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Analysis of Rice Husk Pellet Combustion Test for Co-Firing in Pulverizer Coal (PC) Boilers

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Abstract
The increase in population has driven increased demand for energy, especially for transportation and electricity. Meanwhile, fossil energy production continues to decline, forcing the government to import petroleum to meet domestic needs. In order to anticipate the increasingly limited national fossil energy reserves and the increasing public energy needs, the government is promoting the use of renewable energy. One of the efforts is by co-firing biomass in coal-fired power plants. At PLTU Indramayu, the selected biomass is rice husk which has undergone pelletization treatment, compaction, and heating, to obtain biomass with a high density and calorific value better than the physical form of rice husk. Coal as fuel in PLTU Indramayu has an average calorific value of 4200 kCal/kg, while rice husk pellets have an average calorific value of 3400 kCal/kg. Combustion tests for co-firing need to be carried out to determine the operating performance of generating unit equipment. Co-firing tests in this study were still limited to a composition of 1% biomass and 3% biomass which required a total of 43.2 tonnes of rice husk pellets and 3196.8 tonnes of coal. Before the boiler combustion test, computational fluid dynamics (CFD) numerical simulations were also carried out to get an initial description. The results of the simulation and fuel tests show that the operating parameters are in normal limits. Types of equipment also show good and normal performance. Likewise, the resulting emissions support the achievement of the quality standards required in the Minister of Environment Regulation No. 15/2019. Even so, tests still need to be carried out with a higher percentage of biomass composition in order to generate electricity from greater green energy and reduce the use of coal as fuel.

1. Introduction

Indonesia as an agricultural country has considerable potential for biomass. Data from the Ministry of Energy and Mineral Resources through the Directorate of Bioenergy, the potential for biomass as a source of power generation reaches 32,773 MW. There are several types of biomass sources that can be used as an energy source. The sources are oil palm, sugar cane, rubber, coconut, rice, corn, cassava, wood, livestock, and urban waste (Statistics, 2020). The parts of palm oil that can be used are the flesh and seeds. It can be converted to biodiesel oil. Coir and shells can be used as co-firing fuel in coal-fired power plants (Korea, 2014) . Likewise, rice husks, bagasse, rubber tree trunks, coconut shells and coir, corn cobs, cassava stems, and all types of wood can be used as fuel for Biomass Power Plants (PLTBm) or can also be used for cofiring in coal-fired power plants. (PLTU) [D.S. Primadita et al., 2020]

As fuel in a biomass power plant or co-firing PLTU, the potential of the biomass must be selected according to the technical specifications of the generating machine and the potential of the biomass around the generating unit. The area around the generating unit needs to be identified for the large potential of the existing biomass as part of the guarantee for the continued operation of the PLTBm or fuel cofiring at the PLTU (Madanayake et al., 2017). The potential for rice husk-type biomass is quite large in Java and the biggest in West Java. Rice husk, which is currently a burden of waste in the agricultural sector, can be used as a biomass fuel. Its energy content is good enough to be used as a fuel mixture/co-firing in coal-fired power plants (Agbor et al., 2014). Based on observations of farmers, rice husks can be produced by approximately 20% of milled dry unhusked rice. This means that the utilization of rice husk as fuel in the electricity sector is quite large considering that West Java is a national rice-granary area.

Rice production in West Java province in 2022 is 9,432,277.12 tons (BPS, 2022). In the areas closest to PLTU Indramayu, namely Indramayu Regency, Subang Regency, Majalengka Regency and Sumedang Regency produced a total of 3,385,286.78 tons of rice in 2022. PLTU Indramayu has carried out cofiring of biomass with saw dust but the feed stock in the area around PLTU Indramayu is very limited. Using rice husk as an alternative fuel will increase the percentage of cofiring at the Indramayu PLTU and of course it can help achieve the Green Energy performance target. Pelletization is a densification technology, namely the process of compacting residues into products that have a higher density than the original raw material (Arai et al., 2015). The densification process in pellet production has several advantages, including increasing the total calorific value per unit volume, facilitating transportation and storage of the final product, having uniform shape and quality and being able to substitute forest wood thereby reducing forest logging activities (Hiloidhari et al., 2014). The process of making pellets consists of several stages, namely: raw material pre-treatment, drying, size reduction, pelleting, cooling, and silage [Fantozzi S. et al. al., 2009].

With rice husk pellets, technically operational in the boiler is expected to obtain higher biomass calories close to the coal calories required in burning boilers at PLTU Indramayu. With rice husk pellets that have a higher density, you can increase the calories. However, prior to cofiring the coal power plant, rice husk pellets still need to be technically analyzed by focusing on the formulation of the problem. What are the specifications/properties of rice husk pellets that can be used as cofiring fuel for coal power plants How does the operational performance of the cofiring coal power plant boiler with rice husk pellets simulated using Computational Fluid Dynamics (CFD) (ISO, 2014). How does the operational performance of the PLTU Indramayu boiler when the cofiring test is carried out with rice husk pellets (Pode, 2016). The purpose of this study was to obtain data on specifications for rice husk pellets that are suitable for use as a cofiring mixture for coal-fired power plants using the fuel test method. Obtain operational parameter data for cofiring biomass with rice husk pellets from Computational Fluid Dynamics (CFD) simulations. Obtain operational parameter data for cofiring biomass with rice husk pellets resulting from trials of combustion in a boiler (Tsuchiya & Yoshida, 2017).

2. Materials and Methods

This research begins with a literature study from various literature both from books and research journals. Then proceed with a survey of the potential of rice husks in Indramayu Regency. In this study, the area of Indramayu Regency was selected based on the existence of PLTU Indramayu and its large agricultural sector. The data were obtained from field observations from PLTU Indramayu and farmers in the area around PLTU Indramayu. From PLTU Indramayu, boiler technical data were obtained as a reference for making CFD modeling, while from the surrounding farming community, data on rice husk prices and their potential continuity were obtained. The modeling is made according to the boiler geometry of the Indramayu PLTU, then the parameters of coal and biomass are included as mixed fuels (Conrad & Prasetyaning, 2014). After completing all the parameters, the CFD modeling is run to obtain the operating parameters of combustion (combustion).

