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Performance Analysis of Air Preheater in 210mw Thermal Power Station

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Abstract*: The efficiency of boiler in thermal power station is greatly depending on the utilization of waste heat in the flue gas by air pre heater and economizer. The increasing in efficiency of boiler can be achieved by increasing the performance of air pre heater and economizer. Enhancing heat transfer rate by changing profile of air pre heater will lead to increasing in performance of the air pre heater and economizer. The changing profile and increasing heat transfer area will increase the heat transfer rate. In 210MW Mettur thermal power station, notched flat profile is used as heat transfer area in air pre heater segment. In order to improve heat transfer rate, notched flat profile are replaced by double undulated profile and single seal are replaced by double seal. Hence heat loss in the air pre heater is minimized. The performance of economizer is enhanced by increasing the diameter of the coils. Hence the economizer and air pre heater absorbs additional heat from exhaust flue gas. The changed profile in air pre heater and increased diameter in economizer were analyzed by using ANSYS fluent software. Based on the results the percentage of efficiency in air pre heater and economizer is significantly increased.

Keywords:

1. INTRODUCTON

The place where the heat energy of fuel is converted into Electrical Energy is called Thermal Power Plant. Energy Conversion: This part of the lesion outlines the various conversion processes which are carried out at power station indicating where possible the efficiency of the conversion process or in other words, indicating how successful the operation is of converting one form of energy into another. Remember, energy cannot be destroyed, but its conversion incurs difficulties, which results in not all the energy being usefully converted

Chemical Energy to Heat Energy: Chemical energy is stored in coal is converted into heat by the process known as combustion. The carbon and other combustible elements in coal are made to unite with Oxygen of air in furnaces. This process converts chemical energy into heat energy. Many pieces of equipment are used for this first conversion, including chain grate stroke, pulverized fuel furnaces, forced and induced draught fans, chimney stacks and many other items of boiler house plant.

2. AIR PREHEATER

An air preheater (APH) is a general term used to describe any device designed to heat air before another process (for example, combustion in a boiler) with the primary objective of increasing the thermal efficiency of the process. They may be used alone or to replace a recuperative heat system or to replace a steam coil.

In particular, this article describes the combustion air preheater used in large boilers found in thermal power stations producing electric power from e.g. fossil fuels, biomass or waste.

The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the conveyance system and the flue gas stack. It also allows control over the temperature of gases leaving the stack (to meet emissions regulations, for example).

3. LJUNGSTROM AIR PREHEATER

The Ljungstrom air preheater is more widely used than any other type of combustion air preheater in the power industry, because of its compact design proven performance and reliability, and its fuel flexibility. The model 27 VI T M 72(80) means a Ljungstrom air preheater with rotor diameter of 8229.6 mm is used in power plant. The heights of heating elements of 3 sections are respectively 8500mm, 850mm, 300mm from top to bottom of the rotor. The cold end heating elements of 300mm height are made of carbon plate while the hot end heating elements are made of common carbon steel. The metal weight of one air preheater is approximately 620 tons, including 465 tons for the rotor assembly (about 75 percent of the total weight).

The air preheater is tri sector type. Specially corrugated heating elements are tightly placed in the sector compartment of the rotor. The rotor turns at a speed of 0.99 rpm and is divided into gas channels and air channels. The air side is mad channels and secondary air channels. When gas flows through the rotor, it releases heat and delivers it to the heating elements and then the gas temperature drops; when the heated elements turn to the air side, the air passing through them is heated and its temperature is increased. By continuing maintaining such a circulation, the heat exchange is achieved between gas and air. As the rotor slowly revolves the mass of the elements alternatively through the air and gas passage, heat is absorbed by the element surfaces passing through the hot gas stream. These are the same surfaces are carried through the air stream.

