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THERMAL ANALYSIS OF ECONOMIZER USING ANSYS BY VARIATION IN GEOMETRIC PARAMETERS AND TUBE MATERIAL.

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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 economiser. The investigation focuses on varying two key parameters: tube thickness and tube material, to optimize heat transfer efficiency and overall performance.**

In the present work we have taken 3 different thickness values of economiser Tube through which the feed water flows. the dimensions are 3mm,4mm and 5mm keeping the inner diameter same for each tube. SolidWorks software is used for model design and Ansys workbench is used for analysis. The analysis is performed on different tube thickness models and a comparison is made between them. Also, the material is changed to achieve a better heat transfer rate.

The research begins with the development of a finite element model representing the economiser geometry. ANSYS is utilized to simulate heat transfer processes within the economiser for different geometric parameters and same operating conditions. By systematically altering tube thickness and material properties, the impact on heat transfer rate, pressure drop, and overall thermal efficiency is evaluated.

IndexTerms **- Economiser, FEA Analysis, Ansys.**

I. INTRODUCTION

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.

ECONOMIZER:

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 it is 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 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. 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 [4]. PATIL stated that "economizers reduced the potential for thermal shock and strong fluctuations in water temperature as the feed water enters the drum or water walls. Ever stricter ecological regulations limiting emissions of nitrogen oxides and sulfur dioxide can also affect the design of the economizer [5]. Our target economizer the design is to achieve the necessary heat transfer at low cost. In our case, we take an economizer in a power plant named (Emisal Salt Industry located in El-Fayme Governorate, Egypt) 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.

TYPES OF ECONOMIZERS:

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%." 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 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. Ultimately, this analysis aids in enhancing the performance, reliability, and lifespan of economizers, contributing to overall energy savings and operational efficiency in industrial processes. 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.

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The paper is structured as follows: Section 2 provides a comprehensive review of related literature, highlighting previous research efforts and advances in the field of Economizer. Section 3 describes the methodology and details the numerical simulations performed using ANSYS software. Section 4 presents the results of the thermal analysis, discussing the effects of material and thickness changes of tube on economizer performance. Section 5 concludes the paper with a summary of key findings, implications and avenues for future research.

II.LITERATURE SURVEY

Literature review is part of discussion of different author's paper comparatively. In this paper we discussed about the economizer efficiency considering change in dimensions effect on efficiency and the values for heat flux with various in materials and find out the better result to improve economizer efficiency and also, we discussed about what the authors states.

1. Mahmoudi Lahijani* And Eris E Supeni. 2018. Introduction: 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 is 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. A.E. Atabani1, R. Saidur1 , A.S. Silitonga1,2, T.M.I. Mahlia1 , A.H. Sebayan. 2013. Energy introduction: Economical and Environmental Analysis of Industrial Boilers using Economizers,
   Conclusion: 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 CO_2, 6,324 kg of SO_2, 41,488 kg of NO_x, 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
   Conclusion: Hence from the analysis, it is found that the heat transfer rate has been enhanced by providing the new area in case 2. There is a significant increase in heat transfer rate. And this heat energy is transferred to water flowing in the tube. So, in this way, we experience increased heat transfer and increase fuel saving by 1 %, this also will give maximum boiler efficiency.
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 analysed 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. Efficient 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. We have to use the advanced technology and management 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. Lahijani Ahmad Mahmoudi, Supeni Eris.E., Kalantari Fatemeh.2018. introduction: In this paper, the efficiency analysis of fire tube steam boilers according to pertinent parameters is presented
    Conclusion: In this paper indirect method (heat loss method) is explored for boiler calculation of boiler efficiency. The indirect method is the most accurate method to determine boiler efficiency. In this method, the parameters that effect on efficiency be measured and different types of losses be calculated. Three of the most effective parameters are flue gas temperature, ambient temperature, and the fuel type. The heat loss method shows reduce the flue gas temperature and increasing the ambient temperature have a significant effect on improving the efficiency of steam boiler; in addition, the fuels with higher gross calorific value is effective on the increasing the efficiency in fire tube steam boilers.

