SURFACE NETWORK MODELING FOR MULTIPHASE FLOW

By

Doaa Abdelwahab Shaker Abdelwahab

A Thesis Submitted to the
Department of Mining, Petroleum, and Metallurgical Engineering,
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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Under the Supervision of

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Professor of Petroleum Engineering Faculty of Engineering, Cairo University	Professor of Petroleum Engineering Faculty of Engineering, Cairo University

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Title of Thesis:

Surface Network Modeling for Multiphase Flow.

Key Words:
Surface Production Network; Gathering System; Production or Pressures Constraints; Network Optimization; Multiphase Flow.

Summary:

The main objective of this work is to develop a surface network program that is capable of modeling the network components from the reservoir to the gathering stations. It has the ability to optimize the production for different applications and optimize several variables at the same time for multiple components. The developed program is verified using many comparison cases with well-known commercial network simulator. The program was then used to simulate and optimize an actual field case.

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Dedication

To my parents and my beloved sisters.
This humble work is a sign of my love to you.

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Nomenclature

A_1	Cross section area of tubing, ft^2
A_2	Cross section area of choke, ft^2
bhp	Brake horsepower, HP
C_D	Choke discharge coefficient, 0.62–0.90
C	Clearance, which varies from 0.04 to 0.16
C_p	Specific heat at constant pressure, Btu/ lb/ ˚F
C_v	Specific heat at constant volume, Btu/ lb/˚F
C_L	Liquid specific heat constant
DP	Differential pressure, psi
D_c	Choke diameter (64th in.)
d_T	Tubing inner diameter, ft.
d_p	Piston diameter, ft.
d_{pr}	Piston rod diameter, ft.
e	Choke downstream to upstream pressure ratio
e_m	Mechanical efficiency, usually is taken about 0.85
e_v	Volumetric efficiency, is usually taken to be 0.88–0.98
E	Pump efficiency, less than 1
E_k	Kinetic energy
E_p	Polytropic efficiency
f	Friction factor
f_n	Normalization friction factor
F_{wo}	Water to oil ratio
F	Correction factor for pressure drop between stages
g	Acceleration gravity, 32.2 ft/s^2
G_2	Mass flux at downstream, lbm/ ft^2/s
GOR	Gas to oil ratio (scf/ STB)
j	Productivity index, STB/D/psi
h	Thickness, ft
H	Pump head or length, ft
HP	Horsepower, hp
H_{PMM}	Required theoretical compression power, hp/MMcfd
H_p	Polytropic head, ft-lb/lb
H_{pg}	Gas horse power, hp
ΔHpm	Mechanical power losses, usually used as 50 hp
H_L	Liquid holdup
M	Mass influx, lbm/s
MD	Measured depth, ft
m	Mass flow rate, lb
N	pumping speed in strokes per minute
N_s	Number of stages
N_{Re}	Renold number
N_{Fr}	Froud number
n	Polytropic gas exponent
k	Specific heat ratio, Cp/Cv
kr	Relative permeability, md
k_o	Effective permeability of the oil, md

l	Stroke length, in.
L1, L2, L3, L4	Transition boundaries
p_{wf}	Bottomhole pressure, psi
p	Pressure, psi
p_r	Current average reservoir pressure, psig
P_{up}	Upstream pressure at choke, psi
P_{down}	Downstream pressure, psi
Δp	Pressure drop, psi
Q_o	Oil rate at p_{wf}, STB/D
$(Qo)_{max}$	Maximum oil flow rate at zero wellbore pressure, STB/D
Q_g	Gas flow rate, Mscf/d
q_r	Real outlet flow rate, bbl/day
q_{th}	Theoretical outlet flow rate, bbl/day
R_s	Solution gas oil ratio, scf/STB
R	No-slip gas/liquid volume fraction
R_{const}	Gas constant given by 1,544/ M_{wa} in psia-ft^3/ lbm-R.
r	Compression ratio
r_w	Wellbore radius, ft
r_e	Drainage radius, ft
s	Skin factor
S	Compressor speed, rpm.
TVD	True vertical depth, ft
T_{wf}	Bottomhole temperature,˚F
T	Temperature,˚F
ΔT	Temperature rise, ˚F
V	Specific volume at upstream, ft^3/ lbm
V_s	Superficial velocity, ft/sec
V_m	Mixture velocity, ft/sec
WC	Water cut
w	Power required, HP/ MMscf/D
x	Mass fraction
y_c	Critical pressure ratio
y_a	Actual pressure ratio
z	Compressibility factor, psi^{-1}
Greeks	
ρ	Density lb/cuft
β	Formation volume factor, scf/STB
μ	Viscosity, cp
η_p	Polytropic efficiency
σ	Surface tension at upstream conditions, dynes/cm
θ	Deviated angle
ψ	Liquid holdup correction factor
ρ_m	Mixture density, lbm/cu ft
ρ_n	Non slip density, lbm/cu ft
ρ_s	Slip density, lbm/cu ft
γ	Specific gravity
λ_L	Liquid content

Subscripts

G	Gas
o	Oil
W	Water
L	Liquid

Abbreviations

FL	Flowline
IPR	Inflow performance relationship
M	Manifold
MM	Main manifold
Sep	Separator
Comp	Compressor
WHP	Wellhead pressure
WHT	Wellhead temperature
FWHT	Flowing wellhead temperature
VLP	Vertical lift performance

Superscripts

sc	Standard conditions
tp	Two-phase
1	Upstream
2	Downstream