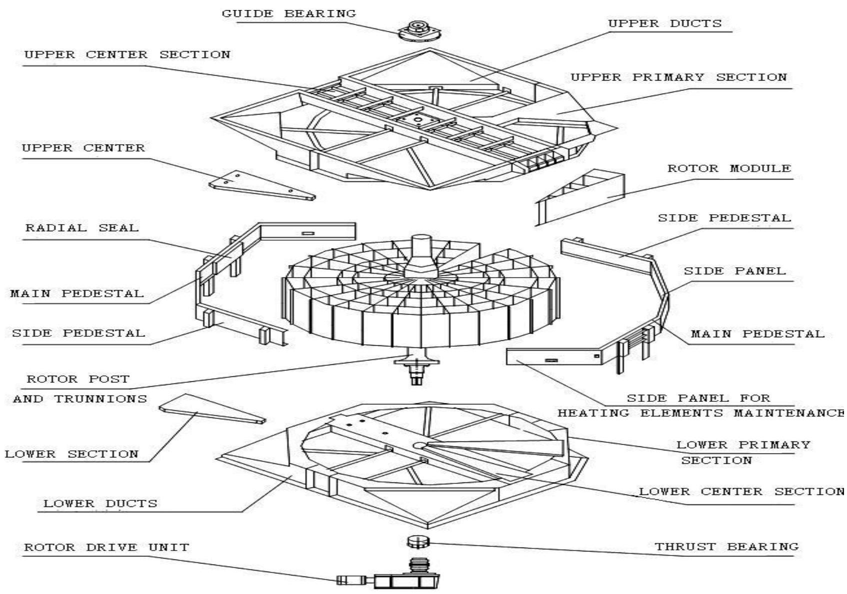


Fig 1: Ljungstrom Air Preheater (over view)

4. WORKING PRINCIPLE OF LJUNGSTROM AIR PRE HEATER

As the name implies the tri-sector pre-heater design has three sections. Use for flue gas. One for primary air (used for drying and transport of coal through mill to the burner) another for secondary air (additional air for combustion around the burners). These helps in avoiding wastage of heat pick up by air due to primary air flow and also help in selecting different temperatures for primary air and secondary air.

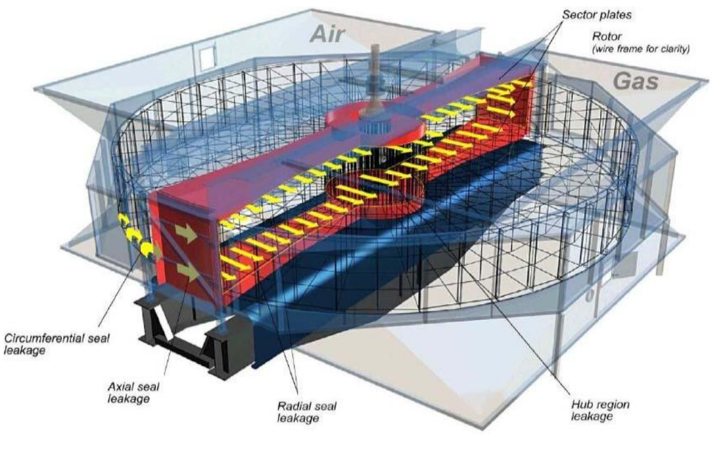


Fig 2: Ljungstrom Air Preheater (3D view

Whatever is not utilized in primary air can be picked up by secondary air stream. Thousands of these high efficiency elements are spaced compactly arranged with in 12 sectors shaped compartments for heater size from 24.2 to 27 inches, and 24 sector shaped compartments for heater size from 28 to 33 of radically divided cylindrical shell called the rotor. The housing surrounding the rotor is provided with duct connections at both ends and is adequately sealed by radial and axial sealing members forming an air passage through one half of the pre-heater and a gas passage through the other. As the rotor slowly revolves the mass of the elements alternatively through the air and gas passage, heat is absorbed by the element surfaces passing through the hot gas stream. These are the same surfaces are carried through the air stream. The Ljungstrom air pre-heater is more widely used than any other type of heat exchanger for comparable service. The reasons for this world wide acceptance are its proven performance and reliability, effective leakage control, and its adaptability to most, any fuel burning process. It is both designed and built to operate over extend periods with durable, uninterrupted service. Simplicity of design also makes it easy and economical to maintain while in operation and at scheduled outages.

