Consulting Service Report for Improving the Efficiency of Carbonizing Plant for PKS Charcoal In Malaysia

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Japan Consulting Institute
JP Steel Plantech Co.

KEIRIN
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1. Preface

Palm oil production is a large industry in Malaysia and Indonesia. 16 –17 million tons of palm oil is produced every year in Malaysia and Indonesia each. Its production and the price in both countries are increasing every year in parallel with global food and energy tightness. Effective use of biomass wastes from palm oil industry has been investigated in these years. Of such biomass wastes, Palm Kernel Shell (PKS) is utilized in large scale on the grounds that its generation is concentrated in palm oil mills, and property resembles fuel coal with its relatively uniform particle size. PKS generates 20-25 % of the palm oil weight, namely 3.5 – 4.0 million ton/y in each country. Charcoal made from the PKS also resembles metallurgical coke, but it is produced in relatively small scale only for activated carbon use. JP Steel Plantech Co. has been studying the use of PKS charcoal as an alternative to the metallurgical coke for steel industry. The study revealed that the quality of the current PKS charcoal for activated carbon was not stable and could not be widely accepted by steel industry, in addition to the small-scale supply problem. Based on this situation, JP Steel Plantech Co. applied for and adopted the subsidy from JCI (Japan Consultant Institute), named as "Service of Diagnosis and Renovation for Industrial Plants in Developing Countries", and continued to investigate the possibility of application of PKS charcoal for steel industry. This report is the results of the activity supported by the JCI subsidy.

2. Palm oil industry and its wastes

Oil palm tree is a native of Africa, and does not grow in Asian countries naturally. Oil palm trees are planted in Southeast Asian countries in large scale, and oil mills to produce CPO (Crude Palm Oil) are scattered in these plantations. CPO is harvested 3 years after the planting of oil palm tree, and refined CPO is used as food oil or as raw material of detergent. It is also gaining the spotlight as a bio-fuel. The oil palm trees are renewed every 20-25 years because of their deterioration. FFB (Fresh Fruit Bunches) are harvested from the root of roof. 30-40 fruits are collected from one FFB. Weight of one FFB is about 20 kg. EFB (Empty Fruit Bunches) is the remainder when fruits are collected from FFB. Outer portion of the yellow fruit contains much oil. Fiber is the remainder of oil squeezing from the fruit, and it is a good fuel with the oil contained in it. Core of the fruit is called PKS (Palm Kernel Shell). PKS itself can be used as a fuel because of its small and even particle size, in addition to low moisture and impurities. PKS had been simply incinerated or wasted until several years ago, but now it is traded as a fuel for cement industry or power generation with the price of 40-45 US$/ton. Demand and supply of PKS are active in Malaysia, but much of the PKS is not used in Indonesia yet. Carbonized PKS is used as a raw material of activated carbon. Most of the palm oil trunks are not used and neglected after the renewal of the plantation because of its high moisture. Effective use of EFB and trunk are highly expected.

Indonesia and Malaysia are the two largest PKS producing countries. Their CPO productions amount to 16-17 million ton/y each. Sum of the estimated volume of the wastes from palm oil industry in two countries are as follows;

PKS	7.3 million ton/y
Fiber	17.0 million ton/y
EFB	42.0 million ton/y
Trunk	34.0 million ton/y

Photo 1., Photo 2., and Photo 3. show the oil palm tree and wastes.

Photo 1. Oil palm tree and FFB on the tree.

Photo 2. Palm oil factory and collected FFB

Photo 3.　Fruit, PKS, and Fiber

3. Usage of PKS charcoal and metallurgical coke in steel-making process

Although the property of the PKS charcoal resembles metallurgical coke, it is difficult to use the PKS charcoal in blast furnace as a reductant, which requires larger particle size and higher strength. Instead, with the cooperation of steel companies in Japan and in Indonesia, we studied to use it in electric arc furnace (EAF) which melt and refine steel scrap as an iron source. Though the main energy source of EAF is electricity, auxiliary energies such as oxygen, liquid/gaseous fuel, and coke breeze are used to save electricity and to expedite melting and refining. Ratio of auxiliary energy to electrical one is roughly 50 : 50 in modern EAFs. Most important auxiliary energy source, not only as a thermal source but as a process promoter, is coke (lump and powder) which contains fixed-carbon as a main constituent. The use of coke at each stage of EAF process is described below.　Unit consumption of coke is usually 20 - 30 kg/ton-steel.

(1) At the early stage of melting (Fig. 1 left) oxygen is blown into the EAF for smooth meltdown and scrap cutting. Some part of the scrap is oxidized by oxygen and melted., Lump coke is pre-mixed in scrap or coke powder (coke breeze) is injected into the hot point In order to retard scrap oxidation and to lower the melting temperature.

(2) At the end of melting and temperature rising stage (Fig. 1. center) high temperature arc tends to lose much energy and to injure wall lining.　In order to avoid the effect of this bare arc, oxygen and coke powder are injected into the slag to formulate “foaming slag”.　Foaming slag is made by CO foam and encloses the arc to improve thermal efficiency and heat transfer to the molten bath.

(3) At the end of the refining stage (Fig. 1. right) coke powder is injected into the slag to reduce FeO to recover Fe and to control carbon percentage in steel.

