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RESEARCH ARTICLE

DESIGN, FABRICATION AND EXHAUST GASES ANALYSIS OF CORN COB FEEDING UNIT INSTALLED WITH STEAM BOILER

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ABSTRACT

A sustainable approach towards energy production is the need of time due to the ongoing energy and food crisis. Due to increase in demand of energy the demand of fossil fuels will increase. The limited fossil fuels cannot meet the demand of the current energy produced. Many new technologies are being adopted by scientists. New developments in boiler technology have made the industries work well so they can move towards an economic and environment friendly approach. The boilers used in industries have a high operational cost and their harvesting/collection mechanism is difficult and time consuming. Using conventional fossil fuels there is a lot of risk of hazardous air pollution which causes skin and infectious diseases. The current study is on corn cob feeder reactor where the reactor will be efficiently design in a textile mill. The impact of this boiler on environment was analyzed towards a sustainable approach and the different air emissions were measured and they were compared with the emissions of conventional fossil fuels where a significant reduction in using corn cob was found as compared to the conventional fossil fuels.

KEYWORDS

Corncob, Fossil Fuels, Energy, Emissions.

1. INTRODUCTION

Energy is a secret instrument in human race. Today's high living standard is only due to best energy use. The proper use of energy is only possible if it utilized properly by reducing operational cost. The increase in plants increases the boiler units and installations. Heat loss test and energy analysis is done to analyze the poor boiler efficiency and major heat losses. Heat loss can be reduced by proper operation. A large amount of air increases the heat loss because air leaves at high temperature in boiler and air enters at ambient temperature (Gupta et al., 2011). Energy pollutes environment the most. One of the most burning challenges is to be talking about environmental problems. The alignment of energy and environment is difficult task. Sustainability rules must not be compromised in energy sector. In 21st century 20% target for Renewable energy is achieved. Sustainable and rational renewable energy sources are being discovered and a lot of work is being done on it instead of large dependence on fossil fuel renewable energy will become best investment.

A lot of energy usage is major reason on the impact on environment. So, in order to develop a healthy relationship between energy and Environment renewable sources must be considered. Human health apart from Environment should also be considered (Ondrejk et al., 2081). By applying heat water is converted into steam in boiler. Chemical energy is converted into heat in an effective way. The designing should be made to produce good quality steam (Odigure et al., 2005). Corn is a most used agriculture crop which is nowadays used in heating and drying also. Due to high crops in villages sustainable use of energy is the best option to reduce carbon footprint (Lizotte et al., 2015). Energy plays an important role in national economy. After the invention of steam engine only countries which adopted industrialization techniques progressed. After the Second World War need of alternative fuels other than fossil fuels increased.

Almost 50% of the U.S. production is powered by coal generation. A rupture in alloys at higher temperature for long term is identified by U.S. Department of Energy. They are economical i.e. they have low cost of electricity and low carbon footprint. He used Ni in design of plant. Renewable energy source gives so much environmental advantages (Yildizhan and Sivrioglu, 2017). The first energy source used by humans was Biomass. In total energy of world biomass contributes 14%. Renewable energy sources are becoming very important to reduce global warming. During the last decade, biomass is becoming alternate to fuels. If proper management is done it can easily become a good source in developing countries. Burning of biomass produces low SOX's and NOX's. It will also contribute less to carbon release (Cuiping et al., 2004). Renewable energy is divided into tides and solar (Chaudhary, 1990). In the last 50 years fossil fuels are playing an important part to improve steam efficiency (Masuyama, 2001). In 21st century 20% target for Renewable energy is achieved.

