IMPACTS OF LOW RANK COAL UTILIZATION IN THE COAL FIRED POWER PLANT THAT WAS DESIGNED TO USE SUB - BITUMINOUS COAL

Cahyadi and **Hari Yurismono**
Balai Besar Teknologi Energi (B2TE) – BPPT
Kawasan Puspiptek , Tangerang 15314, Indonesia
Email: cahyadi_mail@yahoo.com

ABSTRACT

Most of the existing coal fired power plants in Indonesia that have capacity of 400-600MW is designed using sub-bitumonous coal intake. This coal has a caloric value of 5,000 kcal/kg (a.r.). Considering the coal price of sub-bituminous tends to raise, some power plant have switched to use a low rank coal having a caloric value of 4,200 kcal/kg (a.r.).

Indonesian Coal Index (ICI), in November, 2008 indicated that the coal having caloric value of 5,800; 5,000 and 4,200 kcal/kg (a.r.) are US$ 93, 68 and 41 per ton (FOB) respectively**.** Low rank coal utilization in the existing coal fired power plant that was designed for the sub-bituminous coal intake are reviewed both in technical and economic aspect and its impacts on the power plant performance.

Key words: Coal fired power plant, Sub-bituminous, Low rank coal and Performance

ABSTRAK

Pada umumnya, hampir semua pembangkitl listrik berbahan bakar batubara di Indonesia dengan kapasitas 400-600MW didisain menggunakan batubara sub-bituminus. Nilai kalor batubara ini adalah 5.000kcal/kg (a.r.) Oleh karena harga batubara sub-bituminus yang semakin tinggi, beberapa pembangkit beralih menggunakan batubara peringkat rendah dengan nilai kalor 4200kcal/kg (a.r.).

Indonesian Coal Index (ICI), pada bulan November, 2008 menunjukkan bahwa batubara dengan nilai kalor 5800, 5000 dan 4200 kcal/kg (a.r.) adalah masing-masing US$ 93, 68 dan 41 per ton (FOB)**.** Penggunaan batubara peringkat rendah pada pembangkit listrik batubara yang didisain dengan batubara sub-bituminus dievaluasi baik dari aspek teknis, ekonomis maupun kinerja pembangkit listrik.

Kata kunci: Pembangkit listrik batubara, Sub-bituminus, Batubara peringkat rendah dan kinerja

I. INTRODUCTION

Coal production in Indonesia reached 152 million tons (MT) in 2005, increase of nearly 15 percent over the year before. Domestic coal consumption was 41 MT in 2005. See also data in **Fig. 1.**

Coal exports were 107 MT in 2005 and account for 70% of production. Japan and Taiwan remain the largest consumers of Indonesian coal and bought over 38% of exports, followed by South Korea, Hong Kong and Malaysia (WCI, 2009).

Domestic coal demand increase five percent to 41.3 MT in 2005. Coal-fired power plants were the single largest consumers, accounting for 22.9 million MT or 63 percent of total demand. Cement plants were the second largest consumers, comprising 15 percent of domestic demand. Additional demand for coal will come from several new coal-fired power projects in West and Central Java: Tanjung Jati B (1,600 MW), Cilegon (740 MW) and Cilacap (600MW) have been in operation since 2005.

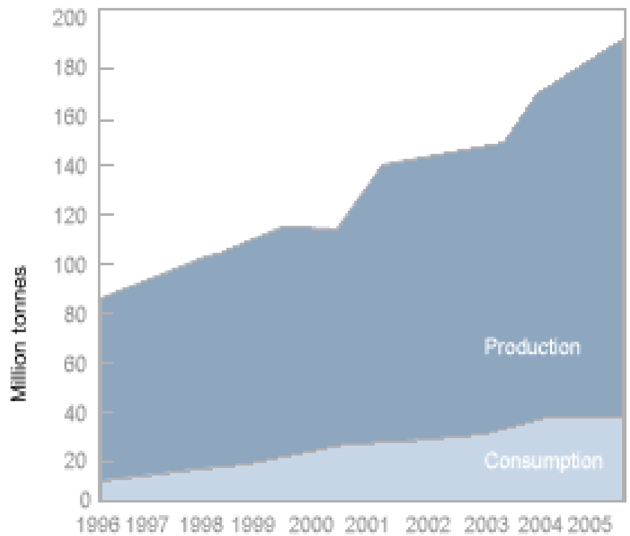

Fig. 1. Production and consumption of Indonesian coal in the period of 1996-2005 (WCI, 2009)

