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SUB BITUMINOUS COAL BLENDED ANALYSIS BITUMINOUS COAL

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Abstract

The purpose of the study is to examine the blended coal specification which was selected as a main fuel in thermal coal power plant. Due to limited preferred coal and designed coal to the thermal power plant specification, the coal blending facilities was carried out. However, before firing the blended coal the coal specification must be determine to predict the coal performances and characteristics. Having said that, the chemical analyses and testing of a coal sample are generally done at the first stage at off-site in a laboratory. Therefore, the quality and rank for the blended coal with its intrinsic characteristics between two types of sub-bituminous coal were evaluate first. The study also presents the ash analysis for blended sub bituminous coal in prediction for slagging and fouling affects in the boiler furnace. The results show, the coal blended specification by looking at the slagging index and fouling index which is categorize at the same level, medium. Summaries of the sub bituminous; coal medium calorific value, moderate moisture content, high HGI, low ash content, moderate fuel ratio, medium Nitrogen content, moderate ash fusion temperature, low content of SiO_2 and moderate content of total Sulphur.

Keywords: Sub Bituminous coal, blended coal, Proximate Analysis and Ultimate Analysis.

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1. Introduction

In 2018, coal plays a large role in Malaysia's energy scheme and is fully imported. Some 63%, is imported from Indonesia, with another 24% coming from Australia and the remainder from nations as far away as Russia (11%) and South Africa (2%). Reported by The Star business news (July 2018), Peninsular Malaysia's power generation is highly dependent on fossil fuel with 53% coal, 42% natural gas and 5% hydro, together with other forms of renewable energy (RE). Australian thermal coal prices have broken through US$120 per tonne for the first time since 2012, driven by strong consumptions in Asia. Spot prices for thermal coal from Australia's Newcastle last closed at US$119.30 per tonne, the highest level since October 2011. Similarly, Indonesia's Ministry of Energy and Mineral Resources set its July thermal coal reference price at a six-year high of US$104.65 per tonne, recording a rise of 8.3% month-on-month and 32.6% from a year ago. For the first quarter ended March 31, Tenaga Nasional Berhad (TNB) average coal price stood at US$92.1 per tonne. The utility giant consumed 7.1 million tonnes of coal during the quarter to generate electricity (Energy, 2018).

In addition, global natural gas prices are increasing for the first time in two years as demand jumps in Asia, Europe and the United States. The escalating cost of electricity generation has to be adjusted in the form of imbalanced cost pass through (ICPT) rate. In Peninsular Malaysia, electricity tariff is determined by the Government through a globally-accepted framework called Incentive Based Regulation (IBR). The IBR provides a mechanism called ICPT which allows adjustment of fuel prices for electricity sector every six months. Changes in prices of fuel for electricity generation are reflected as a varying rate of a rebate or surcharge (Energy, 2018).

In response to the criticality of the coal price and demand, the thermal coal plant had put same effort to manage the situation. The fuel, coal and performance of the coal need to improve by looking at the several techniques, technology and methodology (Van Krevelen, 1993). By improving the coal performance, the coal usage can optimize accordingly (Karri, 2012). According to Nuraini, Salmi, and Aziz (2018), the sub bituminous coal performance increase directly to the coal with high Calorific Value (CV). Different types of sub bituminous coal results indicate coal with different Calorific Value (CV) and properties give different efficiency to the boiler (Nuraini et al., 2018). Due to that, this study interest to investigate the opportunity to look performance of sub bituminous coal blended. The proximate analysis and ultimate analysis was carried out to the two types of sub bituminous coal and the blended sub bituminous coal (Qian Zhu, 2014).

2. Problem Statement

Coal has many important uses worldwide. Normally coal applied for power generation thru thermal power plant, steel industry, cement industry and others application. Manners (2019) explained the most significant uses of coal are in electricity generation, steel production, cement manufacturing and as a liquid fuel. Till the date, billions of tonnes of coal are traded in local and international market. Besides, looking at coal commercial operation the price of coal is followed the market demand and coal quality. The price of the coal not only affects to the quantity of coal but reflect to the coal quality in terms of coal specification. In facts, coal with different specification and quality resulted the desire performance (Nurani et al., 2018).