Computational fluid dynamics (CFD) is a method used to analyze fluid dynamics using a computer. CFD can be used to analyze many types of fluids, including air, water, and gases. Cofiring tests with a percentage of 3% rice husk pellet mixture were carried out at PLTU Indramayu 3x330 MW to determine the effect of cofiring on the reliability and main parameters of PLTU Indramayu and to obtain an overview of cofiring implementation which includes aspects of operational technical evaluation, evaluation of production costs and environmental evaluation.

The next stage is to analyze the impact of cofiring coal with biomass. The CFD modeling simulation results can obtain the emission impact of a mixture of coal and biomass fuel. By obtaining the emission data, it can be used as a reference and the percentage that can minimize the resulting emissions is selected. In the final stages of this research, it discusses the operating parameters of the results of the CFD modeling run and the burning test of rice husk pellets with coal and draws conclusions from this research. Cofiring of biomass with rice husk pellets also has the potential to cause corrosion in the boiler tube (Mirmohamadsadeghi & Karimi, 2020). To determine the potential for corrosion and slagging from cofiring results obtained by analyzing the physical properties and chemical content of a mixture of coal and biomass through laboratory tests (Parinduri & Parinduri, 2020). The required laboratory tests are Proximate Analysis, Ultimate Analysis, Ash Analysis, Ash Fusion Temperature, and Chlorine Analysis.

3. Results and Discussions

3.1 CFD modeling

In order to use CFD for simulating co-firing of biomass, it is first necessary to determine the geometry of the combustion system to be studied, as well as the initial conditions of the fluid to be analyzed. Then enter information about the fuel used, including the composition of the mixture of biomass and fossil fuels, as well as operating conditions such as temperature and pressure .

This research was conducted at the Indramayu PLTU whose design uses a Puverizer Coal (PC) Boiler. The modeling carried out in this study consists of four compositions, namely:

a. with 100% coal
b. with 99% coal and 1% rice husk pellets
c. with 97% coal and 3% rice husk pellets
d. with 95% coal and 5% rice husk pellets

Parameters that need to be included in the combustion simulation *co-firing* This biomass is:

a. *mass flowrate* for combustion air (primary air & secondary air) that enters *coal pulverizer* and every *coal burner*
b. *pressure* from the combustion air (primary air & secondary air) that enters *coal pulverizer* and every *coal burner*
c. *mass flowrate* for the incoming *coal pulverizer* and every *coal piped*
d. *mass flowrate* for husk pellets that go into *coal pulverizer* and every coal *pipe*
e. coal particle distribution, coal particle size and mass *flowrate* for each particle size
f. distribution of husk pellet particles, the particle size of the husk pellets and mass *flowrate* for each particle size
g. *ultimate analysis* and proximate *analysis* for coal and husk pellets

The greater the composition of the husk pellets based on numerical simulations the impact on the increase in value *COWARD* as shown in the graph in Figure 4.5 above. The amount of the increase in value *COWARD* with the composition of the husk pellets respectively 1%, 3%, and 5% of the value *COWARD* coal alone by 15.26%, 15.15% and 15.15%. This is due to the increase volatile *matter* in the fuel mixture that enters the combustion chamber comes from the content *volatile matter* in husk pellets is much higher than that of coal (Basu, 2018).

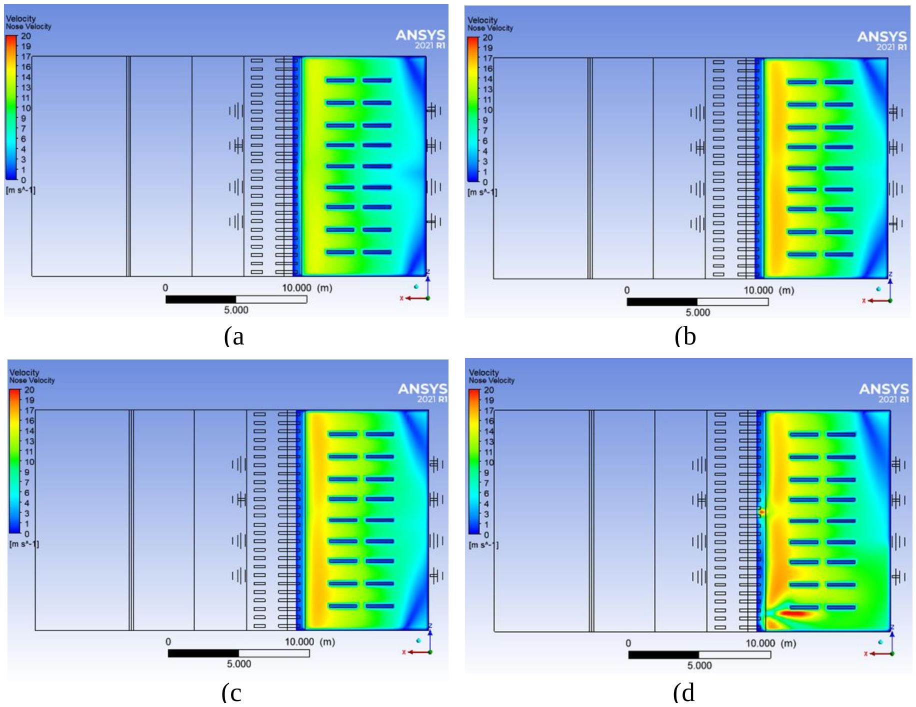

Figure 1. Speed distribution over area *boiler nose* (a) 100% coal, (b) 99% coal and 1% rice husk pellets, (c) 97% coal and 3% rice husk pellets, (d) 95% coal and 5% rice husk pellets

The fluid flow velocity profile (Figure 4.6) at elevation *nose* indicates concentration or color with high-velocity throughout nose *tubes bend* follow the contours of the physical structure furnace. So that this area suffers from a high fluid flow velocity and directs the fluid flow in the row-platen *superheater tube bundle* in front of him.