Indonesian Coal Index (ICI report, 2008), in August 1, 2008 indicated that the price of coal having caloric value of 5800, 5000 and 4200 kcal/kg (a.r.) are US$150, 130 and 50 per ton (FOB), respectively.

Most of the existing coal fired power plants with capacity of 400-600 MW in Indonesia are designed to use coal having caloric value of 5000 kcal/kg (a.r.) classified as sub-bituminous coal. Considering the sub-bituminous coal price tends raise too high, some management of coal fired power plants have decided to change the intake to low caloric coal of 4200 kcal/kg (a.r.).

Low rank coal utilization in the existing coal fired power plant need is reviewed both in technical and economic aspect. This paper will focus on the impact of low rank coal utilization in the view of technical aspect. This paper also described the influence of burning low rank coal in a coal fired power plant with the capacity of 600MW that was designed to use sub-bituminus coal having an average heating value of 5,200 kcal/kg (a.r.).

2. POWER PLANT PERFORMANCE

Steam power plant mainly consists of boiler, turbine-generator and balanced of plant. The performance of each equipment will affect the overall power plant performance. Power plant performance is calculated based on the heating value of fuel input.

Heating value of coal as fuel / energy input can be defined based on either in higher heating value (HHV) or lower heating value (LHV). HHV is the full energy content of fuel including the latent heat of vaporization of water, while LHV excludes the energy of water vapor from the fuels. Efficiency is commonly represented by the heat rate, which is the reciprocal of the thermal efficiency and is described in the units of kcal/kWh or Btu/kWh.

Heat rate is an index of the efficiency of power generation expressing by the ratio of fuel energy input in the form of coal to electrical power produced by the turbine generator.

Gross plant heat rate (GPHR) is based on the total or gross power (GP) produced by the turbine generator while the net plant heat rate (NPHR) is based on the gross power reduced by the auxiliary power (AP). NPHR depends on the turbine heat rate (THR), boiler efficiency (BE) and gross power and auxiliary power (AP) (EPRI, 1996).

Turbine heat rate is an index of the efficiency of the steam cycle and generator in converting heat supplied as superheated or reheated steam to electrical power.

$$NPHR = \frac{100xTHR}{BE} x \frac{GP}{GP - AP} \tag{1}$$

$$GPHR = \frac{100xTHR}{BE} \tag{2}$$

Boiler efficiency is calculated by heat loss method that means collecting the amount of the heat losses from boiler and assuming that the remainder of the heat is absorbed to produce superheated steam or reheated steam. Procedure to calculate using heat loss method is:

1. Dry gas loss
2. Heat loss due to fuel moisture
3. Heat loss due to combustion of hydrogen in the fuel
4. Heat loss to combustibles in the ash
5. Heat loss due to radiation
6. Uncounted heat loss

3. CASE STUDY OF LOW RANK COAL IMPACTS ON POWER PLANT

3.1. Coal Handling and Pulverizing

Low rank coal utilization in sub-bituminous coal power plant will increase the quantity of coal consumption. Power consumption and fuel cost in coal handling activities will be higher than sub-bituminous coal. Many fine particles in low rank coal will tend to make dusty environment while coal handling. Spontaneous combustion in coal yard tends to high with low rank coal because of high volatile matter and fine particles.

The performance of pulverizing mills is measured in terms of the following parameters:
a. capacity and throughput
b. pulverized coal fineness
c. power required
d. wear rate of pulverizing elements

Full-scale operation of pulverizing mills involves the optimization of primary factors as pointed in (a) and (b). Also involves the secondary factors pointed in (c) and (d). The factors above are interrelated and influenced by fuel related parameters including coal mass flow rate and volumetric flow rate, size distribution, and coal properties such as moisture, ash, hardgrove index (HGI) and abrasiveness; and operational parameters such as load applied to the pulverizing elements (particularly for vertical spindle mills), coal/primary air ratio, and classifier setting.

