Case Studies in Engineering Failure Analysis 2 (2014) 1–8

Contents lists available at ScienceDirect

Case Studies in Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/csefa

Case study

Analysis of internal corrosion in subsea oil pipeline

M.N. Ilman *, Kusmono

Department of Mechanical and Industrial Engineering, Gadjah Mada University, Jl. Grafika No. 2, Yogyakarta 55281, Indonesia

ARTICLE INFO

Article history:
Received 22 July 2013
Received in revised form 14 October 2013
Accepted 5 December 2013
Available online 28 December 2013

Keywords:
Subsea pipeline
Crude oil
Flow pattern
Flow-induced corrosion

ABSTRACT

Failure of a subsea crude oil API 5L X52 steel pipeline which led to oil leakage has been reported to occur after 27 years in service. Some leaks were found to form at the bottom of the horizontal API 5L X52 steel pipeline near an elbow section which connected the pipeline to a riser. The present investigation aims to analyze the main cause of failure by conducting standard failure analysis methods including visual examination, chemical and mechanical characterizations, metallurgical examinations using optical microscopy in combination with scanning electron microscopy (SEM) equipped with energy dispersive X-ray (EDX) analysis and corrosion test using a three-electrode potential technique. Results of this investigation suggest that the cause of failure is electrochemical corrosion combined with mechanical process known as flow-induced corrosion. The failure mechanism is discussed with specific attentions are paid to fluid flow rate and chloride-containing water phase.

1. Introduction

Pipeline plays an important role in oil and gas industries. Up to now pipeline is perhaps the most economical and efficient means of large scale fluid transportation for crude oil and natural gas compared to rail, truck and tanker transportation in term of the flexibility of routes and large quantities to be moved on. Pipeline is commonly made of carbon steels due to some reasons, i.e. carbon steels have good mechanical properties, low cost and wider availability despite their corrosion resistance is relatively low [1]. Normally, as an oil well ages, the production of oil starts to decline whereas water and gas flow rates tend to increase. The presence of high corrosive agents such as CO_2, H_2S and chlorine compounds which are dissolved in the fluids can accelerate corrosion process inside the pipeline [2,3]. Therefore, the impact of changes in fluid composition on a pipeline should be anticipated during maintenance program.

Recently, oil leaks have been reported to occur at a horizontal crude oil subsea pipeline after 27 years in service. A schematic diagram of the crude oil flow and the actual picture of the failed crude oil pipeline under investigation are shown in Fig. 1. During operation, crude oil was pumped from subsea wells into the horizontal pipeline. The crude oil then flowed out the pipeline directly into a long radius elbow section which turned the crude oil flow vertically allowing the flow to pass through a riser for further processing in platform.

Some oil leaks were observed at the bottom of the horizontal pipeline just before the flow entered the elbow section. No other areas of damage were identified during inspection. Details of the failed pipeline and its operating data are as follows.

* Corresponding author. Tel.: +62 274 521673; fax: +62 274 521673.
E-mail address: ilman_noer@ugm.ac.id (M.N. Ilman).

2213-2902
http://dx.doi.org/10.1016/j.csefa.2013.12.003

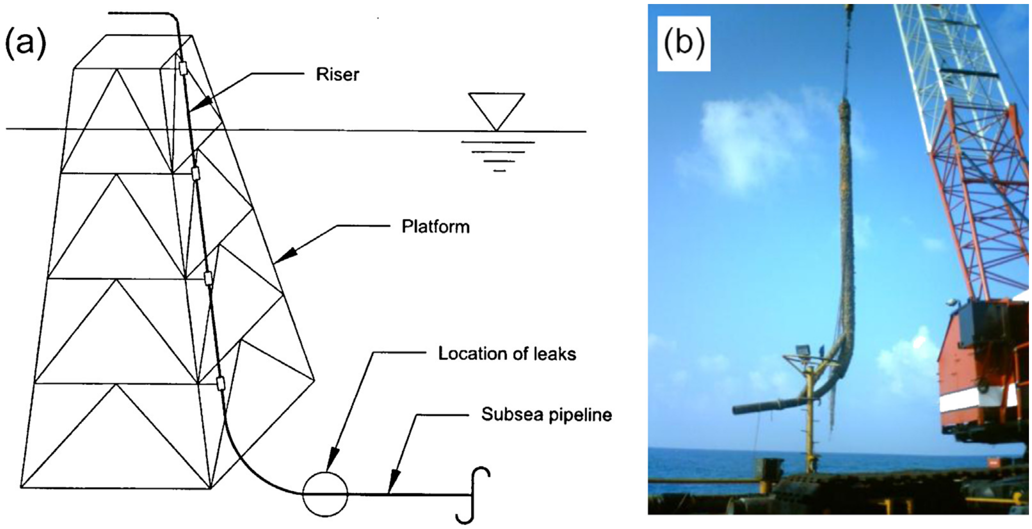

Fig. 1. (a) A schematic diagram of subsea pipeline-riser configuration, (b) a view of the failed subsea pipeline.

Specification and operating data	Value
Pipe outside diameter	16 in.
Length	10,677 ft
Wall thickness	0.5 in.
Material	API 5L X52
Design pressure	1480 psi
Test pressure	2225 psi
Operating pressure	170 psi (incoming) and 130 psi (outcoming)
Operating temperature	152 F (incoming)
Production (crude oil + water + gas)	2576 bopd (barrel oil per day), 28.345 bwpd (barrel water per day) and 0.441 mmscf gas per day

2. Analytical techniques

2.1. Visual examination

Fig. 2 shows visual examination results of leaks found in the pipeline. As is seen, the leaks were mainly observed at the inner surface of the pipeline. These leaks were nucleated locally at the bottom of pipeline (6 o'clock position) in the form of teardrop-shaped pits or grooves which elongated parallel to the fluid flow direction. This type of failure leads to hypothesis that the leaks are resulted from combined effect of electrochemical corrosion and fluid flow. However, this preliminary analysis needs to be verified by more detailed characterizations as shown later.

2.2. Analysis of crude oil pipeline material

Characterizations of the pipeline material were conducted using chemical composition analysis, microstructural examination and mechanical property tests including tensile test and hardness measurement. Table 1 shows chemical composition results obtained using emission spectrometer with the corresponding composition specified according to API 5L X52. The main alloying elements specified by API 5L X52 are C, Mn, Nb and V with impurities of P and S. Referring to Table 1, it can be seen that the pipeline composition fulfills that specified by API 5L X52. Of note is that elements such as Nb and V are normally added to steels as grain refiners during thermomechanical control process (TMCP).

Fig. 3 shows an optical photomicrograph of the pipeline under study. It can be seen that microstructure of the pipeline is composed of ferrite and pearlite as commonly seen in low carbon steels. These fine grained ferrite and pearlite are elongated along rolling direction known as texture. Such microstructure can give high strength in steels via grain refinement according to Hall–Petch relationship and good impact toughness to meet stringent requirements of pipeline material.