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Optimization of an Industrial Boiler Operation

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Abstract - As a significant thermal source, the boiler system consumes a large amount of energy for industrial and commercial use. The high efficiency of the boiler is essential for system performance. Boiler efficiency called to some amount of total thermal energy which, can be regained from the fuel. Boiler efficiency losses are due to some factors. As well as boiler water treatment is an essential part of boiler operations. Many industries found the Usage of alternative fuel is one of the critical objectives for cost reduction. Power is the capacity to do work. And work is energy transfer one form to another form. The primary purpose of energy management is to produce goods and provide services with low cost and low environmental effects. This paper presents the boiler water treatment improvements, alternative fuel use in the boiler for cost reduction, energy management, heat recovery, and efficiency improvements.

Index Terms—Alternative fuel, Biomass, Boiler, Efficiency, Heat recovery.

1 INTRODUCTION

A boiler is a steel pressure vessel in which fluid under pressure converted into steam. There are two main types of boilers used in the industry. They are water tubes and fire tubes boilers. In the fire tube boiler (Fig 1.), hot flue gases flow inside the cells and submerge in water within a cell. In the water tubes boiler (Fig 2.), water flows through the tubes, and hot combustion gases in the shell surround that.

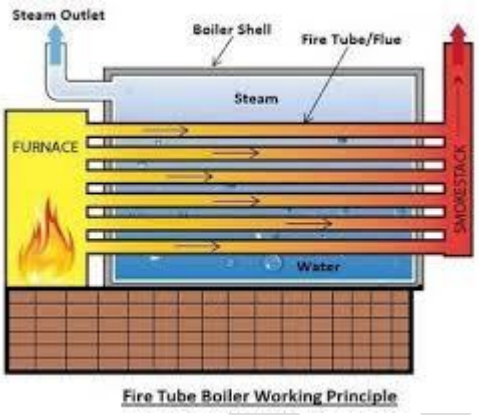

Fig. 1. Fire tube boiler

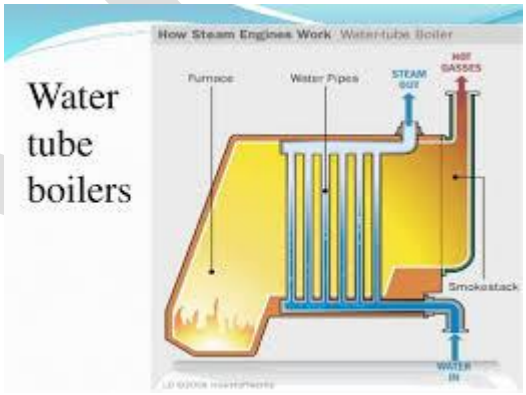

Fig.2. Water tube boiler

The working conditions of the boiler should always be monitoring. It must highlight that boilers are working under the high temperature and the pressurized status; hence the explosion is a severe risk, threatening the boiler operation. In the boiler design procedure, there need several aspects, including financial, fuel cost, and maintenance factors, should be covered and noticed [1]. Optimizing the performance of a boiler is reducing running costs and improves site operations. The Performance Optimization for industrial boilers can result in reduced boiler trips, fuel conserved from reduced air/fuel ratio, extended boiler operational range. For boiler optimization, it is essential to address both the combustion and the steam and feedwater systems.

2 BOILER WATER TREATMENT IMPROVEMENTS

Boiler water treatment is used to control alkalinity, control conductivity, correct pH, and prevent scaling. The boiler water wants to be alkaline and not acidic. Therefore, that is not damaging the tubes.so that does not ruin the pipes. The water can be too much conductivity in the feed water when too many dissolved solids are in there. These proper treatments are controlled by an efficient operator and use to treatment chemicals. The primary purpose of treating and condition boiler water is to swap heat without scaling, protect against scaling, and produce high-quality steam. The best way to remove impurities is to remove the contaminants before they enter the boiler. A small number of pollutants can be effectively treated inside the boiler to keep them in solution or discharged via blowdown.

2.1 External treatment

External treatment refers to the chemical and mechanical treatment of the water source. The goal is to develop this source before its use as boiler feedwater, external to the operating boiler itself. Such external treatment may include:

Clarification - removes solids, extensive boiler system
Filtration - removes solids
Softening and demineralization - remove dissolved minerals
De-alkalization - remove unwanted ions from a water
De-aeration and heating - remove oxygen and other corrosive gases.

2.2 Internal treatment

External treatment of the water source is the best and most appropriate treatment if boiler feed water still contains impurities that could adversely affect boiler operation. Then applied internal boiler water treatment here will minimize the potential problems and avoid any catastrophic failure, regardless of external treatment malfunction.

