

Super Heater Tube Analysis for Oxide Scale Growth at Various Operating Conditions

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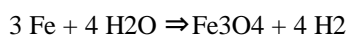
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ABSTRACT: super heaters are widely used in steam generators and heat-recovery steam generators (HRSGs). Their purpose is to raise steam temperature from saturation conditions to the desired final temperature, the steam flowing through the super heater tubes is usually heated at a very high temperature to ensure that all saturated steam is converted into superheated steam. In fact, the elevated temperature will cause the formation of oxide scales on the inner surface of the tube. This oxide scale reduces the heat transfer from the hot flue gas into the steam within the tube. This thermal barrier will cause failure of tubes. Finite element modeling is used for finding the overheating of the tubes with oxide scale.

KEYWORDS: Boiler tube, Ultrasonic testing, Energy Dispersive X-ray (EDS).

I. INTRODUCTION

Super heater tubes that operated at elevated temperature (in excess of 800 degrees Celsius), this elevated temperature will cause the formation of oxide scale at various operating conditions. The main causes of the metallurgical failure of the tubes in water tube boiler are due to tube temperature higher than expected in the original design. Internal oxide scale formation or deposit formation usually results in long term overheating that gradually increases the temperature. At high temperatures, water vapor will react with the iron in the steel to form magnetite and hydrogen according to the formula



The speed of this reaction increases with temperature. Oxygen atoms will spread inward through the oxide layer, and iron atoms will diffuse outward, so the scale continues to grow even after the tube surface is completely covered. Oxide scale acts as thermal barrier on the pipe and reduces the heat transfer from the hot flue gas into the steam within the tube. The main concern here is the consequence of failure of boiler tube can be expensive and tragic. Failure of super heater tubes during operation is a major cause of chemical plant shutdowns. These failures will cause a delay in the production process and considerable financial losses but also necessitate immediate attention with respect to repair and maintenance. According to statistical surveys of boiler failures in the past, 48–60% of failures were caused by overheating and 15–20% was caused by different modes of corrosion. Long-term overheating is the major effect of formation of oxide scale layers, which will lead to failure due to accelerated creep.

Therefore the prevention of the oxide scale and improving the super heater by applying the different alloyed steel. Scaling on the tube wall also increases at increased steam temperature and the resistance of scaling is essentially determined by the chromium content. Higher Cr-containing steels to produce thinner scales.

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II. DETAILS OF EXPERIMENT

A. Materials and Procedures

Commercial water tube boiler setup was used to subject the thermal transient cycle to cylindrical specimens 0.0508 m in diameter and 1m long. Different combinations of maximum transient temperature and oxide scale were evaluated by Ultra Sonic Testing Machine and cross checking the result by weight gain measurement and Energy Dispersive X-ray (EDS). The specimens were examined that had been cycled in 10 hr. Oxide scale thickness tests were performed on different material over a wide range of conditions: temperatures varying from 540°C to 860°C.

The test facility is composed by main sub-systems that are: solution makeup system, solution feed & bleed system, and test vessel. In the solution makeup system there are two main reservoirs; one is a main water reservoir and the other is a mixing reservoir. The water is filled in the mixing reservoir and the makeup water is transferred to the main reservoir. The test solution in the mixing reservoir is fed through a high-pressure pump. The solution feed & bleed system is mainly composed of a water chemistry monitoring system, a high-pressure pump, a pre heater, a cooler and back pressure regulator,

In water tube boilers, water is passing through the tube and hot gases pass over and around the outside of the tubes. This hot gas converts the water in to steam. The flow of steam and water within the super heater is called circulation. This circulation is crucial for preventing the tubes from overheating. When tubes are overheated, it will cause the formation of oxide scale. In water tube boiler, bubbles of steam will form in the heated tubes or "risers". and rises to a steam drum at the top of the water tube boiler. Here the bubbles rise up and the steam is released. The water then flows from the drum down through the "downcomers", completing and repeating the cycle. The water circulation in a water tube boiler is shown in Fig 1.

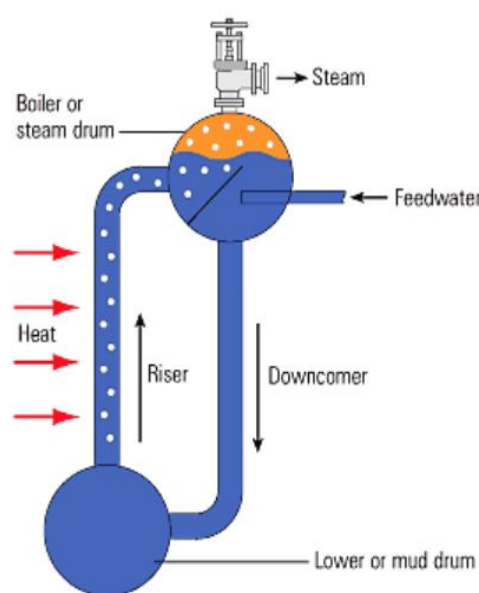


Fig .1. Water circulation in a water-tube boiler

Assessment of boiler tube is made of 9 Cr-1Mo, 12Cr-1Mo, 18Cr-1Mo. Chemical Compositions of different alloyed Steels are shown in Table 1.

