The influence of sea water corrosion on the resistance cracking performance of carbon steel

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Abstract As carbon steel immersed in seawater with loading, particularly with defect, its performance lead degradation and reduction in bear capacity. For the specimen of carbon steel immersed in seawater with notch and defects, its macro-mechanical properties was tested and also analyzed with electron microscopy equipment. The fracture behavior of specimen was analyzed in different test conditions, and their bearing capacity was contrast each other for loading before and after soaking. Some relation curves are gotten as the curve of crack tip opening displacement and loading, or relation between loading and the displacement of loading point for specimen before or after soaking in seawater. The specimen with plastic zone of crack-tip was soaked in seawater for short-term, according to the analysis of experimental results, the length of plastic curve between reloading and displacement is become shorter, and the material is more brittle. In the area of meso-analysis, fracture performance of seawater corrosion steel were investigated by electron microscopic observation, and checked the difference of characteristics parameters and meso-morphologies of material specimen. As to plastic, the effect of seawater on carbon steel dislocation and slip were also researched in the paper.

Key Words Carbon steel；seawater corrosion；elasto-plastic fracture；microscopic analysis；bearing capacity of structure with crack

1. Introduction

Seawater corrosion affects the mechanical properties of steel, and complex water environment is a source of metal corrosion[1-3]. For the complex corrosion process of Q235 steel in seawater, its behavior shows that the factors of affecting corrosion is including not only the voltage and pH value of them, but also microbial perturbation on the metal surface near[4-5]. The magnetic detection is also effective means to analyze the corrosion. The consequences of corrosion of metallic materials is not only reflected its weight reduction, but also it is the deterioration of bearing capacity and mechanical properties of its structure. So, the stress corrosion and fracture properties of steel is an important investigate field for anti-corrosion and material scientists.

2. Influence of seawater immersion on steel fracture process curve

The steel material were made into the test specimen of beam with prefabricated crack, and it were placed on an experiment equipment for the loading of three point bending. As shown in Figure 1, the curve of loading and the displacement of load point are expressed by series of point. For the point of square or triangle, the size of its specimen is that high

60mm, thickness 60mm, the length of prefabricated crack 18mm, the loading span 240mm and so on. The square point indicates the data of specimen without seawater immersion, and the triangle is for the specimen in seawater 60d. The hollow dots is for the specimen (H60B40A18) of dimension high 60mm, thickness 40mm, prefabricated crack length 18mm, and it is a load-displacement curve of initial loading, unloading and reloading continuously. Obviously, unloading and reloading curves are basically coincident. But the slope of curve is larger compare to the curve slope from zero load, and the results shows the material having harden characteristics. The solid circular point indicates the load-displacement curve of specimen that the 'H60B40A18' were loaded into the plastic phase, and unloaded to zero, then it immersed in seawater for 30d, and reloading on the same equipment. However, the displacement had been added the original plastic residual displacement after unloading. It can be seen that the curve slope of plastic seawater loading is lower than the unloading curve. And the curve segment become shorter over linear loading part. It shows the material performance having deterioration. For two kinds of thickness of specimen, the thicker specimen is increased significantly for the bearing capacity and deformation resistance ability of it