13. 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

14. Vosough Amir, Falahat Alireza, Vosough Sadegh, Esfehani Hasan Nasr.2011. introduction: In this study, an energy and exergy analysis as well as the effect of varying the condenser pressure on the subcritical model power plant has been presented. Conclusion: The analyses show that the condenser pressure is an important parameter that affects the output power, power potential and thermal and exergy efficiency of the cycle. Considering the inherent limitation of this parameter as well as the turbine limitation, the minimum allowable condenser pressure should be chosen to produce maximum efficiency and output power. This pressure should be always controlled during the power plant operation. The maximum energy loss was found in the condenser where 60.86% of the input energy was lost to the environment. The exergy analysis of the plant showed that lost energy in the condenser is thermodynamically insignificant due to its low quality. In terms of exergy destruction, the major loss was found in the boiler where 86.271%, of the fuel exergy input to the cycle was destroyed at it. The percent exergy destruction in the condenser and other components was 13.22%. The calculated thermal and exergy efficiency of the power cycle was found to be 38.39%, 45.85.

III.PROBLEM DEFINITION

In this paper, we are pursuing efforts to boost the efficiency of boilers, recognizing that by enhancing the efficiency of economizers, 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.

We have taken three different dimensions of economizer pipe through which the feed water flows the dimensions are 3 mm, 4 mm and 5 mm it is of thickness inlet diameter will be same for each one. SolidWorks software is used for model design and Ansys workbench is used for analysis. The analysis is performed on different tube thickness models and a comparison is made between them. Also, the material is changed to achieve a better heat transfer rate.

CAD MODEL

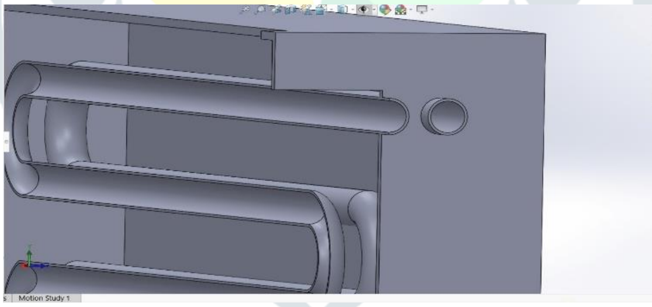


FIG.4.1

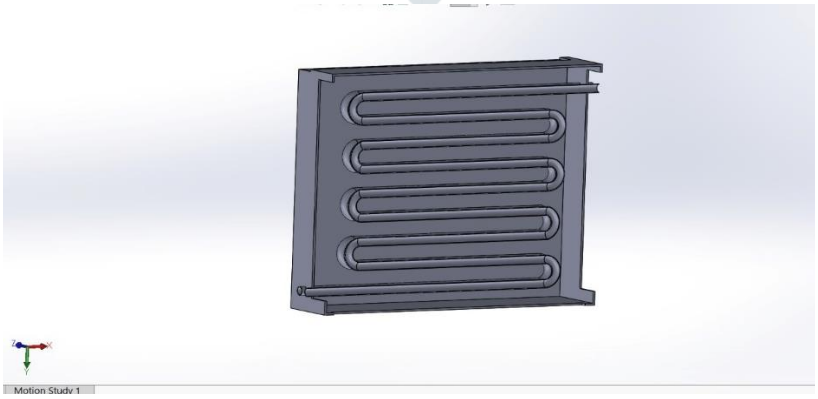


FIG.4.2

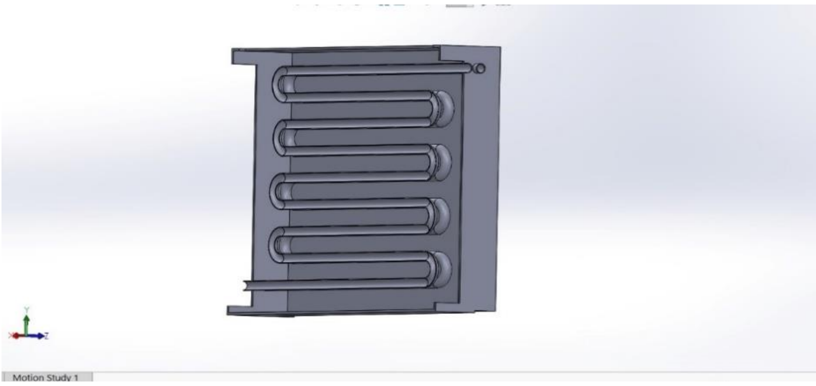


FIG.4.3

IV.METHODOLOGY

The Economizer has been modelled for tube thickness 4mm using Solid Works. The standard dimensions are used for Economizer modelling.

The CAD model is imported in ANSYS.