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Table 1: Chemical Compositions of different Steels (wt. %)

Material	C	Si	S	P
T91 (9Cr-1Mo)	0.10	0.5	0.025	0.025
HCM12 (12Cr-1Mo)	0.10	0.59	0.007	0.006
800H (18Cr-1Mo)	0.099	0.32	0.42	0.10

Mn	Cr	MO	Co
0.6	9.89	1.01	0.024
0.50	12.2	1	0.031
9	18	1	0.0

B. Ultrasonic Instrumentation and Transducers

An ultrasonic thickness measurement (UTM) technique is used for measuring the oxide scale thickness. These systems are effective for measuring the oxide scale thickness, but it is not convenient for commercial use, because it is expensive. Internal oxide scale Measurement by small hand-held ultrasonic gages with software. This device is capable of detecting appropriate echoes and measuring the interval between the two echoes that represent the steel/oxide and oxide/air boundaries, as shown in fig 2.

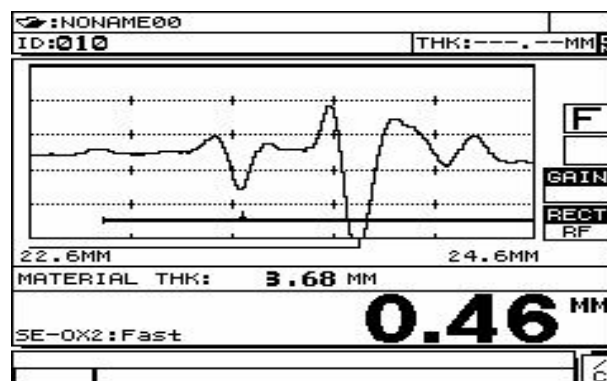


Fig . 2. Oxide scale measurements by Model 37DL PLUS

The 37DL PLUS is a nondestructive ultrasonic thickness gage that combines powerful measuring features and output capabilities for applications involving tanks, pipes, and other metal structures subject to internal corrosion or erosion. The Oxide Scale option measures and display the thickness of the oxide scale on the inside of boiler tubes. Using an “Alpha” type straight beam Shear Wave probe is used to obtaining thin oxide layer measurements.

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C. Energy Dispersive X-ray (EDS) analysis

Cross-sections from the samples were analyzed by conducting energy dispersive x-ray analysis to determine the composition profile of the oxides.

D. Computational Fluid Dynamics (CFD) analysis

In order to find a deposit rate in boiler tubes CFD analysis has been done. This analysis was done using ANSYS Fluent 15 Software.

III. RESULTS AND DISCUSSION

The temperature distribution in the boiler tube is affected by the variables such as; boiler tube material, and scale thickness. Therefore, those variables are considered to be applied in this analysis.

A. Relationship between oxide scale and time

Various alloyed steels are used for preventing the super heater tubes from oxide scale. Higher Cr-containing steels to produce thinner scales. Relationship between oxide scale and time is shown in fig 3.

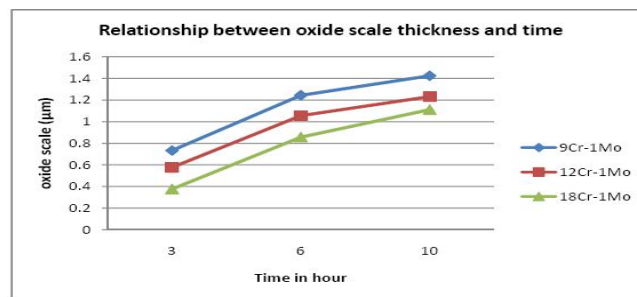


Fig . 3. Relationship between oxide scale and time

B. Relationship between oxide scale and pressure

During wet oxidation, if the oxygen makes the part of the process recipe, it will reduce the water vapor partial pressure and slowing the overall growth rate. Because the oxidation rate of silicon with oxygen molecules to water molecules is almost ten times slower. Relationship between oxide scale and steam pressure as shown in fig 4.

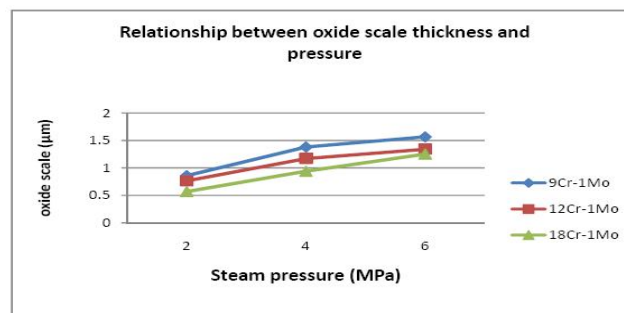


Fig. 4. Relationship between oxide scale and steam pressure

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IV. CONCLUSIONS

Behavior of oxide scale thickness on various materials was studied and major conclusions are as follows:

- 1) Oxide formation was identified as the main failure mechanism in super heater tubes.
- 2) Oxide formation was a result of overheating in super heater tubes.
- 3) Higher Cr-containing steels to produce thinner scales.

V. ACKNOWLEDGMENT

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