Pontifícia Universidade Católica do Rio de Janeiro

Phillip Afonso de Melo Grainger

Numerical Analysis Of The Mechanical Behavior Of Cement Sheaths In Wells Through Salt Formations

DISSERTAÇÃO DE MESTRADO

DEPARTAMENTO DE ENGENHARIA CIVIL
Programa de Pós-Graduação em Engenharia Civil

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Advisor: Prof. Eurípedes do Amaral Vargas Jr.
Co-advisor: Profª. Raquel Quadros Velloso

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Bibliographic Data

Grainger, Phillip Afonso de Melo

Numerical analysis of the mechanical behavior of cement sheaths in wells through salt formations / Phillip Afonso de Melo Grainger; Advisor: Eurípedes do Amaral Vargas Junior; coadvisor: Raquel Quadros Vellos. – 2012.

134 f. il. (color) ; 30 cm

Dissertação (mestrado) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engeharia Civil, 2012.

Inclui bibliografia

1. Engenharia civil – Teses. 2. Cimento. 3. Fluência de sal. 4. Pré-sal. 5. Carregamento não uniforme. 6. Abaqus. I. Vargas Junior, Eurípedes do Amaral. II. Velloso, Raquel Quadros. III. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Engenharia Civil. IV. Título.

CDD: 624

Acknowledgements

My Lord Jesus Christ, who has opened many doors for me; his intervention testifies of his existence. Thank you for loving me unconditionally and for changing me from the inside out;

My advisor, Dr. Eurípedes do Amaral Vargas Jr., for your guidance, patience and for believing that I had the capacity for this sophisticated research. The knowledge you passed down to me has helped make me a more valuable worker. I am so pleased with your availability which surpasses many other professors at the university;

My co-advisor Dr. Raquel Quadros Velloso for your willingness to help and for teaching me how to analyze any engineering problem. Your remarkable patience and instruction have tremendously helped prepare me for my career. I thank you for your time, availability and sincere collaboration in this project;

My grandparents Jarbas Afonso de Melo and Maria Lourdes Dubeux Afonso de Melo, Jocelyne Grainger and grand-uncle Jairo Albuquerque for your love, hospitality and support;

My dear parents Willard and Flávia Grainger for your unfailing love;

My fiancé Rosangela, for the love, encouragement and partnership you have provided;

My brothers Marcos and Will for your love and care; my cousins Bruno, Carla and Ricardo, for your love, faithfulness and help; your support has been very meaningful to me and may we continue our relationships.

To my pastors Ebert, Renata, Sergio and Cynthia; helping me in my walk with Jesus and with loving others;

To my classmate Thiago Pessoa, for the times you have invested in teaching me the fundamentals of finite elements, and program techniques in Matlab and Abaqus. You helped me gain understanding and technical skills that would prepare me for this thesis;

To my dear friends at PUC-Rio University, Nilsthon and Juliana, Thiago Carnavale, José Consuegra, João Pinto, Perlita, Rafael, Sandra, Nathaly, Ricardo, Vanessa, Débora, Paula, Antonio, Gino, Gerson, Martin, Luis Fernando;

To Dr. Sergio Augusto Barreto da Fontoura and Dr. Erik Slis Raggio Santos , members of the examining board, for the corrections, comments and suggestions for this work;

To PUC-Rio University, for giving me the opportunity to study here in Brazil. May this work increase your name and recognition;

To the University of South Carolina in Columbia, S.C. United States, especially to my professors Dr. Imran, Dr. MacNally, Dr. Bradburn and Dr. Meadows, for instructing me basic engineering concepts in my undergraduate courses;

To California Polytechnic State University (Cal Poly), San Luis Obispo, C.A., United States, especially to my professors Dr. Hansen, Dr. Daza, Dr. Alongi and Dr. Macfarlane.

To CAPES, for granting me a scholarship and stipend during the entire graduate program;

To Rita, for the assistance in times of need.

Resumo

Grainger, Phillip Afonso de Melo; Vargas Jr., Eurípedes do Amaral. **Análise numérica do comportamento mecânico de bainhas de cimento em poços através de formações salinas.** Rio de Janeiro, 2012. 134p. Dissertação de Mestrado - Departamento de Engenharia Civil, Pontifícia Universidade Católica do Rio de Janeiro.

