A Mini Project-2 Project report on

Analysis of Economizer to optimize the Heat transfer by recovering heat from exhaust gases

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DECLARATION

We are the Project associates of the entitled with **"Analysis of Economizer to optimize the heat transfer by recovering heat from exhaust gases"** and hereby declare that the matter embodied in this project is genuine work, done by us and has not been submitted to any other university of the requirement of any course of study.

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Abstract

Economisers play a crucial role in enhancing the efficiency of thermal systems by recovering waste heat from exhaust gases. This study employs ANSYS, a powerful computational tool, to conduct a comprehensive thermal analysis of an economizer.

This study aims to optimize a helical fin for an economizer tube to maximize heat transfer. Ansys Fluent will be used to simulate fluid flow and heat transfer, and results will be used to design a more efficient tube. The efficient tube will have a higher heat transfer rate, leading to enhanced energy efficiency and reduced operating costs. Furthermore, the optimized helical fin design can be applied to various heat exchangers, aiding in improving industrial processes and reducing energy consumption.

.**Keywords:** Economiser, FEM, Analysis, Thermal efficiency

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Chapter -1

INTRODUCTION

1.0 INTRODUCTION TO THERMAL POWER PLANT

A thermal power plant is a facility that generates electricity by using heat energy, typically from the combustion of fossil fuels (like coal, oil, or natural gas), though some thermal plants can also use nuclear reactions, biomass, or even geothermal energy. Here's a detailed look at how thermal power plants work and the key components involved:

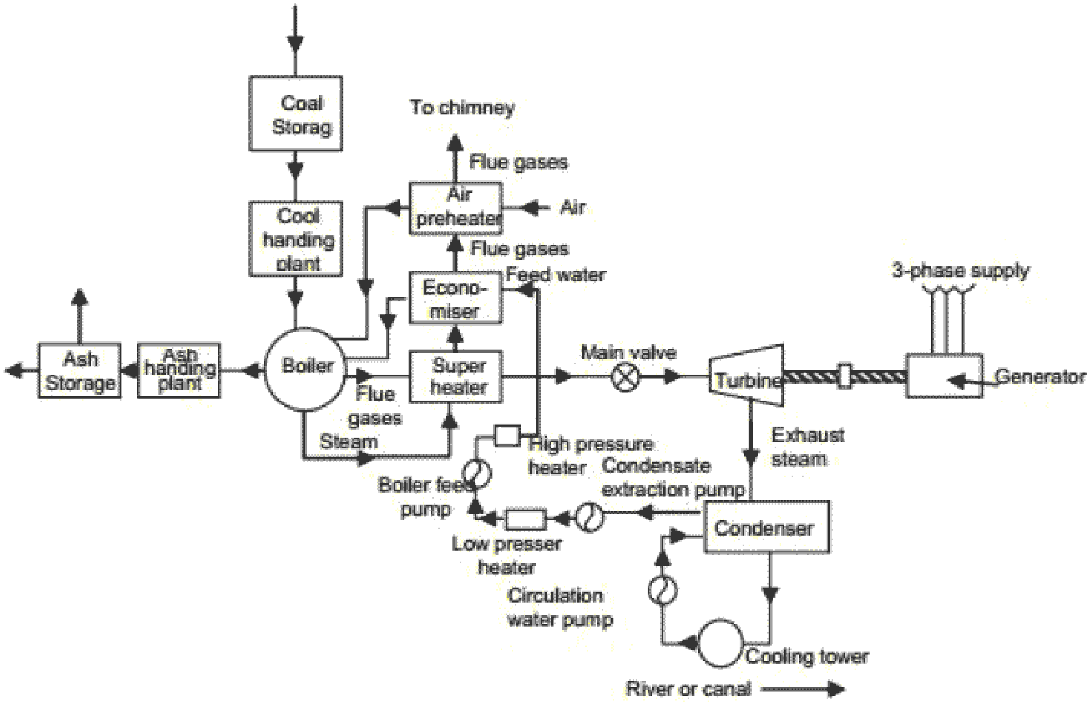


Fig-1 Thermal power plant layout

1.1 How a Thermal Power Plant Works

Thermal power plants operate based on the Rankine cycle. In this process, water is heated to create high-pressure steam, which drives a steam turbine connected to an electricity generator. The main steps include:

1. Fuel Combustion: Fuel is burned to generate heat.

2. Steam Production: Heat turns water into high-pressure steam in the boiler.

3. Turbine Operation: Steam drives the turbine, converting thermal energy into mechanical energy.

4. Electricity Generation: The turbine is connected to a generator, which transforms mechanical energy into electrical energy.

5. Steam Condensation: After passing through the turbine, the steam is condensed back into water for reuse.

1.2 Main Components of a Thermal Power Plant

1. Boiler or Furnace

- The boiler is the heart of the power plant. It burns fuel (such as coal, oil, or natural gas) to produce heat.
- Inside the boiler, water is heated and turned into steam under high pressure and temperature. This high-energy steam is what drives the turbines.
- Superheaters within the boiler further increase the temperature of the steam, which boosts efficiency.

2. Steam Turbine

- The steam turbine converts thermal energy (from high-pressure steam) into mechanical energy by spinning a set of blades attached to a shaft.
- As the steam expands through the turbine, it loses pressure and temperature but spins the turbine shaft at high speeds.
- Turbines are typically divided into high-pressure and low-pressure stages to maximize efficiency.

3. Generator

- The generator is coupled to the turbine shaft and converts the turbine’s mechanical energy into electrical energy using the principle of electromagnetic induction.
- As the shaft spins, it rotates magnets within coils of wire, generating electricity.

4. Condenser

- After passing through the turbine, the low-pressure steam enters the condenser, where it is cooled and turned back into water.
- Cooling is essential, as it allows the water to be reused in the boiler and maintains a low pressure on the turbine’s exhaust side, enhancing efficiency.
- Cooling towers or water from natural sources are often used to cool the condenser.