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Due to limitation of coal stock available in market, there is a need to enhance the coal usage as fuel in thermal coal plant. According to Shih and Frey (1995), coal blending is one of several options available for reducing sulphur emissions from coal-fired power plants. However, decisions about coal blending must deal with uncertainty and variability in coal properties, and with the effect of off-design coal characteristics on power plant performance and cost (Shih & Frey, 1995). Supported by Carpenter (1995), blending of coals of different types at pulverised coal-fired power stations is becoming increasingly common as electric utilities attempt to save costs, meet SO2 emission limits and improve the combustion behaviour of their coals.

3. Research Questions

The study purposely to examine the coal blended method by looking the impact of coal blend specification. The research question for this study is: What is the result of ultimate analysis for blended coal? In addition, approximate analysis for coal blend specification for sub-bituminous coal?

4. Purpose of the Study

Fundamentally, coal was form in hard rock which can fired as a non-renewable solid fossil fuel. Coal contents with carbon, hydrogen, sulphur, oxygen and nitrogen. The four types of coal include peat, lignite, bituminous, and anthracite, with anthracite being most desirable due to its high heat content (Speight, 2015). The properties of coal which have an impact on combustion and environmental performance often form the basis of sale contracts, and they include calorific value, volatile matter, moisture, sulphur, chlorine and ash which are elemental composition of content of coal. These properties are all measured at samples taken during loading of the coal. Payment for the coal is based on the analytical results. Also, knowing the quality of coal is essential for the applications of that coal (Qian Zhu, 2014).

The coal analysis was applied approximate analysis and ultimate analysis (Speight, 2015). In fact, the coal analysis applied will measure the coal physical structure and chemical content of the coal. Specific test method for coal was designed and applied widely in the industry. The coal analysis method was firm to predict the coal behaviour during coal in used. Proximate analysis and ultimate analysis is the method applied to analyse the coal properties and specification. According to Qian Zhu (2014), proximate analysis which is measuring the coal fixed carbon, the coal moisture content and coal ash content can be evaluate in the simple way. The proximate analysis simply can be measured by simple apparatus with sampling method.

In measuring the coal properties and chemical composition in coal, the ultimate analysis method will be applied. According to Karr (2013), the ultimate analysis test will be carry out in laboratory with special equipment and apparatus. The proper method of test was designed to suit the purpose for chemical composition. In addition, the amount of air require during firing coal and combustion process is measuring with applied the ultimate analysis. As mentioned by Karr (2013), the volume and composition of combustible gas, the flame temperature and performance, design of flue gas ducting and flue gas temperature can be predicted upon carry out the ultimate analysis.

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Therefore, the study intent to investigate the coal properties of blended coal which potentially can be used to the thermal plant. Therefore, the proximate analysis which determine the physical coal and ultimate analysis for chemical composition was applied for determined the blended coal characteristic. The coal analysis result will help the organisation to predict the behaviour and consequently make decision to proceed with coal blended or not.

5. Research Methods

The standard method and technic for coal analysis applied for this research. Stipulated by Karr (2013), the coal selected for blending must compliance with international standards such as ASTM, ISO, AS, and standard. Indeed, the coal blending testing purposely to optimized plant operations which highly considering safety method of execution, inclusive procedure and inspection to be carried out. The environment factor, law and regulation stated for this power plant is highly consider as well Qian Zhu (2014). For that purpose, the analysis of coal was carried out such as below:

5.1. Coal moisture content

The coal moisture content is determined from the sample of coal or namely as pulverised coal. Throughout milling process, the pulverised coal is producing in size between 150-200 micron. The pulverised coal was placed in the oven at temperature 108 + 2 °C without covered for drying process. After 3-4 hour the sample was taken out from the oven to the room temperature for cooling process. Compare the weigh before and after the sample heated in the oven. The moisture content is presenting through the weight loss during the heated process.

5.2. Coal volatile matter

Coal was taken from the mining pile and transfer to coal stock yard. Normally, the coal size is below 50 centimetres was taken for a sample. The sample is weighted and heated in the furnace or oven operate at 900 + 15 °C. Sample in crucible was covered as well. with crucible and Before the sample was heated, the sample was weighted and placed in covered crucible. After sample was heated 3-4 hours, sample was placed at room temperature for cooling process. The volatile matter is presenting throughout the different of weight before and after sample weighed. The balance of coal not burning during heated process called as coke.

