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CFD ANALYSIS OF AN ECONOMIZER FOR 25MM DESIGN BEND RADIUS IN A FIRE TUBE BOILER

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Abstract—Economizer plays a vital role in increasing the overall thermal efficiency of the boiler by recovering the energy from the flue gas before it is exhausted in to the atmosphere. The ultimate goal of economizer design is to achieve necessary heat transfer at minimum cost. Economizer uses the burnt gases to heat the feed water that is entering in to the boiler. In general economizers are basically the tubular heat transferring surfaces used to pre heat boilerfeed water before it enters into the steam drum or furnace. As the water from the economizer is pre heated approximately to its boiling temperature, it reduces the amount of fuel need to be burned to heat the water in the furnace, thereby reducing the capital cost of fuel. It is observed that in most of the thermal power plants in India economizer is the zone where leakages are found more. The main reason for the failure of the economizer is due to erosion. The past failure details reveals that erosion is more in U-bend areas of Economizer Unit because of increase in flue gas velocity near these bends. Efforts are made to measure the velocity and Temperature distribution of flue gases at the bends of the economizer coil. The flue gas temperature, pressure and velocity field of fluid flow within an economizer tube using the actual boundary conditions have been analyzed using CFD tool. Later the design is altered by reducing the number of tubes and increasing the cross sectional are of the tubes. Thus the variation of temperature, pressure and velocity of flue gases is compared and results can be analyzed for better design. The modeling required for the CFD analysis is done in the CATIA and the computational fluid dynamic analysis is performed in Solid works flow simulation
Keywords— Economizer, CFD analysis, CATIA, Computational fluid dynamic analysis, Solid works.

I. INTRODUCTION

A thermal power station works on the basic principle that heat liberated by burning fuel is converted into mechanical work by means of a suitable working fluid. The mechanical work is converted into electrical energy by means Of generator. In a steam power station, heat is realized by burning fuel, this heat is taken by water, which works as the working fuel. Water is converted into steam as it receives heat in the boiler. The steam then expands in turbine producing mechanical work, which is then converted into electrical energy through a generator. The exhaust steam from the turbine is then condensed in the condenser and the condensate is there after pumped to the boiler where it again receives heat and the cycle is repeated. The basic theoretical working cycle is of a steam power plant is ‘THE RANKINE CYCLE’. The modern steam power plant uses ‘MODIFIED RANKINE CYCLE’, which includes reheating, superheating and regenerative feed water heating.

1.1. Principle of Power Generation at Coal Based Power Plant

The main function of oil and coal burning system is to convert chemical energy into heat energy, which is utilized by the components of the boiler to convert water into the steam, which drives the turbine. The combustion element of fuel consists of carbon, hydrogen and small amount of sulphur. The exhaust gases released after combustion contains CO2, SO2 and CO, etc. When the coal is burnt with oxygen following reaction takes place and large amount of heat is released.

The average composition of air is
79% nitrogen and 21% oxygen by volume
77% nitrogen and 23% oxygen by weight

- During combustion process nitrogen does not burn but passes through the chimney.
- The amount of air required to burn any fuel can be calculated if the amount of the elements present in the fuel are known.
- The amount of air to burn is known as theoretical air. If this quantity is not sufficient for complete combustion process then extra amount of air is supplied, known as excess air. In combustion process, turbulence, time, temperature and combustion efficiency are the important parameters to be considered.
- The maximum combustion efficiency depends on

1. Design of boiler
2. Fuel used
3. Skill in obtaining combustion within the minimum amount of excess air.

1.2. Boiler (Steam Generator)

Boiler or the steam generator is the main part in the power generation process. Boiler acts as a medium in which the water is converted into the steam by using the heat released in the process of combustion of coal in the presence of oxygen.

The steam generator is a natural circulation, single drum type, corner fired, and natural draft unit of water tube type. In water tube boiler, boiler feed water flows through the tubes and enters the boiler drum. The circulated water is heated by the combustion of gases and converted into steam at the vapor space in the drum. These boilers are selected when the steam demands as well as the steam pressure requirements are high as in the case of process cum power boilers.

