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INTENSIFICATION OF HEAT TRANSFER CO-EFFICIENT IN ECONOMIZER AND VALIDATION OF EXPERIMENTAL RESULTS BY ANALYSIS OF FLOW THROUGH CFD

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ABSTRACT

The thermal energy is the main concern in the present economic world. The effective utilization of raw materials towards the meet of energy crisis is requires in this current technology. The present study focus on co-generation method, which uses bagasse as a raw material. Bagasse as a by-product after sugarcane crushing unit. This bagasse is maintained with consistent moisture for economic stability of equipment for longer duration. Sugarcane bagasse approaching will have a key role in the combine of global energy. The 5000 ton per day bagasse is generated, which meets the load requirement to generate power from the turbine, the rejected heat from the turbine is used as secondary thermal load to heat external liquid products like, cane wash, juice blending and syrup. The end product of bagasse is used in distilleries. This paper explains about one of the ways to increase the heat transfer rate of economiser. Heat transfer is always enhanced by to the surface which enhances heat transfer of the above mentioned two methods, which ever gives more heat transfer that passive method will be optimized. Modelling has been carried out in CATIA, imported to ICEM CFD where meshing is done. Further analysis carried out through CFX.

Keywords: Bagasse, CFX, CFD, Economizer, ICEM

I. INTRODUCTION

India is one of the largest consumers and producers of sugar in the world. Country has made remarkable growth in the bagasse cogeneration. As the Conventional fuel such as Bagasse is limited and its demand for generation of electricity is increasing there by emphasizing the need for new renewable sources Cogeneration industry using bagasse as the main raw material is attached to several sugar factories efficiencies. The fibrous material from the sugar cane after extracting the juice. In sugar making industry requires both steam as well as electrical energy. Bagasse is the available by product of the sugarcane after crushing and is burnt as a fuel in the boiler of mill side. Via bagasse for cogeneration has been running in mill section since long to gather sugar mills own energy requirements.

These produce steam & electricity for use in the sugar mills section & also sell the remaining power to the grid. Sugarcane is represents an ethanol & sugar source, as well as the biomass residue (bagasse) that is used for

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power production. Due to its growing possible uses, sugarcane bagasse was analyzed for energy & non-energy utilization in this work. However, the environmental impacts of power production from bagasse necessity be quantified to evaluate whether it is really advantages for the environment. This study considers a 26 Megawatt bagasse fired power plant at SCSL in maddur.

The size of sugarcane bagasse production has increased year by year, & it is potential to observe that there is a further amount of available bagasse being used for power production, decrease the sugar price, support and motivate the formers to earn additional revenue to actual rate of selling of cane. Separately from the bagasse that provides all energy essential by sugarcane process, mill sides can generate an energy surplus & sell it to the grid. Sugarcane bagasse has been today the largest renewable source of energy. Sugarcane can not only provide food products, but also diversify renewable source energy options and reducing its dependence on hydropower.

The optimum calorific value of bagasse has been finding for varying the moisture contents of bagasse. The requirement is to measure the impact of the moisture content of bagasse on the sum of heat transferred to steam from bagasse during combustion in the boiler furnaces. The aim is maintain moisture content that has a significance influence on the performance of a boiler and overall efficiency of plant. In DM plant maintain the quality of supply of fresh boiler water along with recirculation of water also plays important role in the improvement of efficiency and performance of system.

Economizer is generally tubular heat transfer surfaces used to preheat the boiler feed water before it enter into boiler drum. The economizer enables the boiler to operate at a less amount of fuel usage to get higher rate of efficiency. This is due to recycling of waste heat and that heat captured by tubes. The recovered heat has used to increase the temperature of the feed water, which in turn reduce the amount of additional heat required for steam production. This has a direct impact by reduce the bagasse fuel requirement, hence reduced the running cost. An added benefit is the lowered environmental impact linked to reduce the volume of flue gases entering the atmosphere and the amount of carbon via the boiler chimney. Hence there is necessity for analysis of economizer to increase the efficiency of boiler and also reduce emissions from co-generation plant. The ultimate goal of economizer design at minimum cost has to achieve necessity of heat transfer. A key design criterion for economizer has large velocity of flue gas. Large velocity provide better heat transfer and reduced the cost. The detail simulation of flue gas flow has necessity to improve the heat transfer coefficient and duct is designed. CFD model has a good tool to improve the efficiency of economizer. Duct having cross sectional area of rectangular has normally used in power plant. Gas flow distribution over heat equipment has critical problems in co- generation power plant.

