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A Review on Optimization of Steam Generator in Thermal Power Plants by Reduction of Unburned Carbon

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ABSTRACT

Modern electricity consumption is rising, which has increased the need for better power-producing technology, particularly in emerging nations like India. The urgent need to reduce greenhouse gas emissions can be met by significantly increasing the coal-fired power stations' efficiency. The operation of a boiler that is not optimized can result in a variety of problems, including decreased boiler efficiency, increased surplus air needs, delayed combustion, increased heat rate, high CO and NOx emissions, and more. Today, every thermal power plant must priorities optimizing combustion in pulverized coal-fired boilers. The quality of the coal, the fineness of the pulverized coal, the burner tilting angle, the air fuel ratio, and the production of slagging and NOx all have an impact on the combustion in a pulverized coal fired boiler. The review of several optimisation methods has been completed.

Keywords – Wear Rate, Pin, Disc, Load And Speed.

I. INTRODUCTION

The expansion of the world's energy consumption has slowed, and in 2019, coal-based power output decreased by 3%. Nevertheless, with 36% of all power generated coming from coal, it continues to be the world's leading energy source for producing electricity. The three primary types of pulverised coal (PC) boilers in Asia are tangentially fired down-fire and wall-fire. The tangentially fired boiler offers the potential benefits of flexible coal use, air-staging combustion to reduce gas emissions, and improved combustion efficiency among others[1][2] [3].. Tried to implement a comprehensive programme for power plants to reduce emissions to extremely low levels. The nitrogen oxides and sulphur oxides emission limitations are 50 ppm and 50 ppm, respectively. In order to comply with stringent emission standards [4] [5]. Literature survey has been done to understand the different work which already done in the field of optimization of steam generator. Various work has been done for optimization of unburned carbon using artificial neural network model (ANN). Detail study

of these papers help a lot in our present work problem formulation[6].

II. LITERATURE REVIEW

Viet Thieu Trinh et al. In order to determine the optimal operation condition based on CFD models, we examined the NOx mechanism and char burnout in the real-scale biomass sample in six situations in connection to the effect of the secondary air ratio and placement of the burner standby. These are the outcomes: (1) The SAR and burner standby positions generally had an impact on the particle release at the hopper output, with poor char conversion of 35.0 to 60.0% and high biomass ash. (2) Based on the findings of the standard deviation temperature, the optimal air and biomass combination under the impact of SAR (from 30 to 50%) was 40%. (3) In addition, the burner A standby with 40.0% SAR was the ideal scheme case after comparing six instances based on the char conversion, NOx emissions. Wall evaporator, platen, and superheater heat exchangers were affected by slagging and fouling during operation. The temperature settings and ash particle trajectories used to calculate the ash deposition rate were very close to those of the heat exchanger. The tendency towards relatively high temperatures may help with the deposition issues that biomass boilers have. This study is also a step towards reducing the corrosion and fouling brought on by the burning of renewable fuels [1].

Prosper Ndizihiwe et al. The techniques mentioned by the many writers under evaluation improved the air-fuel ratio specifically and the boiler's ideal operating circumstances generally. To further improve the boiler's efficiency, there is still additional work to be done. This may be accomplished by maintaining the AFR very near to the stoichiometric value, reducing gas losses to the absolute minimum, and making the system temperature sensitive. Diverse studies in the literature shown that a rise in temperature increases the boiler's efficiency, but they didn't look into the point at which it becomes negative; that limit would be investigated. Better performance may be obtained by combining the algorithms for separating oxygen from the air ([23]) and the control ([13]) and altering the control to the method ([22]) provided. The literature justifies the decrease of losses owing to the temperature reduction that produces minimal exhausts in the situation of the dependency of the meteorological condition, specifically the temperature change. When analysing the instance of Rwanda, temperature data will be used to determine the actual change in boiler efficiency for each degree Celsius rise in temperature while holding other independent factors of the efficiency constant. If the temperature is predicted to vary in some way to account for the necessary demand, it will be important to determine what can be done with another variable [2].