5. Cooling System

- The cooling system removes the waste heat from the condenser.
- In many power plants, cooling towers release heat into the air by evaporating water, while others might use river or seawater.
- Efficient cooling helps maintain power plant performance by preventing overheating.

6. Feedwater Pump

- The feedwater pump raises the pressure of the condensed water from the condenser before sending it back to the boiler.
- This closed loop increases efficiency by minimizing water waste and energy loss.

7. Air and Flue Gas Path

Air Preheater: Heats incoming air for combustion, increasing fuel efficiency.

Economizer: Uses residual heat from flue gases to preheat water entering the boiler, saving energy.

Chimney: Exhausts gases into the atmosphere after passing through a series of scrubbers and filters to reduce emissions.

Thermal power plants are essential for large-scale energy production, though increasing efficiency and reducing environmental impact remains a priority in modern designs and operational improvements.

1.3 Boiler

A boiler is a sealed container designed to heat water, creating steam or hot water. This steam or hot water serves numerous functions, such as heating buildings, powering turbines for electricity generation, and sanitizing equipment. Boilers function by transforming water into either steam or hot water, adaptable for diverse applications like heating, steam-driven processes, and electricity generation. They come in various configurations tailored to suit the unique requirements of different sectors.

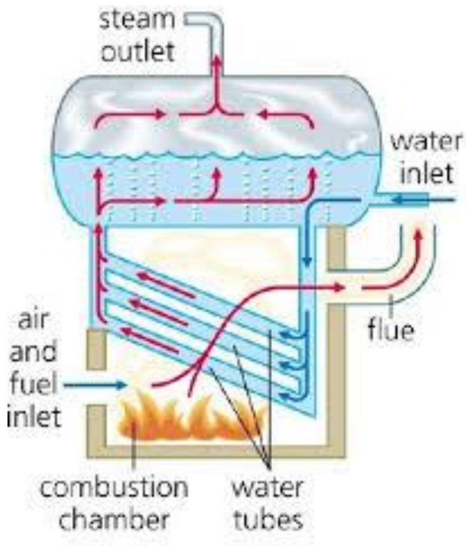


Fig-2 Boiler

1.4 Economiser

A boiler economizer, also referred to as an economizer, serves as a mechanical apparatus aimed at curbing energy usage or executing beneficial tasks like preheating. This crucial component enhances the energy efficiency of the system by capturing heat from the circulating water while ensuring an adequate level of enthalpy for the boiler's operation. Consequently, it contributes to a more efficient and enhanced boiler room environment. The extremely high temperature of the flue gas from the boiler ranges between 180-350 °C

1. This energy carries valuable energy that would otherwise be lost to the atmosphere, a large amount of heat energy is lost to the flue gas from the boiler or the flue gas extremely around 10-20% of the input energy can be lost to high-temperature flue gas.

2. Therefore, we could increase the efficiency of the boiler recovery of a part of the total thermal content of flue gases. Recovered heat can be used to preheat combustion air and boiler feed water in a boiler or as a driving heat source for other purposes such as an absorption chiller.

3. Economizer is the best method of recovery of waste heat in flue gas and its use in preheating feed water, strategy to recover this heat depends in part on the temperature of the waste heat gases and the associated economics by regeneration it would be possible to save a considerable amount of primary fuel.

4. The energy lost in the waste gases cannot be fully recovered but with a well-designed economizer, we can reduce the fuel consumption of the boiler by at least 5-10% For every 220 0C reduction in flue gas of the gas temperature by passing through the economizer or preheater, there is a 1% fuel saving in the boiler. In other words, for every 6◦C increase in the temperature of the feed water via the economizer or 200C increase in the temperature of the combustion air via the air preheater, there is a 1% fuel saving in the boiler.

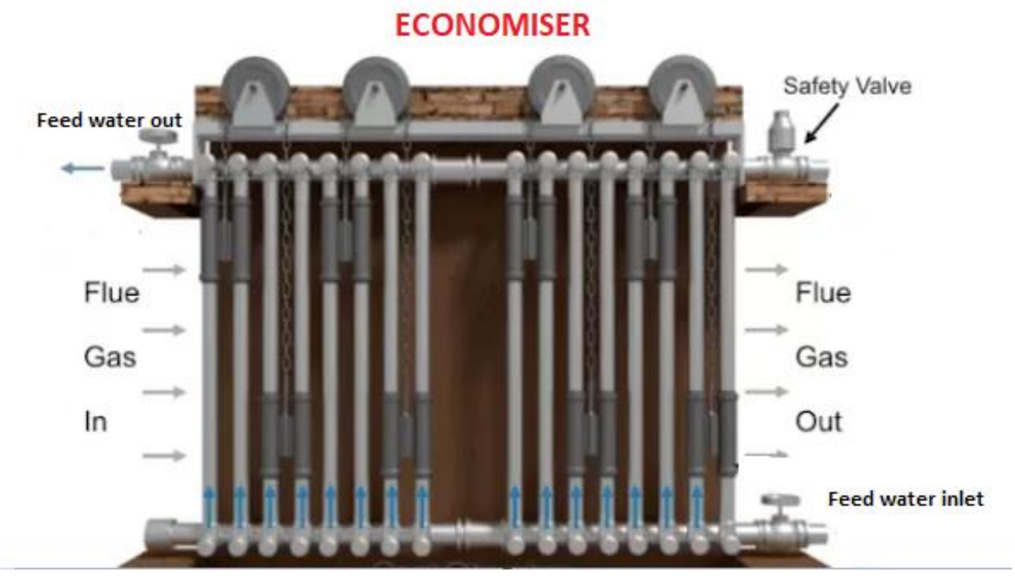


Fig-3 Economiser

5. Our target economizer design is to achieve the necessary heat transfer at a low cost. In our case, we take an economizer in a power plant named (NTPC - Vijayawada) as a case study. This economizer with its construction restores 5% energy losses, with a new design we can improve its efficiency and recover over 8% of heat losses.