5. HEATING ELEMENTS

Heating elements are made of carbon steel sheets with special corrugations formed by pressing; the hot end heating assemblies are profiled in accordance with shapes and sizes of individual sub by alternately piling up notched undulation sheets with vertical undulations and inclined turbulent corrugations and sheets only with the same inclined corrugations one by one as shown in Fig. All the assemblies of both hot and cold end heating elements are fastened by welding flat bars and angle steels together.

In old air pre-heaters, the cold end baskets are provided with 1.2 mm thick elements of NF6 profile. For Indian operating conditions, this

can be changed to 0.8 mm DU profile. This will increase the heat transfer area, thereby reducing the flue as outlet temperature. It is calculated that by changing the profile as suggested, the as outlet temperature will decrease by 4^0C, that means 0.2% improvement in efficiency. This change has already been incorporated in the current design.

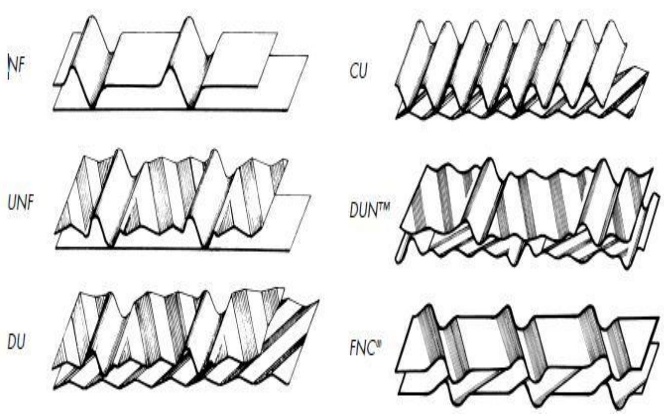


Fig 3: profiles

New Profiles: A highly efficient element profiles are available to improve the thermal performance. Case Study-I is presented to show the performance changes with the introduction of new profiles. With the introduction of new profile, the gas outlet temperature can be achieved to 135.6^0C.

Fig 4: Notched Flat (NF) Profile

Fig 5: Double Undulated [DU] Profile
NF ----TO ---DU PROFILES

6. DESIGN CALCULATION

CALCULATION OF AIR PRE HEATER: DOUBLE UNDULATED [DU] PROFILES

O_{2ge} - Percentage of O_2 in gas entering air heater

O_{2gl} - Percentage of O_2 in gas leaving air heater

C_{pa} -The mean specific heat between temperature T_{ae} and T_{gl} =1.023 KJ/Kg°K

C_{pg} -The mean specific heat between temperature T_{gl} and T_{ae} =1.109 KJ/Kg°K

T_{ae} - Temperature of air entering air heater

T_{al} - Temperature of air leaving air heater

T_{ge} - Temperature of gas entering air heater

T_{gl} - Temperature of gas leaving air heater

T_{gnl} - Gas Outlet Temperature Corrected For No Leakage

X_r - X-Ratio

AL - Air Heater Leakage

GSE - Gas side efficiency

ASE - Air Side Efficiency

SASE - Secondary Air Side Efficiency

PASE - Primary Air Side Efficiency

Air Heater Leakage (AL):

$$AL = \frac{(O2gl - O2ge)}{(21 - O2gl)} \text{ x } 0.9 \text{ x } 100$$

Collected data:

