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Production Optimization and Frictional Loss Energy Analysis for a Multiphase Heavy Oil Subsea Well

Antonia Şugar, Doru Stoianovici

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti 39, 100680, Ploieşti
e-mail: sugarantonia93@gmail.com; doru.stoianovici@yahoo.com

Abstract

The article outlines the process of production optimization for an offshore oil well, using the method known as Nodal Analysis to analyse the well. This method allows the determination of the production capacity for any combination of components and the locations of excessive flow resistance or pressure drop in any part of the system.

Special attention needs to be given to the influence of water cut as and the type and thickness of the flowline isolation on the pressure drops in the whole system, but also on the rate of flow. The inflow and outflow curves will be also plotted in relation to phasing skin, perforation density, tubing size and flowline size.

The effect of a change in any of the parameters above mentioned will be analysed by recalculating the solution point using the new characteristics of the parameter that has been modified.

Key words: *Production optimization, skin, phasing skin, producing well system, flowline size, flowline isolation*

Production Optimization

NODAL analysis is used to optimize the completion design to suit the reservoir deliverability, identify restrictions or limits present in the production system and identify any means of improving production efficiency. Fluid flows from the reservoir to the stock tank because of the pressure gradients within the system.

“Nodal” analysis refers to the fact that we have to choose a point or “node” in the system at which we evaluate the pressure - in this case, the wellhead. The total pressure drop from the reservoir to the separator is the sum of the individual pressure drops through four different segments: in the reservoir, across the completion, up the wellbore, and through the flowline .

It has 2 main components: Inflow Performance Curve, also called IPR, and Outflow Curve.

The IPR depends on fluid properties, inflow correlations used, formation properties such as skin, permeability, while the outflow curves depends on fluid properties, outflow correlations used, friction and completion: tubing size, tubing restriction, tubing roughness.

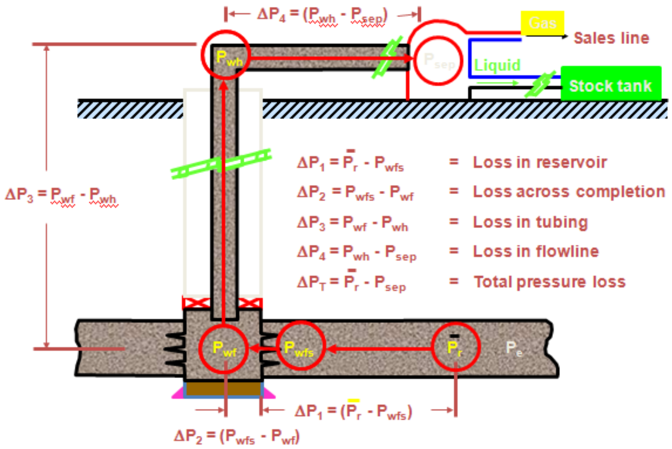

Fig. 1. Pressure losses in complete well system

Input Data

Environment Conditions

Medium waves height	90 m
Average water depth	12 m

Water depth	Temperature
0 – 60 m	7 °C
60 – 80 m	5 – 7 °C
80 – 450 m	9 °C

Fluid Properties

Oil Gravity	0.930 g/cc
Sg Gas	0.650
GLR	300 ml(g) / ml(l)
Water cut	10%
Salinity	92710 mg/l

Completion Data

Permeability Ratio	0.8
Damaged Zone Permeability	2 mD
Damaged Zone Radius	1200 mm
Casing	7 in

Reservoir Data

Reservoir Pressure	450 bar	Reservoir Temperature	72 °C
Reservoir Radius	2450 m	Wellbore Radius	88.9 mm
Reservoir Skin	5	Reservoir Thickness	21.5 m
Vertical Permeability	4 mD	Horizontal Permeability	36 mD
Horizontal Tunnel Length	250 m		

Sensitivity Study

The production rate can be severely restricted even by the performance of a single component in the system. If the effect of each component on the total system performance is isolated, the whole system can be optimized in the most economical way. This sensitivity study allows to determine the production capacity for any combination of components in order to optimize the production. In the following slides I focused on the effect introduced by phasing skin, perforation density, tubing size, flowline size, flowline isolation thickness, separator pressure and water cut.

The phasing skin depends on the perforated wellbore geometry, the phase angle, which is the angle between 2 perforations. Considering different phase angles , the adequate phasing skin can be calculated, 60° - 9.5 skin, 45°-11.15 skin and for 120° - 13.9 skin.

