

Design and Performance Analysis of Water Tube Boiler

¹Mr.Vivek M, ²Dr.Annamalai P, ³Dr. Saravanan P

¹(ME Student, Department of Mechanical Engineering, MEC, Mallasamudram, Namakkal DT - 637503)

²(Assistant Professor, Department of Mechanical Engineering, MEC, Mallasamudram, Namakkal DT - 637503)

³(Head of the Department, Department of Mechanical Engineering, MEC, Mallasamudram, Namakkal DT - 637503)

Abstract

The boiler tube has an essential role in converting water from liquid to vapour. Nevertheless, it requires a variety of materials that has a role to play in finding the best properties of materials, primarily at a steam power plant. One of the properties, when a boiler is run, is to obtain pressure. Several pieces of the literature indicated that surface characteristics influence a material's life after receiving continuous stress with the pH quality of feed water which leads to failure. This study aims to suggest feedwater pH and different materials for boiler tubes by using CFD. We choose pH values that are used in feed water (6.5 and 8.8), and the materials are carbon steel (ST20 and ST 45.8) for the boiler tube.

By analyzing these tubes with parameters of temperature difference & pH range of feed water, the erosion rate of the boiler tube has been shown by the above parameters of feed water. So we analyze the boiler tube in different materials using CFD that the results of fluid temperature difference. By this comparison, we can find which material is suitable for a boiler tube with pH value.

I. INTRODUCTION

A water tube boiler is such a type of boiler where inside tubes the water is steamed and surrounded by the hot gasses. This is the basic water tube boiler concept. This boiler is just opposite the fire pipe boiler where hot gasses travel through tubes that are surrounded by water.

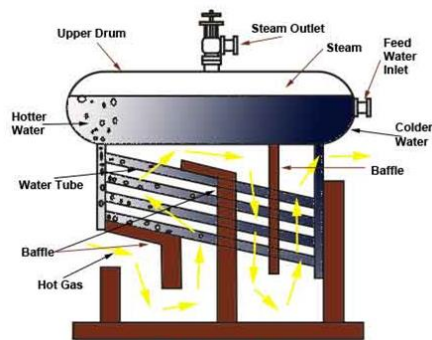


Fig. 1.1 Longitudinal Drum Water Tube Boiler

One cylindrical drum is mounted longitudinally above the steam chamber in the longitudinal water tube boiler. The corner pipe is filled in the back of the drum downward and is positioned in front of the drum riser pipe, as shown in Fig. 1.1. Such downstream tubes and riser tubes are connected by 5 ° to 15 ° straight water pipes.

II. LITERATURE REVIEW

ShajiKumar & Tide [1] the biomass-fired boiler quality review was performed in Palm Oil Mill, and the actual value was 82% (Indirect method) and 65% (Direct way) and was found to deviate from the standard value due to losses. In the present study,

the boiler's output has decreased by 5 to 10 percent. After an extended period, the boiler output test in Palm Oil Mill was performed, and a 10 percent reduction in efficiency was found. Corrosive condensate produced by condensing leaked steam from superheater pipes, activating SCC wall tubes protected where the poor section has been found. The supply of SS plate transfers heat to the Super Heater Tube in a safe manner. Good quality coal suggested by the metallurgical department should be used with an adequate content of chlorine, carbon, and sulfur. The safe outer anti-corrosion and erosion layer will be protected by adequate fire impingement, draft, and air ingress with soot blower to say the **Patel Sunny Sanjay et al. [4]**.

AgusWibawa et al. [5] High-pressure heater is redesigned to overcome the problem after several analyzes with higher flow rate efficiency. However, when introduced, the new high-pressure heater has better performance. After a year of testing, the new design also proved more effective. When applied in power plants, the above solutions not only reduced tube failure, but also reduced tube repair costs, increased boiler efficiency, reduced power generation interruption. The general recommendation to minimize tube failure is to use low coal to reduce the rate of erosion and also to reduce the major problems of tube failure. The future presents several challenges, with the expected tightening of the electricity market likely to increase the cost of boiler tube failure at a time when it is set to raise the number of failures to say the **Sakthivelet al. [6]**.

Sarken et al. [11] the equation was developed to estimate the Steel20 temperature rise for



different thicknesses of the oxide scale. As all previous research on Cr-Mo steels has been done, this is an original work. Under the grant extension, this work is continued to develop a complete correlation between the thickness of the internal scale and the degree of creep damage in Steel20 material. This paper is one of the first attempts to establish guidelines for combined treatment of a few different types of tube degradation in Steel20. In contrast, the current rejection/removal requirements separately consider each of these mechanisms. As it provides the internal helical ribs in the boiler tube, when compared to the normal boiler tube, the pressure variations are in the optimum range. Compared to the normal boiler pipe, the temperature distribution is high at the pipe outlet. This process was developed by Muchhu Siva Naga Muneendra et al. [8].