5.3. Carbon and Ash in Coal

The measurement for carbon and ash content in coal continue from the 5.2 Coal volatile matter measurement. The sample covered in crucible was removed and continue heated the remaining sample with Bunsen burner. Heated the sample until all the carbon is proper burned. The incombustible ash from the sample is weighted then. Fixed Carbon (FC) is determining from the different weight before and after the sample was heated from Bunsen burner. In conclusion, the measurement of FC is the total weight of the sample with deduction of weight of moisture content, deduction weight of volatile matter and deduction weight of ash content.

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5.4. Coal proximate analysis

As mentioned before, the proximate analysis measuring the coal physical structure. This analysis approximately determines the weight of FC, volatile matters, coal moisture content and ash of the coal. According to Qian Zhu (2014) the FC is indicating the coal energy which is present in heating value of the coal during combustion. The coal used as main fuel and performing as the main heat source for heat transfer process. Meanwhile, the ignition of the coal is represented by the amount of volatile matter content in the coal. Higher volatile matter means easy the particular coal to ignite. The ash content from the coal is the incombustible product. Critically, is important to measure the ash percentage in the coal whereby its affects the design of the boiler in coal power plant, ash handling system and environmental issues.

5.5. Amount of fixed carbon in coal

As discussed in 5.4 Proximate analysis, the amount of energy in coal is represent by fix carbon content whereby its predicting the heat value. According to Marshall (2010), fix carbon is so called fix solid fuel which content with carbon in high percentage. Besides carbon, the coal is content with hydrogen, sulphur and nitrogen in the firm of solid as well. In nature, these contents are still performing in solid fuel and not performing to gasses. In results, the higher of fixed carbon contents, the higher heating value and calorific value of the particular coal.

5.6. Amount of volatile matter in coal

Volatile matter is the fuel ratio in form of gaseous content in the particular coal. In volatile matters consist with several chemical compositions such as methane, hydrocarbons, hydrogen, carbon monoxide and incombustible gases. The carbon dioxide and nitrogen are the example of incombustible gases found in coal during combustion process. Normally, the coal volatile matter content between 20 to 35 percent where the higher of volatile matters contents, the easier coal to ignite. In meantime, the volatile matter of the coal indicates the minimum limit of the furnace height for the combustion chamber.

5.7. Coal ash content

Ash is the product from coal combustion process. Coals ash typically consist with fly ash and bottom ash. The fly ash and bottom ash are called as incombustible product which is not burning during combustion process. Normally, the ash content for sub-bituminous coal ash is less than 10 percent and the ash content for bituminous coal is between 11 to 20 percent. The higher ash content of the coal, the higher ash product from combustion product produced. According to Tiwary (2001), the fly ash in flue gas outlet potentially causes the clinker slagging and fouling formation in the boiler. The maintenance and handling of clinker in the boiler increase the operation cost in order to increase the boiler efficiency. Therefore, to minimize the effects of slagging and fouling in the boiler coal with low ash contents is preferable as main fuel for combustion in the boiler.

5.8. Moisture content

The coal collected from the coal mine consist with water which is part of mineral matter. The percentage of water contents in all form in the coal namely as total moisture contents. Thus, water contents or moisture contents is the quantity of water contained in a material, such as soil, mineral, ceramics crops

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or disposable material. Inclusively, the moisture content is managing properly to ensure the good of coal quality. Previously, the coal moisture contents is significantly determining the calorific of heating value. During combustion, the combustible matter was take place and its decrease the heat amount per kg of coal. In facts, there is between 0.5 to 10 percent of moisture represent in the particular coal. Besides that, the moisture content contributes to the heat transfer process which is firmly can perform as heat loss, conduction, convection and vaporization process.

5.9. Sulphur content

The coal also contents with sulphur. In facts, the sulphur content is affects by the environment factors. Thus, sulphur contain in coal and during combustion sulphur oxides will take place where it combines between sulphur and oxygen. The normal range for sulphur content in sub-bituminous coal is between 0.5 to 0.8 percent. The coal with less than 1% sulphur is classified as low-sulphur coal. Coal with 1% to < 3% sulphur is medium-sulphur coal. The content of sulphur in coal affects the combustion product which is the fly ash behaviour. The fly ash is firming the clinkering as slagging and fouling in the boiler and cause reduction in boiler efficiency.

6. Findings

For this study, the blended coal was inspecting, observed and monitor directly at coal yard. Besides, the coal analysis was applied to determine the coal specification characters to the boiler performance. According to Marshall (2010), the ash analysis was important to carry out in detail in measuring the coal blended ash properties. The ash analysis refers to the inorganic residue remaining after either ignition or complete oxidation of organic matter in a foodstuff. A basic knowledge of the characteristics of various ashing procedures and types of equipment is essential to ensure reliable results (Marshall, 2010).

