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Case study

Failure analysis of a leaked oil pipeline

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ABSTRACT

An oil pipeline embedded in an underground trench had failed. Through the accident investigation we found that there was a perforation at the leak point of the pipeline. Macroscopic observation revealed that some pits collectively located at the exterior surface of the failed pipeline. In addition, raised ridges and circumferential cracks were observed inside the large pits with stereoscope and scanning electron microscope. After careful analysis it is concluded that the leakage of the pipeline was mainly caused by the liquid impingement erosion.

1. Introduction

Liquid erosion is one type of wear that is the progressive loss of original material from a solid surface due to mechanical interaction between the surface and a fluid in a very small area. This can be further classified into two types: i.e., the cavitation erosion and the liquid impingement erosion. The cavitation erosion is usually caused by the formation and collapse of cavities or bubbles within the liquid. In engineering practice, lots of machines and structural components suffer cavitation damages, which makes cavitation erosion become very active research topic all the time [1–7]. However, the liquid impingement erosion, which originates from the impact by liquid drops or jets, has been rarely reported as the dominated reason [8–10]. Actually, in most of previous failure cases, the liquid impingement erosion often appears together with corrosion [11–16].

In this work, failure analysis of a leaked oil pipeline was carried out. Through careful macroscopic and microscopic observations, the leakage of this pipeline was found to be fully caused by the liquid impingement erosion. The pipeline is made of one kind of low-carbon steel, and its wall thickness is 4.5 mm. The pipeline was located in an underground trench that is covered by cement boards, and had been used for about ten years. In addition, while it was usually empty in the pipeline, some oil with temperature of ~80 °C could flow through the pipeline during the period of the equipment maintenance.

2. Visual observation and experimental procedure

Two pipe samples cutting from the failed pipeline are shown in Fig. 1. Apparently, it can be found that some pits locate on the exterior surface of the both two pipes. Furthermore, in one pipe sample, a perforation can be found inside one large

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Fig. 1. Examples of the failed pipes. The leak point is indicated by the white arrow.

pit, which is also one leak point of the pipeline, as indicated by the white arrow. No perforation was observed in another pipe.

Chemical analysis was performed to examine the composition of the material. Then, in order to conveniently observe and analyze the failure mechanism, the failed pipes were cut into small samples from the positions near the pits and the perforation using a wire electrical discharge machining (WEDM) method. A stereoscope and a LEO Supra 35 scanning electron microscope (SEM) were used to observe the pits macroscopically and microscopically, respectively. Energy dispersive spectrometer (EDS) analysis was performed to determine whether there are some other elements inside the pits. Furthermore, with the method of grinding and polishing, a metallographic section plane of one large pit was made and observed by SEM, to further examine the morphology of the pit.

3. Experimental results

3.1. Chemical composition analysis

The failed pipes had been initially designed to be made of low-carbon steel. The chemical compositions of the as-received pipes were examined by chemical analysis, and the results are shown in Table 1. In order to determine whether the material of the pipeline was qualified or not, the national standard values of the compositions were also listed in Table 1 for comparison. Clearly, the compositions are in consistent with the standard.

3.2. Macroscopic observation

The macroscopic morphology of the pits and the perforation were observed by the stereoscope, as shown in Fig. 2. Comparing Fig. 2a with Fig. 2b, three common features can be found. First, both two damaged sites show the aggregation of pits. Second, in each pit-aggregation, there is always a large pit, as indicated by the red arrows. Third, around and inside the large pit, many small pits with different size can be observed. However, the differences between the morphologies of two damaged sites are also evident. For example, for the pipe sample showed in Fig. 2b, all pits seem to be

Table 1
Chemical compositions of the as-received pipeline.

Chemical compositions								
C	Si	Mn	Cr	Ni	Cu	P	S	Fe
Testing value (wt%)								
0.21	0.24	0.45	0.031	0.034	0.12	0.010	0.008	Margin
The national standard of chemical compositions (wt%)								
0.17–0.23	0.17–0.37	0.35–0.65	≤0.25	≤0.3	≤0.25	≤0.035	≤0.035	Margin