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Utilization Of Waste Heat Recovery to Reduce Water Content in Low-Calorie Coal with Fluidized Bed Dryer

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Abstract

Coal drying process using FBD (fluidized bed dryer) which utilizes low temperature waste heat, especially from industrial air heaters, has been developed in the United States by the GRE (Great River Energy) team since 1997. Technology is still considered an expensive investment. This study uses a prototype FBD with a drying heat source is an air heater that simulates the amount of water content that can be removed in low-calorie coal for boiler use. Furthermore, it can be considered the use of waste heat recovery from machines in the industry as a substitute for the energy source of the dryer by the air heater. The water content or Total Moisture Content that can be removed by using FBD with an air heater dryer energy source is 20%. The savings due to TM which has decreased by 20% in the industrial scale of the power plant can be calculated as 650,289 EUR/Year. The savings will be even greater, if the energy of the air heater dryer is replaced with waste heat recovery from industrial machines such as air heaters or boilers.

Index Terms: Fluidized Bed Dryer, Coal, Drying System, Waste Heat Recovery;.

Introduction

The power generation system in Indonesia mostly uses fossil fuels (coal or fuel oil), as a heat source to produce superheated steam at high temperature and pressure to be converted into electrical energy.

Electric steam power plant is the most efficient power plant to be developed in Indonesia compared to other power plants. Coal consumption for the total generation capacity of coal-fired power plants is 23,233 MW, requiring coal fuel of approximately 44.7% of the total national power generation capacity [1]. The government will limits the energy mix from coal up to 50% and fuel oil up to 1% by 2025, and increases the portion of NRE to 25% and gas to 24% [2]. Future energy policies are directed at the use of technology that is high efficiency and low emission from the use of coal, several alternatives including:

1. Utilization of super-critical and ultra-supercritical boilers for coal-fired power plants.
2. The use of a coal drying device called a Steam Tube Dryer (STD) which uses steam for the drying process.
3. Coal drying process using FBD (Fluidized Bed Dryer) by utilizing low temperature waste heat from the air heater, as has been developed in the United States by the GRE (Great River Energy) team since 1997. This technology is patented under the name Dry Fining.

Of the three efforts offered above, of course, investment cost is the main consideration. But there is one thing that is interesting, namely the use of Low Temperature Coal Drying Process Technology using FBD.

Waste heat recovery from steam boilers, for example, is wasted and not utilized in industry. The amount of energy from potential waste heat recovery in the industry in the form of hot air is simulated as a coal dryer in the FBD. Thus, it can save energy use to dry the coal and can reduce the impact of rising electricity prices in the future. In addition, expanding the use of lignite, which is low-calorie coal, as a power plant fuel and increasing the reliability of power plants.

Method

Fluidized Bed Combustion (FBC) technology is a closed combustion furnace that uses a heat transfer medium as well as a burner, stirrer and heat absorber above the bed/furnace, has been known since 1920. It has developed relatively quickly since the 1960s because of the combustion process, faster and produce a product with better quality than that obtained by conventional hot air drying [3], [4]. Since 1970 it has been used in power plants [5].

The Fluidized Bed Dryer (FBD) replaces the combustion function with a drying function. Air heaters are used as the main component of air dryers to reduce the moisture content of coal. Iron sand is generally used as a heat transfer medium, not used, only drying air is flowed by the blower through the bottom of the dense bed after passing through the heater chamber. Components of an FBD can be seen in Figure 1.

Figure 1. *Fluidized Bed Dryer Component*

Coal seams can be lifted and visible interstitial spaces between the particles, when the pressure from the blower air flow reaches a certain point, where the pressure in the area of the material above the bed, is equal to the pressure of the pressure above the bed, then the material or coal above the bed will begins to lift from the bed and will float in the drying chamber, this condition is called fluidization [6]. Energy consumption varies with dryer operating conditions, namely drying temperature, air velocity and batch size [7].

Coal commonly used by companies in Indonesia is low-calorie coal which has a total moisture of 46%. The low total moisture causes the boiler efficiency to be low as well, which is around 80 -81% and CO2 emissions increase. Coal characterization (proximate analysis, ultimate analysis, Thermo Gravimetric Analysis (TGA), BET, High Heating Value (HHV) and Lower Heating Value (LHV)) was carried out to determine the effect of changes in water content in coal [8].

NOx in the formation in lignite coal will decrease very significantly [9] and increase the desulfurization process [10] according to the high drying temperature [11]. The air heater as a heat source for FBD in this study is illustrated as wasted heat from the use of energy from boilers, air heaters or rotary kilns in industry or generators as waste heat recovery.