Sustainable and rational renewable energy sources are being discovered and a lot of work is being done on it instead of large dependence on fossil fuel renewable energy will become best investment (Ondrejka et al., 2018). Corn is a most used agriculture crop which is nowadays used in heating and drying also. Due to high crops in villages sustainable use of energy is the best option to reduce carbon footprint (Lizotte et al., 2015). Renewable energy sources are becoming very important to reduce global warming. During the last decade, biomass is becoming alternate to fuels. If proper management is done it can easily become a good source in developing countries. Burning of biomass produces low SOX's and NOX's

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(Cuiping et al., 2004). Burning of fossil fuels results in increase in CO2 which eventually does global warming (Yin et al., 2017). The major disadvantage of biomass is considered a food vs fuel debate.

In present Biomass is used without considering its sustainable use i.e.: greenhouse emission and air emission etc (Muazu and Stegemann, 2015). Fossil fuels like coal, natural gas and oil are major source of energy nowadays. The problem is they may deplete in next 40-50 years. The expected damage in Environment forced world community to focus on renewable sources. In early days there was biomass with limitations. Utilization of biomass in boilers is cheap and environmentally friendly. Such as financial net saving, conservation of fossil fuel resources, job opportunities creation. Upcoming days of biomass depends on the development on fossil fuel market (Saidar et al., 2011). Combustion of coals and wood contains many metals and a large amount of toxic organic compounds. Despite less amount of power from biomass, bio power production potential still exists. To compensate the less biomass which has arisen due to seasonal variation. In supply of biomass special care should be done.

According to handling of biomass i.e. to reduce size and its storage is converted into the conversion equipment. Many types of Equipment are used to move fuels. Growing energy and climate change security means more attention is on bioenergy. 80% state total electricity is still produced from fossil fuels which is greater than average 45%. Climate Change and acid rain contribute very more adverse effect on human health (Skodras et al., 2002). A large amount of biomass is considered economical. Different parts of boiler should be cleaned. High Ca, K and Si and Ca are abundant in volatile elements. Many technologies are used for heat and power production in biomass, but major are still combustion, moreover pyrolysis and gasification are still in the development stage.

Heat transfer by modelling is more suitable. The vapor can also be collected on material boiler through the process of condensation. Fuel mixing can also be lowered by K/Si Molar ratio (Bashir, 2012). The major energy crisis in Pakistan started about 25-30 years before when it was decided to import furnace oil. Energy demand in Pakistan is increasing 9%/annual since last 20 years and is likely to double up to 2030. By applying heat water is converted into steam in boiler. Chemical energy is converted into heat in an effective way. The designing should be made to produce good quality steam (Mills, 2012).

2. METHODOLOGY

2.1 Study Area

The feeder will be installed in Mujtaba Masood Textile mills located on Jhang Road approximately at distance of 15 Km from Faisalabad City. The transportation to the feeder was a major challenge. The steam produced in boiler is supplied to the textile industry.

