Analysis and Numerical Study of Boiler in Sugar Cane Industry

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Abstract-*The bagasse is used as fuel in sugar mills; in order to burn the bagasse primary and secondary air is supplied. The forced draught fan sucks the primary air (atmospheric air) and passes through the air preheater to furnace. In air preheater atmospheric wet air enters, it reacts with the metal tubes causes' corrosion. The aim is to avoid the corrosion of cold end in air preheater and increase temperature of the supply air to furnace. To resist the corrosion, the atmosphere air temperature is increases up to above dew point temperature (70°C). Air flow analysis in air preheater has done using computational fluid dynamics*.

Keywords: **Air preheater, corrosion, computational Fluid dynamics**

1. INTRODUCTION

The power plant process contains different types of fuels; these fuels contain different sulphur percentage. The flue gas which enters the air preheater contains sulphur units yields a potential hazard of sulphur corrosion at the cold end of air preheater. This corrosion in airprehater depends on many features based on percentage of sulphur in fuel, moisture in flue gas, excess air.

If the percentage of sulphur in the fuel is higher then the risk of cold end corrosion in the air preheater will be high. During combustion the sulphur in the fuel gets converted in to sulphur dioxide. Based on the other impurities in fuel and execess air levels,some portion of suphur dioxide gets converted to sulphur trioxide.

The existence of moisture in flue gas due to moisture in fuel and air, suphur dioxide and sulhur trioxide, reacts with moisture and forms sulphuric acid.the basic reactions takes place are

$S + O2 \rightarrow SO2$

$SO2 + O2 \leftrightarrow SO3$

$H2O + SO2 \leftrightarrow H2SO3$
$H2O + SO3 \rightarrow H2SO4$

Based on the ppm of SO_3 and water-vapor concentration, the dew point temperature of flue gas may vary around 90 degree centigrade to 140 degree centigrade.
Condensation of these acids may results in failure in boiler tubes, metal wastage, air preheater corrosion and flue gas duct corrosion.in order to avoid this corrosion the inlet atmospheric air which enters in to the air preheater should be above the dew point temperature of flue gas.
If the sulphur percentage increases up to 1%, gradually the dew point temperature of flue gas increases steeply from 70 degree centigrade to 135 degree centigrade.

Prevention of Cold End Corrosion

There are several methods used to contain cold end corrosion. These methods fall in the two categories,

1. In-combustion reduction
2. Post-combustion reduction.

In-combustion reduction methods include:

- Burning low sulphur fuel
- Low excess air burners
- Fuel additives
- Fluidized bed combustors

Burning of low sulphur fuel in the steam generators is sometimes economically useless.

Nowadays many low excess air designs are available; these kinds of burners adopt to reduce the excess air requirement without affecting the unburnts in the flue gas after combustion.

Fuel oil additives like simple magnesium oxides are used to contain cold end corrosion due to sulphur. Fuel additives like magnesium oxide is injected in to the furnace which combines with sulphur oxides to form magnesium sulphate.

In fluidized bed combustors, addition of lime is a simple method to reduce sulphur corrosion.

The post-combustion technologies adopted are:

Designing with higher exit air temperature

Wet air pass into the air preheater, reacts with metal tube cause corrosion. The objective is to avoid the corrosion of cold end in air preheater and increase the temperature of the supply air to furnace.

Due to corrosion forming cold end air preheater tubes are damaged with in few years. To avoid corrosion, the steam preheater is installed in between FD fan and APH, this steam preheater preheats the atmospheric air up to 70 degree centigrade before the enters in to cold end of air preheater By increasing the temperature of the atmosphere air prevents the corrosion in air preheater tubes, which is supplied to furnace.

2. PROBLEM STATEMENT

Wet air pass into the air preheater, reacts with metal tube cause corrosion. The objective is to avoid the corrosion of cold end in air preheater and increase the temperature of the supply air to furnace.

Due to corrosion forming cold end air preheater tubes are damaged with in few years. To avoid corrosion, I have designed the steam preheater which is installed in between FD fan and APH, this steam preheater preheats the atmospheric air up to 70 degree centigrade before the enters in to cold end of air preheater By increasing the temperature of the atmosphere air prevents the corrosion in air preheater tubes.

Most of the sugar cane industries has long bend air duct ,due to this pressure drop occurs .so to reduce the pressure drop I have changed the air duct in to inclined position, hence pressure drop get reduced and velocity of flow increased.