Kamlesh Dewangan et al. [9] a model was developed to predict the erosion rate for the impingement of fly ash particles on the surface of the boiler portion and the variance of erosion rate with different parameters & velocity and found to be in good agreement with the experimental data. However, if the highly erosion-resistant particles are densely packed into a matrix layer that allows the impacting particles to impinge on a higher percentage of the hard object, the resistance to erosion increases significantly. As compared to other stuff, tungsten carbide is stronger. When the boiler is worked in the dynamic power generation mode at a minimum load of 180 MW for a long time, there may be variations in the tube temperature difference between the parallel tubes; it's presented by Liping Pang et al. [10].

III. EFFECT OF BOILER TUBE PROPERTIES

As the boiler tube's life reaches its peak, there will be failure such as rupture. Since the boiler is worked at high temperature and pressure, any rupture of the pipe will cause the surrounding tubes to significant physical harm.

The main reasons for the damage can be classified into three major categories:

- Mechanical
- Corrosion
- Erosion

IV. MATERIAL SELECTION

Based on the processing and environment of the boiler tube, the material of carbon steel ST20 exists. There was a problem with tube life that the erosion occurs, for this error, replace the new tubes shortly. To recover this problem, we may select other material for the boiler tube, carbon steel ST 45.8 (Proposed grade). This material will give better performance than the existing material. The properties of these materials are discussed below:

CARBON STEEL ST20: (Existing)

Density	- 7850 kg/m ³
Specific heat	- 502.416 J/kg K
Thermal conductivity	- 36 W/m K
CARBON STEEL ST45.8: (Proposed)	
Density	- 7850 kg/m ³
Specific heat	- 461 J/kg K
Thermal conductivity	- 51 W/m K

V. pH VALUE OF FEED WATER

It is necessary to maintain the pH value of boiler water and feed water. Corrosive water quality can be understood from pH value as it shows alkaline, neutral, or acidic water quality. However, the pH value does not show the amount of alkaline or acid content in water.

FEED WATER pH WITH PROPERTIES

pH 6.5

Density (Kg/ m ³)	= 1000
Specific heat (J/kg-K)	= 4181.4
Thermal conductivity (W/m-K)	= 0.579
Viscosity (Kg/m-s)	= 1.00x10 ⁻³

pH 8.8

Density (Kg/ m ³)	= 971.8
Specific heat (J/kg-K)	= 1996
Thermal conductivity (W/m-K)	= 0.68
Viscosity (Kg/m-s)	= 0.000354

VI. DESIGN OF WATER TUBE BOILER

CREO is a versatile technology that incorporates different design tools. It is commonly used by many of the world's leading manufacturing companies. To water tube boiler model created in the Creo Parametric software.

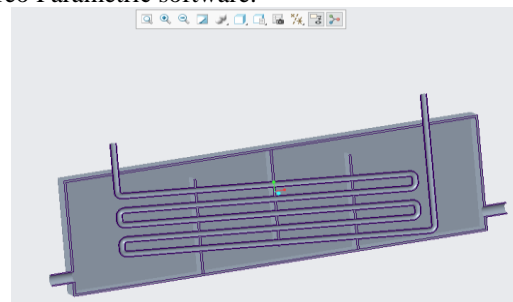


Fig. 6.1 Water Tube Boiler Model

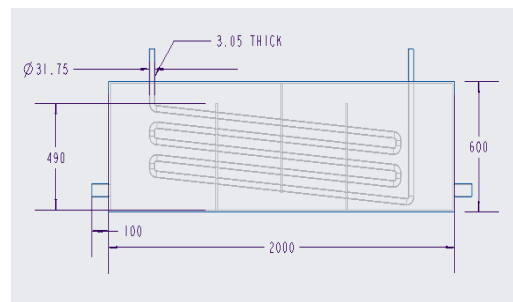


Fig. 6.2 Water Tube Boiler Dimension

VII. ANALYSIS OF WATER TUBE BOILER

CFD is a mathematical study of fluid flow, heat transfer, & associated phenomena. CFD solvers contain a complex set of algorithms that are used to model and simulate fluid, gas, heat, and mechanical flow. Without CFD, it would not be possible to achieve most technological advances in automobiles, aeronautics & space.