1.1 Company Profile

Sri Chamundeswari sugars limited (SCSL), incorporated in December 1970, are promoted by Dr.N.Mahalingam of the ‘sakthi Group’ Coimbatore, Tamil Nadu. The company’s Board comprises of one Non-Executive chairman, one managing director, one Executive director, and seven non-executive directors.

SCSL started its operation to manufacture suagar with an installed capacity of 1250 TCD in 1974 at K.M.Doddi, Maddur District in Karnataka. It undertook expansion of its sugar manufacturing capacity from 1250 TCD to 2400 TCD in 1986 and further to 4000 TCD in 2006.

In the year 2002-03, the company set up a distillery unit to manufacture rectified spirit, denatured sprit and extra alcohol from molasses with an installed capacity of 50 kilo liters per day (KLPD).along with the distillery plant,

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biogas and bio-compost unit has been setup to treat and add value to the effluent form the distillery. The bio-compost unit was put up to produce Bio-fertilizer by biologically assimilating wastewater effluent into press mud originally without causing any damage to the environmental factors. It is the one of the model units in India, which are treating effluents.

In March 2004 the company put a unique plant for extracting methane forcibly from wastewater of distillery plant. This plant is in conformity to the norms of UNFCCC as a project of clean development mechanism. The project eliminates incidental emission of methane gas to the atmosphere while in storage. The project is eligible for carbon credits under CMD.

The co-generation plant of 26MW has been started operation with effective from 02.04.2008. During year 2007-2008 the company has taken on lease 1250 TCD capacity Hemavathi sakkare kharkani niyamit situated at shrinivasapura, chennarayapattana taluk, Hassan district of Karnataka for a period of 30 years commencing from 26/10/2007. The company has commenced operations in the leased facility from December 2007.

1.2 Specification

Pitch of the tube = 200 mm

Diameter of the tube =38.1 mm   O.D×4.06 mm thick

No. of tubes = 264

Length of tube =5820 mm

Area of Economizer =3142 m²

Area of the boiler =3090 m²

1.3 Observation Value

- Flow rate of water =50TPH
- Flue gases inlet temperature of economizer = 357.3º C = 630.3 K
- Flue gases outlet temperature of economizer = 189.8º C = 462.8K
- Inlet temperature of water = 172.2°C = 445.1 K
- Outlet temperature of water =264.6ºC = 537.6 K
- Economizer material =SA 210 Gr.A1
- Specific heat of water =4.187 KJ/Kg K
- Specific heat of flue gases =1.12 KJ/Kg K

The above results will be validated through CFD and further passive method enhancement of heat transfer will be done through CFD

II. BOILER EFFICIENCY CALCULATION USING FLUE GAS TEMPERATURE

For Bagasse Fired Boiler: The following data collected from a boiler and bagasse as the fuel. Tabulate the η_B by indirect method.

Calculation:

Calculation formula taken from Hugot book 1986.

W = 50%

S = 3 %

Gross Calorific Value (GCV) = 8280(1-w)-2160s

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GCV = 8280(1-0.50)-2160 x 0.03

GCV = 4075.5

GCV = 4075.5 x 2326

GCV= 9478450 J/Kg

Net Calorific Value (NCV) = 7650-8730w-2160s

NCV= 7650-8730 x 0.5 – 2160 x0.03

NCV = 3220

NCV = 3220 x 2326

NCV= 7489720 J/Kg

η_B on the basis of flue gases temperature t = 205.60C = 402.080 F

q = Sensible heat lost in the flue gases in J/Kg (BTU/lb) of fuel

t = Temp of gases = **402.080 F**

w = weight of moisture /unit weight of bagasse

m = Ratio of weigh of actual air required for combustion to weight off theoretical = 1.50

q = [(1-w) (1.4m -0.13) + 0.5] (t - 32)

q = [(1-0.50) (1.4 x 1.50 -0.13) + 0.5] (402.08 - 32)

q = 457.048 BTU/lb

q= 457.048 x 2326

q = 1063093.648 J/Kg

The quantity of heat transferred to steam is calculated

M_v= [7650-210s-8730w-q](α x β x γ)

α = co – efficient representing heat loss due to unburnt solids for spreader stroker furnace, its

