

ANALYSIS OF CORROSION BEHAVIOR OF LOW CARBON ALLOY STEEL

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In this study, a 72-h neutral salt spray test was conducted on two low-carbon alloy steels and their corrosion kinetic equations were constructed, and tensile tests were conducted on specimens with different corrosion cycles to evaluate the mechanical properties of the two experimental steels. The test results showed that the corrosion resistance of TZ750MS was better than that of H750MS during the whole test cycle; however, the predicted results of the corrosion kinetic equation showed that the corrosion resistance of TZ750MS was lower than that of H750MS after 144 h. The tensile test results showed that the strength of both steels did not change substantially after corrosion, and the tensile stress-strain diagram showed that the specimens would fracture earlier after passing through the plastic deformation zone

Keyword: alloy steel, chemical composition, corrosion mechanisms, neutral salt spray, static stretching

INTRODUCTION

Low carbon martensitic steel as a manufacturing material for vehicle crash bars, corrosion will have an irreversible effect on its mechanical properties, and will fail under the effect of long-term corrosion, which cannot guarantee the safety of occupants, therefore, it is important to study the corrosion behavior of low carbon martensitic steel for the prevention of its corrosion failure. Yan [1] et al. through the study of atmospheric particles on the initial corrosion of mild steel, found that the particles deposited on the surface of carbon steel directly or indirectly involved in the corrosion process of carbon steel, and the corrosion effect is more serious in a humid environment; Yi [2] et al. found through salt spray tests on M152 steel that the products of the corrosion process gradually and gradually transformed into dense brown products and inhibited the diffusion of O_2 and Cl, thus slowing down the corrosion process; gradually and gradually transformed into dense brown products and inhibited the diffusion of O_2 and Cl, thus slowing down the corrosion process; Chen [3] et al. played a role in promoting the corrosion of 38CrMoAl steel, but with the increase of corrosion time, the protective properties of the corrosion product layer gradually emerged.

At present, the corrosion research on metal is mainly divided into the natural state of corrosion and salt spray test designed according to the actual service environment conditions, to the natural state of metal corrosion

research although to a great extent to obtain the real corrosion data.

However, because of its long test cycle is too high cost, not suitable for this test research. Therefore, considering that the actual service environment of the square tube is the general atmospheric environment, the neutral salt spray test can simulate its corrosion behavior well.

Experimental

The test materials were two different types of crash bars TZ750MS and H750MS, and their main chemical compositions are shown in Table 1. The dimensions of the specimens used in the experiment are shown in Figure 1, and the thickness of the specimens is 1,2 mm.

The concentration of 5 % sodium chloride solution was prepared as the salt spray solution, and the pH value was kept in the range of 6,5~7,2. Set the spraying temperature of the salt spray box for $(35 \pm 2) ^\circ C$, the continuous spraying time is 4h, after stopping the spraying set

Table 1 **Chemical composition of H750MS and TZ750MS**
/wt. %

Steel	C	Si	Mn	Cr	Ti
H750MS	0,21	0,20	1,3	0,31	0,018
TZ750MS	0,16	0,21	1,4	0,40	0,022

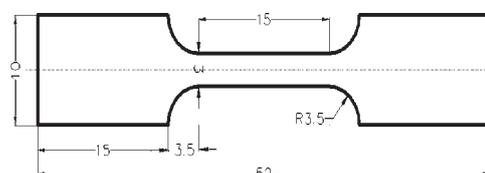


Figure 1 Specimen size/mm

W.P. Zhao, T. Li, H.C. Ji, (E-mail: jihongchao@ncst.edu.cn), North China University of Science and Technology, Hebei, Tangshan, China. L. Sun, J.Y. Li, Tangshan Iron and Steel Group Co., Hebei Tangshan, China, X.P. Guo, School of Materials Science and Engineering, Chongqing University, Chongqing, China.

the temperature inside the box to 40 ± 2 °C, the duration of 2 h , and finally removed and placed in the dry environment to rest for 2h, 8 hours for a cycle. Before the test on the specimen ultrasonic cleaning, drying and weighing using an electronic scale with an accuracy of one ten thousandth; specimens in the salt spray box placed on the surface and the vertical surface is 20 ± 5 °.