Performing a CFD Analysis

This takes place in three stages: pre-processing, processing, and post-processing. It involves problem-solving, meshing, and creating a computational model in the pre-processing stage, all the activities that take place before the numerical solution process. Processing involves the use of a computer to solve fluid flow mathematical equations. This is a very intensive process, and usually, it requires the computer to solve many thousands of equations. In each case, the equations are integrated, and boundary conditions are applied to it. This software is used to evaluate the data generated by the CFD analysis in the post-processing stage. The findings can be evaluated numerically as well as graphically when the model has been resolved. The water tube boiler model, meshing, and boundary condition shown in Fig. 7.1, 7.2 & 7.3.

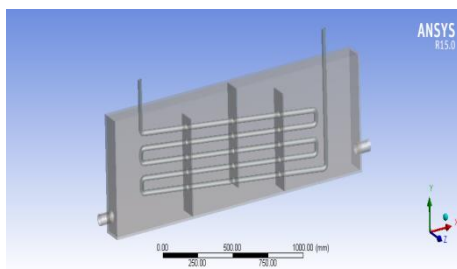


Fig. 7.1 Model in Analysis Software

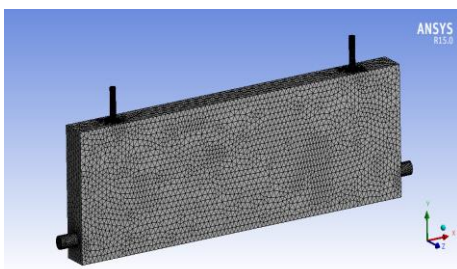


Fig. 7.2 Meshing

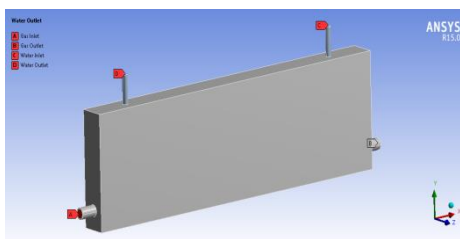


Fig. 7.3 Boundary Condition

FEA as useful in engineering possibly will be a machine tool for performance arts engineering analysis. It consists of the operation of mesh creation techniques for dividing a difficult problem into tiny parts, moreover because of the use of software package program coded with FEM rule. The water tube boiler model should create tiny parts based on meshing.

Table 7.1 Number of Elements & Nodes

Number of Elements	Number of Nodes
1772478	490573

A. CARBON STEEL ST20: (Existing)

The carbon steel ST20 is one of the existing materials of the water boiler tube. So its check the temperature difference based on two different pH value of feed water. The difference should show graphically and numerically in Fig below.

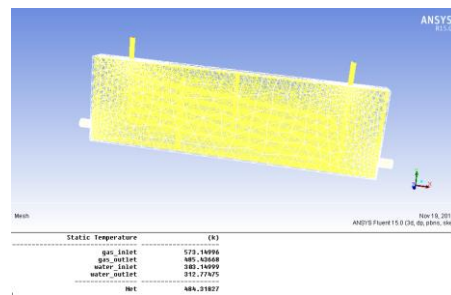


Fig. 7.4 Numerical Temperature Difference in ST20 (pH 6.5)

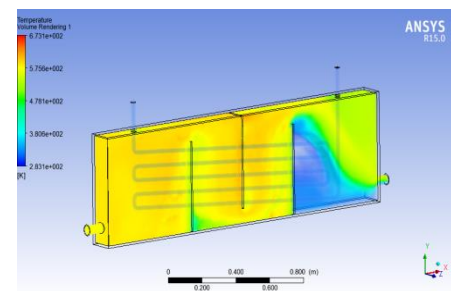


Fig. 7.5 Graphically Temperature Difference in ST20 (pH 6.5)

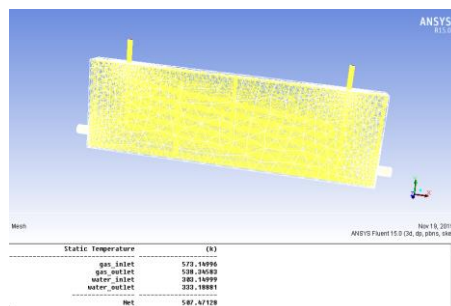


Fig. 7.6 Numerical Temperature Difference in ST20 (pH 8.8)