Result and Discussion

Coal with a CV (Calorific Value) ≥ 4,300 kCal/kg can be used directly for the combustion process in the combustion chamber. Coal that has a CV value ≤ 4,300 kCal/kg is placed in the stockpile and the coal drying process is carried out with FBD to reduce Total Moisture. After the coal is dried, then an analysis is carried out on the sample to be used in the combustion chamber to determine the CV value as a quality control. The higher the Total Moisture value, the inversely proportional to the CV value in the coal content. Lowering the Total Moisture value will increase the Calorific Value.

The data obtained in testing coal on a steam boiler in an industry are as follows:

REPORT OF ANALYSIS

PRINCIPAL :

TYPE OF SAMPLE : Coal
TESTED FOR : Total Moisture, Proximate Analysis, Total Sulfur, Gross Calorific Value and Ultimate Analysis
DESCRIPTION OF SAMPLE : Weight of Sample : ± 5 Kg
Packing : Plastic Bag
DATE RECEIVED :
DATE OF TESTING :
SAMPLE MARK :
STANDARD METHOD : ASTM STANDARD

Result :

PARAMETERS	UNIT	TEST RESULTS	METHODS
Total Moisture, AR	% wt	29.28	ASTM D - 3302M - 2017
Moisture In Analysis the Sample, ADB	% wt	16.89	ASTM D - 3173M - 2017
Ash Content, ADB	% wt	4.15	ASTM D - 3174 - 2012
Volatile Matter, ADB	% wt	41.05	ASTM D - 3175 - 2017
Fixed Carbon, ADB	% wt	37.91	ASTM D - 3172 - 2007
Total Sulfur, ADB	% wt	0.18	ASTM D - 4239 - 2014
Gross Calorific Value, ADB	Kcal/kg	5268	ASTM D - 5865 - 2013
Gross Calorific Value, AR	Kcal/kg	4482	ASTM D - 5865 - 2013
Ultimate Analysis			
Carbon, ADB	% wt	49.04	ASTM D – 5373 – 2016
Hydrogen, ADB	% wt	3.28	ASTM D – 5373 – 2016
Nitrogen, ADB	% wt	0.66	ASTM D – 5373 – 2016
Oxygen, ADB	% wt	0.15	ASTM D – 3176 – 2009

Figure 2. *Coal Test Report*

The results of the tests carried out by researchers to obtain the value of the water content can be seen in Table 1 as follows:

Table 1. Table Caption

Parameter	Symbol	Units	Value
Length	L	M	0.3
Power	P	watt	500
Outside Diameter	Do	m	0.011
Heat Flow Rate	q	watt/m^3	17,546,630
Air Flow Rate	Q	watt/s	5.28
Air Ambient Temperature	Db	°C	32.88
	Wb	°C	25,636
	RH	%	56.782
Heater Temperature	Db	°C	150
Specific Humidity	ω	kg/kg	0.018
Specific Enthalpy	h		0.248
Specific Volume	v	m^3/kg	1.289
Dew Point Temperature	Tdp	°C	23.169
Relative Humidity	RH	%	0.556

Table 1 shows the amount of water content of the material that can be removed or removed by 4.7 to 17.7% or rounded up to 20%. This of course can save the amount of energy needed to dry the coal before it is put into the combustion chamber of the boiler. But in this FBD still requires a source of energy that is not small which can be seen from Table 1, namely the use of heaters and air blowers. This of course can be converted from the amount of energy value that can be obtained from energy waste heat recovery from machines in the industry. Taking into account the magnitude of the temperature values ranging from 50 to 300°C used by the air heater to dry coal in the FBD room.

In Table 1, it can be seen that there is a difference in temperature from the amount of temperature released by the air heater with the amount of temperature received by the material. This is because the air blower function blows air from the environment through the heater which then enters the drying chamber. The decrease in temperature in the supply of air that enters the drying chamber, results in the amount of heat energy from the heater being reduced, but it can still dry the material at the amount of heat energy received by the material, with the magnitude of the temperature value received by the material. The air that flows into the drying chamber is air with low humidity, also known as dry air. By flowing dry air into the material, the water vapor that is on the surface and even inside the material, will evaporate along with the air flow rate from the heater chamber to the drying chamber. The drying chamber is designed with a very small hole at the top of the drying chamber (0.5 cm), so that the air will continue to circulate in the drying chamber, as read in Table 1, namely the air measured above the material.

