INCREASING MATURE OIL FIELDS PRODUCTION BY GAS LIFT OPTIMIZATION

By

Mohamed Mokhtar Mansour

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

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Title of Thesis:

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Key Words:
Integrated Asset Modeling; Production Optimization; Intermittent Gas Lift Evaluation; Optimum Gas Lift Injection Depth; Flow Assurance.

Summary

Field wide optimization became mandatory in producing mature oil fields. Integrated asset model was created to optimize injection gas in mature oil field and saved 19 MMSCFPD with 330 bbls/day oil gain. Gas lift injection depth was deepened for some wells resulting in increasing oil production by 1700 bbls/day and saving 14 MMSCFPD. Intermittent gas lift was applied on low potential wells and saved 55% of injection gas requirements. The field was optimized for the best operating conditions to improve production.

Acknowledgments

I would like to express my sincere gratitude and appreciation to Professor Ismail Mahgoub and Professor Eissa Mohamed Shokir for their valuable guidance and continuous support throughout this thesis work.

I would like to thank all those who helped me with any respect to complete this thesis work, special gratitude to Gulf of Suez Petroleum Company and Cairo University for helping me to write this thesis.

I am hearty thankful to all my professors at Cairo university and petroleum and mining engineering at Suez, who spent their time and health to help me to be an engineer without any compensation.

I would like to express my thanks to all my friends in District Engineering, Base management, and Production departments for their kind cooperation and support with data and experience throughout this thesis work.

I deeply thank my lovely wife and children, Adam and Aser, for their love and support in relinquishing our time together to complete this work. I am also so grateful for the prayers and support of my parents.

Dedication

In the name of Allah, I would like to dedicate this thesis to my parents who paid their time, money and support without any compensation to provide me with an outstanding education from the primary to post graduate studies. Their help and support encouraged me to improve myself and be a good engineer. This support always motivates me in all my works.

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Nomenclature

A	Cross section area of the pipe, m2
AOF	Absolute open flow, MMSCFPD
A_p	Valve port Area, in^2
A_b	Bellows Area, in^2
BOPD	Oil Rate, bbls/day
BFPD	Liquid Rate, bbls/day
B_g	Gas formation volume factor, bbl/scf
B_w	Water formation volume factor, bbl/stb
D/S	Downstream Pressure, psi
FPHP	Flowing Bottom Hole Pressure, psi
GOR	Gas Oil Ratio, scf/stb
GLVC	Gas Lift Valve Change
H	Height of perforated interval, ft
PI / J	Productivity Index, bbls/day/psi
P_i	Initial reservoir pressure, psi
P_t	Tubing Pressure, psi
P_R	Reservoir pressure, psi
P_{wf}	Bottom hole flowing pressure, psi
P_c	Closing Pressure, psi
P_b	Valve bellows pressure, psi
SCF	Standard cubic feet
SSSV	Subsurface Safety Valve
U	Heat Transfer Co-efficient, BTU/hr/ft
U/S	Upstream Pressure, psi
W.C	Water Cut, Percentage
Z	Gas compressibility factor
ρ_g	Gas density, bound per gallon
ρ_m	Gas / liquid mixture density, lbs/ft3 (or kg/m3)
ρ_w	Water density, bound per gallon
ΔP	Draw down pressure, Psi
STBOPD	Stock tack barrel oil per day

Abbreviations

a	Laminar flow coefficient.
CO2	Carbon dioxide
GAP	General Allocation Program
H_2S	Hydrogen Sulphide
IPR	Inflow Performance Relationship
IPO	Injection Pressure Operated
PPO	Production Pressure Operated
IAM	Integrated asset model
I.D	Inside Diameter
MMSCF	Millions Standard cubic feet
PVT	Pressure, Volume, and temperature
VLP	Vertical lift performance
N_2	Nitrogen

Abbreviations (cont.)

P/F	Platform
LPG	Low-pressure gas
IGL	Intermittent Gas Lift
PLT	Production logging tool
HPG	High Pressure Gas
TGLR	Total Gas Liquid Ratio

Abstract

Gas lift is an artificial lift method in which gas is injected with high pressure into the tubing string through gas lift valve to reduce the formation fluid density and assist its production to surface.