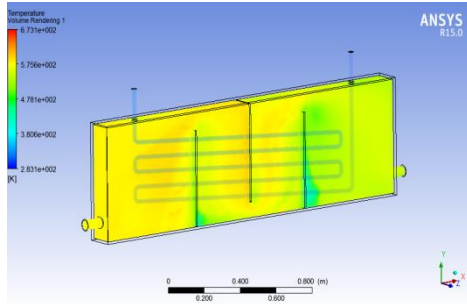


Fig. 7.7 Graphically Temperature Difference in ST20 (pH 8.8)

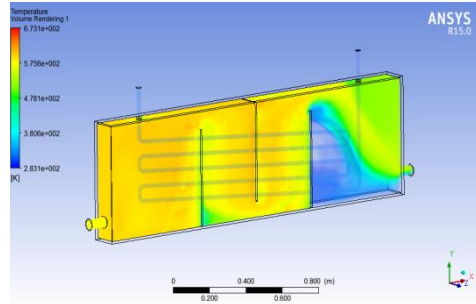


Fig. 7.9 Graphically Temperature Difference in ST45.8 (pH 6.5)

Comparative of Carbon Steel ST20

Table 7.2 Comparative of Carbon Steel ST20

Description	CARBON STEEL ST20	
	pH 6.5	pH 8.8
Hot Gas Inlet (°C)	300	300
Hot Gas Outlet (°C)	212.28	265.19
Water Inlet (°C)	30	30
Water Outlet (°C)	39.62	60.03

The hot gas flow in 15 LPM at 300°C and at the same time feedwater flow in 10LPM at 30°C. It's observed the above Table 7.2 is Feedwater pH 8.8 is better performance of the water tube boiler.

B. CARBON STEEL ST45.8: (Proposed)

The carbon steel ST45.8 material used in the project of water boiler tube, So its check the temperature difference based on two different pH value of feed water. The difference should show graphically and numerically in Fig below.

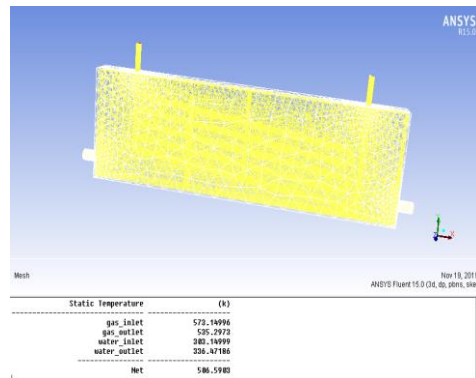


Fig. 7.10 Numerical Temperature Difference in ST45.8 (pH 8.8)

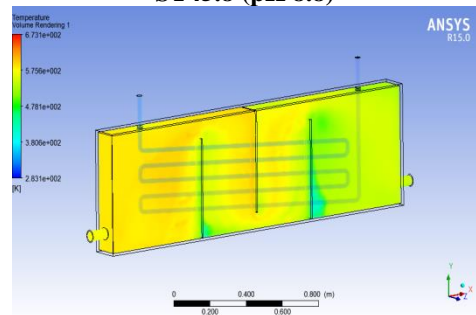


Fig. 7.11 Graphically Temperature Difference in ST45.8 (pH 8.8)
Comparative of Carbon Steel ST45.8

Table 7.3 Comparative of Carbon Steel ST45.8

Description	CARBON STEEL ST45.8	
	pH 6.5	pH 8.8
Hot Gas Inlet (°C)	300	300
Hot Gas Outlet (°C)	212.43	262.14
Water Inlet (°C)	30	30
Water Outlet (°C)	42.55	63.32

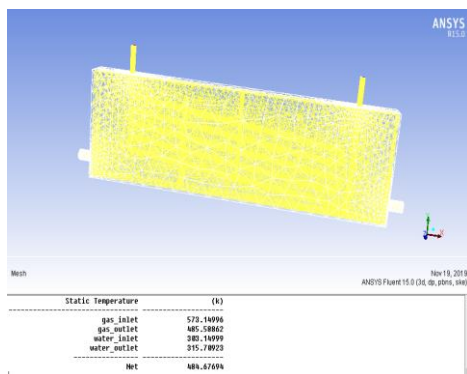


Fig. 7.8 Numerical Temperature Difference in ST45.8 (pH 6.5)

The hot gas flow in 15 LPM at 300°C and at the same time feedwater flow in 10LPM at 30°C. It's observed the above Table 7.3 is Feedwater pH 8.8 is better performance of the water tube boiler.