2.2 Material Design and Mechanism

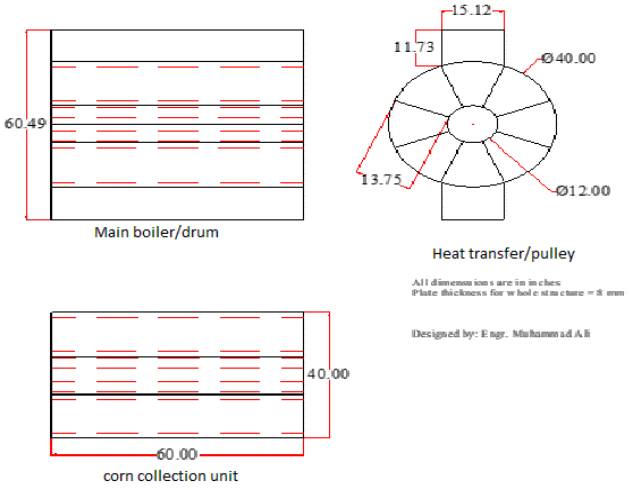

Figure 1: 2D design of corn cob feeding unit

In designing care was be taken that it reduces the working time of Engineers and make them more efficient. The design will help Engineers in manufacturing. Following factors were considered in designing of material: Working condition of material, to check either material is easily available in market, keeping in view the economic condition, calculation in designing, making sure it's rusts free and environmental condition of boiler i.e.: making sure proper emissions and waste storage. In designing of corncob different emission standards like carbon monoxide (CO), hydrogen chloride (HCL), Mercury (Hg), Particulate Matter (PM), selected metals (arsenic, beryllium, cadmium, chromium, lead, manganese, nickel and selenium) as well as major harmful and toxic greenhouse gases such as CO_2 and for SO_2 and NOx were considered. Emission depended on load fuel and the corn cob feeder type. The focus on steam boiler was to make it more market competitive. There are although many types of boilers used but, in this research, the Industrial steam boilers was used. Before designing it was made sure that the designer should be designed in such a way that it can bear intense heat and pressure. As mentioned above the rust and corrosion was also considered. Before the start a 2D design on Auto-CAD was made. Latest Software of AutoCAD 2017 student version was used.

2.3 Designing

Boiler designing is done in Forging, Rolling, Spinning and Wire drawing. In large area process hot rolling is done. To make thee material in its desired shape especially edges forging is done.

By Fusion process welding is performed (i.e. by applying heat and pressure). In designing of boiler following working conditions are considered: Intake water (The water entered in boiler during the operation is Feed water.), outside treatment, Type of boiler, Pressure of boiler, Quantity of steam, Maintenance and cleaning, Purity of steam, Health and safety concern, Economic considerations, No. of boilers, Switch for pressure control and Switch for temperature control. Before the final design it was made sure it is designed in such a way that it reduces the working hours of labors. The performance of boiler is directly proportional to heat absorbed. The pipes should be properly fitted. Following material was used in designing: Furnace, Pressure vessel**,** motor gear**,** return chamber**,** Smoke Sack and Burner.

The work done by boiler whose results and calculations are shown in performance evaluation was calculated by the following formula:

The balance between distributed the heat is balanced heat.

Work done by boiler =Qin+Qout

M=Total mass of corncob used

Where Qin=Heat transferred in

M=12700.6kg, Cp=0.386J/g^{o}c, T_1=250^{o}C

=MCpT_1

=12700000.6g*0.386j/g^{o}c*250

=1225550058 J

Q out=Heat transfer out

M=12700.6kg, Cp=0.386J/g^{o}c, T_2=200^{o}C

=MCpT_2

=12700000.6g*0.386j/g^{o}c*200

=980486.32 J

(Qout was considered negative because heat is getting out of the system and Qin was considered positive because heat is getting out of the system.

2.3.1 Furnace

The furnace was made by the process of casting. The reason behind using furnace was its affordable and corrosion resistance. The furnace was made up of Aluminum. The advantage of making a furnace drawing is it helps us in designing.

A = b × t

=40*60=240 ft.

Heating Surface area of Furnace= 3.14*diameter*number of tubes

Diameter=150mm

Number of tubes=3

Area=3.14*150*3

=141mm^2

So, the area of furnace will be 1413mm.

For the direct flow of gasses proper heating arrangements should be done. Selection of furnace

Cost, efficiency, composition, cleanliness.

2.3.2 Pressure Vessel

Between the burner and heat transfer system there was a pressure control valve. The pressure vessel is made up of wrought iron and steel. It is a ductile material and less labor is used in this. The pressure vessel consists of motor gear and pulley. The diagrams of the motor gear and pulley are shown ahead in the figures. These motor gear and pulley control the pressure.

2.3.3 Motor Gear/Pulley

The gear motor was designed according to:

Shaft diameter= 13.75mm

Number of teeth's=18

RPM=1(RPM stands for revolutions/minute)

The cyclone was designed in such a way that burner and primary air is introduced in the burner causing flow pattern to flow over the boiler tubes. The dust particles in the corn cob are separated by the cyclones. Corncob burns in main cyclone. In the above space of the heater the air is passed for cooling. Primary air passed through the valve as shown in the above figure. Inferior air is passed through tubes. From the outward tube the burnt corn and heat is transferred to the main boiler.

