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Computational Fluid Dynamics Analysis of Airpreheater Cold End

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Abstract: *Generally in the sugar mills, they are using bagasse as the fuel, to burn the bagasse primary and secondary air is supplied. Forced draught fan supply primary air and sail air fan supply secondary air. Primary air is sucked by forced draught fan and passed through the airpreheater to furnace. In airpreheater the flue gases coming out of economizer are further utilized for preheating the atmosphere air before supplying to the furnace. Atmosphere wet air enters into the airpreheater, reacts with the metal tubes causes corrosion. The main aim of this project is to avoid the corrosion of cold end in airpreheater 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 (65°C). Air flow analysis takes place from FD fan to furnace using computational fluid dynamics.*
Keywords: *Airpreheater, corrosion, dewpoint temperature, Computational fluid dynamics.*

I. Introduction

Wet air enter into the air preheater, reacts with the metal tube causes corrosion. The main aim of the Project is to avoid the corrosion of cold end in air preheater and increase the temperature of the supply air to furnace.

The principal reaction is

$$2Fe + O_2 \rightarrow 2FeO$$

Due to corrosion forming cold end airpreheater tubes are damaged with in few years. To avoid corrosion, the atmosphere air is preheated by the steam preheater from the exhaust steam. By increasing the temperature of the atmosphere air prevents the corrosion in air preheater tubes, which is supplied to furnace. Installing the steam preheater in between FD fan and APH for increasing the temperature of air at the same time pressure drop will occur due to the number of tubes available in the steam preheater. To minimize the pressure drop in the steam preheater should increase the area of flow between the tubes. Calculate the velocity of the atm air and mass flow rate of air supplied by the forced draught fan. Design should be effective for above dew point temperature (65°) to avoid corrosion. The forced draught fan supply air heated by exhaust steam.To maintain the pressure of the supply air to furnace, air duct modify depends upon flow velocity.. In air preheater analysis calculate the temperature of supply air before installating steam preheater. Boiler efficiency increases by increase the temperature of the supply air. The air flow should be analysis from forced draught to furnace using computational fluid dynamics.

II. Forced Draught Fan

Fan is to move a mass of gas or vapour at the desired velocity by the action of rotor. For achieving this objective there is a slight increase in the gas pressure across the fan rotor. However the main purpose of fan is to move a gas without an appreciable increase in its pressure. Axial fan have higher capital cost. Axial fan handles the small volume of air. In the centrifugal fan, gases are accelerated radially through curved or flat impeller blades from rotor to a spiral or volute casing. FD fans are installed at inlet to the air-preheater. They handle cold air, so they have less maintenance problem, consume less power capital and operating cost are lower is the highest for backward curved and lowest for the forward curved blades.

A. SPECIFICATION

Type	: Centrifugal fan with backward curved blade
Diameter	: 935 mm
Speed	: 1475 rpm
Discharge	: 13.4 m³/s
Pressure	: 210 mm of WG
Temperature	: 40°C

III. Design Of Steam Preheater

Steam preheater is nothing but like a heat exchanger. The purpose of steam preheater in this work is transfer the steam temperature to the atmosphere air and increase the air temperature. The steam temperature available at the sugar mill is 400°C and 42 kg/cm² pressure. This steam is utilized for the power production by rotates the turbine. After the turbine steam leaving with 200°C temperature and 1.5 kg/cm² pressure. This superheated steam is further used for the boiling house, from this some amount of steam will be utilized for heat the atm air in the steam preheater. When the heat exchanger is to be designed for a particular application, the following consideration almost always taken into account. Here air temperature is increased above dew point temperature for reducing corrosion.

A. STEAM SPECIFICATION

Steam inlet temp = 200°C
Steam pressure = 1.5kgf/cm²
Mass flow rate = 0.833 kg/s
Specific heat capacity Cp = 4.4895 kJ/kg-K

B AIR SPECIFICATION

Air inlet temp = 40°C
Mass flow rate = 15.11 kg/s
Volume of air = 13.4 m³/s
Specific heat capacity Cp = 1.005 kJ/kg-K
Table I shows comparison between air and steam mass flow rate

C. AREA OF THE STEAM PREHEATER

Height of the exchanger = 2150mm
Width of the exchanger = 1390 mm
Diameter of the tubes = 21.3 mm
Breath of the exchanger = 1005 mm
Length of the exchanger = 1.255 mm
Number of tubes = 168

In steam preheater 3 tones per hour of mass of steam utilized for attain the dew point temperature. Table II shows temperature difference with number of tons.

