluid kick and circulation loss encountered [*Prentice, 1970*]. The paper presents the design of casing string using graphical method. The calculations of the different casing are based on collapse, burst, tensile loads, bending, shock and biaxial loading conditions. In this approach a graph of pressure against depth is first constructed. Calculated collapse and burst pressure are drawn on the graph. Strength values of the available casing grades (taking into account the safely factor) are then plotted as vertical lines on this graph. The intersection of the load line with the calculated pressure line indicates the depth to which that particular grade of casing can be used. Steel grades which satisfy the maximal existing load requirements of collapse and burst pressure are selected. Once the weight, grade, and sectional lengths which satisfy burst and collapse loads have been determined, the next is to calculate the tension load and accordingly the pipe section can be upgraded if it is necessary [*Rahman and Chilingarian, 1995*]. Considering the above facts the newly planned well is designed for severe collapse conditions. This paper ignores the beneficial effect of cement void spaces and instead assumes that the drilling fluid is present outside the casing in the annulus. This newly planned well trajectory have encountered high dogleg severity which means that the borehole wall is irregular. In the above context there is a possibility that the casing may be in continuous contact with the borewall so for a long string section their may arise the bending of the casing which may affect the top joint. If the horizontal forces acting on the casing due to bending is more than the axial tension, it may prematurely deform the casing, so together with buoyant forces, bending forces is also taken into account while calculating total tensile load acting on the top joint of the casing. Casing grade are usually reciprocated and rotated during landing and cementing operations which results in an additional axial load due to mechanical friction between the pipe and the borehole. This extra forces results in drag force. Due to complex geometry of the deviated wells, the drag force is a major contribution to the total axial load for that particular well. Again due to running of the casing sometimes the casing is stopped by applying brakes or slips at the rotary table, in such cases there may be a possibility that the casing joint get damaged. So keeping this in mind we considered the shock load while designing the casing grade for tensile load. So, in selection of pipe grade for combination string, the total tensile load is checked while taking all these above factors into consideration and comparing the calculated values with the joint or pipe body yeild strength to determine the safety factor. The final step is to check the biaxial effect on collapse and burst loads. If the strength in any part of the section is lower than the potential load, the section should be upgraded and the calculation repeated. Thus, a systematic procedure for selecting steel grade, weight, coupling and sectional length is presented.

Case Study

We have designed a casing policy for an oil well from Mumbai offshore field. The most important parameter in determining the reliability and success of a casing design is the pore pressure. In estimating the casing setting depth accurate knowledge of pore pressure gradient (estimated from well log data and seismic data) and fracture gradient calculated from Eaton's formula is obtained [*Eaton, 1969*]. The casing setting depth has been chosen based on the figure below.

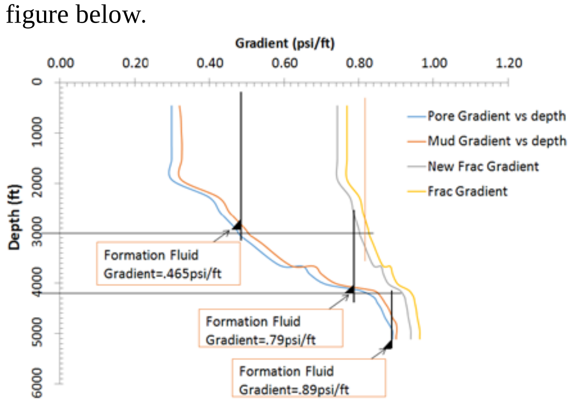

Figure 1: Depth (ft) vs Pressure Gradient (psi/ft) curve for determination of CSD and casing policy (Eaton's chart).

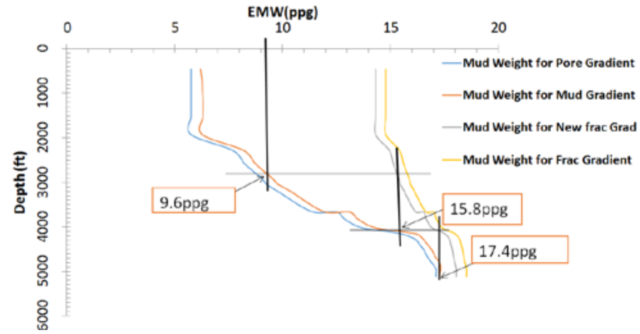

Figure 2: Equivalent Mud Weight vs Depth for X well.

From the equivalent mud weight (EMW) analysis the casing programme is designed.

Tyoe of Casing	Casing OD	Casing Depth (ft)	Equivalent Mud Weight (ppg)
Conductor	20	463	8.6
Surface	13.375	2940	9.6
Intermediate	9.625	4100	15.8
Production	7	5106.97	17.4

Table 1: Casing programme for X well.

