A BOUNDARY ELEMENT METHOD FORMULATION TO MODELING THE GAS CONING PHENOMENON IN OIL WELLS

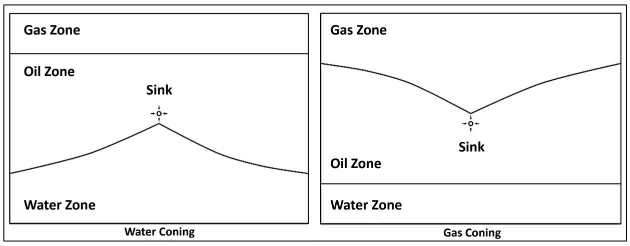
Pedro Lucas Sanches Fonseca Silva (Eng. de Petróleo - UniCEUMA);
Jennifer Slayder Santos Sousa (Eng. De Petróleo – UniCEUMA);
Prof. Dr. Luís Jorge Mesquita de Jesus (Orientador, Departamento de Eng. de Petróleo – UniCEUMA);
plfonseka@gmail.com; slayder.je@gmail.com; luisjorged25@hotmail.com

CEUMA UNIVERSIDADE

Introduction

For years the water/gas coning phenomenon in oil reservoirs has been a big challenge for the upstream industry. It happens because the conification causes serious limitations on the well productivity, increasing the production costs.

Figure 1 - Water and Gas coning formation.



From: Author

Methodology

This research considers the model of a potential two-phases flow in steady state, operating in a homogeneous porous medium with isotropic permeability and incompressible fluid.

Starting by the Darcy's Law, equation that governs fluid flow in porous media, we have the average velocity given by:

$$q = K\nabla\Phi \quad (1)$$

Where q is the apparent velocity, K is the hydraulic conductivity of the porous medium and Φ is the velocity potential given by the piezometric height.

By the principle of mass conservation applied in eq. (1) and, in our case, the addition of a punctual sink, we have a Poisson's equation formulated by:

$$\nabla^2\Phi = \frac{Q}{K}\delta(x - x_0) \quad (2)$$

Where Q is the volumetric flow rate, δ is the Dirac Delta and x_0 is the sink position.

FUNDAMENTAL SOLUTIONS

The fundamental solution of the potential given by:

$$\Phi^* = -\frac{1}{2\pi K}\ln(r) \quad (3)$$

Where r is the distance of the source point to the field point.

As a fundamental solution of the velocity we have:

$$q^* = \frac{1}{2\pi r^2}[(x - x_0)n_x + (y - y_0)n_y] \quad (4)$$

Where (x_0, y_0) are the coordinates of the source point.

INTEGRAL BOUNDARY EQUATION

$$c \cdot \Phi(x_d, y_d) = \sum_{j=1}^{n}\left(\int_{\Gamma j}\Phi\, q^* d\Gamma_j\right) - \sum_{j=1}^{n}\left(\int_{\Gamma j} q\, \Phi^* d\Gamma_j\right) \quad (5)$$

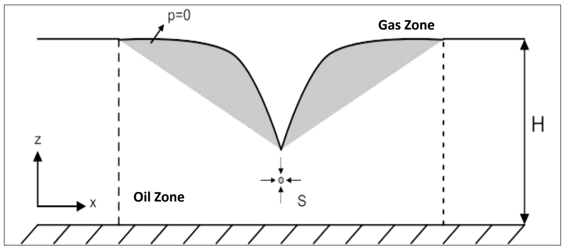
Where c is:

$$c = \begin{cases} 0 \\ \frac{\theta_{int}}{2\pi} \\ 1 \end{cases}$$

- When the source point is out of the domain
- When the source point is on the boundary
- When the source point is inside the domain

BOUNDARY CONDITIONS

Figure 2 – Scheme of the conditions adopted



From: Author

Table 1 – Boundary Conditions

Boundary Conditions	Base	Lateral Boundaries	Free Surface
Potential		Φ=H	Φ=z(x)
Velocity	q * (- k̂)= 0		

From: Author

Results and Discussion

Table 2 – Comparison of the results obtained

Simulator	Critical Flow (m^3/s)	Error (%)	Center node height (m)	Error (%)
Analytical Result (Gontijo, 2015)	0,00254	-	0,04243	-
Single-phase potential flow (Gontijo, 2015)	0,00259	1,97	0,04228	0,45
Single-phase potential flow (Gauss Quadrature)	0,00263	3,54	0,04298	1,29
Single-phase potential flow (Telles Transform)	0,00260	2,36	0,04220	0,54

From: Author

Conclusion

This research presented a Boundary Element Method (BEM) formulation for modeling the gas coning phenomenon in oil reservoirs. The Laplace's Equation was used as the fundamental solution in the terms of potential and velocity. The developed simulator achieved good and accurate results. The numerical solution of the H and G matrices by the Telles Transform method has proven effective for situations involving fluid flow. These results present the method as a good formulation of the BEM, showing good performance and accuracy in that kind of problem.

Acknowledgements

The authors would like to thank the Laboratory of Modeling and Simulation of Energy Systems and the CEUMA University for all the granted support.

References

C. A. BREBBIA. & J. DOMINGUEZ. 1992. ***Boundary elements - an introductory course***. 2. ed. WIT Press. ISBN 1-85312-160-6.

GONTIJO, G. S. V. 2013. ***Estudo do fenômeno do cone de água em poços de petróleo usando o método dos elementos de contorno***. Tese de graduação, UnB – Universidade de Brasília.

GONTIJO, G. S. V., Fortaleza, E. L. F. & Albuquerque, E. L. 2014. ***Study on the water coning phenomenon in oil wells using the boundary element method***. In: International Conference on Boundary Element and Meshless Techniques XV, 2014, Florença. Advances in Boundary Element & Meshless Techniques XV. Eastleigh: EC Ltd, 2014. p. 201-206.

TELLES, J. C. F. *A.* 1987. ***Self-adaptive co-ordinate transformation for efficient numerical evaluation of general boundary element integrals***. International Journal for Numerical Methods in Engineering. 24:959–973.

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
PROPESQI PRÓ-REITORIA DE PESQUISA E INOVAÇÃO
UNIVERSIDADE FEDERAL DO PIAUÍ