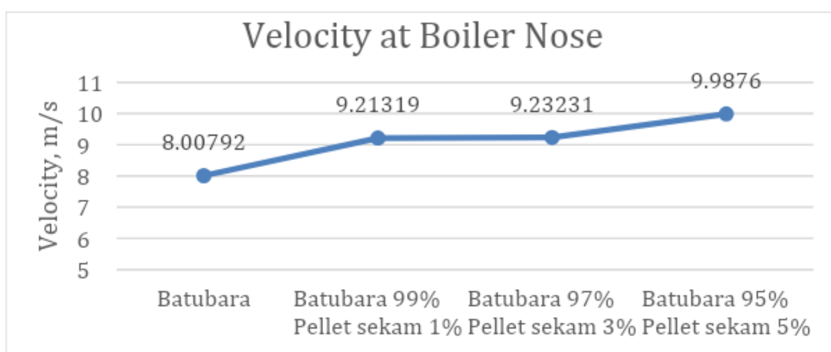

Figure 2. Graph of the average speed of the simulation results in the area boiler *nose*

The condition of the average velocity of fluid flow in the Boiler nose area from the results of coal and composition simulations-firing Rice husk pellets showed an increase with the increase in the ratio of husk pellets used. The increase in the composition of the 5% husk pellets causes an increase in the average velocity of the boiler nose by 2 m/s. But this is still safe because the maximum speed in the area is still below the maximum limit of 20 m/s, so it doesn't have a significant erosion impact on tube *bundle (platen superheater)* and nose *tubes*.

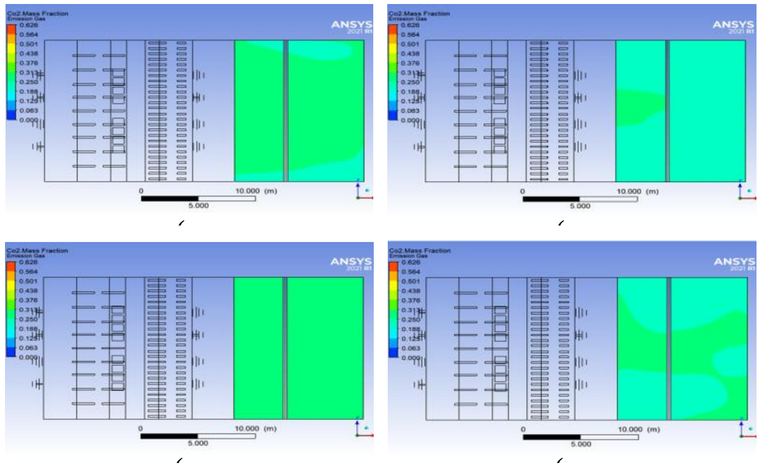

Figure 3. Distribution of CO gas emissions$_2$ on the area *back pass*, (a) 100% coal, (b) 99% coal and 1% rice husk pellets, (c) 97% coal and 3% rice husk pellets, (d) 95% coal and 5% rice husk pellets

CO emission value$_2$ The simulation results are shown in Figure 4.8, in the back pass area it ranges from 24.9% – 25.6%, this means that the composition of the husk pellets does not have a significant impact on CO gas emissions.$_2$.

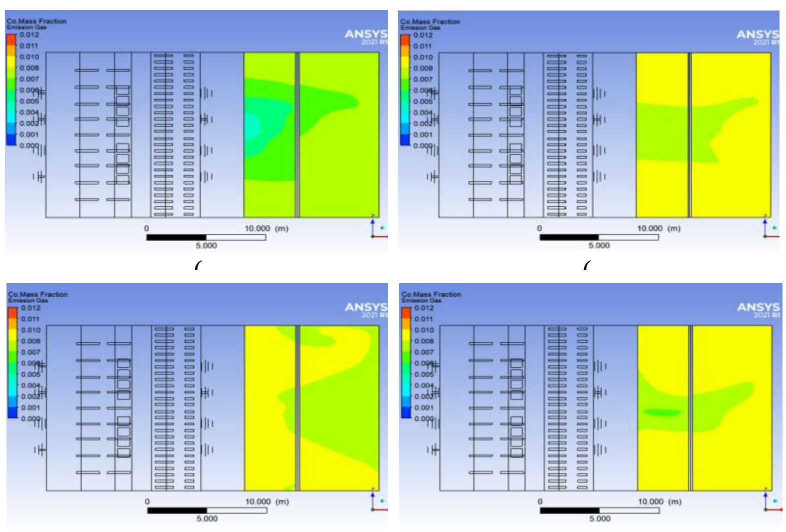

Figure 4. Distribution of CO gas emissions in the area *back pass*, (a) 100% coal, (b) 99% coal and 1% rice husk pellets, (c) 97% coal and 3% rice husk pellets, (d) 95% coal and 5% rice husk pellets

The simulation results show that the greater the composition of the husk pellets the higher the CO emission, which indicates further combustion after elevation. *boiler nose*. The value of CO gas emissions with the three compositions of husk pellets experienced an average increase of only 0.1%.

3.2 Co-firing Test of Rice Husk Pellets

Test burn *co-firing* rice husk pellets on *Pulverizer Coal (PC) Boiler* PLTU Indramayu will be carried out on 6 – 8 February 2023 with three stages, namely:

a. Combustion stability testing *(compatibility test)*, aims to ensure that the biomass used has good milling properties so that it can be sent to *burner* to the maximum and not wasted as pyrite.
b. Combustion performance testing *(performance test)*, aims to ascertain the impact of combustion on the performance of the generating unit
c. Combustion resistance testing *(durability test)*, aims to determine the long-term effect on the condition of generating equipment (Madejski, 2018).