Addition of chemicals - pH control, oxygen removal
Blowdown - remove accumulated solids from boiler water

The current boiler water treatment process analyzed in terms of achieved water quality, quantity, and quality of the wastewater and some amount of chemicals needed. Consumption of a large number of chemicals is the main disadvantage of the current process [7].

3 USES OF ALTERNATIVE FUEL IN THE BOILER FOR COST REDUCTION

A fuel source must release its energy from the form of combustion in the boiler furnace. Fuel systems play a critical role in the performance of the boiler. The most commonly used fuels in power boiler are natural gas, oil, coal, and wood. Those can categorize as fossil fuel and biomass fuel. Petroleum-based oils, coal, and natural gas are fossil fuels. Commonly used for the boilers while firewood and alternative firewood (sawdust, paddy husk, bagasse) consider as biomass fuels.

3.1 Sawdust

Fig. 3. Sawdust

Sawdust (Fig. 3.) is a by-product or waste product of woodworking operations such as milling, sawing, routing, sanding, drilling. Sawdust is flammable, and it is water absorbent. Swells when absorbs water and shrinks when moisture content decreases from the required amount. Texture and color vary from trees to trees. The high heating value of sawdust is about 18.23 MJ/kg, and the low heating value is approximately 16.54 MJ/kg [3].

3.2 Rice husk and rice straw

Fig. 4. Rice husk

Fig. 5. Rice straw

Rice husk (Fig. 4.) is a by-product of rice milling, accounts for roughly 22% of paddy weight [4]. So, rice mills can use the rice husk as aa biomass for their biomass boilers. Rice straw (Fig. 5.) is a by-product of rice production at harvest. Rice husk easily procurement, but the rice straw collection is delicate, and its availability is limited to harvest time. Rice straw has calorific value around 13-19 MJ/kg [5]. By using the rice straw, the industry can minimize their main fuel requirement for boilers. There are many ways to optimize industrial boilers. They used alternate fuel, improve water treatment, and manage energy usage, etc.

3.3 Bagasse

Fig. 6. Bagasse

Bagasse (Fig. 6.) is a by-product of the crushing of sugarcane. It is the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks crushed to extract its juice. Cellulose, hemicellulose, pentose, lignin, sugars, wax, and minerals are some of the contaminants in bagasse as well as most mills produce bagasse of 48% moisture content and most boilers designed to burn bagasse at around 50% moisture [6]. Usually, the sugar factory produces nearly 30 tons of wet bagasse using 100 tons of sugarcane [6].

3.4 Gliricidia sepium (dendro plant)

Fig. 7. Gliricidia sepium plantation

Fig. 8. Gliricidia sepium wood

Gliricidia sepium(Fig. 7.) is a shrub or a medium-sized tree. It is a leading sustainable biomass source for biomass power generation. It has a high growth rate and high coppicing ability. The calorific value of dry Gliricidia sepium wood (Fig. 8.) is 20.5 MJ/kg [5].

4 ENERGY MANAGEMENT

Energy management is the most critical function of the boiler operation system. When talking about energy management, mainly consider how to adequately used energy into the system and how-to saving energy. Boiler efficiency there has a significant influence on heating related energy saving. When talking about energy saving, it is essential to maximize the heat transfer and minimize the heat losses in the boilers. In boilers, heat can lose by a variety of methods, including blown-down damages, hot flue gas losses, and radiation losses, etc. To optimized the boiler operation, it is necessary to identify where the energy wastage is occurring. A significant amount of energy lost through flue gases as all the heat produced by the burning fuel can't transfer to the water in the boiler. The temperature of flue gas leaving a pan typically ranges from 150°C to 250°C, and about 10-30% of the heat energy lost through it. There is enormous savings potential of a boiler energy saving by minimizing energy losses [2]. In the boiler, there can save energy from using alternate fuel, use heat cascading, use the proper heating method, and reduce flue gas oxygen content, etc. By right energy management, there can be increased the boiler efficiency and reduce the operation cost too.

5 HEAT RECOVERY

In the boiler, the primary heat recovery method is the flue gas heat recovery. For that, it uses a heat recovery unit in the pan. It can be more efficient by capturing and reusing the heat energy, which would have escaped out of flue in the boiler. In all boilers are burning the fuel to produce electricity that wants boilers. Flue gas heat recovery gives a considerable advantage of heat with waste flue gasses resulting from the combustion of gasses. This recovery heat used to preheat cold water, which is entering the boiler. It helps to reduce the amount of energy need to warm the feed water up to the required heat level. On the market today, there is the most efficiency Boiler also has 90% efficiency. Due to the result of heat loss in the flue gas, the installation of a heat

recovery system helps drive up energy efficiency and helps to save money on energy bills. This system requires very little maintenance and no need for leading electricity [1].