IV. AIR DUCT

The design of duct is a compromise between first cost and cost of energy loss friction. This means compromise between cross sectional area and velocity. Combustion requires oxygen and their air, to move this air through the fuel bed and to produce a flow of the gaseous products of combustion out of the furnace, then through the boiler, economizer etc., requires a difference of pressure equal to that necessary to accelerate the gasses to their final velocities, plus friction head losses. This difference of pressure is called draft. Air ducts generally extend from the outlet of a forced draught fan to the combustion chamber. Where air heaters are used the air duct is necessarily in two sections, the cool selection, fan and hot section. Normally all sugar mill air duct is bend section with long radius. Due to bend and long radius of air duct pressure drop occurs in the boiler. So to reduce the pressure drop have to change the air duct in to inclined position. In this position pressure drop is reduced and increase velocity of the flow. Air duct modification before and after is shown in figure I.

The loss may be computed with the following equation

$$D_4 = d\,\frac{fv2H}{2gR} \text{ cm water}$$

V. Analysis Of Airpreheater

The heat carried with the flue gas coming out of economizer is further utilized for preheating the air before supplying to the combustion chamber. It has been found that an increase of 20ºC in the air temperature increases the boiler efficiency by 1%. At such a high temperature of exit gases the losses of energy with stack exhaust is high and efficiency of the boiler will be low. While flue gases enters the airpreheater at temperature varying between 325 ºC to 450ºC and are cooled to 135ºC to 180ºC, air is heated from FD fan outlet temperature 60ºC to 400ºC and some times still higher. The air heater not only considered in terms of boiler efficiency in modern power plants, but also necessary equipment for supply hot air for drying the coal in pulverized fuel system to facilitate grinding and satisfactory combustion of fuel in furnace. In sugar mill, they are using tubular type air preheater, because of it gives the more contact of time between air and flue gases. Dew point of the air lies in the region of 60 -65ºC, hence it may be supposed that the danger of condensation on the walls of the heater. Atmosphere air is supply to air preheater by the FD fan with 40ºC temperature. In this temperature limit tubes reacts with air causes corrosion, that's why temperature increased above dew point temperature (65ºC). Table III comparison of air duct before and after modification

A.BOILER EFFICIENCY

The present working pressure of the steam in sugar mills is 42 kg/cm^3 at 420ºC. If we increase the pressure of the steam, then the power production increases mean while the efficiency of boiler is also increases. the present water tube boiler has the capable of producing 64 tones of steam/hr. if we increase the steam production by changing the design, then also increase boiler efficiency increase. In most of the sugar mills bagasse is used as a main fuel. Bagasse in India almost have the moisture content of about 50% (ie) if we take 1 kg of bagasse then it contains 0.5 kg of water in it. If we decrease the moisture content in the bagasse by simply increase the boiler efficiency.use of heat recovery apparatus such as air preheater,economizer,superheater etc.will also increase the boiler efficiency. In the airpreheater the air to the boiler is heated by the flue gas. So the efficiency of the boiler increases with the usage of the air preheater. The efficiency of the boiler is dependent upon the efficiency of combustion and the heat transfer within the boiler. Boiler efficiency is calculated by heat loss method as

Boiler efficiency = 100 -- various losses

B.VARIOUS LOSSES

Dry flue gas loss = 5.27%
Fuel moisture = 14.47%
Hydrogen moisture loss = 8.33%
Air moisture loss = 0.27%
Unburnt carbon loss = 2.00%
Ash sensible heat loss = 0.01%
Radiation & convection loss = 0.55%

Total losses = 30.90%

Present boiler efficiency = 100 – total various loss
= 100 – 30.90
Boiler efficiency = 69.10%

Boiler efficiency after modification of air duct with increasing combustion temperature

1.Dry flue gas loss
$= 100 \times [C\% + S\% - C \text{ in ash}] \times 30.6 (T_1 - T_2) / 12 (CO_2 + CO)$
Where
T_1 is temperature of the flue gases before air preheater
T_2 is temperature of the flue gases after air preheater
Dry flue gas loss = 1.94%
2. Hydrogen moisture loss
$= 9 \times h \{1.2(T1 – 25) + 2.442 + 2.99(25-T2)\}$
= 15.10%
3. Fuel moisture loss
$= \{1.2(T1 – 25) + 2.442 + 2.99(25-T2)\}$
= 9.43%
4. Moisture loss in air
= weight of the flue gas x moisture in air x 2 (T1- T2)
= 1.02%
5. Heat loss in fly ash = 0.983%
6. Ash sensible heat loss = 0.01%
7. Radiation & convection loss = 0.55%

Total losses = 27.03%
Boiler efficiency = 100 – 27.03
= 72.97%

If increase the combustion temperature, losses are reduced in the furnace and increase the boiler efficiency.

