Degradation of the ultimate load about a corroded subsea pipe repaired with CFRP under long-term seawater immersion

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ABSTRACT

Corroded pipes are increasingly repaired with composite material because of its low cost, simple and quick process. However, the repair effect will be affected by factors such as long time loads, seawater immersion and so on. This paper studies the effect of prolonged seawater immersion on the ultimate load of a corroded pipe repaired with CFRP using Finite Element Method (FEM). This FEM model considering the damage of CFRP, adhesive and steel could simulate the failure of pipes repaired with CFRP, and the error between experimental results and FEM results is within 6%.

KEYWORDS: Degradation; CFRP repaired pipe; seawater; ultimate load; Finite Element Method.

INTRODUCTION

The subsea pipes are important in the development, production and transportation of oil and gas, and corrosion in pipes is a common kind of failures. Generally, there are three methods of repairing subsea pipes: welding, fixture and composite material. Corroded pipes are increasingly repaired using CFRP because of its low cost, simple and quick process (Michael BJ, 2009). However, the repair will be affected by factors such as long time loads and seawater immersion. With the increase of the service time, the repair effect will degrade, it may even cause the failure of the pipe, resulting in serious environmental pollution and huge economic losses (Xin JH, 2019). Therefore, it is of great significance to study the effect of these factors on the ultimate load of repaired pipes, such as the seawater immersion and loads.

At present, a great deal of researches have been done on the CFRP repaired pipes and the degradation of composite material. Mableson AR (2000) introduced a glass fiber composite material repaired steel pipe system, which can repair external corrosion and mechanical damage of pipe.Besides, based on the fracture mechanics criteria, a mathematical model was established to analyze the repair effect of composite materials. Peck JA (2004) used simple four-point bending and internal pressure experiments to evaluate the mechanical properties of the composite repaired pipes, and used a finite element method to do comparative analysis, it was found that the finite element analysis results were in good agreement with experimental results. Secica VM (2007) studied the repair effect of FRP for tubular steel members and the structural performance of composite system through experiments. The results showed that the composite material could enhance and improve the mechanical properties of pipes. Duell JM (2008) used FRP material to repair and strengthen the corroded pipe through experiments, and analyzed the results through a finite element method. It showed that the defect width had no effect on the ultimate internal pressure, but would affect the stress of the pipe. Ahmed S (2011) studied the ultimate compressive strain of CFRP repaired pipe under combined loads by finite element method. It was found that the maximum strain would not appear in the defect area, and local bending appeared in the undamaged area of pipe. Chan PH (2015) studied the mechanical properties of steel pipes repaired by CFRP under a bending load using experimental method and finite element method. The results showed that CFRP could increase the bending stiffness of the corroded pipe. Zhang Y (2018) studied the stress distributions of adhesive in a cracked steel plate repaired with CFRP. It was found that the maximum shear stress and peel stress in the adhesive were obtained from products of stress ratios and stresses, and the adhesive failure or the maximum load could be simply predicted by using quadratic stress criteria. Sirruk A (2014) studied the water absorption of the composite in tap water, distilled water and seawater. The results showed that the ultimate strength and elastic modulus of the composite decreased due to long-term immersion in seawater. The cyclic tensile load test of the composite was also carried out, which indicated that the fatigue life of the composite was reduced by 30%. Kabir MH (2016) studied the durability of CFRP structural members under long-term low temperature environment by means of experiments and finite element analysis. It showed that the strength and stiffness of CFRP structural members would be reduced in 12 months under low temperature environment. Kabir MH (2016) used two adhesives to study the durability of the mechanical properties of steel structure strengthened by CFRP in cold weather for three months and six months. It showed that low temperature immersion has adverse effect on the durability of steel structure. Xin JH (2019) studied the ultimate load of CFRP repaired pipes under long-term seawater immersion and bending moment, the experiment showed that the ultimate bending load decreases with the increasing of time, and the decrease of the interfacial bonding strength of CFRP repaired pipe and CFRP strength resulted in the decline of the ultimate load.

This paper study the effect of prolonged seawater immersion on the ultimate load of CFRP repaired corroded pipe by using a finite element approach. The mechanical properties of CFRP and adhesive after different seawater immersion time are obtained from experiments, and