1.5 Types of Economiser

There are two primary types of Boiler Economizers utilized in steam boilers: Condensing Economizers and Non-Condensing Economizers.

Condensing Economizers:

Condensing economizers are further categorized into two variants: heat exchanger and direct contact. These economizers are engineered to handle corrosive fluids produced during the condensation process of moisture from flue gas. By absorbing more heat, condensing economizers enhance the boiler's overall efficiency by 10% to 15%.

Non-Condensing Economizers:

Non-condensing economizers represent the most prevalent type. They consist of finned heat exchanger coils positioned within the flue gas ducting at the boiler's exit. Designed to maintain the flue gas temperature above its condensing point, non-condensing economizers prevent corrosion of the flue gas ducting. They elevate the boiler's overall efficiency by 2% to 4%.

Advantages of Economiser:

- It improves the boiler efficiency. It has been found that about 1% efficiency of the boiler is increased by increasing the temperature of feed water by 6 °C with the help of an economiser.
- It reduces the losses of heat with the flue gases, The temperature of flue gases is about 370°C to 540°C at the exit of the last superheater or reheater, having a large amount of heat energy that otherwise would have been wasted.

- It reduces the consumption of fuel. It has been estimated that about 1% of fuel costs can be saved for every 6 °C rise in temperature of the boiler feed water.

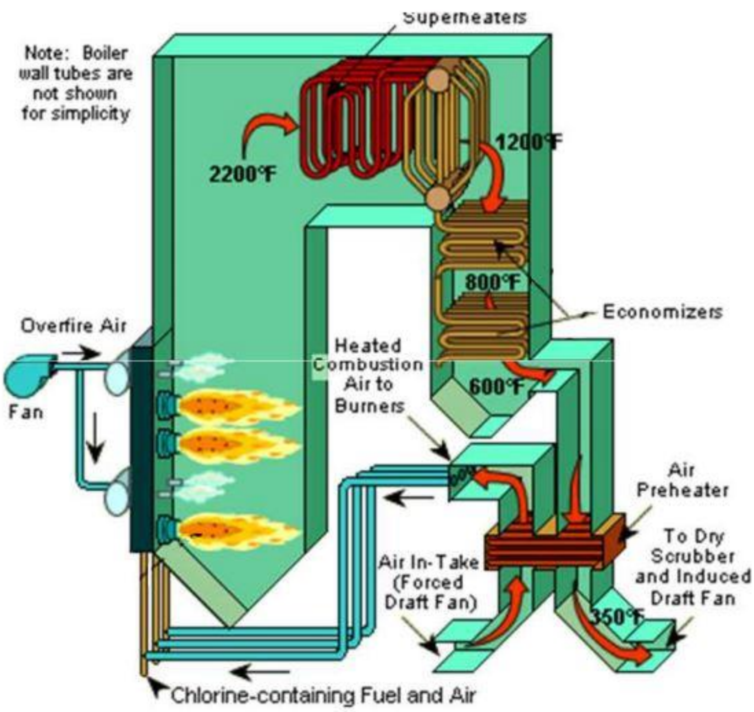


Fig-4 Power plant maintenance and operation

In this context, this study focuses on the Thermal analysis of an economizer using ANSYS involves studying the effects of varying geometric parameters and tube materials on its performance. Economizers are crucial components in boiler systems, designed to improve energy efficiency by preheating feedwater using waste heat from flue gases. By utilizing ANSYS, engineers can simulate different scenarios to optimize economizer design and material selection. Varying geometric parameters such as tube diameter, length, spacing, and arrangement allow for evaluating their impact on heat transfer efficiency and pressure drop across the economizer.

Chapter -2

Literature Survey

1) **Evaluating the Effect of Economizer on Efficiency of the Fire Tube Steam Boiler**

Mahmoudi Lahijani And Eris E Supeni. 2018 The present paper focused on the effect of using economiser on the reduction of heat losses and increasing the efficiency of the fire tube steam boiler. As well, it is aimed to determine the various types of losses and calculating the exact amount of efficiency before and after using economiser in examined fire tube boiler. conclusion: It has been proven that the initial cost of a boiler is a small part of total cost of boiler during its lifetime. The major costs resulting from the fuel costs. Therefore, it is important to use a highly efficient steam boiler that consume lower rate of fuel, for this purpose some equipment can be used in steam boilers that one of them used in this project that is economizer. The highest heat losses in boilers are related to dry flue gas that is around 12% of the total heat lost through the exhaust that resulting in efficiency equal to 77.2293% for "Boiler 1", since the type of fuel and ambient temperature is the same in both boilers; therefore, using economizer concludes in a significant reduction of 103 °C in flue gas temperature. It shows the flue gas temperature of "Boiler 2" equal to 123 °C, and this declining the flue gas temperature declines the dry flue gas loss up to around 6 percent and it increases the efficiency of "Boiler 2" up to 84.5462%, which is a 7.3169% improvement in efficiency. It is found that the method of heat recovery from flue gas by economizer is one of the effective ways to save energy in fire tube boilers.

2) **Economical and Environmental Analysis of Industrial Boilers using Economizers**

A.E. Atabani1, R. Saidur1 , A.S. Silitonga1,2, T.M.I. Mahlia1 , A.H. Sebayan. 2013. This study is concerned with an energy saving, economic and environmental analysis of industrial boilers in paper and pulp industries Malaysia. Installing heat recovery systems (economizers) has been investigated in this study. Installation of economizers has been proved to be an effective method.

It has been found that a total amount of 2,529,779 kWh, 2,150 ton of CO2, 6,324 kg of SO2, 41,488 kg of NOx, 506 kg of CO and RM 238,573 could be saved annually. These results indicate that economizer is an energy saving, economically viable and emissions reduction application and can be used in a small developing country like Malaysia

3) Asmaa S. Hamouda. 2019. Introduction: This paper presents an approach for the optimization of economizer design with increasing number of tubes which added an additional area for economizer. The aim of this work is to develop an economic study which finds the optimization of economizer design and to increase the amount of heat saving .