And finally the supply air temperature to the furnace is increased due to the modification, so I have calculated the boiler efficiency before and after modification.

3. FORCED DRAUGHT FAN

The forced draught fan i.e.(primary fan) are used to supply air to furnace for drying the coal(bagasse).the primary air enters in to the air preheater before going to the furnace. Forced draft fans supply air at pressure higher than atmospheric pressure will produce the positive pressure inside the system i.e. furnace. The capital cost of Axial fan is high, axial fan handles only small volume of air. In centrifugal fan the gases are accelerated radially through flat impeller blades from rotor to a spiral casing. FD fan is installed inlet to air preheater, less maintenance, consume less power

SPECIFICATION

Type: centrifugal fan with backward curved table
Diameter: 935 mm
Speed: 1475rpm
Discharge volume: 13.4 m^3/s
Pressure: 210 mm of WG
Temperature: 40°C

4. DESIGN OF STEAM PREHEATER

Newly designed Steam preheater work is to preheat the atmospheric temperature above the dew point temperature of flue gas i.e. from 40°C to 70°C . In sugar mill the steam leaving the boiler has temperature 400°C and 42 kg/cm^2 pressure. The steam which leaves the boiler is utilized for power production using turbine. After the steam leaves the turbine, temperature and pressure drops to 200°C and 1.5 kg/cm^2. This superheated steam is further utilized in boiling house, from this some amount of steam is used to preheat the atmospheric air in steam preheater. Here the steam preheater is nothing but the heat exchanger, hence the following considerations has been taken,

TABLE NO. 1 Parameters for air preheater.

S.NO	PARAMETERS	SYMBOL	QUANTITY
1	Air inlet temperature	t_1	40 °C
2	Air oulet temperature	t_2	72 °C
3	Steam inlet temperature	T_1	200 °C
4	Heat transfer	Q	1488.5 Kw
5	Specific heat of air	Cp	1.005 kJ/kg-K
6	Specific heat of steam	Cp	4.4895 kJ/kg-K
7	Mass flow rate of air	m	15.11 kg/s
8	Viscosity of air	μ	0.0723 Kg/mh
9	Density of air	ρ	1.287 Kg/m^3

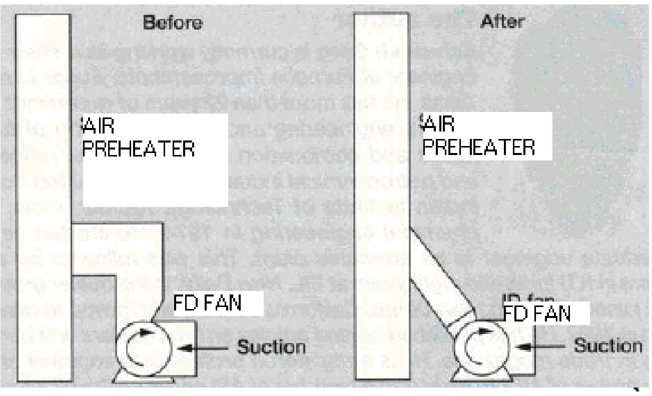
TABLE NO.2 Air preheater geometry

S.NO	PARAMETER	VALUE
1	Height of exchanger	2150mm
2	Width of exchanger	1390mm
3	Breadth of exchanger	1005mm
4	Tube side diameter	63.5mm
5	Tube thickness	3.25mm
6	Tube material	Carbon steel
7	Number of tubes	64

5. AIR DUCT

The design of air duct is based on cost and energy loss due to friction. Air ducts extends from forced draught fan to the combustion chamber. In most of sugar mill air duct is long with bend suction, due to that pressure drop occurs. So to reduce the pressure drop I have changed the air duct in to inclined position, hence pressure drop get reduced and velocity of flow increased.

FIG NO.1&2 shows the air duct before and after modification



6. Analysis of Air preheater

An air preheater is generally designed to preheat the air before it enters in to another process (for example combustion in boiler). The major objective is to increase the thermal efficiency of the process. The purpose of air preheater is to recover the heat from boiler flue gas is utilized to preheating the air before supplying to combustion chamber.it has been noted that if air temperature increases to 20°C then the efficiency increases by 1%.the flue gas which enters the air preheater with varying temperature between 325°C to 450°C are cooled to 135°Cto260°C.

While passing through the air preheater, Atmospheric air from the FD fan outlet has increased in temperature from 40°Cto 115°C or sometimes higher.in most of the modern power plants the air preheaters is an necessary equipment to supply hot air for drying the coal in pulverized fuel system to facilitate satisfactory combustion of fuel in furnace and also act major role in boiler efficiency.