In this study, the fuel test *co-firing* was carried out several times with a burning composition of 0%, 1% and 3% rice husk pellets calculated from the total *coal flow* 180 t/h (at a maximum load of 300 MW) with a test duration of 6 hours. Thus, the total need for rice husk pellets is 43.2 tons and the need for coal is 3,196.8 tons (Table 4.3).

Table 1. Requirement of coal and rice husk pellets in testing

No	Composition Scenario	Duration (Hours)	Coal (ton)	Biomass (ton)	Total	Note
1	100% Coal, 0% biomass	6	1080	0	1080	Coal Flow
2	99% Coal, 1% biomass	6	1069,2	10,8	1080	180 t/jam
3	97% Coal, 3% biomass	6	1047,6	32,4	1080	
	Total		**3196,8**	**43,2**	**3240**	

Rice husk pellets are sent from suppliers using trucks to PLTU Indramayu which are then *unloaded* and stored in the area *coal yard (stockpile)*. Mixing*(mixing)* biomass with coal is carried out in the *coal yard.* Figure 4.10 shows the coal flow cycle from the coal yard to the chimney.

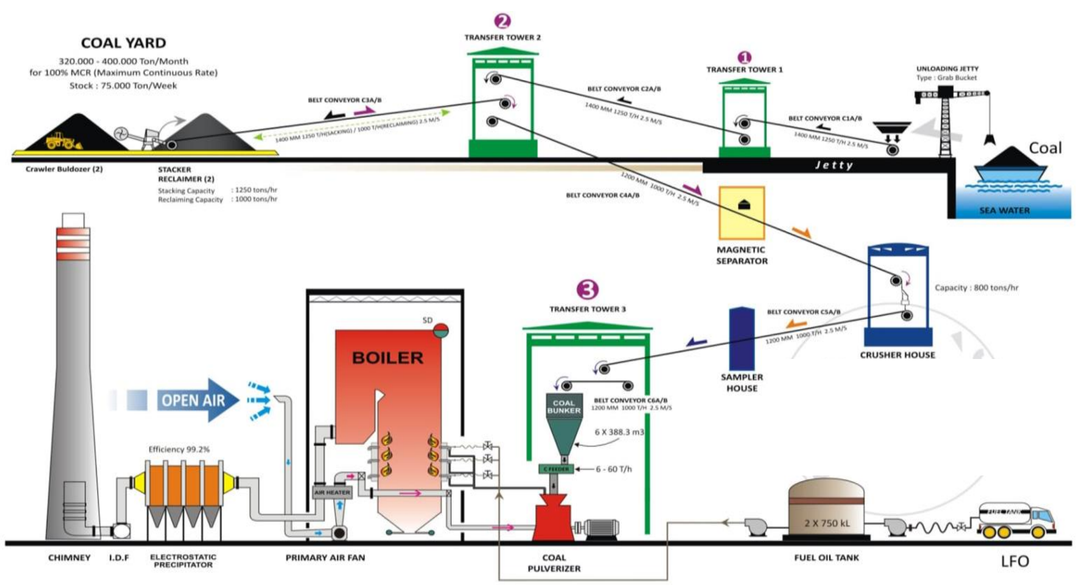

Figure 5. The process of coal flow from the coal yard to the chimney

Coal yard PLTU Indramayu is quite protected from rain and weather because it is equipped with *coal shelter / coal dome*. *Mixing* rice husk pellets with coal is done with the help of heavy equipment*(excavator)* to get an even mixture. To determine the characteristics of the fuel used in *co-firing* can be analyzed by looking at the physical properties and chemical content of the fuel mixture (a mixture of coal and biomass) which can be determined through laboratory tests (Demirbaş, 2003). Laboratory tests required include: *proximate analysis* and *ultimate analysis*. It is important to carry out laboratory tests on the fuel mixture used in addition to knowing the calorific value, it can be known the substances contained in the fuel and the substances formed in the combustion products so that the potential for the formation of *slagging, fouling* and agglomeration as well as the potential for corrosion in the boiler. Testing *sample* fuel (coal, biomass and rice husk pellets *mixing co-firing*) was carried out by PLN Research and Development Center which then tested the characteristics of the fuel in the ESDM Tekmira laboratory.

Table 2 Test results for the characteristics of coal and rice husk pellets

Parameter		COAL PLTU INDRAMAYU		PELLET SEKAM PADI		COAL + 3% SEKAM PADI (COAL FEEDER)		COAL + 1% SEKAM PADI (COAL FEEDER)		COAL + 3% SEKAM PADI (COAL YARD)		COAL + 1% SEKAM PADI (COAL YARD)	
	units	AR	ADB	AR	ADB	AR	ADB	AR	ADB	AR	ADB	AR	ADB
Proximate Analysis													
Total Moisture	%wt	32,82		9,19		31,25		33,80		28,92		34,59	
Moisture in analysis sample	%wt		21,18		8,18		18,33		20,17		18,28		18,26
Ash content	%wt	4,89	5,74	19,12	19,33	5,5	6,54	5,00	6,03	5,97	6,86	4,86	6,07
Volatile Matter	%wt	31,45	36,9	57,08	57,71	32,29	38,36	31,9	38,47	32,93	37,86	31,43	39,28
Fixed Carbon	%wt	30,84	36,18	14,62	14,78	30,95	36,77	29,3	35,33	32,18	37,00	29,12	36,39
Total Sulfur	%wt	0,31	0,36	0,038	0,038	0,27	0,32	0,3	0,36	0,38	0,44	0,28	0,35
GCV (Gross Calorfic value)	kCal/kg	4.243	4.978	3.363	3.400	4.365	5.185	4.082	4.922	4.494	5.167	3.390	4.986
Ultimate Analysis													
Total moisture	%wt	32,82		-		-		33,8		28,92		34,59	
Moisture in analysis sample	%wt		21,18		8,18		18,33		20,17		18,28		18,26
ash content	%wt												
carbon	%wt	45,02	52,82	35,61	36,01	45,63	54,20	43,32	52,24	47,05	54,09	42,52	53,14
hydrogen	%wt	3,23	6,16	4,32	5,28	3,43	6,13	3,24	6,17	3,6	6,18	3,14	5,97
nitrogen	%wt	0,82	0,96	0,42	0,42	0,83	0,99	0,69	0,83	0,89	1,02	0,71	0,89
sulfur	%wt												
oxygen	%wt	12,91	33,96	31,3	38,92	13,09	31,82	13,65	34,37	13,19	31,41	13,9	33,58
Chlorine	%wt		0,003		0,12		0,009		0,013		0,023		0,017

