

Novel Hybrid Model for Under Deposit Corrosion Risk Assessment of Crude Pipeline in Sand Producing Field

Lay Seong Teh, Faisal M. Al-Abbas, Nayef M. Al-Anazi, Qasim Saleem
Saudi Arabian Oil Company
Dhahran 31311, Eastern Province
Saudi Arabia

ABSTRACT

Oil and gas production pipelines are susceptible to internal corrosion at locations where flow conditions promote water accumulation and solid particles settlement (precipitation). These deposits form diffusion barrier between the produced fluids and underlying substrate, which results in water chemistry near the steel surface different from that in the bulk fluids. This can potentially lead to an accelerated localized corrosion through under deposit corrosion (UDC). Successful corrosion management of UDC is based on risk assessment, mitigation and monitoring. As a normal practice, mechanical scraping along with chemical treatment is commonly applied as the mitigation for UDC. However, for this case, installing a scraper facility was not economically viable for new pipelines connected to an ageing platform that was meant for temporary period. Therefore, an assessment was conducted to determine if solids deposition and associated corrosion risks could be completely eliminated or tolerated to an acceptable level for safe continuous operation before diverting the pipelines permanently and equipped with scraping facility. The assessment utilized a novel approach consisting of advanced precipitation modelling, UDC laboratory testing including solids characterization in addition to flow assurance and corrosion simulation. The results showed that the overall deposition and associated corrosion risk is low. By implementing the recommended measures, these pipelines can be operated safely without scraping facilities temporarily, after which the pipelines will be routed to future scraping facility

Key words: under deposit corrosion, precipitation, corrosion risk, solids deposition

INTRODUCTION

Pipeline under-deposit corrosion (UDC) is a localized corrosion phenomenon that develops beneath or around solid deposits, which settle at the bottom of low flow/intermittent flow pipelines. These deposits are complex mixtures of water, organic, inorganic, and biological materials, and their composition can vary significantly depending on the properties of the product being transported and the operating conditions in the pipeline.

The inorganic solid deposits can be transported from the formation, produced in the system due to corrosion, precipitate from the water, or debris/fragments from the degraded coating¹. Whereas, the organic deposits, which can precipitate from the crude oil or being formed on the surface due to microbiological activity, are not considered in this paper for being ruled out in case study.

For pipelines transporting production fluids, solids coming from wells may deposit and accumulate in certain locations of the line, depending on the particulate size and density, flowing velocity, density and viscosity of the production stream, and pipeline topography. Anywhere deposits (sludge, scale, salts, etc.) may form inside the pipeline is a potential location for under-deposit corrosion.

Mixture velocity below the limit deposit velocity, v_c , below which a stationary bed (where solids settle and accumulate) starts to form³ at the pipeline bottom. Even if fluid velocities during normal operations are high enough to maintain solids entrain in the liquid, it is still possible to have solid settlement during production shutdowns. Note that fluid velocities required to re-entrain deposited solids in the liquids are generally higher than those required to maintain solids entrained.

Mitigation of UDC² is commonly by design, mechanical removal of deposits, or inhibition through chemical treatment. Depending on the severity and other production issues, combinations of these three strategies are typically adopted.

Case Study

Two new pipelines are designed to tie into an ageing offshore platform for temporary service. Due to space limitations at an ageing offshore platform to accommodate for scraping facility, several design options were proposed to mitigate UDC. These design options include using an internally coated carbon steel with chemical treatment (the most economical option) as the base case. The other alternatives are to use corrosion resistance alloy cladding, flexible pipelines or constructing new platform to accommodate for scraping facility.

This study was established to evaluate the risk of UDC for the base case throughout the intended temporary service duration. The work utilized a novel UDC risk assessment model consisting of fundamental corrosion simulation, advanced particle flow modeling, and UDC laboratory evaluation will be described in the following sections and demonstrated with the corresponding results.

UNDER DEPOSIT CORROSION RISK ASSESSMENT MODEL

The UDC risk assessment, in a structured approach, consists of the subsequent sections to assess the corrosion rates by corrosion simulation software, evaluate the risk of particles settlement using advanced precipitation modelling and examine the corrosivity under deposit through laboratory testing.

System Corrosivity Evaluation

Corrosion simulation was performed to predict the corrosion rates in carbon steel through Honeywell⁽¹⁾ Predict® 7.1 software using the gas phase CO₂ contents, the forecast production profile (from 5% to 30% in water cut) at the given operating conditions projected for both pipelines. Geochemical water analysis data for the formation water representatives of the field were considered in the simulation. Inhibitor likelihood success score (ILSS)⁴ that takes account of operating temperature, wall shear stress, total dissolved solids and uninhibited corrosion rate was considered for the corrosion rates estimation under inhibited condition.

⁽¹⁾ Honeywell Process Solutions, 1250 West Sam Houston Parkway South, Houston, TX 77042.

© 2022 Association for Materials Protection and Performance (AMPP). All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise) without the prior written permission of AMPP.

Positions and opinions advanced in this work are those of the author(s) and not necessarily those of AMPP. Responsibility for the content of the work lies solely with the author(s).

$$ILSS = \frac{Temp (C)}{40} + \frac{WSS (Pa)}{240} + \frac{TDS (ppm)}{125,000} + \frac{CR_u (mm/year)}{10}$$

The simulations were limited to inlet (receiving) and outlet (arrival) conditions. Likelihood of stagnant water accumulation at the bottom of the pipelines was evaluated by determining the actual liquid velocity along the pipeline elevation profile through flow assurance study using OLGA⁽²⁾ Dynamic Multiphase Flow Simulator® software.

Precipitation Risk

An analysis to evaluate particle settling trends at the bottom of both pipelines was crucial to establish a basis for the UDC risk assessment. Simulations were performed using OLGA v2018.1.1 with Particle Flow Module (Advanced) software.

Particle size distribution and concentration from field samples were analyzed and the results are shown in Table 1. Maximum particle size of 250 micron and maximum total suspended solids (TSS) loading rate of 371 ppm were considered. Particle size of 100 micron was applied for sensitivity case.

Table 1: Particle distribution and concentration

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Particle Size (micron)	Total Counts/ cc				
<1	0	0	0	0	0
1-5	0	0	0	0	0
5-15	0	0	0	0	0
15-30	0	0	0	0	0
30-50	0	0	0	0	0
50-100	1061	1159	589	1180	1148
>100	80	0	335	0	0
	Total Suspended Solids (mg/L)				
	371	136	148	291	242

UDC Laboratory Evaluation

High-temperature/ high-pressure static autoclave testing was used to simulate under-deposit corrosion at the given field conditions and the respective water geochemical analysis. CS-X60 weight loss coupons were cleaned before and after testing in accordance with ASTM⁽³⁾ G1-03⁵.

The collected formation water in autoclave vessel was purged with nitrogen gas for 30 minutes to remove dissolved oxygen then the reactor. The coupons were fully immersed in the solid deposit and then placed in the autoclave chamber. Finally, the chamber was pressurized to the field conditions for a month exposure. A blank test with no deposit was carried out as a reference (or base) case.

RESULTS

Results of each evaluation integral to the overall UDC risk assessment are presented in the following sections.

⁽²⁾ Schlumberger Ltd, 3600 Briarpark Drive, Houston, Texas, 77042.

⁽³⁾ ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.