International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review of Energy and Exergy Analysis for Different Thermal Power Plant

Lokesh Techand Basone, Punam Kumar Agade

Patel College of Science and Technology

ABSTRACT

The objective is to study number of paper on energy and exergy of different thermal power plants.Through this study it helps to evaluate the energy and exergy efficiencies and exergy destruction rate of the power plant system components, with a view to identifying systems that have potential for significant performance improvement.

Exergy analysis is a useful concept for ecology and sustainability because it can used as a common measure of resourse quality along with quantity. By analysis the exergy destroyed by each component in a process, we can see where we should be focusing our efforts to improve system efficiency. The main objective is to analyse the various system components to identify the parts due to which loss of energy and exergy at large amount takes place. The result of the research can enable to find the desirable modifications to maximize the efficiency of system components and to minimize the loss of exergy in the power plant. Exergy analysis will support the engineers for improvise system design and performance by providing informations.

Keywords: Exergy analysis; exergy efficiency; Exergy destruction; dead state; steam power plant**.**

1. Introduction

1.1 Exergy definition

It is evident that the content of energy in the universe is constant. But very often, we come through different dialogues and articles on the topic that "How to conserve energy". Since time immemorial it is known that energy is constant in nature, what need to conserve the energy which is already conserved. The content required to be conserved is exergy which is the vital parameter and work potential of the energy. Exergy is irrecoverable i.e. once it is wasted can never be recovered. Simply, it means that when energy is used, the conversion of energy in a less powerful form i.e. exergy is used not the energy. Hence, energy is never exhausted.

Exergy defines the maximum capacity of a system to produce useful work as it proceeds from a specified state to a final state which is in equilibrium with its surroundings. Exergy cannot be conserved like energy as it is destructed in the system. Exergy destruction is the measure of irreversibility that is the source of performance loss. Therefore, exergy analysis enables us to identify the location, the magnitude and the source of thermodynamic inefficiencies in the overall system The minimum exergy that has to be rejected to the sink by the second law is called unavailable energy (U.E.).

Therefore,

Q_1 = U.E. + Exergy

W_{max} = Exergy = Q_1 - U.E.

Exergy analysis is a method for the evaluation of the performance of system devices or processes. It examines the exergy at different locations of a system through a series of energy conversion steps. Exergy analysis helps to evaluate exergetic efficiencies and to identify the system components having max. exergy loss. Broadly speaking, the exergy analysis provides a more authenticated and realistic view of the process or system analysis to improve the efficiencies of the power plant.

1.2 Exergy analysis

Exergy is a generic term for a group of concepts that define the maximum possible work potential of a system, a stream of matter or heat interaction; the state of the environment being used as the datum state. In an open flow system there are three types of energy transfer across the control surface namely working transfer, heat transfer, and energy associated with mass transfer or flow. Energy analysis is based on the first law of thermodynamics, which is related to the conservation of energy. Second law analysis is a method that uses the conservation of mass and degradation of the quality of energy along with the entropy generation in the analysis, design and improvement of energy systems. Exergy analysis is a useful method; to complement but not to replace energy analysis. The irreversibility maybe due to heat transfer, through limited temperature difference, mixing of fluids at different temperature and mechanical friction. Exergy analysis is an effective means, to identify losses due to irreversibility in a real situation.

1.3 Classification and Decomposition of exergy

The classification of exergy can be done in a way that is similar to the classification of energy, with some exceptions. Emphasis in the course Engineering Thermodynamics is on thermo-mechanical exergy

