Advanced Materials Research *Online: 2011-08-16*
ISSN: 1662-8985, Vols. 317-319, pp 236-239
doi:10.4028/www.scientific.net/AMR.317-319.236

Ultra-low Carbon High Strength Weathering steels

Zhiyong Liu [1,2,a], Xinlai He [1], Shanwu Yang[1],Qianxue Zhou[2]

[1]School of Materials Science and Engineering University of Science and Technology Beijing, Beijing 100083, China

[2]Research and Development Center of Wuhan Iron and Steel (Group) Corp, Wuhan Hubei 430080,China

[a]liuzyhappy@126.com

Keywords: Ultra-low carbon, high strength, weathering steels, corrosion

Abstract. The ultra-low carbon high strength weathering steel was trial manufactured. By Optical micrographs observation, scanning electronic microscope (SEM), transmission electronic microscope (TEM), accelerated corrosion test, the corrosion resistant performance of test steel and CortenB steel were studied. The results showed that yield strength, tensile strength, elongation and -40 ℃ impact energy of test steel reached 510MPa, 600MPa, 22% and 115J, respectively. Corrosion resistance of test steel was superior to that of CortenB. The microstructure of ferrite and bainite, quickly forming adhesive dense rust layers to improve the corrosion resistance of test steel.

Introduction

Weathering steels, atmospheric corrosion resistant steels, which are low alloy high strength steels containing a small amount of alloying elements, have a good corrosion resistance performance in atmosphere, lower cost compare with stainless steels. Weathering steels have widely used in bridges, buildings, vehicles, container, transmission tower, and other industries on account of their excellent atmospheric corrosion resistance. As an efficient steel, the corrosion resistant steel product has been a hot topic.

Weathering steels are generally based on copper-phosphorus system, and then adding the other alloying elements to improve corrosion resistance of steels, weathering steels of research and development have been carried out this idea, so far no breakthrough. A large number of alloying elements improve the cost of weathering steels, which is a serious hindrance to promote and use of weathering steels. The trend of development of weathering steels is high strength and toughness, the high phosphorus content of weathering steels limits the mechanical properties, but phosphorus is the most effective and economy element to improve the corrosion resistance of steels. How to effectively improve strength and toughness, but also to maintain the economy of steels, which is contradictions for developing to weathering steels. The typical microstructure of traditional weathering steels are ferrite and pearlite, pearlite significant deterioration in the corrosion of steel. For improving strength and toughness, but also maintaining the corrosion resistance of steel, the components designed and microstructure controlled for weathering steels must be different from the traditional development ideas. In this paper, the yield strength 450MPa high strength weathering steel was pilot studied by ultra-low carbon, reducing phosphorus content, controlling the microstructure, which explored the new ideas to development high strength weathering steels.

Experimental materials and methods

Test materials.

The test steel was melted in a 50kg vacuum induction furnace and cast into ingots. The chemical compositions of test steel were shown in Table 1. The ingot was soaked in 1220℃ for 90 minutes, and was forged into 65×100 × 600mm specimen, which was rolled to plate with a final thickness of 6mm,the open rolling temperature was 980℃, the final rolling temperature was 860℃, followed by cooled in water, the cooling temperature was 650℃.

Table 1 Chemical compositions of the test steels (wt.%)

C	Si	Mn	S	P	Cu,Cr,Ni	Nb+Ti
0.021	0.30	1.25	0.007	0.017	Proper quantities	≤0.08

Test methods.

The tensile specimens and tensile properties were evaluated in accordance with chinese industrial standards GB / T 228. tensile and chart V notch impact specimens were cut from the as-rolled plates in the transverse direction. Impact tests were carried out at the temperature of -40˚C. The specimens were mechanically polished and etched with 3% nital for optical microstructure. The carbon replica specimens were analyzed by TEM. The specimens for corrosion test were cut to the size of 4 × 50 × 100mm. All pieces were ground with 800 grit silicon carbide paper, cleaned with acetone, and then rinsed with distilled water. The immersion solution of wet-dry cycle test is 1.0×10^{-2}mol / l $NaHSO_3$ solution, PH value is 4.4 to 4.8.Each wet/dry cycle consists of a wetting period(18 minutes at 45˚C, RH 100%)plus a drying period (62 minutes at 45˚C, RH 75%).The accelerated corrosion test lasted for 72~144 hours. The rust layers were analyzed by SEM.

Results and discuss

mechanical properties.

