

Corrosion behavior of carbon steel in the CO₂ absorption process using MEA activated K₂CO₃ aqueous solutions

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Abstract: Corrosion of carbon steel in the CO₂ absorption process using MEA activated K₂CO₃ aqueous solutions was investigated. The effects of the mass concentrations of MEA, solution temperature and CO₂ loading on the corrosion rate of carbon steel were demonstrated. The experimental results provided comprehensive information on the appropriate concentration range of MEA aqueous solutions under the situation which low corrosion of carbon steel can be achieved.

1. Introduction

In recent years, with the rapid growth of population and enormous use of fossil fuel, the increasing concentration of CO₂ became the major contributor to global warming [1]. Generally, CO₂ emissions from thermal power plants can be removed by many methods including pre-combustion capture and post-combustion capture [2]. Among these methods, chemical absorption [3,4] is the most efficient and popular way.

Potassium carbonate (K₂CO₃) and amines, such as monoethanolamine(MEA), diethanolamine(DEA) and N-methyldiethanolamine(MDEA), can remove acid gas constituents from sour gas streams for a large-scale implementation. K₂CO₃ has a number of advantages over the amine-based solvents, including low cost, low toxicity, characteristic of refractory [5]. Hendy et al. [6] found that at 336.2K, the addition of MEA in small quantities (1.1 M (5 wt.%) and 2.2 M (10 wt.)) can accelerate the overall rate of absorption of CO₂ in a 30 wt.% K₂CO₃ solvent by a factor of 16 and 45, respectively.

Previous research shows that the loss caused by corrosion is the most rigorous issue of CO₂ capture pilot. The serious affect of corrosion, such as unplanned downtime, production loss, reduced equipment life, and even injury or death, might result in great damage [7]. Therefore, controlling corrosion is of great significance for improving the production capacity and the production efficiency of power plant [8].

By far, there are some experiments concerning the absorption of CO₂ in MEA-K₂CO₃ aqueous solutions [6]. However, studies concerning the corrosion behavior in CO₂-MEA-K₂CO₃ aqueous solution have been rarely reported as yet. The main purpose of this work is to investigate the corrosion behavior of carbon steel in carbonated K₂CO₃-MEA. The mass fraction of K₂CO₃ was 0.15 and mass fraction of MEA ranged from 0.025 to 0.075. The temperatures ranged from 313.2K to 333.2k and CO₂ loading ranged from 0.1 to 0.3.



2. Experiment

2.1 Materials

The corrosion test specimen in this experiment is No.20 carbon steel. Chemical composition of standard JB/T6057-92 steel is: C(0.17~0.23), Si(0.17~0.37), Mn(0.36~0.65), P(≤ 0.035), S(≤ 0.035), Ni(≤ 0.030), Cr(≤ 0.025), Cu(≤ 0.035).

Chemicals used in this work are detailed in Table 1. K_2CO_3 and MEA were purchased from Fuchen Chemical Reagent and Kermel Chemical Reagent, with mass purity $\geq 99\%$. They were used without further purification. Aqueous solutions of MEA- K_2CO_3 were prepared by adding doubly distilled water. The uncertainty of the electronic balance (FA1604A) is $\pm 0.1\text{mg}$.

Table 1 sample description.

Chemical name	CAS	Purity (mole fraction, as stated by the supplier)	source
K_2CO_3	584-08-7	$\geq 99\%$	Fuchen Chemical Reagent
MEA	111-42-2	$\geq 99\%$	Kermel Chemical Reagent
carbon dioxide	124-38-9	$x \geq 0.9999$	Hanjiaangxue Gas
water	7732-18-5	Electrical resistivity $> 15\text{M}\Omega\text{ cm}$ at $T = 298\text{ K}$	Heal force ROE-100 apparatus

2.2 Apparatus and Procedure

During the absorption experiment, the CO_2 in the high pressure tank first flowed into the mass flow controller to maintain the CO_2 flow rate at 100 mL/min. A fixed flow rate of CO_2 enters the absorption bottle and is absorbed by the solution. The residual gas first flows into the dryer, then into the CO_2 analyzer, and finally into the mass flow meter (MFM). The CO_2 concentration was measured by the CO_2 analyzer, and the flow rate was measured by the MFM. The data was recorded by a computer [9,10].