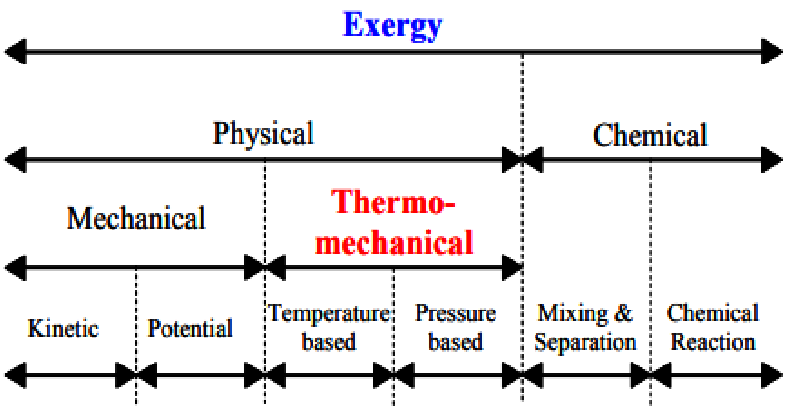

Fig. 1.1 Classification of exergy

The exergy total can be divided into two primary forms, mechanical and thermal exergy. The mechanical exergy consists of kinetic and potential exergy. Since kinetic and potential exergy are evaluated relative to the environment, its exergies are zero.

1.4 Introduction of power sector

Now-a-days, electricity is a basic need to human life. From personal to professional life, from home accessories to industrial machineries nothing can be imagined making aside the electricity. As such, power generation industry reflects a major role in the economic upliftment of the country. Presently, 80% approx. of total electricity consumed in the world is being produced from fossil fuels i.e. coal & petroleum products and only 20% approx. is produced from other sources like wind, water, hydraulic, solar, biogas, geothermal etc.

Now a day exergy analysis of power plant is of scientific interest for making efficient utilization of energy resources as they are constant in nature. The analysis of an energy conversion process is normally carried out by the first law of thermodynamics. But now a day, there is an increasing interest in the combined utilization of the first and second laws of thermodynamics, using both the law exergy and irreversibility can be calculated. By which one can evaluate the efficiency with which the maximum available energy is consumed. Exergy analysis method is a tool for clear distinction between the energy losses to the environment and internal irreversibility of the process.

1.5 Thermal power plant

Thermal power plants are the back bone of Indian power sector. In India 68.14 % of electricity is generated by the thermal power plant. A thermal power plant continuously convert the energy stored in fossil fuels (coal, oil, natural gas) into shaft work and ultimately into electricity. Thermal power plant converts heat energy of the working fluid into electrical energy. The working fluid is sometime in the liquid phase and sometime in the vapour phase during its cyclic operations.

2. Literature Survey

Arpit et. al. (2023) In the present paper, a rigorous analysis of a sub-critical steam power plant (120 MW) with reheating and regenerative configuration is presented, using energy and exergy analysis. The total work output from the power plant is 121.80 MW, which is close to the real value of 120 MW. The calculated energy efficiency of the steam power plant is 34.7%, while its exergy efficiency is 32%

Omar J. Khaleel et. al. (2022) This study is a comparative evaluation of the energy & exergy analyses of coal and gas-fired TPPs. Details of different studies on TPPs over the years were critically reviewed, followed by independent thermodynamics analysis of each component of the TPPs system. Improvements in the performance of power plants were also highlighted. From the outcome of the comparative analysis, combustion chambers were identified as the main contributors to exergy destruction owing to their associated high irreversibility. The results show that the exergy efficiency of the entire system is about 20%. The main exergy loss were occurred in the boiler and the steam turbine in the system.

Xianzhi Tang et. al. (2022) The main role of advanced exergy analysis is to help engineers improve system design and performance by providing information. This provision of information is done by isolating the exergy destruction. Separation of exergy destruction into endogenous/exogenous and unavoidable/avoidable components presents a new development in the exergy analysis of energy conversion systems, which in this paper combines both concepts. This separation increases the accuracy of the exergy analysis and facilitates the improvement of a system. The method used in this paper for separation is the thermodynamic cycle method, which is based on determining the temperature levels for ideal and irreversible cycles.