VI. Analysis Of Air Duct

Computational fluid dynamics analysis takes place from forced draught fan to furnace by using fluent with Air duct is modeled by gambit which is an integral division of Fluent. After modeling the air duct using the given co-ordinates the model is meshed using Gambit Mapped mesh. Quadrilateral cells were used for this simple geometry because they can be stretched easily to account for different size gradients in different directions. The coupled solver is recommended when dealing with applications involving high speed flow.

A. COMPUTATIONAL FLUID DYNAMICS

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. The fundamental bases of any CFD problem are the Navier-Stokes equations, which define any single-phase fluid flow. These equations can be simplified by removing terms describing viscosity to yield the Euler equations. These equations can be simplified by removing terms describing viscosity to yield the Euler equations. Further simplification, by removing terms describing vorticity yields the full potential equations. Finally, these equations can be linearized to yield the linearized potential equations. The stability of the chosen discretization is generally established numerically rather than analytically as with simple linear problems. The Euler equations and Navier-Stokes equations both admit shocks, and contact surfaces. The governing equations are solved on discrete control volumes. FVM recasts the PDE's of the N-S equation in the conservative form and then discretize this equation. Moreover this method is sensitive to distorted elements which can prevent convergence if such elements are in critical flow regions. This integration approach yields a method that is inherently conservative (i.e. quantities such as density remain physically meaningful)

$$\frac{\partial}{\partial t}\iiint Q\,dV + \iint F\,d\mathbf{A} = 0,$$

Where *Q* is the vector of conserved variables, *F* is the vector of fluxes *V* is the cell volume, and $\mathbf{A}$is the cell surface area. After modeling the air duct given co-ordinates the model is meshed using Gambit Mapped mesh. Quadrilateral cells were used for this simple geometry because they can be stretched easily to account for different size gradients in different directions. The coupled solver is recommended when dealing with applications involving high speed flows. The Spalart-Allmaras model was designed specially for aerospace applications involving wall-bounded has been shown to give good results for boundary layers subjected to adverse pressure gradients.

