1
Introduction

This chapter presents an introduction, giving the motivation behind this work, the objective, and lastly the outline.

1.1
Motivation

Oil reserves across the globe are explored and maintained for the production and supply of petroleum—a natural resource that is in high demand and will continue to be in years to come. According to the United States Oil Fund, petroleum is one of the most important physical commodities in the global economy, as well as being used as a raw material for several industrialized products. Developed countries, such as the United States, have developed a life standard highly dependent upon crude oil—not to mention that it is also the world's largest consumer. Statistics indicate that U.S. citizens use about 21 million barrels of oil a day, or 25 percent of the oil produced in the world. If present trends continue, U.S. consumption is expected to rise to 27 million barrels a day by 2020, and U.S. oil demand will increase by 34 percent by 2030 (Samuelson, 2006). Developing nations have been rapidly increasing in oil demand. China is a great example and it has been on the headlines since 2005 for its explosive economic growth. Stapleton Roy, former U.S. Ambassador to China, once stated "Never before has a country risen as fast as China is doing," (Newman, 2005). With 1.3 billion people, it is the second largest consumer of oil (Economist); China's oil imports doubled from 2000 to 2005 (Forney, 2004) and at the current rate of growth, its need for oil will increase by 150 percent by 2020. Besides the United States and China, the rest of the world has a growing demand for oil, which in turn leads to further oil exploration along with maximizing production efficiency.

Well drilling costs may range from the $10,000 to well over $100 million (Lafarge Well Cements, 2011). In order to ensure efficiency and minimize operational risks, oil wells must be carefully designed. Robust projects require the anticipation of any possible problems. Issues related to poor cementing have been reported in offshore oil drilling for over thirty years (Weiss, 2011) and thus require special attention. Complementary to this is understanding the behavior of the rock formation. Some oil reserves around the world are adjacent to or capped by salt rock bodies, which present a singular time-depending behavior. According to Poiate et al. (2006), cylindrical cavities within salt bodies may close at rates as great as 0.05 inches in diameter an hour.

One of the largest oil discoveries in the past few years have been sited off the coast of Brazil. Currently ranked as the world's 15th largest oil reserve, it has been estimated that the pre-salt basins hold between 50 million to 70 million barrels, enough oil to move Brazil up to the top five by 2020 (Bevins, 2011). Recently, there have been discoveries of oil reserves within the Santos and Campos Basins. On February 24th, 2012, a 27° API oil was found in the Santos Basin in block BM-S-9 in the Carioca Sela well. In the Campos Basin, a hydrocarbon column was found having a pay zone of about 350 m located in block BM-C-33 on February 27th, 2012. These discoveries confirm the potential of Brazil's pre-salt reservoirs, encouraging further oil exploration.

Both the Santos and Campos basins contain salt formations under very high rock stresses due to the high depth of nearly 2 kilometers below the sea floor. Drilling in such environments become challenging as the technology boundaries are constantly being pushed forward. Cement failure problems due to salt loading, for instance, have been somewhat studied but still present a growing concern. Attaining a better understanding of the cement behavior under non-uniform loading in salt formations can significantly help anticipate risks, increase project robustness and improve overall economically.

Weiss (2011) from Associated Press reports that incidents relating to poor cement job have been documented for offshore wells 34 times from 1978 to 2010 and frequent problems in the recent years call for further studying to avoid the substantial economic and environmental consequences it leaves behind.

The additional motivation by Petrobras through its research and development center (CENPES) strongly encouraged the development of this thesis. Prioritizing deepwater salt drilling within the Campos and Santos Basin, further research is needed at CENPES in order to fulfill their long-term drilling plans for the years to come.

1.2
Objective

The objective of this work is to obtain a deeper understanding on how the salt body and cement sheath behave and transfer load to the casing, considering the cement sheath geometry is not optimal. Data natural to the pre-salt basins are employed to ensure direct field applicability. This was achieved by performing well simulations through the application of the finite element program *Abaqus*. Cement failure scenarios were analyzed, accounting for the effects contributed by casing eccentricity, casing ovality, and the salt formation. The following key factors were not found in literature and therefore were investigated in this research for a 28-day period:

- The type of stress that governs cement failure for different scenarios within a salt formation;
- The location(s) in the poorly-cemented annulus in which the maximum stresses occur;
- The percent reduction of the cement's elastic and strength parameters that trigger failure;
- The contribution casing ovalization and eccentricity may have upon the poorly-cemented annulus; and
- How the cement defect affects the stress, strain and displacement in the casing.

1.3
Thesis Outline

This thesis is divided into 7 chapters. Chapter 2 provides background information on evaporites and discusses evaporites in Brazil, focusing on Sergipe, Campos and Santos Basin in the Southeast of Brazil.

In Chapter 3, an overview of salt creep theory is given followed by a summary of popular rheological models, empirical and physical laws of creep. Here, the constitutive law selected for the salt rock in this research is discussed.

An overview of failure and yield criteria is given in Chapter 4. Both the steel casing and cement are assigned a yield and failure criterion, respectively, while none is necessary for the salt rock.

Chapter 5 goes into detail about the oil well materials simulated in this research, namely the casing and cement. A succinct review is given in light of casing eccentricity and ovalization. As for the cement, its composition, field process, strength properties and mechanical behavior are discussed. The end of the chapter discusses the cementing challenges that will be addressed in the following chapter.

Chapter 6 explains the adopted scenario for this work, followed by a brief literary review of the finite element method and details about the analyses and simulations implemented in Abaqus®. This chapter shows the results of the three modeling stages: the cement as an elastic material, the cement as an elastic perfectly plastic material, and continuing the elastic perfectly plastic cement model with casing eccentricity.

Chapter 7 presents the conclusions for this thesis with suggestions for future work.