The features of water tube boilers are:

- ➢ Forced, induced and balanced draft provisions help to improve combustion efficiency.
- ➢ Less tolerance for water quality calls for water treatment plant.
- ➢ Higher thermal efficiency levels are possible.

There are many mountings to the boiler, which are compulsory for the safe run of the boiler. Also, there are accessories, which increase the efficiency of the boiler.

II. OBJECTIVE AND METHODOLOGY

2.1. OBJECTIVE

The main objective of this project is to analyze flue gas temperature, velocity field of fluid flow within an economizer tube using the actual boundary conditions. Later the analysis is extended by altering the design by changing the number of tubes and varying the cross section of the tubes. Thus the variation of temperature, and velocity of flue gases is compared and results can be analyzed for better design. The temperature variation of the feed water is also measured to find the extent to which it is gaining the heat.

2.2. METHODOLOGY

The solid model of the economizer is created using the Catia.

- ➢ The fluid model is required for the analysis is extracted .i.e. created using the Catia software.
- ➢ The created fluid model is imported in to the solid works flow simulation software to perform the CFD analysis.
- ➢ The above steps are repeated for the different designs with modified bend radius of the tubes (25 mm,30 mm,35 mm and 40 mm) and the results are tabulated and compared.

III. 3D MODELING OF ECONOMISER

The economizer is also one of the important components in boiler of thermal power plants as it makes use of burnt flue gases to pre heat the feed water to the boiler. In fire tube boiler the gases are made to pass through the tubes of the economizer to heat the water surrounding the tubes in the economizer. This helps to increase the temperature of the water before entering in to the boiler. Thus there is reduction in the amount of energy that is needed for converting the water into steam in the boiler. The total assembly of economizer of fire tube boiler is designed by using Catia and also a fluid model of assembly is designed which is used to perform CFD analysis on fluid model.

Table 1: Parameters taken into consideration for economizer design.

Length of economizer	2010 mm
Height of economizer	400 mm
U tube outer diameter	44 mm
U tube internal diameter	38mm
Number of Tubes	3
Distance between ends of tube (horizontal)	1740 mm
Distance between ends of tube (vertical)	240 mm
Outlet diameter of hot gases port	90 mm
Inlet diameter of hot gases port	84 mm
Outlet diameter of water outlet	65 mm
Inlet diameter of water inlet port	60 mm

