

**RESERVOIR CHARACTERISTICS INTERPRETAION BY USING
SPECIFIC ENERGY WITH DOWN-HOLE TORQUE AND DRAG**

Lertsak Laosripaiboon


A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science
The Petroleum and Petrochemical College, Chulalongkorn University
in Academic Partnership with
The University of Michigan, The University of Oklahoma,
Case Western Reserve University, and Institut Français du Pétrole
2015

I 28 3 69 40 x


580081

Thesis Title: Reservoir Characteristics Interpretation by Using Specific Energy with Down-Hole Torque and Drag
By: Mr. Lertsak Laosripaiboon
Program: Petroleum Technology
Thesis Advisors: Assoc. Prof. Chintana Saiwan
Dr. Ruktai Prurapark

Accepted by The Petroleum and Petrochemical College, Chulalongkorn University, in partial fulfillment of the requirements for the Degree of Master of Science.

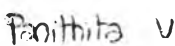

..... College Dean
(Asst. Prof. Pomthong Malakul)

Thesis Committee:


.....
(Assoc. Prof. Chintana Saiwan)


.....
(Dr. Ruktai Prurapark)


.....
(Asst. Prof. Kitipat Siemanond)


.....
(Dr. Panithita Vithayasricharoen)

ABSTRACT

5673013063: Petroleum Technology Program
Lertsak Laosripaiboon: Reservoir Characteristics Interpretation by
Using Specific Energy with Down- Hole Torque and Drag
Thesis Advisors: Assoc. Prof. Chintana Saiwan, and Dr. Ruktai
Prurapark 68 pp.
Keywords: Down-hole specific energy/ Down-hole torque/ Down-hole drag

This research studied the effect of down-hole specific energy using down-hole torque and drag on potential zone evaluation by developing a computer program via Matlab. An analytical method model by Aadnoy *et al.* and Hareland *et al.* was used to calculate down-hole parameters, which are friction coefficient, down-hole torque and weight on bit, by the back calculation method. The down-hole drilling specific energy (DSE) was used as a specific energy calculation. The DSE was calculated every two meters. The high DSE indicates the hard formation or high inlet pressure. The inlet pressure means the pressure of water, oil or gas from the reservoir. Thus, the high DSE may indicate a potential zone. However, well logging data can only locate the reservoir zone but may not be the potential for commercial, because it could suggest the perforation zone but could be low inlet pressure. In this study, the well logging, lithology and production data from two onshore wells belonging to Pan Orient Energy Siam (POES) were cooperated with DSE to interpret the potential zone. The results of interpretation help select the most appropriate perforation zone and thus reduce the perforation cost.

บทคัดย่อ

นาย เลิศศักดิ์ เหล่าศรีไพบูลย์: การวิเคราะห์ความเป็นไปได้ของแหล่งกักเก็บปิโตรเลียมโดยการคำนวณจากแรงบิดและแรงเสียดทานภายในหลุมเจาะปิโตรเลียม (Reservoir Characteristics Interpretation by Using Specific Energy with Down-Hole Torque and Drag)
 อ. ที่ปรึกษา : รศ. ดร. จินตนา สายวรรณ และ ดร.รักไทย บุรพภาค 68 หน้า

งานวิจัยนี้ศึกษาผลของพลังงานจำเพาะจากการใช้แรงบิดและแรงเสียดทานภายในหลุมเจาะเพื่อประเมินหาโซนที่มีศักยภาพ โดยการพัฒนาโปรแกรมคอมพิวเตอร์แมทแล็บ ใช้โมเดลวิเคราะห์ของอาดันอยและคณะ และของฮาร์แลนด์และคณะเพื่อคำนวณด้วยวิธีคำนวณจากด้านหลังหาค่าตัวแปรภายในหลุมเจาะ คือค่าสัมประสิทธิ์แรงเสียดทานและแรงกดที่หัวเจาะ ค่าพลังงานจำเพาะจากการเจาะภายในหลุม (ดีเอสอี) ถูกใช้ในการคำนวณค่าพลังงานจำเพาะซึ่งคำนวณที่ทุกๆ 2 เมตร หากพลังงานจำเพาะมีค่าสูงบ่งบอกว่า ที่ความลึกนั้นหัวเจาะอยู่บริเวณชั้นหินแข็ง หรือมีความดันสูงจากแหล่งกักเก็บปิโตรเลียมเข้ามาในหลุมเจาะ ซึ่งเป็นความดันที่มาจากน้ำ น้ำมัน หรือจากแก๊สธรรมชาติ ดังนั้นค่าพลังงานจำเพาะสูงจึงอาจบ่งบอกถึงโซนที่มีศักยภาพ อย่างไรก็ตามข้อมูลจากหลุมเจาะเพียงอย่างเดียวสามารถกำหนดเพียงตำแหน่งของแหล่งกักเก็บปิโตรเลียมเท่านั้นแต่อาจไม่ใช่โซนที่มีศักยภาพในเชิงพาณิชย์ เพราะว่าโซนที่เจาะลงไปนั้นอาจเป็นโซนที่มีความดันต่ำ งานวิจัยนี้จึงผนวก ค่าพลังงานจำเพาะ, ข้อมูลหลุมเจาะ, ภาพธรณีของชั้นหิน และข้อมูลของผลผลิตบนฝั่งจำนวน 2 หลุมของบริษัทแนน ออเรียนท์ เอ็นเนอร์จี สยาม (พีโออีเอส) รวมกับค่าดีเอสอีเพื่อตีความหมายของโซนที่มีศักยภาพ ผลของการตีความหมายช่วยในการเลือกโซนที่จะทำการเจาะได้เหมาะสมที่สุด และช่วยลดต้นทุนของการขุดเจาะลงได้

