Research Article

Effect of Microstructure on the Corrosion Fatigue Crack Growth of Low and Medium Steels

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This article studies the effect of microstructure on the corrosion fatigue crack growth behavior of low and medium carbon steels. 45 steel and 15CrMo were selected and five typical microstructures were obtained by different heat treatment processes. The microstructures of 45 steel and 15CrMo after annealing and normalizing are both ferrite and pearlite, but the proportions of ferrite and pearlite in the four microstructures are different. The quenching and tempering microstructure of 45 steel is tempered fine pearlite. Corrosion fatigue tests were conducted on specimens with different microstructures of the two materials. Expressions of corrosion fatigue crack growth rate and $da/dN\sim\Delta K$ fitting curves of different microstructures were obtained. Comparison of $da/dN\sim\Delta K$ curves of 45 steel shows that tempered fine pearlite has the best resistance to corrosion fatigue crack growth, and the content of pearlite has a great impact on the corrosion fatigue crack growth behavior for specimens with the microstructure of ferrite and pearlite. In the low $\Delta K$ region, the corrosion factor plays a dominant role in fatigue crack growth, and the corrosion resistance of pearlite is weak, which leads to a higher $da/dN$ in the normalized state. In the high $\Delta K$ region, fatigue factor dominants, since the fatigue resistance of pearlite is strong, $da/dN$ of the annealed state is higher. The experimental results of 15CrMo showed the same crack growth rate change regulation as that of 45 steel, which further proves the effect of pearlite on the corrosion fatigue crack propagation behavior.

1. Introduction

For the safety needs of energy and petrochemical industry, hydrogen corrosion has become the focus of concern in the engineering application circles. Oil and gas storage and transportation devices, such as pipelines, pressure vessels, and petrochemical machinery have been in a corrosive environment containing hydrogen sulfide (H$_2$S), most of which also serve under alternating stress. Steel exposed to acidic environment will lead to hydrogen embrittlement (HE) [1], thereby reducing the fatigue life and fatigue strength of the material [2].

In industry, heat treatment, cold rolling, hot rolling, and other processes are often used to optimize the properties of metals by changing their microstructures [3]. The previous works found that the microstructure has a great influence on both hydrogen corrosion performance and fatigue crack propagation performance. For example, Nanninga et al. [4] obtained different microstructures by controlling tempering temperature, and studied the HE resistance of steels with the same carbon content but different other components. Results revealed that the chemical composition has little effect on the degree of HE of the steel, and the change of microstructure has a great impact on HE resistance of the steel. Jang et al. [5] changed the volume fraction of bainite of dual-phase (bainite/martensite) steel by using different heat treatment methods, and studied the relationship between bainite content and HE resistance. The result means that the material with the highest bainite content has the best HE resistance. Besides good hydrogen corrosion resistance, bainite also has good fatigue resistance. Hui et al. [6] studied the high-cycle fatigue behavior of bainite steel 25MnCrVS.
and ferrite and pearlite steel 38MnVS by experiments, and found that the fatigue crack growth rate (FCGR) of bainite steel is significantly lower than that of ferrite and pearlite steel, which shows that the fatigue resistance of bainite is better than that of ferrite and pearlite. In addition, Wu et al. [7] recently studied the FCGR of hot rolled 316 austenitic stainless steel in hydrogen environment by controlling rolling temperature and rolling strain. They found that the rolling strain had little effect on the FCGR of the material in hydrogen environment, and the effect of rolling temperature on the FCGR was mainly reflected in the austenite-martensite conversion near the crack. The higher the temperature, the lower the martensite transformation content, the slower the FCGR of the material in hydrogen environment.

From these works, we can see that most of the studies are only concerned with the effect of microstructure on corrosion resistance property or fatigue property. However, corrosion fatigue behavior is affected by the coupling interaction of corrosion and fatigue behavior. Thus, it is necessary to highlight the significance of the microstructure on corrosion fatigue property.

45 steel is a common medium-carbon high-quality structural steel, which is often used as an example of metallographic structure contrast test because of its simple components, good mechanical properties, and obvious changes in microstructure after heat treatments. 15CrMo is a widely used steel for pressure vessels with good toughness, corrosion resistance, and oxidation resistance, and its phase transformation law is similar to 45 steel. Therefore, this article takes 45 steel and 15CrMo as the research objects, obtains typical microstructures through different heat treatment processes, and the effect of different microstructures on fatigue crack propagation performance in H2S corrosion environment was investigated through a corrosion fatigue test. This can provide basic data support for safety evaluation and life prediction of petrochemical industry equipment, and provide guarantee for engineering application.

