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Review on Performance Analysis of Fire Tube Boilers

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Abstract

Boilers in which hot flue gasses flow inside the tubes and water is surrounded by the tubes, thereby heat interaction taking place are called fire tube boilers. One of the most important performance factors that we know is the thermal efficiency of the boiler. So, the boiler is to be designed in such a way that there should be minimum heat losses through exhaust gases, and fully insulated boiler drum and minimum thermal resistance between heat transfer surfaces. The boiler auxiliaries such as the economizer, air preheater, superheater, heat recovery parts must be included. Consumers expect new and custom designs, so there is a need to change in design aspects and to increase the efficiency of the boiler.

Keywords: *Heat transfer, Modelling, Performance, Fire-tube boiler.*

1. INTRODUCTION

The tubes of a fire tube boiler are all perfectly straight, and the boiler's exterior casing is filled with water. The tubes are set up in a way that allows hot combustion gases to pass through them. Water in the vicinity of the tubes is heated by the incoming hot gases. The boiler's casing keeps the water contained. Fire tube boilers are commonly utilized in reduced-pressure operations since they do not require a heavy outer casing. Recent years have seen a rise in the size of fire tube boilers, which formerly had heat input capacity of 50 mbtu per hour or less.Fire tube boilers are used in various industries namely food, textile, chemical, etc, for commercial purposes. Even though it has some limitations like radiation and convective heat losses, unburnt fuel loss, and exhaust heat loss, it has its importance due to low-pressure operation, less maintenance, no hazard. So, by making a heat balance sheet we can measure the performance of fire tube boiler. The conservation of energy is crucial. In today's global society, constant access to energy is essential.We can use biodiesel and diesel as fuel in the fire tube boiler. We can increase the efficiency of the boiler by recovering waste heat. The efficiency of boiler can be enhanced by changing the position of air supply place. By increasing the percentage of air by 20-30, oxygen level by five percent, efficiency of boiler can be improved.

2. STUDIES OF FIRE TUBE BOILERS

Ortiz (2011) has done his work on modelling a fire tube boiler which works using an algorithm principle for solving equations involved in the motion of hot flue gases and heat and mass transfer equations. This helped to compare the fire tube boilers when ruining with different fuels. It helps a lot in comparison when using new fuel is used instead of old fuel. The model has a good scope in the new projects which involves the combustion process and a variety of fuel. The nonlinear equations involved in the modeling are not easy to solve by conventional mathematical techniques, so we need to simplify the model by considering the boiler's steady state condition after starting. We can easily adopt MATLAB for solving simplified model equations. The model requires much more data to prove its capability.

Beyne et al. [2] worked to evaluate the performance of fire tube boilers by considering the different turn boxes under steady and dynamic conditions by making a model. Food, Chemical, Cosmetic, and other similar industries use fire tube boilers mainly in the need of steam and hot water. So, there is a need to improve the boiler construction features so that it can be easily adopted for these applications as mentioned above. The boiler model to be designed, so that it has easily optedfor these conditions and model should consider the effect of turn boxes in heat transfer. In this paper he compared the results of the plug flow model under various conditions like with and without radiation for effectiveness – NTU method and the current model, decided that the current model is not suitable for lower loads, because at these loads radiation heat transfer cannot be ignored. By considering the heat transfer in submerged turn boxes, there is an increase of seven percent heat to the total heat. There is a reduction in heat with the non-submerged turn boxes of about twelve percent of total heat which can be reduced by the tight insulation and increasing furnace length and no of passes. By including the turn boxes there is an increase in the efficiency and volume of shell, which leads to an increase in peak load capacity of boiler. Ganan et al. [3] worked on connecting two three-stage fire tube boilers in parallel to evaluate the most favorable working conditions using gas and oil, by varying values of injection pressure and quantity of burners. By doing so, it discovered that the quantities of carbon dioxide and heat transported by the exhaust gases had risen. The boiler's output increased as the carbon monoxide levels dropped.Increase in heat carried by exhaust gases has less impact on boiler efficiency rather than increase in unburnt gases in exhaust. TESTO model 300 M-I analyzer is used in this analysis and probe is attached in the exhaust gases. This study also helps in reduction of pollutants in the atmosphere and following the boiler pollution acts.

