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The research of axial corrosion fatigue on 10Ni3CrMoV steel

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Abstract. Fatigue life had been studied with 10CrNi3MoV steel at different load ratios and in different environmental medias. The microstructure and micro-topography had been observed and analyzed by means of SEM, EDS and TEM. Our findings indicated that, the fatigue life of 10Ni3CrMoV steel in seawater was shorter than in air, the difference in longevity was larger with the decreasing of axis stress. Corrosion pits had a great influence on corrosion fatigue life.

1 Introduction

10CrNi3MoV steel, because of its material mechanical performance, can meet the demand of many Marine machinery equipment strength design. In addition, the hull was hit repeatedly in the water, which required the pressure hull structure have the ability to resist the failure of fatigue, so the research on the fatigue test performance of the pressure hull was of great significance. Many literatures mentioned the morphology and mechanism of initiation crack, however the conclusion was not uniform. In this article, after the test of the initiation life of 10Ni3CrMoV steel in air and in seawater, we found that the mechanism of the longevity gap between the fatigue life in seawater and in air.

2 Test material & methodology

Chemical composition of 10CrNi3MoV steel was shown in Table 1. 10CrNi3MoV steel was supplied in quenched and tempered state, its mechanical properties were shown in Table 2, and its metallographic structure was illustrated in Fig.1, indicating 10CrNi3MoV steel was mainly composed of tempered sorbite.

The size of fatigue test specimens were shown in Fig.2. The axial stress was set at three constant value of $0.65R_{0.2}$、$0.75R_{0.2}$、$0.85R_{0.2}$ respectively , ratio=0.5, f=1HZ. The corrosion fatigue test was conducted in artificial saltwater prepared according to Standard Test Method for Fatigue Fracture Growth Rates of Metallic Materials (GB6398-2000) Schedule C on MTS Landmark. During the test, SEB specimens were constantly sealed in an environmental test chamber specially converted for corrosion fatigue test, the environmental test chamber was used for storing artificial saltwater, and recharged solution in terms of test duration. At the end of the test, observed microstructure with SEM, EDS, TEM.

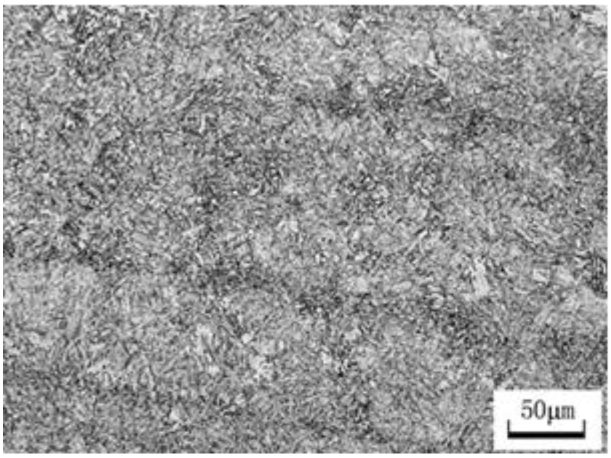

Fig.1 Metallographic Microstructure of 10CrNi3MoV Steel

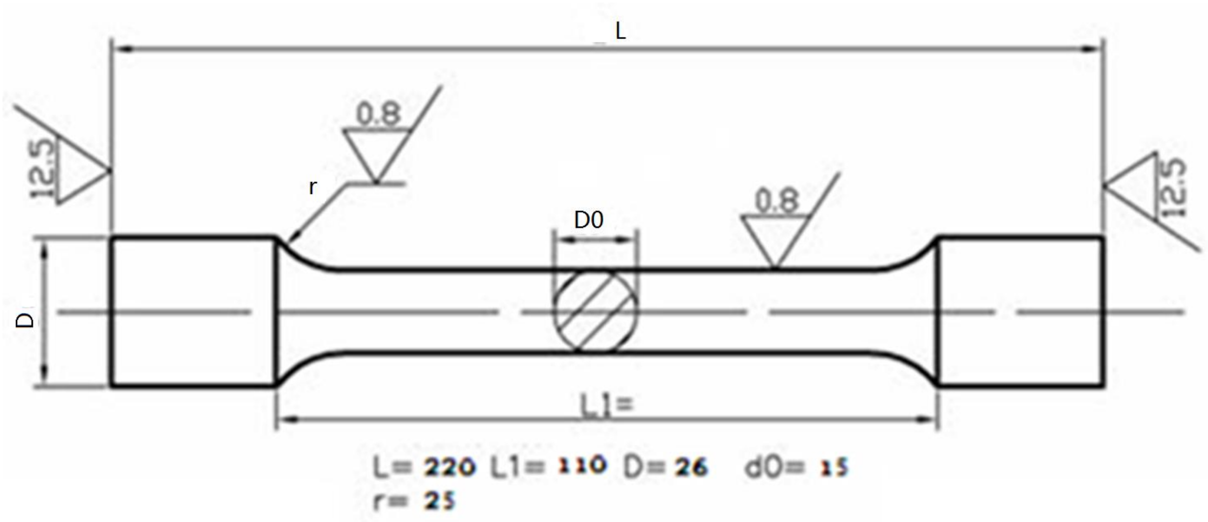

Fig.2 Specimen Size

Table 1 Component of 10CrNi3MoV steel (mass fraction /%)