Table 1. Coal pulverizer mill while burning design coal and low rank coal

Parameter	SB	LR #1	LR#2	Design sub-bituminous coal
HV (kcal/kg)	5148	4295	3781	5200
Number mill in operation	5	6	6	5 operation 1 standby
Mass flowrate (ton/jam)	57.7	56.8	57.5	67
% Capacity	86.11	84.84	85.82	100

The mill performance is based on the variation of mill power (kW) as a function of mill capacity (C, kg/s) times product fineness (F, mass fraction passing 75 um).

As a case study of low rank coal utilization in existing coal fired power plant, burn test is performed in a coal fired power plant that was designed by sub-bituminous coal intake. The range of design coal is indicated in **Table 5**. The average value of design coal can be classified as a sub-bituminous coal. Burn test has been performed with burning of the three different coals. The coals are one sub-bituminous coal (SB), and two low rank coals (LR#1 and LR#2). The coal specifications are shown in **Table 6**.

Based on the burn test, the impacts on pulverizer can be noted.

a. To supply the energy input to boiler, SB (Sub-bituminous) coal was supplied with only 5 mills in operation, but with LR#1 and LR#2 required 6 mills in operation. Burning SB coal.
b. For a given mill throughput and neglecting the effects of coal moisture content, the LR#1 and LR#2 coals require significantly higher power than design coal.

3.2. Power Plant Performance

Heat rate of power plant while burning low rank coal will tend to increase. In the other word, the power plant efficiency will be decrease while burning low rank coal compare with sub-bituminous coal. **Table 2** shows a data of coal power plant performance that burning sub-bituminous coal and low rank coal or lignite (LR#1 and LR#2). The coal power plant using sub-bituminous coal intake was able to achieve 600 MW with 5 mills in operation and 1 mill stand by. Low rank coal intake (LR#2) was only attain 510 MW with 6 mills in operation. Low rank coal intake (LR#1) was able to reach 600 MW, but all of 6 mills in operation.

Table 2. Heat rate performance of sub-bituminous coal (SB) and low rank coal (LR #1 & LR#2) burning

Parameter	Unit	SB	LR#1	LR#2
Load	MW	600	607	510
HV coal	Kcal/kg	5148	4295	3781
Turbine HR	kcal/kwh	1904	1915	2092
Inhouse P	MW	23.4	26.8	19.06
Boiler Eff	%	88.49	86.42	87.30
GPHR	kcal/kwh	2151.7	2215.5	2396.19
NPHR	kcal/kwh	2239.0	2317.8	2489.24

3.3. Pulverized Fuel Combustion

Based on observation during burnt test, furnace exit temperature with burning design coal was higher than low rank coal. FEGT (Furnace Exit Gas Temperature) while burning low rank coal and design coal were 1083-1041 ^{o}C and 1100-1163 ^{o}C, respectively.

Table 3. Spray water flow while burning design coal and low rank coal

Water flow	Unit	SB	LR#1	LR#2
FEEDWATER FLOW	Ton/hr	1854.50	1532.91	1553.56
REHTR SPRAY WATER FLOW	Ton/hr	10.63	17.01	15.23
P PRIMARY SUPERHTR SPRAY WTR FLOW	Ton/hr	89.86	135.68	127.38
S SECONDARY SUP HTR SPRAY WATER FLOW	Ton/hr	80.73	110.63	100.52

During burning design coal, distribution of heat absorption in the furnace was 34% and super heater-reheater was 15%. With burning low rank coal, heat absorption in the furnace was decreased and in super heater-reheater was increased. See in the **Table 3**. Spray water flows (primary and secondary super-heater, and reheater) while burning low rank coal were higher than design coal, despite furnace exit temperature of low rank coal was lower.