Normal value is taken as 0.975

β = co – efficient to account for heat losses by radiation 0.97

γ = co – efficient of incomplete combustion 0.95

M_v Heat transferred to steam per found of bagasse in J/Kg (BTU/lb)

M_v= [7650-210s-8730w-q] (α x β x γ)

M_v = [7650-210 x0.03 -8730 x 0.50 – 457.048](0.975 x 0.97 x 0.95)

M_v = 2763.152 x 0.898462

M_v = 2482.58

Mv= 2482.58 x 2326 = **5774481.08 J/Kg**

Boiler efficiency = Mv / NCV

Boiler efficiency= 5774481.08/ 7489720

η_{boiler} = 77.09 %

η_{cycles} = 0.52 %

$\eta_{turbine}$= 0.95 %

$\eta_{generator}$= 0.96 %

$\eta_{auxilaries}$= 0.95 %

$\eta_{overall}$ = 77.09 x 0.52 x 0.95 x 0.96 x 0.95

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$\eta_{turbine}$ = **34.69 %**

Only the 34.69% of the energy in fuel is converted to electricity and **65.5 %** of energy is lost.

Table Content of Experimental readings:

Sl.no	Moisture content of bagasse(w) in %	Sucrose in bagasse (s) in %	Gross calorific values(GCV) in j/kg	Net calorific value(NCV) in j/kg	Heat transfer/found of bagasse j/kg	η in %
1	45	3	10441879.2	85054842	6427188.83	75.56
2	46	3	10249286.4	83024244	6300756.66	75.89
3	47	3	10056693.6	8099364.6	6086253.08	75.14
4	48	3	9864100.8	7896304.8	5913194.87	74.88
5	49	3	9671508.0	7693245	5867887.52	76.27
6	50	3	9478450.0	7489720	5896363.48	78.72
7	51	3	9286322.4	7287125	5561540.42	76.32

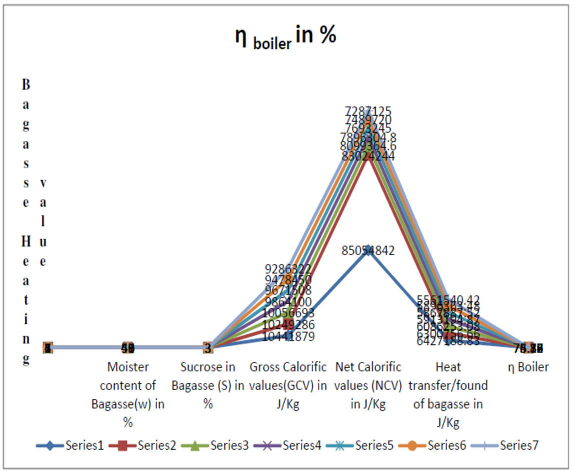

Fig1: Overall efficiency of boiler

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Sl No.	Moisture content of Bagasse(w) in %	Gross Calorific values(GCV) in J/Kg
1	45	10441879.2
2	46	10249286.4
3	47	10056693.6
4	48	9864100.8
5	49	9671508.0
6	50	9478450.0
7	51	9286322.4

Using the various w in % of obtain the GCV in J/Kg of heat generated:

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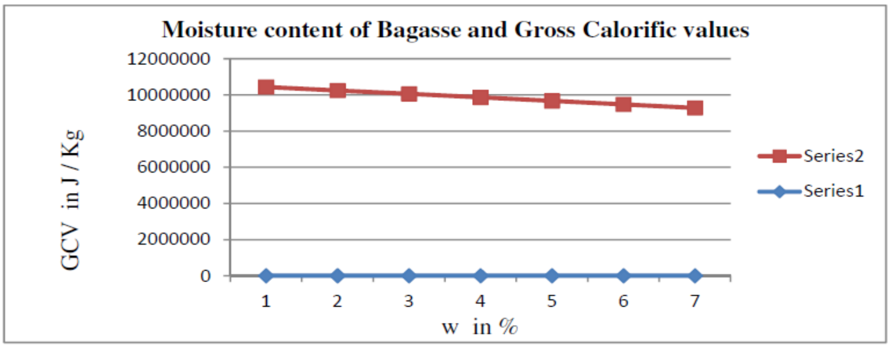

Fig.1:Moisture content of Bagasse and Gross Calorific values

Using the various w in % of obtain the GCV in J/Kg of heat generated.