Rahmani and Dahia, [4] have worked on the 3-pass fire tube boiler performance under in the point thermal and hydraulics. A numerical system program was utilized to simulate operations of boiler under various steady state conditions. The evolved program is grounded on heat interactions of flue gases and internal walls of flue tubes. The well stirred furnace model is utilized to simulate the heat transfer in furnace of the boiler. To make the heat balance between hot flue gases and bank of firetubes, convection heat analysis is used. The plants steady state data is used to compare the results in the previous case heat balance. It is observed that there is not much difference in the obtained results and operational data of the plant. Adding to this analysis, they are done a case study, the performance of boiler under variant conditions of atmosphere temperature, working pressure, rich air flow rates and fuel flow rates, etc. The heat transport in the four pass fire tube steam generator was studied quantitatively by Rahmani and Trabelsi [5]. Hot flue gases and the inside walls of the fire tube are simulated for their heat transport qualities using a numerical approach. With particular attention paid to the density of heat flow and the surface temperatures it generates under different circumstances of use. The heat balance on these wall surfaces is calculated with radiation and convection into account. The collected findings show little variation from the boiler's operating data. They also looked at how the boiler's working pressure affected its heat output. In this scheme, the flue tubes are partitioned into sections along the gas flow direction, each of which functions as a control volume. In a firetube boiler, the majority of the heat is transferred to the water by convection (80%), while the remaining 20% is transferred via radiation and conduction.

Huanget al. [6] studied the performance of fire tube boiler under steady state and non-linear variation was done. The model has two equations which are derived numerically, the equation has radiative heat flux term to evaluate heat transfer from the hot flue gases to hot water and heat loss flux to evaluate heat transfer between boiler shell to atmosphere. We can draw the performance curves for various boilers under steady state conditions by using this model and we can compare them. We are mainly interested in the best procedure to evaluate the boiler performance without any deviations from the actual measured data. The model is thoroughly verified for all ranges of data and permits us to simulate performance at any working conditions. This simulation is interpolation of boiler performance at fixed working condition, and it is not changed during the test run. Khaustov et al. [7] He used most widely used and present demanded simulation software ANSYS Fluent. The software easily solves problems related to heat transfer and fluid flow if we provide correct geometric dimensions and initial conditions and boundary conditions. The software uses the Finite Element Method to solve the equations obtained by the heat analysis in the fire tube boiler and provides more or less accurate results. It will show the results, temperature variation at all surfaces and heat flux available at the surfaces. It provides data regarding dryness fraction of steam from start of boiler if we model and input data accordingly. Only chemical-treated water free from salts, other undesirable compounds is to be used in the boiler operation. And also, continuous operation without blowdown is not allowed.

Huang and Ko [8] worked on the development of a new model for fire tube boiler. In his approach, considered the non-linear unsteady dynamic model based on the motion mechanism in fire tube boiler. Later steady state time-invariant dynamic working model is designed. He made empirical relations to the main parameters and again modified to correct for the variation in the working conditions. So, this is a semi-empirical model and evaluates the performance of a steam generator over a wide range of operations. The test results and model results are the same with some percent of error.

Using system identification techniques, Vasquez et al. [9] determined the dynamic characteristics of steam pressure within a fire tube boiler. All relevant information is provided or delivered to the computer and is considered throughout the operation, from experimental design to model validation. The industrial-scale boiler is worked on and then the full-scale boiler is deployed. Observations indicate that the Second Order Linear ARMAX model structure and time delay will produce the best results for the dynamic fluctuation of system pressure within the fire tube boiler.A precise dynamic model of an industrial fire-tube boiler and five distinct geometrical configurations, each corresponding to a boiler model, have been examined by Tognoli et al. [10].The Proportional Integral Derivative (PID) Controller is utilized for steam pressure control and is set specifically for each configuration. It has been found that, based on the average efficiencies, the performance of vast size boilers does not increase once a certain size threshold has been reached. It is possible to manufacture a boiler of a smaller size in an effective manner, and such a boiler might live up to the requirements of the client.

3. CONCLUSION

The detailed literature review on performance analysis of fire tube boilers has revealed the following the points

- Various researchers apply various methodologies for the investigation and development of boiler efficiency.
- Evaluation of performance criteria is crucial to the economics of power generation.
- The efficiency of a plant is greater when it is operating at peak load than when it is operating at a lower load. Thus, the facility should be operated at full capacity.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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