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Technical Inspection of High Strength Bolts in Hydropower Plant: Physical and Chemical Inspection

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Technical Inspection of High Strength Bolts in Hydropower Plant: Physical and Chemical Inspection

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Abstract.As an important connection part of metal equipment, bolt is widely used in hydraulic power plant. However, the bolt fracture of hydropower plant occurred occasionally, which seriously affected the stable operation of hydropower plant. Based on the analysis of the fracture bolt, the quality problems of the bolt were found: (1) the material is not qualified, (2) the mechanical properties of the bolts are not qualified. Because the misuse of the material and the wrong execution of the heat treatment, the actual strength of the bolts could not meet the nominal strength, leading to the fracture of the bolts during term of service. The detection of chemical composition and hardness testing can effectively monitor the testing quality of bolts, and prevent unqualified bolts into the installation and operation.

1. Introduction

Bolt connection is widely used in industrial equipment as an important connection mode of metal parts. However, the high-strength bolt, as an important bearing part of the connecting bolt, plays a very important role in the normal operation of the equipment [1-4]. In recent years, a number of bolt fracture accidents have occurred in hydropower plants in Hunan province, which has brought great hidden dangers to the safe operation of hydropower plants, and caused many non-stoppage accidents. This greatly affected the stable operation of hydropower plants [5-6]. Therefore, it is necessary to inspect and supervise the critical components of the hydraulic power plant. It should be established the important bolt ledger according to the importance of the bolt to manage the bolt gradually. It is supposed to use the opportunity of unit maintenance to non-destructive test the important bolt and replace the bolt found defects, to ensure the safety of the unit.

2. Test methods

In order to test the physical and chemical properties of the broken bolts, metallographic examination (ZEISS observer AIM), mechanical properties test (UTM5105) and component analysis (OXFORD FOUNDRY MASTER PRO) were conducted.

3. Results and analysis

3.1 Connecting bolt of blade rod and piston cylinder



The broken of the connecting bolt of blade rod and piston cylinder occurred in hydropower plants, resulting in the shutdown of the water-turbine generator set. The nominal material of the bolts is 35CrMo, and the nominal strength grade of the bolts is 10.8.

The chemical composition of the bolt meets the requirements of 35CrMo steel. The nominal strength of the bolt is 10.9 grade, that is, the tensile strength (R_m) of the bolt is $\geq 1000\text{MPa}$, the yield strength (R_{eL}) is $\geq 800\text{MPa}$, and the elongation (A) is $\geq 9\%$. According to the test results, the tensile strength of the broken bolts is 792 and 853 MPa, and the yield strength is 605 and 643 MPa, respectively, which obviously not up to standard [7].

Table 1 Mechanical Property Testing of Bolts

number	tensile strength R_m (MPa)	Yield strength R_{eL} (MPa)	Total elongation at break A (%)
1	792	605	20.5
2	853	643	16.8

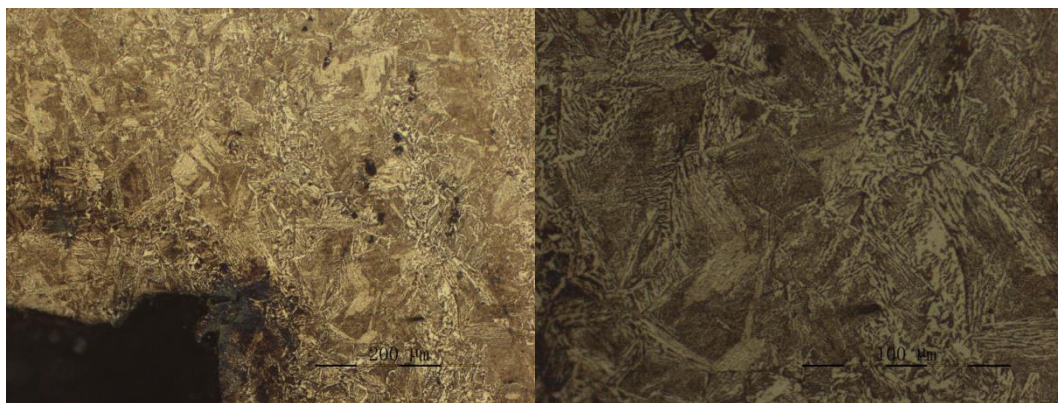


Figure 1. Metallographic structure near fracture surface of bolt.