2. Experimental Investigation

2.1. Materials. Here, some typical heat treatment processes were conducted to gain different microstructures. Tables 1 and 2 are chemical compositions of 45 steel [8] and 15CrMo, respectively, and heat treatment processes [8] are presented in Table 3. A sample with the dimensions of 70 mm × 60 mm × 20 mm was used to perform the heat treatment process, after heat treatment, the steel block was machined into a test specimen.

The VHX-500K electron microscope was used to observe the microstructures of the specimens. The microstructures of 45 steel under three heat treatment states are illustrated in Figure 1, and the microstructures of 15CrMo under two heat treatment states are illustrated in Figure 2.

As can be seen from Figure 1, the full annealed microstructure of 45 steel is mainly ferrite, with some pearlite doped in it, and the microstructure is homogeneous, the pearlite content is about 40%. The microstructure of the normalized specimen is also homogeneous and consisted of pearlite and ferrite, and the content of pearlite is about 70%. The microstructure of quenched and tempered specimen is mainly tempered fine pearlite, showing a homogeneous acicular structure distribution.

From Figure 2, it can be seen that the full annealed microstructure of 15CrMo contains a large amount of ferrite, and the pearlite is loosely distributed in the ferrite matrix, with the content below 10%. The normalized microstructure is also typical of ferrite and pearlite, which contains about 40% pearlite and 60% ferrite.

2.2. Specimens. The modified wedge-open loading (WOL) specimen is selected for the corrosion fatigue test. The diagram of the specimen is shown in Figure 3, the thickness of specimen B = 15 mm, the width of specimen W = 48.5 mm, and the initial crack length a is set to be 0.45 W.

2.3. Experimental Procedure. The corrosion fatigue tests are carried out on 45 steel under three heat treatment states and 15CrMo under two heat treatment states. These tests are performed according to standard GB/T6398-2017 "Fatigue Crack Growth Rate Test Method of Metal Materials" [9]. Alternating stress is applied to the specimens immersed in saturated H2S solution by a corrosion fatigue testing machine. The data are collected automatically by computer and calculated in MATLAB software.

The relationship between FCGR and stress intensity factor range (ΔK) near the crack tip can be described by the Paris equation:

\[
\frac{da}{dN} = C(\Delta K)^n, \tag{1}
\]

where ΔK is the stress intensity factor range, C and n are constants related to the specimen material and can be received by curve fitting.

ΔK can be calculated by equation:

\[
\Delta K = \frac{\Delta P \cdot C_3(a/W)}{B \cdot \sqrt{a}}, \tag{2}
\]

where ΔP = P_{max} - P_{min} is the alternating load, a is the length of crack, W is the width of specimen, and B is the thickness of specimen, C_3(a/W) is the dimensionless compliance, and it is the function of a/W:

\[
C_3\left(\frac{a}{W}\right) = \left[30.96\left(\frac{a}{W}\right) - 195.8\left(\frac{a}{W}\right)^2 + 730.6\left(\frac{a}{W}\right)^3 - 1186.3\left(\frac{a}{W}\right)^4 + 754.6\left(\frac{a}{W}\right)^5\right]. \tag{3}
\]
Since the alternating load $\Delta P$ is constant, $\Delta K_i$ in every moment can be obtained from the crack length $a_i$ by using the compliance equation:

$$
\frac{V}{P} = \frac{C_6 (a/W)}{EB},
$$

(4)
where \( V \) is the crack opening displacement, in the experimental process, \( V \) can be measured by a clip gage; \( P \) is the load and can be recorded by the test machine automatically; \( E \) is Young’s modulus; \( B \) is the thickness of the specimen; and \( C_6 (a/W) \) can be obtained by the following equation:

\[
C_6 \left( \frac{a}{W} \right) = e^{\left[4.495 - 16.130 \left( \frac{a}{W} \right) + 43.830 \left( \frac{a}{W} \right)^2 - 89.123 \left( \frac{a}{W} \right)^3 + 46.815 \left( \frac{a}{W} \right)^4\right]}.
\]

(5)

The compliance equation shows that the crack length \( a_i \) can be calculated as long as the crack opening displacement \( V \) is gained by a clip gage.