P. Stephan Heyns et. al. (2021) In this article, energy, exergy, and environmental (3E) analysis of a 400 MW thermal power plant is investigated. First, the components of the power plant are examined in terms of energy consumption, and subsequently the energy losses, exergy destruction, and exergetic efficiency are obtained. It is shown that the highest energy losses are in the closed feedwater heaters Nos. 1 and 5 and the boiler with amounts of 7.6 × 10 J/s and 6.5 × 10^7 J/s, respectively. The highest exergy destruction occurs in the boiler and amounts to 4.13 × 10^8 J/s. The highest exergetic efficiency is 0.98 and is associated with the closed feedwater heaters Nos. 4 and 8. It is observed that the exergetic efficiency and exergy destruction in the boiler are the primarily affected by changes in the environmental temperature.

Osman Shamet et. al. (2021) In this study, the energy and exergy analysis of Garri 4 power plant in Sudan is presented. The primary objective of this paper is to identify the major source of irreversibilities in the cycle. The equipment of the power plant has been analyzed individually. Values regarding heat loss and exergy destruction have been presented for each equipment. The results confirmed that the condenser was the main source for energy loss (about 67%), while exergy analysis revealed that the boiler contributed to the largest percentage of exergy destruction (about 84.36%) which can be reduced by preheating the inlet water to a sufficient temperature and controlling air to fuel ratio.

Abdullah Duzcan et. al. (2021) Exergoeconomic analysis is conducted by using specific exergy costing (SPECO) method and cost values corresponding to each exergy flows are calculated. According to exergoeconomic analysis, unit exergy cost and exergy cost of steam sent to high-pressure turbine are calculated as 17.94 $/GJ and 22,854 $/h, respectively. The highest exergoeconomic factor is measured in pump (*P*2) and followed by *P*3. For the life cycle assessment (LCA) analysis, eco-indicator 99 impact assessment method is selected.

Davor Poljancic et. al. (2021) This paper presents a calculation of energy and exergy efficiency with energy and exergy losses of the entire nuclear power plant and all of its constituent components. The main idea of the performed analysis is to be a baseline for further improvements and optimizations of the entire nuclear power plant or any of its components.

Aisha Saad et. al. (2021) focuses on identifying the type, location and causes of thermodynamic losses in the plant. The first as well as the second law of thermodynamics was applied to each component of the plant and the exergy balance for each of the plant components derived. The analysis was conducted by varying the ambient temperature between 294 and 306 K through the use of the Microsoft excel software. The results show that the combustion chamber with the highest exergy destruction efficiency of 53.5% for Jatropha biodiesel, 50.7% for conventional diesel and 50.2% for natural gas while the turbine component of the engine had the least of 13%, 24% and 4% for Jatropha biodiesel, conventional diesel and natural gas respectively at maximum ambient temperature. On the other hand the highest exergy efficiency was obtained with natural gas but was observed to drop with increase in the ambient temperature.

Dr. Rakesh Kumar Jain et. al. (2020) in this paper we present how to improve the efficiencies and whether a further inspection required of 125 MW coal fired power plant. So Energy and Exergy analysis have been carried out in order to evaluate the energetic and exergetic efficiencies of the plant and its components at 100% loading condition, but most of the power plants are designed on the basis of energetic performance and is based on the First Law of Thermodynamics only. The real useful energy loss cannot be justified by the First Law of Thermodynamics because it does not differentiate between the quality and quantity of energy. Energy analysis presents only quantity based result while Exergy analysis presents quality along with quantity based results of the power plant and is based on the principle of Second law of thermodynamics. This paper presents that how the Exergy analysis is more useful as Energy analysis for coal fired thermal power plants.

PDF

Altug Alp Erdogan et. al. (2020) This study investigates the exergetic effects of the hot-windbox repowering option for a coal-fired thermal power plant. The hot-windbox repowering option consists of a gas turbine, an air-to-water heat exchanger for feedwater heating, and an air-to-air heat exchanger to preheat the combustion air. An air dilution part is also needed for the required temperature set at the inlet of burners. A burner modification can also be necessary without air dilution dampers. Exergy calculations for the power plant before repowering were performed according to the design data of Soma-A Thermal Power Plant and were repeated for the hot-windbox repowering (HWB) scheme. According to the results, the percent exergy destruction in the boiler decreased from 84.70% to 68.80%, which that in the combustion chamber of the gas turbine (GT) was 14.77%.