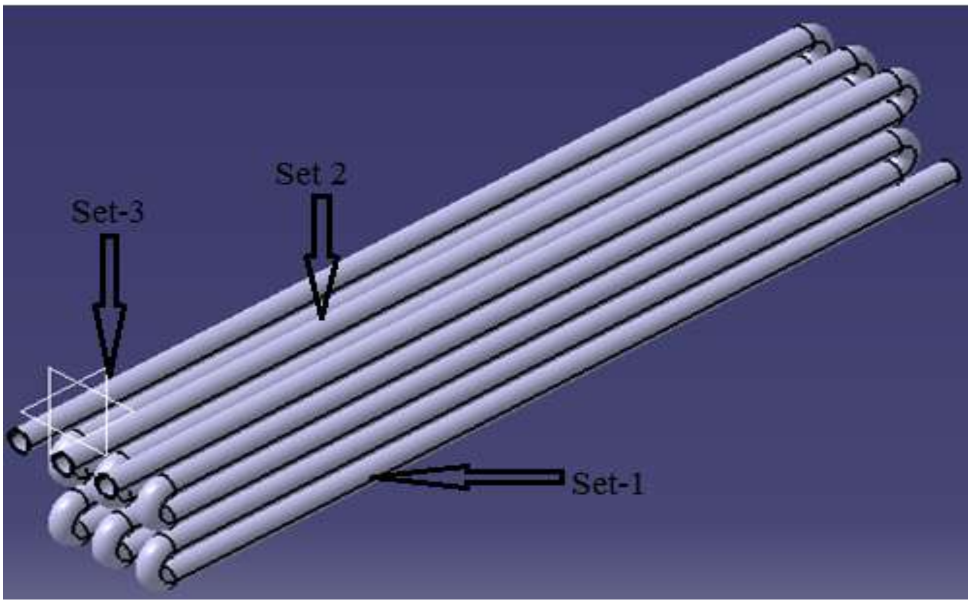

Figure 1.Three dimensional modeling of economizer

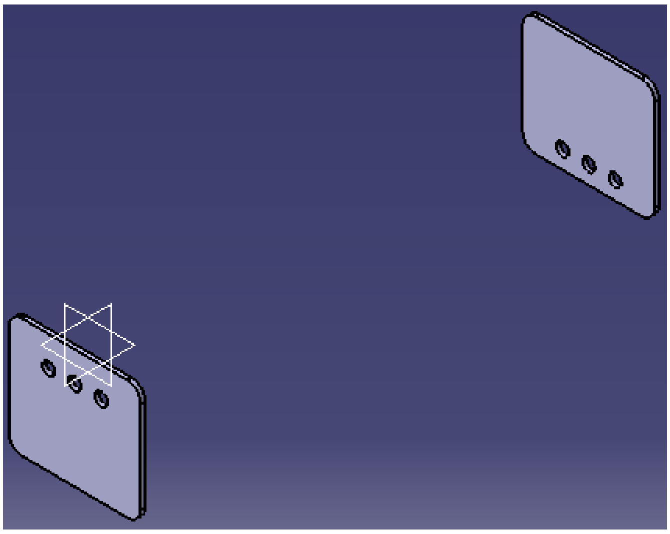

Figure 2. The plates with tube ports

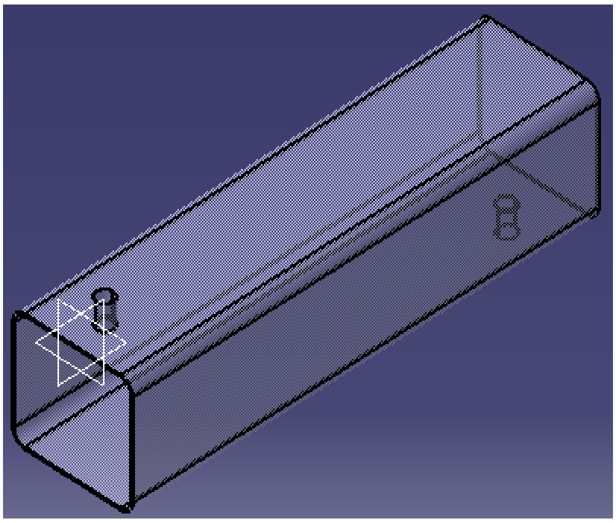

Figure 3. Designed shell of the economiser.