The material selected for the Economizer Tubes is SA210.

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 contours of Temperature and Heat Flux.

By applying the thermodynamic analysis performance of Economizer is obtained in the form of efficiency.

Same steps are repeated for Tube thickness 3mm and 5mm and comparison is carried out.

2 other materials were also used which are SA213T22 & SS304 & the performance is compared for three different materials too.

SELECTION OF MATERIAL:

We have selected 3 materials :

SA 210 - This typically refers to ASTM A210, which is a standard specification for seamless medium-carbon steel boiler and superheater tubes. These tubes are used in boilers, heat exchangers, and other pressure vessels in various industries.

SA 213 T22 - This refers to ASTM A213 Grade T22, which is a specification for seamless ferritic and austenitic alloy-steel boiler, superheater, and heat-exchanger tubes. T22 is a type of chromium-molybdenum alloy steel widely used in high-temperature applications.

SS 304 - This likely refers to Stainless Steel 304, which is a common type of austenitic stainless steel. SS 304 is often used in applications requiring corrosion resistance, such as in the food industry, chemical processing, and in architectural applications. The best thickness of tube material would be that with the highest thermal conductivity and suitable thickness to ensure maximum heat transfer rate. Thermal resistance of the material, resistance to corrosion and the weight of the material are also an important factor, especially high temperatures.

V. RESULTS AND DISSCUSSIONS

5.1 SA 210, 3 mm model Heat flux:

5.1.1 Heat flux 1.

Heat exchange rate of water from flue gases Max 109.83 W/mm^2.

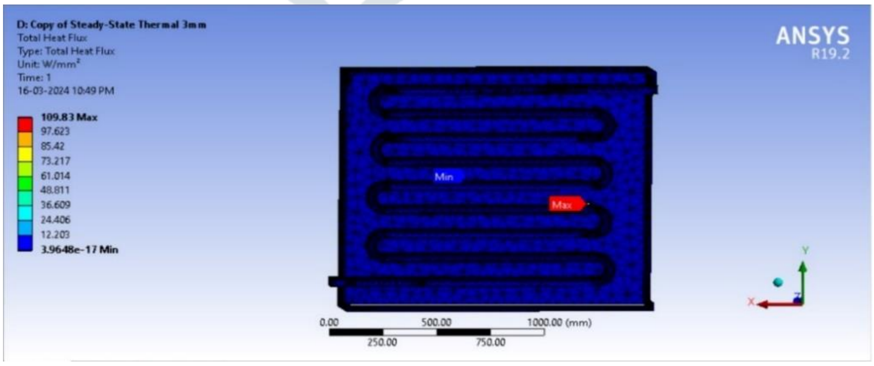


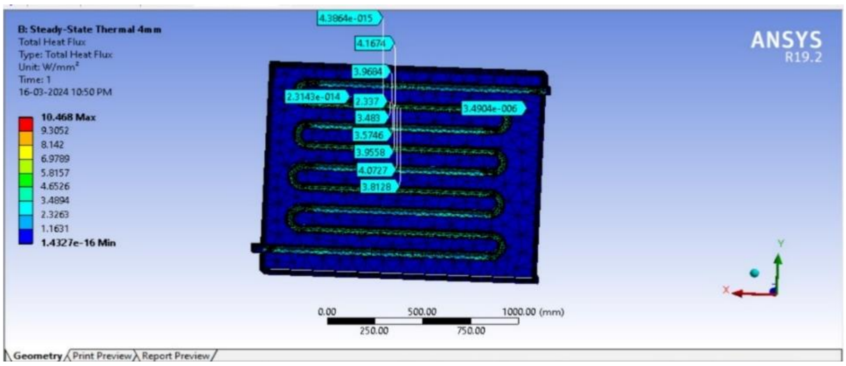
FIG.5.1.1

5.2 SA 210, 4 mm model Heat flux:

5.2.1 Heat flux 1.

Heat exchange rate of water from flue gases Max 10.468 W/mm^2.

FIG.5.2.1



5.3 SA 210, 5 mm model Heat flux:

5.3.1 Heat Flux 1.

Heat exchange rate of water from flue gases Max 4.947 W/mm^2.