Table2 showed that the mechanical properties of the test steel. Yield strength, tensile strength, elongation and -40 ℃ impact energy of the test steel reached 510MPa, 600MPa, 22% and 115J, respectively.

Table2 Mechanical properties of the test steel

Yield strength/MPa	tensile strength/MPa	Elongation/%	-40℃impact energy*/J		
515	610	22	114	122	110
500	590	22.5			

*Half thickness of standard specimen.

corrosion resistance performance.

Accelerated corrosion test results shown in Fig.1. Different corrosion cycle, the corrosion rate of test steel was less than that of CortenB, which indicated that the corrosion resistance of test steel was superior to CortenB. With the corrosion time prolonging, the trend of corrosion rate of test steel and that of CortenB was the same. In 72~96h, the corrosion rate of test steel and CortenB sharply declined, and the corrosion rate of steel test was more severe, which indicated that the adhesive dense and stable rust layers of test steel quickly formed to protect matrix. In 96~144h,the corrosion rate of CortenB was still slight downward trend, otherwise that of test steel was very stable, which indicated that rust layers of CortenB steel were still developed, but that of test steel had been formed and were very stable on the protective effect of steel.

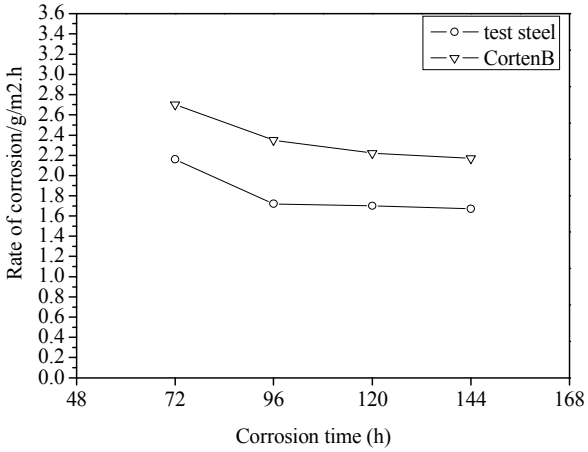

Fig. 1 Relation between rate of corrosion and corrosion test

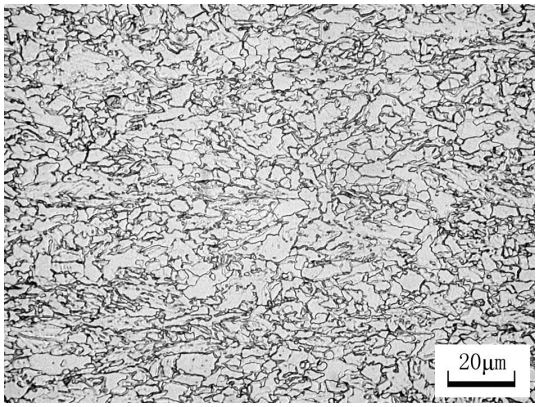

Fig. 2 Optical micrographs of test steel

Microstructure.

Optical micrographs of test steel are shown in Fig.2. The microstructure of test steel were ferrite + bainite, which different from ferrite + pearlite of traditional weathering steels, which no significant potential difference between phases, reducing the generation of corrosion sources, improving the corrosion resistance of steel.

Precipitates and energy spectrum of test steel as shown in Fig. 3 and Fig. 4. Precipitates uniform distribution in matrix, one is round, rectangular or cube-based precipitates, size 40~100nm, which is (Ti, Nb) (C, N) (Fig.3) playing major role in increasing the strength of steel. Adding micro-alloying elements Nb, Ti in test steel. In the rolling process, the deformation induced Nb (C, N) or (Ti, Nb) (C, N) precipitation in austenite grain boundaries, dislocations or deformation bands (Fig.3~4), which prevent grain coarsening and recrystallization nucleation, inhibit recrystallization, so that the ferrite grain refinement, played the role of fine grain strengthening, improving strength and toughness of steel. And the second phase particles evenly distributed in the matrix, and kept semi-coherent relationship with matrix, which increased the resistance to dislocation motion, improved the strength of steel. The other is size 5~30nm precipitates, which is ε-Cu (Fig. 4 and Fig. 5) by high-resolution electronic microscope. Copper is one of the most important alloying elements to improve the corrosion resistance in weathering steel, but the precipitation of ε-Cu as obstacles and the interaction of moving dislocations can produce some precipitation strengthening effect (Fig. 4) [1].