4) P. Ravindra Kumar1, V.R. Raju2, N. Ravi Kumar3, Ch.V. Krishna4. 2012. Introduction: This paper addressed the problem of heat energy which is wasted away from coke oven in the form of flue gases. Conclusion: A heat recovery unit needs to be installed to recover the heat potential from this stream so that, power can be produced. Design of such equipment to recover this heat and power saving through that is must be carried out to improve the efficiency of plant.

5) Satyam Purseth, Jayprakash Dansena. 2021. Introduction: The main objective of this paper is to find out the boiler efficiency calculation and method to improvement. Conclusion: This paper reviewed the literature on performance analysis of boiler in the period of 2011 to 2020. Different methods used for the analysis and improvement of boiler efficiency applied by different researchers. Literature review of performance analysis and efficiency improvement of boiler.

6) Qin Cai, Xiaoyang Wu, Young Huang, Xi Wang. 2020. Introduction: The influence of operating parameters on thermal efficiency was analyzed by thermal balance experiment of the boiler. Calculation: According to the method of inverse balance analysis, the thermal efficiency can be calculated. The results showed that the thermal efficiency decreased with the increase of exhaust gas temperature.

7) Johnson, I., Choate, W.T., And Davidson, A., introduction: Did case study on “Waste heat recovery”, Conclusion: The results from this investigation serve as a basis for understanding the state of waste heat recovery and providing recommendations for RD&D to advance waste heat recovery technologies. Technology needs are identified in two broad areas: 1) extending the range of existing technologies to enhance their economic feasibility and recovery efficiency, and 2) exploring new methods for waste heat recovery, especially for unconventional waste heat sources

8) Patel Chetan T., patel Bhavesh K., Patel Vijay K. 2013. Introduction: The main motive of this study is to analysis of Atmospheric fluidized bed combustion boiler and circulating fluidized bed combustion boiler and generate a plan to reduce the maximum loss areas by using exergy analysis conclusion: The results show that boiler losses and boiler efficiency depend on boiler load and percentage of excess air

9) Kumar Ashutosh, Kumar Raj. 2017. Introduction: This paper presents an approach for the efficiency improvement of the Atmospheric Fluidized Bed Combustion boiler Conclusion: Data were taken from 3 shift log books on a 24-hour average basis & applying the indirect method of heat losses and find that upon decreasing of 31 0 C, efficiency improved by 1 0 C. This paper addresses the various approach for the efficiency improvement of a boiler

10) Bora Moni Kuntal and Nakkeeran S. 2014. Introduction: The current paper puts forward an effective methodology for the efficiency estimation of a coal fired boiler, comparison with its design value and enlists some of the factors that affect the performance of a boiler Conclusion: This paper is convergent on the diverse aspects of the operation of Boiler efficiently. Effi cient operation of boiler is likely to play a very big role in following years to come. Industries all over the world are going through increased and powerful competition and increased automation of plants.

The suspension cost of such system is expected to be very high. To get away with this challenge, it is clearer by this paper. skills in all spheres of activities to perform its effective role in the turnover of the company.

11) Manikandan T, Velmurugan P, Selvam P.Tamil. 2017. Introduction: The main objective of this paper is to find out the boiler efficiency calculation and method to improvement Conclusion: This paper reviewed the literature on performance analysis of boiler in the period of 2011 to 2020. Different methods used for the analysis and improvement of boiler.

12) Gulhane Sarang J, Thakur Amit Kumar. 2013. The aim of this paper is to be find out losses of boiler generated in boiler of 35 TPH boiler in 6 MW captive power plant .in order to operate the power plant properly by operation engineer As per our above discussion it is now found that load increases losses reduced so that plant should be run in the Pick load ,in 5.6 MW the boiler efficiency is 83.03% and 1.1 mw it was 76.63% ,the proper operation engineering is require For driving the boiler only when it is possible to reduce the losses .and also found that energy destruction at full load 16.91% and energy destruction at 1.1 MW was found 23.37 % ,this also shows that minimum load maximum energy destruction and pick load minimum energy destruction.

Chapter -3
PROBLEM MODELLING

3.0 INTRODUCTION

We are pursuing efforts to boost the efficiency of the boiler, recognizing that by changing the efficiency of the economizer, we can drive improvements in boiler efficiency. Steam boilers are vital for manufacturing processes, serving purposes like heating, drying, and sterilization. They rely on combustion-derived heat to generate steam. However, heat loss is a common issue for plant managers, impacting efficiency and raising costs. Detecting and preventing these losses is challenging with boilers typically operating at 75% to 80% efficiency, leaving 20% to 25% as losses.

This hampers performance and increases expenses. As we all know the efficiency of any system holds significant importance across various sectors worldwide. Whether discussing energy from renewable or non-renewable sources, maintaining Efficiency is crucial for sustaining the economy and ecosystem. It is essential to optimize input for maximum output. With this in mind, we aim to present an efficient approach through which the economizer can enhance overall efficiency.

We focus on adjusting its design parameters to achieve optimal results and maximize efficiency. a helical fin for an economizer tube to maximize heat transfer. Ansys Fluent will be used to simulate fluid flow and heat transfer, and results will be used to design a more efficient tube. The efficient tube will have a higher heat transfer rate, leading to enhanced energy efficiency and reduced operating costs. Furthermore, the optimized helical fin design can be applied to various heat exchangers, aiding in improving industrial processes and reducing energy consumption.

By utilizing ANSYS, engineers can simulate different scenarios to optimize economizer design and material selection. Varying geometric parameters such as tube diameter, length, spacing, and arrangement allows for evaluating their impact on heat transfer efficiency and pressure drop across the economizer.

Similarly, exploring different tube materials enables assessing their thermal conductivity, corrosion resistance, and overall durability under operating conditions. ANSYS facilitates comprehensive thermal analysis by simulating heat transfer mechanisms, fluid flow patterns, and structural integrity within the economizer.