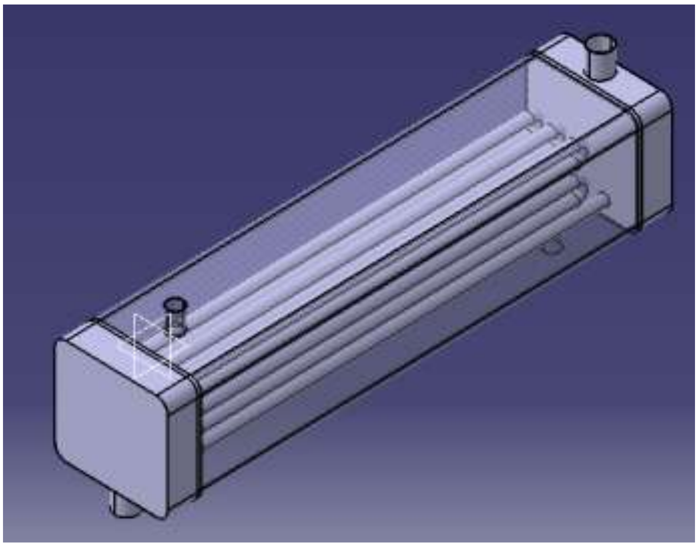

Figure 4. Isometric view of the assembly of the economizer

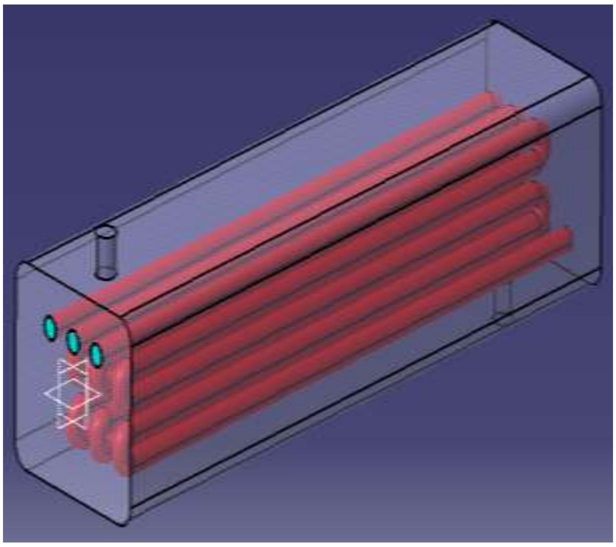

Figure 5. Fluid model required for the CFD analysis

IV. FLOW SIMULATION OF ECONOMISER USING SOLIDWORKS FLOW SIMULATION

Flow analysis is carried out using solid works flow simulation. The model was generated in CATIA and imported into Solid works flow simulation using Parasolid file. The assumptions followed in this analysis are shown below.

4.1. Assumptions

- The flow analysis is assumed to be steady state.
- All physical properties of fluid and solid are assumed to be constant throughout the analysis.
- Steady and turbulent flow of fluid is considered.
- The flow enters with constant temperature and uniform velocity.
- Model of turbulence adopted is K-epsilon.

➢ In this project the economizer used in Chandarpur thermal power 210MW unit is considered for flow simulation.

4.2. Material used for economizer tubes

The below figure shows the selection of material properties, The material used for economizer tubes is Aluminum Material and the properties of the material used is shown in the below table

Table2: Material properties of aluminum

Density	2700.00 kg/m^3
Specific heat	1300.0 J/ (kg*K)
Conductivity type	Isotropic
Thermal conductivity	170.0000 W/ (m*K)
Electrical conductivity	Conductor