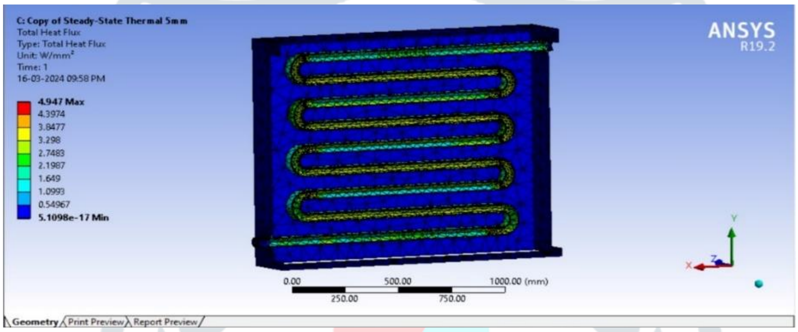


FIG.5.3.1

5.4 SA 210 3 mm model Temperature:

5.4.1 Temperature 1

Flue gases inlet temperature 360 rise in temperature to 380 because of heated water at inlet.

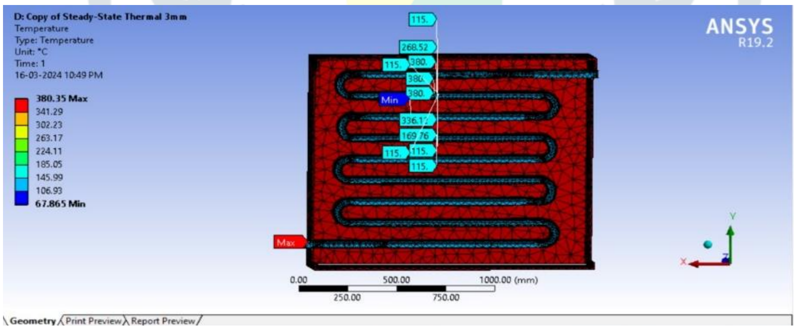


FIG.5.4.1

5.4.2 Temperature 2.

The temperature absorbed by water from flue gas is 201.18 ^{0}C.

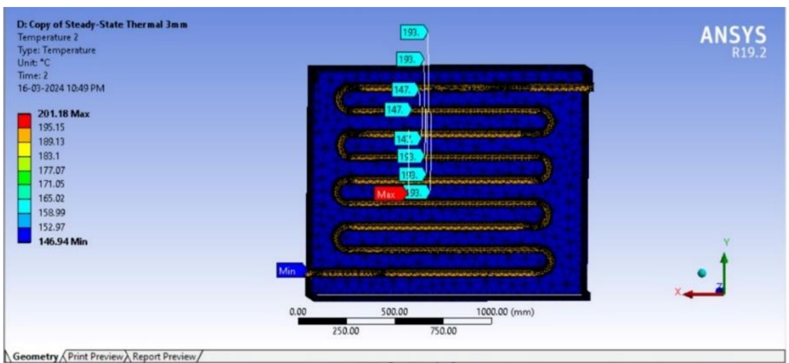


FIG.5.4.2

5.5 SA 210, 4 mm model Temperature:

5.5.1 Temperature 1

Flue gases inlet temperature 360 rise in temperature to 380 because of heated water at inlet.

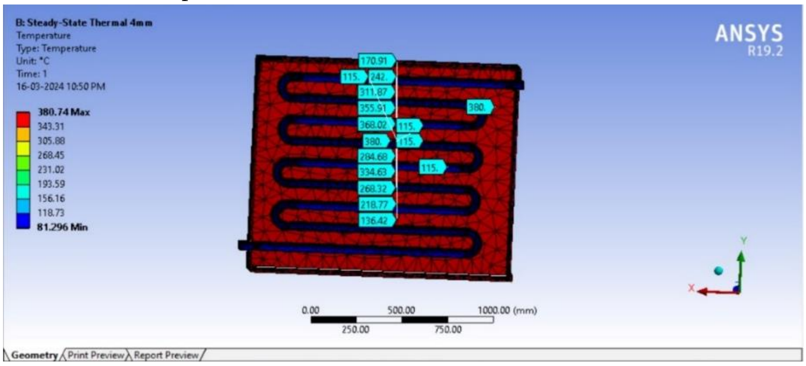


FIG.5.5.1

5.5.2 Temperature 2

The temperature absorbed by water from flue gas is 198.85 ^{0}C.

