Calcareous Deposit Study

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Abstract

Calcareous deposits are a well-known phenomenon and a large percentage of subsea assets experience them. It is a recent and important issue on the North West Shelf, where deposits cause issues for operability, reliability and functionality. The primary objective of the project is to develop two models that will predict if a problematic deposit will form and the deposit's composition. A secondary objective is to develop a testing strategy to refine these models and enhance the understanding of the deposit's growth mechanisms. The strategy would be implemented after this project. The models will be developed using data from previous studies, available data and new testing. The objective is that they will identify and optimise subsea intervention to reduce the impact of deposits on subsea assets.

1. Introduction

Chevron Australia is a natural gas operator which is responsible for operating Gorgon and Wheatstone LNG and domestic gas projects. It is also the operator for Australia's largest onshore oilfield on Barrow Island. The majority of this production is from subsea wells which are 150 metres to 1500 metres below sea level. At these depths, Chevron's aim is that there is as little unplanned intervention as possible. This is due to the large costs of the vessels required for a maintenance campaign.

Calcareous deposits play a detrimental role during intervention in that they can inhibit the movement of the desired subsea interface causing issues for operability, retrieval and integrity. These deposits can generally be overcome through mechanical cleaning and/or acid washes however, these remediation methods have limitations.

The inability to remove calcareous deposits from the subsea interface can lead to more severe monetary consequences to Chevron, if knowledge of their characteristics are not improved. Calcareous deposits are a scale that develops on metal exposed to seawater. This is due to the cathodic protection provided on the structure to protect it from corrosion.

These issues generate large monetary fees due to the extended intervention time by the Vessel to clean and access the subsea interface. Further this can also result in the loss of production through the time associated for deposit removal/access or change-out of the critical component. Historically industry has had a reactive approach to dealing with deposits, but due to increased formation rates and issues associated this is no longer acceptable.

Calcareous deposits occur all around the world, however their growth appears to be accelerated in the North West Shelf (NWS) where Chevron and numerous others are operating. The accelerated growth means there are more issues associated with deposits, occurring more frequently, and more severely than anywhere else in the world.

The primary objective of this project is the development of a set of models that can estimate the formation composition and estimate the formation likelihood based on environmental conditions. The likelihood model is an initial stage model that will be developed in further studies into a model capable of predicting formation rate. Once the models are developed, they will assist in intervention planning and effectiveness. A secondary objective is the development of a testing strategy for the formation of deposits in crevices. This is a critical step in the understanding of the deposit nature, as most academic knowledge is based off flat surface formation and is not reflective of what is being experienced in industry.

1.1 Background

Calcareous deposits occur due to the cathodic protection implemented on subsea structures to protect them from the corrosive nature of the ocean. Deposits consist of calcium carbonate and magnesium hydroxide, which have electrically resistant properties, and due to this are incorporated in cathodic protection calculations, which count on the growth to extend the life of the protection system and subsequently the asset.

The growth mechanism begins to develop as soon as the asset comes immersed in seawater and the cathodic protection system is activated. Installing a structure requires enormous initial capital expenditure, and all of Chevron's current subsea assets require and have cathodic protection installed. As the root cause of the deposit cannot be eliminated in brownfields (currently installed fields) a deeper understanding of the formation characteristics and mechanics is needed.

The cathodic protection implemented on the current subsea assets is in the form of sacrificial anodes. The anodes are installed directly onto the subsea structures and corrode in place of the steel (cathode). When the anode corrodes, it supplies electrons to the cathode via a metallic connection. This causes a rise in the alkalinity at the metal-water interface, causing a chemical imbalance that brings about the formation of calcium carbonate and magnesium hydroxides on the steel. These formations are calcareous deposits. The deposit is initially soft then turns hard over time (like a cement), after which removal generally requires mechanical cleaning and/or the use of washes.