6.1. Coal management

Coal management covered the observation of the coal spontaneous heating and coal handling mechanism. The management of the spontaneous heating of the coal since coal was unloaded from shipment to the coal yard. Meanwhile, the coal handling is covered the coal unloading processing from coal mines to the shipment, from coal shipment to the coal yard and from the coal yard transfer to the furnace.

6.2. Spontaneous heating

Spontaneous heating occurs at coal storage and it might cause serious problems. The main cause is exothermal reaction based on air oxidation of coal, therefore, the potential of spontaneous heating of lower rank coal is higher and thus sub-bituminous coal requires particularly more attention. In order to prevent spontaneous heating, countermeasures such as depression of contact between coal and air by pile compaction, spray of inhibitor or water and diffusion of oxidation heat from pile are required. It is important to measure spontaneous heating and to carry out proper coal storage management. During the storage period for this coal blended, no incidences of spontaneous combustion have been observed. Figure 01 shows the blended coal which was stack from shipment to the coal yard.

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Figure 01. Blended coal at coal yard

6.3. Coal handling

The plugging of hopper and chute blockage which can cause some troubles in coal handling operation. Inadequate particle size distribution, adhered moisture and clay minerals content are major causes of coal handling troubles. When the amount of < 2mm fraction in coal exceeds 30%, the coal tends to cause difficulty in handling and, if particle size of coal is 0.5mm, the coal is inclined to adhere on the wall of facility. In other words, the amount of < 2mm fraction in coal should be less than 30% and the amount of particles of < 0.5mm should be less than 10%. Clay minerals, particularly montmorillonite on coal surface tends to absorb moisture and is prone to cause handling problem. In addition, clay materials deteriorate coal fluidity by forming strong agglomerate.

During observation, there were no problems related to the handling of blend coal. However, the amount of carry back was minimal. There were no issues of belt skewing or other abnormalities. There were also no reported incidents of chute plugging.

6.4. Dust emission and stockpile slumping

There was no appreciable dust emission observed by the station staff during unloading. Dust clouds were not visible during discharge from the unloaders. Dust was also not observed during reclaiming. The stockpile of blend coal has average integrity, with significant amounts of slumping observed after heavy rain. The pile was seen to be soft but it was actually hard after heavy rain due to coal sticking together. This might cause blockages at chutes.

6.5. Coal analysis

The results of coal testing are utilized mainly for characterization, commercial grading or assigning ranks, and deciding the utilization for different purposes. Evaluation of two types of coal sample. GCV both of two coal samples show similar GCV, 5099kcal/kg of Coal type A and 5165kcal/kg for coal type B. Sulphur content is also similar, while moisture content shows higher for coal type A. Fuel ratio is determine by the proposition of Fixed Carbon to the Volatile matter is also similar as both samples. Calculated fuel ratio is around 1.0 which is suggesting good burn-out performance.

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The selected analysis and test was performing in the laboratory. Results test for the Total Moisture, percentage (Inherent Moisture), percentage of both coals are similar. The difference would be due to surface moisture. GCV which is indicate energy of heat show similar GCV, no significant difference. Ash percentage and almost similar about 5 percent. HG1 indicates the hardness of coal showed same reading which is 41. Table 01 shows the coal analysis result between coal types A, coal type B and coal blended for moisture analysis, proximate analysis and ultimate analysis.

Table 01. Shows the coal analysis results

Analysis	Units	Coal Type A	Coal Type B	Coal Blended A+B
Moisture analysis				
1. Total moisture	wt%	26.0	23.3	23.2
2. Air dry moisture	wt%	12.2	11.9	15.9
Proximate Analysis				
3. Fixed Carbon	wt%	42.0	41.6	37.3
4. Volatile matters	wt%	40.7	42.0	35.1
5. Ash	wt%	5.1	4.5	4.4
Calorific Value (air dry base)				
6. High Heat Value	kJ/kg	25330	24840	24930
7. High Heat Value	kcal/kg	6050	5933	6010
Ultimate Analysis (dry base)				
8. Total Sulphur	wt%	0.58	0.42	0.58
9. Combustible Sulphur	wt%	0.16	0.29	0.22
10. Incombustible Sulphur	wt%	0.42	0.13	0.31
11. Carbon	wt%	70.94	70.07	77.31
12. Hydrogen	wt%	5.45	5.44	5.54
13. Nitrogen	wt%	1.29	1.07	1.60
14. Ash	wt%	5.80	5.10	4.90
15. Oxygen	wt%	15.78	17.61	14.79
16. Hard Grove Index (HGI)	-	41	41	41

6.6. Ash analysis

For the ash related data coal type A (GCV5000) and coal type B (GCV5500) shows lower of Slagging/Fouling Factors as of conventional evaluation, while FKP shows higher Base/Acid. Table 02 shows the ash properties for types of coal.

