PRODUCTION ESTIMATION OF OIL RIM RESERVOIRS WITH INJECTED GAS BREAKTHROUGH

By

Ahmed Ali Hassan Abu Elhassan

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
GAS PRODUCTION ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under Supervision of

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Production Estimation of Oil Rim Reservoirs with Injected Gas Breakthrough

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Oil Rim- Gas Cap- Gas Injection- Production Data

Summary:

Gas reservoirs with oil rim are good oil producers when the oil leg is sufficiently large. Concurrent oil and gas production is usually a development technique for such fields. Sometimes, produced gas is partially reinjected in order to maintain reservoir pressure for higher oil recovery and sweep gas rich with condensate. In a single well, oil, condensate, mixed gas and dry injected gas are produced. In this case, the oil and condensate production cannot be easily differentiated from each other.

This work presents a mathematical approach to estimate the true free oil rim production and differentiates it from the associated condensate production while using only production data and PVT data as input. This approach is applied on three synthetic models and an actual field case in Arab peninsula; and yielded a good match with the results of reservoir simulation.

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Nomenclature

B_{gi}	formation volume factor at initial pressure, bbl/scf
B_{gnj}	gas formation volume factor at injected gas , bbl/scf
B_{oi}, B_o	oil formation volume factor at initial and current, bbl/stb
k_o	effective oil permeability, md
m	dimensionless gas cap volume
μ_o	oil viscosity, cp
N	initial oil in place, stb
N_p	cumulative oil production, stb
ρ_o, ρ_g	density of oil and gas , lb/ft3
q_g	gas production of the well
q_{gc}	gas cap production, scf
q_{giBT}	breakthrough of the injected dry gas, scf
q_o	oil production of the well
q_{of}	free oil production, stb
q_{og}	condensate production
R_p	cumulative gas oil ratio, scf
R_{si}, R_s	gas solubility at initial and current pressure, scf/stb
R_v	condensate yield of gas cap, stb/scf
R_{vd}	condensate yield of the injected gas , stb/scf
re, rw	drainage and wellbore radius, ft
S_g	gas saturation
S_{gc}	critical gas saturation
S_o	oil saturation
S_{or}	residual oil saturation
S_w	water saturation
S_{wi}	initial water saturation

Abbreviations

bbl	barrel
Cum	cumulative
CGR	condensate gas ratio
EOR	enhanced oil recovery
EUR	estimated ultimate Recovery
GAGI	gas assisted gravity injection
GOC	gas oil contact
GOR	gas oil ratio
ICD	Inflow Control Device
MB	material balance
GIIP	original gas in place
OOIP	original oil in place
PVT	pressure , volume , temperature
RF	recovery factor
RFT	repeat formation tester
scf	standard cubic feet
SI	shut-in
THP	tubing head pressure
VLP	vertical Lift Performance
WAG	water alternating gas
WOC	water oil contact

Abstract

Gas reservoirs with oil rim are good oil producers when the oil leg is sufficiently large. Concurrent oil and gas production is usually a development technique for such fields. Sometimes, produced gas is partially reinjected in order to maintain reservoir pressure for higher oil recovery and sweeping gas rich with condensate. In a single well, oil, condensate, mixed gas and dry injected gas are produced. In this case, the oil and condensate production cannot be easily differentiated from each other.

This work presents a mathematical approach to estimate the true free oil rim production and differentiates it from the associated condensate production while using only production data and PVT data as input. This approach is applied on three synthetic models and an actual field case in Arab peninsula; and yielded a good match with the results of reservoir simulation.

Chapter 1 : Introduction

Oil rim reservoirs are gas reservoirs with the ratio of Gas in place to oil in place ratio is greater than one.($m > 1$)

The recovery factor of the oil rim reservoirs may be very low for thin oil rims due to gas and/or water breakthrough. On the other hand, it can be as high as 45% for thick oil rims (>100 ft) in homogenous permeable reservoirs. For such high recovery reservoirs, the combination drive mechanism of gas and water would give very good pressure maintenance.

Gas cycling is a very good strategy to maintain reservoir pressure and maximize oil and condensate recovery. However, periodic gas shut-offs are required as well as a sizable gas plant to extract oil from gas and compress this gas back to the reservoir.

For such reservoirs, the produced condensate associated with gas production stream is mixed with the produced oil in the production separators. The present work discusses a simplified approach to differentiate between liquid oil production and gas condensate production using minimal data. The minimal required data is solely production data and PVT data. This technique would be a quick alternative for the simulation modelling that requires extensive data and work to deliver the same results.

Chapter 2 presents the literature review while Chapter 3 defines the problem. The derivation of the equations is in Chapter 4 and the applications are in Chapter 5 and Chapter 6 .

Chapter 2 : Literature Review

2.1 Gas Cap Reservoirs Production Performance

These are oil reservoirs where oil is overlain by a segregated gas. The gas is referred to as a primary gas cap. If the gas cap is bigger than the oil zone, this type of reservoirs is referred to as (Gas reservoirs with Oil Rim) and the oil zone is called (Oil leg). But, they still are the same type.

The Gas cap would be originally found during exploration or later is formed with production and pressure depletion. That is, for a saturated oil reservoir, as the reservoir pressure declines below the bubble point, gas begins to bubble out and forms the gas phase (Figure 2-1). The gas would start to migrate upward due to gravity difference and form a (Secondary Gas Cap). For the gas cap itself, it contains vaporized oil within it and as the reservoir pressure depletes the oil in vapor condenses into liquid. However, due to lower mobility of the oil, it is often kept stranded within the gas cap and may not be produced at all [1]

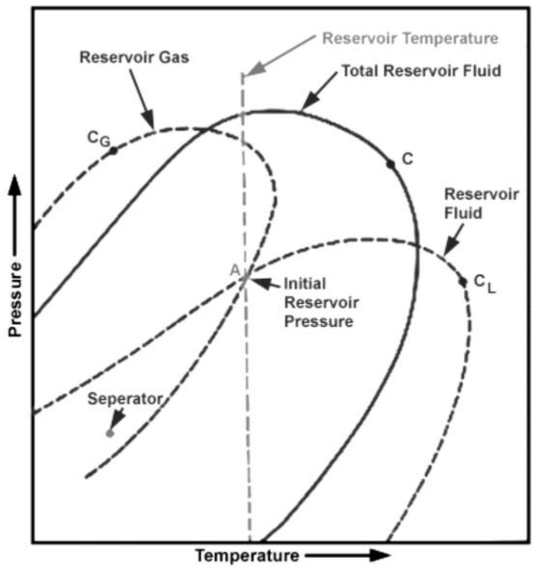

Figure 2-1 Phase behavior of hydrocarbon phases in a Gas Cap reservoir [2]

As production continues to decline and for a reservoir with good vertical permeability, the Gas cap begins to grow, and the gas oil contact starts to move downward as shown in Figure 2-2. That is due to two mechanisms:

1. Expansion of the original gas cap gas due to reducing pressure
2. Upward migration of gas dissolved in oil when it is liberated

The first mechanism is called passive segregation or segregation drive [4] without counterflow [1] .The latter mechanism is called active segregation [4] or segregation drive without counterflow [1].