Louay Elmorsy et. al. (2020) In this paper, a novel natural gas-fired integrated solar combined-cycle power plant was proposed, evaluated, and optimized with exergy-based methods. The proposed system utilizes the advantages of combined-cycle power plants, direct steam generation, and linear Fresnel collectors to provide 475 MW baseload power in Aswan, Egypt. The proposed system is found to reach exergetic efficiencies of 50.7% and 58.1% for day and night operations, respectively. In economic analysis, a weighted average levelized cost of electricity of 40.0 $/MWh based on the number of day and night operation hours is identified. In exergoeconomic analysis, the costs of thermodynamic inefficiencies were identified and compared to the component cost rates. Different measures for component cost reduction and performance enhancement were identified and applied.

Omar J Khaleel et. al. (2020) In this paper, exergy analysis method is theoretically studied and modeled, and the exergy matrix equation is established. The exergy analysis method based on the second law of thermodynamics is studied and modeled, and the exergy matrix equation is derived. The main contents include: the overall analysis and partial quantitative analysis of the thermal system of the unit from the perspective of thermal equilibrium analysis, the exergy analysis of the thermal system under variable operating conditions from the perspective of exergy analysis, to find out the system's defects and deficiencies.

Maryam Fani et. al. (2020) In the present study, a new suggested sketch of adding latent heat storage (LHS) filled with commercial phase change material (PCM) to a 500-kW STPP case study has been investigated. Solar system details and irradiation amounts for a case study, including total and beam radiation have been determined. Also, the theoretical energetic and exergetic analysis of adding PCM storage to STTP is conducted, which showed a 19% improvement in the exergetic efficiency of the power plant to reach 30%. Besides, an optimized storage tank and appropriate PCM material have been investigated and selected concerning the practical limitations of the case study.

Bayu Rudiyanto et. al (2019) The exergy analysis of steam power plant system in PT. Jawa Power-YTL, East Java unit 5 was performed based on the first and second law of thermodynamics. Exergy flow and exergy efficiency were calculated for each component of the plant i.e. the boiler, HTP, IPT, LPT, deaerator, condenser, HPH, LPH, CEP and FWP. The exergy steam-flow of 970288 kW produced 610.000 kW of electricity with an exergy efficiency of 26.36%. Sankey diagram showed the exergy loss on each component of the steam power plant.

Eflita Yohana et.al. (2019) This research is used to analyze energy and exergy on the components of a steam power plant. From the results of this research, the largest of destruction exergy boiler is 881.08 MW and the exergetic efficiency is 48.66%. While the rate of the smallest destruction exergy in LPH 3 is 0.6 MW and the exergetic efficiency is 94.45%. The contribution of the largest Losses energy in the boiler is 231 MW and energetic efficiency is 87.05%. While the contribution of the smallest energy Losses in HPH 6 is 0.74 MW and energetic efficiency is 99.23%

Onyejekwe et. al. (2018) A component based energy and exergy evaluation was performed on a 220MW thermal power plant in Nigeria. The component based exergy analysis examines and compares the energetic and exergetic performances of each component by identifying the deficiencies of each component. Design and operating data were obtained from Egbin power plant in Nigeria. The result of the analysis showed that the total exergy that was destroyed in the power plant was 400.015 MW. The major contributors to the exergy destruction in the power plant were the boiler (87%), the three turbines (a combined total of 9%) and the condenser (2 %).The effect of increasing the High Pressure turbine (HPT) inlet temperature at constant boiler pressure incresses the exergy efficiency of the component as well as the second law efficiency of the power plant, thus reducing the exergy destruction of the component.