Si	Mn	Ni	Cr	Mo	C	S
0.25	0.54	2.88	0.86	0.40	0.09	< 0.005

Table 2 Mechanical properties of 10CrNi3MoV steel

$\sigma_{0.2}$/Mpa	σ_b/MPa	δ/%	ψ/%	K_{IC}/（MPa·$\sqrt{m}$）
636	690	22	79.3	86

3 Test Result & Analysis

3.1 fatigue life

As was shown in Fig.3, the fatigue life of 10CrNi5MoV and its difference in longevity in two kinds of corrosion environment were larger with the decreasing of axial stress.

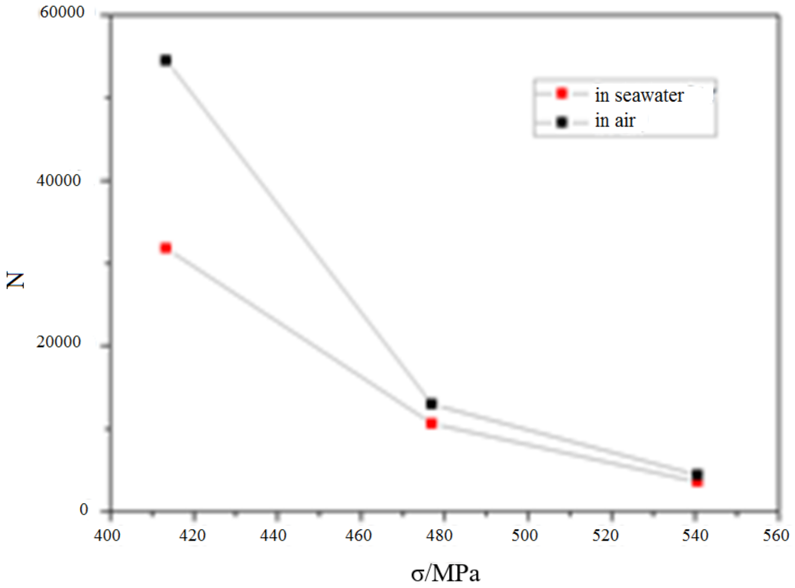

Fig.3 the fatigue life in air and in seawater

3.2 Analysis of microstructure

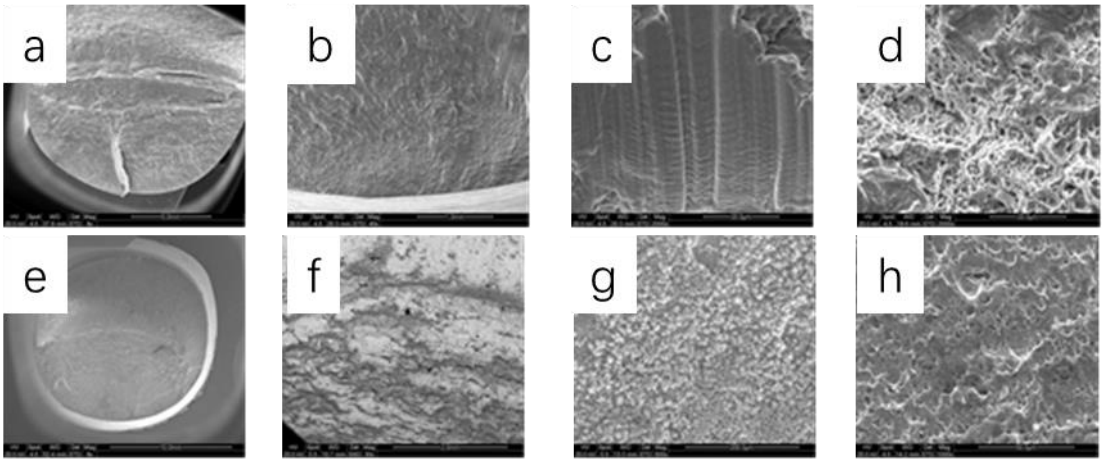

Fig.4 fatigue fracture (a, b, c, d in the air; e, f, g, h in the seawater)