O_{2ge} - Percentage of O_2 in gas entering air heater: 3.7

O_{2gl} - Percentage of O_2 in gas leaving air heater: 5.6

Calculations:

$$AL = \frac{(O2gl - O2ge)}{(21 - O2gl)} \text{ x } 0.9 \text{ x } 100$$

AL $= \frac{(5.6-3.7)}{(21-5.6)}$ x 0.9 x 100

= 0.123 x 0.9 x 100

= 11.10%

AL =11.10%

GAS SIDE EFFICIENCY:

Gas Outlet Temperature Corrected For No Leakage (T_{gnl}):

$T_{gnl} = \left[AL \text{ x } Cpg \text{ x } \frac{(Tgl-Tae)}{(100 \text{ X } Cpg)}\right] + T_{gl}$

Collected data:

C_{pa} -The mean specific heat between temperature T_{ae} and T_{gl} =1.023 KJ/Kg°K

C_{pg} -The mean specific heat between temperature T_{gl} and T_{ae} =1.109 KJ/Kg°K

T_{ae} - Temperature of air entering air heater =38°C

T_{ge} - Temperature of gas entering air heater =360°C

T_{gl} - Temperature of gas leaving air heater =117°C

Calculations:

$T_{gnl} = \left[AL \text{ x } Cpg \text{ x } \frac{(Tgl-Tae)}{(100 \text{ X } Cpg)}\right] + T_{gl}$

$T_{gnl} = 11.12 \text{ x } 1.023 \text{ x } \left[\frac{(117-38)}{(100 \text{ X } 1.109)}\right] + 117$

T_{gnl} = (11.12 x 1.023 x 0.7124) + 117

= 8.1035 + 117

= 125.103

T_{gnl} = 125.1°C

Gas side efficiency (GSE):

$GSE = \left[\frac{(Tge-Tgnl)}{(Tge-Tae)}\right] x100$

Collected data:

T_{ae} - Temperature of air entering air heater =38°C

T_{ge} - Temperature of gas entering air heater =360°C

T_{gnl} - Gas outlet temperature corrected for no leakage =125.1°C

Calculations:

$GSE = \left[\frac{(Tge-Tgnl)}{(Tge-Tae)}\right] x100$

GSE $= \left[\frac{(360-125.1)}{(360-38)}\right]$ x 100

$= \left[\frac{(234.9)}{(322)}\right]$ x 100

= 0.7294 x 100

= 72.94%

GSE = 73%

7.2.2 Air Side Efficiency (PA & SA):

ASE $= \left[\frac{(Tal-Tae)}{(Tge-Tae)}\right] \times 100$

Collected data:

T_{ae} - Temperature of air entering air heater =38°C

T_{al} - Temperature of air leaving air heater =347°C

T_{ge} - Temperature of gas entering air heater =360°C

Calculations:

ASE $= \left[\frac{(Tal-Tae)}{(Tge-Tae)}\right] \times 100$

ASE $= \left[\frac{(347-38)}{(360-38)}\right] \times 100$

$= \left[\frac{309}{322}\right] \times 100$

= 0.9596 x 100

= 95.96%

ASE = 96%

X-Ratio:

X-Ratio (X_r) = $\frac{\text{Gas Side Efficiency (GSE)}}{\text{Air Side Efficiency(ASE)}}$

$= \left[\frac{0.73}{0.96}\right] = 0.7604$

X_r = 0.760

Gas Leaving Temperature Without Leakage (T_{gl}):

$T_{gl} = T_{ge} - X_r (T_{al} - T_{ae})$

= 360 – 0.760 (347-38)

= 360 – 0.760 (309)

= 360 – 234.84

= 125.16

T_{gl} = 125.2°C

Pre Heater Air Side Efficiency (SA & PA):

Air Side Efficiency (SA & PA) = $\left[\frac{(Tge-Tae)}{(Tge-Tae)}\right] \times 100$

ASE (SA & PA) = $\left[\frac{(360-125.16)}{(360-38)}\right] \times 100$

$= \left[\frac{234.84}{322}\right] \times 100$

= 0.7293 x 100 = 72.93%

ASE (SA & PA) = 73%

Secondary Air Side Efficiency (SA):