RESULTS AND DISCUSSION

Use a concentration of 20 % hydrochloric acid to remove corrosion from the surface of the specimen, and use alcohol to clean the surface of the specimen again after drying and weighing. After weighing, use the weight loss method to calculate the corrosion rate of the specimen under different test time.

$$V = \frac{m_0 - m_1}{S} \tag{1}$$

Where, V for the corrosion rate of the metal/ mg/mm^2 ; m_0 for the mass of the measured parts before corrosion/ mg ; m_1 for the mass of the measured parts after corrosion/ mg ; S for the area of the measured parts/ cm^2 .

For a long time, many scholars have conducted a large number of corrosion tests on different metal specimens and studied the corrosion behavior of steel by constructing corrosion kinetic equations as a way to evaluate its corrosion resistance behavior [7]. The most commonly used corrosion kinetic equation is shown in equation (2),

$$V = A_c t^{n_c} \tag{2}$$

Where, t is the salt spray corrosion time, A_c and n_c are constants, related to the nature of the material itself and the corrosive environment.

Table 2 Corrosion kinetic parameters

Steel	A_c	n_c	R^2
H750MS	3,61334	0,39536	0,97862
TZ750MS	1,75604	0,54242	0,97815

As shown in Figure 2, the corrosion laws of both metals are consistent with the corrosion kinetic equation, and show a trend of corrosion rate gradually slowing down as the corrosion time increases.

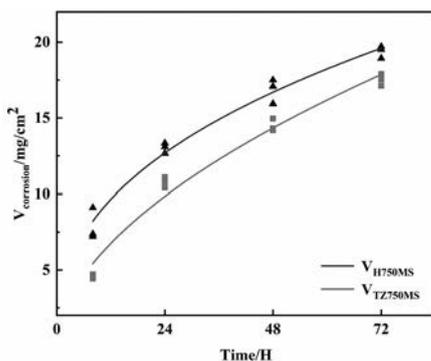


Figure 2 Corrosion rate fitting graph

By fitting the corrosion rate results for 72h, the corrosion rate of TZ750MS was lower than that of H750MS throughout the test, which showed a better corrosion resistance. However, according to the predicted results of the fitted curve, when the corrosion time increased to 144h, the corrosion rate of the two specimen steels reached the same, and as the corrosion time increased, the corrosion rate of TZ750MS would exceed that of H750MS, and its corrosion resistance began to show a decline. According to CHOI[4], in the solution containing chloride ions, chromium can promote the formation of Cr_2O_3 during the corrosion of mild steel, thus improving its corrosion resistance, which has the same performance in TZ750MS with higher chromium content, as also proved by Bousselml[5]. The corrosion kinetic equation about TZ750MS predicts that the subsequent corrosion degree is more severe than that of H750MS, it has been pointed out that although chromium helps to suppress the corrosion rate of low-alloy steel in the early stage of corrosion, it will play a role in accelerating corrosion in the later stage of corrosion.

