International Journal of Future Generation Communication and Networking
Vol. 13, No. 3s, (2020), pp. 980–986

Design And Optimization Of 10tph Boiler Chimney To Reduce Fouling And Enhance Boiler Efficiency

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Abstract

The heat lost in boilers is through many ways such as discharge of hot combustion gases to the atmosphere through chimneys, discharge of hot waste water, and heat transfer from hot surfaces. This energy loss can be recovered through heat exchangers and be put to other use such as preheating other industrial fluids such as water or air. This project focuses on recovering heat that is lost through boiler chimney flue gas. The major advantages of heat recovery include increasing the energy efficiency of the boiler& decreasing thermal and air pollution dramatically. In this project scope, an initial design of chimney for heat recovery in heat exchanger is provided. The design had a completely fabricated heat exchange core, furnace system but an incomplete ducting system. This report is based on the work undertaken to redesign the flue gas duct in chimney to have effective heat recovery from flue gases in heat exchanger system. This system was specifically designed for boiler chimney and therefore the systems ducting was designed to confirm to the general boiler stack. In the completion of the design, the major factor to consider was to redesign duct to reduce the fouling in heat exchanger system.

Keywords— flue gas; energy efficiency; heat recovery; fouling; boiler stack; heat exchanger system.

I. INTRODUCTION

A. Industrial waste heat

This is heat lost in industries through ways such as discharge of hot combustion gases to the atmosphere through chimneys, discharge of hot waste water and heat transfer from hot surfaces. This energy loss can be recovered through heat exchangers and be put to other use such as preheating other industrial fluids such as water or air. This project focuses on recovering heat that is lost through boiler chimney flue gas.

The advantages of heat recovery include:

- Increasing the energy efficiency of the boiler.
- Decreasing thermal and air pollution dramatically

B. Challenges to recovering low temperature waste heat

Corrosion of heat exchanger surface: as the water vapor contained in the exhaust gas cools some of it will condense and deposit corrosive solids and liquids on the heat exchanger surface. The heat

ISSN: 2233-7857 IJFGCN

exchanger must be designed to withstand exposure to these corrosive deposits. This generally requires using advanced materials, or frequently replacing components of the heat exchanger, which is often uneconomical. Large heat exchanger surface required for heat transfer; since low temperature waste heat will involve a smaller temperature gradient between two fluid streams, larger surface areas are required for heat transfer. This limits the economy of heat exchangers. Finding use for low grade heat: recovering heat in low temperatures range will only make sense if the plant has use for low temperature heat.

C. *Fouling*

The deposition of any undesired material on heat transfer surfaces is called fouling. Fouling may significantly impact the thermal and mechanical performance of heat exchangers. Fouling is a dynamic phenomenon which changes with time.

Fouling increases the overall thermal resistance and lowers the overall heat transfer coefficient of heat exchangers. Fouling also impedes fluid flow, accelerates corrosion and increases pressure drop across heat exchangers.

Fouling tendencies depends on the type of heat exchanger and the fluids. During the design stage certain considerations may help minimize fouling experienced in the field:

1. If possible, allocate the more fouling fluid to the tube side
2. Design for a fouling fluid velocity of 5 ft/sec on the tube side and 3 ft/sec on the shell side
3. Try to keep the fluid velocity constant
4. Allow for easy access for cleaning
5. In water service, ensure the tube wall temperature is not too high to create salt deposits or render treatment chemicals ineffective
6. Do not throttle water flows in winter time

D. *Types of fouling*

1. If possible, allocate the more fouling fluid to the tube side
2. Macro-fouling [2]
3. Micro-fouling [2]
4. Precipitation fouling [3]

E. *Why Fouling Occurs?*

Fouling from chemical reactions in the fluid stream which results in the deposition of material on the heat exchanger surface occurs when biological organisms grow on heat transfer surfaces. It is a common fouling mechanism where untreated water is used as the coolant. Fouling is a general term that includes any kind of deposits of extraneous material that appears on the heat transfer surface during the lifetime of the heat exchanger.

Fouling reduce heat transfer across the exchanger surface hence reduces efficiency of the heat exchanger. The fouling deposits also reduce flow cross-section area causing a pressure deferential across the heat exchanger which in turn increasing on the fan power required. It might also eventually block the heat exchanger.

ISSN: 2233-7857 IJFGCN

Different kinds of fuel produce different degrees of fouling most fuel produce just soft black soot that get deposited on the exchanger surface.

This can easily be removed by brushing and sand washing. However lower grade fuel oil (principally no.6.oil or resid) contain large quantities of alkaline sulfates and vanadium pentoxide that causes scaling due to their lower fusion temperatures. [3]

The forms of fouling may therefore include

- Particulate fouling.
- Scaling/precipitation.
- Chemical/corrosion fouling.
- Solidification.