2.3.4 Heat Transfer System

The shaft / axle transfer power from 1 shaft to another. The above figure is the heat transferred through pulley with the help of induced fan. The steam is provided to boiler with the help of motor and the induced fan and pulley helps to transfer heat. The belts transfer power from 1 shaft to another.

Ratio of velocity (V.R.)

VR= N1/N2=T2/T1

N1= speed of smaller driver

N2=large driver speed

T1=teeth of small

T2=Larger pulley's teeth

Stress, σ = P/A where P = Force or load acting on a body, and A = Cross-sectional area of the body.

2.3.5 Steel Pulleys

Steel pulleys are of great strength.

Steel pulleys are generally made in two halves which are bolted together. (Reaffirmed1990).

Length of hub =2*Width of face

Thickness of rim = 5 mm for all sizes

Length of hub =2*Width of face

Thickness of rim = 5 mm for all sizes

2.4 Corn Collection Unit/Burner

Corn is collected in this area. The corn is loaded in that corn collection area mechanically. Special safety precautions were made to avoid the contact of workers with the fire. Boiler drum collects hot water generated in boiler. To mechanically hold the boiler steam is generated. At the bottom of the tank non-combustible materials settle.

The area of corn collection:

According to Auto CAD drawing:

Length=40 feet

Width=60 feet

Wall thickness=8mm

(It is ignored due to small size)

Area=LW

=2400feet

2.4.1 Combustion Zone

It is an oxidizing zone. Combustion takes place by consuming the free oxygen. The temperature in this zone is t to more than 1000 o c.

$C+O_2 \longrightarrow \Delta CO_2$ + Heat

$Si+O_2 \longrightarrow \Delta SiO_2$ + Heat

$2Mn+O_2 \longrightarrow \Delta T_2MnO$+ Heat

2.4.2 Reducing zone

In reducing zone, CO2 was changed to CO, so the temperatures fall.

CO_2 + C (coke) $\longrightarrow \Delta 2CO$ + Heat

2.4.3 Melting zone

In this zone metal starts melting. Combustion of fuels takes place in burner. It is the main burner where after burning of corncob heat is transferred and the main steam is produced.

The area of corn collection:

According to Auto CAD drawing:

Length=60.49 feet, Width=40 feet

Wall thickness=8mm (It is ignored due to small size)

Area=LW

=2400.49 feet

2.5 Main Boiler

It consists of drum which withstands internal pressure. The economizer transferred heat from combustion products to boiler feed water. Fluid enters the tubes with the help of feed water pump. Boiler tubes carry water steam in it. Baffles were built with partitions to allow the flow of gasses. The boiler efficiency is directly proportional to baffle positions and numbers. Gage glass checks the accuracy of boilers. Soot blowers keeps ash away from the walls of the burner. It keeps the burner safe from multiple impacts.

2.6 Smock Sack

Flue gas temperature is the temperature when gasses exit the boiler. Stack was made up of steel. Caged ladders were installed. It was properly guarded. To interconnect stack and boiler Flues and ducts was used. Heating surface should be properly arranged. Make sure that it is proper combustion in the furnace. Economizer increases boiler efficiency. Economizer was made in such a way that its water flows up and gas flow down to avoid water hammering. There should be valves in economizer. To prevent smoke and ash make sure they are at high elevation.

There are different types of chimneys but in this study an Industrial Steam boiler was designned in this study. The Following radius and height were considered in the designing of the Chimney.

Base radius=80cm

Height of chimney=12.5m

Cap radius of Chimney=7cm

Dianmeter of Chimney=$3.14(80+7/2)^2$

=5860cm

Chimney was installed above the burner for the emission of gasses like: NO_2, NO3, SO_2, SO3, CO, CO2, Particulate Matter and other harmful gasses. These emissions were measured by a flue gas analyzer. Although there are many major gasses produced but the major is mentioned above.