Hyunbin Jo et al. In order to optimise the air distribution with a separated over fire air installation, the performances of a 500MWe tangential-firing coal boilers was examined in this study. The reference scenario was developed with the use of CFD, and various air distributions were assessed for important performance factors. Because the NO reductions processes were more actives inside the burner zones, increasing the separated over fire air ratio reduced NO emission. However, excessive separated over fire air ratios increased the likelihood of corrosion and slagging while having a detrimental influence on the boiler's performance. The NO reductions were also active between the separated over fire air level and close-coupled over fire air level with a modest amount of air staging, allowing the OFA distribution to be optimised for both optimal boiler performance and a low NO output. Due to insufficient mixing between the char particles collected along the wall and the powerful air jets reaching deep into the core, too high close-coupled over fire air or separated over fire air ratios at the set OFA ratios quickly increased the unburned carbon. The allocation between close-coupled over fire air and separated over fire air had no

discernible impact on the heat absorption pattern or boiler efficiency [6].

Wook Kim et. al. The usage of NOx control retrofits has recently dramatically increased as a result of greater regulatory tightening brought on by global environmental concerns. The majority of generators include SCR or OFA systems, with some generators having both systems, to minimise NOx emissions. Here, we provide experimental support for increased boiler efficiency with effective NOx management that takes into account impacts on unburned carbon, provided that the boiler complies with all applicable local, state, and federal emissions regulations. By improving OFA and cutting back on surplus air, a newly installed SCR system has been able to attain a greater boiler efficiency. A 500 MW coal-fired boiler was used for the test, which lasted six months. At a nominal rating of 500 MW, stepwise shutting of the OFA dampers was performed both with and without concurrent surplus air optimisation. We verified that the following advantages result from our new operation: A decrease in UBC owing to a higher main combustion zone temperature in the boiler, a better flyash recycling ratio, a decrease in spray water entering the reheater due to a lower second combustion zone temperature, and a decrease in exhaust gas loss. As a consequence, UBC has decreased by 0.8% and boiler efficiency has enhanced by up to 0.4%. In conclusion, we verified that under operational conditions involving both mixed coal burning and freshly installed SCR systems, our new operation mode improves boiler efficiency [3].

Tharayil James Joseph et al. The following findings may be obtained from analysing the literature on coal burning boiler combustion optimisation. It is possible to analyse the boiler unit's performances, including its working circumstances, nitrogen oxide emissions, and thermal efficiency. There are significant discrepancies between burning coal and design coal as a result of coal diversification, which has an impact on operating safety. The properties of coal may be examined at the rated load. In the article, three mixed coals were experimentally and chosen investigate by industrial and elementary analysis. The findings showed that under the condition of the experiment and the severity of the slag, three mixed coals were delivered in a serial arrangement. Compared to mixed coal B and C, mixed coal A had a greater boiler efficiency. An alternate method of modelling process behaviour is provided by artificial neural networks (ANN). It is founded on the practise of removing embedded patterns from data that represent the connection between input and output in any process phenomenon. It can analyse information quickly, handle complicated and non-linear issues, and decrease the amount of technical work needed for model creation. With the aid of various algorithms, such as the Cellular Genetic Algorithm, Archive-Based Hybrid Scatter Search, Multi Objective Particle Swarm Optimizer and Strength Pareto Evolutionary Algorithm for Multi Objective Optimisation, comparisons in terms of divergence, accuracy and quality can be made. It is stated that the ANN approach is more practical and straightforward when compared to other modelling techniques, such as the CFD approach, and may produce good prediction effects under a variety of operating situations. However, ANN also has its limits. Due to the trial-and-error method, network construction for big projects is challenging and time intensive. A clear logical network might be difficult to design. Personnel skilled in the network approach is required for network planning and deployment [5].