### 2.4. Experimental Parameters.

Standard A solution recommended by the National Association of Corrosion Engineers International (NACE) [10], namely 5% NaCl + 0.5% CH₃COOH + 94.5% deionized water, saturated with H₂S gas, is used as the corrosion environment.

Based on the research of Schmidt and Paris [11] and through our test, it is found that when the stress ratio is less than 0.5, crack closure phenomena may occur at the crack tip. In order to avoid the influence of crack closure, the stress ratio is set to 0.7. Since pipelines, pressure vessels, and chemical equipment in the petrochemical industry generally work under low-cycle loading, after considering the factors such as test cycle and instrument capacity, the test loading frequency is set to 0.01 Hz, and the loading waveform is set to trapezoidal.

### 3. Results

Incremental polynomial method recommended in GB/T6398-2017 “Fatigue Crack Growth Rate Test Method of Metal Materials” [9] is applied to obtain the crack growth rate \( (da/dN) \) under each cycle, and \( \Delta K \) of each cycle is calculated by equation (2), then the \( da/dN-\Delta K \) curves of 45 steel and 15CrMo are plotted in log-log space, respectively, as illustrated in Figures 4 and 5. The Paris equations of the corrosion fatigue curves of the two materials under different heat treatment states are listed in Tables 4 and 5.

### 4. Discussion

Taking the logarithm of both sides of the Paris equation of crack growth rate, we can get:

\[
\lg (da/dN) = \lg C + n \cdot \lg (\Delta K).
\]

It is manifested from equation (6) that in log-log space, the fitting curve of the Paris equation can be considered as a straight line, where \( \lg C \) is the intercept and \( n \) is the slope. The intercept of the straight line represents the initial crack growth rate. The larger the intercept, the faster the initial crack growth rate. The slope of the straight line represents the accelerating trend of the crack growth rate. The larger the slope is, the faster the FCGR grows. Table 4 lists the material constants \( C \) and \( n \) of 45 steel with three microstructures under corrosion fatigue conditions. As illustrated in the table that the order of magnitude of the \( C \) value of the annealed state is at the \( 10^{-14} \) level, it is much smaller than that of the normalized state \( (10^{-10}) \) and the quenched and tempered state \( (10^{-11}) \). The \( n \) value of the quenched and tempered state and the normalized state are very close, 3.37 and 3.02, respectively. However, the \( n \) value of the annealed state is the largest, about 4.8 times that of the normalized state. The material constants \( C \) and \( n \) of 15CrMo of two microstructures are given in Table 5. Although the \( C \) value of 15CrMo of the annealed state \( (10^{-11}) \) is smaller than that of the

![Figure 2: Microstructures of 15CrMo: (a) full annealing, (b) normalizing.](image)

![Figure 3: Modified WOL specimen (mm).](image)
The normalized state (10^{-8}) in order of magnitude, the n value of annealed is larger than that of the normalized state, about 2.3 times.

In order to more intuitively present the fatigue crack propagation of materials under different heat treatment states, the da/dN-ΔK fitting curves of all specimens are shown in log-log space.

4.1. Effect of Pearlite Content on FCGR. Figure 6 demonstrates the da/dN-ΔK fitting curves of 45 steel under three heat treatment states, the change trend of the crack growth rate of specimens under three heat treatment states can be seen intuitively. Considering that the microstructure of the annealed state and the normalized state are both ferrite and pearlite, the fitting curves of the annealing state and normalized state are compared. From Figure 6, we can know that when the ΔK is less than 18.7 MPa-m^{1/2}, that is, in the low ΔK region, the crack growth rate of the annealed state is lower than that of the normalized state, but the accelerating trend of the annealed state is very obvious. When the ΔK is more than 18.7 MPa-m^{1/2}, the crack growth rate of the annealed state is much higher than that of the normalized state.