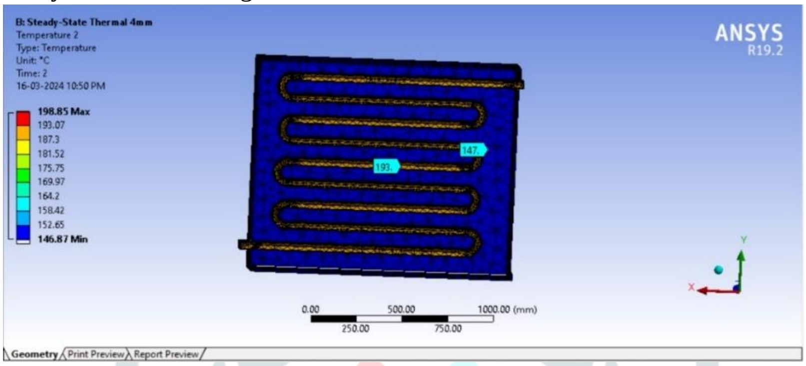


FIG.5.5.2

5.6 SA 210, 5 mm model Temperature:

5.6.1 Temperature 1. Flue gases inlet temperature 360 rise in temperature to 380 because of heated water at inlet.

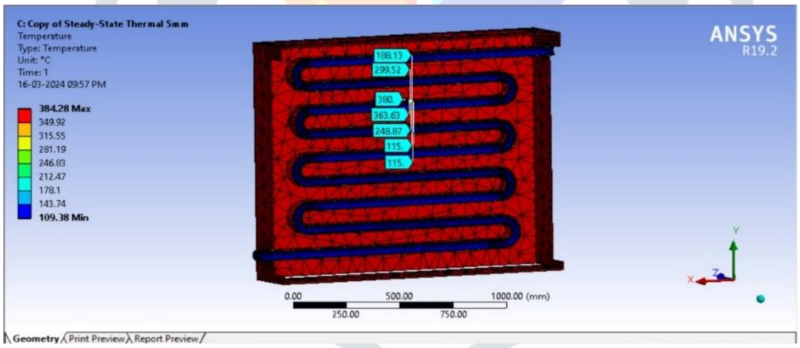


FIG.5.6.1

5.6.2 Temperature 2.

The temperature absorbed by water from flue gas is 193.98 ^{0}C

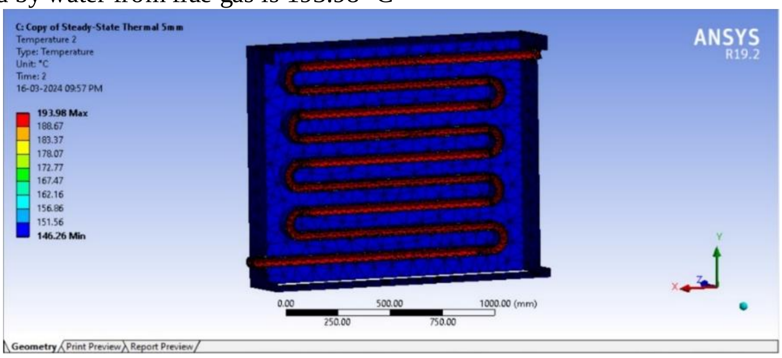


FIG.5.6.2.