Byoung-Hwa Lee et al. A power generation boiler cannot run at full capacity during the deep peak phase of the grid load. Different operational parameters have been analysed and optimised in order to achieve stable combustion of a 550.0 MW tangentially fired pulverised coal boiler and ultra-low pollutant emissions under half-load circumstances. In this work, the combustion stability, pollutant emissions and boiler's flow field characteristics were simulated under

half-load circumstances using the numerical technique. Different burner group configurations, separated over fire air/close-coupled over fire air distributions, and surplus air ratios were all part of the operating circumstances. The middle burner group layout has an excellent flow field distribution, according to the findings of the simulation's forecast. This maintains a greater rate of pulverised coal burnout than the lower burner group configuration while reducing NOX by around 62.0 ppm in comparison to the upper burner group arrangement. The ratio of close-coupled over fire air of 5.0% and separated over fire air of 15.0% was recommended as the operating parameters for the air-staging distribution due to the stability of the combustion and lowest emissions. While the combustion temperature in the boiler dramatically decreased due to the excessive surplus air, the boiler exit gas temperature was too low, which had an impact on the steam temperature. Additionally, the field test results and the modelling results of the optimised system agreed well. [4].

C.S. Baladhiya et al. For the thermal processing of dairy and food products, steam is a common heating medium. The natural gas, the fuel oil, the Coal, the biogas, and other forms of fuels are used in boilers to create steam. There is a need to reduce energy use in light of the recent drop in fuel availability and sharp increase in fuel price. Including the combustion process, monitoring of flue gas temperature, Regular monitoring of operational parameters, excess air management, routine maintenance, water treatment, etc., is essential for effective steam production. The optimisation of the steam producing system necessitates a fundamental understanding of the numerous performance-affecting factors. Modern boilers contain automated controls that increase boiler efficiency by maximising operational parameters needed for safe fuel operation and an effective combustion process. Boiler operation under ideal circumstances not only lowers the cost of producing steam but also lowers air pollution. [7].

A. Sivakumar Power is a crucial component of every nation's growth. In India, thermal power plants produce around 64% of the country's electricity. Thermal power stations generally use fossil fuels like coal and oil. In order to evaluate the functionality of the 210 MW Boiler, a research was carried out at the Mettur Thermal Power Plant. The unburned fuel is the main factor for the boiler's planned efficiency to differ somewhat from its calculated efficiency. Extra air was provided to the boiler to prevent unburned fuel in order to increase boiler efficiency. A research was done in which the boiler's efficiency was calculated by adjusting the amount of extra air from 10% to 31% at 3% intervals. The amount of extra air is optimised [8].

Yiding Zhao et al. In order to maximise the unburned carbon and thermal efficiency and in fly ash of a coal-fired utility boiler, this research suggests an ANN-GWO technique. Mathematical models of thermal efficiency and unburned carbon in fly ash are developed using ANN. Both models estimate thermal efficiency and unburned carbon with a high degree of accuracy. A coal-fired utility boiler's air distribution is then optimised using the GWO algorithm to increase thermal efficiency and decrease unburned carbon. The usefulness of the GWO method was proven by the optimisation outcomes of test cases. The effectiveness of GWO is also further examined by contrasting its optimisation outcomes with those of the PSO and GA techniques. It has been demonstrated that GWO can produce more stable solutions and increase thermal efficiency to a greater degree. The GWO algorithm optimisation, on the other hand, needs less time to run and is ideal for online applications. The findings of this research improve boiler combustion optimisation performance and shorten optimisation runtime. Future studies should take into account changes in the coal's characteristics and some severe operating

situations to minimise experimental performance mistakes [9].

Herminé Nalbandian et al. In order to increase capacity, efficiency, and performance, decrease operating and maintenance costs, improve dependability and availability, and/or ensure compliance with more stringent environmental regulations, it may be cost-effective to upgrade older power plants. The potential and commercial opportunities for modernising traditional pulverised coal-fired facilities are covered in this research. It encompasses NOx abatement and control methods, particle control, flue gas desulphurization, and the retrofitting and upgrading of pulverisers and their fuel distribution system. Also mentioned is process optimisation to reduce pollutant generation and increase boiler effectiveness. Circulating fluidized bed boilers and the use of a natural gas turbine to create a combined cycle are the two repowering alternatives described. For each of these possibilities, a case study of a renovated or repowered facility is provided. Every power plant, however, is likely to have varied needs and technical conditions. Therefore, before any significant performance improvement plan is offered, extensive technical, economic, financial, legal, and environmental evaluations must be conducted on each eligible facility. If the temperature is predicted to vary in some way to account for the necessary demand, it will be important to determine what can be done with another variable. [10].