3.1 FIXING GEOMETRY

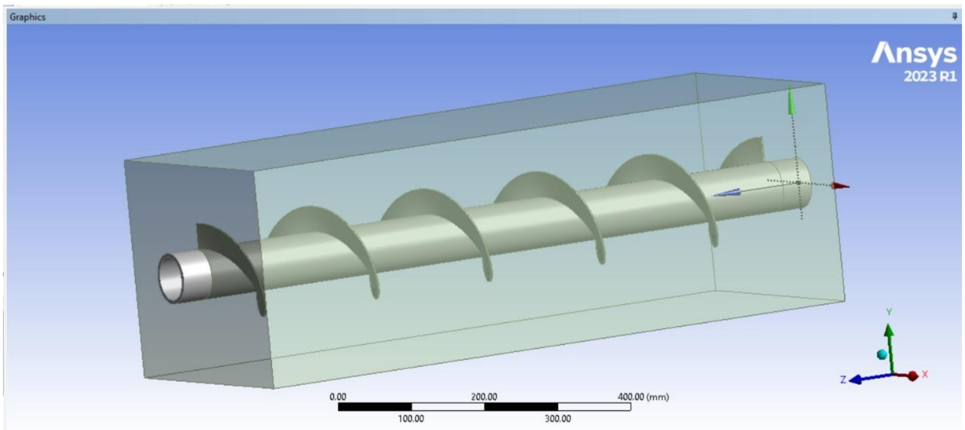
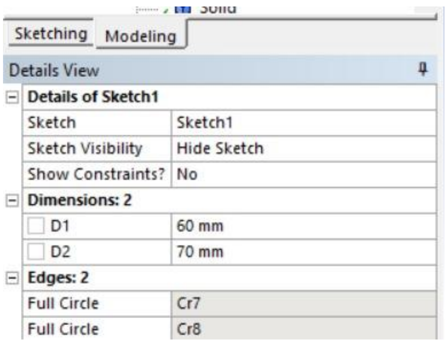