It has been briefly discussed [12] that the resistance to corrosion fatigue crack propagation (CFCP) of material is a comprehensive result of the coupling interaction of corrosion factor and fatigue factor, so the effect of microstructure on the corrosion performance and fatigue performance of the material should all be considered. In the low ΔK region, owing to the low strain rate around the crack tip, the corrosion factor dominates the crack propagation. Li and Wang [13] studied the static hydrogen resistance of 45 steel with different microstructures by layer-by-layer micro-hardness method with thickness of hydrogen embrittlement affected layer and hydrogen induced hardness increment (ΔHV) as parameters. Their main findings are shown in Figures 7 and 8. It can be seen from Figure 7 that in the normalized and annealed specimen with the same pearlite and ferrite microstructure, the thickness of hydrogen embrittlement affected layer with higher pearlite content is larger, indicating that the hydrogen permeation resistance of pearlite is weak. In the case of non-corrosion, the hardness and strength of the normalized and the quenched and tempered specimens have little difference, while the thickness of hydrogen embrittlement affected layer of tempered fine pearlite was significantly smaller than that of pearlite and ferrite, indicating that the hydrogen permeation resistance of tempered fine pearlite is strong. Figure 8 shows the relationship between the ΔHV and the microstructure of 45 steel. The ΔHV of annealing specimen is 24.67HV0.2, normalizing specimen is 42.67HV0.2, and quenching and tempering specimen is about 17HV0.2. The hardness change is related to the hydrogen content. The greater the hardness increment is, the greater the amount of hydrogen permeation into the metal is, and the worse the hydrogen sensitivity of the material is. The above results all show that the hydrogen permeation resistance of tempered fine pearlite is the best, and the hydrogen resistance of pearlite is weaker than that of ferrite. Therefore, in the low ΔK region, the da/dN of normalizing specimen with high pearlite content is higher than the annealed da/dN.

Figures 9(a) and 10(a) are the fracture morphology of the annealed specimen and the normalized specimen at the initial stage of corrosion fatigue crack growth at low magnification (100x), respectively. It can be seen from Figure 9(a) that at the initial stage of crack propagation, there are a large number of wide and deep secondary cracks on the fracture surface of the annealed specimen. For the normalized specimen with the same ferrite and pearlite microstructures as the annealed specimen, the fracture is relatively flat at the initial stage of crack propagation, and only a small amount of short secondary cracks exist. The generation of a large number of secondary cracks will consume the driving energy of crack propagation, thereby
reducing the crack growth rate and enhancing the crack resistance of materials. Therefore, the initial corrosion crack growth rate of the annealed specimen is much lower than that of the normalized specimen.

![Figure 6: The da/dN-ΔK fitting curves of 45 steel.](image)

![Figure 7: The variation law of hydrogen embrittlement influence layer of 45 steel with different microstructures.](image)

Table 4: The Paris equations of the corrosion fatigue curves of 45 steel under three heat treatment states.

<table>
<thead>
<tr>
<th>Heat treatment process</th>
<th>Microstructure</th>
<th>ΔK range (MPa√m)</th>
<th>C</th>
<th>n</th>
<th>Paris formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full annealing</td>
<td>60% ferrite + 40% pearlite</td>
<td>17-21</td>
<td>1.12 × 10^{-14}</td>
<td>14.41</td>
<td>da/dN = 1.12 × 10^{-14} × ΔK^{14.41}</td>
</tr>
<tr>
<td>Normalizing</td>
<td>30% ferrite + 70% pearlite</td>
<td>17-26</td>
<td>3.53 × 10^{-10}</td>
<td>3.02</td>
<td>da/dN = 3.53 × 10^{-10} × ΔK^{3.02}</td>
</tr>
<tr>
<td>Quenching and tempering</td>
<td>Tempered fine pearlite</td>
<td>16-27</td>
<td>1.38 × 10^{-11}</td>
<td>3.73</td>
<td>da/dN = 1.38 × 10^{-11} × ΔK^{3.73}</td>
</tr>
</tbody>
</table>

Table 5: The Paris equations of the corrosion fatigue curves of 15CrMo under two heat treatment states.

<table>
<thead>
<tr>
<th>Heat treatment process</th>
<th>Microstructure</th>
<th>ΔK range (MPa√m)</th>
<th>C</th>
<th>n</th>
<th>Paris formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full annealing</td>
<td>90% ferrite + 10% pearlite</td>
<td>12-21</td>
<td>7.56 × 10^{-11}</td>
<td>4.08</td>
<td>da/dN = 7.56 × 10^{-11} × ΔK^{4.08}</td>
</tr>
<tr>
<td>Normalizing</td>
<td>60% ferrite + 40% pearlite</td>
<td>17-25</td>
<td>3.00 × 10^{-8}</td>
<td>1.77</td>
<td>da/dN = 3.00 × 10^{-8} × ΔK^{1.77}</td>
</tr>
</tbody>
</table>