Sl No.	Moisture content of Bagasse(w) in %	Net Calorific values (NCV) in J/Kg
1	45	85054842
2	46	83024244
3	47	8099364.6
4	48	7896304.8
5	49	7693245
6	50	7489720
7	51	7287125

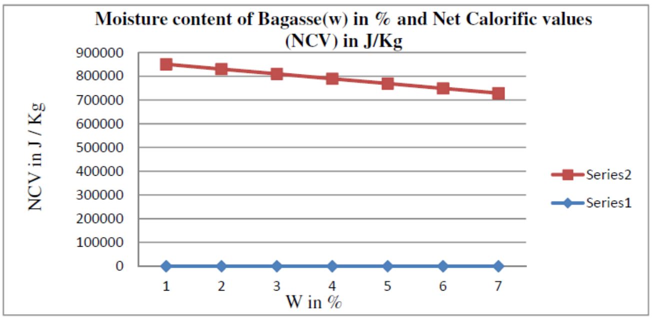

Figure 1.2: Moisture content of Bagasse and Net Calorific values

Using the various w in % of obtain the Heat transfer in J/Kg of heat generated

Sl No.	Moisture content of Bagasse(w) in %	Sucrose in Bagasse (S) in %	Heat transfer/found of bagasse in J/Kg
1	45	3	6427188.83
2	46	3	6300756.66
3	47	3	6086253.08
4	48	3	5913194.87
5	49	3	5867887.52
6	50	3	5896363.48
7	51	3	5561540.42

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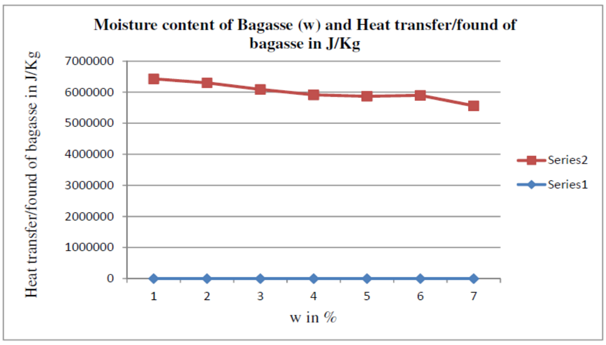

Figure 1.3: Moisture content of Bagasse and Heat transfer of bagasse

Using the various Moisture content of Bagasse (w) in % and η Boiler in %:

Sl No.	Moisture content of Bagasse(w) in %	η_{Boiler} in %
1	45	75.56
2	46	75.89
3	47	75.14
4	48	74.88
5	49	76.27
6	50	78.72
7	51	76.32