5.7 Contours showing

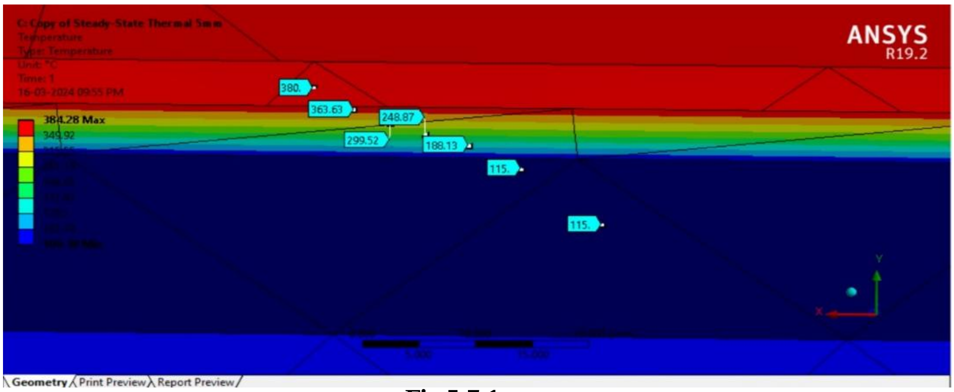


Fig 5.7.1

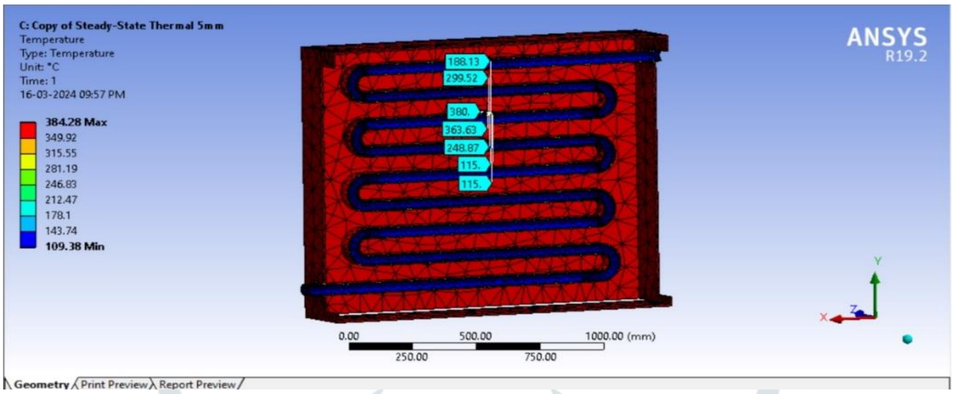


Fig 5.7.2

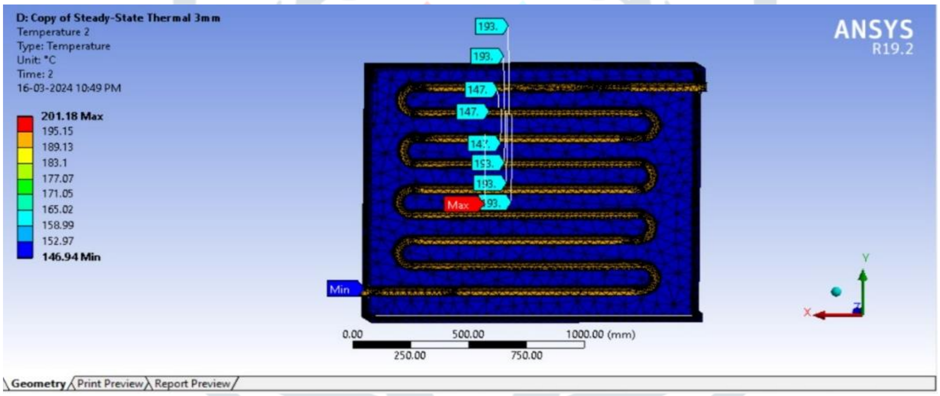


Fig.5.7.3

5.8 ASTM SA 213 GRADE T22:

5.8.1 3mm Heat flux 1:

Heat exchange rate of water from flue gases Max 66.31 W/mm^2.

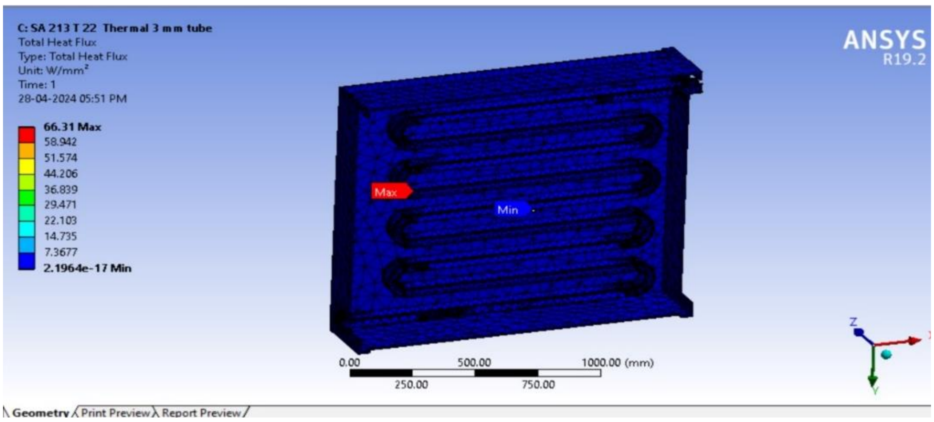


Fig 5.8.1

5.9 Stainless steel: SS 304:

5.9.1 3mm Heat flux 1:

Heat exchange rate of water from flue gases Max 44.552 W/mm^2.