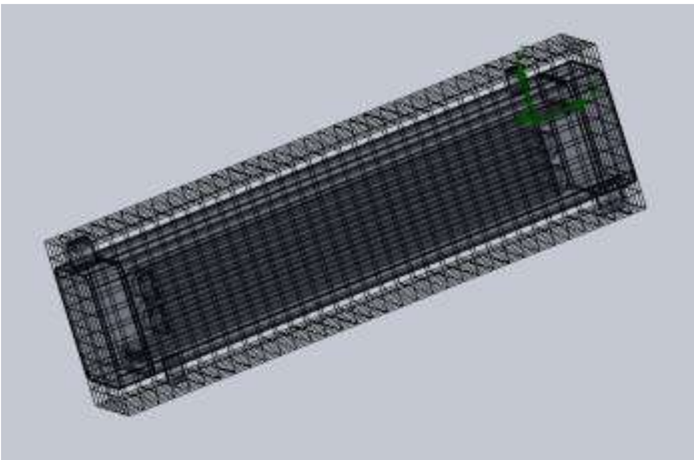

Figure 6. Meshed model of economizer

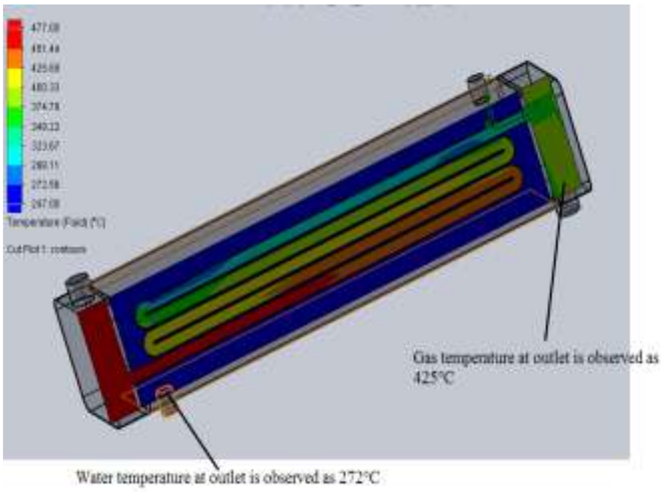

Figure 7. Results obtained from flow analysis for Bend radius of 25 mm

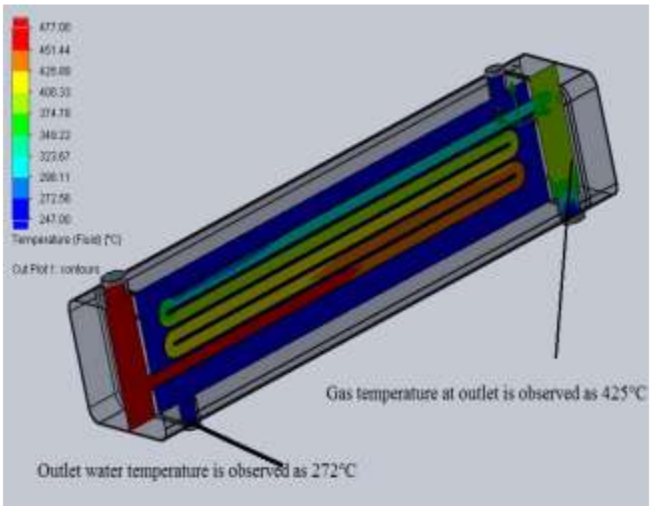

Figure 8. Temperature distribution across the 1st set of tubes for 25mm bends radius condition

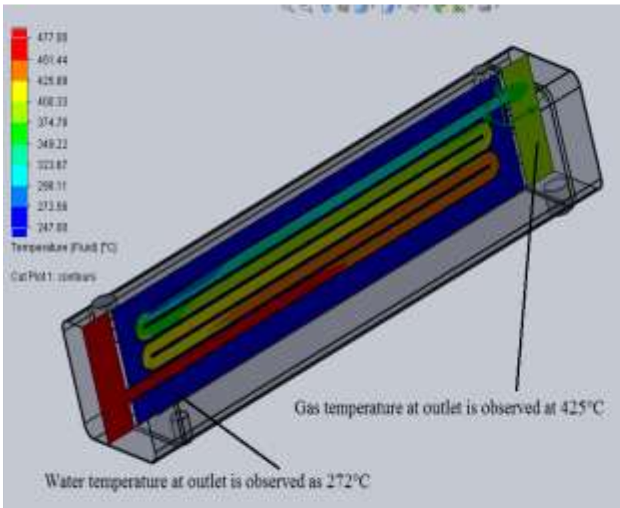

Figure 9. Temperature distribution across the 2nd set of tubes for 25mm bends radius condition

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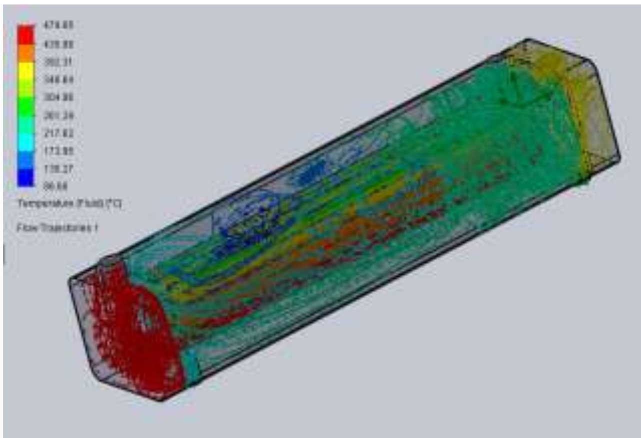