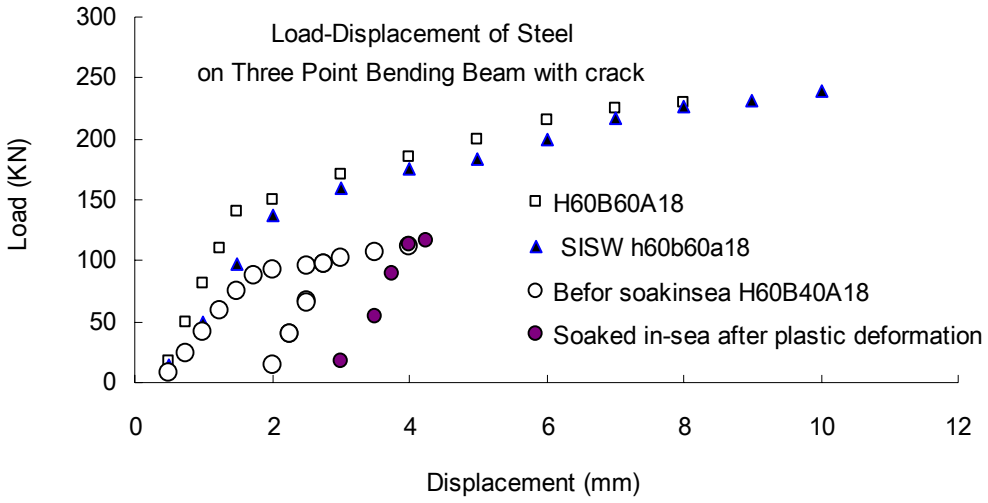


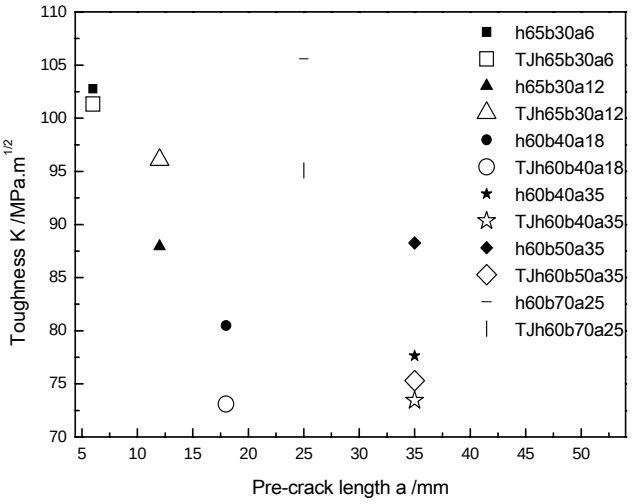
Fig 1. The curve of load-displacement for three point bending steel beam with crack

3. The influence of seawater immersion on specimen toughness

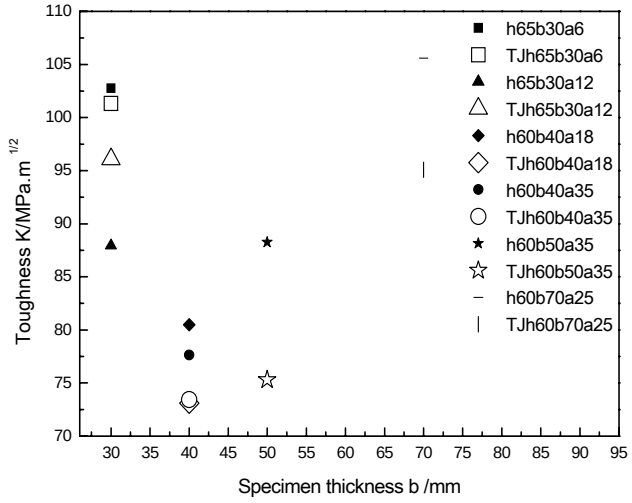
For the specimen of three point bending beam with incision, its stress intensity factor near incision root can be expressed as follows[6]

$$K_I = 1.5PS\sqrt{a}\,\frac{1.99-\frac{a}{h}\left(1-\frac{a}{h}\right)\left(2.15-3.93\frac{a}{h}+2.7\left(\frac{a}{h}\right)^2\right)}{bh^2\left(1+\frac{2a}{h}\right)\left(1-\frac{a}{h}\right)^{3/2}} \qquad (1)$$

Here, the symbol h, b, a and s are respectively represent the height, thickness, crack length and loading span. The fracture toughness of many specimens with different thickness or different prefabricated crack length, are shown in Figure 2 (a, b). Among them, the solid symbol indicates the fracture toughness of specimen without seawater immersion. And, the hollow symbols or vertical line is for the toughness value of specimen soaked in seawater for short-term that were unloading to zero after loaded firstly into the plastic stage. Figure 2(a) shows the variation of specimen fracture toughness with crack length. And Fig 2 (b) express the variation of toughness with specimen thickness. It can be seen that the toughness of seawater immersion specimen after plastic deformation is smaller than that of specimen without seawater immersion. The fracture toughness increases of specimen with the increasing of its thickness, and its toughness decreases with the increase of prefabricated crack length.



