UNIVERSITI TEKNOLOGI MARA

TOP-OF-THE-LINE CORROSION AND BENZYLAMINE INHIBITION UNDER WATER-HYDROCARBON CO-CONDENSATION

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ABSTRACT

Wet gas pipelines transport unprocessed natural gas that contains water and carbon dioxide (CO_2), which combination is corrosive to carbon steel. Under specific conditions, severe CO_2 corrosion occurs at the top section of the pipeline, known as top-of-the-line corrosion (TLC), which can be mitigated through volatile corrosion inhibitor (VCI) injection. The focus of this study is to investigate TLC and VCI inhibition mechanisms in water-hydrocarbon environment, which effect is often ignored in TLC and VCI tests. This study conducted an improved simulation of the condensation occurring in a wet gas pipeline and showed the effect of hydrocarbon volume ratio and gas temperature towards TLC and VCI inhibition mechanism. This study is divided into three parts: first, VCI selection using molecular modelling, second, TLC glass cell experiments in uninhibited and inhibited conditions, which include condensed water analyses, uniform corrosion rate and pitting rate analyses, and corroded surface characterisation and finally, response surface methodology (RSM) analyses to evaluate the relationships between factors and TLC responses. Benzylamine was selected as the VCI through a score-based method that covered frontier molecular orbitals energy, total energy and adsorption energy calculated in BIOVIA Materials Studio. In TLC glass cell experiment, the pipeline condition was simulated using water and *n*-heptane at 0 vol%, 10 vol% and 25 vol% to create water-hydrocarbon co-condensation. The presence of *n*-heptane in TLC tests caused sharp decrease in water condensation rate (WCR), leading to lower uniform corrosion rates, downward trend of pitting rates and altered the condensed water chemistry. Possible iron carbonate containing precipitates were only observed in water-hydrocarbon co-condensation tests via scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX), which were absent in control tests. Benzylamine inhibition was affected by the test conditions with inhibition efficiency between 4.8 % - 58.3 % to mitigate uniform corrosion rate (UCR) and between 0 % - 88.9 % to mitigate pitting. Its inhibition efficiency to mitigate UCR is temperature dependent; it decreases with the increase in temperature, and it shows antagonism behaviour when combined with *n*-heptane. However, its inhibition efficiency to mitigate pitting did not show temperature dependence, and it showed potential synergism behaviour when combined with *n*-heptane. The proposed benzylamine TLC inhibition mechanism is a combined pH neutralisation and film formation. Finally, the RSM analyses were able to provide preliminary RSM models to predict the gas temperature for the TLC glass cell setup, and the pH of the condensed water within the boundary of the test conditions conducted in this study.

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"…And We sent down iron with its great might, benefits for humanity…"

Surah Al-Hadid, 57:25

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Pipeline is a form of transportation that functions to transport fluids over long distances. In the oil and gas industry, pipeline plays a critical role to transport dangerous and flammable fluids safely. The spread of pipeline network in the world has reached millions of kilometres in length. The 2023 Annual Report for Pipeline Mileage and Facilities by the Department of Transport of the United States of America (USA) [1] reported that pipeline network in the USA alone consists of 228,699 miles (368,055 km) of pipeline transporting hazardous liquid and 1,367,846 miles (2,201,334 km) of pipeline transporting gas.

Pipeline has many advantages over other modes of transportation; it can transport large volumes of fluids over hundreds and thousands of kilometres and is highly reliable as each pipeline is dedicated for only one specific service, one delivery point, and one receiving point. It is also attractive from operational aspect as it can be operated remotely using control automation technology and product losses to the environment is minimal, which keep the operating costs low. It can be built in remote locations and can be hidden from the public e.g., buried or in subsea.

Natural gas is often extracted from remote locations such as offshore fields. By using pipeline to transport natural gas from the production well to the processing plant, the natural gas can be transported immediately upon extraction and can be processed at other location. This method avoids the investment of a new processing plant at the production well and minimizes the cost to develop and operate the gas field [2]. When the natural gas is extracted from the reservoir, it contains multi-components hydrocarbon in the form of gas and gas condensate with some amounts of water and other impurities such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), organic acids such as acetic acid (HAc) and chlorides. Natural gas is usually extracted at elevated pressures and temperatures and when it is immediately transported via pipeline, the pipeline is often referred as “wet gas pipeline” due to the presence of liquid condensate inside the pipeline. The fluid inside a wet gas pipeline is often considered to be in 3