Tubular type air preheaters are used in sugar mill because it gives more contact of time between flue gas and air.

7. BOILER EFFICIENCY

There are various methods to increase the boiler efficiency such as

In sugar mill they are using water tube boiler which is capable of producing 64 tons of steam/hr. if we increase the production of steam by changing he design boiler efficiency get increased.

The working pressure and temperature of the steam is 42 kg/cm3 at 420ºC. If we increase the pressure of the steam, then the power production increases mean while the efficiency of boiler is also increases.

In India most of power plant they are using bagasse as fuel which contain 50% of moisture content in it, if we take 1 kg of bagasse then it contains 0.5 kg of water . If we decrease the moisture content in the bagasse by using heat recovery apparatus like air preheater, economizer, super heater, certainly increase the boiler efficiency.

Boiler efficiency is calculated by various heat loss methods

The individual boiler losses include:

a) Dry flue gas.
b) Wet flue gas (this includes the loss due to combustion of the hydrogen in the fuel plus that due to moisture in the fuel).
c) Moisture in combustion air.
d) Unburnt carbon loss.
e) Radiation and unaccounted loss.

Boiler efficiency = 100 -- various losses

TABLE NO.3 Ultimate analysis of coal

Parameter	Coal
Moisture	5.98
Carbon	41.11
Hydrogen	2.76
Nitrogen	1.22
Sulphur	0.41
Mineral matter	38.63
Oxygen	9.89

a) Dry flue gas loss

The only components of a fuel which burn to form dry products of combustion are carbon and sulphur.

Dry flue loss= $\left[\frac{100}{12(CO_2+CO)}\left(\frac{C}{100}+\frac{S}{267}-\frac{C\ in\ A}{100}\right)\right]30.6(T_2-T_1)$

$=\left[\frac{100}{12(138.92+51)}\left(\frac{41.11}{100}+\frac{0.41}{267}-\frac{34.69}{100}\right)\right]30.6(115.3-40)$

Dry flue gas loss =6.71%

b) Wet flue gas loss

The wet products of combustion are derived from the moisture and the hydrogen in the fuel. The combustion of hydrogen is represented by:

$$2H_2+O_2=2H_2O$$

Expressed as masses 4+32=36

So the combustion of 1 kg of hydrogen produces 9kg of moisture.

Wet flue gas= $\frac{M+9H}{100}[1.88(T-25)+2442+4.2(25-t)]$

Where

M = % moisture per kg fuel

H = % hydrogen per kg fuel

T_2 = temperature of the flue gas after air preheater

T_1 =Ambient Air temperature at F.D. intake (ºC)

Hydrogen loss= $\frac{9H}{100}[1.2(T_2-25)+2.442+2.99(25-T_1)]$

$=\frac{9\times2.76}{100}[1.2(115.3-25)+2.442+2.99(25-40)]$

Hydrogen moisture loss =16.29%

c) Fuel moisture loss

Fuel loss= $\frac{M}{100}\{1.2(T_2-25)+2.442+2.99(25-T_1)\}$

$=\frac{5.98}{100}\{1.2(115.3-25)+2.442+2.99(25-40)\}$

Fuel moisture loss=3.94%

d) Moisture in combustion air loss

Moisture in combustion air loss = $M_a\times h\times1.88(T_2-T_1)$

Where

M_a = Dry air for combustion fuel kg/kg fuel

h =kg moisture per kg of dry air.

A reasonably accurate value of M_a for solid and liquid fuels is given by

$$M_a=\frac{3.034\ N_2}{CO_2+CO}\left(\frac{C}{100}+\frac{S}{267}-\frac{C\ in\ A}{100}\right)$$

$=\frac{3.034\times1.22}{138.92+51}\left(\frac{41.11}{100}+\frac{0.41}{267}-\frac{34.69}{100}\right)$

= 0.00129

= 0.00129 $\times0.015\times1.88(115.3-40)$

Moisture in combustion air loss

=0.002%

e) Unburnt carbon loss

The mass of carbon monoxide in gas is given by the expression:

$=\left[\frac{CO}{CO_2+CO}\times\left(\frac{C}{100}+\frac{S}{267}-\frac{C\ in\ ash}{100}\right)\times23\ 717\right]/100$

$=\left[\frac{51}{138.92+51}\times\left(\frac{41.11}{100}+\frac{0.41}{267}-\frac{34.69}{100}\right)\times23717\right]/100$

Unburnt carbon loss =4.23%

f) Radiation and unaccounted loss

Radiation loss is given by

$log_{10}B$=0.8167-0.4238log_{10}C

Where,

B = radiation and unaccounted loss.