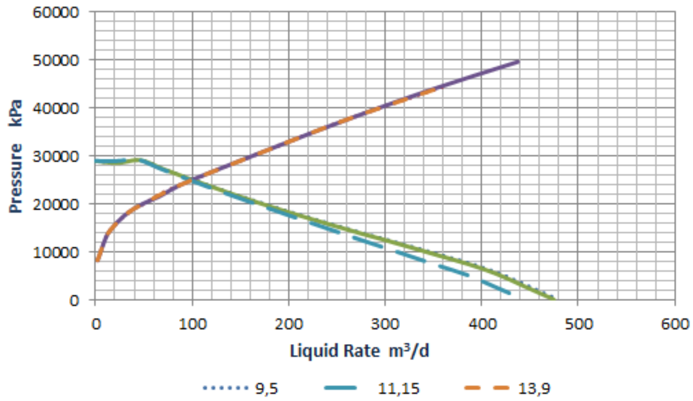

Fig. 2. Wellhead pressure vs liquid rate for different phasing skins

For the 3 perforation density values: 8 spm, 12 spm and 16 spm the effect is also very small.

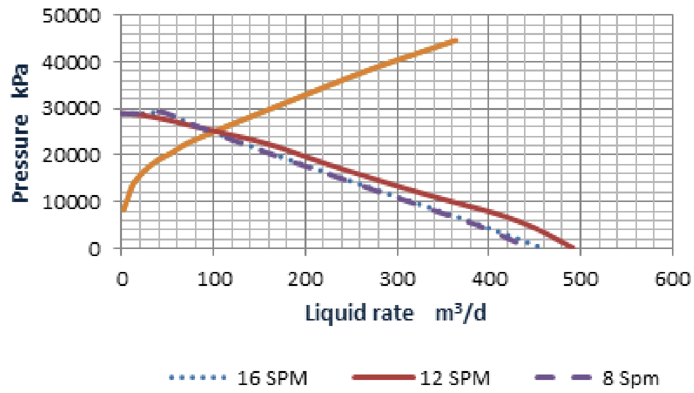

Fig. 3. Wellhead pressure vs liquid rate for different perforation density

Considering 2 tubing diameters: $2^{7/8}$ in and $3^{1/2}$ in, even if observing that the influence induced is small, the well will be equipped with a $3^{1/2}$ in tubing.

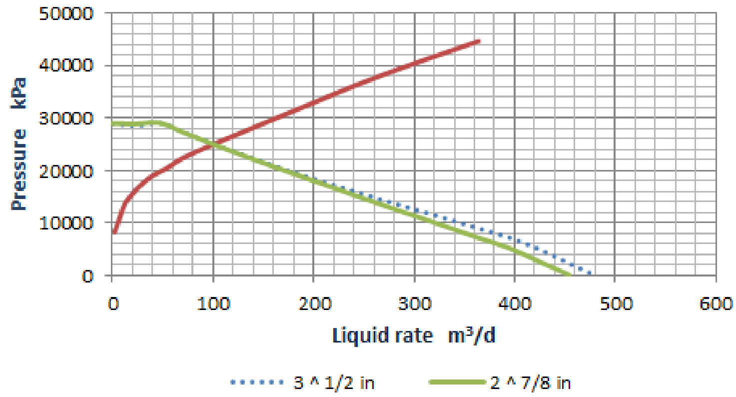

Fig. 5. Wellhead pressure vs liquid rate for different tubing diameters

From the plot we can observe what a big influence the flowline diameter has, so the connection with the production platform will be made by a 6 in flowline.

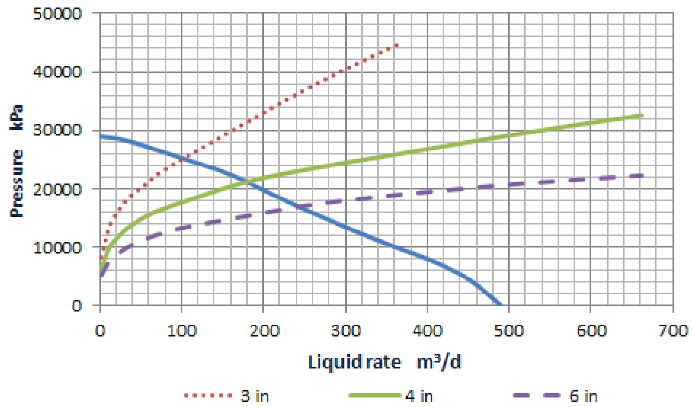

Fig. 6. Wellhead pressure vs liquid rate for different flowline diameters

Taking into consideration that the flowline is submerged, the isolation has a essential role in the optimization process. Due to economical reasons, a 15 mm thick isolation is chose.

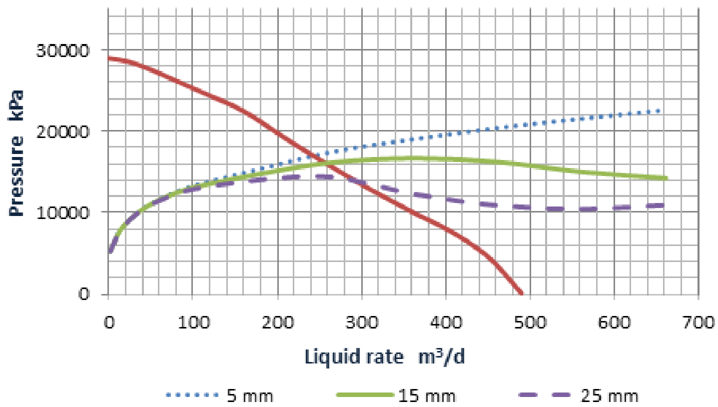

Fig. 7. Wellhead pressure vs liquid rate for different flowline isolation thicknesses

The separator pressure has a very small influence on the operating point, and because of production platform's technological reasons, the pressure at the separator will be 16 bar.

