Failure analysis of Desuperheater

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Abstract—Temperature regulation by desuperheater spray is an important part to ensure the stable operation of utility boiler. However, due to the bad working conditions, the spray pipe of Desuperheater will produce strong vibration, and the connected equipment will have alternating stress. At the same time, due to design or manufacturing reasons, abrasion or cracking occurs at the welding part or the contact part between the water spray pipe and other parts. Taking measures to ensure stable operation, reasonable design and qualified manufacturing can effectively guarantee the safe operation of power plant equipment.

1. INTRODUCTION

During the operation of power plant boiler, the operating environment such as combustion condition and unit load will often change. Sometimes, the flue gas temperature will rise or the steam temperature at the inlet of the heating surface will be on the high side, which may cause the wall temperature of the heating surface to exceed the allowable value, resulting in over burning, spheroidization and even explosion of the heating surface pipe. It is very important to regulate the temperature of steam by various methods to protect the safe operation of equipment.

At present, a large part of the units in service in the west of Inner Mongolia are a batch of 300MW units built after 2000. There are two main ways of regulating the steam temperature of the heating surface in this batch of units: steam side regulation and flue gas side regulation. The flue gas side can be adjusted by means of burner swing, flue gas recirculation, etc.; while the steam side is usually adjusted by putting desuperheating water into the temperature adjustment, that is, by setting a desuperheater on the connecting pipe between the low-temperature heating surface and the high-temperature heating surface. Cooling water is directly injected into the steam, and the cooling water will evaporate into water vapor in the pipe, and mix with the steam to reduce the steam temperature [1]. Because of its sensitive response and high regulation accuracy, desuperheater temperature regulation has become an important auxiliary means of boiler equipment temperature regulation.

For 300MW units, two-stage desuperheater is generally set between superheaters. The primary desuperheater is set between the low-temperature superheater and the platen superheater, and the secondary desuperheater is set between the platen superheater and the high-temperature superheater. Different units will have different changes. For reheater, micro spray desuperheater is set between low temperature reheater and high temperature reheater, and emergency desuperheater is set in front of reheater inlet. Each type of desuperheater is set in pairs, which is placed on the pipeline at the side A and B, and spray desuperheating water from both sides respectively.
At present, the commonly used spray pipe of desuperheater is cantilever type. There are many small holes in the spray pipe. The desuperheating water is ejected from the small holes and atomized, and mixed with the steam flowing in the same direction to reduce the steam temperature. The working environment of the desuperheater nozzle is very bad. On the one hand, it needs to bear the action of high temperature steam, on the other hand, it also needs to bear the fast cooling of low temperature desuperheating water, which is very easy to cause thermal fatigue damage of materials [2].

2. FAILURE CASE ANALYSIS
In October 2018, during the boiler internal inspection of a power plant, the spray pipe of the micro spray desuperheater arranged from the side wall of a and B to the platen tube was cut for inspection. Through the endoscopic inspection, it is found that the nozzle bridge is broken and seriously damaged. The endoscopic inspection results are shown in Figure 1.

Figure 1. Endoscope inspection of micro spray desuperheater nozzle

After that, the nozzle on both sides was checked for pipe drawing, as shown in Figure 2 and Figure 3. It was found that all the bridges were broken, the spray holes were connected, the matrix was obviously thinned, and the whole nozzle was severely rusted. There are obvious signs of friction and impact at the contact between the nozzle and the mixing tube. On the one hand, a large amount of desuperheating water is frequently put into use, which leads to serious abrasion on the front of the nozzle, even to the punching of the orifice bridge; on the other hand, a large amount of desuperheating water is mixed with steam, which leads to serious vibration of the nozzle, and frequent friction and collision between the two ends of the nozzle and the mixing pipe. The damage of the nozzle parallel to the medium direction is obvious. It can be seen that it is caused by impact, while the upper and lower side traces are shallow, mainly due to friction.

Figure 2. Downstream side of nozzle
3. COMMON FAILURE MODES OF DESUPERHEATER

3.1. Racking or falling off of positioning bolt, support bolt and base plate of mixing pipe

The structure of porous spray desuperheater is shown in Figure 4. The desuperheater mixing pipe is fixed in the boiler connecting pipe to protect the pipe. Because when a large amount of desuperheating water is put into the process, the desuperheating water contacts with the steam in the pipeline, which will cause strong vibration and water hammer to the surrounding metal [3]. The mixing pipe is located inside the pipe and does not bear the internal pressure of steam. It is mainly scour by water hammer and steam. The outer tube seat of the desuperheating water spray pipe is welded to the outer wall of the pipe in the form of fillet weld. The internal spray pipe is inserted into the pipe and mixing pipe. The spray direction of the nozzle is the same as that of the steam to avoid strong convection and greater impact and vibration.