C = specific boiler capacity in kg/s.

$log_{10}B$=0.8167-0.4238$log_{10}\left[\frac{64\times14000}{3600}\right]$

Radiation and unaccounted loss (B) = 0.81%

Total losses = 32.26%

Boiler efficiency = 100 – total various loss

=100−32.26

Boiler efficiency =68.01%

Boiler efficiency after modification of air duct

Dry flue gas loss = 8.6%
Hydrogen moisture loss =9.8%
Fuel moisture loss =2.36%
Moisture in combustion air loss =0.264%
Unburnt carbon loss = 4.23%
Radiation and unaccounted loss = 0.81%
Total losses = 26.064%

Boiler efficiency = 100 – total various loss

=100−26.064

Boiler efficiency =73.8%

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8. RESULTS AND DISCUSSIONS

Computational fluid dynamics (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows.

Air preheater simulation results:

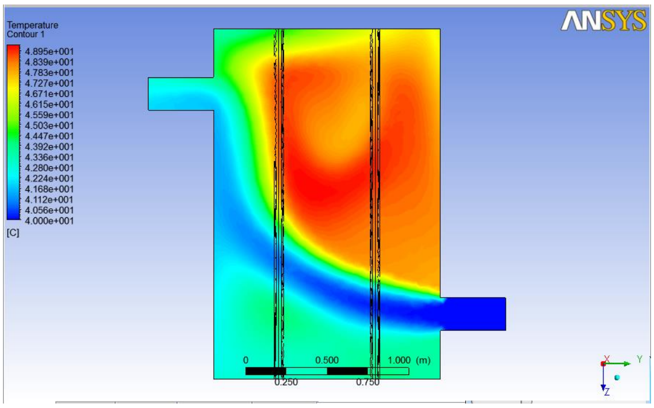

Fig no 3 contour plot of temperature in air preheater

In Above contour we can see that temperature increases from 40°C to 42°C .temperature increases by 2°C if we use 4 no of tubes inside air preheater, so if we use 64 no of tubes inside the air preheater temperature vary from 40°C to 70°C.

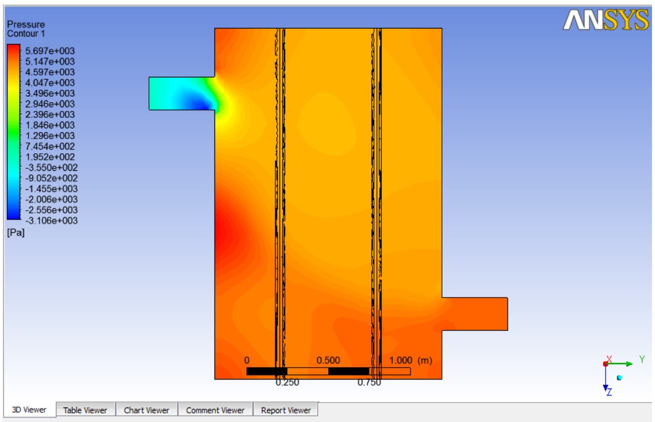

Fig no 4 contour plot of pressure in air preheater

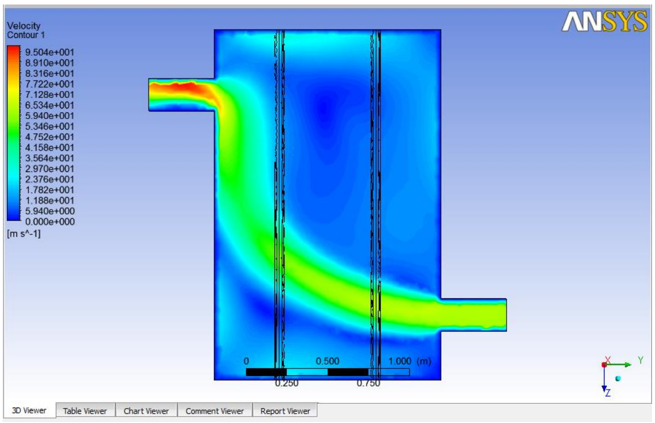

Fig no 5 contour plot of velocity in air preheater

Air duct simulation results:

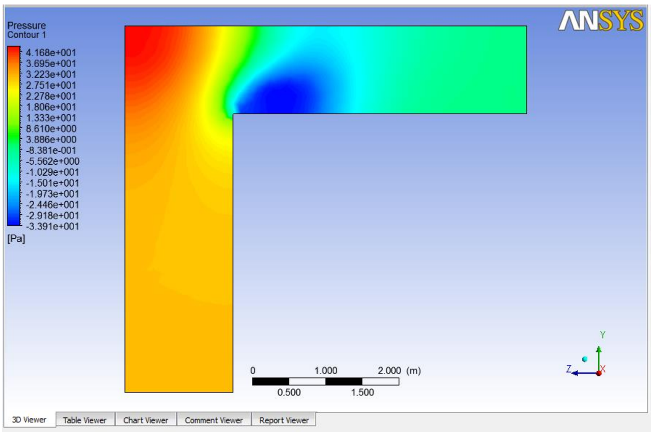

Fig no 6 contour plot of pressure in air duct before modification

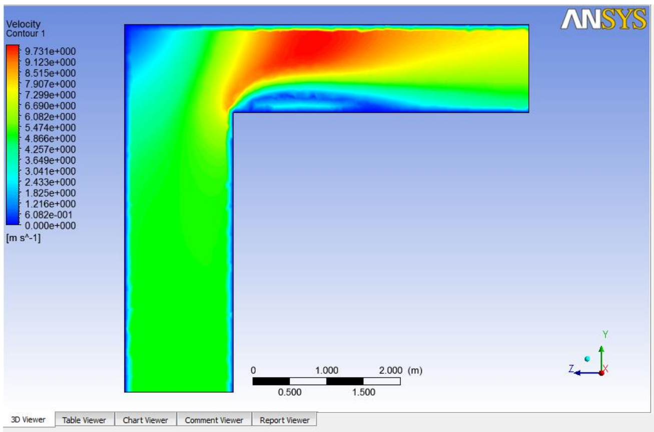

Fig no 7 contour plot of velocity in air duct before modification

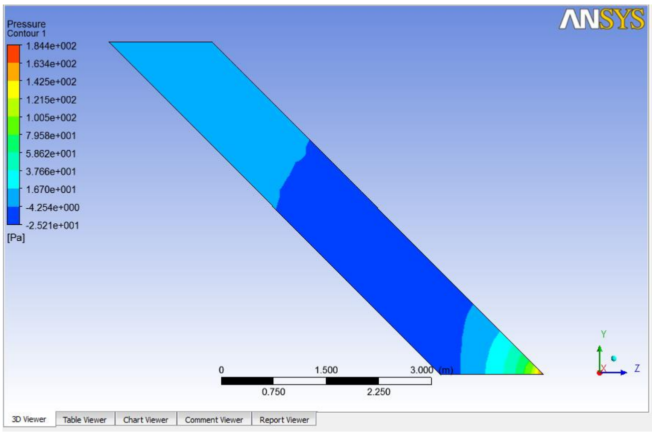

Fig no 8 contour plot of pressure in air duct after modification

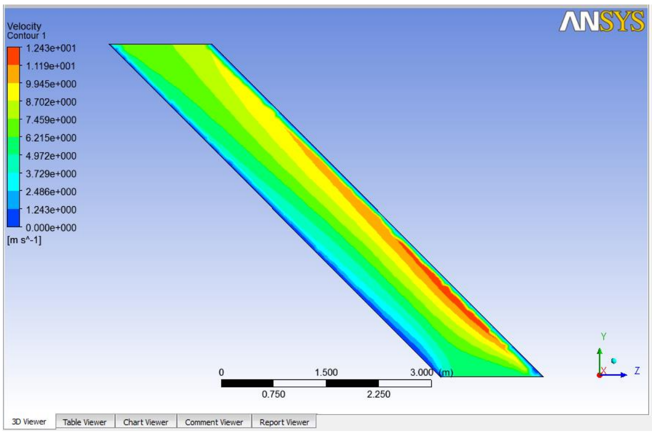

Fig no 9 contour plot of velocity in air duct after modification

Above simulation results of air duct before and after modification shows that the pressure drop reduces and flow velocity increased.

9. Conclusion:

The outlet temperature of air preheater increase from 40°C to 72°C and supply air temperature to furnace is increased up to 30°C .At the same time efficiency of boiler also increased by 5%. By analyzing the air duct modification of inclined position gives the more performance than the straight bend air duct.

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