Table 02. Shows the coal analysis results for ash properties

Analysis	Units	Coal Type A	Coal Type B	Coal Blended A+B
1. SiO2	wt%	42.20	30.30	38.17
2. A12O3	wt%	23.80	18.20	21.05
3. TiO2	wt%	0.87	0.71	0.71
4. Fe2O3	wt%	11.00	10.30	12.66
5. CaO	wt%	7.10	15.90	8.26
6. MgO	wt%	2.65	4.34	2.60
7. Na2O	wt%	0.87	0.96	0.73

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8. K2O	wt%	1.95	1.08	1.27
9. P2O5	wt%	0.77	0.71	0.38
10. MnO	wt%	0.06	0.11	0.08
11. SO3	wt%	6.86	14.40	8.50

Boiler slagging and fouling are among the most common causes of maintenance headaches at coal-fired power plants. Based on the different mechanisms involved in ash deposit on the heated surface, two general types of ash deposition have been defined as slagging and fouling. Slagging is the formation of molten or partially fused deposits on furnace walls of boiler or convection surfaces exposed to radiant heat. Fouling is defined as the formation of deposit on convection heat surfaces such as super-heater and reheaters. Table 03 show the conventional index for slagging and fouling.

Table 03. Show the conventional index for slagging and fouling

Index Factors	Factor	Low	Medium	High
(1) Slagging Index				
Base / acid ratio (B/A Ratio)	$(Fe_2O_3+CaO+MgO+Na_2O+K_2O)$ wt.% / $(SiO_2+Al_2O_3+TiO_2)$wt.%	<0.3	0.3-0.6	>0.6
Slagging factor	(Base / Acid) x Total sulfur	<2.0	2.0-2.9	>2.9
Iron Content	Fe_2O_3 wt %	<10	10-25	>25
(2) Fouling Index				
Sodium content	Na_2O (wt.%)	<2.0	2.0-5.0	>5.0
Fouling factor	(Base / Acid) x Na_2O (wt.%)	<0.5	0.5-1.25	>1.25
Alkaline metal content	$Na_2O + K_2O$ (wt.%)	<3.0	3.0-6.0	>6.0

7. Conclusion

The blended coal has high risks of spontaneous combustion. However, handling should not cause any issues. During the coal blended test period, observed same experience utilizing the similar sub-bituminous coal in power plant had shown that the coal tends to self-heat at the coal yard after unloading from the port. According to the results of desktop analysis, major problems are unlikely to occur for this coal. However, the risk of fouling and slagging is moderate, based on indices, and should be monitored closely. The higher sulphur content contributes to higher SO2 emissions, thus it will be monitored closely to prevent the emission exceeds environment limit. The coal is a blended coal, which leads to the following concerns:

- Difficulty in determining consistency
- Risk of “unblendable properties” being present, eg Low AFT, Low HGI, Different Ash Constituents
- Possibility of uneven behaviour

The features of Blended Coal recognized from analysis data are summarized as follows:

- Medium calorific value
- Moderate Moisture content
- High HGI

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- Low Ash Content
- Moderate fuel ratio (FC/VM)
- Medium Nitrogen
- Moderate ash fusion temperature
- Low content of SiO2
- Moderate content of total sulphur

Based on risks posed by the coal, the following points will be monitored closely:

- Handling and Storage of Coal
- Slagging deposits in the boiler
- Fouling deposits at the super-heaters
- Effectiveness of Soot-Blowing
- Drying effectiveness of the coal
- Stack/chimney emission observation

The utilization of blends can significantly affect several areas of boiler operation which impact overall power plant performance and generating costs. Areas examined include the pulveriser (assessed by the Hargrove grindability index), combustion behaviour and efficiency with the assessed in terms of the ignition, flame stability, reactivity and burnout characteristics), ash deposition behaviour, and SO2 and NO2 emissions.

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