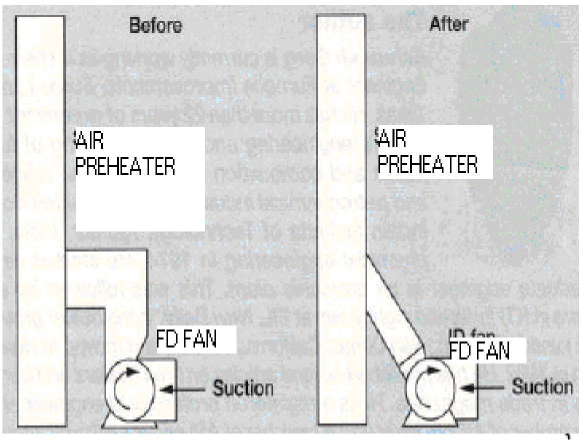

FIGURE I AIR DUCT MODIFICATION

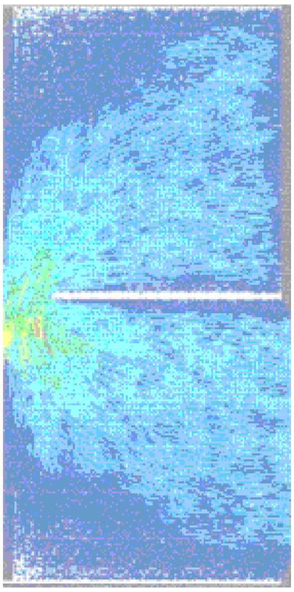

FIGURE II VIEW OF AIRPREHEATER WITH INLET AND OUTLET FLOW VARIATION

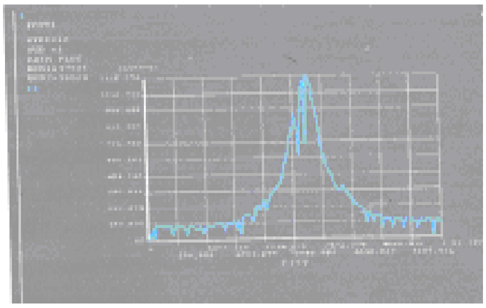

FIGURE III VELOCITY VARIATION FOR BEFORE MODIFICATION OF AIR DUCT

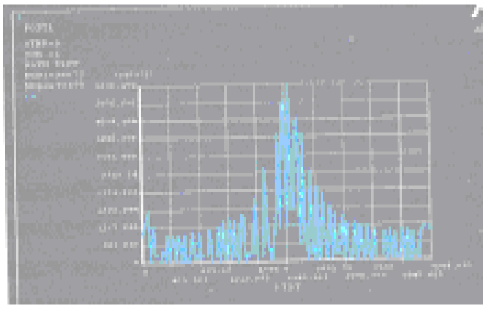

FIGURE IV VELOCITY VARIATION FOR BEFORE MODIFICATION OF AIR DUCT

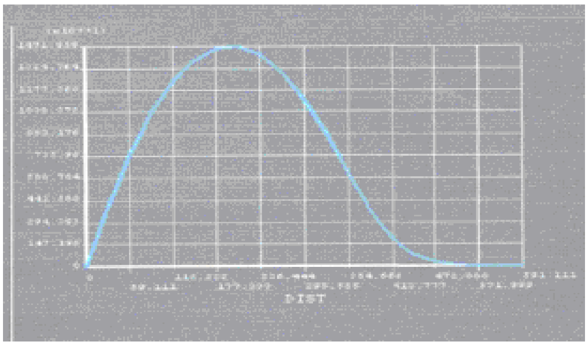

FIGURE V VELOCITY AT THE EXIT OF AIRPREHEATER BEFORE MODIFICATION OF AIR DUCT

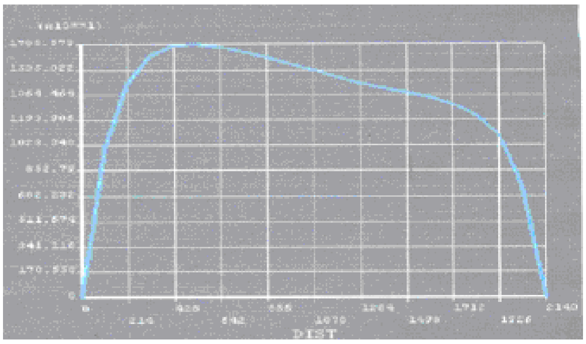

FIGURE VI VELOCITY AT THE EXIT OF AIRPREHEATER AFTER MODIFICATION OF AIR DUCT

Gases	Mass flow rate(ms) Kg /s	Specific heat(Cp) KJ / kg- k
Air	15.11	1.005
Steam	0.833	4.4895

TABLE I COMPARISION BETWEEN AIR AND STEAM MASS FLOW RATE

Content	Before modification of air duct	After modification of air duct
Pressure drop	94 mm of Hg	72 mm of Hg
Mass flow rate of air	15.35 kg/sec	24 kg/sec
Outlet temperature of APH	115.3 ºC	147.7 ºC
Efficiency of boiler	69.10 %	72.97 %

TABLE II COMPARISION OF AIR DUCT BEFORE AND AFTER MODIFICATION

No.	No of tons Tons/hr	Mass flow rate Kg / s	Temperature increased °c
1	1.5	0.416	41.5
2	2.0	0.555	46.3
3	2.5	0.694	52.8
4	3.0	0.833	68.2

TABLE III TEMPERTAURE DIFFERENCE WITH NUMBER OF TONES

VII. Result And Discussion

Normally all the power plant FD fan air duct will always kept bend, but we have modified the air duct in to inclined position. In this position pressure drop is reduced and heat transfer is increased in air preheater. Table I shows the comparison between air and steam mass flow rate and Table II shows comparison of air duct before and after modification, efficiency of boiler is increased from 69.10% to 72.29% and outlet temperature is 147ºC, pressure drop is reduced upto 72mm HG. Table III shows temperature difference with number of tones with mass flow rate of steam 0.833 and temperature is 68.2ºC. In this temperature tubes are protected from corrosion forming. Figure III and IV shows the velocity variation before and after modification of air duct.

Before modification of air duct velocity is gradually increased with distance of air preheater, but in the after modification of air duct, with in the small distance velocity is increased. Figure V and VI shows the exit velocity of air preheater, before modification velocity is increase and suddenly decreased but in the after modification velocity increase at the end of whole distance of air prehaeter.

VIII. Conclusion

By analyzing the air duct modification of inclined position gives the more performance than the straight bend air duct. Steam preheater increase the temperature from 40°C to 68°C and supply air temperature is increased by 20°C at the same time combustion temperature is increased by 1% and efficiency also increased by 3%.

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