Coarse and uneven martensite structure was observed in the microstructure of the bolts, as shown in Fig.1. High strength bolts with 10.9 grade should be quenched and tempered according to the standard to obtain fine tempered martensite structure with combination of favorable strength, plasticity and toughness. The appearance of coarse martensite in the fracture bolt indicates that the heat treatment of bolt does not meet the requirements.

3.2 Tie bolts of a manhole door

The tie bolts of a manhole door of hydropower plant broke. The nominal material of the bolt is 45 steel, and the nominal strength grade is 8.8.

Table 2 Mechanical Property Testing of Bolts

number	tensile strength R_m (MPa)	Yield strength R_{eL} (MPa)	Total elongation at break A (%)
2-1	657	400	25.0
2-2	649	397	23.0
2-3	656	397	21.3



Figure 2. Metallographic structure of bolts.

The nominal material of the bolt is 45 steel. The chemical composition of the bolt meets the requirements of the standard. The nominal strength of the bolt is 8.8 grade, which means that the tensile strength of the bolt can reach 800 MPa, and the yield strength can reach 640 MPa. The test results show that the average tensile strength of the three broken bolts is only 654 MPa and the average yield strength is only 398 MPa, which does not meet the standard requirements, as shown in Table 2. The metallographic structure of the bolts shows that the structure of the bolts is ferrite + pearlite, as shown in Fig. 2. According to the standard requirements, bolts with strength grade of 8.8 should be quenched and tempered to obtain fine tempered martensite. The structure of the bolt is obviously not in conformity with the requirements, which indicates that there is no heat treatment of quenching and tempering at all, therefore, the mechanical properties of the bolts do not meet the requirements.

3.3 Tie bolts of swing water ring tie bolts

The swing water ring bolts of a hydropower plant were broken and two bolts were sent for inspection. The nominal type of the bolt is C3-80, and the nominal material is Cr17Ni2 steel, according to the standard requirements, the strength of the bolts should reach 8.8 grade.

Table 3 the chemical composition of the bolts

Chemical element	standard requirements	Sample 1	Sample 2
Cr	16~18	17.3	17.2
Ni	1.5~2.5	8.00	8.01

Table 4 Mechanical Property of Bolts

number	tensile strength R_m (MPa)	Yield strength R_{eL} (MPa)	Total elongation at break A (%)
1-1	681	340	72
2-1	674	334	68

According to GB/T 3098.6-2000 《Mechanical Properties of Fasteners Stainless Steel Bolts and Bolts》, the chemical composition of the bolts is 16%-18% Cr, 1.5%-2.5% Ni. The chemical composition analysis of the bolts shows that the average content of Cr is 17.2%, and the average content of Ni is 8.00%, as shown in Table 3. The chemical composition of the bolts does not meet the requirements. The mechanical properties of the bolts were tested, and it was found that the tensile

strength and the specified plastic elongation strength of the bolts could not meet the requirements, as shown in Table 4.