C. EROSION CORROSION

Erosion corrosion is the wear and corrosion caused by a rapidly flowing liquid. The extent of the attack depends on the degree of turbulence... Erosion corrosion may occur in water pipes when the flow velocity is high and particularly where the flow is disturbed, e.g., at unsuitably formed branches, connections, or bends.

The proposed material is the best material of temperature difference, so it's to predict the erosion in Carbon Steel ST45.8 material based on both pH value feed water.

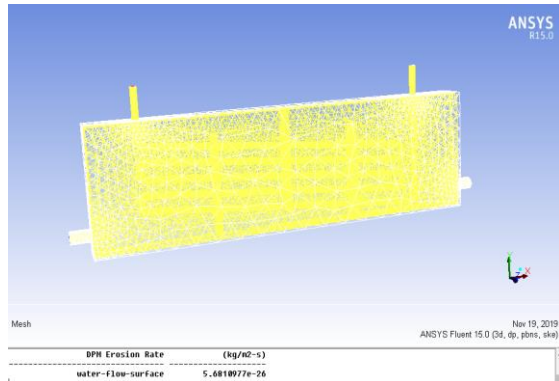


Fig. 7.12 Feed water using pH 6.5 in Erosion Rate

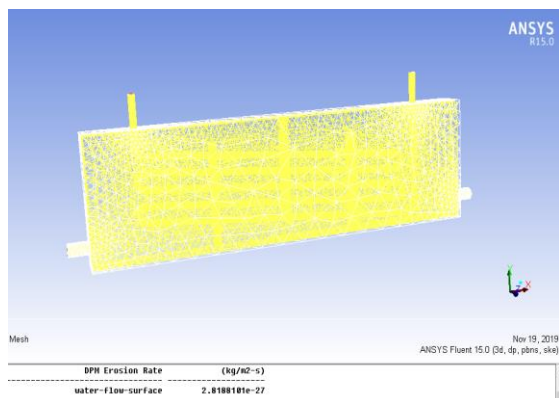


Fig. 7.13 Feed water using pH 8.8 in Erosion Rate

Comparative of Erosion Rate

Table 7.4 Comparative of Erosion Rate

Description	pH 6.5	pH 8.8
Erosion Rate (kg/m ² s)	5.68109 e ⁻²⁶	2.81881 e ⁻²⁷

The comparatively above Table 7.4 is the Erosion rate is better feedwater is pH 8.8 Value in Carbon Steel ST45.8 material. Furthermore, refer to Fig. 7.12 & 7.13.

VIII. RESULT & CONCLUSION

Table 8.1 Comparison of Carbon Steel ST20 & ST45.8

Description	CARBON STEEL ST20		CARBON STEEL ST45.8	
	pH 6.5	pH 8.8	pH 6.5	pH 8.8
Hot Gas Inlet (°C)	300	300	300	300
Hot Gas Outlet (°C)	212.28	265.19	212.43	262.14
Water Inlet (°C)	30	30	30	30
Water Outlet (°C)	39.62	60.03	42.55	63.32

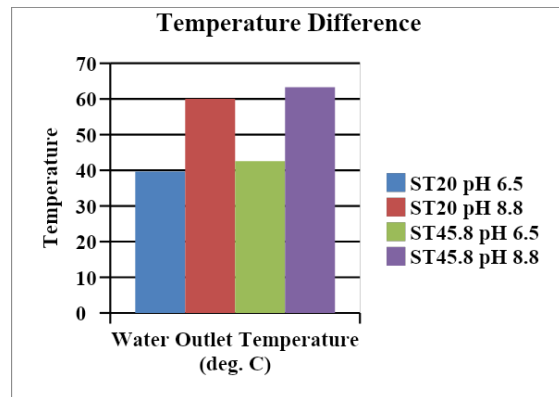


Fig. 8.1 Temperature Difference in Water Outlet

Conclusion

This paper has presented a review of the primary considerations related to internal erosion and the development of piping features that can lead to the development of a seepage failure mode. Three-dimensional influences have long been suspected to be a significant factor in the internal erosion process. Still, until recently, sufficient computer modelling tools were not widely available to allow for a deeper examination to inform our understanding of these 3-D effects. A 3-D model using computer simulation software (ANSYS-CFD) has been analyzed in this paper. Its key findings are summarized as follows.

The results obtained from the modelling can be helpful for the water tube boiler. The erosion rate and temperature difference find the two different materials (ST 20, ST45.8) with feedwater pH value (pH 6.5, 8.8) of the result is discussed above in the boiler tube. By this comparison, we can find ST 45.8 (include pH 6.5& 8.8) material is suitable for a boiler tube with better efficiency.

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