

# On-site Parameter Measurements and Corrosion Coupon Tests on Buried Pipeline Subjected to AC Interference from High Speed Railway

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## Abstract

Field measurements and corrosion coupon tests were carried out on a long-distance pipeline close to a high-speed railway. The spacing between the buried pipeline and high-speed railway is less than 500m and the parallel length of them is about 40 km. There are three intersections along the way, and the pipeline is subjected to dynamic AC interference. The AC and DC parameters were tested for 24 hours, and the dynamic interference characteristics were obtained by analyzing the tested data. In addition, corrosion coupons were buried at three locations along the pipeline. Through 11 months, the corrosion morphologies, corrosion products and corrosion rates of corrosion coupons under dynamic AC interference were obtained, and the correlation between dynamic interference parameters and corrosion behavior was analyzed, which provided

a reference for corrosion risk evaluation under dynamic AC interference.

## Introduction

With the rapid development of the economy and acceleration of urban modernization, many high-speed railways and buried pipelines have been built in China. Due to the limitation of space or geographical location, high-speed railways are often constructed in parallel or crossing with long-distance pipelines in some locations. The interference of high-speed railways on pipelines is the result of inductive and conductive coupling, which brings about AC corrosion and other safety issues <sup>[1-2]</sup>. In recent years, different countries have successively reported AC corrosion leakage cases on buried pipelines near high-speed railway <sup>[3-6]</sup>. Different from the steady state AC interference caused by high-voltage AC transmission lines, high-speed railways produce pulse interference to nearby buried pipelines, and the AC voltage and AC current on the pipelines are in a periodic state of fluctuation. How to accurately evaluate the corrosion risk under dynamic AC interference has become an urgent need in practical production <sup>[7-8]</sup>. Many studies have been carried out steady state AC corrosion in the world, and a lot of progress has been made in recent years on corrosion risk assessment of steady state AC interference <sup>[9-12]</sup>. However, as there are only a few studies on AC interference from high-speed railway on nearby buried pipelines, which could not provide enough support for accurately evaluating the corrosion risk of buried pipelines under AC interference from high-speed railway.

In this work, field measurements and coupon tests were carried out on a buried pipeline in parallel with an AC high-speed railway working in direct power supply mode. The buried pipeline is in parallel with the high-speed railway for 40 km, and the spacing between them is less than 500 m. There are three intersections along the way. The relative position relationship between the two is shown in Figure 1.

In order to evaluate the AC corrosion risk of the buried pipeline interfered by high-speed railway, corrosion coupons were buried at #1, #2 and #3 test stations along pipeline, and the AC and DC parameters of the coupons were monitored for 24 hours. The measured data were statistically analyzed to obtain the dynamic fluctuation characteristics of AC interference parameters on the pipeline interfered by high-speed

railway. After the corrosion coupons were buried for 11 months, the corrosion morphology, corrosion products and corrosion rates of the corrosion coupons under dynamic AC interference were obtained, and the correlation between dynamic AC interference parameters and corrosion behavior was analyzed, which could provide some reference for corrosion risk evaluation under dynamic AC interference.