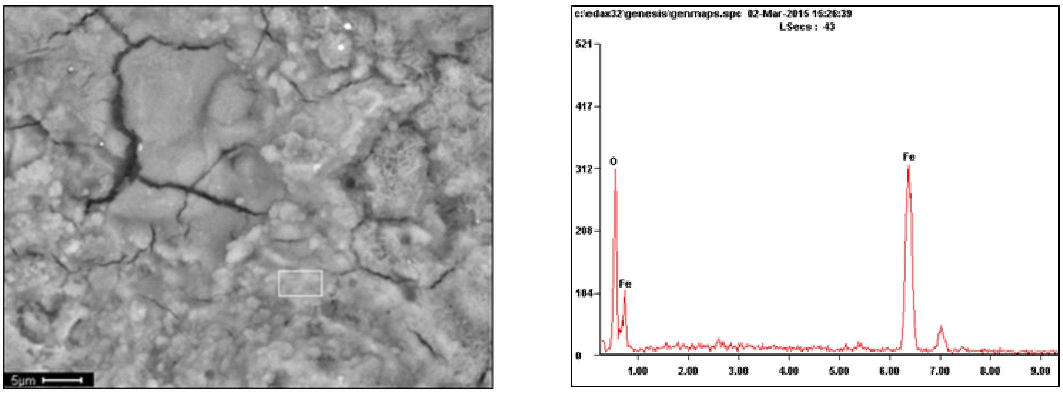

Fig.5 EDS analysis of corrosion fracture

Crack initiation zone in air was shown in Fig.4b, we could find the concentration of fatigue bands. In Fig.4c, distinct striations which had an appearance of tire can be observed in crack extension zone.

And the striations had an right angle to the direction of crack propagation. The area full of dimples was called the instantaneous fracture zone in Fig.4d, it had a typical feature of ductile fracture. Fig.4f,g were crack initiation zone and crack extension zone respectively in seawater. Because of the corrosion of seawater, fracture surface was covered by oxidation products, so its morphology characteristics were difficult to distinguish. But in Fig.4h, it still maintains the feature of ductile fracture. It explained that the seawater did not enter the area before ultimately fracture. The EDS analysis of corrosion fracture which were shown in Fig.5 indicated corrosion products of Fe oxides.

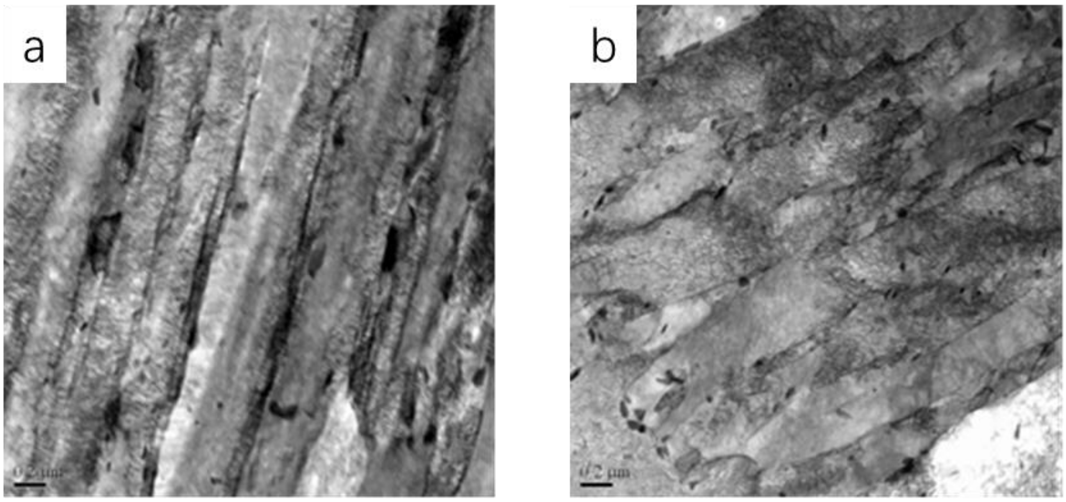

Fig. 6 TEM image (a. Normal Part; b. The area near fracture)

Make film specimens from normal part and the area near fracture before TEM observation. By comparing Fig. 6a and b at the same magnification, we could find lath in the area near fracture was seriously distorted in contrast with original structure, lath boundary was unclear in profile, obvious fragmentation occurred. Furthermore, dislocation clustering was visible in the laths in the zone close to crack tip, resulting in the appearance of fine sub-crystal cell and dislocation wall. We can conclude that severe plastic deformation had occurred in the area near the fracture.

4 Conclusion

With the decreasing of axial stress, the fatigue life was longer, and the difference in longevity was larger between in air and in seawater. The mechanism of crack initiation of 10Ni3CrMoV steel between in air and in seawater was different. There was a larger dislocation density and plastic deformation near the fracture in air than in seawater. Fracture surface was covered by oxidation products in seawater, it indicated that the mechanisms of cracking and extension of crack were influenced by corrosion environment.

References

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