International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 11, pp 205-210, November-2024

https://doi.org/10.47001/IRJIET/2024.811025

Operation Analysis of Cofiring Wood Biomass Based on 330MWe PC Boiler

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Abstract **- The purpose of this research is to analyze operating parameters and flue gas emissions of 330 MWe coal fired power plant Pulverized coal boiler type on cofiring test, using wood biomass based, compared to low range coal firing operation. Wood biomass based was chosen because it is most widely available and has great potential to reduce emission and achieve the target of increasing NRE.**

The biomass percentage for coal substitution is 5% wood pellets and 5% sawdust. Each scenario was tested at a load of 310 MW gross for 6 hours of operation. Direct cofiring was used in this experiment. Coal and Biomass blended at the coal yard, then through the fuel feeder enters to the pulverized mill evenly to be burned in all positions of furnace burner. The main operating parameters of the biomass cofiring test are mill current, mill outlet temperature, Furnace Exit Gas Temperature (FEGT) and unburned carbon. The environmental impact analyzed are SO_2 and NOX emission on exhaust gas.

Compared to coal firing operating parameters, all biomass cofiring experiments are still within safe limits for operation. The average mill current & MOT has increased but still within the maximum operating limits 40 ampere & 65℃. The average FEGT has decreased but still within maximum operating limit below 1200℃. SO_2 and NOx flue gas emission parameters for all cofiring experiment did not show significant changes compared to coal firing operation. Through CEMS equipment, coal firing and biomass cofiring tests are monitored while comply to government regulations with a maximum value limit of 550 mg/Nm^3 for coal fired power plant.

The results of this research can be a consideration for implementing biomass cofiring in safe conditions for operating and environment parameter for maximum percentage of 5% wood biomass based without equipment modification in similar capacity pulverized coal fired power plant.

Keywords: Biomass Cofiring, Wood Pellet, Pulverized Coal Boiler, Operations, Emission.

I. INTRODUCTION

To reduce greenhouse gas (GHG) emissions, the Indonesian government is committed to decrease use of fossil fuels by setting a new & renewable energy target of 23% in the national energy mix until 2025 [1]. However, this target is not easy to achieve, the Ministry of Energy and Mineral Resources said that the NRE mix at the end of 2023 has only reached 13.1%.

Specifically in the energy sector, the emission reduction target is 314 million tons CO2.e or 11% of the total 29% GHG emission reduction target in 2030_from Business as Usual (BaU). In order to achieve this target in Electricity Supply Plan, State Electricity Company (PLN) plans to reduce emission by building 16.7 GW renewable energy's based power plants, converting fuel from high-speed diesel to biodiesel B20 to B30, providing roof top solar PV to the customer and green booster program which contain implementation of co-firing with biomass in coal fired power plant. [2]

The dependence of electricity production in Indonesia on coal fuel and also the high cost of investment to build renewable energy-based power plants is challenge. PLN operates coal-fired power plants with a total capacity of 18,895 MW on 52 locations throughout Indonesia, and 82% from total capacity is Pulverized boiler (PC) type. Cofiring 12% biomass in coal-fired power plants has the potential to produce 11.8 TWh of green energy and 10.75 million tons CO2.e emission reduction per year or contribute 3.59% to the NRE mix in 2025.

Implementing biomass cofiring in existing coal fired power plants is the most effective step to achieve the target of reducing emissions [3] and increasing NRE, especially in Pulverized Coal (PC) boiler power plant which have a larger capacity than CFB and Stoker boiler type. Biomass cofiring studies in sub-bituminous PC boilers power plant using 5%

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wood pellets percentage has been carried out [4] [5], but low economic value and more sustainable availability of industrial wood products/waste biomass (sawdust) cofiring really needs to be studied. Wood industry by product (sawdust) which lower quality characteristics than low range coal can be used as an alternative to biomass cofiring because it is widely available in tropical country.

In this paper, we show that lower economic quality of biomass can applied for cofiring in PC sub-bituminous power plant up to a certain percentage, according to suggestions from this study [6]. Method of this study is combination of laboratory tests of coal and biomass characteristics and firing eksperiment on power plant to analyze the operating parameters and emissions of cofiring biomass compared to normal coal firing 100% coal operation. Table 1 shows coal firing and biomass cofiring test scenarios on observations of operating parameters and flue gas emissions.

