Research on and Application of On-line Cleaning of Stainless Steel Tube Condense

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Abstract. Based on the analysis of the scaling of the stainless steel condenser in a power plant, through a large number of tests, the proper cleaning formula is selected to clean the scale in the condenser on line. After cleaning, the effect is obvious. After cleaning, the end difference of the condenser decreases from 10 °C to 5 °C, which saves a lot of fuel.

1. Introduction
The chemical cleaning and film-forming of condenser is an important measure to clean the inner surface of heat exchanger tube, improve the heat exchange rate and prevent the accident caused by scaling and corrosion of heat exchange tube. It is also one of the effective measures to improve the vacuum degree of condenser, reduce the end difference and improve the water vapor quality. At present, condenser cleaning mainly includes online cleaning and offline cleaning. Off line cleaning requires the unit to shut down and cut the inlet and outlet pipelines of the condenser, which increases the labor cost and equipment cost. Online cleaning is to add cleaning agent and chemical cleaning for condenser when the unit can not be shut down. It can not only reduce the cost of labor and equipment, but also improve the utilization hours of the unit.

The condenser tube of a power plant is 304 stainless steel tube, and the tube plate is 20 steel. The make-up water of the circulating water of the power plant is the mixture of the drainage water and the secondary discharge water of the sewage treatment plant, which is discharged through the reverse osmosis in the plant. The combined treatment process of scale inhibitor and acid is adopted for the treatment of the circulating water. Since the operation of the condenser of unit 2, the operating vacuum degree of the condenser has gradually decreased, and the end difference has gradually increased to 10 °C, which has a serious impact on the safety of production. Through the leak detection of the vacuum system and the inspection of the circulating water system, it is finally determined that it is caused by the scaling of the stainless steel pipe of the condenser.

After the shutdown, the extraction inspection of the condenser of unit 2 found that the scale in the pipe was mud colored, and a layer of white scale was found after the outer layer was peeled off. After the scale was cleaned, no corrosion pit was found on the surface of the pipe. The results are as follows:

| component | Fe₂O₃ | CuO | CaO | MgO | P₂O₅ | SiO₂ | ZnO | Al₂O₃ | K₂O | SO₃ |
|-----------|------|-----|-----|-----|------|------|-----|-------|-----|-----|
| Content(%)| 6.63 | 0.03| 60.18| 5.08| 4.02 | 3.6  | 0.01| 0.24  | 0.45| 1.09|

From the analysis results, it can be concluded that the main reason is calcium scale. Because stainless steel is sensitive to chloride ion, it can not be cleaned by hydrochloric acid, but by nitric acid.
Take a section of pipe sample about 80mm long, clean the outer wall of the pipe sample, weigh the weight of the pipe sample \( W_1 \) and measure the inner surface area of the pipe sample \( S \), immerse the sample in the nitric acid solution with 0.3% inhibitor and pH of 1.5, stir it with a glass rod at room temperature until the scale is completely dissolved, record the pickling time, take out the pipe sample immediately, wash it with water, and shake it in anhydrous ethanol for 1 minute. Put it into the dryer for drying for 1 hour, weigh it \( W_2 \)

\[
\text{weight of scale (g/m}^2\text{)} = \frac{W_1(g) - W_2(g)}{S(m^2)} = 685.43(g/m^2) \quad (1)
\]

Total weight of scale = \( 17000 \times 685.43 = 11652 \) (kg) \( (2) \)

2. Scope of chemical cleaning of condenser

Scope of chemical cleaning: stainless steel pipe of condenser, water chamber before and after condenser, water distribution equipment of cooling tower and circulating water pipe. See Table 2 for parameters of circulating water system.