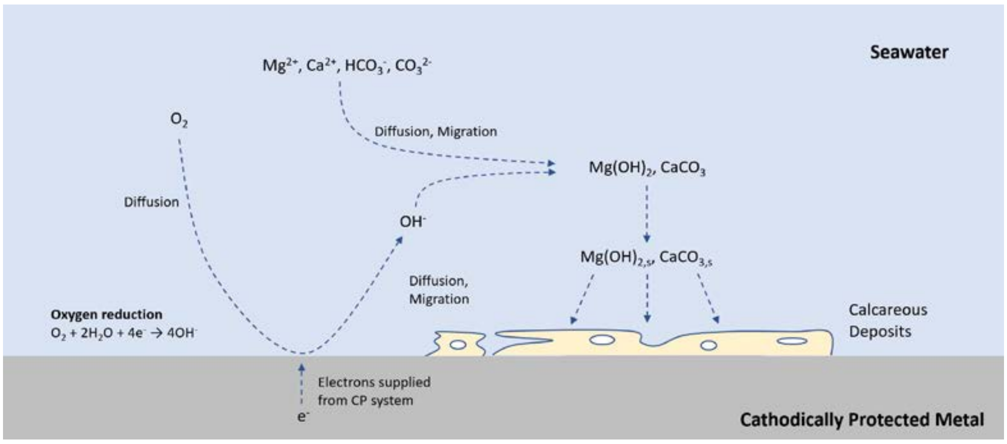

Figure 1 Growth process of calcareous deposits.

1.1.1 Factors Affecting Calcareous Deposits

Potential: The potential is the voltage difference between the anode and the cathode. This is a physical property and stays relatively constant even with varying area ratios of cathode and anode. The potential at which steel is considered protected is from -950 mV to -1100 mV V/SCE (Yang, Scantlebury and Koroleva, 2015). Depending on the potential, the composition of the calcareous deposit formed changes (Barchiche et al., 2003). It has been concluded that the potential directly affects the interfacial pH generated.

pH: The interfacial pH is controlled by the cathodic protection, and will increase with the potential. The reaction rates for the nucleation and growth of calcium carbonate will increase correspondingly. (Fischer, Thomason and Eliassen, 1996)

Current Density: Current density (also known as the current protection density) is potential (voltage) driven, and is the current that is supplied to the cathode as a result of the cathodic protection. The higher the cathodic current the higher the formation rate of the deposit. (Yan, White and Griffin, 1993) The current density starts off high at the time of installation, then decreases towards a steady state as deposit forms on the cathode. (Yan et al., 1993)

Temperature: Earlier studies indicate that the growth rate of deposits is also likely to be affected by the increased temperature of the seawater in the NWS. In one study, the amount of calcareous deposit found at 35℃ was approximately 7 times greater than the deposit retrieved at 3.5℃. (Caseres, 2013). Temperature does not just affect the deposit directly, it has also been found that the lower the temperature, the lower the initial current density. However, the steady state current density was found to be higher than at warmer temperatures. (Barchiche et al.,2004)

Salinity: Salinity is a measure of how the amount of dissolved salt is in the seawater. Different salts have different effects on the deposition. Sulphates within the seawater slow down the deposition of aragonite (a form of calcium carbonate). (Barchiche et al., 2004) The amounts of calcium and magnesium present in the seawater affect the likelihood of them precipitating as a solid.

Time: Deposit formation and adherence to the structure are both dictated by time of exposure (Extrin, 2014). The thickness of the deposit was found to have increased linearly with exposure time (Wolfson and Hartt, 1981)

Location of Deposit: The locations where the deposit forms are a focus of the project. It has been found that the deposit formed on a flat surface was different to the deposit forming in a crevice (Binks, 2003). This is currently theorised to do with the closer proximity of numerous hydroxide producing layers raising the pH to a higher alkalinity than would be found on a flat surface.

1.2 Summary of Objectives

The overall contribution of this project to the state of the art includes:

1. A model for the likely formation composition.
2. A model for the likelihood of a damaging deposit forming.
3. A testing strategy to enhance understanding of deposit growth variables

2. Modelling

The initial stage of the modelling was data identification and collection. Brainstorming with Chevron Australia staff and other industry experts, identified a list of variables that could potentially affect the growth. However, the data available for some of these variables is limited (or non-existent), as such the models will be constrained by the availability of data.

Current subsea assets are not equipped with external environmental measuring devices, all the monitors are internal, to monitor the safety and integrity of the flow. Data had to be secured from other sources such as ROV (Remote Operated Vehicles) and AUV (Automated Underwater Vehicle) campaigns, which are conducted intermittently. Data was also inferred from DPR (Daily Progress Reports) which are a recorded history of work done during vessel maintenance operations. The variables in the dataset are described in Table 1.

Data	Source
Potential, Depth, Time, Temperature	ROV
Seawater Density, Time, Salinity, Depth, Temperature	AUV
General observations, Time, Impact of the Deposit, Cleaning Details	DPR’s

Table 1 List of data utilised as variables and respective sources.