F. Forms of Fouling

- Scaling/precipitation:
- Particulate fouling
- Chemical /corrosion fouling
- Solidification fouling

G. Fouling Factor

The performance of heat exchangers usually deteriorates with time due to accumulation of deposits on the heat transfer surface. The accumulation of deposits leads to increased resistance to heat transfer and causes the rate of heat transfer in a heat exchanger to decrease. This accumulation of deposits on the heat transfer surface is known as fouling and the net effect of fouling is represented by a fouling factor, Rf, which is a measure of the thermal resistance introduced by fouling. [3]

H. Design against Fouling

It was our duty to consider the effect of fouling upon the heat exchanger performance during the desired operation lifetime and make provisions in our design for sufficient extra capacity to ensure that the exchange will meet process specifications up-to shut down for cleaning. We we re also to consider the mechanical arrangements that are necessary to permit easy cleaning.

In our design, the following measures have been taken to reduce the rate of fouling.

- Provision for particulate filters.
- Introduction of turbulent flow upstream of the exchanger core.

II. LITERATURE REVIEW

N. Afgan, M. G. Carvalho and P. Coelho. at, [1] presented paper on Concept of expert system for boiler fouling assessment: a review. This paper will give an explanation about the expert system

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which is a modification for fouling assessment development. This is one approach to reduce seriousness of deposit formation on boiler heat transfer surfaces. In this fouling object is defined. Its structure is composed of the respective attributes and values linked with number of situations to be selected for the assessment. Deposit formation on boiler surfaces is an eminent problem for fuel-oil and coal-fired fouled boilers. It is a result of the fouling process of solid particles in the flue gases on the boiler heat transfer surfaces, affecting heat transfer processes from the flue gases to the working fluid. In this respect it is of interest to investigate the different aspects of this problem, in order to concentrate attention on all possible methods which are of interest to be used in the prevention and control of the fouling process.

The expert system has proved to be a feasible tool for the operational control and mitigation of the deposit formation on boiler heat transfer surfaces.
Paper gives idea about the expert system which can control and mitigation of the deposit formation on boiler heat transfer surfaces. [1]

Sagar Kae, Seung Hee Euh, et al [2] have discussed Tar Fouling Reduction in wood pallet boiler using additives. In this paper research focuses on reducing fouling tar and improving efficiency of boiler additives. The pellets with the additives are therefore, found to be better option to reduce tar in wood pellet boiler and are recommended. The fouling of tar decreases the thermal efficiency of the boiler by reducing the thermal heat transfer and, after long period of operation, it can damage the boiler by erosion. This method increases the boiler efficiency, mechanical durability, bulk density, higher reduction of tar foul about 76 %. The result showed that additives could reduce the tar foul and can be a really good substitution. Paper gives idea about reducing the fouling by using additives. [2]

Cai Yongtie, Yang Wenminga, Zheng Zhimin, Xu Mingchen, Siah Keng Boon[3], This paper will give a brief introduction to the traditional method about ash deposition. Ash deposition process in biomass boiler can induce many ash related problem. To understand the nature of ash deposition in biomass boiler, full attention should be paid to the ash deposition process. The ash deposit process is extremely complicated and it is of great importance to understand the mechanisms of the process. This paper will present an overview of the mechanisms and models of ash deposition that have been developed for coal combustion systems and propose different predictive tools and techniques for combustion systems. Generally, there are four major mechanisms for ash deposition process, including inertial impaction, condensation of vapours, thermophoresis, and chemical reactions. The ash deposition process causes many problems to the utility boilers. Some predictive approaches should also be developed to predict the ash deposition process. In addition, the mechanisms of the ash deposition should be deeply understood to look into the nature of deposition process. What's more, the ash formation process should be characterized to depict the ash deposit structure. Then, the ash deposit build-up process can be modelled by using some sub-models.
Paper gives idea about mechanism of ash deposition. Understand the concept about of deposition. This will help address the ash-related problems to some extent. [3]
Yuanhao SHI and Jingchang WANG [4], an online ash fouling monitoring model based on dynamic mass and key variables analysis technique is to be introduced to study the internal behaviour of soot blowing system. In this process, artificial neural network (ANN) are used to optimize the boiler soot blowing model. Ash fouling monitoring can be accomplished by means of an online calculation and special power plant instrumentation or a combination of both techniques. Online calculation always need to be calculate the heat absorption of heat transfer surface. ANN has also been used in the

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system modelling, identification, control, forecasting, power system and optimization. Online ash fouling monitoring model can correctly show dynamic tendencies of ash fouling deposit on heat transfer surface. Key variables of ash deposited and boiler efficiency, the final model can be used to measure the ash fouling and optimize the boiler operation. Paper gives an Idea about the ash fouling monitoring. [4]

III. DESIGN CONSIDERATIONS

In the designing of the exchanger following factors were put to consideration.