Figures 9(b) and 10(b) are the fracture morphology of the annealed specimen and the normalized specimen at the initial stage of corrosion fatigue crack growth at high magnification (1000x), respectively. It is manifested from the figure that the fracture surface of the annealed specimen covered a thick layer of corrosion products. The corrosion products are analyzed by EDS, and the results are shown in Figure 9(c). It can be found that the corrosion products are mostly sulfides. This is because hydrogen sulfide will ionize H⁺ and S^{2-} when it enters water, and Fe reacts with S^{2-} to generate iron-sulfur products with different valences (Fe₃S₄, FeS₂, FeS, etc.), which are deposited on the fracture surface of the specimen. At the same time, the hydrogen ions generated by the cathodic reaction diffuse into the metal and are induced by stress to gather at the crack tip because of the triaxial tension stress state, which promotes the propagation of the crack. For the annealed specimen, due to the low crack growth rate at the initial stage and the long time of chemical reaction between metal and corrosion solution, the corrosion products are more and the cover thickness is thicker. However, for the normalized specimen, due to the high initial crack growth rate, although corrosion products can also be seen on the fracture surface, the number and thickness of corrosion products are less than those of the annealed specimen. It can also be seen from Figure 10(b)
Figure 9: Fracture morphology of the annealed specimen at the initial stage of corrosion fatigue crack propagation: (a) 100x. (b) 1000x. (c) EDS analysis.

Figure 10: Fracture morphology of the normalized specimen at the initial stage of corrosion fatigue crack propagation: (a) 100x. (b) 1000x.
that at the initial stage of crack propagation, the fracture of the normalized specimen shows obvious brittle characteristics, and there are river patterns on the fracture which are the same as the direction of corrosion fatigue crack propagation, indicating that the local fracture presents the characteristics of cleavage fracture.

\[
\begin{align*}
H_2S &\rightarrow H^+ + HS^-, \\
HS^- &\rightarrow H^+ + S^{2-}, \\
\text{Anode reaction: } Fe &\rightarrow Fe^{2+} + 2e, \\
Fe^{2+} + S^{2-} &\rightarrow FeS \downarrow, \\
Fe^{2+} + HS^- &\rightarrow FeS \downarrow + H^+, \\
\text{Cathodic reaction: } 2H^+ + 2e &\rightarrow 2H\uparrow \rightarrow H_2.
\end{align*}
\]

On the other hand, the study of Shved and Bilyi [14] noted that the effect of hydrogen on the crack growth rate decreased with the increase of \(\Delta K\). For that reason, in the high \(\Delta K\) region, fatigue factor dominates the crack propagation. In terms of fatigue resistance, relevant research [15] has shown that compared with ferrite, pearlite has higher fatigue strength and better crack resistance, and the fatigue cracks are mostly initiated at the ferrite/pearlite boundary of the specimen surface. Accordingly, in the high \(\Delta K\) region, due to the high fatigue strength, the \(da/dN\) of the normalized state is much lower than that of the annealed state. A conclusion can be drawn from the above results that the content of pearlite has a great impact on CFCP behavior.

Figures 11(a) and 11(b) show the fracture morphologies of the annealed specimen and the normalized specimen at the final stage of corrosion fatigue at high magnification (1000x), respectively. As shown in the figure that at the final stage of crack propagation, both specimens showed obvious brittle characteristics, and with the increase in growth rate, the corrosion products on the fracture surface also decreased a lot. However, compared with the normalized specimen, the fracture surface of the annealed specimen shows more obvious cleavage steps and grain boundary contour, indicating that the brittleness of the annealed specimen is more severe. So it can be seen that the \(da/dN\) at the final stage of crack propagation for the annealed specimen is higher than that for the normalized specimen.