Fig-5 Geometry



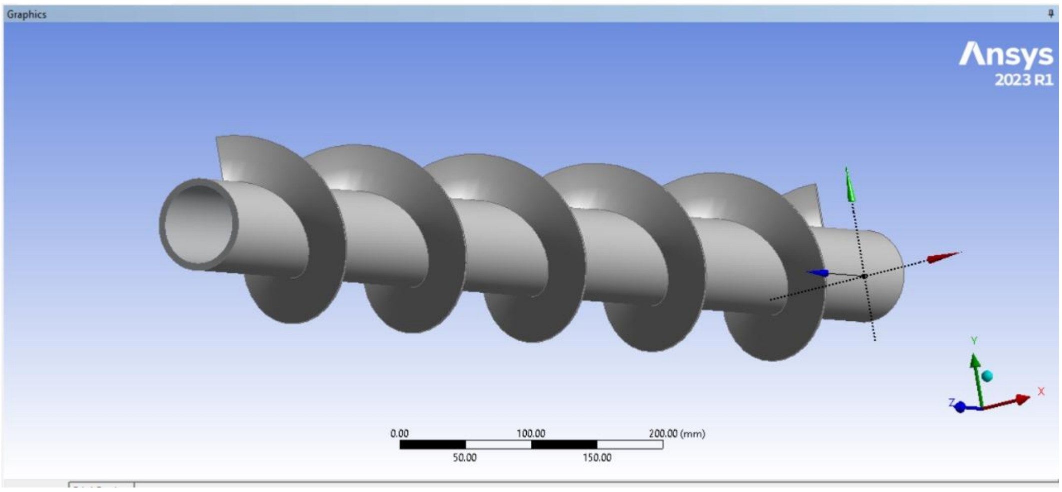


Fig-6 Tube with Helical Fin

Helical Fin Dimensions

Height - 35mm

Width - 1.8 mm

Length - 35mm

Distance from the bottom - 50mm

Distance from centre - 35mm

No. of Turns - 5

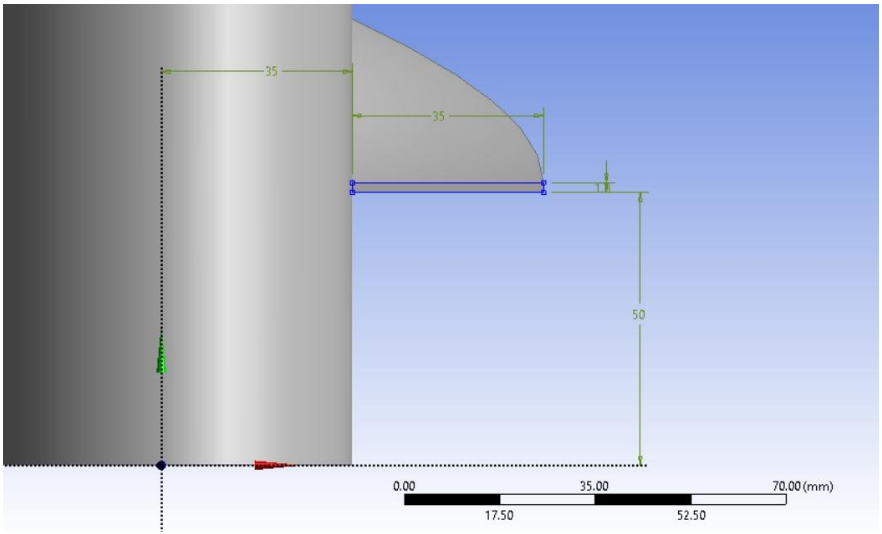


Fig-7 Tube with Fin

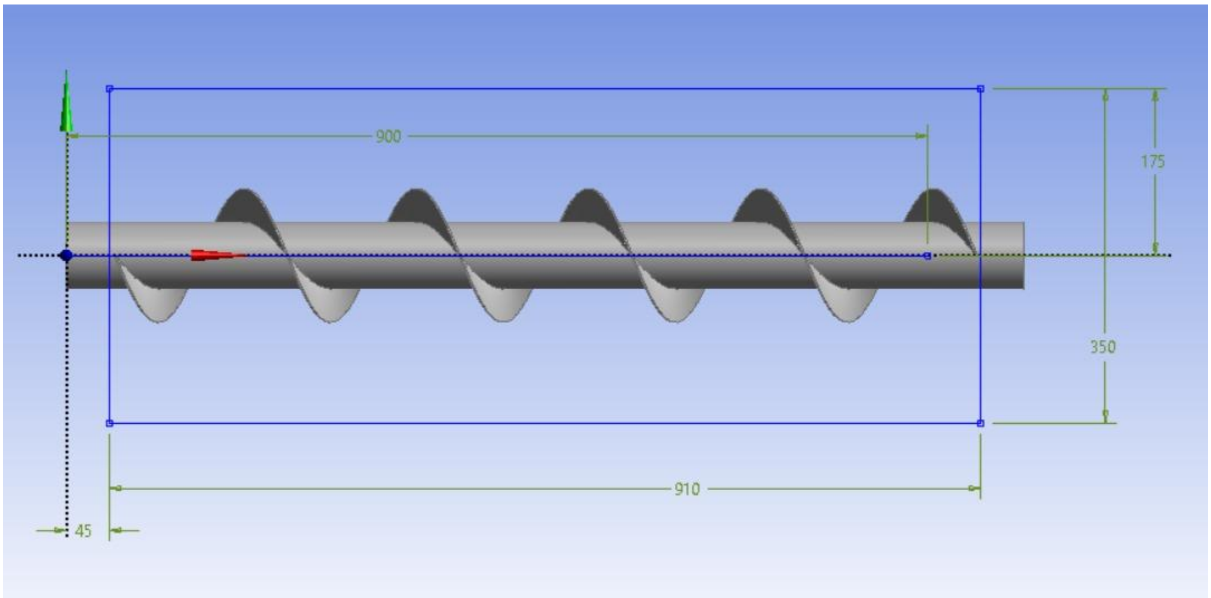


Fig-7 Outer Shell Dimensions

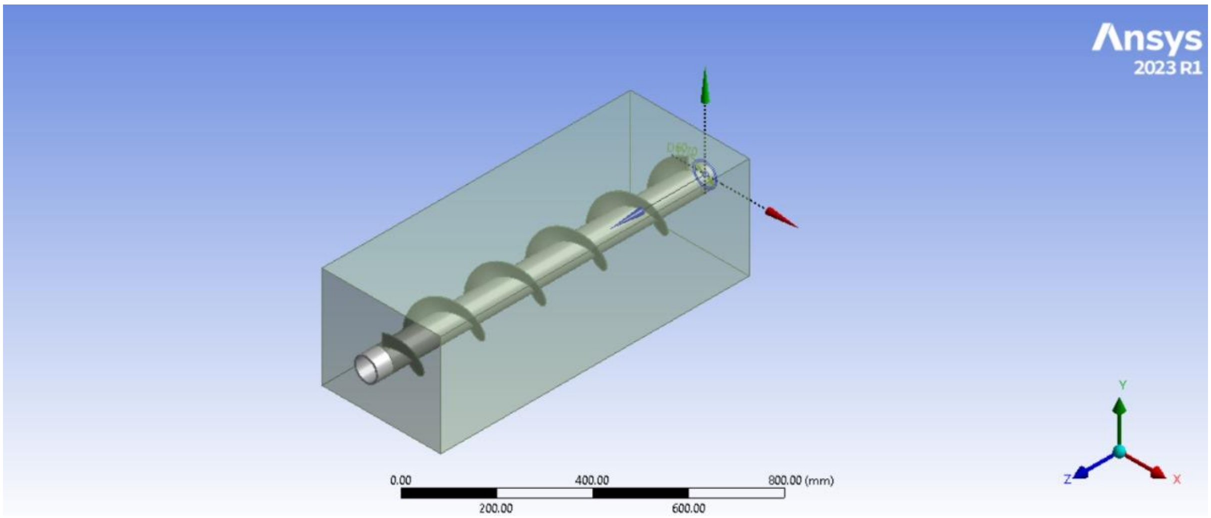


Fig-8 Geometry

3.11 Steps used to draw Geometry

- Create the hollow cylinder with the given dimensions and extrude it up to the length of the tube.
- Create the rectangle fin and use the sweep command to get a helical fin with 5 no.of turns.
- Use the Boolean, fill commands to avoid setup errors.
- Create a rectangle box and extrude it to get the flue gas chamber
- Finally calculate the volume to compare the weight of this model with other models

3.2 Mesh Quality Setup

Commands used are

- Edge meshing
- Face meshing
- Meshing Method – Path confirmation method
- Inflation
- Tetrahedral Mesh
- Named sections