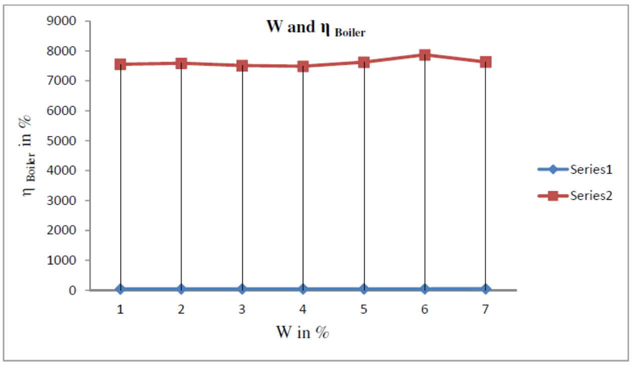

Figure 1.4: Moisture content of Bagasse and η Boiler

CFD RESULTS AND ANALYSIS

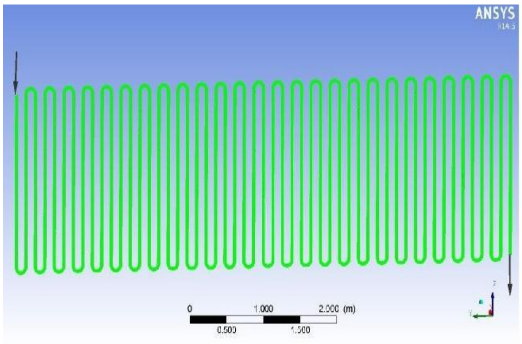

Figure 2: Geometry model-1

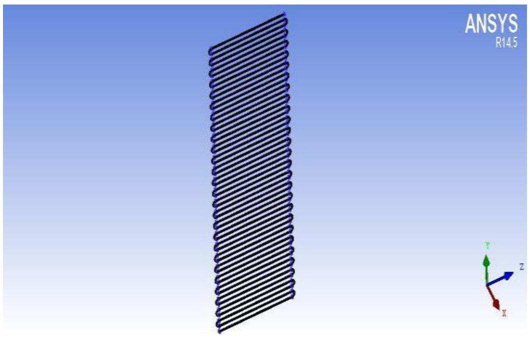

Figure 2.1: Meshing geometry of model-1

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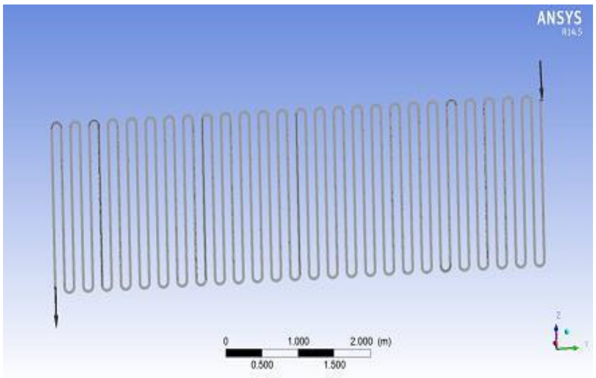


Figure 2.2: the CFX model - 1

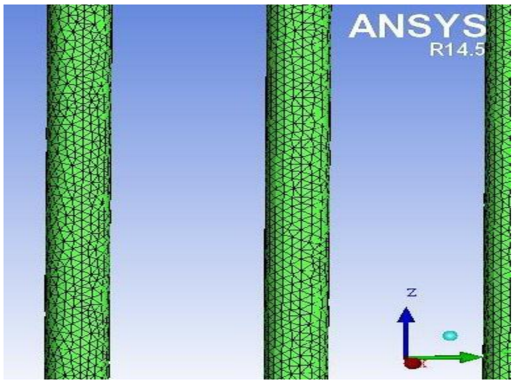


Fig 2.2: the CFX model -2

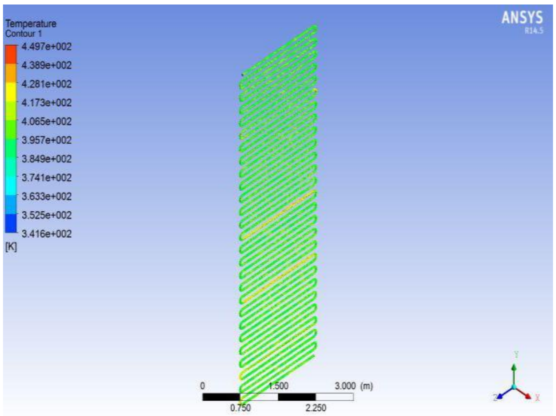


Figure 2.3: the meshing area zoomed view

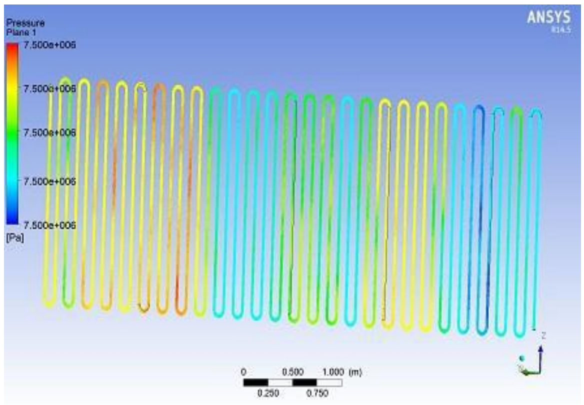
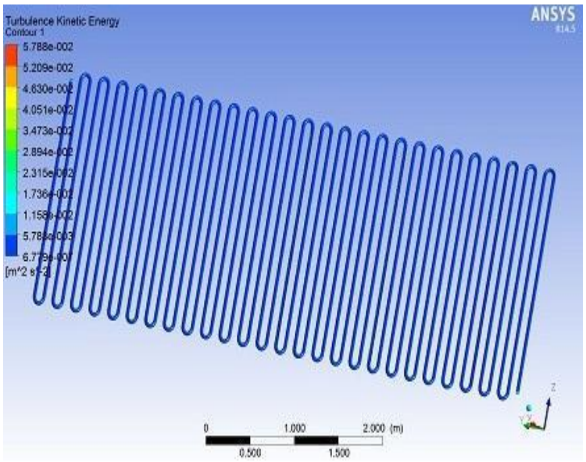