Table 1: Coal Firing & Cofiring Eksperimen Scenario

Eksperimen	Fuel	Analysis Parameter
Coal firing	100% Low Range Coal	Operation & Emision
Cofiring	5% Wood pellet	
	5% Sawdust	

II. MATERIAL AND METHOD

2.1 Study Area

Biomass cofiring eksperiment was carried out at the 3x330Mwe capacity sub critical pulverized coal boiler type. Boiler specification is BGWB-1050/18.44-M, Natural Circulation, Single Drum Once-through Middle Reheater, Front Rear Wall Combustor with DRB-XCL Burner specifications and Manufacturer by Babcock & Wilcock Beijing Co, Ltd. Sub bituminous low range coal of 4200 kcal/kg calorific value average is typical fuel of the power plant.

2.2 Biomass Cofiring Test Method

Cofiring is the burning of two (or more) different types of material at the same time [7]. In electricity or power generation, the term of biomass cofiring is the process of fuel partial biomass subtitution for coal fired power plant.

There are 5 biomass cofiring scenarios in conventional boilers as shown in Fig.1 [8]:

1. Pre-mixing biomass and coal, milling process and combustion of the fuels through the existing coal pipe.
2. Biomass through separate milling process and move directly into the existing coal pipe.
3. Direct injection of biomass into furnace with coal burner modification.
4. Biomass gasification, and gas (syngas) combustion in boiler.
5. Biomass torrefaction to increase the calorific value before pre-mixing with coal.

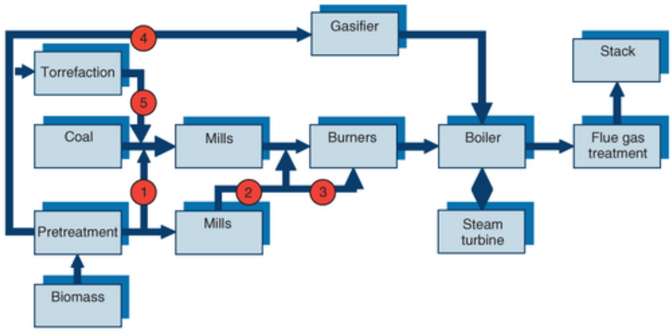

Figure 1: Biomass Cofiring Scenarios for conventional boiler [8]

The cofiring method used in this experiment is the first scenario or direct cofiring. The biomass is treated via the same or different grinding and feeder equipment, and then combined with coal into the same boiler for combustion, while the coal and biomass may use the same burner or individual ones [9]. There will not be specific equipment cost with this approach that it is the most direct and cost-effective way of cofiring and most widely adopted way of less than 10% biomass ratio on PC Boiler.

2.3 Fuel Characteristics

The characteristics of coal and biomass fuel are analyzed through laboratory tests using the Proximate and Ultimate Analysis methods to determine the physical properties and chemical content. Proximate Analysis is an analytical approach regarding the energy content of biomass through parameters such as the amount of carbon, volatiles (decomposed hydrocarbons), moisture (moisture or water content) and ash in terms of mass percent. Ultimate Analysis is a detailed analysis that defines the energy content of biomass in the form of the chemical composition of its constituents such as the values of C, H, O, N, Sulfur, Chlorine and several other minerals. The C, H, O values in ultimate analysis are a detailed form of carbon, volatile and moisture values in the proximate. Meanwhile, some mineral elements are detailed forms of ash. [10] Laboratory sample tests purpose of coal and biomass is to find out the differences of energy content, and also to analize the substances contained in the fuel and the substances formed as a result of combustion, so potential risk for slagging, fouling, agglomeration and corrosion in the boiler can be estimated. Table 2 shows fuel characteristics of laboratory test results in the form of ultimate analysis, proximate analysis and heating value.

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Table 3 shows the content of ash analisys of coal and biomass fuel material for experiments.

Table 2: Ultimate & proximate analysis of coal and biomass characteristics

Analysis (as Received Basis)	Unit	Sub Bituminous Coal	Wood Pellet	Sawdust
Ultimate				
Carbon	%wt	45.02	45.53	20.83
Hydrogen	%wt	3.23	6.31	2.52
Nitrogen	%wt	0.82	0.3	0.42
Sulphur	%wt	0.31	0.08	0.01
Oxygen	%wt	12.91	n/a	n/a
Proximate				
Total Moisture	%wt	32.82	8.59	51.42
Ash Content	%wt	4.89	1.3	7.57
Volatile Matter	%wt	31.45	74.05	32.97
Fixed Carbon	%wt	30.84	16.06	15,39 (adb)
Total Sulphur	%wt	0.31	0.08	0.01
Gross Calorific Value	kCal/kg	4243	4613	1944
Hargrove Grindability Index	Point	53	18	< 32