2.7 Dust Collection Area

The dust is collected in the backward area of boiler. The waste of corn cob emits here. The dust particles are dumped in the landfilled. With the help of dust measuring instrument the different emissions and harmful gasses were measured. The major gasses found in dust particles were Methane, Carbon, Pollens, Lead, Hydrocarbons, Mercury and Particulate Matters. Check valve regulates water flow in boiler and avoids overflow of water in case of failure.

2.8 Working Principle

The corn was collected by local villagers and different places. Our mechanism used in this study was the: Feedstock (corncob) and Yield. A dry environment was used for the storage and collection of corns. It is put into the burner directly because in in chipping process more energy is required. Before putting corn in burner, it is properly cleaned. According to Michigan state university newsletter less than 15% moisture content

suggested was used. Fine particles were cleaned properly. There was a big burner to burn the corn. Corn was put into the burner manually. A good quality oil was used in the generator to run the boiler. A circulation pump was fitted and is given a pressure of 80psi. The pressure vessel was there to control the pressure of steam flowing. A pulley and motor will be designed to collect corn cob in the main boiler.

Figure 2: Working area

The temperature varied from 200-250^{o}c. To boil water and the generation of steam there was a heat transfer system. The pulley and motor of steam converted kinetic energy to heat energy and steam. The steam was supplied to the manufacturing unit. Many harmful gasses like hydrogen, nitrogen and carbon will be produced. For this purpose, an induced drop fan will be fitted which will remove the volume of gasses. At the top of the reactor a cyclone will be fitted. When the Chimney will be heated dust particles will be separated with the help of cyclone. With the help of flue gas analyzer, all harmful gasses emitted were measured as shown in table.

The flue gas analyzer was placed near stack/chimney, main gate and all the major areas where there was a probability of more emission/pollution. Sample was collected with the help of flue gas analyzer when most of the gasses were moist. The energy produced will be given to textile industry which will be used for different purposes like drying and coloring etc. The efficiency will be measured by applying different treatment methods like changing feel feed rate, combustion air and fuel size. Oxygen was provided in boiler to improve its efficiency. Oxygen was measured by flue gas analyzer. The performance of boiler by providing oxygen is shown in table.

A small economizer was installed, and which can control emission which unfortunately it did not work. Fuel input was checked and necessary changes if needed will be made. Before closing boiler ensure its cleanliness and maintenance. Replace the fittings. Check the leaks and enter heated oil. Close the air checks expect the burner. Make the firing rate as lower as possible. Adjust air supply. Keep the firing rate steady. Boiler is extended from economizer to stop valve. The boiler must be protective against any shock. During filling check for leaks. Test the thickness of plate boilers by ultrasonic test. Gas inspection should be avoided until internal examination is done.

3. Results and Discussions

In design and fabrication, the main parts which were designed were:

Burner, Corn Collection Area, Heat transfer unit, Motor/Pulley, Pressure valve, Main boiler, Chimney and Dust Collection Area.

3.1 Waste Produced

As very toxic and harmful material is produced so unfortunately it cannot be produced in composting and incarnation. As a large amount of organic waste is produced so it is dumped in the landfill. In dumping the waste into landfill special care must be done to avoid environmental damage. All the Occupational health and safety guidelines were followed in dumping of waste. In waste the major substance were dust particles which can be further studied.

3.2 Emissions Standards

A large number of gasses was emitted during the operation, but I have only discussed the primary major gasses. The reason to discuss only these gasses is that they are the major gasses and from these major primary gasses all other gasses are formed.