Owing to the reason of specimen dimensions, this article did not obtain the test data of \(\Delta K<17\) MPa·m\(^{1/2}\) of the normalized specimens, but from the variation trend of \(da/dN, \Delta K\) fitting curves of 15CrMo (imaginary line part in Figure 12), the two curves still have an intersection point of \(\Delta K=13.56\) MPa·m\(^{1/2}\). Then with the increase of \(\Delta K\), the crack propagation rate of the annealed state began to be higher than that of the normalized state, that is, the trend of the accelerated crack propagation of the annealed state is obvious. In the low \(\Delta K\) region (\(\Delta K<13.56\) MPa·m\(^{1/2}\)), when the corrosion factor plays a dominant role in initial FCGR, the corrosion fatigue crack growth rate of the normalized specimen with higher pearlite content is faster. In the high \(\Delta K\) region (\(\Delta K>13.56\) MPa·m\(^{1/2}\)), when the fatigue factor occupies the dominant position, the advantages of pearlite with strong fatigue resistance gradually emerged, which makes the corrosion fatigue crack growth rate of the normalized state lower than that of the annealed state. This is consistent with the discussion of the corrosion fatigue test of 45 steel, which further illustrates the influence of pearlite on CFCP behavior and proves the reliability of the conclusion of 45 steel.

4.2. Effect of Tempered Fine Pearlite on FCGR. Test result indicates that the fatigue life of quenched and tempered specimen is significantly longer than that of the full annealed specimen and normalized specimen, and the approximate conclusion can be obtained from Figure 6. The \(da/dN, \Delta K\) fitting curves of the normalized state and the quenched and tempered state are close to parallel, but on the whole, the crack growth rate of the quenched and tempered state slows by almost an order of magnitude in comparison with the normalized state, which is considered to be equal to the results of Guo et al. [16]. In the three heat treatment states, the quenched and tempered state showed the best corrosion fatigue resistance. Based on the literature research [13], we think there are two reasons for this result. In terms of

\[
\begin{align*}
\text{Figure 11: Fracture morphology at the final stage of corrosion fatigue crack propagation: (a) annealed specimen, (b) normalized specimen.}
\end{align*}
\]
corrosion resistance, tempered fine pearlite has the best corrosion resistance among the three microstructures. In terms of mechanical properties, the internal compressive stress in the quenched and tempered state is also the largest in the three heat treatment states. Relevant research [17] has shown that compressive stress can reduce the effective \( \Delta K \) at the crack tip, thereby reducing the FCGR. Consequently, we believe that the difference in crack growth rate between quenched and tempered state and normalized state is caused by the coupling effect of hydrogen corrosion resistance factor and mechanical factor.

Figure 13 is the fracture morphology of corrosion fatigue crack propagation of the quenched and tempered specimen at different crack propagation stages. We can see from the figure that the fracture morphologies at the initial and final stages of crack propagation are very similar, both of which contain secondary cracks with high density but short size, and the length of secondary cracks is about 50–80 \( \mu m \). Compared with the annealed specimen which has secondary cracks with a length of more than 1 mm, the energy dissipation effect of the secondary crack of the quenched and tempered specimen is weakened. By comparing the \( da/dN \) curves of three specimens in Figure 4, it can be seen that the crack growth rate of the quenched and tempered specimen is higher than that of annealed specimen at the initial stage of crack propagation. However, in the final stage of crack propagation, a large number of secondary cracks still exist on the fracture surface, and some small dimples can be observed in the fracture, and the brittleness of the fracture is far less than that of annealed and normalized specimens. Therefore, on the whole, the crack growth rate of the quenched and tempered specimen is the lowest among the three.

5. Conclusion

Through the study of corrosion fatigue resistance of 45 steel under three heat treatment states and 15CrMo under two heat treatment states, the effect of different microstructures
on the CFCP resistance of low and medium carbon steel was investigated. The following conclusions were drawn:

1. The expressions of corrosion fatigue crack growth rate of 45 steel and 15CrMo under different heat treatment states were obtained.

2. From the research results of the corrosion fatigue test of 45 steel, under the same experimental conditions, the content of pearlite has a great influence on the CFCP behavior: when the corrosion factor occupies the dominant position affects the corrosion fatigue crack propagation, due to the weak corrosion resistance of pearlite, the corrosion fatigue crack growth rate of the specimen with high pearlite content is fast. When the fatigue factor dominates, due to the strong fatigue resistance of pearlite, the specimen with high pearlite content has better CFCP performance. 15CrMo shows the same change regulation of corrosion fatigue crack growth rate as 45 steel, which further illustrates the influence of pearlite on corrosion fatigue crack growth rate.

3. Under the coupling effect of hydrogen corrosion factor and mechanical factor, the quenched and tempered 45 steel (tempered fine pearlite) showed excellent CFCP resistance.

**Data Availability**

The experimental data used to support the findings of this study are included within the article.

**Conflicts of Interest**

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this article.

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