The large reduction in TM (total moisture) in the material, will be beneficial for saving the drying energy required for coal before it is used for combustion in the boiler. The amount of savings due to a 20% decrease in TM, is converted as coal consumption in the boiler combustion chamber, which is 650,289 EUR/Year. Figure 3 shows a simulation of the conversion of coal savings resulting from a decrease in TM.

Sampling at Hopper PLTU				BATUBARA DIKERINGKAN TM => 20%		
PROXIMATE ANALYSIS	adb	ar	Unit	adb	ar	Unit
TM		43,50	%		20,00	%
IM	14,71		%	14,71		%
Ash	7,56	5,01	%	7,56	7,09	%
VM	41,81	27,70	%	41,81	39,22	%
Fixed Carbon	35,92	23,80	%	35,92	33,69	%
Total Sulphur	0,09	0,06	%	0,09	0,08	%
CV	5118	3.390	kCal/kg	5118	4.801	kCal/kg
ULTIMATE ANALYSIS						
Carbon	53,51	35,45	%	53,51	50,19	%
Hidrogen	4,23	2,80	%	4,23	3,97	%
Nitrogen	0,92	0,61	%	0,92	0,86	%
Total Sulphur	0,09	0,06	%	0,09	0,08	%
Oxygen + error	18,98	12,57	%	18,98	17,80	%
RATIO ASH						
Bottom ash		0,75			0,75	
Fly ash		0,25			0,25	
GCV of fly ash	403		kCal/kg	403	kCal/kg	
GCV of bottom ash	1.017		kCal/kg	1.017	kCal/kg	
FLUE GAS ANALYSIS (hasil pengukuran)		Unit			Unit	
CO2	8,4	%		8,4	%	
CO	30	ppm		30	ppm	
NOx	102	ppm		102	ppm	
excess air	122,7	%		122,7	%	
O2	11,7	%		11,7	%	
T Flue Gas	109	oC		109	oC	
Udara Teoritis	4,71	%		7,23	%	
% Excees air	125,81	%		125,81	%	
Actual Air Requirement (AAR)	10,64	kg /kg coal		16,33	kg /kg coal	
massa flue gas	11,56	kg /kg coal		17,52	kg /kg coal	
CP flue gas	0,23	kCal/kg		0,23	kCal/kg	
Heat Loss		Unit			Unit	
Dry Flue Gas Loss	6,04	%		6,46	%	
Heat loss due to evaporation of water due to H2 in fuel	4,60	%		4,60	%	
Heat loss due to evaporation of moisture in fuel	0,52	%		0,17	%	
Heat loss due to blow down	3,20	%		2,26	%	
Heat loss due to moisture in air	0,13	%		0,14	%	
Heat loss due to un burnt in fly ash	0,00	%		0,00	%	
Heat loss due to un burnt in bottom ash	0,01	%		0,01	%	
Heat loss due to partial conversion of C to CO	0,03	%		0,02	%	
Heat loss of radiation & convection	1,00	%		1,00	%	
Total of Heat Loss	15,53	%		14,67	%	
BOILER EFFICIENCY	84,47	%		85,33	%	

Figure 3. *Increasing of Boiler Efficiency*

Coal savings due to reduced TM from 43.50% to 20% can be seen from these calculation:

1. Actual coal consumption : 13.69 ton/hour
2. After Improvement : 9.57 ton/hour
3. Different: 4.12 ton/hour ≈ 34,696 ton/year

The size of the reduction in TM from coal for industrial combustion processes is very significant for energy savings and operational costs. This proves that innovation is needed for drying coal before it is used into the boiler combustion chamber.

The amount of energy required for heaters and blowers in FBD is substituted with the use of energy waste heat recovery from industrial machines. This emphasizes how large the utilization of energy waste heat recover is, as well as placing this FBD as an alternative solution for tools that can be developed for use for the power plant industry in particular or industries that use boilers in general.

Conclusion

From the data and discussion that we have obtained, the following conclusions can be drawn:

1. FBD is able to reduce the moisture content of coal in the industry as a coal dryer which is used before being used for combustion in the boiler. The water content that can be

reduced from drying this FBD is 20%.

2. The heater power on the FBD prototype used in this study uses 500 Watts of power, can increase the drying air temperature up to 300°C with a drying capacity of 85 kg/hour. The water content in the material decreases to a moisture content of 20%. This heater power can be replaced by utilizing energy waste heat recovery from the machines in the industry used to dry coal in this FBD room. Assuming the amount of savings due to a 20% decrease in TM, it is converted as the amount of coal consumption in the boiler combustion chamber, which is 650,289 EUR/Year.

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