ASE (SA) $= \left[\frac{(Tal-Tae)}{(Tge-Tae)}\right]$ x 100

Collected data:

T_{ae} - Temperature of air entering air heater =32°C

T_{al} - Temperature of air leaving air heater =347°C

T_{ge} - Temperature of gas entering air heater =360°C

Calculations:

ASE (SA) $= \left[\frac{(Tal-Tae)}{(Tge-Tae)}\right]$ x 100

ASE $= \left[\frac{(347-32)}{(360-32)}\right]$ x 100

$= \left[\frac{315}{328}\right]$ x 100

= 0.9603 x 100

= 96.03

ASE = 96%

X-Ratio:

X-Ratio (X_r) = $\frac{\text{Gas Side Efficiency (GSE)}}{\text{Air Side Efficiency(ASE)}}$

$= \left[\frac{0.73}{0.96}\right]$ = 0.7603

X_r = 0.760

Gas Leaving Temperature without Leakage (T_{gl}):

T_{gl} = T_{ge} - X_r (T_{al} – T_{ae})

= 360 – 0.760 (347-32)

= 360 – 0.760 (315)

= 360 – 239.4

= 120.6

T_{gl} = 120.6°C

Pre Heater Secondary Air Side Efficiency (SA):

Air Side Efficiency (SA) = $\left[\frac{(Tge-Tae)}{(Tge-Tae)}\right]$ x 100

ASE (SA) = $\left[\frac{(360-120.6)}{(360-32)}\right]$ x 100

$= \left[\frac{239.4}{328}\right]$ x 100

= 0.7298 x 100

= 72.98%

ASE (SA) = 73%

Primary Air Side Efficiency (PA):

ASE $= \left[\frac{(\text{Tal}-\text{Tae})}{(\text{Tge}-\text{Tae})}\right]$ x 100

Collected data:

T_{ae} - Temperature of air entering air heater =44°C

T_{al} - Temperature of air leaving air heater =347°C

T_{ge} - Temperature of gas entering air heater =360°C

Calculations:

ASE $= \left[\frac{(\text{Tal}-\text{Tae})}{(\text{Tge}-\text{Tae})}\right]$ x 100

ASE $= \left[\frac{(347-44)}{(360-44)}\right]$ x 100

$= \left[\frac{303}{316}\right]$ x 100

= 0.9588 x 100

= 95.88%

ASE = 96%

X-Ratio:

X-Ratio (X_r) = $\frac{\text{Gas Side Efficiency (GSE)}}{\text{Air Side Efficiency(ASE)}}$

$= \left[\frac{0.73}{0.96}\right]$ = 0.7604

X_r = 0.760

Gas Leaving Temperature without Leakage (T_{gl}):

T_{gl} = T_{ge} - X_r (T_{al} – T_{ae})

= 360 – 0.760 (347-44)

= 360 – 0.760 (303) = 360 – 230.28 = 129.72

T_{gl} = 130°C

Pre Heater Primary Air Side Efficiency (PA):

Air Side Efficiency (PA) = $\left[\frac{(\text{Tge}-\text{Tae})}{(\text{Tge}-\text{Tae})}\right]$ x 100