ACKNOWLEDGEMENTS

The author, Mr. Lertsak Laosripaiboon is grateful for the full scholarship and full funding of thesis work provided by The Petroleum and Petrochemical College.

I would like to say thank to my PPC-advisor, Assoc. Prof. Chintana Saiwan at The Petroleum and Petrochemical College, Chulalongkorn University, for her help in my thesis work and good advices since I was a first year student until graduated.

Another important person in my thesis advisor is Dr. Ruktai Prurapark. I am appreciated in his help and giving me a special experience which is very difficult to find during the studying. Moreover, he is a good supervisor who always gives me an idea when I have problems in my work.

And also my examination committee, Assist Prof. Kitipat Siemanond and Dr. Panithita Vithayasricharoen.

The one, who always help and share the opinion to my work, Mr. Weerapong Panichaporn, my coworker.

I am thankful to all the people of PAN Orient Energy Siam (POES) for allowing me to have the first time of my work experience to access to the on-shored rig site and to provide the actual field drilling data and geological data for my research. Without their help, this research would have less meaning.

Finally, I would like to thank my family, my colleagues and my friends for their continuous support and inspiration throughout my entire study.

TABLE OF CONTENTS

	PAGE
Title Page	i
Abstract (in English)	iii
Abstract (in Thai)	iv
Acknowledgements	v
Table of Contents	vi
List of Tables	ix
List of Figures	x
Abbreviations	xii
List of Symbols	xiii
 CHAPTER	
I INTRODUCTION	1
 II LITERATURE REVIEW	 3
2.1 Specific Energy (SE)	3
2.2 Drilling Specific Energy (DSE)	4
2.3 Hydro Mechanical Specific Energy (HMSE)	4
2.4 Application of Specific Energy	5
2.5 Down-hole Parameters	6
2.6 On and Off Bottom Drilling	8
2.6.1 On Bottom Drilling	8
2.6.2 Off Bottom Drilling	8
2.7 Fundamental Concept of Torque and Drag	9
2.7.1 Normal Contact Force	9
2.7.2 Friction Coefficient	9
2.7.3 Torque	10
2.7.4 Drag	10
2.8 Torque and Drag Equation	11
2.8.1 Torque and Drag in 2-Dimensional Wellbore	11

CHAPTER	PAGE
2.8.2 Torque and Drag in 3-Dimensional Wellbore	12
2.8.3 DTOR and DWOB Relationship	18
2.9 Well Logging	18
2.9.1 Resistivity Logs (R-Logs)	19
2.9.2 Neutron Porosity	19
2.9.3 Gamma Ray	20
III EXPERIMENTAL	22
3.1 Materials and Equipment	22
3.1.1 Equipment	22
3.1.2 Software	22
3.2 Research Procedures	22
3.3 Software Methodology	23
3.3.1 Data Preparation by User	23
3.3.2 Data Preparation by Program	23
3.3.3 Down-hole Parameters Calculation	23
3.3.4 Drilling Specific Energy Calculation	23
3.4 Interpretation Methodology	23
IV RESULTS AND DISSCUSSION	25
4.1 The Results from Studying Torque and Drag Model	25
4.1.1 Well Trajectory	25
4.1.2 Fazelizadeh's Model	26
4.1.3 Purapak's Model	27
4.1.4 Hareland's Model	29
4.2 The Effect of Number of Intervals	30
4.3 The Data Screening	33
4.4 Results from Field Data	35
4.4.1 Well Trajectories	35

CHAPTER	PAGE
4.4.2 Down-hole Parameters	36
4.4.3 Drilling Specific Energy	41
4.4.4 Interpretation	43
V CONCLUSIONS AND RECOMMENDATIONS	51
5.1 Conclusions	51
5.2 Recommendations	51
REFERENCES	52
APPENDICES	54
Appendix A Well Trajectory Calculation Methods	54
Appendix B R and R_{turn} Calculation	55
Appendix C Well Trajectories Data of Wells A and B	56
CURRICULUM VITAE	68

LIST OF TABLES

TABLE		PAGE
4.1	Perforation stages of well A	44
4.2	Perforation stages of well B	48
C.1	Well A Trajectories	56
C.2	Well B Trajectories	63