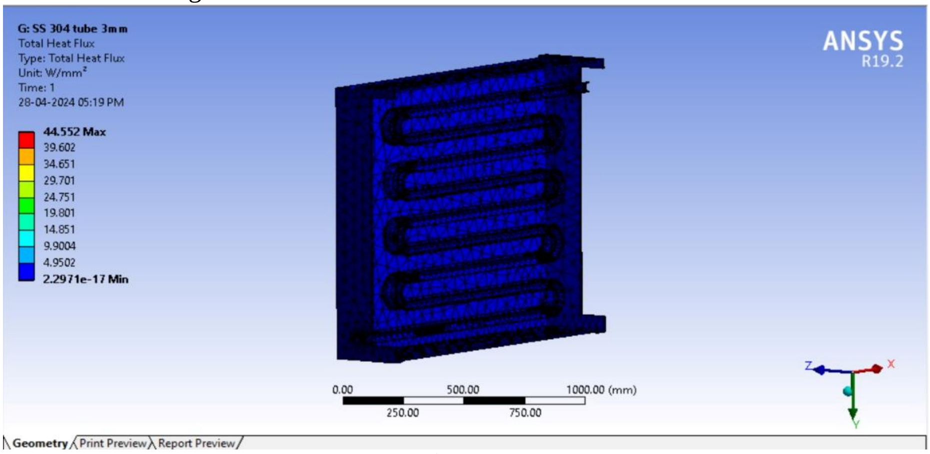


Fig 5.9.1

VI. **RESULT ANALYSIS**

Here we are comparing the calculation changes with different parameter:

- Given constant parameter are:
1. Feed water inlet temperature 116^o C.
2. Flue gas inlet temperature 360^0 C.
- Changeable parameter due to tube thickness:
1. Feed water outlet temperature.
2. Flue gas outlet temperature (but if is mandatory to maintain above 130^{o}C).

*Economizer Efficiency η: $\frac{\text{(feed water outlet temperature – feed water inlet temperature)}}{\text{(flue gas inlet temperature – feed water inlet temperature)}} \times 100$

5.1 Material name SA 210:

1) 5 mm thickness tube:

According to Ansys analysis we find out the outlet temperature of water is 193.98^{o}C.

$$\eta = \frac{\text{(feed water outlet temperature – feed water inlet temperature)}}{\text{(flue gas inlet temperature – feed water inlet temperature)}} \times 100$$

$$\eta = \frac{193.98 - 116}{360 - 116} \times 100$$

$$\eta = \frac{77.98}{244} \times 100$$

$$\boxed{\eta = 31.95\ \%}$$

2) 4 mm thickness tube:

According to Ansys analysis we find out the outlet temperature of water is 198.85^{o}C.

$$\eta = \frac{\text{(feed water outlet temperature – feed water inlet temperature)}}{\text{(flue gas inlet temperature – feed water inlet temperature)}} \times 100$$

$$\eta = \frac{198.85 - 116}{360 - 116} \times 100$$

$$\eta = \frac{82.85}{244} \times 100$$

$$\boxed{\eta = 33.95\ \%}$$

3) 3 mm thickness tube:

According to Ansys analysis we find out the outlet temperature of water is 201.18^{o}C.

$$\eta = \frac{\text{(feed water outlet temperature – feed water inlet temperature)}}{\text{(flue gas inlet temperature – feed water inlet temperature)}} \times 100$$

$$\eta = \frac{201.18 - 116}{360 - 116} \times 100$$

$$\eta = \frac{85.18}{244} \times 100$$

$$\boxed{\eta = 34.90\ \%}$$

Hence from above calculation it is clear shown that the efficiency is greater as compared to other parameter it is find out that 3mm is best now we will examine two more material with 3mm tube thickness.

VII. CONCLUSION

As there is a lot of heat losses in boiler it is significant to come up with the solution which reduces the directly heat loss and increase the boiler efficiency.

We worked on economizer to make the waste heat comes from flue gases can be used significantly efficient, we have successfully showed that on doing the comparison of different parameter of economizer tube we bring the difference in efficiency of economizer which will be increase the boiler efficiency Hence from the analysis It is found that the heat transfer rate has been improved by doing variations in sizing of tube and. There is a significant increase in heat transfer rate. And this heat energy is transferred to water flowing in the tube thus the efficiency has improved by 1%. We have also performed analysis by comparing the main material from other two opted material and find out the best material on the basis of heat flux values.

On doing comparison we find that SA 210 as the best material.

VIII. REFERENCE

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