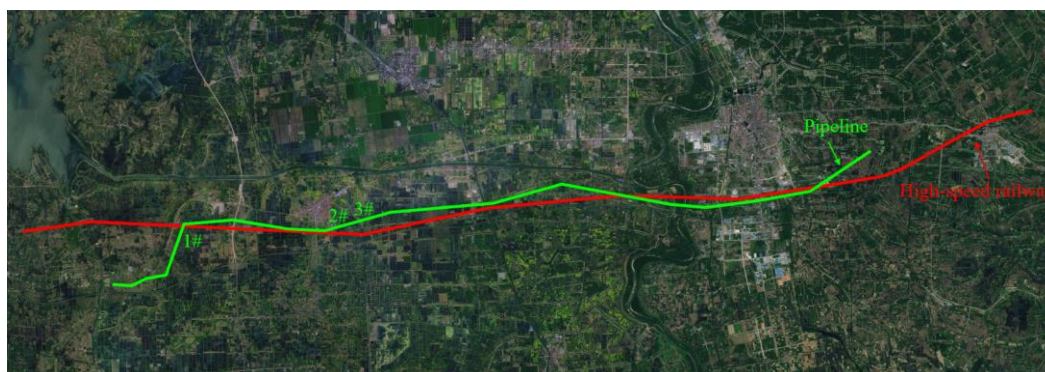


**Figure 1: Relative position between high-speed railway and pipeline**

## **Experimental Procedure**

### **Corrosion coupons tests in the field**

Corrosion coupons were buried at #1, #2 and #3 test stations along the pipeline to detect AC corrosion on the buried pipeline near high-speed railway. Natural corrosion coupons with surface area of  $1\text{cm}^2$  and  $6.5\text{cm}^2$  and AC interference coupons with surface area of  $1\text{cm}^2$  and  $6.5\text{cm}^2$  each were buried at the above test stations. In addition, the Wenner Four-Pin Method was used to measure the average soil resistivity at the buried depth of the pipeline.

After the corrosion coupons were buried for at least 24 hours, the parameters such as on-potential, off-potential, AC interference voltage, and the AC current density of the AC interference coupons were monitored for 24 hours. A copper/copper sulfate reference electrode and uDL-2 data recorder were used in the field test. The data acquisition frequency is 1 Hz, and the off-potential of the coupon is recorded every 20 s.

## Laboratory testing of corrosion coupons

The corrosion coupons were taken out after being buried for 11 months, and the coupons were sealed with plastic wrap and a sealing bag so that they could be brought back to the laboratory for further analysis. Dynamic AC corrosion behavior was investigated by weight loss test, morphology analyses and X-ray diffraction (XRD).

After recording the macro corrosion morphology of the corrosion coupons by digital camera, the coupons were placed into the prepared pickling solution (500 ml hydrochloric acid, 500 ml deionized water and 3.5 g hexamethylenetetramine) <sup>[13]</sup>, and then the coupon surfaces were gently brushed until the corrosion products attached to the surface were completely removed. The corrosion morphology of the coupon surface was then photographed again with the digital camera. The mass loss was measured with an electronic balance, and the corrosion rate was calculated according to Equation (1).

$$K_d = 8.76 \times \frac{w_0 - w_1}{St\rho} \times 10^4 \quad (1)$$

Where,  $K_d$  is the corrosion rate,  $\text{mm} \cdot \text{y}^{-1}$ ;  $W_0$  is the initial weight of coupon, g;  $W_1$  is the weight of coupon after pickling, g;  $S$  is the area of the coupon,  $\text{cm}^2$ ;  $t$  is the buried time, h;  $\rho$  is the density of the coupon,  $\text{g} \cdot \text{cm}^{-3}$ .

## Field Test Results

### The soil resistivity and information of coupons buried at three test stations

The specific information of buried coupons and soil resistivity measured by Wenner Four Pin Method is shown in Table 1. It could be seen from Table 1 that the soil resistivity along the pipeline is lower than  $20 \Omega \cdot \text{m}$ . According to DD CEN-TS 15280-2013 and SP21424-2018, the corrosion risk was very high <sup>[14-15]</sup>.

**Table 1: Information of corrosion coupons and soil resistivity at three test stations**

| Test station | Soil resistivity/ $\Omega \cdot \text{m}$ | Coupon type       | Coupon number | area of coupon / $\text{cm}^2$ |
|--------------|-------------------------------------------|-------------------|---------------|--------------------------------|
| 1            | 12.56                                     | Natural corrosion | 130           | 6.5                            |

|   |       |                          |     |     |
|---|-------|--------------------------|-----|-----|
| 2 | 16.33 | coupon                   | 03  | 1   |
|   |       |                          | 107 | 6.5 |
|   |       | AC interference coupon   | 01  | 1   |
|   |       |                          | 108 | 6.5 |
|   |       | Natural corrosion coupon | 02  | 1   |
|   |       |                          | 122 | 6.5 |
|   |       | coupon                   | 06  | 1   |
|   |       |                          | 116 | 6.5 |
|   |       | AC interference coupon   | 04  | 1   |
|   |       |                          | 119 | 6.5 |
|   |       | Natural corrosion coupon | 05  | 1   |
|   |       |                          | 140 | 6.5 |
|   |       | coupon                   | 09  | 1   |
|   |       |                          | 123 | 6.5 |
|   |       | AC interference coupon   | 07  | 1   |
|   |       |                          | 137 | 6.5 |
| 3 | 13.82 |                          | 08  | 1   |