The desuperheater mixing tube is positioned by a set screw. There are 4 support screws at upstream and downstream respectively to support and fix them. However, due to the poor welding quality in the manufacturing process, and the vibration of the mixing pipe in the operation process, the weld between the screw and the pipe cracks or even falls off. Falling objects entering into the downstream header may cause pipe hole blockage, which may lead to pipe explosion.
3.2. Root defect of Desuperheater nozzle
The structure of Desuperheater spray pipe is cantilever type. When put into use, the part that extends into the steam pipe will be affected by steam impact, medium temperature difference and flow rate, and the spray pipe will produce high-frequency vibration. At the joint of water spray pipe and tube seat and the fillet weld of tube seat and pipe joint, the alternating stress transmitted by high frequency vibration causes fatigue crack at the weld joint. At the contact between the spray pipe and the pipe and the mixing pipe, the vibration of the spray pipe will cause friction and impact, resulting in damage [4]. In order to support the nozzle, two steel plates will be welded on the inner wall of the mixing pipe at the contact between the nozzle and the mixing pipe. However, in the case of vibration, the edge of the steel plate and the edge of the mixing tube will also cause damage to the nozzle. At the same time, at the gap between the nozzle and the inner wall of the tube seat, it is easy to cause the concentration of corrosive substances, which will cause corrosion damage to the nozzle. Therefore, the fillet welds of nozzle and desuperheater are prone to crack and other failures.

3.3. Effects of mixing pipe
The mixing tube is usually spliced. If there are welding defects such as incomplete penetration and undercut in the manufacturing process, the vibration during operation may lead to cracking. At the same time, when the desuperheater is put into operation, the mixing pipe is in a large temperature change, which will lead to thermal fatigue and even fatigue cracking.

4. Failure reason of Desuperheater
The defects of Desuperheater mainly come from the following three aspects:

   Design defect. One end of the nozzle of the desuperheater with cantilever structure of the nozzle is fixed, and the other end is suspended to ensure a certain expansion margin. In actual operation, due to the vibration of the spray pipe, the displacement of the suspended end is large, which further leads to the large swing of the spray pipe. At this time, the root of the spray pipe is subjected to a large transverse moment.

   Manufacturing defects. There are many parts involved in the desuperheater, and each part needs close cooperation. Especially for the welding parts, such as the welding between the water spray pipe socket and the pipe, the welding between the pipe socket and the water spray pipe, the welding of the support screw, the welding of the mixed pipe plate, etc., there may be welding defects. The existence of welding defects will lead to cracks or even cracks under the action of vibration. At the same time, the welding defects or the gap produced in the welding process will cause the accumulation of corrosion products, and stress corrosion will occur under alternating stress. Moreover, at the contact of different parts, due to the looseness of manufacturing links, friction or impact will occur under the action of vibration, resulting in equipment damage or fracture.

   Operation problem. After the desuperheater is put into operation, with the impact of high-pressure steam, the change of steam pressure, the switch on and off of desuperheating water and the change of desuperheating water pressure, the suspended end of the nozzle is in the working state of shifting towards the steam flow direction and constantly swinging. Under the impact of high-pressure steam and the reaction of water spray, the nozzle is in repeated vibration, and the fixed end of the nozzle bears huge shear stress. Because of the huge destructive force, if there are welding defects such as lack of fusion at the root of the nozzle with large stress concentration, it will become the crack source, which will lead to cracking until fracture, and some desuperheaters will produce defects even in a short period of operation [5]. In addition, the thermal stress produced by the nozzle in the medium of high temperature steam and low temperature desuperheating water under the action of alternating temperature will also accelerate its failure process. When there is a crack at the root of the nozzle, the desuperheater will lose its temperature reducing effect, and the desuperheating water will be directly ejected from the crack, resulting in direct contact with the tube of the desuperheater, which will cause cracks on the inner wall of the tube of the desuperheater in a short time of operation [6,7].
5. REATMENT OF DESUPERHEATER FAILURE

According to the problems found in the use of the desuperheater, the failure of the desuperheater can be effectively solved by taking targeted measures.

Under the normal and stable operation state of the equipment, the desuperheater does not spray water or less. Only when the temperature rise speed of flue gas or steam at the inlet of the heating surface is too high, can it be put into use in large quantities [8,9]. Therefore, the application of Desuperheater can be effectively reduced when the coal quality is qualified and uniform, the load is stable and the equipment is stable.

Improving the structure design of Desuperheater or adopting advanced desuperheater structure can effectively fix the free end, reduce the vibration and swing of water spray pipe, and effectively reduce the damage to connecting equipment. Using high-grade material and heat-resistant steel instead of carbon steel can effectively damage the spray pipe by corrosion and scouring.

In terms of manufacturing, strictly implement the welding process to ensure that all welds are free of welding defects. The fixing of positioning, limit and other parts shall be tight to prevent friction and impact caused by vibration.

In terms of management, first of all, ensure that the temperature measuring points of Desuperheater at all levels are accurate and reliable, and then pay attention to the flow and temperature change of desuperheating water in time [10]. Finally, metal personnel should take advantage of the opportunity of unit maintenance to strengthen supervision and inspection. According to DL647-2004 inspection code for boiler and pressure vessel of electric power industry, the desuperheater shall be inspected by endoscopy every 15000-30000 hours. In order to ensure the overall inspection of all parts, the water spray pipe shall be taken out during each inspection. When the water spray pipe is deformed, even the handhole on the opposite side of the water spray pipe shall be cut, and the welding and heat treatment shall be carried out again during recovery [8]. At the same time, cut the handhole of header, check the temperature mixing pipe with flashlight, and check the connection thread of water chamber surface and water spray pipe with endoscope.

6. ONCLUSION

In the design of desuperheater, because of its cantilever setting, the vibration of desuperheater is too large. At the same time, the welding defects in the remanufacturing process combined with the bad operating environment lead to equipment corrosion, cracking, wear and other failures. In terms of design, manufacturing and operation management, taking targeted measures can effectively control equipment failure and improve the safety and reliability of equipment operation.

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