| number | Equipment name          | specification | data   | remarks          |
|--------|-------------------------|---------------|--------|------------------|
| 1      | Model                   | N-17000-3     |        |                  |
| 2      | Steel pipe brand        | TP304         |        |                  |
| 3      | Number of steel pipes   | 根            | 21212  |                  |
| 4      | Specification of steel pipe | mm | Φ25    |                  |
| 5      | Cooling water volume    | m³            | 36211  |                  |
| 6      | Circulating water pump flow | m³/h | 12000  | Single operation |
| 7      | Velocity of water flow  | m/s           | 0.33   | Single operation |
| 8      | area of cooling surface | m²            | 17000  |                  |

3. Selection of cleaning process

3.1. Determination of acid pickling drugs

In this cleaning, nitric acid is used as the main cleaning agent for cleaning, and composite corrosion inhibitor is used for corrosion inhibition of the circulating system. Before cleaning, the concentration of acid and corrosion inhibitor is determined through small-scale test. The test pipe sample is the condenser extraction pipe sample, and the best cleaning technology is selected. The test data are as follows:
Table 3: dynamic test and results

| nitric acid concentration (pH) | Inhibitor concentration | test phenomena and results |
|-------------------------------|-------------------------|---------------------------|
| 1.0                           | corrosion inhibitor 0.3%| after 4 hours dynamic cleaning, clean all the dirt on the inner surface of the pipe sample, no residue, Metal surface is metallic gray |
|                               | Auxiliary 100mg/L       |                           |
| 1.5                           | corrosion inhibitor 0.3%| after 6 hours dynamic cleaning, clean all the dirt on the inner surface of the pipe sample, no residue, Metal surface is metallic gray |
|                               | Auxiliary 100mg/L       |                           |
| 2.0                           | corrosion inhibitor 0.3%| after 8 hours dynamic cleaning, clean all the dirt on the inner surface of the pipe sample, no residue, Metal surface is metallic gray |
|                               | Auxiliary 100mg/L       |                           |
| 2.5                           | corrosion inhibitor 0.3%| after 10 hours dynamic cleaning, there are still some residual scales on the inner surface of the pipe sample |
|                               | Auxiliary 100mg/L       |                           |
| 3.0                           | corrosion inhibitor 0.3%| after 15 hours dynamic cleaning, Most of the scale on the inner surface of the tube sample remains |
|                               | Auxiliary 100mg/L       |                           |

The test results show that the best choice is to use acid washing solution with pH of 2.0, which can not only clean, but also save a lot of drugs.

4. Preparation before cleaning
The acid resistant probe in the circulating water pipe must be removed or effectively isolated, and put into normal operation after cleaning.

Screening test of scale cleaning agents and auxiliaries.
At the outlet of the condenser, the acid washing liquid is led out to clean the monitoring pipe section, and the flow rate in the stainless steel pipe of the condenser is kept the same during cleaning.

Prepare 4 pieces of corrosion indicator with the same material as the steel pipe, and polish them with sandpaper to the required finish. Test piece specification 25 × 50 × 2mm.

Prepare enough chemical analysis reagents for hardness and iron ion analysis (large capacity analysis method) during acid pickling, and equip with two pH acidimeters (one at the inlet and one at the outlet).

The cleaning site is equipped with 4 walkie talkies for unified command.

5. Chemical cleaning process of condenser
In view of the material and scaling of the circulating water system of the unit, it is decided to adopt the non-stop cleaning technology for the condenser, and the cleaning medium is nitric acid.

According to the results of small-scale cleaning test, the cleaning process is divided into two steps, i.e. sludge cleaning step and scale cleaning step.

5.1. Space considerations
Organic solvent is used for sludge removal. The cleaning agent is composed of desliming agent, defoamer and wetting agent. The cleaning concentration is controlled between 200-300mg / L and the cleaning time is 6-8 hours.

5.2. Salt scale cleaning
When the 5.1 step is over, directly enter the carbonate scale cleaning step. The cleaning solution is composed of nitric acid, corrosion inhibitor, auxiliary agent, etc. The cleaning system process is: water
tower → circulating water pump → condenser water inlet pipe → condenser return pipe → water tower. Medicine is added to the square well of circulating water pump forebay.