In the table of characteristic test results above, the sulfur content in rice husk pellets is very low at 0.038% compared to coal which is around 0.31%, so the addition of rice husk pellets in the test *co-firing* Rice husk pellets has the potential to reduce SO emissions$_2$, this condition can reduce emissions to achieve the quality standard targets set by PERMEN LHK Number 15 of 2019. Content of *volatile matter* in rice husk pellets is also much larger than coal, this makes rice husk pellets burn faster than coal it helps speed up the combustion process in the boiler as a whole. Rice husk pellets also contain *ash* that is lower than coal so as to reduce the amount *ash* formed/produced from the combustion process in the boiler either on *fly ash* nor *bottom ash* (Singh, 2018). The calorific value of the rice husk pellets for the combustion test in Indramayu is 3,363 kCal/kg, indicating that the energy content is relatively not much different from coal. *low rank* which has a calorific value of 4.243 kCal/kg.

Some of the characteristics of the rice husk pellets became an important supporting factor in carrying out the trials *co-firing* at the Indramayu PLTU. Trials *co-firing* conducted on 6 – 8 February 2023 in Unit # 2 by giving *feeding* mixed fuel of coal and biomass. Testing with a load at *set* at a maximum load of 300 MW the duration of the test is 6 hours. For actual data comparison, the operating parameters were observed under the conditions prior to the test *co-firing* or in the condition of operating units with 100% coal (0% biomass). This operating data will be used as a baseline or comparison for operating data *co-firing*. The operating conditions of the units tested will be treated the same and use the same type of coal for both the 100% coal operation test and the operation test *co-firing* 1% biomass dan 3% biomass (Moraes et al., 2014).

Operational data collection for 100% coal conditions was carried out at PLTU Indramayu Unit # 2 on 6 – 8 February 2023 using coal with a heating value of 4,230 kCal/kg. Monitoring of operating parameters is carried out at a load setting of 300 MW. The main parameters or critical points observed are: *total air flow, total coal flow, main steam temperature, main steam pressure, gas economizer outlet temperature, gas outlet temperature air heater, spray reheater total flow, dan spray superheater total flow* (Wu et al., 2015).

From the test results, several data parameters were obtained which were analyzed for their operational feasibility. Observation of operating parameters on *coal pulverizer (mill)* on *critical point* like a current *coal mill*, *coal feeder flow*, *mill outlet temperature* which shows a small deviation, and is still within safe limits. At each test, current *mill is* normal throughout mill which operates as shown in the following table below.

Table 3 Designation of parameters *mill* on testing composition of biomass 0%, 1% and 3%

Parameter	Mill A				
	0% Biomassa (Avg)	1% Biomassa (Avg)	3% Biomassa (Avg)	Deviasi Max.	Keterangan
Coal feeder flow (t/h)	36,86	37,02	35,47	-1,39	Aman
Mill current (A)	29,37	30,68	31,23	+1,86	Aman
MOT Avg (^{o}C)	61,42	61,61	62,09	+0,66	Aman
MOT Set (^{o}C)	63,5	63,5	63,5	-	Aman

Parameter	Mill B				
	0% Biomassa (Avg)	1% Biomassa (Avg)	3% Biomassa (Avg)	Deviasi Max.	Keterangan
Coal feeder flow (t/h)	35,89	33,43	33,22	-2,68	Aman
Mill current (A)	35,19	35,06	36,28	+1,09	Aman
MOT Avg (^{o}C)	61,42	61,61	62,09	+0,66	Aman
MOT Set (^{o}C)	63,5	63,5	63,5	-	Aman

Parameter	Mill C				
	0% Biomassa (Avg)	1% Biomassa (Avg)	3% Biomassa (Avg)	Deviasi Max.	Keterangan
Coal feeder flow (t/h)	36,15	34,3	35,29	-1,75	Aman
Mill current (A)	29,8	32,3	32,62	+2,82	Aman
MOT Avg (^{o}C)	60,5	61,24	62,93	+2,43	Aman
MOT Set (^{o}C)	63,5	63,5	63,5	-	Aman

Parameter	Mill E				
	0% Biomassa (Avg)	1% Biomassa (Avg)	3% Biomassa (Avg)	Deviasi Max.	Keterangan
Coal feeder flow (t/h)	36,37	35,63	35,35	-1,02	Aman
Mill current (A)	35,6	35,36	35,16	-0,44	Aman
MOT Avg (^{o}C)	60,48	61,26	62,12	+1,64	Aman
MOT Set (^{o}C)	63,5	63,5	63,5	-	Aman

In Table 4.8, testing *co-firing* 3% visible *mill outlet temperature (MOT)* tends to be higher than in other tests. This is because *flow* fuel at the moment *co-firing* 3% lower, especially in mills C and D. The average difference in MOT in the three tests ranged from 0 - 1 °C. The increase in MOT is due *volatile matter* rice husk pellets being much higher in comparison *volatile matter* coal.