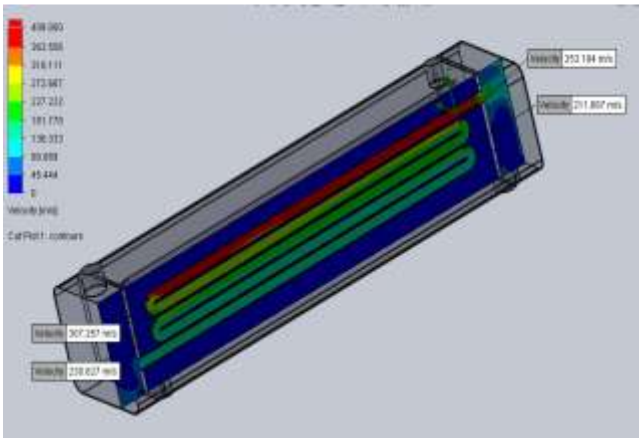

Figure 10. Temperature distribution across the 3rd set of tubes Figure 11. Velocity across tubes for 25mm bend radius for 25mm bends radius condition condition

V. RESULTS

Description	Value (25 mm bend radius)	Units
Water outlet Temperature (1st set of tubes)	272	°C
Gas outlet Temperature (1st set of tubes)	425	°C
Water outlet Temperature (2nd set of tubes)	272	°C
Gas outlet Temperature (2nd set of tubes)	425	°C
Water outlet Temperature (3rd set of tubes)	272	°C
Gas outlet Temperature (3rd set of tubes)	425	°C
Velocity (bend 1)	211	m/s
Velocity (bend 2)	230	m/s
Velocity (bend 3)	253	m/s
Velocity (bend 4)	307	m/s

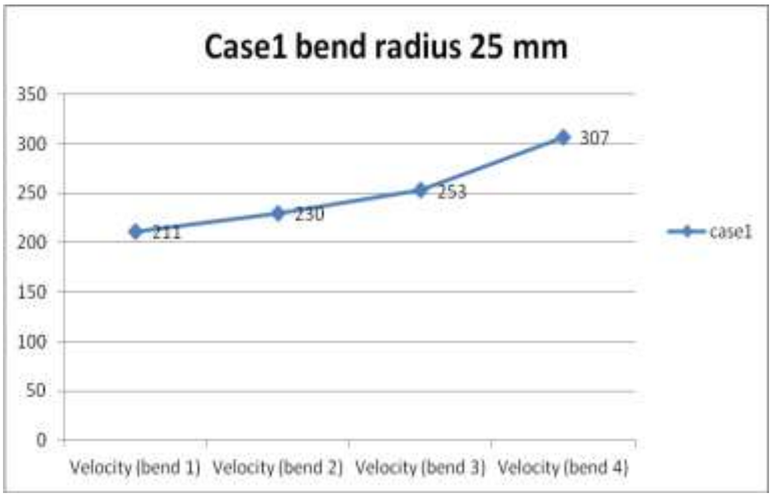

Figure 12. Velocity across the tubes for case-1 (25mm) bend radius condition

VI. CONCLUSION

In this project the economizer used in Chandarpur thermal power 210MW unit is considered for flow simulation. The main objective of this project is to analyze flue gas temperature and velocity field of fluid flow within an economizer tube using the actual boundary conditions. The past failure details reveals that erosion is more in U-bend areas of Economizer Unit because of increase in flue gas velocity near these bends. In this project different iterations were made by measuring the velocity and Temperature distribution of flue gases at the bends of the economizer coil for varied bend radius of the tubes. The analysis was carried out for 25 mm,. From the results obtained it is concluded that as the bend radius of the tube is increased the velocity of the flue gases at the u bend decreases. Thus failure from erosion at the bends due to high velocity of flue gases can be reduced.

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