Walsh, et al. In this discussion on the physical distributions of particle size of coal, residence time of coal in furnace , and mixture of air and fuel for modelling of evaluating Unburned carbon loss.. In this study model has been develop to know the how quantity and size of coal distribution affect the unburned carbon in ash. Coal characteristics like ash content moisture and volatility also affect the burning of coal larger extent. Sensitivity of Coal and Air Flow Balancing on Combustion. Research paper publish in EPRI The objectives of this work are to determine the effect of coal and air imbalance on boiler performance and emissions, to determine the amount of fuel flow control that adjustable coal flow distributors can induce, and, if possible, to determine the effect of those adjustments on air flow. [11].

Saeid R. Dindarloo, et. al. [5] Predicted the carbon content which remain un burned in both fly fly ash and bottom ash. It is a valuable index in both designing and optimization of thermal power plant. In this study it is highlighted the use of supported regression vector method of study for finding unburned carbon content in fly ash. In this study it is also highlighted that even one percent reduction in unburned carbon substantial saving in coal consumption. It also highlighted that by reducing we able to increase boiler efficiency hence reduction in environmental pollution.

Yan Shi, et. al. [6] Combustion optimization of USC boiler based on AI method for optimizing the combustion in USC steam generator has been developed in 660 MW supper critical power plant .In this study Artificial Neural Network optimization technique are used to predict the operating condition which give best result and minimum losses in steam generator. To enhance the boiler best optimization model, computational fluid dynamics simulation model has been generated to train ANN such that real relationship can be developed. All input and output data which is used for training are historical data. In put used in ANN are the total coal flow, unit load, total coal flow, air distribution and boiler efficiency. Based on ANN model, GA is used to optimize various input parameter. The prediction of boiler efficiency and NOX emission depend on the how the input data taken for training. This application can be used in practical problem formulation in mlti objective function to give better result and improved boiler efficiency.

Francesco floris. For applications to gas turbine-steam turbine combined engines, the ignition stability,

combustion efficiency, CmHm, NOx and CO profiles of experimental combustors were examined in a 15 Kg/h pulverised fuel two-dimensional furnace under oxygen-lean and variable excess vitiated air conditions. Investigations were conducted on domestic bituminous coal extracted in Sardegna. In order to prevent a carbon loss of more than 3.0% wt. and unstable flame production, the results suggest that the oxygen content in the primary stream must fall below 17.0% and total vitiated air excess must be kept above 30.0%. The tests conducted show that an amount of 15.0% oxygen is sufficient to support a steady flame with over 0.97 combustion efficiency, provided that the proper swirl generator is used and that the total excess of oxidizer is above the limit of 30.0%. The secondary air oxygen content has a less significant impact on combustion efficiency. A technique of successfully producing swirling turbulent coal flame and smoke, CO, and unburned hydrocarbons under climatic circumstances using secondary vitiated air temperature and an inertial vortex generator [12].

Peter M. Walsh, et al. Given that the quantity of unburned carbons in fly ash from pulverised coal-fire boiler is such a negligible part of the combustibles in the fuel, rather than being a normal characteristic of the fuel and boiler, its origin is typically in atypical attributes of the fuels and boilers. This issue has been approached from the perspective of reactor engineering, which takes into consideration that produced 136 000 kg of steam per hour (h-1'). The size distribution and amount were used to gauge how effectively the simulation of char combustion worked. The distribution of residence time in the boiler and the mixing of the coal and air are crucial factors in the calculation, without which it is impossible to explain why there are little unburned particles in fly ash. The calculations need the following information about the coal and the plant: proximal and ultimate analyses, excess oxygen, screen analysis of the pulverised coal, heating value, furnace exit gas temperature, furnace dimensions, air preheat, and a representative sample of fly ash. The carbon content of the fly ash samples was calculated for each size cuts after screening. The models accurately captured the observe relationship between grind and volatile matter and the volume. The rate coefficient for char combustions, the mixtures of air and fuel at the ends of volatile flame, the typical mixed duration in the post-flames zone, and the average gases temperatures in the boiler are the main variables that may be changed in the calculation. The sluggish char combustions rates necessary to suit the results shows that unreactive char may have contributed disproportionately to the unburned, even if particles-to-particles variations of char reactivity were not added. The model is consistent with Babcock and Wilcox's findings about the reliance. The Wilcox and Babcock correlation is more sensitive to extra air than the model, though [11].