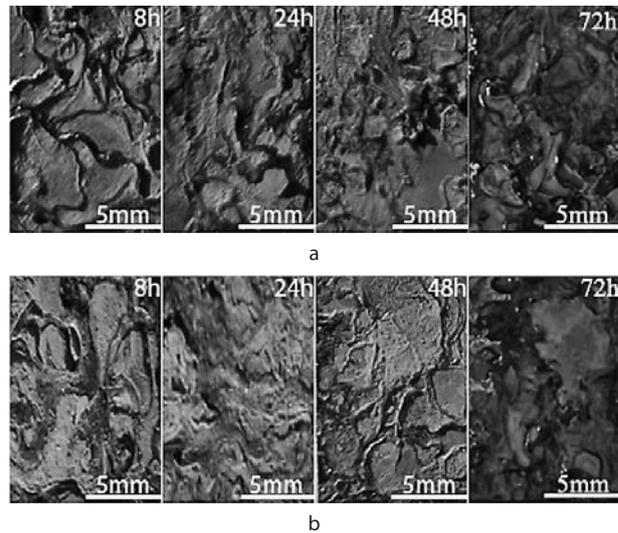


Figure 3 Morphology after different corrosion cycles a-TZ750MS; b-H750MS

Figure 3 shows the surface morphology of the specimen after corrosion, it can be seen that the surface of the corrosion 8h specimen is almost completely covered by yellow-brown corrosion, there are multiple black corrosion in the form of grooves embedded in it. With the increase in corrosion time. The surface of the specimen along with the corrosion off, near the matrix of the large area of black corrosion exposed. By observing the corrosion morphology of the specimen appearance under different corrosion times, we believe that in the early stage of corrosion, due to the metal substrate surface without any protective measures, directly exposed to the salt spray environment occurred more serious corrosion. With the test, a large number of corrosive materials generated and attached to the surface of the substrate to form a protective layer, to a certain extent, delayed the corrosion of the substrate to produce a certain protective effect.

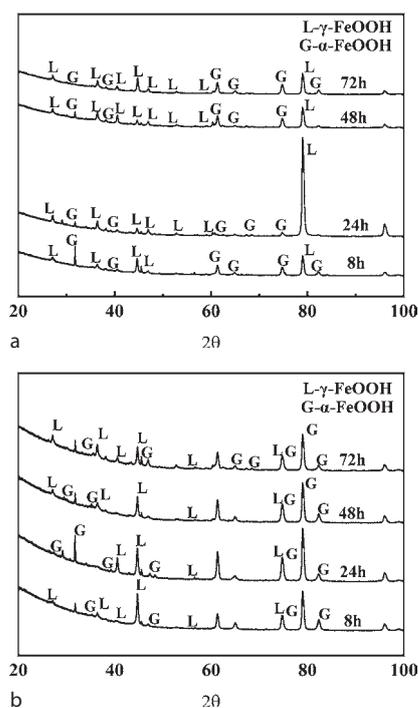


Figure 4 XRD analysis results of corrosion products under different corrosion cycles a-TZ750MS; b-H750MS

As shown in Figure 4, the X-Ray Diffraction analysis (XRD) of the specimens with different corrosion cycles was measured, and the results showed that a large amount of γ -FeOOH, and with the increase of corrosion time. The content of α -FeOOH also increased one by one, which is the same with our macroscopic observation of the specimens after corrosion. But the measurement results did not find Fe_3O_4 . The possible result is that the generation of iron oxide requires a lot of contact with oxygen, but due to the dense nature of the corrosion products, resulting in oxygen can not effectively enter the interior of the corrosion layer combined with iron. In the low concentration of O_2 and the invasion of the rust layer of the internal role of a small amount of Cl⁻, prompting Fe^{2+} to generate a finer size of needle iron ore, in close proximity to the surface of the substrate Generate a more dense protective layer, organize the attack of corrosive materials, so as to achieve a certain anti-corrosion effect.

As shown in Figure 5, in the corrosion process, Fe becomes the anode of the battery due to the characteristics of the active metal and is the first to undergo an oxidation reaction leading to the destruction of the metal, corresponding to the reduction reaction of certain substances at the cathode of the battery. The corrosion cell is short-circuited, so the current generated in the reaction process will be consumed in its internal, and the whole process of the reaction is carried out in the maximum irreversible way.