Nonetheless, content volatile *matter* at a higher biomass than coal still provides value mill *outlet temperature* monitored safely, did not show a significant increase, so it is safe for operation coal *mill* (Bajaj & Mahajan, 2019). The deviation that occurs is not significant and is classified as safe. Even in terms of fuel consumption, *coal feeder flow*, there is a decreasing trend after using rice husk pellet biomass, which means that the use of fuel can be reduced to produce electricity at the same load. *Mill* D and *mill* F is not included in the table because at the time of the second data collection *mill* is in a condition that has not been operated according to the needs of coal flow and calories have been fulfilled by 4*mill*. on condition normal, 5 *mill* operated and 1 *mill* *standby* and the selection of mill operations is adjusted to the needs of boiler operations.

Table 4. Designation of mill flows in testing the composition of 0%, 1% and 3% biomass

Mill	Arus Mill (A)		
	0% Biomassa	1% Biomassa	3% Biomassa
A	29,7	30,7	31,2
B	35,2	35,1	36,3
C	29,8	32,3	32,6
D	OFF	OFF	30,4
E	35,6	35,4	35,2
F	28,3	33,2	OFF
Min	**28,29**	**30,68**	**30,40**
Max	**35,40**	**35,36**	**36,28**
Avg	**31,71**	**33,31**	**33,14**
Deviasi	**7,30**	**4,68**	**5,88**

Motor current indication *mill* the biggest deviation is seen when burning with 0% biomass. For combustion with 1% and 3% current biomass *mill* the average is higher than burning at 0% biomass composition. To find out the cause of the increase in current *mill* need to be checked/calibrated on *mill*. For the designation of value *Air Fuel Ratio (AFR)* and *flow* fuel on test *co-firing* The rice husk pellets in the table above appear to vary in terms of both 1% and 3% biomass composition. Both of these parameters show a downward trend when testing 1% biomass or 3% biomass.

a. At 0% biomass composition, AFR ranged from 1.83 to 2.53 with a deviation of 0.70 and an average AFR of 2.18.*Fuel flow* ranges from 35.8 to 37.98 with a deviation of 2.7 and an average of 36.46.
b. At a composition of 1% biomass, the AFR ranges from 1.85 to 2.39 with a deviation of 0.54 and an average AFR of 2.01.*Fuel flow* ranges from 35.6 to 3.7 with a deviation of 3.07 and an average of 37.04.
c. At a composition of 3% biomass, AFR ranged from 1.69 to 2.61 with a deviation of 0.93 and an average AFR of 1.99.*Fuel flow* ranges from 32.06 to 36.25 with a deviation of 4.19 and an average of 34.15.

The combustion temperature in the boiler and the exit temperature from the boiler are also very important indicators to determine the combustion performance in the boiler. Boiler design involves an energy balance between the fireside and the steam side. In boilers there is generally sufficient monitoring of the steam side, but not sufficient fire monitoring and control. Beginning with the mixing of fuel and air, combustion then occurs in the furnace, and subsequent monitoring in the exhaust gas path until the exit temperature *furnace boiler*. The control point between the exit of the burner to the exit of the boiler furnace, of which is *Flue Gas Exit Temperature (FEGT).* At this FEGT control point it has a major impact on the performance and reliability of the boiler (Quispe et al., 2017).

Basically, the exit point of the furnace separates the radiation zone from the convection zone. FEGT defines the ratio of heat absorption by *radiant heating* and *convective heating*. The FEGT control point also observes potency *fouling* from the boiler tube in the convection area. If the FEGT is above the coal ash initial deformation temperature (IDT), it can cause *fouling boiler tube* which is severe by liquid ash*(molten ash).* Exhaust gas temperature at intake *Superheater / Reheater* should also be monitored lower than *Ash Fusion Temperature (AFT).*

FEGT testing is carried out using a thermogenic at several points in the area *furnace* in different areas. The results of the FEGT test are shown in Table 5 below.

Table 5. Designation of FEGT measurements in testing the composition of 0%, 1% and 3% biomass

Titik Ukur	FEGT (°C)		
	0% Biomassa	1% Biomassa	3% Biomassa
Barat	867	887	907
Tengah	953	915	921
Timur	925	924	896
Min	**915**	**908**	**908**
Max	**867**	**887**	**896**
Avg	**953**	**915**	**921**
Deviasi	**86**	**28**	**25**

From the FEGT measurement data table above, it is obtained that the average composition test at 3% tends to be lower by 6.93 °C compared to 100% coal operating conditions. FEGT decreasing trend under operating conditions *co-firing* composition of 3% biomass is still within normal limits and on average tends to decrease from the previous 915.23 °C to 908.47 °C at a composition of 1% biomass and to 908.3 °C with a composition of 3% biomass. FEGT when *co-firing* has a lower value than when coal firing, this is comparable to the calorific value of a mixture of biomass coal which is lower than the calorific value of coal.

The highest deviation occurred at 86 °C in the 0% biomass test, while the lowest deviation occurred at*co-firing* 3% biomass. *Furnace temperature* east, central and west side boilers at the moment *co-firing* and coal firing is not uniform at the same load. This can be caused not only because of the calorific value of the fuel but also because of the non-uniformity of the resulting combustion *coal fineness* non-uniform. The next observation is on *unburned carbon (UBC)* what needs to be done to determine the carbon content that is not burned out in the combustion process in the boiler. The higher the UBC value, the more inefficient the combustion or fuel is, because more energy has not been converted. UBC test observation results can be seen in the following table.