LIST OF FIGURES

FIGURE	PAGE
2.1 SE in determining efficient drilling zone.	6
2.2 Flowchart of DWOB calculation.	7
2.3 Flowchart of DTOR calculation.	7
2.4 (a)Rotating on bottom, (b)Rotating off bottom.	8
2.5 Drag force and Torque acting on drill string.	9
2.6 Forces acting on drill string.	11
2.7 Forces applied to drill string in build-up section.	14
2.8 Forces applied to drill string in hold section.	15
2.9 Forces applied to drill string in drop section.	16
2.10 Principle of resistivity log.	20
2.11 Principle of neutron logging.	21
3.1 The back calculation flow chart	24
4.1 Well trajectory in vertical view.	25
4.2 Well trajectory in side view.	26
4.3 The results of Fazaelizadeh's model.	27
4.4 The results of Purapak's model.	29
4.5 The results of Hareland's model.	30
4.6 Real and simulated gaps.	31
4.7 Hook load versus measured depth for 4 intervals.	31
4.8 Hook load versus measured depth for 9 intervals.	32
4.9 Hook load versus measured depth for 14 intervals.	32
4.10 Field hook load from depth log.	34
4.11 Hook load after data screening.	34
4.12 Well trajectories of well A.	35
4.13 Well trajectories of well B.	36
4.14 DWOB for well A.	38
4.15 DWOB for well B.	38

FIGURE	PAGE
4.16 Friction coefficient for well A.	39
4.17 Friction coefficient for well B.	39
4.18 DTOR for well A.	40
4.19 DTOR for well B.	40
4.20 DSE for well A.	42
4.21 DSE for well B.	42
4.22 DSE interpretation for well A, 800-1,100 m.	46
4.23 DSE interpretation for well A, 800-1,100 m.	47
4.24 DSE interpretation for well A, 800-1,100 m.	47
4.25 DSE interpretation for well B, 650-850 m.	50

ABBREVIATIONS

2-D	Two-dimensional
3-D	Three-dimensional
BHA	Bottom-hole assembly
DSE	Drilling specific energy
DTOR	Down-hole torque
DWOB	Down-hole weight on bit
FF	Friction coefficient
GUI	Graphic user interphase
HL	Hook load
HMSE	Hydro mechanical specific energy
MSE	Mechanical specific energy
N	Normal contact force
SE	Specific energy

LIST OF SYMBOLS

A_{Bit}	Area of bit, in ²
A_t	Total flow area of nozzles, in ²
C_d	Drag coefficient
d	Diameter of borehole, inches
DSE	Drilling specific energy, psi
DTOR	Down-hole torque, ft.-lbs.
DWOB	Down-hole weight on bit, lbs.
DWOB	Down-hole weight on bit, lbs.
$E_{\text{hydraulic}}$	Mechanical specific energy of bit hydraulic, psi
ΔEast	Deviation of drill string in east direction, ft.
EFF_M	Mechanical efficiency for any bit type
F_n	Axial force at element n, lbs.
F_{n+1}	Axial force at element n+1, lbs.
F_{n+1}	Axial force at element n+1, lbs.
ΔMD	Difference of measure depth, ft.
HMSE	Hydro mechanical specific energy, psi
HP_B	Bit hydraulic power
HP_B	Bit hydraulic power
N	Normal contact force, lbs.
ΔNorth	Deviation of drill string in north direction, ft.
ΔP_B	Pressure drop across the bit, psi
Q	Flow rate, gal/min
r	Radius of drill string, ft.
R	The radius of curvature of the string element while the wellbore is in the build or the drop section on vertical view, ft.
R_{turn}	The radius of curvature of the string element while the wellbore is turning on horizontal view, ft.
ROP	Rate of penetration, ft./h
RPM	Down-hole rpm, Rotary RPM + GPM*, Rev/GPM of motor
Spp	Stand pipe pressure

T_n	Torque at element n, ft.-lbs.
T_{n+1}	Torque at element n+1, ft.-lbs.
V_h	Hoisting / lowering speed, ft./s
V_r	Tangential speed due to rotation, ft./s
Δ Vertical	Deviation of drill string in vertical direction, ft.
w	Weight in air, lbs./ft.
W_b	Buoyed weight of drill string at element per length, lbs./ft.
W_A	Work done by the weight on bit onto the formation
W_B	Work done by the torsional motion of the bit onto the formation
W_C	Work done by the jetting action of the fluid onto the formation
α	Inclination, degree
α_1	Inclination of string element 1, degree
α_2	Inclination of string element 2, degree
$\bar{\alpha}$	Average inclination of element, rad
η	Dummy factor for energy reduction
θ	Absolute change in direction
λ	Dimensionless bit-hydraulic factor depending on the bit diameter
μ	Friction coefficient
ρ_m	Mud density, lbs./ft. ³
ρ_s	Density of steel, lbs./ft. ³
Φ	Azimuth, degree
ϕ_1	Azimuth angle of string element 1, degree
ϕ_2	Azimuth angle of string element 2, degree
Ψ	Angle of the friction vector, degree