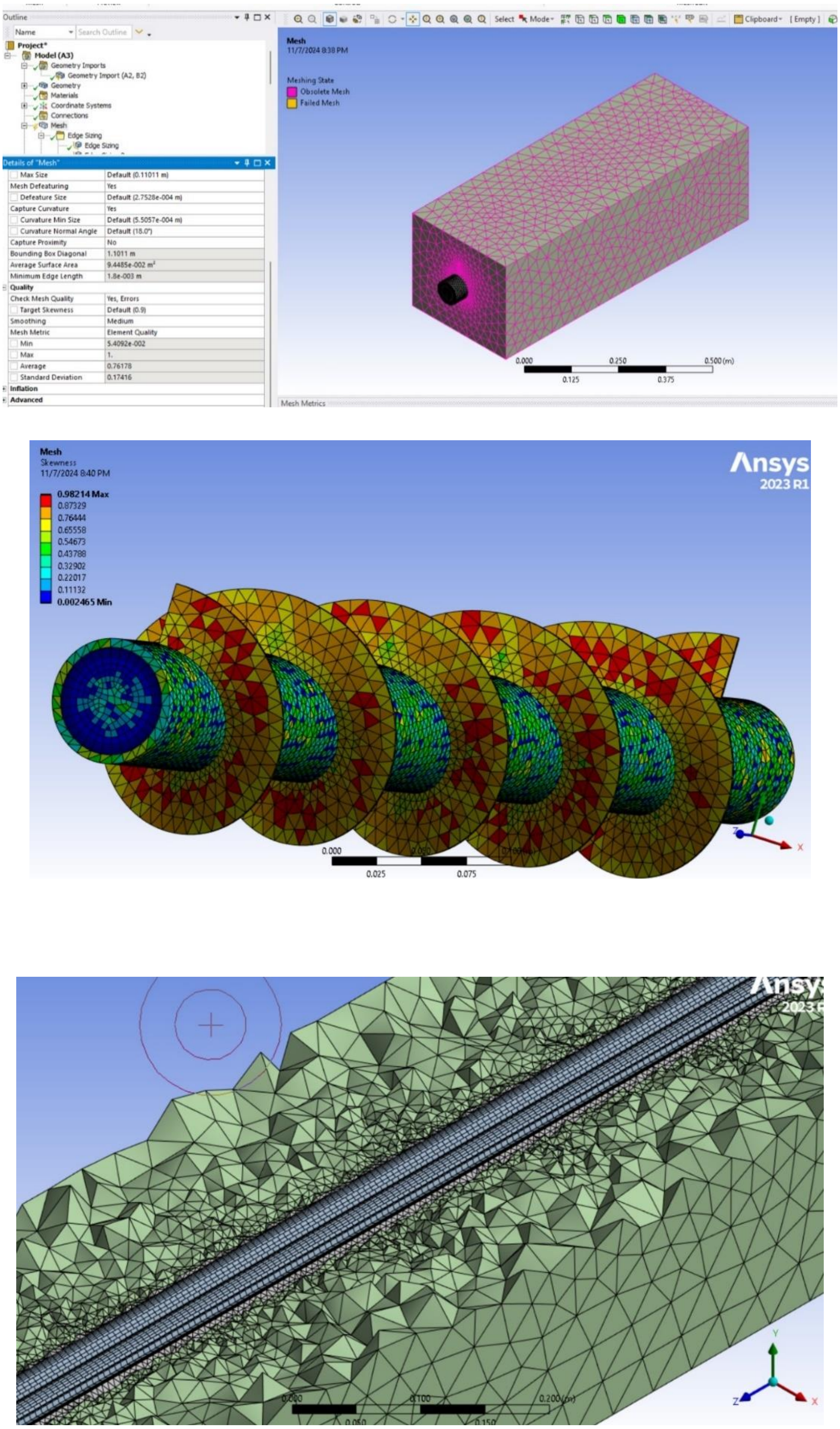


Fig-9 Skewness & Orthogonal mesh setup

3.3 Analysis Setting and Boundary Conditions

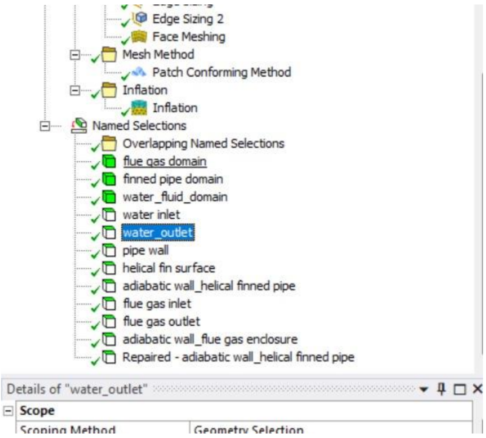


Fig-10 Creating named selections for applying Boundary Conditions

Commands Used:

- Energy equation
- Laminar flow
- Reference values
- Hybrid Initialization
- Material selection
- Monitors
- Residules

Material Selections

Flue gases

Density – 1.125 kg/m^3

Specific heat – 1120 j/kg k

Thermal Conductivity – 0.046 w/mk

Viscosity – 0.000101 kg/ ms

Water – Liquid

Density – 998.2 kg/m^3

Specific heat – 4200 j/kg k

Thermal Conductivity –1 w/mk

Viscosity – 0.001003 kg/ ms

Aluminium

Density – 2719 kg/m^3

Specific heat – 187 j/kg k

Thermal Conductivity – 202.4 w/ms

Steel

Density –8030 kg/m^3

Specific heat – 502.48 j/kg k

Thermal Conductivity – 16.27 w/ms

Boundary Conditions

Parameter	Value
Flue gas Inlet Temperature	781 K
Flue gas Inlet Massflow rate	17.6 kg/s
Water Inlet Temperature	300 K
Water Inlet Massflow rate	6.5 kg/s

- Residual value is taken as 1e-6
- Use the Hybrid Initialization
- No. of Iterations is given as 1000