The electrolytic cell consists of a working electrode, a reference electrode, and a platinum electrode. Corrosion test was carried out in an electrolytic bath heated by a thermostatic water-circulator bath. An electrochemical analyser (CHI 602) connected with the electrolytic cell and the Tafel curve and data of the corrosion process were derived through the computer. The corrosion data is processed into linear graphs and figure out more detailed corrosion rates for further analysis [11].

3. Result and Discussion

The corrosion rates of carbon steel in CO_2 - K_2CO_3 -MEA aqueous solutions under different mass fractions of MEA, temperature and CO_2 loading are shown in Table 2. The mass fraction of K_2CO_3 is 0.15.

Table 2 Corrosion rates of carbon steel in CO₂-K₂CO₃-MEA aqueous solutions under different mass fractions of MEA, temperature and CO₂ loading. Pressure (p) =101kPa.

W _{K2CO3}	W _{MEA}	α	Corrosion Rates (mpy)		
			313.2K	323.2K	333.2K
0.1500	0.0250	0.1	1.23	2.23	3.78
		0.2	1.87	3.42	5.68
		0.3	2.75	4.38	8.69
	0.0500	0.1	2.83	2.99	6.23
		0.2	3.68	2.62	9.45
		0.3	2.96	7.89	12.56
	0.0750	0.1	4.32	6.23	9.78
		0.2	3.68	8.02	15.45
		0.3	7.56	13.45	20.14

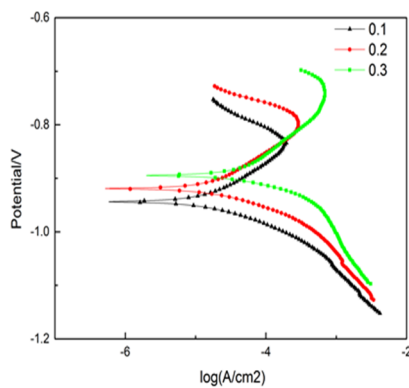


Figure 1. Effect of CO₂ loading on polarization behavior of carbon steel in CO₂-MEA-K₂CO₃ aqueous solutions. $\omega_{K_2CO_3}/\omega_{MEA} = 0.15/0.075$; T=40°C. Symbols: ■ $\alpha=0.1$; ● $\alpha=0.2$; ▲ $\alpha=0.3$. Lines: trend lines.

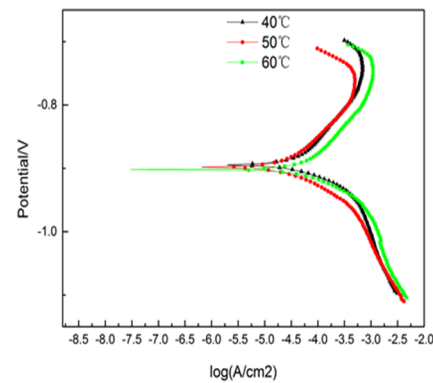


Figure 2. Effect of temperature on polarization behavior of carbon steel in CO₂-saturated aqueous solutions of K₂CO₃-MEA. $\omega_{K_2CO_3}/\omega_{MEA} = 0.15/0.075$, $\alpha=0.3$. Symbols: ■ T=40°C; ● T=50°C; ▲ T=60°C. Lines: trend lines.

Figure 1 shows the influence of CO₂ loadings on polarization behavior of carbon steel in CO₂-MEA-K₂CO₃ aqueous solutions. With the increase of the CO₂ loading, the corrosion potential decreases. The cathode current density increases obviously, and the anode current density changes slightly.

Figure 2 shows the influence of temperature on polarization behavior of carbon steel in CO₂-saturated aqueous solutions of K₂CO₃-MEA. Temperature has a significant effect on corrosion. With the increase of temperature, the cathode current density increases and the cathodic corrosion rate is accelerated. As the temperature increases, the anode current density increases in the area near the corrosion potential, and the anode current is reduced in the range of corrosion equilibrium potential.

4. Conclusions

The corrosion behavior of carbon steel in CO₂-MEA-K₂CO₃ aqueous solution was investigated. The effect of the mass fractions of MEA, temperature and CO₂ loading on the corrosion rate of carbon steel were demonstrated. Our results show that:

1) At given CO₂ loading and given concentrations of K₂CO₃ and MEA, the corrosion rate of carbon steel increases with the increase of the temperature;

2) At given temperature and given concentrations of K₂CO₃ and MEA, the corrosion rate of carbon steel increases with the increase of CO₂ loading;

3) At given temperature, CO₂ loading and given concentrations of K₂CO₃, the corrosion rate of carbon steel increases with the increase of the concentration of MEA.

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