Keep the normal operation mode of the unit, add the cleaning agent into the square well 2 at the inlet of the circulating water pump in the sludge cleaning stage, and the dosing speed is appropriate to add all the sludge cleaning agents within 30min. The dosing of salt scale cleaning stage is as follows: firstly, add cleaning aids (including corrosion inhibitor, organic AIDS, etc.) into square well 2 to pre inhibit the system for 5min, then add nitric acid from square well 1, and the nitric acid is directly injected into square well 1 by acid truck. The amount of acid added is determined by the analysis results after sampling the condenser at the inlet of the site. The best acidity is to control the pH value of the water sample at the inlet of the condenser to be about 2.0 during the whole pickling process. When the sampling analysis results of the condenser inlet and outlet are the same, it means that the cleaning has been basically finished. Finally, the final cleaning end time can be determined according to the monitoring pipe section.

6. Conclusion
After the chemical cleaning of No. 2 condenser, open the air door of No. 2 condenser, and comprehensively check and evaluate the chemical cleaning effect of the condenser.

The comparison between the inspection and inspection results of condenser chemical cleaning quality and the quality indexes of condenser chemical cleaning specified in "DL / T 957" standard is shown in Table 4.

| Inspection items | “DL/T 957” Provisions in the standard | Actual inspection and test results |
|------------------|-----------------------------------------|----------------------------------|
| check whether there is residual oxide on the inner metal surface of the condenser and whether there is over washing | "After cleaning, the metal surface shall be clean, free of residual carbon film and basically free of residual hard dirt" | (1)There is no residual oxide on the surface of condenser, and there is no over washing phenomenon of coarse metal crystal precipitation; (2)There is no carbon film or residual hard scale on the surface of condenser, and the passivation film is relatively uniform |
| removal rate of corrosion products in condenser | Excellent:≥95% | After cleaning, the stainless steel pipe surface of condenser is uniform silver gray, and the scale removal rate is 99% |
| whether the fixed equipment of condenser is damaged | "Fixed equipment, valves, instruments, etc. of condenser body shall be free from damage" | After inspection, the fixed equipment, valves and instruments of the condenser body are not damaged. |
| Average corrosion rate | <1 g/m².h | 20 steel test piece: 0.65g/m².h 304 stainless steel test piece: 0.58g/m².h |

Through small-scale simulation test and careful preparation before chemical cleaning of condenser, chemical cleaning of condenser is carried out by using nitric acid chemical cleaning process without shutdown. After chemical cleaning of No.2 condenser, the effect evaluation is excellent. After the condenser is cleaned, the inner surface of the heat exchange tube is clean and the heat exchange rate is increased, and the accidents caused by scaling and corrosion of the heat exchange tube are effectively prevented. The cleaning practice shows that the cleaning process is reliable and achieves the expected cleaning effect. At the same time, it provides a reference for the chemical cleaning of similar condensers in the future.
Acknowledgement
This study was successfully completed, with the help of colleagues and the support of relevant power plants. Thanks a lot.

References
[1] Zhou, D., Li, B. (2016) Study on On-line Chemical Cleaning of Condenser with Titanium Tubes in 330 MW Thermal Power Plant. Northeast Electric Power Technology, 37: 34-37.
[2] Xu, J. W., Jiang, G. C. (2009) Chemical Cleaning of Stainless Steel tube Condenser of 330 MW Thermal Power Plant. Cleaning World, 25: 38-42.
[3] Zhu, Y. J., Liu, W., Liu, G., Hang, X. F. (2012) Review of Condenser Cleaning Technology. Cleaning World, 28: 34-37.
[4] Wang, Y. L., Yao, L. C., Liu, X. C., Wang, M. Z. (2012) Implementation of the new type of acid pickle process of condenser unit 135 MW. Industrial Water Treatment, 32: 90-92.