Linear statistical models (Fox, 2016) will be fitted to the data. These models predict the average value of a variable based on the value of other related variables. The composition model will comprise of two separate linear statistical models that will detail the magnitude of magnesium hydroxide and calcium carbonate as responses, with the other variables in Table 1 as explanatory variables. The models are expected to reveal some structure regarding the formation of magnesium and calcium deposits.

2.1 Testing

It was identified in initial literature review that deposits formed in crevices exhibited different physical and chemical properties. As the majority of the issues experienced by the assets due to deposits are in tight crevices, it was deemed this is a variable requiring testing.

The test will utilise 2 tanks (one at 4℃ and another at 25℃) to simulate on site conditions for two of Chevron’s assets. Each tank will contain 6 samples, 3 being a carbon steel and the other 3 being a stainless steel to replicate the materials used on a subsea tree. The samples will have cuts along the bar of increasing width that will replicate the crevices found on subsea components. The samples will be polarised with a DC power source to a potential similar to a subsea piece of equipment. Water will be stirred so it is not stagnant and the replenished regularly to maintain the bulk pH and water composition.

Testing will be conducted for 2 years, with sample retrieval being 3 months, 1 year and 2 years. Once a sample is recovered it will undergo compositional analysis on all the crevices, which will give insight into the effects of the crevice characteristics on formation composition and rate.

3. Results and Discussion

A60N conducted composition analysis on recovered samples from the field. The composition analysis shows that there is a difference between samples and using the data the models can be designed and applied to understand why that is the case.

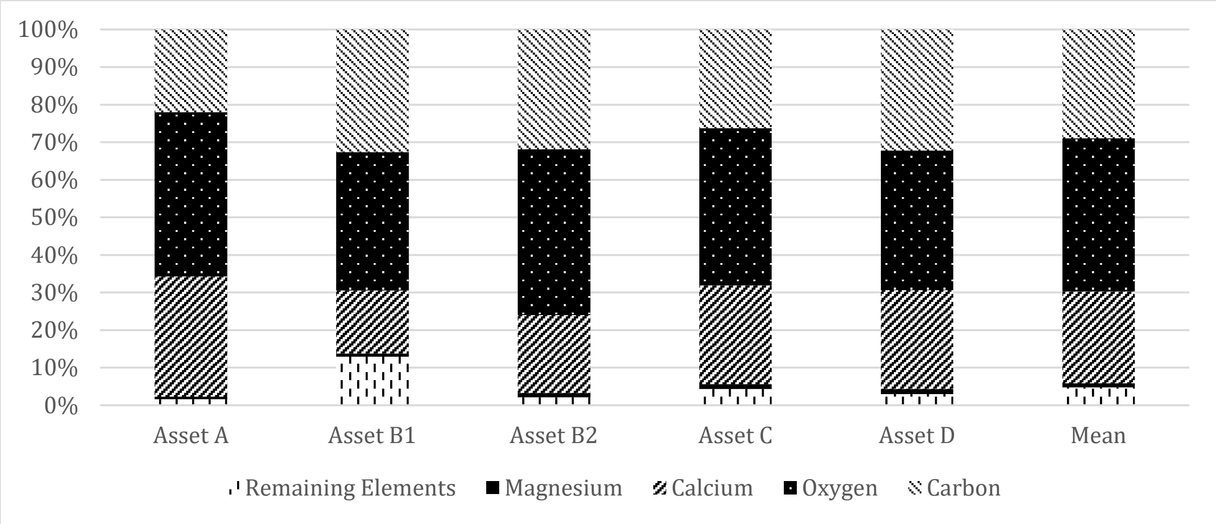

Figure 2 Deposit composition analysis results.

Analysis of a water sample taken from a North West Shelf (NWS) asset found it to have relatively the same composition as water recovered from Hillary's Boat Harbour in Western Australia. It was therefore deemed more practical and cost effective to use the Hillary's Boat Harbour as a water source rather than attempting to obtain NWS water samples for the whole test.

4. Conclusions and Future Work

Chevron's scope for the project is intended to be over 4 years starting in 2019. The current one-year project will focus primarily on describing the current understanding of deposit formation.

Future work will include the following;

1. Update of the formation likelihood model to a formation rate model;
2. Collection of the results from the testing;
3. Update of the two models using inputs from the testing;
4. Construction of a third model that uses inputs from the previous models as well as the crevice formation component.

This will allow the model to indicate a risk to a certain component based on the environmental conditions and its location on the asset. Further work will need to be done to rank the criticality of failure of a given component then the model will be complete. The model will then be utilised for planning the prevention or mitigation of calcareous deposits on subsea structures.

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