ASE (PA) = $\left[\frac{(360-130)}{(360-44)}\right]$ x 100

$= \left[\frac{230}{316}\right]$ x 100

= 0.7278 x 100

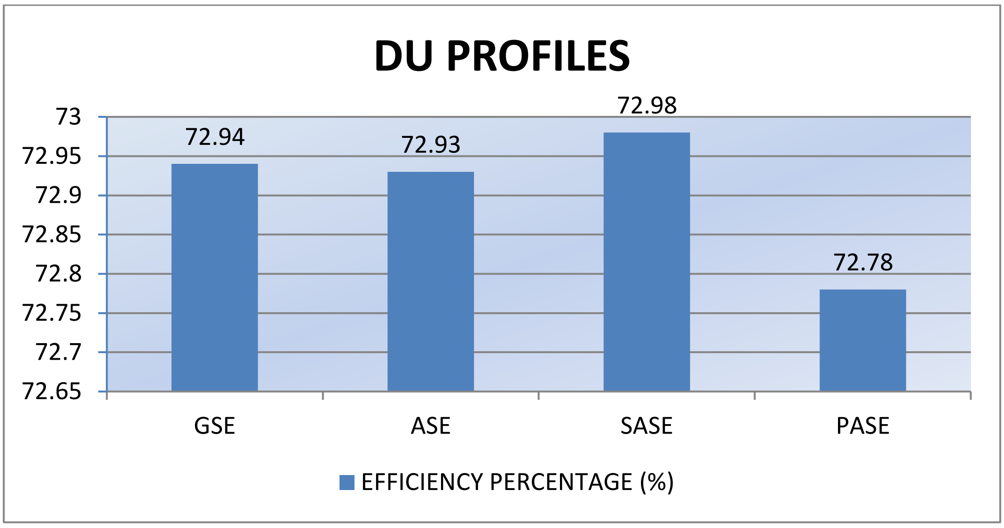
= 72.78%

ASE (PA) = 73%

DU PROFILE RESULTS

AIR PRE HEATER EFFICIENCY'S

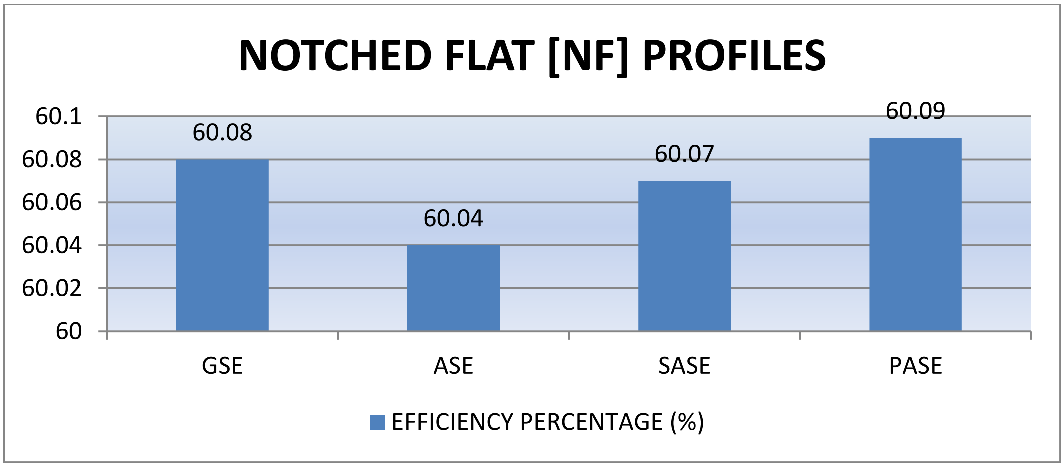
Gas side efficiency (GSE)	= 72.94%
Pre Heater Air Side Efficiency (ASE)	= 72.93%
Pre Heater Secondary Air Side Efficiency (SASE)	= 72.98%
Pre Heater Primary Air Side Efficiency (PASE)	= 72.78%