H.K. Ma et. al. When Australia Woodland coal and blast furnace gas were cofired in one of the China Steel company 55MWe tangentially fired boilers, a major carbon burnout issue resulted. In order to investigate the possible effects of BFG cofiring on flow pattern, temperature and flue gas residence time, both computational calculations and experimental work calculations were done. An isothermal flow model of a CSC boiler with a 1/12 scale factor that uses air as the working fluid is constructed in experimental research to examine the flow processes. In order to maintain the turbulence in the model, the Reynolds number base on burners diameters is maintained above the crucial values of 25,000. The mean velocity is determined by use of a five-hole pitot tube. As tracers for the qualitative measurement of the flow field, monosize helium bubbles are also included into the model. A 2-D furnace heat transport and combustion model was used in numerical calculations to evaluate the performance of the furnace. Model predictions were used to identify and analyse boiler operational characteristics that have an

impact on the amounts of ultimate carbon burnout [13].

A.M. Dubinin et al. The study discusses the production of synthesis gases for electrochemical generators using autothermal steams gasification of coals from Borodino deposit. The boiler and battery of SOFC used to heat the cathode air and produce superheated waters steams for a gases generator have their thermal balances summarised here. On the basis of these balances, the temperature in the anode, the electrical efficiency, the loss through flue gases and to the environment through the thermal insulation, as well as the fuel cell EMF, has been estimated. Additionally, the precise amount of Borodino coal used to generate thermal and electrical power has been established [14].

Jiseok Lee et. al. With modest equipment changes, biomass may completely replace coal in an existing power station for the generation of renewable electricity. A 125MWe power station in Korea that mostly burns anthracite was recently modified for specialised wood pellet combustion with a switch from arch firing to wall firing in the boiler layout. However, this boiler experiences operating issues since the bottom ash has large levels of unburned carbon (UBC). In this study, several strategies to cut NOx emissions while reducing unburned carbon release are investigated. For typical operational data, the computational fluid dynamics technique was developed and verified. It was then used to analyse operational factors for increasing boiler performance as well as to clarify the flow features causing and particles combustion the high unburned carbons contents. It was discovered that the high unburned carbon contents in the bottom ash was a results of the arch-firing boiler's large burner zone's low gas velocity and poor fuel grindability. The operations with deeper air staging for reduced NOx emissions was therefore precluded. The only practical method for decreasing the unburned carbon and NOx emission with deeper air staging and improving boiler efficiency was to reduce the particle size to 1.50 mm by altering mills or pre-treating the fuels use Torre technology [15].

Dennis Johnston et al. The ash reburn systems, which is discussed in this article, was created in response to the growing need in the wood burning sector for boilers that burn existing wood fuel more efficiently and with less ash. On earlier boiler designs, improvements in conventional ash reinjection or overfired air systems would not produce the large improvement that are presently required, according to experience in wood and fuel burning as well as customer comments. As a result, a method that uses a tandem with the current stoker was devised. In turn, the current boiler recovers the heat produced by the reburn cell. The system that will be covered is made up of an ash reburn cell, which receives ash from an existing ash handling system that has been modified to redirect ash to the chambers, intake air ducting, controls and output gas breeching. A separate combustions air fan is used to supply the combustion chamber with combustion air [16].