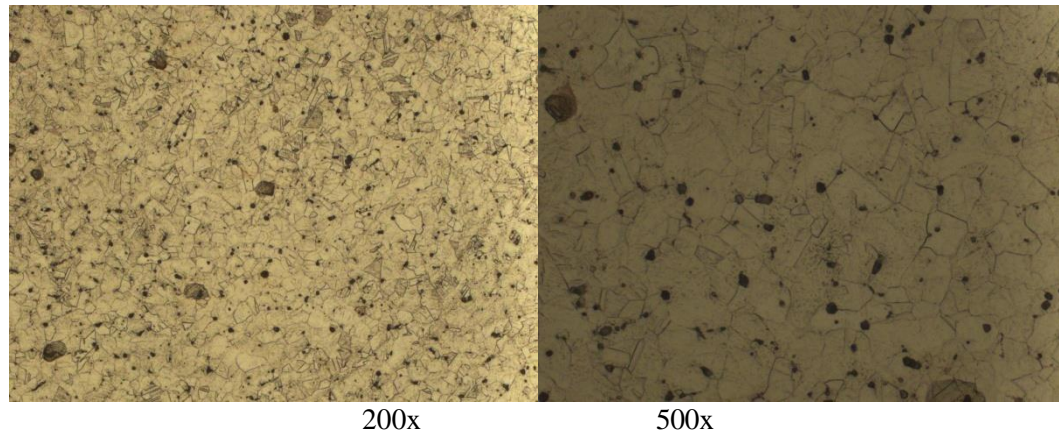


Figure 3. Metallographic structure of bolts.

The metallographic observation of the bolt shows that the microstructure of the bolt is austenite, as shown in Fig. 3. According to the requirement of standard [8], the microstructure of the bolt should be martensite, and the quenching and tempering process should be carried out. The above test results show that the bolts completely do not meet the requirements of the standard and are completely unqualified products.

4. conclusion

At present, the main materials for manufacturing high-strength bolts are high-quality carbon steel (45 steel), alloy structural steel (35CrMo, 42CrMo, 45MnMo steel), and stainless steel (0Cr18Ni9, 0Cr17Ni12Mo2 steel). The preliminary judgment of material can be completed by hand-held alloy analyzer [9]. According to the standard requirements, bolts with strength higher than 8.8 grade generally require quenching and tempering to obtain uniform and fine tempered martensite with excellent comprehensive mechanical properties. It can be found that there are problems in the microstructure of bolts whose mechanical properties do not meet the requirements, and the mechanical properties of the bolt can not be guaranteed. The hardness of bolts can effectively characterize the mechanical properties of bolts. The mechanical properties of bolts with qualified hardness basically meet the requirements [10].

For the quality Inspection of Bolts in hydroelectric power plant, the existing inspection technology is mainly ultrasonic detection. Although ultrasonic detection can effectively detect the internal defect of bolts, the material and mechanical properties of bolts can not be monitored. On the basis of the ultrasonic detection, combined with chemical composition analysis and mechanical properties test, the quality of bolts can be effectively controlled to ensure the safe operation of the water-turbine generator set.

Reference

- [1] Deng,D., Dai,feng F.,Zhong, Z.L.(2007) Disassembly and fixing technique about joint bolt of runner blade in the feilaixia. Large electric machine and hydraulic turbine,4: 49-52.
- [2] Yang, C.L., Hong, J.(2013) Hydropower station blade joint bolt replacement technology. Hydropower station electromechanical technology, 36: 53-64.
- [3] Huang, Q.H. (2004) Analysis on the brittleness fracture mechanism of high temperature bolts for the generation unit. Water conservancy & electric power machinery, 26: 9-10.
- [4] Liu, S.X., Song, X.P. (2013) Fatigue characteristic analysis of connecting bolts for large fans. Hydropower energy science, 31: 169-172.

- [5] Lin, Z.J., Chen, G.D., Wang, W.Q. (1995) Vibration of unit 2 ansha hydropower station and fracture analysis of fixing bolt of upper guide bush frame. Electricity and electricians, 1:25-27.
- [6] Huang, Q.S., Xie, G.S., Chen,H.D., Xie, Y.Y., Wan, K.Y.(2013) Research on crack formation mechanism of turbine axle bolts. People's Yangtze river, 43: 51-53.
- [7] GB/T 3098.1-2000 "Mechanical Properties of Fasteners Bolts, Screws and Bolts".
- [8] GB/T 3098.6-2000 "Mechanical Properties of Fasteners Stainless Steel Bolts and Bolts".
- [9] Zhang, D.W.(2005) Talking about metal inspection of high temperature bolts in thermal power plant. North China electric power technology, 8: 40-41.
- [10] Xie, A. M., Chen, H.D.(2013) Discussion on safety management of important bolts in hydropower plant. Hunan electric power, 33: 54-62.