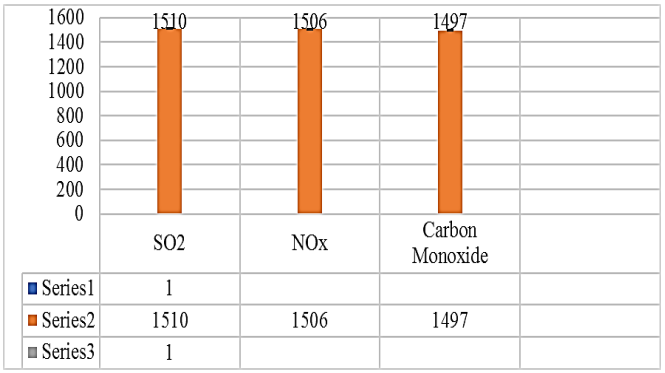

Figure 3: Graphical Representation of Pollutant Emissions from corn cob unit

Nothing in this world is pollution free. We cannot control the pollution. We cannot take the emission to zero level, but we can minimize it. The above table shows the values of emission standards if we use the corn cob feeding unit. In the above table I will compare it with conventional fossil fuels.

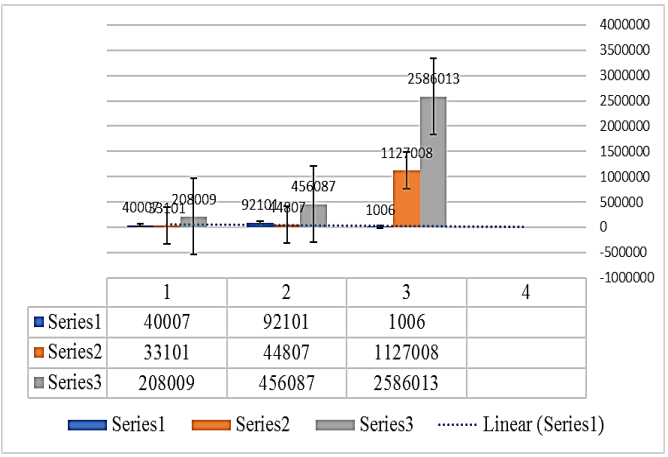

Figure 4: Comparison of different emissions using conventional fossil fuels

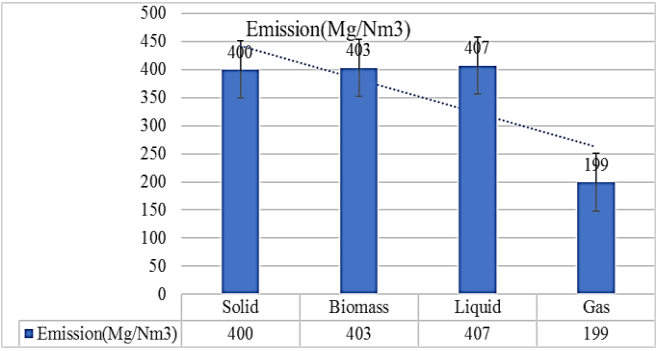

Figure 5: NOx Emissions Using different elements

They were measured only to check the different type of the emissions produced without the boiler. From the above data we can found that using solids like corn cob produces less emissions. Reason behind the low level of emission using gas is that it is not passed through a long process like the boiler. The NOx emissions were measured using different type of fuels in a corn cob feeding unit using different type of the solids, the liquids and the gasses. The solid used was corn cob collected by farmers. Biomass used was the wood and the conventional fossil fuels. As we see there is a not a lot of difference in values. The reason behind these low values are they were not tested on boiler. They were burnt manually to check both the corn cob produces less emission only on boiler or other ways along also and the results shows that easily they have more emissions.