5.1. Economizer

In the boiler systems, it uses an economizer or naturally a heat exchanger unit to heat recovery. In a boiler, usually, the flue gas temperature is around 300 Celsius. This economizer recovers heat from flue gasses and preheated boiler water up, but it is not generally beyond the boiling point. Economizers can make the enthalpy in a fluid stream; those are hot but not hot enough to use in the boiler. It can recover more useful enthalpy from improving the efficiency of the boiler system. Economizers are the devices fitted to boiler and save energy by using the exhaust gasses of it to preheat the cold water used to fill it. Steam boilers use a massive amount of energy, rising feed water to the boiling temperature of it by converting the water steam and superheating that steam than the saturation temperature in the industry. In the high-pressure boilers usually have larger economizer surfaces than a low-pressure boiler. Tubes of economizer often have projection like fins for increasing the heat transfer surface on the combustion gas side. It uses an economizer; it can take 80% to more than 95% of boiler efficiency on average over the years. Economizers produce by using aluminum and stainless steel alloy. The flue gasses pass through the cylinder, and water passes through the finned tube to the economizer [2]. When using an economizer, it saves 15% to 20% of the fuel to heat the boiler's feedwater.

5.2. Heat Exchanger

A heat exchanger can describe as a component; it allows heat that exchanged between two fluid like water and gas without letting those substances mix together. Heat Exchanger can find in many industries. It most commonly found in boilers. The heat exchanger, boiler, works by converting the energy from gas over to water. In this operation, water passes through the heat exchanger for heating up in the process. The water fed into the central heating system through a flow pipe. After it circulates the heating system and that water returns via the return pipe. After that, the water passes through radiators, pipework, and towel to raise its losses temperature. That water was going again to the heat exchanger and reheated continuously. But this has low efficiency than an economizer. Heat exchangers also use many more industries.

6 EFFICIENCY IMPROVEMENTS

Complete combustion of fuel is one of the most significant variables impacting boiler optimization to improve energy efficiency. Boiler combustion air blowers have a few functions, turbulence in the firebox promotes maintains metal surface temperatures in the firebox and boiler tubes and complete combustion. Cells would overheat and rupture, without the blower.

Energy leaving the boiler in products of combustion through breaching is another significant variable to control. Power is not transferring to the water indicates by the high stack temperature. If operators find they are rising over time. It means heat-transfer surfaces that need cleaning. High stack temperatures mean combustion products of more than 600 degrees. Stack temperatures and the parasitic losses associated with it can reduce by Cleaning heat transfer surfaces via punching tubes and proper water chemistry [11]. An optimizing the purge cycle and modulating the burner at a lower continuous level. Rather than cycling the boiler on and off frequently involved in the third control strategy. To safely ignite burners, Pre- and post-purging of the boiler's firebox was required. But the number of purge cycles can be minimized by operating the heater continuously at a lower setting. When limited purge cycles, it is a low-cost measure for a worthwhile energy efficiency upgrade.

To reducing steam pressure or scheduling heating hot water based on outside air temperature are the final control strategy. Operators need to validate the load requirements to implement one of these measures.

Burner replacements and heat-recovery systems involve improving the energy efficiency of boilers and water heaters. DDC and flame-shaping technologies to improve significantly operating efficiency throughout a unit's range of operations have incorporated New-generation burners. Heat-recovery ECMs on both the airside - in the form of a stack economizer - or the waterside, can be used in the kind of blowdown heat recovery [12]. Burner replacement yields attractive payback periods, and it is a higher-cost measure. The technology advances in boiler burner design for years have incorporated by Facilities in Europe, and also, validating their effectiveness. DDC technology has to provide significantly higher control of fuel-air mixtures and replaced mechanical linkages. New burners controlled the shape of the flame, and the turbulence imparted to the fuel-air mixture, enhancing fuel-to-water efficiency.

Products of combustion and directed to preheat combustion air or boiler feed water extracted energy. Economizers have a high load factor. It lowers the stack temperature, and it increases the make-up-air temperature by Installing a heat-recovery system. About 2 percent for every 100-degree decrease in the stack temperature, increased boiler efficiency. Diverting energy contained in hot blowdown to preheat make-up water or for some other low-grade thermal energy use in the central plant, involved in heat recovery by the second method. Continuous boiler blowdown used by Candidates and had a constant load that can use this waste energy [11]. Boiler efficiency improves, increase in make-up water by about 1 percent for every 10 degrees. Typically, Heat recovery is 20-30 degrees, 2-3 percent improved Overall efficiency.

7 CONCLUSION

In the present world, the boiler is an essential part of many industries. Especially boiler systems are using in chemical-based industries. It utilized to generate steam to produce energy that wants to work in industries. This article discussed the boiler working process. There is the process of Boiler as water treatment is necessary, Usage of alternative fuel to the boiler for cost reduction, energy management, and heat recovery. And also, what we have to do to improve the efficiency of the boiler further discussed.

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