Utilization of Coal Fly Ash as Co Gas Adsorbent

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Abstract :

This research focused on coal fly ash fabricated as CO adsorbent. Coal fly ash having grain size of 325 mesh was characterized by XRF, XRD and SEM-EDX. Physical activation was done at temperatures of 500^{0}C, 520^{0}C, 540^{0}C, 560^{0}C, 580^{0}C and 600^{0}C. Chemical activation was undertaken by mixing between fly ash and NaOH with mass ratio of 1: 1.2 with subsequent heating at 750^{0}C for 1 h and followed by washing the specimens until pH=7. The samples were dried at 100^{0}C for 1 h. The major constituents of unactivated coal fly ash are Fe, Ca, K, Si and Al in the form of quatz and anorthite. The chemical activation led to reduce the amount of quartz or increase the amount of anorthite. Physical activation does not affect the amount of minerals.

Keywords: adsorbent, activation, characterization, fly ash

1. Introduction

Coal is one of alternative energy resources. In term of price coal is cheaper than natural oil. Indonesia has a lot of coal resources, and the utilization of coal in Indonesia increases every years. It attains 14,1% from total of other energy resources. It is expected that coal usage will increase until 34,6% at 2025**[1]**. Utilization of coal produces waste that can contaminate environment such as CO_2, NO_X, CO, SO_2, hydrocarbon dan solid waste. The solid waste is in the form of ash, i.e fly ash and bottom ash. According to data of Ministry of Environment in 2006, fly ash production reaches 52,2 ton per day, whereas bottom ash waste production reaches 5,8 ton per day **[1]**.

Coal fly ash is exhaust waste was usually released to air without control. Actually fly ash waste is a kind of hazardous waste. Generally, fly ash can be temporary saved at coal power plant and further thrown in landfill. Accumulation of this coal fly ash may raise environment al problem **[2]**. Coal fly ash can be used for raw material of cement and construction material **[2]**. Another utilization of coal is as adsorbent **[3]**. As adsorbent, fly ash has advantage in term of economical prices and good for gas and liquid waste management **[4]**. Physical and chemical activation is required to allow coal fly ash for being use as adsorbent. Physical activation is done by heating at high temperature, whereas chemical activation is done by mixing of fly ash and acid liquid or alkali.

2. Material and Methods

2.1 Materials

Coal fly ash is exhaust result of kiln I process in PT. Semen Gresik. It has grain size of 325 mesh. Coal fly ash have dark brown colour. This colour depend on type of coal, too. In this research the type of coal is lignite whose quality is the lowest among other type of coals.

2.2 Methods

Two activations were used in this research, namely physical and chemical activations. The physical activation was done by heating the sample at temperatures of 500°C, 520°C, 540°C, 560°C, 580°C, and 600°C for 1 hour. Chemical activation was done by mixing fly ash and NaOH with the mass fractions of fly ash and NaOH are 1 : 1.2. The mixtures were heated at temperature of 750°C for 1 hour followed by grinding process. Then, the samples were mixed with distilled water with L/S of 1/5 in a constant stirring of 400 rpm for 30 minutes. Finally leaching was done until pH = 7, the samples were then subsequently dried at temperature of 100^{0}C for 1 hour.

Raw material coal fly ash was characterized by X-Ray Fluorescence (Minipal4 PanAlytical), X-Ray Diffraction (Brücker AXS D8 Focus) Cu K-α with λ = 1,5418 Å, and Scanning Electron Microscopy (SEM) Zeiss-EVO MA 10 equipped with Electron Diffraction-X (EDX) of Brücker.

3. Result and Discussion.

3.1 Unactivated Coal Fly Ash Characterization

Table 1 shows composition in unactivated fly ash. From Table 1 it is known that the highest contents in the fly ash are Fe, Ca, K, Si and Al, and the highest oxide are Fe_2O_3, CaO, SiO_2, Al_2O_3 and K_2O. The important substance for adsorbent are Si and Al, while Ca is the substance that has to be remove. Ca can disturb the adsorption process because it may lead the reaction to become unstable.