Rakesh Dang et. al. (2017) In this paper, the energy and exergy analysis of a thermal power plant is done at two different loads i.e. 100% and 70% load. The energy and exergy at inlet and outlet point of each component is calculated and specified with the help of data taken from the plant. The first and second law efficiency for each component of thermal power plant is calculated separately for design and off design load. The analysis shows that at design load maximum amount of exergy destruction occurs in the boiler, which is around 42% of the total exergy produced by the burning of coal and maximum energy loss occurs in the condenser which is 68.79%. The comparison of the performance of Plant is done at design and off design load and it is found out that plant performance is better at design load than its performance at off design load.

Francis Chinweuba et. al. (2017) The current study is a comprehensive review of exergy analyses applied in the solid fuels heat and power sector, which includes coal, biomass and a combination of these feedstocks as fuels. The methods for the evaluation of the exergy efficiency and the exergy destruction are surveyed in each part of the plant. The current review is expected to advance understanding of exergy analysis and its usefulness in the energy and power sectors: it will assist in the performance assessment, analysis, optimization and cost effectiveness of the design of heat and power plant systems in these sectors.

Ravinder Kumar et. al. (2016) At a viewpoint of this, a comprehensive literature review over the years of energy, exergy, exergoeconomic and economic (4-E) analysis and their applications in thermal power plants stimulated by coal, gas, combined cycle and cogeneration system have been done thoroughly. This paper is addressed to those researchers who are doing their research work on 4-E analysis in various thermal power plants. If anyone extracts an idea for the development of the concept of 4-E analysis using this article, we will achieve our goal. This review also indicates the scope of future research in thermal power plants.

3. Conclusion

By the comprehensive survey of above papers it stated that the energy, exergy, exergoeconomic and economic analysis and their applications in thermal power plants by different fuel system have been done. Improvements in the performance of power plants were also highlighted. From the outcome of this study, combustion chambers were identified as the main contributors to exergy destruction owing to their associated high irreversibility. The equipment of the power plant has been analyzed individually. Values regarding heat loss and exergy destruction have been presented for each equipment. The main exergy loss were occurred in the boiler and the steam turbine in the system. The first and second law efficiency for each component of thermal power plant is also analysed.

References

1. Arpit, S.1, *, Kumar P.2 , Das, P.K.3 , Dash, “APPLICATION OF EXERGY ANALYSIS IN UNDERSTANDING THE PERFORMANCE OF A COAL-FIRED STEAM POWER PLANT (120 MW) WITH SINGLE REHEAT AND REGENERATIVE CONFIGURATION” Journal of Thermal Engineering, Vol. 9, No. 2, pp. xx-xx, March,2023

2. Omar J. **Khaleel** [a], Firas **Basim Ismail** [a], Thamir **Khalil Ibrahim** **"Energy and exergy analysis of the steam power plants: A comprehensive review on the Classification, Development, Improvements, and configurations"** **Ain Shams Engineering Journal, Volume 13, Issue 3, May 2022, 101640**

3. Xianzhi Tang, Gongxing Yan, "Conventional and advanced exergy analysis of a single flash geothermal cycle" *Geothermal Energy* **volume 10**, Article number: 16 (2022) Published: 08 September 2022

4. P. Stephan Heyns, Siamak Hoseinzadeh **Advanced Energy, Exergy, and Environmental (3E) Analyses and Optimization of a Coal-Fired 400 MW Thermal Power Plant.** *J. Energy Resour. Technol*. Aug 2021, 143(8): 082106 (9 pages) **Paper No:** JERT-20-1764 https://doi.org/10.1115/1.4048982

5. Osman Shamet* 1 , Rana Ahmed1 , Kamal Nasreldin Abdalla1 "Energy and Exergy Analysis of a Steam Power Plant in Sudan" African Journal of Engineering & Technology (AJET) AJET 3 (2021) 1 https://doi.org/10.47959/AJET.2021.1.1.4 Accepted for publication 25 April 2021

