

Characterization of Corrosion Inhibitor with Contact Angle Measurement

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ABSTRACT

Two types of corrosion inhibitors were studied. One of them, is better in adsorption performance in a static environment such as batch treatment. The other shows better inhibitor efficiency under high shear stress conditions. These inhibitors could be differentiated with contact angle measurements. The contact angle is the angle between a tangent to the drop's surface at the contact point and a tangent to the supporting substrate surface. The shape of the drop reveals the wettability and adhesion between the liquid drop and the substrate material.

The steel surface becomes hydrophobic and lipophilic after the inhibitor adsorbing. This is the mechanism of corrosion inhibitor performance on metal surfaces. The contact angle was measured on steel in air or water, where the inhibitor diluted in oil was placed. The two inhibitors showed different behaviors. The higher wettability seems favorable for the chemical adsorption on the metal substrate in a flowing system. In this paper, some ideas of contact angle measurement are also discussed. The test method describes in this work differentiates such inhibitor behavior clearly. This will provide a field operator an important first step to screen the inhibitors.

Key words: Corrosion Inhibitor, Contact Angle, Adsorption, CO₂ Corrosion

INTRODUCTION

Corrosion inhibitors are used to prevent pipelines from corrosion in oil and gas industry. The evaluation of corrosion inhibitors is vital for the corrosion engineers. Corrosion of the metal is prevented by the chemical inhibitor adsorption to the metal surface. Corrosion inhibitors are, in general, surfactants. A surfactant can adsorb on to the internal metal surface of piping and makes a hydrophobic film preventing the contact of water with the metal surface. Most corrosion inhibitors are consisted of mostly organic solvents and a few organic compounds. The corrosion engineers in oil companies decide the inhibitor efficiency by using simulated corrosion tests. The corrosion performance can be determined by utilizing weight loss measurements and/or electrochemical techniques. There are many studies discussing an inhibitor efficiency from the adsorption performance of the surfactants in the corrosion

inhibitor blend,¹ The field corrosion engineers from operating companies may not know the actual compositions of the corrosion inhibitors they apply in the field.

This paper considers a new test method with contact angle measurement. In this study, the components of a corrosion inhibitor were regarded as surfactants in a like a study by Moon and Horsup.² The adsorbing behavior of surfactants were evaluated with contact angle measurements. The contact angle describes the shape of a liquid droplet resting on a solid surface. The contact angle measurement is an easy visualization of interfacial tension,³ which is also a characteristic of chemical bonding. As the real corrosion takes place in a system of "water - oil - steel", the contact angle comes to revealing the influence of inhibitor between those materials. The eventual goal of these studies is to screen corrosion inhibitor performance more effectively in initial stages by the contact angle measurements.

EXPERIMENTAL PROCEDURE

Contact Angle Measurement

Contact angles were measured in air, deionized water and hydrocarbon solvent at room temperature with First Ten Angstroms FTA 1000 B Class^a system. It consists of a light, a syringe, a CCD camera and a data processing computer as shown in Figure 1. An aromatic hydrocarbon solvent (T-SOL 100^b) was used as the condensate in this simulation. If a sample as an adsorbate has smaller density than water, the contact angle is measured on underside of metal substrate in water through J-shape needle. The contact angle was calculated with an appropriate model according to the contact angle volume and the droplet shape.