Fan Peng et al. We have created two measurement systems that can operate in the 12 to 15 GHz band, one base on the free spaces approach and the other based on the waveguide method, to compare the performances of various microwave measuring techniques in unburn carbon content estimation. Samples of fly ash with unburn carbon contents ranging from 0 to 20% are measured. Additionally, this research explicitly examines the waveguide technique test results in the 0 to 2% low unburn carbon content region. To assess these approaches, the measure accuracy and measurement range are examined. Compared to the waveguide approach, the free space method can achieve a larger measuring range of unburn carbon content. To assess accuracy under various test modes, the inaccuracy of unburn carbon content is employed as an accuracy indicator. The results of the estimated accuracy indicators can support the assertions below [17].

Gang Pan et al. The aim of this work is to improve the measurement accuracy and precision of unburned carbon content in fly ash samples by using LIBS in air at atmospheric pressure. Firstly, the carbon emissions detected from fly ash plasma were characterized to combine the atomic and molecular carbon emissions (C&CN) for establishing calibration model. Secondly, the matrix effect of the fly ash samples is presented to find that the necessity for correcting the influence of plasma temperature on the measurement. Thirdly, the correction factor was calculated under different laser energy by using the Mg intensity ratio. At last, the quantitative analysis model with plasma temperature correction is established for the measurement of unburned carbon content in fly ash samples. The coefficient of determination, R, reaches 0.9989, and the absolute error is less than 0.06%, the relative standard deviation is less than 4.7% [18].

A. Schneider et al. In international journal published prediction and monitoring of UB in FA in steam generator. High UC in fly ash is always undesirable because the carbon represents unburned because of this decree in boiler efficiency. Moreover, thus, to satisfy all of the aspects above, modern control techniques need accurate and reliable models which can be provided in near real-time basis. As well-known, the amount of unburned carbon is strongly affected by fuel properties, combustion conditions and mechanical aspects of boiler. However, due to complexity of combustion process, it is difficult to model UBC in FA and BA are related to fuel properties, combustion conditions, boiler configuration and unmeasured variables/disturbances using physical modelling approach [19].

III. CONCLUSION

The following findings may be obtained from analyzing the literature on coal burning boiler combustion optimisation.

- The new combustion control scheme known as Radiant Energy Signal (RES), which is based on flame image processing, is very beneficial in enhancing the performance of installed power plants because it looks into the use of flame images collected in a boiler to provide information on the internal state and it forecasts the ideal air fuel rate, which ensures stability of load and main steam pressure. It is possible to analyse the boiler unit's performances, including its working circumstances, nitrogen oxide emissions, and thermal efficiency.
- There are significant discrepancies between burning coal and design coal as a result of coal diversification, which has an impact on operating safety. The properties of coal may be examined at the rated load. In the article, three mixed coals were chosen and experimentally investigated by elementary analysis and industrial analysis. The findings showed that under the conditions of the experiments and the severity of the slag, three mixed coals were delivered in a serial arrangement. Compared to mixed coal B and C, mixed coal A had a greater boiler efficiency.
- An alternate method of modelling process behaviour is provided by artificial neural networks (ANN). It is founded on the practice of removing embedded patterns from data that represent the connection between input and output in any process phenomenon. It can process information quickly and handle complicated and non-linear issues, which lowers the amount of engineering work needed for model building.
- Different algorithms, such as the Strong Pareto Evolutionary Algorithm, Multi Objective Particle Swarm Optimizer, Archive-Based Hybrid Scatter Search, and Cellular Genetic Algorithm for Multi Objective Optimisation, can be used to compare quality, divergence, and accuracy. This will help determine the best algorithm to reduce nitrogen oxide emissions and unburned carbon in fly ash

under various operating conditions.

- It is stated that the ANN approach is more practical and straightforward when compared to other modelling techniques, such as the CFD approach, and may produce good prediction effects under a variety of operating situations. However, ANN also has its limits. Due to the trial-and-error method, network construction for big projects is challenging and time intensive. It is challenging to create a logical network that is apparent. Personnel that have been trained in the network approach are needed for network planning and implementation.

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