6. Abdullah Duzcan, Yusuf Ali Kara "Exergoeconomic and exergoenvironmental analysis of a coal-fired thermal power plant" *Journal of the Brazilian Society of Mechanical Sciences and Engineering* **volume. Published: 15 November 2021**

7. Davor Poljančić, Vedran Mrzljak, "Energy and exergy analysis of a nuclear power plant" Student Scientific Conference RiSTEM 2021, Rijeka, 10. 06. 2021

8. **Aisha Saad, Ejeheri V. Oghenemarho "EXERGY ANALYSIS OF A GAS TURBINE POWER PLANT USING JATROPHA BIODIESEL, CONVENTIONAL DIESEL AND NATURAL GAS"** 5-6th Thermal and Fluids Engineering Conference (TFEC) May, 26–28, 2021

9. Munshi Ilyas Habib, Dr. Rakesh Kumar Jain, "ENERGY, EXERGY AND ENVIRONMENTAL IMPACT ANALYSIS OF 125 MW COAL FIRED THERMAL POWER PLANT" © 2020 JETIR December 2020, Volume 7, Issue 12

10. Altug Alp Erdogan; Mustafa Zeki Yilmazoglu, "Exergy Analysis of Hot-Windbox Repowering Option For A Coal-Fired Thermal Power Plant" 2020 5th International Conference on Smart and Sustainable Technologies (SpliTech)

11. Louay Elmorsy,[1] Tatiana Morosuk, "Exergy-Based Analysis and Optimization of an Integrated Solar Combined-Cycle Power Plant" Published online 2020 Jun 13. doi: 10.3390/e22060655

12. Omar J Khaleel, Firas B Ismail, Thamir K Ibrahim "Thermal Performance Analysis Of Steam Power Plant Based On Exergy" INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 9, ISSUE 09, SEPTEMBER 2020

13. Maryam Fani, Nima Norouzi "Energy, Exergy, and Exergoeconomic Analysis of Solar Thermal Power Plant Hybrid with Designed PCM Storage" **International Journal of Air-Conditioning and RefrigerationVol. 28, No. 04, 2050030 (2020)**

14. Bayu Rudiyanto[1], Tri Ajeng Kusuma Wardani[1], Saiful Anwar "Energy and Exergy Analysis of Steam Power Plant in Paiton, Indonesia" **Citation** Bayu Rudiyanto *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **268** 012091

15. Energy and Exergy Analysis of Steam Power Plant 3rd Unit PT PLN (PERSERO) Centre Unit Generation Tanjung Jati B Use BFP-T Modification Cycle MSK. Tony Suryo, Eflita Yohana, Syarif Dwi Priyanto. E3S W eb of Conferences 125, (2019) https://doi.org/10.1051/e3sconf/2019125 ICENIS 2019 13003 13003

16. **M. N. Eke1, D. C. Onyejekwe. "ENERGY AND EXERGY EVALUATION OF A 220MW THERMAL POWER PLANT" Nigerian Journal of Technology (NIJOTECH) Vol. 37, No. 1, January 2018, pp. 115 – 123**

17. Rakesh Dang1 , S.K. Mangal1 , Gaurav2 "Energy & Exergy Analysis of Thermal Power Plant at Design and Off Design Load" DOI:10.17148/IARJSET.2016.3507. October 2017

18. **Francis Chinweuba Eboh, Peter Ahlström, Tobias Richards "Exergy Analysis of Solid Fuel-Fired Heat and Power Plants: A Review"** *Energies* **2017**, *10*(2), 165; **https://doi.org/10.3390/en10020165 Accepted: 19 January 2017**

19. Ravinder Kumar "A critical review on energy, exergy, exergoeconomic and economic (4-E) analysis of thermal power plants" Engineering Science and Technology, an International Journal journal homepage: www.elsevier.com/locate/jestch (2016)

20. **S.O.Oyedepo, "Exergy costing analysis and performance evaluation of selected gas turbine power plants" Published online:30 Nov 2015**