

**DRILLING SIMULATION AND USER PROGRAM OF DOWNHOLE
PRESSURE ESTIMATION IN DIRECTIONAL DRILLING**

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ABSTRACT

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Maintaining wellbore stability is challenging in any drilling situation, especially when directional drilling with narrow pressure window are experienced. An imperative parameter to control wellbore stability is downhole pressure or equivalent circulating density (ECD). An accurate downhole pressure is required in order to maintain it in pressure window and also avoid drilling problems which cause interruption during drilling operation, resulting in high non-productive time. Since annular frictional pressure loss increases ECD, it becomes very challenging to estimate accurate annular pressure loss. Many experimental studies have been developed annular pressure loss prediction without validating results with field measurements. This study aims to estimate an annular pressure loss in directional drilling with or without pipe rotation using several developed models with casing program. The performance of the models are tested by comparing the results with field measurements obtained from Kam Phaeng San Basin, Thailand. The conventional annular frictional pressure loss combined with increasing-pressure-loss model gives a good agreement with field measurements, a pipe rotation effect is more influential on annular pressure loss especially in smaller annular space. In addition, a user-friendly software is also developed using MATLAB platform to predict real time downhole pressure and ECD with casing program.

บทคัดย่อ

วีรพงศ์ พานิชารณ์ : การจำลองความดันหลุมเจาะและโปรแกรมการคำนวณความดันหลุมเจาะแบบมีทิศทาง (Drilling Simulation and User Program of Downhole Pressure Estimation in Directional Drilling) อ. ที่ปรึกษา : ผศ. ดร. กิติพัฒน์ สีมานนท์ และ ดร. รัศมี ไทยบุรุษภาค 73 หน้า

การรักษาเสถียรภาพในหลุมเจาะเป็นสิ่งท้าทายอย่างหนึ่งในกระบวนการขุดเจาะ โดยเฉพาะการขุดเจาะหลุมแบบมีทิศทางในพื้นที่ที่มีช่วงความดันของไหลในชั้นหินแคบ ปัจจัยอย่างหนึ่งที่ช่วยควบคุมเสถียรภาพของหลุมเจาะคือ ความดันก้นหลุม (downhole pressure) หรือความหนาแน่นน้ำโคลนที่เทียบเท่าความดันก้นหลุม (equivalent circulating density, ECD) ความดันก้นหลุมที่แม่นยำเป็นสิ่งจำเป็นที่สามารถช่วยรักษาเสถียรภาพของหลุมเจาะและสามารถช่วยลดปัญหาที่อาจเกิดขึ้นระหว่างการขุดเจาะได้ ปัจจัยสำคัญที่ควบคุมการคำนวณความดันก้นหลุมนี้คือความดันที่เกิดจากการไหลของน้ำโคลน มีการทดลองศึกษาลักษณะการไหลของน้ำโคลนในท่อและแต่ละการทดลองได้เสนอทฤษฎีการคำนวณหาความดันก้นหลุมที่แม่นยำ แต่ทว่าทฤษฎีเหล่านั้นได้พิสูจน์เฉพาะในการทดลองเท่านั้น ไม่ได้นำมาพิสูจน์กับข้อมูลจากการขุดเจาะจริง ดังนั้นการศึกษานี้จึงเป็นการรวบรวมทฤษฎีต่างๆ นำมาคำนวณความดันก้นหลุมในการขุดเจาะหลุมแบบมีทิศทาง โดยได้ศึกษาผลกระทบของการหมุนของก้านเจาะต่อความดันก้นหลุม นอกจากนี้ยังได้คำนึงถึงแผนการวางท่อกรและขนาดของท่อกรเข้าไปด้วย ทฤษฎีการคำนวณความดันก้นหลุมต่างๆ ได้นำมาผสมผสานกับผลกระทบของการหมุนของก้านเจาะจนกระทั่งได้แบบจำลองการคำนวณความดัน และนำผลจากการศึกษาแบบจำลองความดันนี้มาเปรียบเทียบกับข้อมูลการขุดเจาะจริงทั้ง 4 หลุมในประเทศไทย ซึ่งตั้งอยู่ในบริเวณแหล่งกัมพูชาในประเทศไทย ผลจากการศึกษาพบว่าทฤษฎีการคำนวณความดันก้นหลุมที่ผสมผสานกับผลของการหมุนของการเจาะสามารถคำนวณค่าความดันก้นหลุมได้ใกล้เคียงกับข้อมูลจากหลุมจริงมากที่สุด และยังพบว่าถ้าช่องว่างระหว่างก้านเจาะกับผนังของหลุมเจาะ (annular space) ยิ่งเล็กลงเรื่อยๆ การหมุนของก้านเจาะส่งผลต่อความดันก้นหลุมมากขึ้น นอกจากนี้งานวิจัยได้ออกแบบและพัฒนาโปรแกรมโดยใช้โปรแกรม MATLAB โปรแกรมที่พัฒนานี้จะสามารถคำนวณค่าความดันก้นหลุมระหว่างการขุดเจาะได้แม่นยำ อีกทั้งยังสามารถแสดงตำแหน่งของการขุดเจาะและลักษณะของหลุมได้อีกด้วย

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ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
Az	Azimuth (degree)
BHA	Bottom hole assembly
BOP	Blowout preventer
CFD	Computational fluid dynamic
CPU	Central processing unit
DF	Density of drilling fluid (lb/gal)
DP	Drillpipe
ECD	Equivalent circulating density
ERD	Extended reach drilling
GL	Ground level
GUI	Graphic user interface
HSE	Health safety and environment
ID	Inner diameter (inches)
Inc	Inclination (degree)
LAS	Logging ASCII file
MD	Measured depth
MWD	Measured while drilling
NPT	Non-productive time
OBD	Overbalanced drilling
OBM	Oil-base mud
OD	Outer diameter (inches)
PLR	Pressure loss ratio
PV	Plastic viscosity
RAM	Random-access memory
RFT	Repeat formation tester
RKB	Rotary kelly bushing
ROP	Rate of penetration

RPM	Revolutions per minute
SBM	Synthetic-based mud
SWOB	Surface weight on bit (lbf)
TD	Total depth
TVD	True vertical depth
UBD	Underbalanced drilling
WBM	Water-base mud
WITS	Wellsite information transfer specification
YP	Yield point

LIST OF SYMBOLS

ΔP_{rotate}	Increased pressure loss
D_e	Hydraulic diameter
D_i	Drillpipe diameter
D_o	Wellbore diameter or casing diameter
F_d	Dimensionless force
N_{ReT}	Total Reynolds number
N_{Rea}	Axial Reynold number
N_{Re_r}	Rotational Reynold number
N_{Re}	Reynolds number
P_{AF}	Frictional annular pressure
P_{BH}	Bottomhole pressure
P_{Hyd}	Hydrostatic pressure
f_f	Friction factor
ϵ_{ave}	Average pipe eccentricity
μ_{ea}	Effective viscosity in axial direction
μ_{e_r}	Effective viscosity in radial direction
μ_a	Apparent viscosity
τ_w	Average value of the shear stress on the pipe or annular space wall
τ_y	Yield stress
ω_d	Dimensionless rotation
K	Consistency index
L	Length section
Ta	Taylor number
g	Gravity acceleration
m	Yield power law exponent
n	Fluid behavior index
t	Time
v	Average velocity

z	Axial coordinate in z direction
γ	Velocity gradient
δ	Distance between center of inner and outer pipes
ε	Eccentricity
μ	Viscosity
ρ	Fluid density
τ	Shear stress
ω	Rotation speed