In the battery anode, Fe loses electrons to generate soluble ions Fe^{2+} , and the small amount of O_2 contained in the film solution covering the substrate surface gets electrons as depolarizing agent to combine with water to generate OH^- and combine with Fe^{2+} to gener-

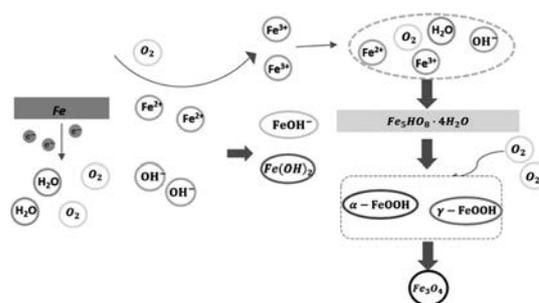


Figure 5 Salt spray test corrosion mechanism diagram

ate (FeOH^+ and $\text{Fe}(\text{OH})_2$), and oxygen absorption corrosion occurs. Part of the O_2 as an oxidizing agent oxidizes Fe^{2+} to produce Fe^{3+} . As the reaction proceeds, the ions generated by the corrosion reaction and O_2 generate $\text{Fe}_5\text{HO}_8 \cdot 4\text{H}_2\text{O}$ on the surface of the specimen [6], but the properties of hydrous iron ore are unstable and easy to decompose, and decompose and react to generate α -FeOOH and γ -FeOOH under the catalytic effect of compounds generated by the combination of divalent iron ions and hydroxide. When the pH value is in the range of 4-9, the presence of Cl⁻ and low concentration of O_2 facilitates the reaction of Fe^{2+} to form α -FeOOH. because needle ferrite has finer particles, it plays a role in delaying the corrosion of the deeper layers of the substrate.

Using the tensile specimen machine for different corrosion cycles of the specimen strain rate of 10^{-4} s^{-1} quasi-static tensile test, Figure 6 shows the stress-strain diagram of the tensile test, from the Figure 6 can be seen visually, the specimen after the corrosion of its strength did not occur significantly decreased, but its tensile strain after crossing the plastic deformation zone.

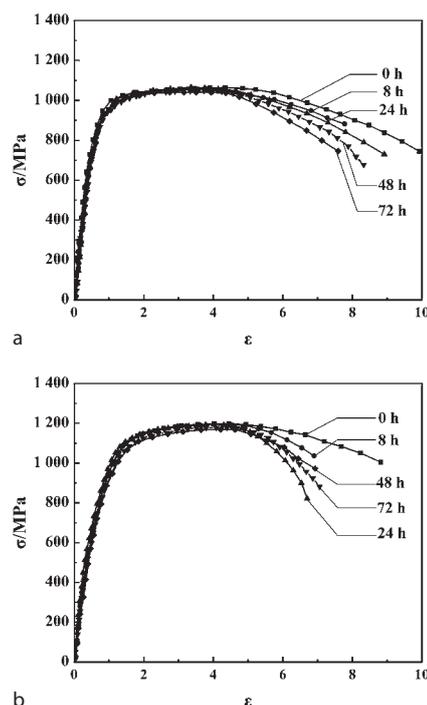


Figure 6 Slow strain rate tensile stress-strain diagram a-H750MS; b-TZ750MS

Overall, the two experimental steel in the occurrence of corrosion behavior, its strength change is small, but its plasticity is affected by the larger, the analysis that the specimen is subjected to axial load process, the specimen surface corrosion pits, especially corrosion holes triggered by local stress concentration, resulting in the rapid growth and spread of cracks, thus triggering the early fracture of the specimen.

CONCLUSION

The corrosion kinetic equation fitted by the experimental results shows that TZ750MS possesses better corrosion resistance during the initial corrosion process, but after 144 h, the corrosion resistance of H750MS appears to strengthen. We believe that this is due to the increase of Cr content effectively improves the corrosion resistance of mild steel in the initial stage, but with the increase of corrosion time, it decreases its own corrosion resistance due to the effect of local corrosion instead. Finally, by performing tensile specimens on the corroded specimens, it was found that corrosion did not affect the strength of the specimens too much, but plasticity appears to decline.

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Note: The responsible translator for English language is M M Li - North China University of Science and Technolog