1. The exchanger surface has to be the most efficient and suitable for gas-gas heat exchange.
2. The design has to consider the fouling effect of the flue gases.
3. The design has to allow for quick maintenance without interfering with the boiler operations.
4. The ducting design has to conform to the boiler chimney design.

Based on the above points, flapper provided at various angles in chimney convergent duct to check the velocity increase of flue gases in chimney area.

IV. BOILER SPECIFICATIONS

Boiler steam capacity	10 TPH
Working steam pressure	16 bar
Fuel	Coal
Boiler efficiency	86%
Dimensions:	
The width of the axes of columns	7,2 м
The depth of the axes of columns	9,6 м
Mark on the top of the boiler	15,5 м

V. CALCULATION & DESIGN

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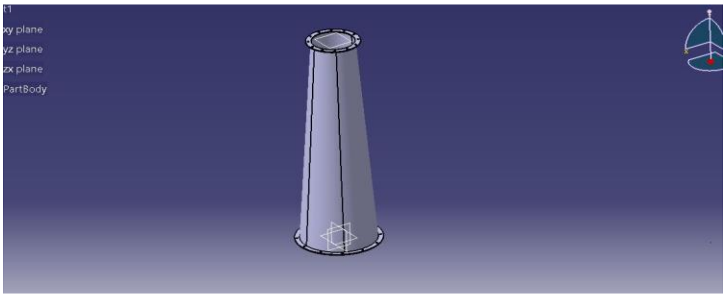

Fig 1. CAD model of segment of chimney

New chimney design with design with flappers

We are the flappers in the segment II to reduce the fouling effect at different angles. CAD model of flappers inserted in chimney is shown in fig 2, 3, 4.

Fig 2 shows the flappers at angle 10°

Fig 3 shows the flappers at angle 12°

Fig 4 shows the flappers at angle 15°

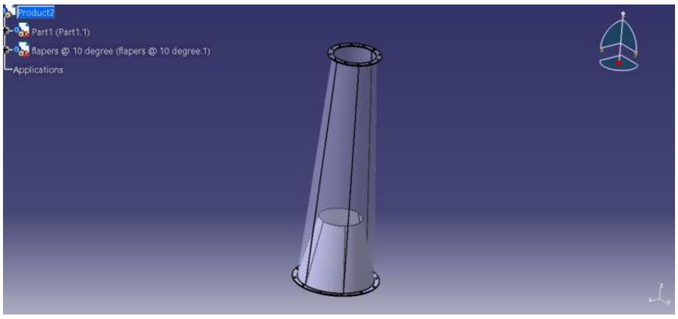

Fig 2. Flappers at angle 10°

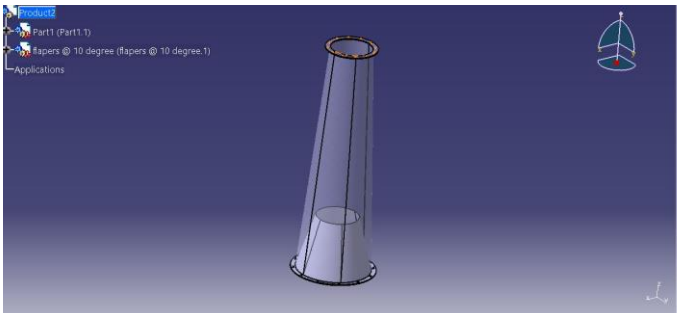

Fig 3. Flappers at angle 12°

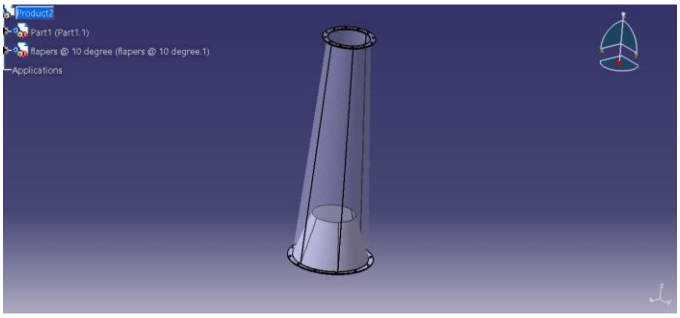

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Fig 4. Flappers at angle 15°

VI. CONCLUSION

This paper is convergent on the diverse aspects of the operation of Boiler efficiently. Efficient operation of boiler is likely to play a very big role in following years to come. Industries all over the world are going through increased and powerful competition and increased automation of plants. The suspension cost of such system is expected to be very high. To get away with this challenge, it is clearer by this paper. We have to use the advanced technology.

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