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Failure analysis of the adhesive metal joint bonded on anticorrosion plastic alloy composite pipe

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ABSTRACT

The break off of adhesive metal joint from the anticorrosion plastic alloy composite pipe has caused serious burst. Investigations are performed to identify the most probable causes of the break off. The development of the composite pipe, the inner liner and outer GRP layer, glass transition temperature (T_g) and bonding strength of the adhesive resin are investigated in detail to understand the reasons of failure. Results have revealed that a fully break off of the adhesive metal joint from the composite pipe causes the burst of the pipeline. The average T_g value of the cured adhesive resin suggests that it is suitable for transporting the media with a temperature lower than 60 °C. Moreover, the shear strength of adhesive resin reaches maximum at room temperature and decreases with either increased or decreased temperature. The continuous higher working temperature of the whole pipeline causes gradual decrease of the bonding strength of adhesive resin and results in final break off of the adhesive metal joint.

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1. Introduction

With the increasing activities of exploiting high pressure high temperature gas reservoir in Tarim Basin of China, anticorrosion plastic alloy composite pipe, as a new composite pipe, has been tentatively used for maintenance of integrity of gathering pipeline system in harsh environment. Plastic alloy composite pipe has unique combination properties, i.e., excellent corrosion resistance, high strength, smooth inner, high abrasion resistance, high ageing resistance, and long life time. The all-round performance of this pipe is due to the double-layer structure, the inner layer of plastic alloy is designed to resist corrosion, which is fabricated by extruding a mixture of two or more homopolymers/copolymers, i.e., chlorinated polyvinyl chloride (CPVC), polyvinyl chloride (PVC), and chlorinated polyethylene (CPE), the outer layer is a glass fiber reinforced thermosetting resin pipe (GRP), which provides circumferential structure strength and supplies the axial tension. Due to these advantages, plastic alloy composite pipe is one of the best choices for replacing steel pipes in oilfield gathering pipeline system in China, especially in Tarim oilfield [1,2]. It has been widely used for water, polymer injection, and oil gathering system.

In order to connect with other pipes, the outer GRP layer at the end of the pipe needs to be polished. Then, a high-performance adhesive resin coated at the polished area will firmly bond the metal joint onto the composite pipe by heating (Fig. 1). However, such composite pipes fail frequently after several years of service, while more than 80% of the failures

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are due to the break off of adhesive metal joint from the composite pipe (Fig. 2), which caused huge lost and thus attracted many research attentions [1].

Replacing the failed pipeline directly can resolve the incidents, but the failure modes of the joint have not yet been well understood. For reliable operation and efficient design, especially the security of this engineering composite pipe, it is urgent to investigate the failure reasons of the joint and to further analyze the factors which affect the pipeline's serving ability. It will be of great benefit to prevent events which could trigger disastrous incidents, thus can reduce much loses in terms of service life and economics.

2. Material and methodologies

2.1. Background of the failure

Anticorrosion plastic alloy composite pipe (DN80 PN5.5 MPa) was used for oil gathering and transportation in Tarim oilfield in China. The whole construction project had been completed on September 2005, while the pipeline had been started to use on December 2005. Unfortunately, the pipeline burst on July 2012, lead to shutting down of the whole gathering system. The failed joint was cut from the burst pipeline, as shown in Fig. 2. Meanwhile, unbroken part from the same pipe was also collected for comparison.

2.2. Failure description

It can be seen from Fig. 2 that the burst of the pipeline is attributed to the break off of the metal joint from the plastic composite pipe. No shape change is observed on the metal joint and the plastic composite pipe. The polished surface of the GRP layer coated with the adhesive resin is undamaged. The inner plastic alloy layer shows a completely tearing rupture in the exfoliated adhesive metal joint (Fig. 2b), while the outer structural GRP layer is undamaged (Fig. 2a). Thus, it is predicted that there was a gradual reduce of the bond strength between the metal joint and the plastic composite pipe during operation. When the bonding strength is lower than the specified operating value, the adhesive metal joint will break off from the plastic composite pipe suddenly and a fully burst of the whole pipeline occurred.

2.3. Methodologies

Many factors may cause the failure of anticorrosion plastic alloy composite pipes and more studies are needed. Firstly, the background information and the operation conditions that might lead to failures of the pipe were investigated in detail. Secondly, probable causes for failure of inner liner, outer GRP layer and the adhesive resin were systematically analyzed by various measurements, such as Vicat softening temperature (VST) test, glass transition temperature (T_g) test, resin content test and shear strength test. After locating the reasons caused the break off of the metal joint, a simulated test was conducted to verify the facticity of the incident. Finally, different measures were put forward to prevent this failure in the future.

The specimens of inner liner and GRP layer for testing were taken from the same failed pipe which was cut from the burst pipeline. By comparison, specimens for above tests were also taken from a new plastic composite pipe which bearing the same batch with the failed pipe. At least three specimens taken along the circumference of the pipe were tested for each measurement to evaluate the results statistically. The "damaged" samples were collected from the area close to the damage region of the failed pipe (as seen in Zone 1 in Fig. 2a). The "undamaged" samples were taken from the new plastic composite pipe.

Heat deformation temperature (HDT) and VST Tester (XRD-300DL, Chengde Jinjian Testing Instrument Co., Ltd, China) with silicone oil as the heating medium was employed to test the VST of the inner layer. Shear strength of the adhesive resin was determined by using a SANS CMT 7104 universal testing machine (Shenzhen SANS material testing machine Co., Ltd,

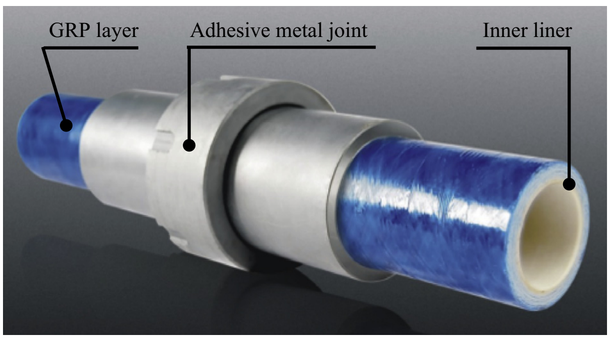

Fig. 1. Structure of anticorrosion plastic alloy composite pipe.

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