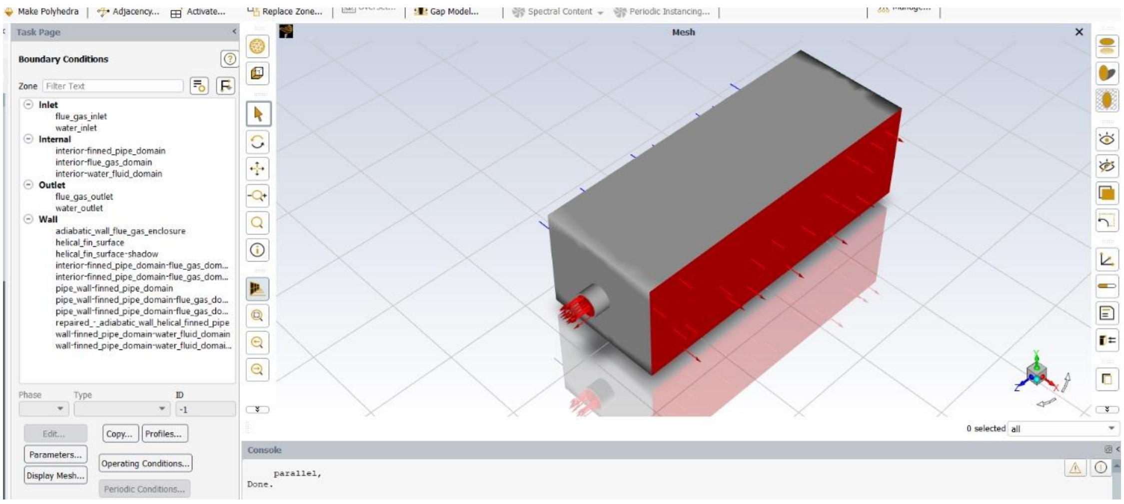


Fig-11 Boundary Conditions applied

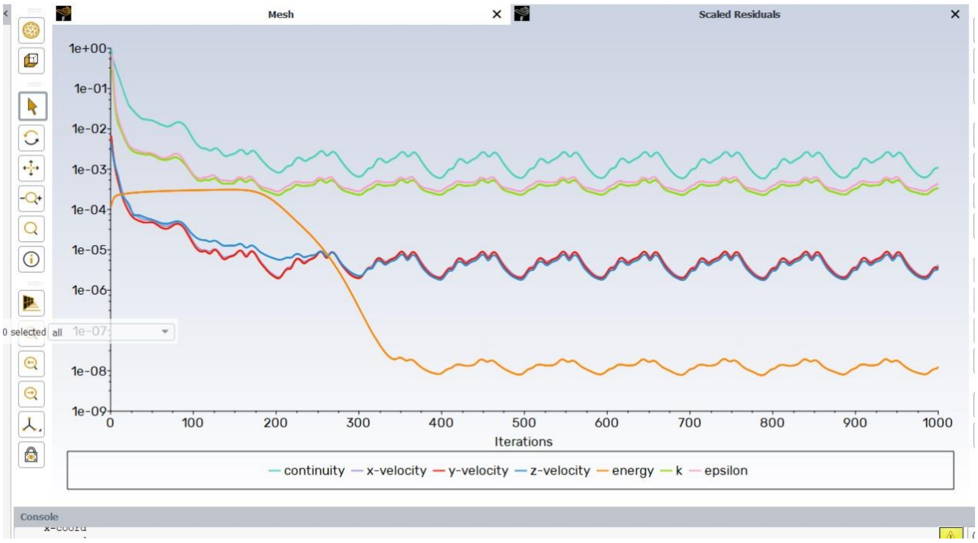


Fig-12 Solution completion graph

3.4 Results Analysis

Tube with and without the Helical fin

Parameter	Temperature	
Flue gas Inlet Temperature	**781 K**	With Helical Fin
Water inlet Temperature	**300 K**	
Flue gas outlet Temperature	**778.68732 K**	
Water outlet Temperature	**302.31268 K**	

Parameter	Temperature	
Flue gas Inlet Temperature	**781 K**	Without Helical Fin
Water inlet Temperature	**300 K**	
Flue gas outlet Temperature	**779.31048 K**	
Water outlet Temperature	**301.68952 K**	

Temperature Difference

With Fin = 781 – 778.68732 = 2.312 K or 2.312 ℃

Without Fin = 781 – 779.31048 = 1.689 K or 1.689℃

Effectiveness

We know that

Effectiveness= Temp of Water out - Temp of Water in / Temp of Flue gas inlet – Temp of water inlet

ε = (302.31268 – 300) / (778.68732–300) = 0.481 (With the helical fin)

ε = (301.68952 – 300) / (779.31048–300) = 0.35 (Without helical fin)

Weight Comparison

By adding the fin to the tubes for the exchanger the weight of the tubes is approximately increased by 9kg for a 1m length tube than the normal tube without fin.

S.no	Material	Density kg/m3	Mass kg	Volume mm3	Weight N	With Helical fin
1	Copper	8978	10.104	0.001	99.119	
2	Aluminium	2719	3.060	0.001	30.018	
3	Steel	8030	9.037	0.001	88.653	

S.no	Material	Density kg/m3	Mass kg	Volume mm3	Weight N	Without Fin
1	Copper	8978	9.167	0.001	89.924	
2	Aluminium	2719	2.776	0.001	27.234	
3	Steel	8030	8.199	0.001	80.429	

Chapter - 4

METHODOLOGY & MODIFICATIONS

The Economizer has been modelled for a tube with a helical fin in ANSYS Fluent geometry.

The standard dimensions are used for Economizer modelling.

Discretization of the model is carried out and tetrahedron meshing is used.

Thermal & Structural Boundary conditions were applied.

Results were obtained in the form of Temperatures.

Chapter - 5

CONCLUSION AND FUTURE SCOPE

5.0 Conclusion

From the conducted study, it was discovered that the addition of helical fins to the economizer tubes in a thermal power plant significantly enhances the working efficiency. The modification increased the economizer's effectiveness from a typical value of 0.35 to approximately 0.48. This improvement enables the economizer to extract more heat from the flue gases, resulting in increased heat recovery. The increased heat recovery contributes to improving the overall efficiency of both the boiler and the economizer. Furthermore, the helical fins induce turbulence in the flue gas flow, which enhances heat transfer by promoting better mixing and contact between the hot gases and the economizer tubes.

This increased turbulence leads to improved heat transfer coefficients, resulting in higher heat recovery rates. Moreover, the helical fins help to improve the structural rigidity of the economizer tubes, making them more resistant to bending and vibration. This enhanced structural integrity ensures the longevity and reliability of the economizer, reducing the need for frequent maintenance or replacement.

5.1 Future scope

Future research could investigate integrating helical-fin economizers with other waste heat recovery systems, such as regenerative air preheaters. This integration could capture and reuse more waste heat, significantly improving the overall thermal efficiency of power plants.

Chapter - 6

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