Erosion and Corrosion Behavior of Solid Particles on the Inner Wall of Titanium Welded Pipe

Yang Xin[1], Bai He[1], Yang Ruiqi[1], Dong Yanni[2], Guo Jialin[2], Xu Yongfeng[3]
[1]College of Mechatronics and Informatics, Baoji Vocational &Technical College, Baoji, China
[2]Bao Ti Group Co., Ltd., Baoji, China
[3]Dongfang Turbine Co., Ltd., Deyang, China

Abstract: To study the internal wall particle erosion corrosion behavior of domestic and imported nuclear power plant condenser titanium welded tubes, the paper dynamically simulated the cooling water system of a steam turbine condenser and subjected domestic and imported titanium welded tubes to artificially configured water quality and flow velocity. The experimental results of erosion corrosion showed that the domestic titanium welded tubes had excellent corrosion resistance in seawater, with a corrosion rate of only 0.001 to 0.002mm/a. By observing the changes in the weld seam and original titanium inner surface of the tubes before and after erosion using a scanning electron microscope, no obvious erosion marks were found on the surface, indicating that domestic titanium welded tubes can match the corrosion resistance of imported titanium welded tubes.

KeyWords: Titanium Welded Pipe; Erosion Corrosion; Weight Loss Method; Corrosion Rate

The condenser is one of the important equipment in a thermal power plant or nuclear power plant. the economic efficiency and reliability of the condenser will directly affect the overall economic benefits and safety assurance of the power plant. However, the environment of a nuclear power plant is unique, and the cooling medium for the condenser is often highly corrosive and complex seawater, which requires a more stringent and demanding requirement for the product's anti-erosion and corrosion resistance to seawater pollutants. [1] Since titanium has a higher mechanical strength, moderate hardness, and heat transfer performance, and more importantly, its seawater corrosion resistance is much higher than that of copper alloys and stainless steels, titanium has become one of the preferred materials for condenser selection [2].

1. Test

The titanium sample ASTM B338 Gr2 was used in the experiment, the size of which was Φ25.4×0.5 mm. Titanium welded pipe from Baoti and Kobe, Japan. For each material, tube samples with a length of 70mm (determined according to the accuracy of the balance and the range before the test) were used in each test, and the corrosion weight loss was averaged.

Every 3 days (72 hours) is a test cycle, and 3 days erosion corrosion, 6 days erosion, 9 days erosion test are completed respectively, after the experiment, the corrosion patterns of the internal surface and the internal surface of the weld of the domestic and imported pipes before and after erosion, and whether there is corrosion, uniform corrosion or pitting corrosion, were observed by Scanning electron microscope scanning electron microscopy (SEM), and the records were made, eDS compare the change of composition. the experiment was carried out in three periods, a total of 200 hours.

The test medium is mainly artificial seawater [3-4]. the formula of artificial seawater is shown in **Table 1**.

Table 1. Chemical Composition of Artificial Seawater

Composition (principal component)	Content g/L	PH was adjusted to 8.2 with 0.1 mol/L NaOH solution. the temperature of artificial seawater is 30 ± 3 °C. Velocity of seawater medium: 3 m/s. the particle size and content of silicon carbide abrasive were 0.01 mm, 0.2‰, 0.10 mm, 0.2‰, 0.20 mm, 0.2‰, respectively.
NaCl	24.53	
MgCl2	5.20	
Na2SO4	4.09	
CaCl2	1.16	
KCl	0.695	
NaHCO3	0.201	
KBr	0.101	
H3BO3	0.027	
SrCl2	0.025	
NaF	0.003	

2. Results and Analysis

For macroscopic examination, the samples were weighed with an electron balance of 1 part per 100, 000. the changes of the inner wall weld and the inner surface of the original titanium tube before and after erosion were observed by Scanning electron microscope, test the composition of inner wall weld and inner surface of original titanium tube.

2.1 Erosion Corrosion Weightlessness

The quality of the domestic and Japanese titanium welded pipes before and after 3, 6 and 9 days erosion corrosion are listed in **Table 2** and **Table 3**.

Table 2. Erosion Wear of Titanium Welded Pipe Produced in China

Made in China	w0	w1	#w	wt%
A	12.17447	12.1735	0.00097	0.007967
B	12.15134	12.1509	0.00044	0.003621
C	12.25372	12.2538	-0.00008	-0.00065
D	12.20602	12.1585	0.04752	0.389316
E	12.09646	12.0982	-0.00174	-0.01438

Table 3. Erosion Wear of Titanium Welded Pipe Made In Japan

Made in Japan	w0	w1	#w	wt%
V	12.21081	12.2494	-0.03859	-0.31603
W	12.28562	12.1603	0.12532	1.020054
X	12.33863	12.3113	0.02733	0.221499
Y	12.32531	12.3507	-0.02539	-0.206
Z	12.24433	12.2435	0.00083	0.006779

Table 4. Erosion Rate of Titanium Welded Pipe

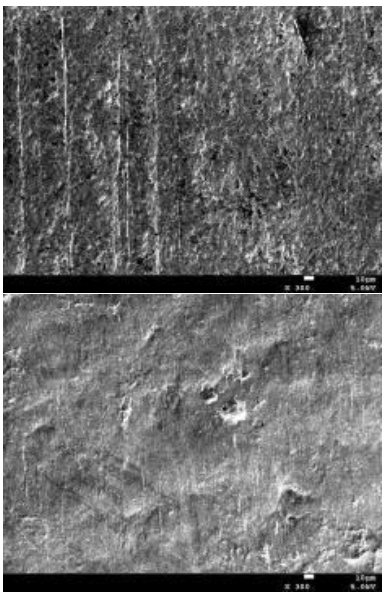
Corrosion rate	wt% 0.0036		mm/a	
Test Time (days)	Made in China	Made in Japan	Made in China	Made in Japan
3	0.0047	0.0024	0.003	0.002
6	0.0068	0.0036	0.002	0.001
9	0.0043	0.0025	0.001	0.001

The erosion wear rate of titanium welded pipe calculated by weight loss method is listed in **Table 4**. the results of seawater erosion corrosion test show that the domestic and Japanese titanium welded pipes have excellent corrosion resistance in seawater, and the corrosion rate is only 0.001-0.002 mm/A, there is no significant difference in weight loss between domestic and imported titanium welded pipe. According to the four-grade standard of metal corrosivity in our country, all of them have excellent corrosion resistance.