The data for Measured Depth (MD), True Vertical Depth(TVD), Inclination(^{o}), Azimuth(N-E/N-W) and dogleg severity(^{o}/30m) provide the input parameters for the following well design. The well was drilled as a deviated well with an inclination ranging from 58^o when entering the reservoir to 74.89^o at the end of the well. This is designed to maximize the production rate and to delay water breakthrough. The well path of well X is modeled by using DEPRO_BETA 6.0 software based on real time data which is shown below in the figure

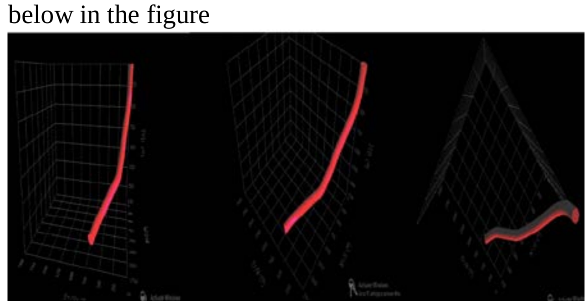

Figure 3: 3D well design for X well modeled by DEPRO_BETA 6.0 showing the a)Front view b)Side view c)Top view.

Dogleg Severity (DLS)

Since the well X is a directional well, so rapid changes in inclination or azimuth over a short interval of course length increases the dogleg severity [*Curry, 1988*]. Due to high DLS, more bending forces are encountered during casing design calculations. The dogleg severity profile of the well is given in figure 4.

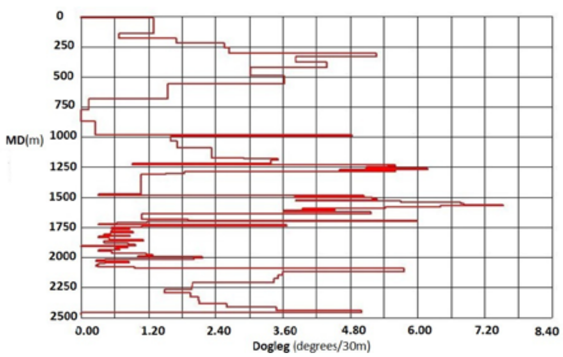

Figure 4: Dogleg Severity (deg/30m) vs. Coarse length (MD) of the new planned well.

Selection of optimum casing outside diameter with variation of hole size depends on the geological conditions of the formation. From the plot of pressure gradient vs. depth mentioned in the figure 3, the casing policy is suggested. Parameters such as ROP and wellbore integrity matters a lot in casing design program. So maintaining a proper mud weight program is also an important criterion while designing the casing selection. Another factor which should also be taken into prior notice while selecting the hole size to casing OD (outside diameter) ratio is the annular space between the casing string and the drilled hole. An adequate space need to be maintained to properly accommodate casing appliances such as centralizers and scratchers and also to avoid premature hydration of cement. The figure 5 mentioned below is the casing profile taking into account all the necessary factors to make the design practically possible [*Woodlan and Powell, 1975*].

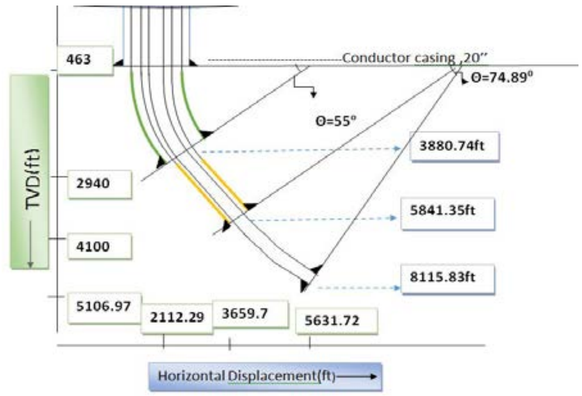

Figure 5: Projection of well trajectory showing MD and HD.

Several assumptions have been made to calculate particular grades of casing such as loss circulation, invading gas kick and pipe sticking problem. Taking into account the forces due to collapse, burst, tension, bending, drag and shock generated load design has been made. The formulations for necessary computation have been taken from *Samuel (2010)*. The final design is presented below

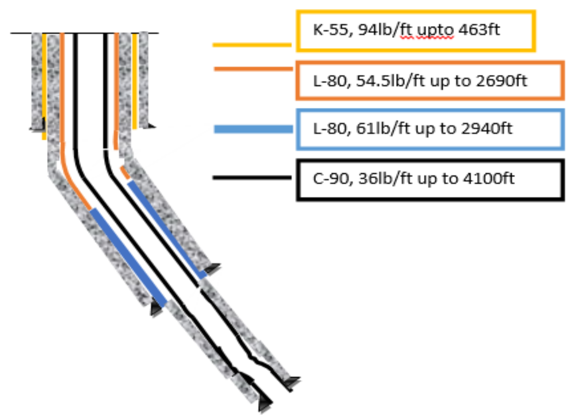

Figure 6: Complete assembly of the casing design using manual approach.

Conclusions

The case study taken from a Mumbai offshore field is presented here. The casing design programme for a particular well is done, with possible oil-field problems that normally encounter while drilling to a 5100 ft depth. Taking the real-time data of the X well, an effort has been made using manual standard calculations and accordingly cross-check is made with API standard safety factor used in field practices to make the casing programme practically possible to implement in that particular well. This paper presents the combination casing design for a target depth of 5180 ft where the inclination angle varies from 0^0 to 74^0. The results of the approach with different casing grades at different casing depth with a aim to minimize the cost and also to provide a safe drilling programme.

References

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