Figure 2.4: shows the Temperature on the Wall surface



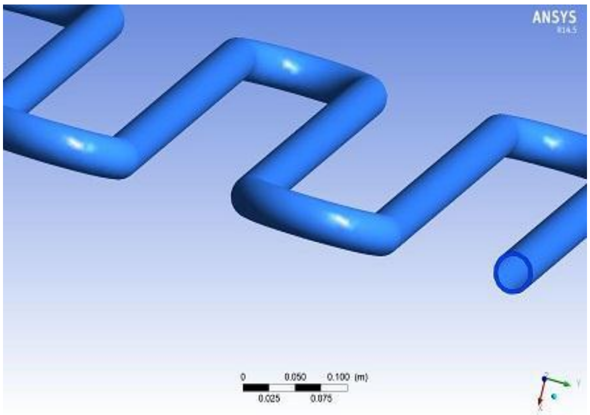


Figure 2.5: Pressure is constant in entire model

Figure 2.6: Turbulence Kinetic Energ

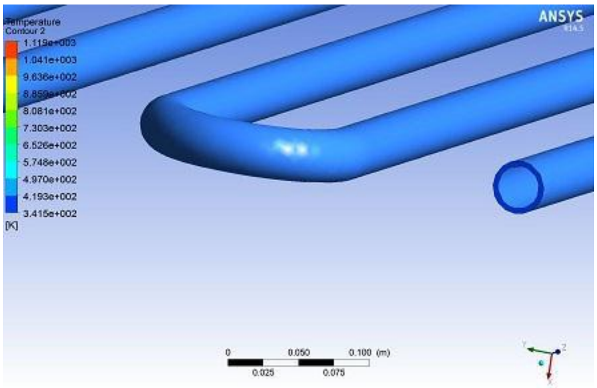


Figure 2.7:Temperature of water at inlet which is a known boundary condition temperature of 445.1K

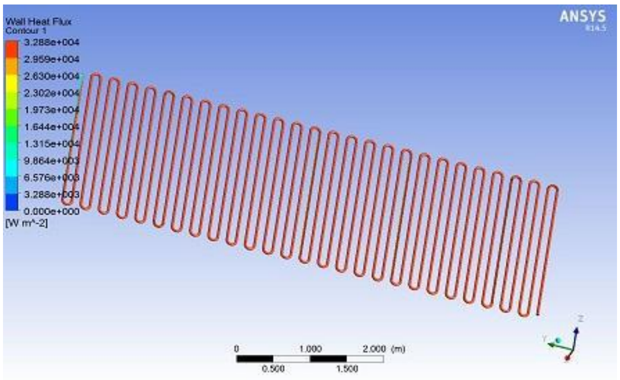


Figure 2.8: wall heat flux

CALCULATIONS

A) Heat transfer Based on water(Based on one layer):

m_w= 50 TPH , m_w =50×1000÷3600 Kg/ s , m_w =13.88 Kg/ s

Q= m_w C_{pw} ΔT

Q= 13.88×4.187×(537.6-445.1)

Q=5375.6893 KJ/s

Q=5375.6893×10³ J/s = **5375.6893×10³ watts**

Q=qA

q=Q/A

q=Q/π×d×l = 5375.6893×10³ /π×0.0381×119.989 = **374298.32 watts/m²**

Q=hAΔT

h=Q/AΔT

h=Q/πdlΔT (T_{wall}=506.6K , $T_{inlet\ water}$=172.1ºc=445.1K)

h=5375.6893×10³ /π×0.0381×119.989×(506.6-445.1) = **608.615 watts/m²K**

B) Heat transfer Based on flue gases Q=m_{fg} C_{pg} ΔT

5375.6893×10³ = m_{fg}×1.12×(630.3-462.8)

m_{fg}=28.65 Kg/s

CALCULATION

Q= m_w C_{pw} ΔT (Tout let of water=543.2K=270.2ºC)

Q=13.88×4.187×(543.2-445.1)