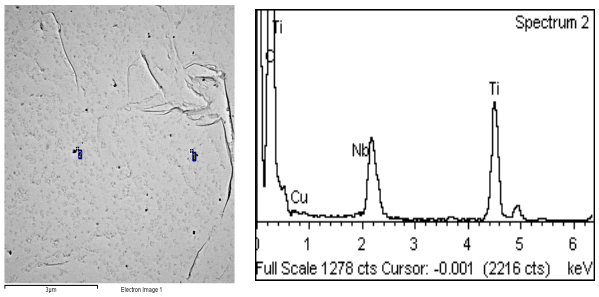

Fig. 3 Precipitates of steel and energy spectrum

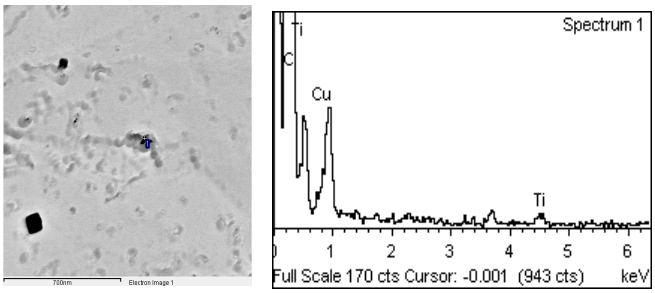

Fig. 4 Precipitates of steel and energy spectrum

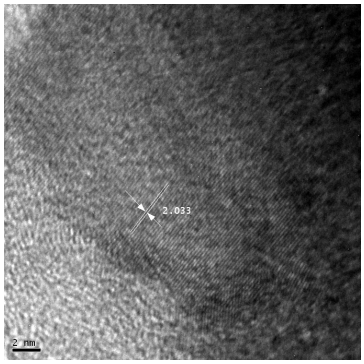

Fig. 5 High-resolution electronic microscope image of ε-Cu

The cross-section of the two steels after 72 hours of accelerated corrosion tests were observed by SEM, as shown in Fig. 6 (a) and (b).The rust layer on the test steel was more compact and thinner than that on CortenB. There were large pores in the rust layers of CortenB. The adhesive dense rust layer of test steel protected matrix and enhanced the corrosion resistant of test steel. Weathering steels will rust because of corrosion, the rust layer of weathering steels is consist of two layers. One is loose, holes and cracks, easy to fall off, which is named outer rust layer. The production of outer rust layer are main α-FeOOH and γ-FeOOH, which don't protect to steel. Another layer is dense, protective, strong adhesion, which is named inner rust layer. The inner layer is corrosion resistant protective film for weathering steels. the production of inner rust layer are main α-FeOOH [2-5].

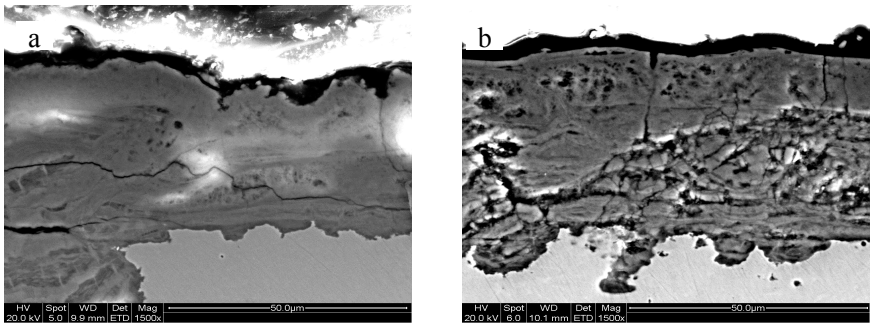

Fig. 6 The rust layers of test steel and CortenB after 72h the accelerated corrosion test

Conclusion

A new 450MPa grade high strength weathering steel was obtained. Corrosion resistance of the test steel is superior to that of CortenB due to microstructure of ferrite and bainite, and quickly forming adhesive dense rust layers.

References

[1] Zongchang Liu, Huiping Ren, Haiyan Wang:Hea. tret. met. Vol.29(2004)P.58

[2] Caifeng Liang, Wentai Hou: J. Chin. Soc. Corros. Prot. Vol.17(1997)P.87

[3] Xuanyi Wang, Guangyong Wang and Zuyu Qu: J. Chin. Soc. Corros. Prot. Vol. 15 (1995)P.124

[4] Yamashita M, Miyuki H and Matsuda Y: Corros. Sci. Vol.36(1994)P.283

[5] Sei JOh, CookDC, TownsendHE: Corros. Sci. Vol.41(1998)P.1687