NF PROFILE RESULTS

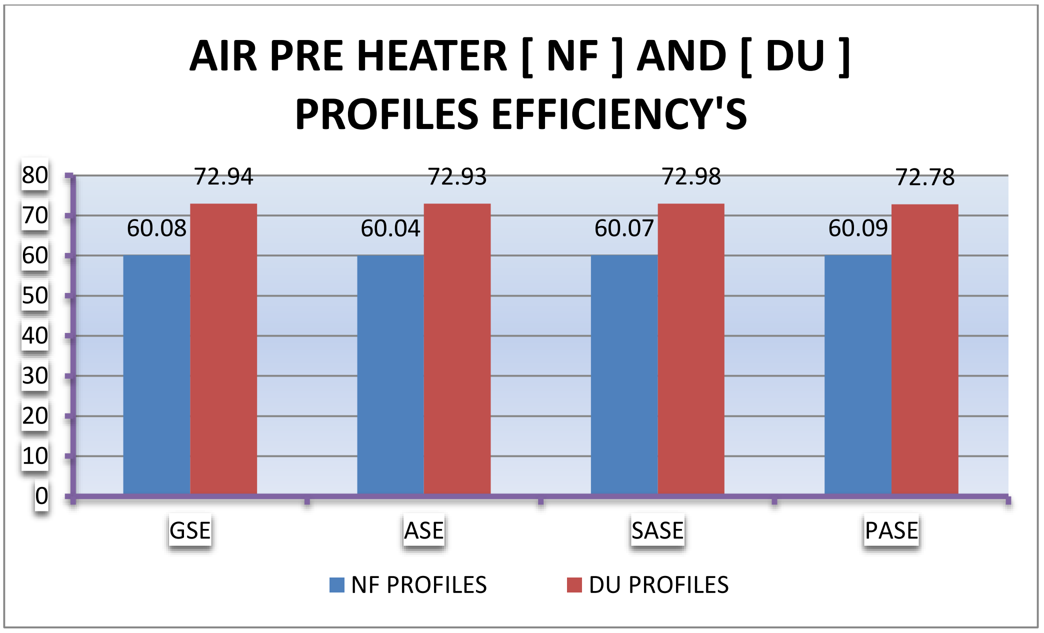
AIR PRE HEATER EFFICIENCY'S: NOTCHED FLAT [NF] PROFILES

Gas side efficiency (GSE)	= 60.08%
Pre Heater Air Side Efficiency (ASE)	= 60.04%
Pre Heater Secondary Air Side Efficiency (SASE)	= 60.07%
Pre Heater Primary Air Side Efficiency (PASE)	= 60.09%

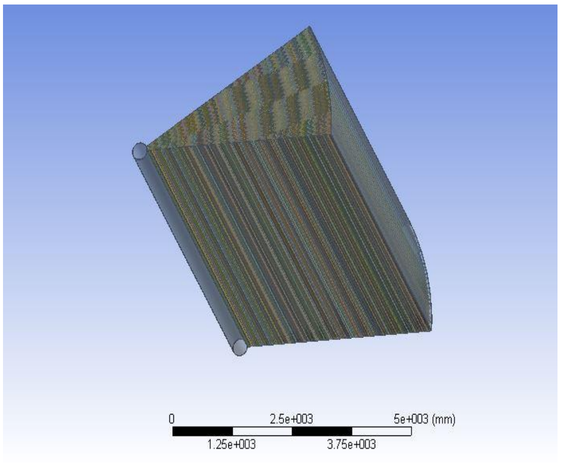


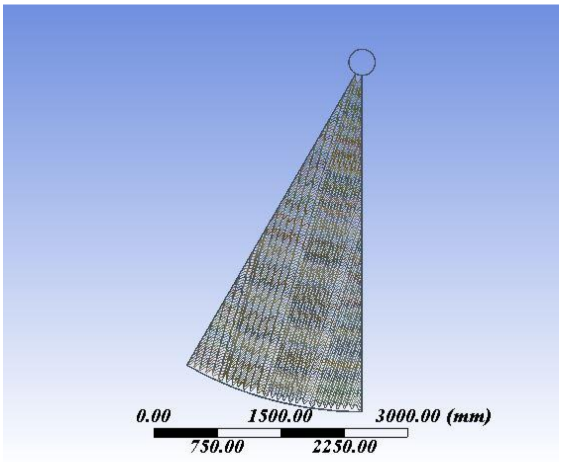
7. AIR PRE HEATER RESULT ANALYSIS

S NO.	EFFICIENCY BETWEEN AIR PRE HEATER [NF] AND [DU] PROFILES		
		NF PROFILES	DU PROFILES
1	Gas Side Efficiency (GSE)	60.08%	72.94%
2	Pre Heater Air Side Efficiency (ASE)	60.04%	72.93%
3	Pre Heater Secondary Air Side Efficiency (SASE)	60.07%	72.98%
4	Pre Heater Primary Air Side Efficiency (PASE)	60.09%	72.78%
5	Over All Efficiency	60%	73%