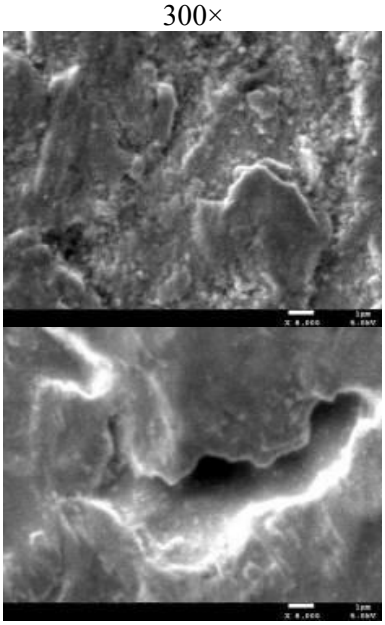
2.2 Erosion Corrosion SEM morphology

Fig. 1 and Fig. 2 are the SEM photographs of domestic and Japanese titanium welded pipe and weld after 9 days of corrosion.

The results of scanning electron microscopy (SEM) show that there are no obvious erosion marks on the surface of the corroded titanium tubes. However, it should be noted that obvious pits were observed in the inner of the titanium tube.

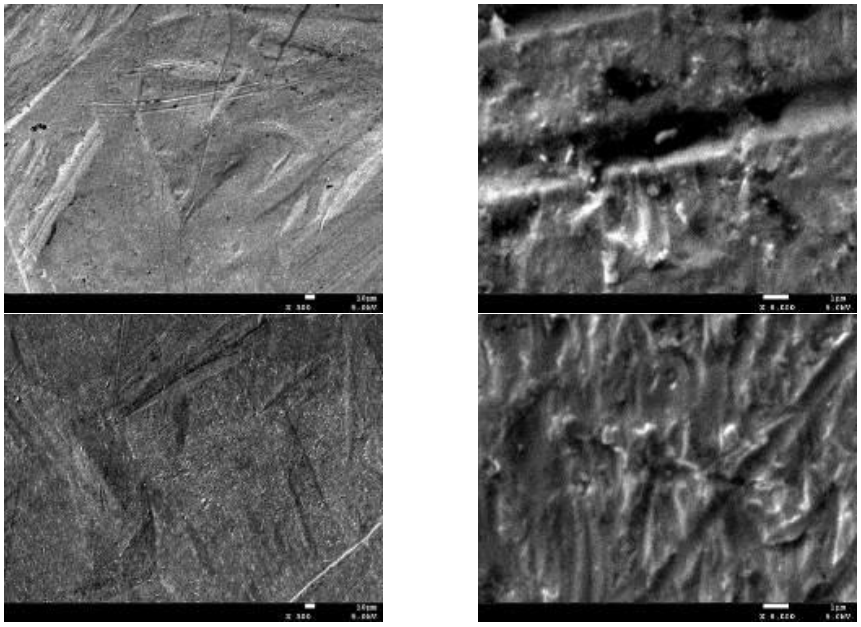


Made in China Made in Japan
300×



Made in China Made in Japan
8000×

Figure 2. SEM Image of Titanium Welded Pipe After Erosion



Made in China Made in Japan 300× Made in China Made in Japan 8000×

Figure 3. SEM Morphology of Weld After Erosion

EDS

2.3 Titanium Welded Pipe Inner Wall Weld

Table 5. EDS Test Results of Erosion-Corrosion Specimen Surface

Flush time		C		Ti		Fe	
		wt.%	at.%	wt.%	at.%	wt.%	at.%
6	Basic materials (China)	0.05	0.15	99.94	99.73	0.8	0.49
	Basic materials (Japan)	0.03	0.14	99.97	99.86	0.46	0.4
	Weld (China)	0.04	0.15	99.96	99.85		
	Weld (Japan)	0.03	0.14	99.97	99.86		
9	Basic materials (China)	0.05	0.13	99.93	99.74	0.74	0.43
	Basic materials (Japan)	0.03	0.13	99.97	99.87		
	Weld (China)	0.04	0.16	99.96	99.84	0.66	0.56
	Weld (China)	0.04	0.16	99.96	99.84	0.66	0.56

3. Conclusion

(1) The results of erosion corrosion test show that the corrosion resistance of the titanium welded pipe in seawater is excellent, and the corrosion rate is only 0.001-0.002 mm/a. there is no obvious difference between the corrosion rate of domestic and imported titanium welded pipe in weight loss.

(2) The results of scanning electron microscope (SEM) show that there are no obvious erosion marks on the surface of the corroded titanium tubes. However, obvious pits were observed in the inner of titanium welded pipe.

(3) EDS analysis shows that the titanium content of domestic and imported titanium welded pipe is more than 99.95%, which is consistent with the use of pure titanium TA2 composite plate. Iron was enriched on the surface of domestic titanium welded pipe after 3 days of corrosion, and on the surface of domestic and imported titanium plate after 6 and 9 days of erosion corrosion.

The results show that the domestic titanium welded pipe produced by BAOTI company has excellent corrosion resistance in seawater and can completely replace the imported titanium welded pipe.

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