Cairo University

OPTIMUM MUD WINDOW TO PROVIDE WELLBORE STABILITY AND REDUCE NON PRODUCTIVE TIME WHILE DRILLING IN MISHRIF FORMATION, SOUTH OF IRAQ

By

Asmaa Hasan Kadhim Manhalawi

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Petroleum Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY,
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Title of Thesis:

Optimum Mud Window to Provide Wellbore Stability and Reduce Non Productive Time While Drilling in Mishrif Formation, South of Iraq

Key Words:
Mechanical Earth Model, Safe Mud Window, Non Productive Time, Wellbore Stability, Rocks Strength Properties

Summary:
This work deals with generating an integrated wellbore stability analysis for Mishrif Formation in South of Iraq area, using the Mechanical Earth Model (MEM). The start was calculating the overburden stress using the density logs, estimating the Pore pressure by using sonic log applying the Eaton method, after that the results have been calibrated using the real pressure data recorded in the well. Fracture pressure is then estimated from the overburden gradient and the pore pressure gradient has been calibrated by the complete losses events in Mishrif Formation and the use of hydraulic fracturing data. The poroelastic strain model is then used to estimate the magnitude of minimum and maximum horizontal stresses. Mohr-Colum Criterion was used to determine the failure conditions of the wellbore walls.

DISCLAIMER

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the reference section.

Name: Asmaa Hasan Kadhim Manhalawi Date:

Signature:

DEDICATION

This thesis is dedicated to the soul of my father, may God have mercy on him, which was pulsing in my heart to reach my goal and overcome the difficulties with all strength, my dear mother who has a nostalgic heart that does not stop giving me in countless ways, my brothers and my sisters who encouraged me to work hard to achieve my goals.

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Nomenclature

CS	Rock Cohesion (psi)
DT	Compressional Slowness (μs/ft)
ESD	Equivalent Static Density (ppg)
$E_{Dynamic}$	Dynamic Young's Modulus (Mpsi)
E_{Static}	Static Young's Modulus. (Mpsi)
E	Young's Modulus (Mpsi)
FANG	Fraction angle (degree)
FPMW	Fracture Pressure in Mud Weight Equivalent
FG	Fracture Gradient (psi/ft.)
G	Gravitational Force (m/s^2)
G_{dyn}	Bulk Modulus Dynamic (Mpsi)
GR	Gamma Ray Log (API units)
Im	Reactivity Coefficient (dimensionless), (ranges from 0 to 1)
K_{dyn}	Bulk Modulus Dynamic (Mpsi)
K	Biot Coefficient (dimensionless)
LWD	Logging While Drilling
LOT	Leak off Test (psi)
MD	Measured Depth (m)
MDT	Molecular Dynamic Tester
MW	Mud Weight (ppg)
NCT	Normal Compaction Trend (dimensionless)
OBG	Overburden Gradient (psi/ft.)
PPG	Pore Pressure Gradient (psi/ft.)
P_p	Pore Pressure (psi)
Phg	Hydrostatic Pressure Gradient (μs/ft.)
P40H	Deep Resistivity (Ohm.m)
P28H	Medium Resistivity (Ohm.m)
P16H	Shallow Resistivity (Ohm.m)
PHIT	Total Porosity (dimensionless)
PPRS-Eaton	Calculated Pore Pressure from Eaton Method (psi)
RHOB	Density Log (gm/cc)

Shmin	Minimum horizontal stress (psi)
SHmax	Maximum horizontal stress (psi)
Ts	Tensile Strength (psi)
TSTR	Tensile Strength (psi)
UCS	Uniaxial Compressive Strength (psi)
Vp	Compressional Velocity (km/s)
Vs	Shear Velocity (km/s)
Z	Depth (m)

Latin Symbols:

σ	Stress (psi)
σ_v	Vertical Stress (psi)
Ø	Porosity (%)
ρ	Density (gm/cm^3)
$v_{Dynamic}$	Dynamic Poisson's Ratio (dimensionless)
v	Poisson's Ratio (dimensionless)
ρb	Bulk Density (gm/cm3)
Δt_{comp}	Compressional Slowness (μs/ft.)
Δt_{shear}	Shear Slowness (μs/ft.)
σ_h	Minimum Principal Horizontal Stress (psi)
σ_H	Maximum Principal Horizontal Stress (psi)
α	Biot Coefficient (dimensionless)
ε_h	Minimum Principal Horizontal Strain (dimensionless)
ε_H	Maximum Principal Horizontal Strain (dimensionless)
$\emptyset$	Friction Angle (deg.)
γ	Wellbore Inclination (deg.)
φ	Wellbore Azimuth from the Direction of $\sigma_{H\,max}$ (deg.)
ΔP_w	Internal Wellbore Pressure (psi)
ΔΠ	Osmotic Pressure (psi)
τ_{tmin}	Effective Minimum Compressional Principle Stress (psi)
σ_{max} and σ_{min}	Maximum and Minimum Principal Effective Stresses (psi)

ABSTRACT

Wellbore instability is one of the major problems that engineers face during drilling and results in nonproductive time which consequently leads to over cost well. The causes of wellbore instability are often classified into either mechanical (for example, failure of the rock around the hole because of high stresses, low rock strength, or inappropriate drilling practice) or chemical effects, which arise from the damage interaction between the rock, generally shale, and the drilling fluid. Often, field instances of instability are a combination of both chemical and mechanical factors. This problem might cause serious complication while drilling. In some cases, this can lead to expensive operational problems. The increasing demand for wellbore stability analyses during the planning stage of a field arises from either economic considerations or the expanding use of deviated, extended reach and horizontal wells.

This work deals with generating an integrated wellbore stability analysis for Mishrif formation in south of Iraq. The motivation for this work is the economic evaluation of many wells in the study area that showed additional well-cost due to instability problems ranged between USD 530,000 and about Two millions. Drilling these wells without finding a solution for mud losses problems is considered a significant waste in time and cost. Estimating the NPT and consequent cost for the studied wells, indicated that the reasons mainly were severe to complete mud losses in Mishrif Formation. A complete Geomechanical model for the studied wells is necessary. The Geomechanical Model requires calculating the overburden stress using the density logs, estimating the pore pressure by using sonic log, and applying Eaton method. The results are calibrated using the real pressure data recorded in the well. Fracture pressure was then estimated from the overburden gradient and the pore pressure gradient and has been calibrated by the complete losses events and hydraulic fracturing data in Mishrif Formation. The Mechanical Earth model (MEM), includes the static and dynamic elastic properties of the rock; Young's Modulus, Bulk Modulus, Shear Modulus and Possion's Ratio. Then an estimation to the rock strength including uniaxial compressive strength (UCS), Friction angle and tensile strength are indispensable. Core data is not available to calibrate the uniaxial compressive strength. The tensile strength has been calibrated from multistage fracturing data. The orientation of horizontal stresses has been concluded from the formation micro imager (FMI). The SHmin has NW-SE orientation, while the SHmax has a NE-SW orientation. The poroelastic strain model is then used to estimate the magnitude of minimum and maximum horizontal stresses. Wellbore stability plot with any given wellbore inclination and azimuth has been constructed using the above generated geomechanical model using Mohr-Colum failure criteria. As the tolerance after calibrating the results with the other well data, the results indicated that when the difference between the mud weight and the fracture pressure approaches 0.5-0.7 ppg the well is subjected to a severe or complete mud losses. When this difference falls within 0.1-0.2 ppg, the well may experience partial losses. Consequently, when the difference is zero, there will be no losses.