In mature oil fields, water cut continuously increases and accordingly produced gas volume decreases to a limit not sufficient to compensate daily gas losses. This limited lift gas volume has to be optimally distributed on the wells to ensure maximum production capacity. Performance of mature field wells changes with production due to change in water cut or reservoir pressure; which results in changing gas lift injection depth and affects total field performance.

Low rate producing wells need high amount of injection gas to be produced continuously; and with limited injection gas volume, they are usually shut in. Finding a cost effective solution to produce these low potential wells is essential.

The work aimed to: (1) identify a road map for gas lift optimization methodology (2) evaluate the effect of changing reservoir pressure and W.C on gas lift injection depth on total field performance (3) evaluate applying intermittent gas lift (IGL) on low rate wells (4) evaluate the pipeline network for any possible bottlenecking or flow assurance problems (5) determine the VLP and PVT correlations that best match mature field performance.

An integrated asset model was developed for the gas lift wells and surface network using PROSPER and GAP software. The developed model was matched with actual well test data and resulted a good match. Analytical approach was used to apply IGL on low potential wells, evaluate their performance, and the requirement to change the entire gas lift system. Simple average method was developed to calculate the average temperature below liquid slug. The results of this method were compared to the enthalpy balance method calculations and yielded a good match.

Applying gas lift optimization and IGL approaches on a mature field (M) resulted in saving 19 MMSCFPD and an oil gain of 330 bbls/day. On the other hand, some wells on (M) field are candidates for deepening the point of gas injection with an oil gain of 1700 BOPD and saving 14 MMSCFPD .

Applying intermittent gas lift on seven low rate wells in (M) field resulted in saving 8.0 MMSCFPD (55% of current injection gas rate). Calculating injection gas rate using simple average temperature showed a deviation of 2% from calculations using enthalpy balance method. In addition, the pipeline network was evaluated for any possible flow assurance problems in order to ensure safe operating conditions. Finally, the best PVT and VLP correlations that match (M) field performance are evaluated..

Chapter 1 : Introduction

1.1. Background

Gas lift is an artificial lift method in which gas is injected with high pressure into the tubing string through gas lift valve to reduce the formation fluid density and assist its production to surface. On the surface, low-pressure gas, formation gas, and injected gas lift are separated from liquid and used as a suction for gas compressors. Gas lift network is a closed system with daily gas losses due to fuel of gas compressors and surface facility in addition to flared gas.

During the life of gas lift well, water cut increases and produced gas volume decreases to a limit not sufficient to compensate daily gas losses in the network. In this situation, the limited injection gas volume has to be optimally distributed to ensure maximum production capacity.

In mature field, reservoir pressure, production rate, and water cut of wells changes and so the vertical lift performance, which results in changing gas lift injection depth. Unfortunately, some gas lift wells are equipped with orifice valves above the deepest gas lift mandrel, which limit further deepening to the point of injection and results in losing oil production.

Low potential wells, due to either low reservoir pressure or low productivity index, need high amount of injection gas to produce continuously. Usually these wells are circulating lift gas or producing with high injection gas rate compared with its oil production. With limited injection gas volume, these wells become not economical to produce and usually shut in. Finding a cost effective solution to produce these low rate wells is essential.

The surface facility of offshore oil field consists of many wellhead platforms connected to the main platform through oil and HPG pipelines. Oil is produced from wells on the wellhead platforms through oil pipeline to production separator on the main complex where LPG is separated and directed to a multi-stage gas compressor. Compressed gas is re-injected back to the wells through HPG network. Oil production through pipelines has to be optimized to prevent bottlenecking and flow assurance problems.

The gas lift well should be tested at different injection gas rates to create its gas lift performance curve, which can be used for gas lift optimization. In Mature fields, the surface network facility is usually not flexible for testing obligations, as only one testing line is available and test separator is usually out of service. So that optimizing well performance by testing it at different injection gas rates is very difficult.

In literature, different methods are used to optimize injection gas on a group of wells. One of the industry standard optimization software that is used to simulate well performance is PROSPER. Each well in the field is simulated separately using PROPSER and matched with actual PVT samples and well test data. Then wells are integrated with the surface network and production facility using GAP software to build an integrated asset model.

In this thesis, integrated asset model is used to optimize injection gas on each well in the network. Then the wells are evaluated for possibility of deepening the gas lift