Table 1. XRF analysis of unactivated coal fly ash

No.	Substance	Concentrate (%)	Oxide	Concentration (%)
1.	Al	1,8	Al_2O_3	2,9
2.	Si	9,3	SiO_2	14
3.	P	0,64	P_2O_5	1,0
4.	K	2,19	K_2O	1,84
5.	Ca	30,0	CaO	29,2
6.	Ti	1,79	TiO_2	2,9
7.	Mn	0,60	MnO	0,49
8.	Fe	51,23	Fe_2O_3	46,51
9.	Ba	0,76	BaO	0,61

Table 2 is mineral composition of unactivated coal fly ash from XRD analysis. XRD analysis shows that the most dominant minerals are amorphous structure and crystalline phase of quartz (SiO_2). Fly ash samples consist mainly amorphous aluminosilicate with a less number of iron-rich part. It is likely that the iron oxide bounds with aluminosilicate to form amorphous phase. While aluminum and silicon form either as sillimanite, quartz, or binds with Ca to form anorthite. Calcium was associated with oxygen, sulfur or with silicon or aluminum. The calcium-rich material is different in elemental composition from the amorphous alumino-silicate parts. It is clearly a non-silicate mineral possibly calcite, lime, gypsum or anhydrite **[5]**.

Table 2. XRD analysis of unactivated coal fly ash

No.	Mineral	Formula	Konsentrasi (%)
1.	Quartz	SiO_2	21,1
2.	Sillimanite	Al_2SiO_5	1,6
3.	Anhydrite	$CaSO_4$	0,7
4.	Magnetite	Fe_3O_4	3,3
5.	Anorthite	Ca_3SiO_5	1,7
6.	Siderite	$FeCO_3$	1,1
7.	Arcanite	K_2SO_4	2,4
8.	Periclase	MgO	6,2
9.	Hematite	Fe_2O_3	0,5
10.	Maghemite	Fe_2O_3	3,9
11.	Wuestite	FeO	1,2
12.	Amorphous	-	54,9

Figure 1 shows elemental mapping of unactivated fly ash. EDX analysis indicates that the big particle contains a lot of Si while Fe and Al distribute evenly in all particles. This evidence indicates intermixing of Fe and Si-Al mineral phases while Ca may in form non-silicate minerals **[5]**. These results are supported with XRD data.

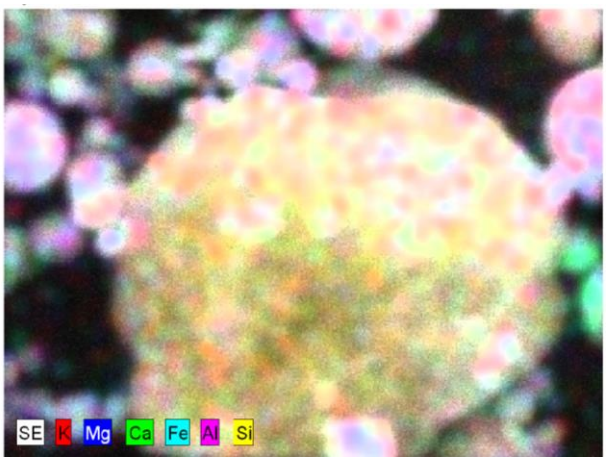

Figure 1. Result SEM of unactivation coal fly ash

3.2 Activation Coal Fly Ash Characterization

From Table 3 and 4 one can observe that amorphous phase and quartz crystalline still dominate in fly ash after physical activation. There is little changes of mineral composition after physical activation. On the other hand, the chemical activation changed the amount of minerals in fly ash. For example, after chemical activation the amount of quartz decreases while the amount of anorthite increases. Figure 2 exemplifies the change in the amount of mineral of fly ash after physical and chemical activation. From Figure 2 it is known that chemical activation plays an important in changing the amount of minerals, while the physical activation does not affect significantly.