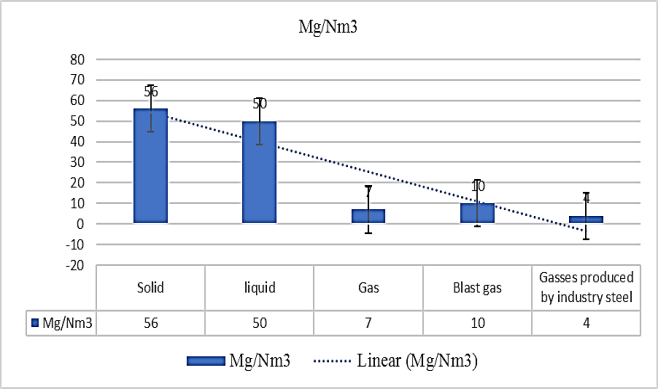

Figure 6: Dust Particle emissions using different elements

The dust particles were measured using different type of fuels in a corn cob feeding unit using different type of solid, liquid and gasses. The solid used was corn cob. Biomass used was wood and the conventional fossil fuels. As we see there is a not a lot of difference in values. The reason behind these low values are they were not tested on boiler. They were burnt manually to check either the corn cob produces less emission only on boiler or other ways along also.

4. Conclusion

The main working principle of corn cob feeding unit was to produce steam. Corn cobs were collected from local farmers and were put in the burner. The temperature 200-250^0 c and pressure are set. The operational cost estimate was which less than the cost of other fuels is. In Environmental Impact Assessment air emissions were measured. The dust particles left over at the end are dumped in the landfill because due to its harmful material it cannot be compost.

Acknowledgment

I would like to thank Mujtaba Masood textile mills for providing area to conduct research and using their feeder unit.

References

Bashir, M.S., 2012. Characterization and Quantification of Deposit Build-up and Removal in Straw Suspension-Fired Boilers. Technical University of Denmark.

Chaudhary, A.P., 1990. Thermodynamics and performance analysis of a biofueled boiler energy system.

Cuiping, L., Chuangzhi, C., and Haitao, H., 2004. Chemical elemental characteristics of biomass fuels in China. Biomas and Energy, 27, Pp. 119-130.

Gupta, R.D., Ghai, S., and Jain, A., 2011. Energy efficiency improvement strategies for industrial boilers: a case study. Journal of Engineering and Technology, 1, Pp. 52.

Lizotte, P.L., Savoie, P., and Champlain, A.D., 2015. Ash content and calorific energy of corn stover components in Eastern Canada. Energies, 8, Pp. 4827-4838.

Masuyama, F., 2001. History of power plants and progress in heat resistant steels. ISIJ International. 41, Pp. 612-625.

Mills, E., 2012. Pakistan's Energy Crisis. US Institute of Peace.

Muazu, R.I., and Stegemann, J.A., 2015. Effects of operating variables on durability of fuel briquettes from rice husks and corn cobs. Fuel Processing Technologies, 133, Pp. 137-145.

Odigure, J., Abdulkareem, A., and Asuquo, E., 2005. Effect of Water Quality on the Performance of Boiler in Nigerian Petroleum Industry. Leonardo Electronic Journal of Technology, 4, Pp. 41-48.

Ondrejka, H.V., Zelenakova, M., Purcz, P., and Olejnik, A., 2018. Selection of the Best Alternative of Heating System by Environmental Impact Assessment—Case Study. Environment, 5, Pp. 19.

Saidur, R., Abdelaziz, E., Demirbas, A., Hossain, M., and Mekhilef, S., 2011. A review on biomass as a fuel for boilers. Renewable and Sustainable Energy Review, 15, Pp. 2262-2289.

Skodras, G., Grammelis, P., Samaras, P., Vourliotis, P., Kakaras, E., and Sakellaropoulos, G., 2002. Emissions monitoring during coal waste wood co-combustion in an industrial steam boiler. Fuel, 81, Pp. 547-554.

Yildizhan, H., and Sivrioglu, M., 2017. Exergy analysis of a vacuum tube solar collector system having indirect working principle. Thermal Science, 21, Pp. 2813-2825.

Yin, L., Liu, G., Zhou, J., Liao, L., and Ma, X., 2017. A calculation method for CO2 emission utility boilers based on BP neural network and carbon balance. Energy Processing, 105, Pp. 3173-3178.