3.4. Fan Power Consumption

As study case for in-house power consumption, power consumption for fans (ID Fan, PA Fan & SA Fan) were tend to increase while burning low rank coal. Burning low rank coal will increase the combustion air requirement, so that the in house power requirement for fans will also increase. The other changes in fan power consumption while burning low rank coal, there was a load change (kW/MWh) from FD fan to PA fan due to huge primary air requirement for carrying pulverized coal from pulverizer to coal burner, see **Table 4**.

Table 4. Fan power consumption

Fan-fan	SB	LR#1	LR#2
POWER MW	600	607	510
ID FAN	3238.4	3784.5	3571.6
%	BASE	16.9	10.3
kW/MWh	5.4	9.7	7.0
FD FAN	1328.8	1293.8	1318.6
%	BASE	-2.6	-0.8
kW/MWh	2.2	2.1	2.6
PA FAN	2838.8	3525.6	3472.5
%	BASE	24.2	22.3
kW/MWh	4.7	5.8	6.8

5. CONCLUSION

This assessment found that the main impact of using low rank coal in a coal fired power plant that was designed to use sub-bituminous coal is the maximum capacity of power plant decrease.

Changing with low rank coal will increase the coal consumption and reduce the capability of system components such as coal handling equipment, pulverizing mills, fans, ash handling equipment, and flue gas cleaning plant.

Burning Low rank coal will decrease boiler efficiency and increase power plant heat rate. The most significant boiler efficiency losses attributable to coal quality, those are:

- heat loss in evaporating the fuel moisture
- heat loss as the specific heat of water from combustion of hydrogen in the fuel
- heat loss due to combustibles (un burnt carbon) in the fly ash

The power consumption in house is becoming high. Burning low rank coal is a significant factor in increasing the power plant heat rate.
Technical and financial aspect need to be review for low rank coal utilization. Cheaper price of low rank coal does not mean lower cost in operation and maintenance of the coal fired power plant that was designed to use sub-bituminous coal. Optimum heating value needs to be calculated to find out the real cost for operation & maintenance.

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Table 5. Typical coal design range of coal fired power plant

Proximate analysis (as received)	"Worst" (or range)	"Average"
Moisture (% by weight) ………………	28.3	23.6
Ash (% by weight) …………………..	12.8	7.8
Volatile Matter (% by weight) ………..	15.1	30.3
Fixed Carbon (% by weight) …………	43.8	38.3
Total (% by weight) …………………..	100.0	100.0
Higher Heating Value HHV (kcal/kg) …	**4,225**	**5,242**
Lower Heating Value LHV (kcal/kg) ….	**4,075**	**5,092**
Grindability Index (HGI) ………………	59.4 – 64.2	61.8

Ultimate analysis (as received)	"Worst" (or range)	"Average"
Moisture (% by weight) ………………	28.3	23.6
Ash (% by weight) …………………….	12.8	7.8
Carbon (% by weight) …………………	45.3 – 64.1	54.2
Hydrogen (% by weight) ………………	2.6 – 4.1	3.9
Sulphur (% by weight) ………………..	0.9	0.4
Nitrogen (% by weight) ……………….	0.7 – 1.1	0.9
Oxygen (% by weight) ………………..	3.0 – 13.6	9.2
Total (% by weight) ……………………		100.0

Table 6. Typical low rank coal analysis (as received)

Parameter	Unit	SB	LR#1	LR#2
PROXIMATE ANALYSIS				
MOISTURE	% w	19.28	28.99	30.93
ASH	% w	8.53	7.18	9.85
VOLATILE	% w	35.04	33.27	32.17
FIXED CARBON	% w	37.15	30.57	27.05
ULTIMATE ANALYSIS				
MOISTURE	% w	19.28	28.99	30.93
ASH	% w	8.53	7.18	9.85
CARBON	% w	54.89	46.67	43.37
HYDROGEN	% w	4.15	3.50	3.26
NITROGEN	% w	4.14	3.44	3.25
TOTAL SULFUR	% w	0.49	0.32	0.17
OXYGEN (by diff.)	% w	8.52	9.90	9.17
CALORIC VALUE	KCal/kg	5,146	4,259	3,781
Rank - ASTM		Sub bit C	Sub bit C	Lignite A