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A comprehensive review of metal corrosion in a supercritical CO_2 environment

Gan Cui[a,b,c,*], Ziqing Yang[a,b,c], Jianguo Liu[a,b,c], Zili Li[a,b,c,*]

[a] College of Pipeline and Civil Engineering in China University of Petroleum (East China), Qingdao 266580, China
[b] Shandong Key Laboratory of Oil & Gas Storage and Transportation Safety, Qingdao 266580, China
[c] Qingdao Key Laboratory of Circle Sea Oil & Gas Storage and Transportation Technology, Qingdao 266580, China

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ABSTRACT

Carbon capture and storage (CCS) is the most effective way to reduce CO_2 emissions. In CCS, CO_2 transportation plays an important role for the transmission of CO_2 from the capturing facility to the location of permanent storage. In order to increase the CO_2 density and avoid two-phase flow, CO_2 needs to be transformed into the supercritical state. The supercritical CO_2 environment poses a threat to pipeline safety because it is a high pressure environment with gaseous impurities. In this paper, the influencing factors of pipeline corrosion under supercritical CO_2 environment and the current prevention and control methods for SC CO_2 corrosion are reviewed. To begin, the supercritical CO_2 corrosion environment and corrosion evaluation methods are introduced. Then, the effects of some factors, such as the water content, gaseous impurities, acids, alkalis, salts, temperature, pressure, flow rate, exposure angle, and pipeline steel, on corrosion are comprehensively reviewed. New research areas, such as the use of coatings and inhibitors, are also reviewed. Finally, future development directions for studying corrosion in a supercritical CO_2 environment are proposed.

1. Introduction

Recently, with the rapid development of industry, the combustion of chemical fuels, such as oil and coal, has produced large amounts of greenhouse gases, which have negative impacts on the global climate. With the increasing emphasis on global climate issues, how to reduce emissions of greenhouse gases, such as CO_2, is receiving increasing attention all over the world (Choi and Nešić, 2011; Sim et al., 2013b). "Safe and economical CO_2 capture and storage technology (CCS) is an important technology for solving global climate change" was proposed by the Global Climate UN – COP24 (Czernichowski-Lauriol et al., 2018). In response to this proposal, CCS is certain to be an important development direction (Bhave et al., 2017; Reiner, 2016).

The process of CCS involves the following three stages: capture of the CO_2 from the power plant or industrial process, transmission of the CO_2, and storage in a geological reservoir (Gibbins and Chalmers, 2008; Lilliestam et al., 2012; Pearson et al., 2013). In terms of the CO_2 transportation, the use of a pipeline is the most economical option. To increase the CO_2 density and avoid two-phase flow, the CO_2 transported through pipelines is typically compressed into a supercritical state (larger than 7.38 MPa, 31.1 °C) (Boot-Handford et al., 2014; Gale and Davison, 2003; Kruse and Tekiela, 1996; Liu et al., 2016; Sim et al., 2013b; Vandeginste and Piessens, 2008). However, high pressure increases the solubility of CO_2 in water, resulting in the production of high concentrations of H_2CO_3 solution, which increases the corrosion rate. Moreover, other impurities such as H_2SO_4, HNO_3, HCl, SO_X and NO_X may also exist in the CO_2 gas. The extreme condition and various possible impurities pose serious challenges to pipeline transportation. The presence of these impurities reduces the solubility of water and lowers the pH of the aqueous phase, thereby altering the structure of the corrosion product film and further exacerbating the corrosion of the material. (Seevam et al., 2008). Substantial experimental and theoretical data are needed to aid in the corrosion protection of the supercritical CO_2 transport pipeline, especially regarding the effect of the interactions between NO_2 and other impurities on the evolution of localized corrosion.

The study of corrosion behaviour in a supercritical CO_2 environment has become a hot spot. (Kang et al., 2013; Kanniche et al., 2010; Merkel et al., 2010; Thiruvenkatachari et al., 2009). Based on the previous studies, in this paper, the research progress on corrosion in a supercritical CO_2 environment is comprehensively reviewed. The effects of different factors on the corrosion rate, corrosion products and corrosion progress in a supercritical CO_2 environment and the antisepsis methods in a supercritical CO_2 environment are categorically summarized. The

* Corresponding authors at: No. 66, West Changjiang Road, Huangdao District, Qingdao, China.
E-mail addresses: chennacuigan@163.com (G. Cui), zilimenhuzu@163.com (Z. Li).

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