## Parameters of AC interference and Cathodic protection

Figure 2 shows the monitoring results of AC current density on some AC interference coupons buried at different test stations. According to the field monitoring data, the AC current density on the pipeline near the high speed railway increases rapidly within a certain period of time and then decreases, and there is a certain interval between each peak of AC current density. The pipeline suffers from pulsed AC interference, and the AC interference parameters are in a dynamic state of fluctuation. Generally speaking, during daytime train operation, the AC current density on the pipeline fluctuates violently. When the trains are out of service at night, the AC current density is low with almost no fluctuation.

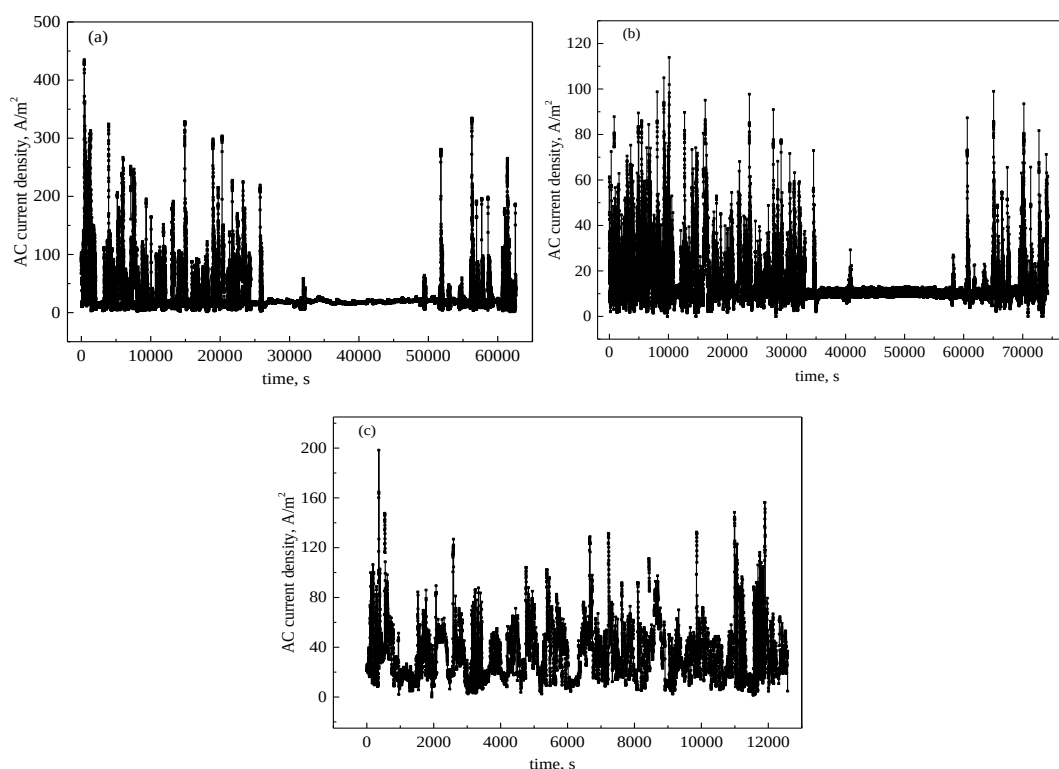


**Figure 2: Monitoring results of AC current density on some AC interference coupons (a) #107 (b) #116 (c) #137**

As the AC current density of the coupons subjected to dynamic AC interference showed pulse fluctuation characteristics, in order to accurately evaluate the corrosion risk of the coupons subjected to dynamic AC interference, further statistical analysis was conducted on the AC current density of the coupons and corrosion rates. The statistical method is shown in Figure 3, the peak of AC current density with high peak but few occurrences is defined as high peak AC current density and the peak of AC current density with low peak but high frequency is defined as high frequency peak AC current density. The high peak AC current density, high frequency peak AC current density and average AC current density on the coupons are statistically obtained. So that the statistical results can correspond to the corrosion rates of the coupons subsequently.