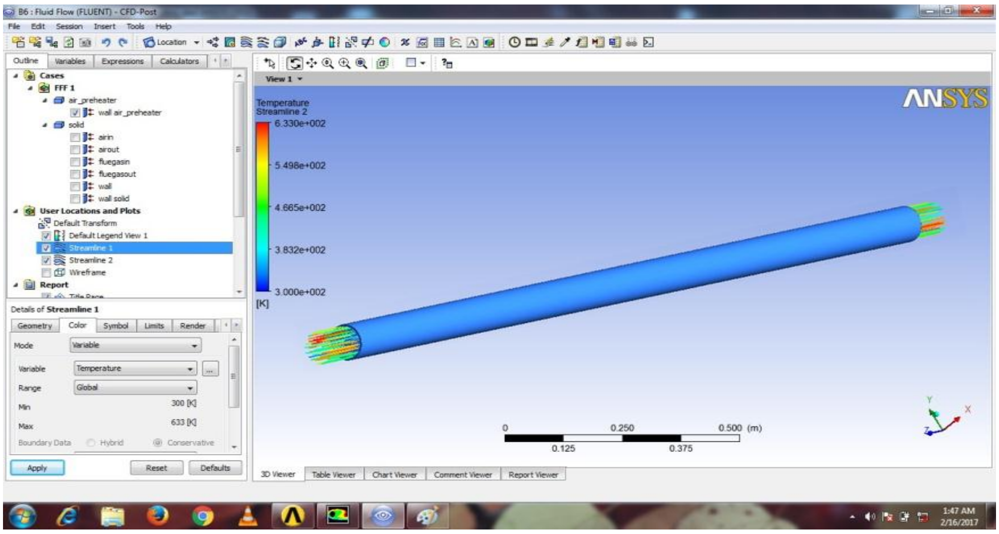


DESIGN ANALTSIS BY SOFTWARES





8. RESULTS AND DISCUSSION



From the above calculations it can be inferred that, by replacing the profiles of the air pre heater, the heat transfer rate can also be increased, thus making the air pre heater for effective. If the flue gas can occupy more profiles inside the air pre heater, the heat transfer is effectively increased. And air pre heater efficiency as been 13 % increased. And the above calculations it can be inferred that, by increasing the area of the economizer the heat transfer rate can also be increased, thus making the economizer for effective. If the flue gas can occupy more area inside the economizer, the heat transfer is effectively increased. It makes the boiler consume less power, there by less utilization of coal, and hence ultimately the efficiency of the power plant is increased considerably.

CONCLUSION

We have detailed methods for improving the gross efficiency of the air pre heater and economizer by the solution minimizing heat losses during the process. Considerable increase in efficiency is achieved by improving the above parts on the design aspect. Even though it is importing these improvements in the generality boiler it would be highly appropriate if it is considered in the design of newly constructed boiler.

In this present work, energy analysis of a coal based thermal power plant is done by using the design data from 210 MW thermal power plants. Performance and analysis of air pre heater and economizer, in the air pre heater segment, notched flat profiles are replaced by double undulated profiles, and single seal are replaced by double seals, so heat loss in the air pre heater will be minimized. Economizer is achieved by increasing the diameter of coils in the economizer so that additional heat from flue gas can be observed from the economizer. Hence the performance of air pre heater will increase. The main advantage of this proposed method is that, the heat transfer rate in the boiler will be increased.

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