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Q= 5701.136Kwatts

Q=5701136.436 watts

Q=qA

q=Q/A

q=Q/π×d×l

q=5701136.436 /π×0.0381×119.989 = **303379.9906 watts/m²**

Q=hAΔT

h=Q/AΔT

h=Q/πdlΔT ($T_{wall\ surface}$=536.6 K =263.6ºC)

h=5701136.436 /π×0.0381×119.989×(536.6-445.1)

h=3315.62806 watts/m²K

% age Enhancement heat transfer co-efficient of strip

Inserted into tube v/s experiment = (3315.62806-608.615)/3315.62806

% h = 81.64%

CALCULATION OF HEAT TRANSFER COEFFICIENT FOR PASSIVE METHOD (SURFACE ROUGHNESS)

Q= m_w C_{pw} ΔT (T_{outlet} of water= 553.4K=280.4ºC)

Q=13..88×4.187×(553.4-445.1)

Q= 6293.915 Kwatts

Q=6293915.148 watts

Q=qA

q=Q/A

q=Q/π×d×l

q=6293915.148 /π×0.0381×119.989 = **438232.52watts/m²**

Q= hAΔT

h=Q/AΔT($T_{wall\ surface}$=526.6K=253.6°C)

h=10966406.17 /π×0.0381×119.989×(526.6-445.1) = **5377.0861 watts/m²K**

% age Enhancement heat transfer co-efficient of strip

Inserted into tube v/s experiment = (5377.0861-608.615)/5377.0861 = **% h = 88.68%**

III. CONCLUSION

In this regard, the Cogenerations application to the sugar industry used in energy utilization was considered for the study. The work is carried out with the collection of heat energy used for process and supply of extra power to the grid. Case studies were carried out to measure the combined mode steam consumption and energy generation determined analytically.The main focus of the above work is to determine the Moisture content in the bagasse and quality of water is supplied to boiler to get the large amount of energy and long life of equipment. In this study concluded the Moisture content is 47-50 % gives transfer in steam and thermal losses in radiation and steam flows in pipes are controlled. The following conclusions were drawn after the detailed study.

- In general, among the all parameters (pH, Thermal conductivity, Turbidity) to improve the life of boiler equipment.
- Suggest the maintenances' of 47-50 % moisture content in the Bagasse, gives the best result of outcome energy. Factory avoids the purchasing of power from outside, due to the bagasse used in production saves billion rupees to the company.
- Using of bagasse gives better life for the equipment of the boiler, the efficiency plant energy will calculated using flue gas and overall efficiency of the plant. Removes the thermal losses in using of energy, only radiation losses and steam flows in long distance in a pipe due to various processes, if process line is compact & reduction in losses.
- The extra revenue for sugar mill by generating surplus power and supplying to the national grid is possible. The whole of the fuel demand of a sugar cane factory with generate surplus power in its cogeneration plant can be answered by producing bagasse as a fuel. The unit cost of power also comes a reduction to users.
- The majorly company used maximum quantity of energy, in that the 34.69% of the energy in fuel is converted to electricity and 65.31 % of energy is losses.

➢ The Wall Heat Transfer Coefficient Was Studied For Economizer with Enhancement Done Through Passive Method.

S.l No	Heat transfer coefficient experimental results (w/m^2K)	Heat transfer coefficient Strip insertion(w/m^2K)	Heat transfer coefficient Surface roughness(w/m^2K)
1	608.615	3315.628	5377.0861

The following conclusions can be drawn from the analysis:

1. It has been observed that irrespective of material, the heat transfer coefficient depends on geometry of the domain and interaction of fluid with the surface.
2. Heat transfer depends on heat flux also.
3. Heat transfer enhancement has been achieved by passive technique (wall roughness, strip).
4. Clearly the boundary layer formation has been observed more at wall
5. Velocity stream line is linear and more at centre of the domain.
6. Due to boundary layer phenomenon pressure is more towards wall side.
7. Finally depending on the wall heat transfer coefficient enhancement has been achieved more with thread surface roughness

IV. ACKNOWLEDGEMENTS

The sense of contentment and elation that accompanies the successful completion of my task would be incomplete without mentioning the names of people who helped in accomplishment of this project, whose constant guidance, support and encouragement resulted in its realization. We are really thankful to Shri Chamudeswari Sugar Mills Pvt. Ltd staff for helping us out with the technical aspect and surveying of the sugar mill.

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