Table 6. Results *unburn carbon (UBC)* testing of the composition of the biomass 0%, 1% and 3%

Komposisi Cofiring	Lokasi Sample	Batasan (%)	Nilai UBC (%)
0% Biomassa	Bottom Ash	< 1	0,55
	Fly Ash	< 1	1,30
1% Biomassa	Bottom Ash	< 1	0,73
	Fly Ash	< 1	1,46
3% Biomassa	Bottom Ash	< 1	0,25
	Fly Ash	< 1	0,80

From the table of the UBC test results, it was found that when testing 0% of the biomass produced *unburned carbon fly ash* which is slightly above the threshold value of 1% (with a value of 1.3%) indicating the inherent UBC of the coal used. While testing *co-firing* 3% rice husk pellets yield *unburned carbon fly ash* which is better and according to the standard threshold, namely with a value of 0.8%.

Furthermore, the observation of the potential for corrosion and *slagging* from the fuel used into-firing. This can be analyzed by looking at the physical properties and chemical content of the fuel mixture (a mixture of coal and biomass) which can be determined through laboratory tests. Laboratory tests that have been carried out include: *proximate analysis, ultimate analysis, analysis abu, ash fusion temperature, dan chlorine analysis*. It is important to carry out laboratory tests on the fuel mixture used in addition to knowing the calorific value, it can be known the substances contained in the fuel and the substances formed in the combustion products so that the potential for the formation of *slagging, fouling* and agglomeration as well as the potential for corrosion in the boiler.

Table 7 Ash analysis of rice husk pellets, coal, and a mixture of coal–rice husk pellets

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Satuan</th><th colspan="8">Ash Analysis</th></tr>
<tr><th colspan="2">Pelet Sekam Padi</th><th colspan="2">Batubara</th><th colspan="2">1% Biomassa</th><th colspan="2">3% Biomassa</th></tr>
<tr><th>AR</th><th>ADB</th><th>AR</th><th>ADB</th><th>AR</th><th>ADB</th><th>AR</th><th>ADB</th></tr>
<tr><td>S_iO_2</td><td>%wt</td><td colspan="2">95,15</td><td colspan="2">44,00</td><td colspan="2">40,7</td><td colspan="2">47,3</td></tr>
<tr><td>Al_2O_3</td><td>%wt</td><td colspan="2">0,15</td><td colspan="2">19,92</td><td colspan="2">20,45</td><td colspan="2">16,91</td></tr>
<tr><td>Fe_2O_3</td><td>%wt</td><td colspan="2">0,11</td><td colspan="2">10,50</td><td colspan="2">11,32</td><td colspan="2">8,53</td></tr>
<tr><td>CaO</td><td>%wt</td><td colspan="2">0,43</td><td colspan="2">4,28</td><td colspan="2">3,86</td><td colspan="2">7,30</td></tr>
<tr><td>MgO</td><td>%wt</td><td colspan="2">0,37</td><td colspan="2">2,75</td><td colspan="2">1,94</td><td colspan="2">4,51</td></tr>
<tr><td>Na_2O</td><td>%wt</td><td colspan="2">0,29</td><td colspan="2">1,41</td><td colspan="2">0,65</td><td colspan="2">1,42</td></tr>
</table>

From *ash analysis* shown in Table 4.13 above, rice husk pellets contain S_iO_2 the highest is 95.15% while the mixture of coal with rice husk pellets is in the range of 40% - 47%. S_iO_2 is abrasive on the equipment so it can cause erosion on the equipment especially *bowl pulverizer*. The CaO content of rice husk pellets has the lowest content, namely 0.43%, while that of coal is 4.28%. The percentage of CaO cannot be ignored because of the potential for sticking *fly ash* on the pipe surface causing ash and *fouling* of *tube boiler*.

Table 7 Ash analysis of rice husk pellets, coal, and a mixture of coal–rice husk pellets

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Satuan</th><th colspan="4">Index</th></tr>
<tr><th>Pelet Sekam Padi</th><th>Batubara</th><th>1% Biomassa</th><th>3% Biomassa</th></tr>
<tr><td>Rasio 2S/Cl</td><td>index</td><td>0,7</td><td>256,36</td><td>61,24</td><td>78,62</td></tr>
<tr><td>Slaging Index (Rs)</td><td>index</td><td>0,002</td><td>0,114</td><td>0,094</td><td>0,113</td></tr>
<tr><td>Fouling Index (Rf)</td><td>index</td><td>0,12</td><td>0,96</td><td>1,29</td><td>1,77</td></tr>
</table>

Potency *slagging* based on *Slagging Index (Rs)* moment *coal firing* (0% biomass) or *co-firing* 1% biomass and 3% low potential biomass where all values *Rs* smaller than 0.4. As for potential *fouling* using numbers *Fouling Index (Rf)* has quite a high potential on the scheme *co-firing* with value *Rf* > 1. The process of releasing sulfur and chlorine into the gas phase during biomass combustion is rather constant (sulfur 80% – 90% and chlorine > 90%) (P. Sommer sacher, et al 2011), the risk of sediment can be evaluated *alkali chlorides* on the superheater and the risk of active oxidation of chloride based on fuel composition.

Table 8. Comparison of the characteristics of coal, rice husk pellets, and a mixture of coal and rice husk pellets