Table 3. XRD Quantitative Data of Coal Fly Ash with Physical Activation

CRYSTAL/MINERAL	FORMULATION	UNIT	PHYSICAL ACTIVATION					
			500	520	540	560	580	600
Quartz	SiO_2	%	20,0	21,1	22,0	22,2	22,3	21,0
Sillimanite	Al_2SiO_5	%	4,2	2,8	3,2	2,5	3,1	2,8
Anhydrite	$CaSO_4$	%	0,4	0,6	0,4	0,8	1,0	0,4
Magnetite	Fe_3O_4	%	2,9	3,2	3,6	3,9	3,2	3,5
Anorthite	Ca_3SiO_5	%	1,6	2,1	2,3	2,7	1,4	1,7
Siderite	$FeCO_3$	%	1,1	0,9	1,4	1,1	1,2	1,3
Arcanite	K_2SO_4	%	2,7	2,8	2,4	2,1	2,8	3,1
Periclase	MgO	%	6,7	6,3	5,9	7,4	6,6	6,4
Hematite	Fe_2O_3	%	0,5	0,6	0,5	0,6	0,6	0,6
Maghemite	Fe_2O_3	%	3,5	3,4	2,7	2,8	3,4	3,0
Wuestite	FeO	%	0,5	1,2	0,8	0,6	0,9	0,9
Amorphous	-	%	54,0	53,7	54,1	52,5	52,7	54,3
R_wp	-	%	2,9	2,9	2,9	2,9	2,9	2,9

Table 4. XRD Quantitative Data of Coal Fly Ash with Chemical Activation

CRYSTAL/MINERAL	FORMULATON	UNIT	CHEMICAL ACTIVATION					
			500	520	540	560	580	600
Quartz	SiO_2	%	13,2	1,0	0,5	5,1	0,2	3,3
Sillimanite	Al_2SiO_5	%	0,0	2,6	4,0	2,5	4,3	8,4
Anhydrite	$CaSO_4$	%	0,0	0,0	0,1	1,2	0,3	0,0
Magnetite	Fe_3O_4	%	3,1	3,4	0,1	0,0	4,3	3,5
Anorthite	Ca_3SiO_5	%	35,6	14,2	7,1	20,8	17,1	24,0
Siderite	$FeCO_3$	%	1,3	0,0	0,0	0,2	0,2	0,2
Arcanite	K_2SO_4	%	14,1	18,0	16,9	18,6	15,3	14,8
Periclase	MgO	%	11,9	15,3	22,5	12,2	9,9	6,5
Hematite	Fe_2O_3	%	0,2	0,0	1,4	0,1	0,1	0,1
Maghemite	Fe_2O_3	%	0,0	0,0	3,0	0,0	0,0	0,0
Wuestite	FeO	%	1,0	2,8	6,2	2,7	4,6	2,0
Amorphous	-	%	15,2	41,1	38,3	34,5	42,7	35,4
R_wp	-	%	5,1	9,6	8,5	7,2	8,5	6,9

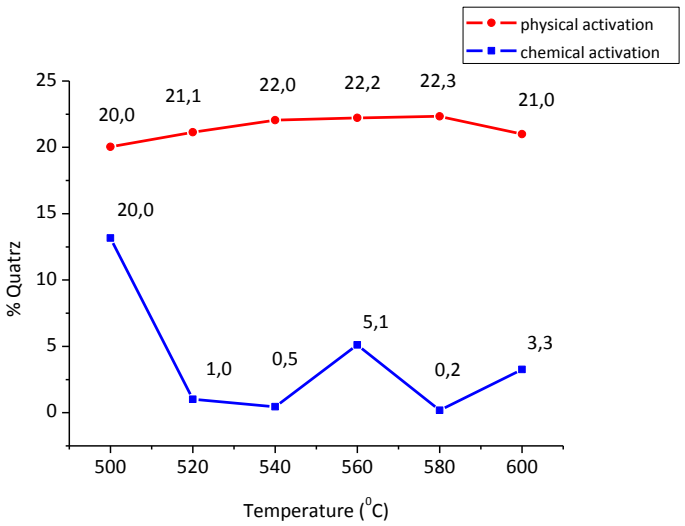

Figure 2. Comparison of quartz contents after physical and chemical activation

Physical activation causes losing water content (intercrystalline water) in fly ash as indicated by thermogravimetry experiments **[6]**. Whereas chemical activation may active the unactivated substances, and finally aids the adsorption process.

4. Conclusion

Unactivated coal fly ash consist mainly of Fe, ca, K, Si, and Al, in the form of quartz and amorphous. The mineral contents were found to change after chemical activation e.g. quartz was reduced, anorthite was increased. Physical activation does not affect it.

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