Table 3: Ash analysis of coal and biomass characteristics

Analysis (as Received Basis)	Unit	Sub Bituminous Coal	Wood Pellet	Sawdust
Ash				
Silicon Dioxide, SiO2	%wt	44	43.32	32.84
Aluminium Oxide, Al2O3	%wt	19.92	11.1	0.64
Ferric Oxide, Fe2O3	%wt	10.5	8.9	3.45
Calcium Oxide, CaO	%wt	4.28	20.62	35.26
Magnesium Oxide, MgO	%wt	2.75	3.82	11
Sodium oxide, Na2O	%wt	1.41	1.28	1.02
Potassium Oxide, K2O	%wt	1.61	4.85	0.72
Titanium Oxide, TiO2	%wt	0.84	0.54	0.11
Manganese, MnO	%wt	0.13	0.167	11
Sulfur Trioxide, SO3	%wt	6.08	3.18	2.58
Phosporus Oxide, P2O5	%wt	0.058	1.312	1.13
Bulk Density	Kg/m^3	926.4	626	140.95
Chlorine, Cl_2	%wt	0.03	0.14	0.1

Coal and biomass material volume for coal firing and cofiring tests for 6 hours of operation per test, is calculated on 310Mwe load operation or approximately 210 tons fuel flow per hour. So, each variable experiment requires 1260 tons fuel material volume of as shown in Table 4. Data collection was carried out after the first hour stable operation of power plant.

Table 4: coal and biomass volume cofiring experiment

Experiment	Label	Cofiring Scenario	time *(hours)*	Volume *(Tons)*		
				Biomass	Coal	Total
1	100LRC	100% Low range Coal	6	0	1260	1260
2	5WP	5% Wood Pellet + 95% Low range coal	6	63	1197	1260
3	5SD	5% Sawdust + 95% Low range coal	6	63	1197	1260
Total			24	126	3654	3780

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2.4 Acceptance Parameter

The operating parameters observed were for the pulverized mill and boiler furnace: mill current, mill outlet temperature, Furnace Exit Gas Temperature, and unburned carbon. The environmental parameters observed are SO_2 and NOx emissions from combustion exhaust gases. Table 5 shows the recommended standard values of operating and environmental parameters.

Table 5: Operation and environment parameter coal firing limitation

Observation Parameters	Limitation *(maksimum)*
Furnace Exit Gas Temperature (FEGT)	1200 °C
Pulverized Mill Current	40 ampere
Pulverized Mill Outlet Temperature (MOT)	65 °C
Unburned Carbon	1 %wt
SO2 & NOx, Flue Gas Emision	550 mg/Nm3

III. RESULT AND DISCUSSION

3.1 Experiment Result

The results of the coal firing and biomass cofiring tests for each scenario experiment on the average current and outlet temperature parameters of the pulverized mill equipment are as in Table 6.

Table 6: Coal firing & cofiring pulverized mill experiment

Parameter *(average)*	Unit	100LRC	5WP	5SD
Mill Current	ampere	31,71	35,25	32,42
MOT	°C	60,6	63,74	61,06

Furnace exit gas temperature (FEGT) is an important physical parameter of energy conservation and environmental protection in a Pulverized coal-fired boiler plant. Table 7 shows the results of average FEGT observations of coal firing and biomass cofiring experiment taken from several different points in the furnace area.

Table 7: Coal firing and cofiring FEGT observation

Furnace Location	unit	100LRC	5WP	5SD
South East	°C	867	926	876
South Middle	°C	953	933	898
South West	°C	925	882	831
FEGT *(Average)*	°C	915	913	868

Unburned carbon testing is carried out to determine the carbon content that is not burned in the mix biomass and coal combustion process. Higher UBC values indicate that the fuel combustion process is less efficient, because more fuel is not converted into energy. Unburned carbon testing was performed on the bottom ash and fly ash samples from silo#2 for each coal firing and cofiring operation as shown in Table 8.

Table 8: Coal firing and cofiring unburned carbon test

Sample Location	unit	100LRC	5WP	5SD
Bottom Ash Silo#2	%wt	0,55	0,73	0,27
Fly Ash Silo#2	%wt	1,3	1,46	0,16

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Observation of exhaust gas emissions was carried out from *the continuous emission monitoring system* (CEMS) facility for SO_2 and NO_X parameters in the coal firing and cofiring biomass operation tests. The results of the observation of SO_2 and NO_X emissions in the exhaust gases of coal firing and cofiring operations of biomass can be seen in Table 9.