a）

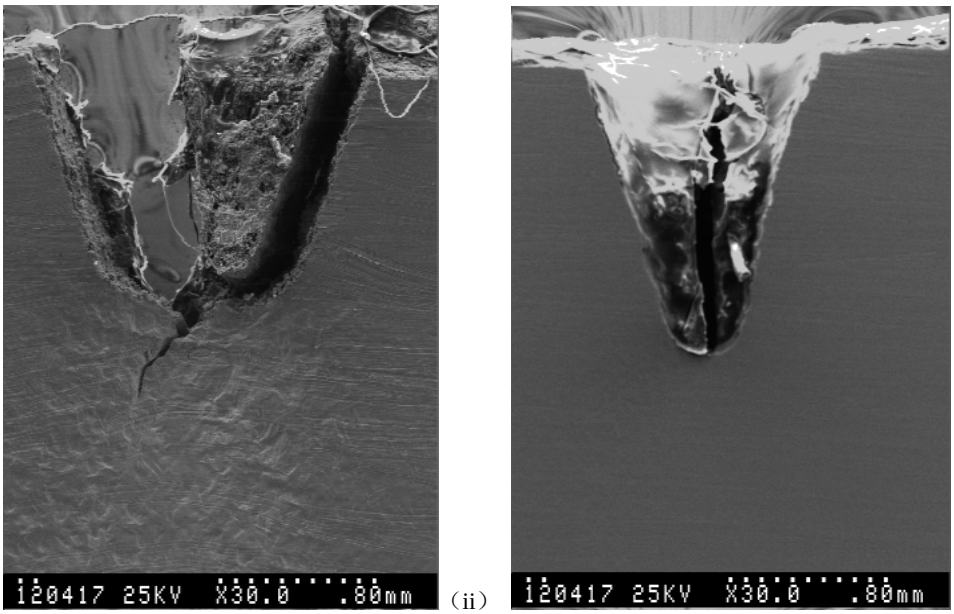


b）

Fig 2 The toughness of steel soaked in seawater or not for different pre-crack (a) or thickness (b)

4.The SEM morphology of specimen in seawater immersion

As shown in Figure 3 (i,ii)， they are the SEM photos of the location of carbon steel specimen in uniaxial tension, and its appearance size is about long 20mm, wide 4mm, thickness 0.6mm. Fig3. (i) is about the specimen soaked in seawater for 90 days, and Figure (ii) is the photo of specimen without seawater. The size and crack length of both specimen is the same about 1.5mm. The specimen shown in Fig 3. (i) is loaded for tension 1240N, and that in Fig 3(ii) is for 1656N. As to the specimen immersed in seawater, it has the phenomena of cracking and slip twinning in disorder. The images show that the steel of soaked in seawater becoming deterioration in the mechanical properties of material, and its performance of resistance damage ability is also reducing obviously.



（i） （ii）

Fig 3 SEM Photos of Steel specimen （i）after soaked in seawater at load 1240 N；
（ii） not in seawater at load 1656N

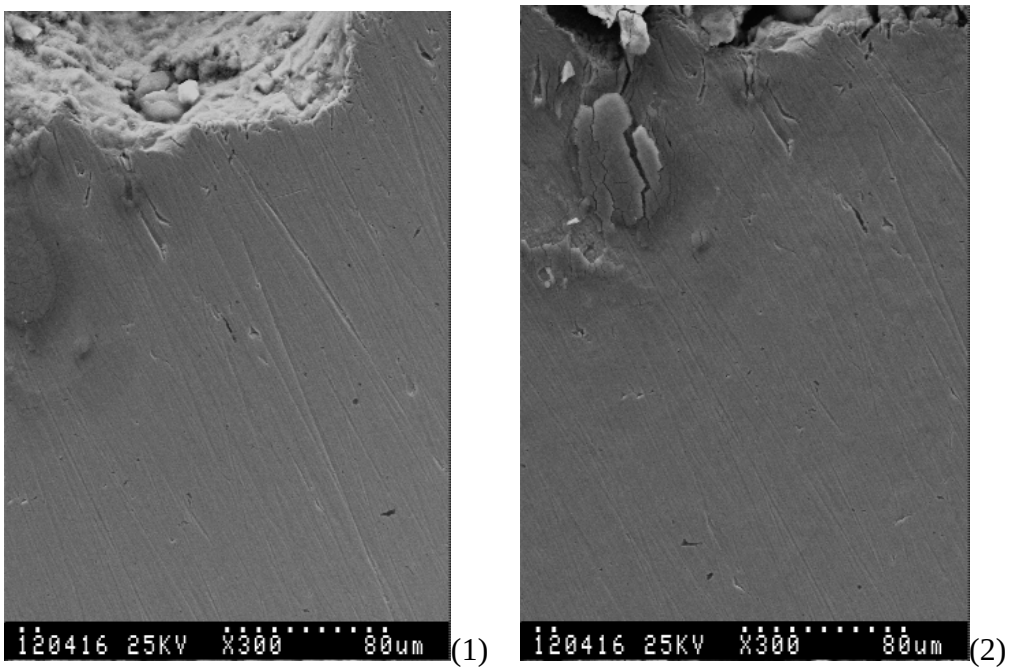
The SEM photos of specimen on local corrosion part in seawater are shown in Fig 4. Here, figure (1) is for conditions without load, and figure (2) for loading 1850N. The corrosion defects and corrosion surface shedding can be seen after loading on specimen in the right picture.

5. Conclusion

1) For the steel specimen of three point bending beam with crack, its seawater immersion of short time is not significant influence on the curve of loading and displacement of experiment. But, the specimen fracture toughness slightly reduced, deformation curve become shorter or becoming brittle, when it were reloaded after loaded to plastic stage

and immersion in seawater for a period time.

2）It is found by scanning electron microscopy that the specimens of short-term sea immersion exists obvious corrosion defects, disorder slip twinning and its capacity of resistance cracking was lower than the specimen without seawater.



(1) (2)

Fig 4 The photos of steel local part corroded in seawater at different load （1）after soaked in seawater at load 0 N, （2） not in seawater at load 1850N

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