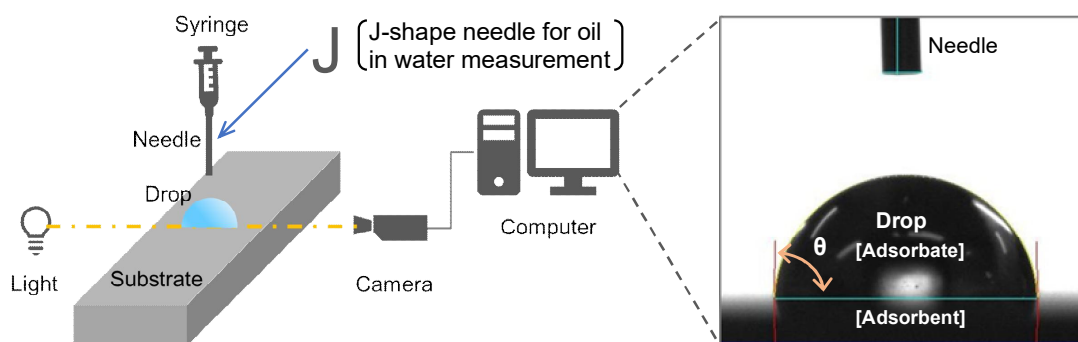


Figure 1: Contact angle measurement system

Corrosion Inhibitor

Two types of corrosion inhibitor were examined. Inhibitor A is better in adsorption performance in a static environment such as batch treatment in a production tubing or a pipeline. Inhibitor B shows better inhibitor efficiency under a high shear stress condition in a flowline.⁴ Inhibitor B indicates lower viscosity than Inhibitor A as shown in Figure 2. The physical properties of the liquid samples were given in Table 1.

^a Trade name

^b Trade name

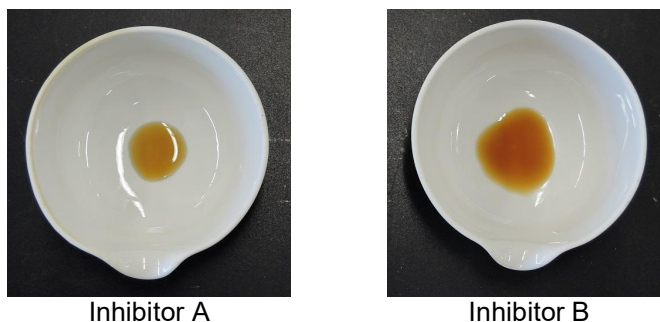


Figure 2: Corrosion inhibitor appearance (5 droplets in 60 mm evaporation dish)

Table 1
Physical properties of liquid samples

	Inhibitor A	Inhibitor B	Solvent	Water ^{*3}
Density ρ at 16°C [g/cm ³] ^{*1}	0.943	0.925	0.879	1.00
Viscosity μ at RT [mP·s] ^{*2}	143	5.49	0.95	0.89

^{*1} Density was measured with Anton Paar DMA 5000 M^c

^{*2} Viscosity was measured with Brookfield Ametec Dial Reading Viscometer^d

^{*3} Interpolated values in CRC Handbook of Chemistry and Physics, 88th edition (2008)

Corrosion Test

The preliminary corrosion tests were conducted to characterize the corrosion inhibitors, using a rotating cage autoclave (RCA).^{4,5} The test coupon is cut into 2 mmWT x 10 mmW x 50 mmL from welded joint of C-steel pipe (ASTM^e A135⁶ Gr. A) and finished by abrasion and rinse in accordance with ASTM G31-12a.⁷ The grade of welding rod is ASW^f A5.28 ER80S-G⁸ (0.08C-0.7Si-1.4Mn-0.5Mo). The welding joint was utilized to identify clearly the inhibitor performance because the field piping suffered often preferential corrosion at welding lines.⁹

The autoclave was filled with 1.6 L deionized water dissolved with 3,000 ppm chloride ions, 300 ppm acetic acid, 200 ppm inhibitor and 4% solvent. After the solution was deaerated with CO₂ gas, it was sealed with 0.3 MPa CO₂ gas at room temperature. When the autoclave reached the test temperature, 70°C, the pressure was increased to approximately 0.8 MPa. The coupons were immersed for one week with rotation speed of 500 rpm. The rotating speed corresponds to 2 m/s in circumferential speed of 80 mm diameter of the cage. The coupon weight was measured before and after the corrosion test to calculate the weight loss.

Metal Substrate

The metal substrate as adsorbent is same as the above corrosion coupon. The surface condition of corrosion coupon may be rougher than a general contact angle measurement, however, this condition was preferred from the corrosion test point of view. Some test coupons were prepared by using dip and

^c Trade name

^d Trade name

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^f American Welding Society, 8669 NW 36 Street, #130, Miami, FL 33166-6672