Table 9: Coal firing and cofiring flue gas emission observation

Emission	Unit	100LRC	5WP	5SD
SO_2	mg/Nm^3	120,84	101,32	106,30
NOx	mg/Nm^3	365,41	277,81	360,46

3.2 Discussion

1) Pulverized mill currant & outlet temperature

The Hardgrove Grindability Index (HGI) value of biomass is lower than coal, so biomass is more "clay" or not easier to grind. Monitoring of pulverized mill operations should be a concern, because HGI index design of pulverized mills operation of coal-fired power plants is ≥45.

The results of observation of mill current and average mill outlet temperature show a relatively small deviation compared to coal firing operations. From 5WP and 5SD cofiring tests, current mills were observed to be normal across all pulverized mills in operation.

Mill outlet temperature (MOT) cofiring biomass did not show a significant increase compared to coal firing operations. The average biomass cofiring MOT increased by 0.71°C - 3.54°C compared to coal firing operations. The increase in MOT is because the volatile matter content of biomass is higher than coal, so biomass substitution will increase the MOT. The MOT value ≥ 63.5°C must be monitored and lowered because of the potential for spontaneous combustion or explosion.

2) Furnace Exit Gas Temperature (FEGT)

FEGT is an important parameter for boilers. FEGT defines the heat absorption ratio by radiant heating and convective heating. FEGT control points also observe the potential for fouling of boiler tubes in convective areas. If the FEGT is above the initial deformation temperature (IDT), it has the potential to cause severe fouling of the boiler tube by molten ash. The temperature of the combustion gas when entering the superheater (SH) / reheater (RH) must also be monitored lower than the Ash Fusion (AFT) temperature.

From the results of coal firing and cofiring biomass testing, the analysis of FEGT parameters is as follows:

a) The average FEGT in all biomass cofiring tests of 5WP and 5SD tends to be lower than that of 100LRC. This is because the specific gravity of biomass is lower than the specific gravity of coal, so that biomass has burned earlier in the area before leaving the furnace boiler.

b) There was a deviation in the furnace boiler temperature on the east, center, and west sides during coal firing and biomass cofiring testing. This can be caused by several conditions, namely: differences in fuel calorific value, uneven fuel messing/fineness, non-uniform combustion air ratio (AFR) and MOT (temperature distribution to furnace) values from each mill, and also from the non-uniformity of furnace pressure.

c) Average FEGT testing of coal firing and cofiring of all biomass is still within the normal limits of operation below 1200°C.

3) Unburned Carbon (UBC)

From the results of the UBC test, it is known that the 100LRC and 5WP tests produce UBC fly ash that is slightly above the threshold of 1% value. In the 5SD cofiring test produced better UBC fly ash and conformed to the threshold standard.

The results of the UBC bottom ash test of 100LRC, 5WP, 5SD all show values according to the threshold standard. So that in general, cofiring with biomass of 5% wood pellets and 5% wood powder can burn well in the boiler.

4) Flue Gas Emission

The average SO_2 and NO_X emissions of biomass cofiring showed a lower tendency than coal firing. The emission values of SO_2 and NO_X coal firing and biomass cofiring still meet government regulations below 550 mg/Nm^3 at coal-fired power plants.

IV. CONCLUSION

From the results of coal fired power plants cofiring biomass simulation 5WP and 5SD are as follows: Operating and emission parameters of cofiring 5% wood biomass based observed mill current, mill outlet temperature, furnace exit gas temperature, and unburned carbon are still within safe limits for operation. The biomass cofiring can reduce SO_2 and NO_x flue gas emission. Cofiring up to 5% wood biomass based can

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Volume 8, Issue 11, pp 205-210, November-2024
https://doi.org/10.47001/IRJIET/2024.811025

implementing on 330 MWe capacity sub bituminous Pulverized coal boiler plant.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the contributions of PT. PLN Nusantara Power and PT PLN Energi Primer Indonesia.

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Citation of this Article:

Hermawan Donny Saksono, MSK Tony Suryo Utomo, & Rifky Ismail. (2024). Operation Analysis of Cofiring Wood Biomass Based on 330MWe PC Boiler. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(11), 205-210. Article DOI: https://doi.org/10.47001/IRJIET/2024.811025

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