Parameter		COAL PLTU INDRAMAYU		PELLET SEKAM PADI		COAL + 3% SEKAM PADI (COAL FEEDER)		COAL + 1% SEKAM PADI (COAL FEEDER)		COAL + 3% SEKAM PADI (COAL YARD)		COAL + 1% SEKAM PADI (COAL YARD)	
	units	AR	ADB	AR	ADB	AR	ADB	AR	ADB	AR	ADB	AR	ADB
Proximate Analysis													
Total Moisture	%wt	32,82		9,19		31,25		33,80		28,92		34,59	
Moisture in analysis sample	%wt		21,18		8,18		18,33		20,17		18,28		18,26
Ash content	%wt	4,89	5,74	19,12	19,33	5,5	6,54	5,00	6,03	5,97	6,86	4,86	6,07
Volatile Matter	%wt	31,45	36,9	57,08	57,71	32,29	38,36	31,9	38,47	32,93	37,86	31,43	39,28
Fixed Carbon	%wt	30,84	36,18	14,62	14,78	30,95	36,77	29,3	35,33	32,18	37,00	29,12	36,39
Total Sulfur	%wt	0,31	0,36	0,038	0,038	0,27	0,32	0,3	0,36	0,38	0,44	0,28	0,35
GCV (Gross Calorfic value)	kCal/kg	4.243	4.978	3.363	3.400	4.365	5.185	4.082	4.922	4.494	5.167	3.390	4.986
Ultimate Analysis													
Total moisture	%wt	32,82		-		-		33,8		28,92		34,59	
Moisture in analysis sample	%wt		21,18		8,18		18,33		20,17		18,28		18,26
ash content	%wt												
carbon	%wt	45,02	52,82	35,61	36,01	45,63	54,20	43,32	52,24	47,05	54,09	42,52	53,14
hydrogen	%wt	3,23	6,16	4,32	5,28	3,43	6,13	3,24	6,17	3,6	6,18	3,14	5,97
nitrogen	%wt	0,82	0,96	0,42	0,42	0,83	0,99	0,69	0,83	0,89	1,02	0,71	0,89
sulfur	%wt												
oxygen	%wt	12,91	33,96	31,3	38,92	13,09	31,82	13,65	34,37	13,19	31,41	13,9	33,58
Chlorine	%wt		0,003		0,12		0,009		0,013		0,023		0,017

The rice husk pellets used for this test have value *Hard grove Grindability Index (HGI)* which is much lower than coal. The HGI value of rice husk pellets is in accordance with the table above, which is 16, while coal is around a value of 45. This indicates the level of ductility of rice husk pellets which will be harder to handle. *grinding* and has the potential to increase the flow of the coal mill as well *reject pyrite.*

Minister of Environment Regulation Number 15 of 2019 sets limits on emission quality standards from power plants. Table 4.18 shows these limits and must be complied with under any operating conditions.

Table 9. Comparison of the characteristics of coal, rice husk pellets, a mixture of coal and rice husk pellets

Parameter	Satuan	Baku Mutu		
		Batubara	Gas	Solar
Sulfur Dioksida (SO_2)	mg/Nm^3	550	50	650
Nitrogen Oksida (NOx)	mg/Nm^3	550	320	450

Mixing fuel, coal with rice husk pellets on *co-firing* will affect the exhaust emissions produced, for this reason, testing of exhaust emissions is carried out to observe changes that occur during the test *co-firing.* Table 4.19 shows the results of emission measurements indicating that they are still below the quality standards and *co-firing* with rice husk pellets is worth continuing.

Table 10. Comparison of the characteristics of coal, rice husk pellets, a mixture of coal and rice husk pellets

Parameter	Satuan	Baku Mutu	Baku Mutu		
			0% Biomassa	1% Biomassa	3% Biomassa
Sulfur Dioksida (SO_2)	mg/Nm^3	550	75,88	63,62	51,46
Nitrogen Oksida (NOx)	mg/Nm^3	550	73,50	55,88	37,19

4. Conclusion

Rice Husk Pellet Specifications

The calorific value of rice husk pellets is lower than low rank coal, however, pelletization is a pre-treatment effort that can increase the calorific value better than in the form of rice husk. Content *sulfur dioxide (SO_2)* and *nitrogen oxide (NOx)* Rice husk pellets are far below the sulfur content of coal, so they can improve SO quality$_2$ and NOx in exhaust gases and can support the fulfillment of emission quality standards required in the Minister of Environment Regulation Number 15 of 2019. Potential *slagging* and *fouling* on the co-firing of rice husk pellets is relatively small because *slagging index* and *fouling index* of Rice husk pellets are much smaller than coal. Content *chlorine* rice husk pellets are higher than the content of *chlorine* coal. This gives a higher corrosion potential to the boiler tube and *grinder mill/pulverizer* so the percentage of rice husk pellets in *co-firing* should be limited to a safe level.

Operation Performance*Co-firing* Rice Husk Pellets Based on CFD Simulation

On burning in *furnace*, temperature in *furnace* and *flue exit gas temperature (FEGT)* shows that the greater the composition of rice husk pellets in the mixture *co-firing* impact on temperature rise *furnace.* This is due to the in crease *volatile matter* in the fuel mixture that enters the combustion chamber comes from the content *volatile matter* in husk pellets is much higher than that of coal. The fluid flow velocity profile at elevation *nose* shows that the higher the percentage of biomass, the higher the fluid velocity along *nose tubes bend* to follow the contours of the physical structure *furnace* and directs the flow of fluid in the row *platen supeher heater tube bundle* in front of him. CO emission value$_2$ and CO simulation results show a very small increase so it does not have a significant impact on exhaust emissions.

Operation Performance *Co-firing* Rice Husk Pellets During Fire Test in Boilers

Rice husk pellet burning test on *co-firing* The composition of 1% biomass and 3% biomass was carried out by observing operating parameters compared to burning only coal*(coal firing).* The main operating parameters provide a safe amount within operating limits, both at 1% biomass and 3% biomass. In general, the performance *boiler* and *mill/pulverizer* are not significantly affected by operations *co-firing* rice husk pellets. Temperature *furnace* and FEGT on *co-firing* the composition of 1% and 3% shows an inconsistent trend. This is very possible because of the non-uniformity of the coal that is burned. *Un-Burned Carbon* (UBC) relatively lower value at *co-firing* compared with *coal firing*. This shows better efficiency as more heat is generated from the fuel that is burned. Rice husk pellets have a value *Hard grove Grindability Index (HGI)* lower than coal. This indicates the level of tenacity of rice husk pellets which will be harder to handle. *grinding* thus potentially increasing the current *coal mill*.

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