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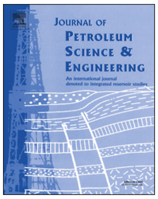

Galvanic corrosion of carbon steel–brass couple in chloride containing water and the effect of different parameters

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ABSTRACT

Galvanic corrosion of carbon steel–brass couple in 3% NaCl solution was investigated under different operating conditions. The effects of ranges of operating conditions such as rotational velocity, temperature, area ratio , and time on the galvanic currents were investigated and discussed. The results showed that, increasing area ratio of carbon steel to brass, led to an increase in the galvanic current. The current density on each metal of the couple and the galvanic potential had unstable trend with area ratio. The rise in temperature from 25 °C to 45 °C, increased the galvanic current two times in stationary conditions and more than three times under flow conditions shifting the potentials to more negative. The rotational velocity of fluid has an appreciable effect on the galvanic current especially in the presence of corrosion products formed on the anode, i.e. carbon steel. The formation of corrosion products with time on carbon steel, reduced the galvanic current in stationary conditions and caused a considerable increase in it in flow conditions.

1. Introduction

In oil and gas industries, corrosion is a serious problem facing the equipments. Galvanic corrosion is noticed in heat exchangers, pipelines, cooling towers, and in all cases in which two different metals come in contact in the presence of water or moisture. The most commonly used material for petroleum pipelines is carbon steel because of its strength, ductility, weldability and it is amenable to heat treatment for varying mechanical properties. For operational necessity, carbon steel comes in contact with other metals resulting in galvanic attack.

In galvanic corrosion, the added anodic currents equal the added cathodic currents (West, 1976; Cifuentes, 1987; Shreir et al., 2000), so that for binary system

$$I_{a.1}+I_{a.2}=|I_{c.1}|+|I_{c.2}| \tag{1}$$

where I_{a1} and I_{a2} are the anodic currents on metals 1 and 2 respectively and I_{c1} and I_{c2} are the cathodic currents. The difference between anodic currents and cathodic currents on one pole equal to the absolute value of this difference on the other pole.

$$I_{a.1}-|I_{c.1}|=|I_{c.2}|-I_{a.2}=I_g \tag{2}$$

where I_g is the galvanic current flowing between the two metals. In terms of current densities and areas

$$i_{a.1}A_1+i_{a.2}A_2=|i_{c.1}A_1|+|i_{c.2}A_2| \tag{3}$$

Often the anodic current on more noble metal is negligible compared with anodic current on the more active, i.e. $I_{a.1} \gg I_{a.2}$, thus Eq. (2) is reduced to

$$I_{a.1}=|I_{c.1}|+|I_{c.2}| \tag{4}$$

Galvanic corrosion is one common form of corrosion in marine environments widely encountered in practical situations. It occurs when two (or more) dissimilar metals are brought into electrical contact in the presence of electrolyte. Due to this contact the corrosion rate of more noble metal decreases lower than its corrosion rate before contact and the corrosion rate of less noble metal increases to higher than its corrosion rate before contact (West, 1976; Cifuentes, 1987). It is influenced by different parameters such as, type of metals, metals area, solution conductivity, distance, temperature, and flow velocity.

The area ratio is very important in the consideration of the likelihood of galvanic corrosion as it affects the values of galvanic corrosion currents and corrosion potentials. Previous studies for various couples in different environments (West, 1976; Cifuentes, 1987; Hwang et al., 1993; Roy et al., 1999; Shreir et al., 2000) showed different trends of galvanic currents with area ratios. Under immersed conditions in a highly-conducting electrolyte, such as sea-water, effective areas will be greater, and severe

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Nomenclature

A_1	area of metal 1, m^2
A_2	area of metal 2, m^2
A_T	total area (=A1+A2), m^2
E	potential, V
E_g	galvanic corrosion potential, V
i	current density, A
I_a	anodic current, A
I_c	cathodic current, A
I_g	galvanic current, A
T	temperature, K

Abbreviations

AR	area ratio
b	brass
CS	carbon steel
SS	stainless steel

Subscript

a	anodic
c	cathodic
g	galvanic

corrosion may be encountered on small anodic areas of many metals. The larger the cathode compared with the anode, the more oxygen reduction, or other cathodic reaction, can occur and, hence, the greater the galvanic current. By correct selection of area ratio, dissimilar metals have frequently been used successfully together (Mahato et al., 1968; Yin, 2008).