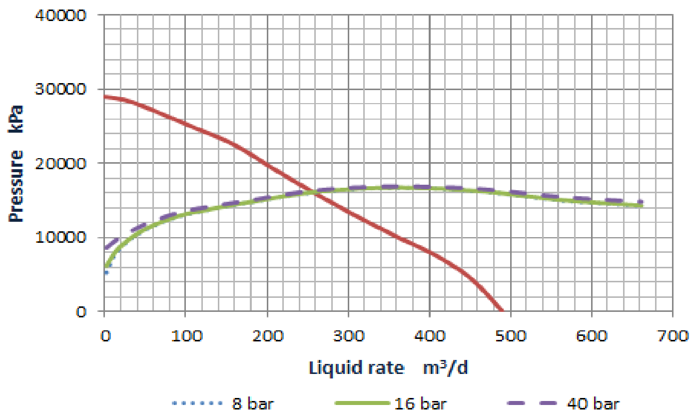

Fig. 8. Wellhead pressure vs liquid rate for different separator pressures

Considering the effects and the values for all the parameters selected: a pashing skin of 9.5, perforation density of 16 spm, tubing diameter of 3 $^{1/2}$ in, flowline size of 6 in, flowline isolation thickness of 15 mm and a pressure at the separator of 16 bar, the 2 coordinates of the operating point are: a liquid rate of 257 m^3/d and a wellhead pressure of 160,7 bar.

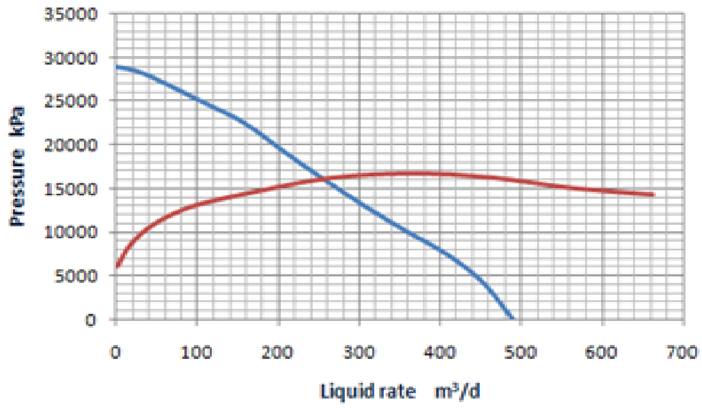

Fig. 9. Solution point for optimized model

The influence of each parameter analysed is better highlighted by the values of the operating point's coordinates according to each choice.

		Liquid rate m^3/d	Wellhead Pressure kPa
Phasing Skin	9.5	100,2	25024
Perforation Density	16 spm	100,5	24961
Tubing Size	3 ½ in	102,3	24925
Flowline Size	6 in	244,0	16912
Flowline Isolation	15 mm	257,9	16044
Separator Pressure	16 bar	258,4	16040

Conclusions

1. Horizontal wells can provide a bigger contact area with the pay layer as well as reduce the risk of high water cut and conning problems.
2. The influence of skin factor is strongly related to the length of the drain: a growth of the length induces a decreased influence.
3. Different values of phasing skin, perforation density and tubing size lead to a very small variation of liquid rate.
4. Analysing different flowline sizes highlights a significant growth of flow rate as the diameter of the flowline is increased.
5. Taking into consideration that the flowline is submerged, the thickness of the isolation has a strong influence on flow rate, for less than 100 m^3/d.

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Optimizarea producției și analiza căderilor de presiune pentru curgerea multifazică în cazul unei sonde marine ce produce țiței greu

Rezumat

Articolul descrie procesul de optimizarea producției unei sonde marine de țiței, folosind pentru analiză metoda cunoscută drept, Analiza Nodală. Această metodă permite determinarea capacității productive pentru orice combinție a elementelor dar și localizarea rezistențelor la curgere excesive sau căderile de presiune,în toate punctele sistemului.

O atenție specială trebuie acordată influenței impurităților, tipului și grosimii izolației conductei de amestec asupra căderilor de presiune din intreg sistemul, precum și asupra debitului. Curbele de comportare ale stratului și cele ale echipamentului vor fi trasate și în concordanță cu factorul skin datorat perforaturilor sondei, densitatea perforaturilor, diametrul tubingului și diametrul conductei de amestec.

Efectul provocat de variația oricărui parametru menționat mai sus, va fi analizată prin recalcularea punctului de funcționare, utilizând noile valori ale acestuia.