



Cavitation erosion behaviour of 20SiMn low alloy steel in Na_2SO_4 and NaHCO_3 solutions

Sheng Li Jiang, Yu Gui Zheng ^{*}, Zhi Ming Yao

*State Key Laboratory for Corrosion and Protection, Institute of Metal Research,
Chinese Academy of Sciences, South Campus, 62 Wencui Road, Shenyang 110016, China*

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Abstract

Most of the former studies on cavitation erosion (CE) in corrosive media were carried out in NaCl solutions. In contrast, the effects of SO_4^{2-} and HCO_3^- ions, which are dominant anions in most rivers of China, on cavitation erosion have not been investigated systematically. In this paper, the cavitation erosion behaviour of 20SiMn low alloy steel in Na_2SO_4 and NaHCO_3 solutions was investigated by using a magnetostrictive-induced CE facility. The micrographs of damaged surfaces were observed by scanning electron microscope (SEM). It was found that the CE rate of 20SiMn low alloy steel in 0.003% Na_2SO_4 solution was higher than that in 0.003% NaCl solution, but in 0.03%, 0.3%, and 3% solutions their CE rate was almost the same. The CE rate of 20SiMn low alloy steel in 0.003–3% NaHCO_3 solutions was higher than that in the equivalent 0.003–3% Na_2SO_4 and 0.003–3% NaCl solutions, which may be related to stress corrosion cracking or corrosion fatigue mechanism in NaHCO_3 solutions. The role of corrosion was analyzed by using polarization curves, electrochemical impedance spectroscopy (EIS), linear polarization resistance and the corrosion potential with or without cavitation. Independent of the test media, cavitation shifted the corrosion potential in the positive direction and strongly enhanced the cathodic current density in the polarization curves. In the interaction of cavitation erosion and corrosion, the corrosion-induced erosion component was predominant. Cavitation also greatly reduced the magnitude of impedance though the initial impedance under cavitation conditions in 3% NaHCO_3 solution was almost one order larger than that in 3% Na_2SO_4 solution.

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^{*} Corresponding author. Tel.: +86 24 2392 8381; fax: +86 24 2389 4149.

E-mail addresses: yzheng@imr.ac.cn, icpmkaist@yahoo.com (Y.G. Zheng).

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1. Introduction

Cavitation erosion (CE) is a serious problem in engineering components in contact with a liquid in which the pressure fluctuates. From a review of existing research, studies on cavitation erosion in corrosive media are relatively few and most of them have been carried out in NaCl solutions [1–4]. Neville and McDougall [1] found that all of the four studied materials (commercially pure Ti and three Ti-alloys) exhibited passive behavior in static conditions and when exposed to a cavitating liquid only commercially pure titanium became active. Al-Hashem et al. [2] conducted a laboratory study on the cavitation corrosion behaviour of a commercial cast duplex stainless steel in seawater using an ultrasonically-induced cavitation facility. Mass loss, free-corrosion potential, potentiodynamic polarization, and microscopic examinations were compared in the absence and presence of cavitation. Based on the polarization curves in the absence and presence of cavitation, the alloy passivated spontaneously without an active-to-passive transition. Cavitation slightly increased the cathodic and anodic currents, shifted the corrosion potential in the noble direction and decreased the breakdown potential. In our research group, Luo et al. [3] investigated the cavitation corrosion behaviour of 20SiMn low alloy steel in both distilled water and 3% NaCl solution using polarization curves, electrochemical impedance spectroscopy (EIS), linear polarization resistance, and the corrosion potential with or without cavitation. The role of corrosion was analyzed and the effect of cavitation on corrosion behavior of 20SiMn steel was compared to that of oxygen bubbling. Cavitation shifted the corrosion potential in the positive direction, strongly enhanced the cathodic current density in the polarization curves and reduced the magnitude of impedance. Kwok et al. [4] studied the cavitation erosion and corrosion characteristics of various engineering alloys including grey cast iron, steels, copper-based alloys and stainless steels in distilled water and in 3.5% NaCl solution. The contributions of pure mechanical erosion, electrochemical corrosion, and the synergism between erosion and corrosion to the overall cavitation erosion corrosion in 3.5% NaCl solution were determined. It was found that in 3.5% NaCl solution, the effect of corrosion on the overall cavitation erosion–corrosion was most pronounced in mild steel and grey cast iron, and negligible in stainless steels. In fact main anions of most rivers in China were SO_4^{2-} and HCO_3^- ions, which were several times higher than the concentration of Cl^- ion [5]. In addition, solutions of these anions in different rivers were varied a lot. For example, contents of SO_4^{2-} and HCO_3^- anions in the Yangtse River were 13.4 mg/L and 128 mg/L, respectively, while in the Yellow River their contents were 82 mg/L and 162 mg/L, respectively [5]. But, the contents of SO_4^{2-} and HCO_3^- anions in Talimu River were as high as 6052 mg/L and 117.3 mg/L, respectively. This causes a problem for flow-handling components of hydraulic turbines and pumps made of carbon steels or low alloy steels, which may suffer the combined damage of cavitation erosion and electrochemical corrosion under solutions containing such anions.

Previous studies on cavitation erosion showed that both mechanical and electrochemical factors are involved in the damage process. In a large number of systems the conjoint action of electrochemical and mechanical factors produce far more damage than if each acted separately [4,6–8]. The erosion and corrosion of cast iron owing to cavitation erosion

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