On the cathode, the excess electrons are consumed by a cathodic reaction that, in salt water, is usually oxygen reduction (Mahato et al., 1968; Yin, 2008):

$$O_2+2H_2O+4e\leftrightarrow 4OH^- \tag{5}$$

For galvanic systems in which iron is the more active metal the following oxidation reaction occurs:

$$Fe\leftrightarrow Fe^{2+}+2e \tag{6}$$

The effect of solution temperature on galvanic corrosion rate has received some attention from researchers. Different trends of galvanic corrosion rate with temperatures have been obtained depending on the system nature. Roy et al. (1999) noticed unstable trend of galvanic corrosion rate with temperature of stainless steel–Ti alloy couple in acidic brine. El-Dahshan et al. (2002) found that increasing solution temperature leads to an increase in the galvanic corrosion current for brass–stainless steel couple in sea water and the galvanic corrosion potential is shifted to more negative. Yin et al. (2008) found that the galvanic corrosion currents increase considerably with temperature for stainless steel and Ni-based alloys in NaCl solution.

Previous works showed different trends of the galvanic current with time for various galvanic couples. Zhang and Valeroite (1993) showed that the galvanic current of Fe–Zn couple in Na_2SO_4 solution decreases appreciably in the first minute reaching constant value. Hara et al. (1997) observed that I_g for Ni–Pt in Na_2NO_3 solution decreases asymptotically with time. Hodgkiess and Lim (1993) for SS-CS and El-Dahshan et al. (2002) for both titanium–brass couple and SS–brass couple in sea water, found that I_g decreases with time. Yin et al. (2008) found that I_g increases with time for stainless steel–Ni alloys in NaCl solution in stationary conditions. The study of Roy et al. (1999) for the galvanic corrosion of 516 steel with six different alloys in acidic brine, indicated that I_g increases with time reaching nearly constant value after 2–4 min. He et al. (2002) found that I_g of different alloys increases with time. Other experimental works on various couples (Al-Hossani et al., 1997; Souto et al., 2007; Tamarit et al., 2007; Idrac et al., 2007) noticed unstable trend with time, that is, I_g increases at the starts and then decreases with time. Song et al. (2004) found that I_g increases considerably with time up to 10 h and then fluctuates around constant value. Accordingly, the variation of galvanic current with time is depending on the galvanic system nature and operating conditions.

In practice, carbon steel commonly comes in contact with other metals for operational necessity leading to affect its corrosion rate depending on the operating conditions. In many situations, carbon steel comes in contact with brass (an alloy of copper and zinc) leading to affect its corrosion behavior. Such situations are the use of brass fittings with carbon steel or galvanized steel pipes, welding of steel by brass, and in practical applications of brass in electrical circuits. Due to potential difference between brass and carbon steel, galvanic currents arise leading to an increase in the corrosion rate of carbon steel.

Despite its practical importance, studies concerning the effect of flow velocity and temperature on galvanic corrosion of carbon steel–brass couple are little in literature. However, studies concerning the effect of hydrodynamics on the galvanic corrosion, in general, are relatively little in literature and this issue needs to be investigated for various couples to gain better understanding of the effect of hydrodynamics on the galvanic corrosion behavior. The present work is devoted to investigate the effect of different operating conditions such as area ratio, temperature, flow velocity, and time on the galvanic corrosion of carbon steel–brass couple in 3% NaCl solution.

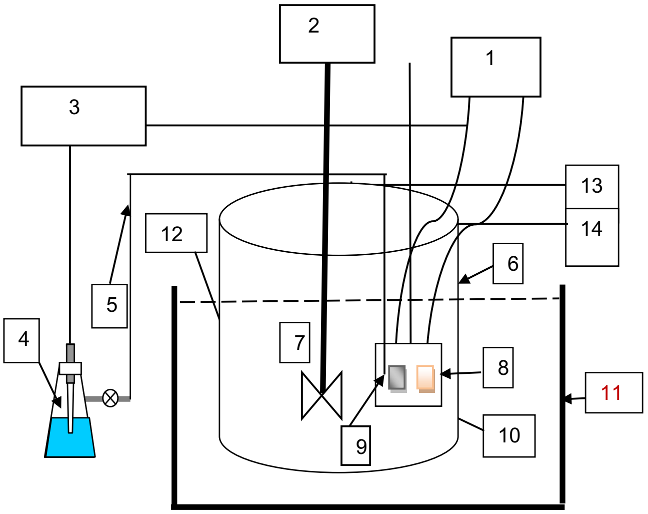

Fig. 1. Experimental apparatus. 1 –Zero resistance ammeter, 2 – agitator, 3 – voltmeter, 4 – reference electrode (SCE), 5 – salt bridge, 6 – beaker, 7 – glass impeller, 8 – specimens-, 9 – Luggin capillary, 10 – specimens holder, 11 – water bath, 12 – 3% NaCl solution, 13 – O_2 solubility meter, 14 – pH meter.