Existem muitas formações no mundo hoje que armazenam uma quantidade significante de petróleo, sendo um grande valor para a indústria petroleira. As bacias de Pré-sal da costa do Brasil atualmente estão em grande foco devido aos descobrimentos recentes de petróleo e os desafios que eles criam na perfuração. Ao contrário de muitas formações, a rocha salina exibe fluência, uma vez que, a perfuração seja realizada a rocha começa se realiviar das tensões geostáticas por fechamento com o tempo. A profundidade e os altos níveis de tensões induzidas pelo sal no revestimento requerem a cimentação para fornecer estabilidade adicional. Mesmo assim, um defeito no cimento complica a análise para os engenheiros a modelar e predizer seu comportamento. Um revestimento bem cimentado não é sempre alcançado em águas profundas. A geometria e o tamanho têm uma grande influência nas tensões no defeito do cimento. A ovalização do revestimento pode reduzir as tensões máximas de compressão induzidas pelo sal dependendo da geometria do defeito. Excentricidade reduz os efeitos da ovalização enquanto muda o estado de tensões do cimento. Portanto, é importante que o cimento e o sal sejam entendidos inteiramente a fim de realizar decisões racionais em engenharia. O foco desta pesquisa é atingir um conhecimento mais profundo de poços de offshore mal cimentados sujeitos ao carregamento não uniforme. Um modelo de elementos finitos foi gerado pelo software *Abaqus* para implementar simulações e análise de vários cenários de falhas no cimento.

Palavras-chave

Cimento; Fluência de sal; Pré-sal; Carregamento não uniforme; Abaqus.

Abstract

Grainger, Phillip Afonso de Melo; Vargas Jr., Eurípedes do Amaral (Advisor). **Numerical analysis of the mechanical behavior of cement sheaths in wells through salt formations.** Rio de Janeiro, 2010. 134p. MSc. Thesis - Departamento de Engenharia Civil, Pontifícia Universidade Católica do Rio de Janeiro.

There exist several salt rock formations in the world today which store a substantial amount of oil, being a great asset to the petroleum industry. The pre-salt basins off the coast of Brazil have been a primary focus due to the challenges they provide in oil drilling. Unlike most formations, salt rock exhibits creep behavior where, once the drilling has been performed, the rock begins to relieve itself from the applied stress by closing gradually with time. This may lead to cases of well collapse and well abandonment, creating an economical issue to oil drillers. Well cementing is always seeked to be performed with excellence, caution and thoroughness. Nevertheless, an unevenly distributed cement job complicates the analysis for engineers to model and predict its behavior. A well-cemented casing is not always achieved in deepwater wells. Geometry and size greatly influence the stresses on the defected area. Hence, it is important that the cement and salt formation be fully understood in order to make rational engineering decisions. The focus of this research study is to attain a deeper understanding of poorly-cemented offshore wells subjected to non-uniform salt loading. A finite element model was generated by the commercial software program *Abaqus* to implement simulations and analyses of various failure scenarios.

Keywords

Salt creep; Brazil; Non-uniform loading, Cement, Abaqus.

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Used Symbols

Roman Letters

A	Cross-sectional area; reciprocal viscosity coefficient (creep)
$[B]$	Transformation matrix relating strains and displacements
c	Cohesive strength
$[C]$	Constitutive (strain-stress) matrix; general diagonal matrix
d	Diameter
E	Modulus of Elasticity (i.e., *Young's modulus*)
G	Shear modulus
ID	Inner Diameter
$[J]$	Jacobian matrix
$[K]$	Assemblage stiffness matrix
k	Stress concentration factor; spring constant
n	Stress power (creep); strain hardening exponent
$[N]$	Coefficient matrix for interpolation field variable (displacement) model
OD	Outer diameter
p	Pressure
Q	Activation energy
r	Radius
t	Time; thickness
T	Temperature
τ_o	Octahedral shear stress
v	Poisson's ratio; displacement
V	Volume
x, y, z	Spatial coordinates

Greek Letters

ε	Normal strain
ε_e	Elastic strain
ε_p	Plastic strain
$[\varphi]$	Coefficient matrix for generalized coordinate model
φ	Angle of internal friction
σ	Normal stress at a point, or in a uniformly stressed member.
λ	Shear strain;
ν	Poisson's ratio
ψ	Dilation angle; interpolation function

Subscripts

c	Creep
e	Elastic (ε_e)
p	Plastic (ε_p)
max	maximum
min	Minimum
m	Mean (σ_m)
x, y z	Direction (σ_x); axis (I_y)
xy, yz, zx	Plane (τ_{xy})
1, 2, 3	Principal direction (σ_1)

Abbreviations

bwow	By weight of water
w/c	Water-cement ratio
ppg	Pounds per gallon
SMYS	Specified minimum yield stress