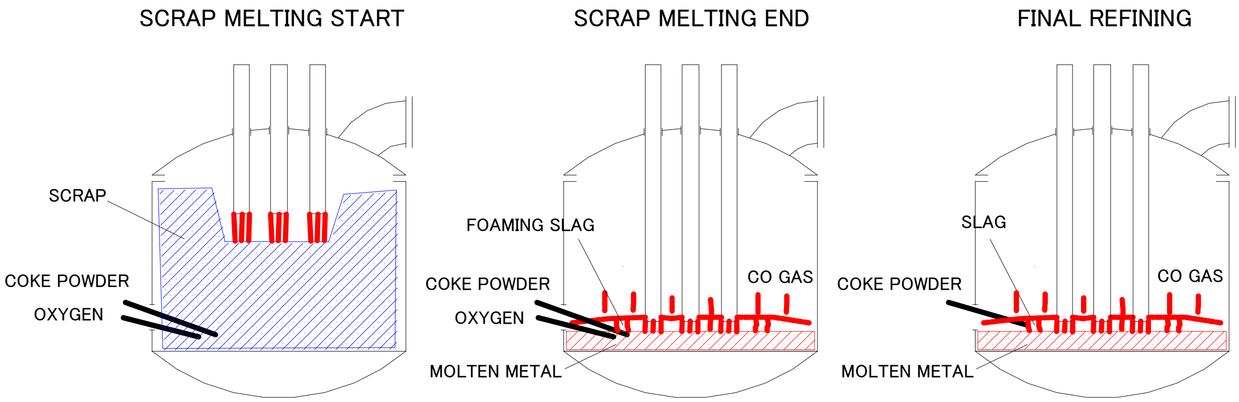


Fig. 1. EAF process and coke

Photo 4. shows the comparison of PKS charcoal and metallurgical coke which were used for the test-use in EAFs in Japan and in Indonesia.   Also Table 1. shows the properties of those for comparison.   Because of the low sulfur and ash content and high calorific value, PKS charcoal can be said better fuel than coke.   In addition to that, as CO2 generated from the charcoal is not counted as Green House Gases, use of charcoal has the possibility of CDM project.   The test use in EAFs showed that no bad effect, which was concerned at first from high volatile matter, was observed. On the contrary, electrical energy saving was better than the case of coke from the high volatile content.

Photo 4.   PKS charcoal (left) and metallurgical coke for EAF (right)

Table 1. Comparison of properties of PKS charcoal and metallurgical coke

		PKS charcoal 5)			Coke 6)	
		Large	Medium	Fine	Lump	Breeze
Items	Unit	3.3 – 8.0 mm	2.0 – 3.3 mm	0.1 – 2.0 mm	1.0 –15 mm	0 – 1.0 mm
Moisture 1)	wt %	7.5	5.9	5.2	13	0.7
Ash	dry wt %	3.2	3.6	13.3	12.1	11.7
Volatile	dry wt %	8.5	8.8	10.9	1.1	1.1
DHV 2)	kcal/kg	7,840	—	6,940	6,650	6,950
(Dried Heating Value)	kJ/kg	32,810	—	29,070	27,820	29,080
HHV 3)	wet kcal/kg	7,250	—	6,580	5,780	6,900
(High Heating Value)	wet kJ/kg	30,350	—	27,560	24,210	28,880
LHV 4)	wet kcal/kg	7,100	—	6,450	5,700	6,880
(Low Heating Value)	wet kJ/kg	29,710	—	27,000	23,880	28,790
C	dry wt %	89.1	—	—	83	85.8
H	dry wt %	2.2	—	2	< 0.1	0.3
N	dry wt %	0.6	—	—	0.5	0.6
S	dry wt %	< 0.1	—	—	0.6	0.5
Cl	dry wt %	< 0.1	—	—	< 0.1	< 0.1
Fe	dry wt %	0.09	—	2.56	0.14	0.33
Ca	dry wt %	0.31	—	0.94	0.21	0.38
Si	dry wt %	0.85	—	2.37	3.49	2.78
Al	dry wt %	0.03	—	0.49	2.34	1.57
Na	dry wt %	< 0.01	—	—	—	0.04
K	dry wt %	0.18	—	—	—	0.08
P	dry wt %	0.02	—	—	0.03	0.04
Mg	dry wt %	0.04	—	0.1	0.04	0.14

1) Moisture is the weight loss when dried at 105 degC two hours.
2) DHV means the measured heating value at the dried condition after dried at 105 degC two hou
3) HHV = DHV x (100 – Moisture %) / 100
4) LHV = HHV – 6 x (9 x Hydrogen (wet base) + Moisture) kcal/kg
   Hydrogen (wet base) = Hydrogen (dry base) x (100 – Moisture %) / 100
5) PKS charcoal is made from palm kernel shell in Malaysia
6) Coke is used at the electric arc furnace in Japan.

4. PKS carbonizing process (charcoal making process)

PKS charcoal is produced in Malaysia by several manufacturers in small scale as a raw material of activated carbon, but it is not produced in Indonesia. Indonesian PKS is simply sold out as an alternative fuel of coal. JP Steel Plantech Co. searched for the PKS charcoal manufacturers in Malaysia who can supply their product as an alternative of metallurgical coke. Two companies were found out, EC SDN. BHD. in Johor and BC SDN. BHD. in Sarawak. Outline of the two companies and their equipment are as follows;

(1) EC SDN. BHD.

Type of carbonizer : Fixed bed batch furnace (Fig. 2.)

Site : Johor, Malaysia

Production capacity : 9,000 ton/y

Features

* Primitive and simple furnace, three days of carbonizing time
* Good charcoal quality (refer to Table 1.)
* Environmental problem by un-combusted gas and dust
* Small amount of PKS supply in Johor
* Labor-intensive process, difficult to enlarge scale

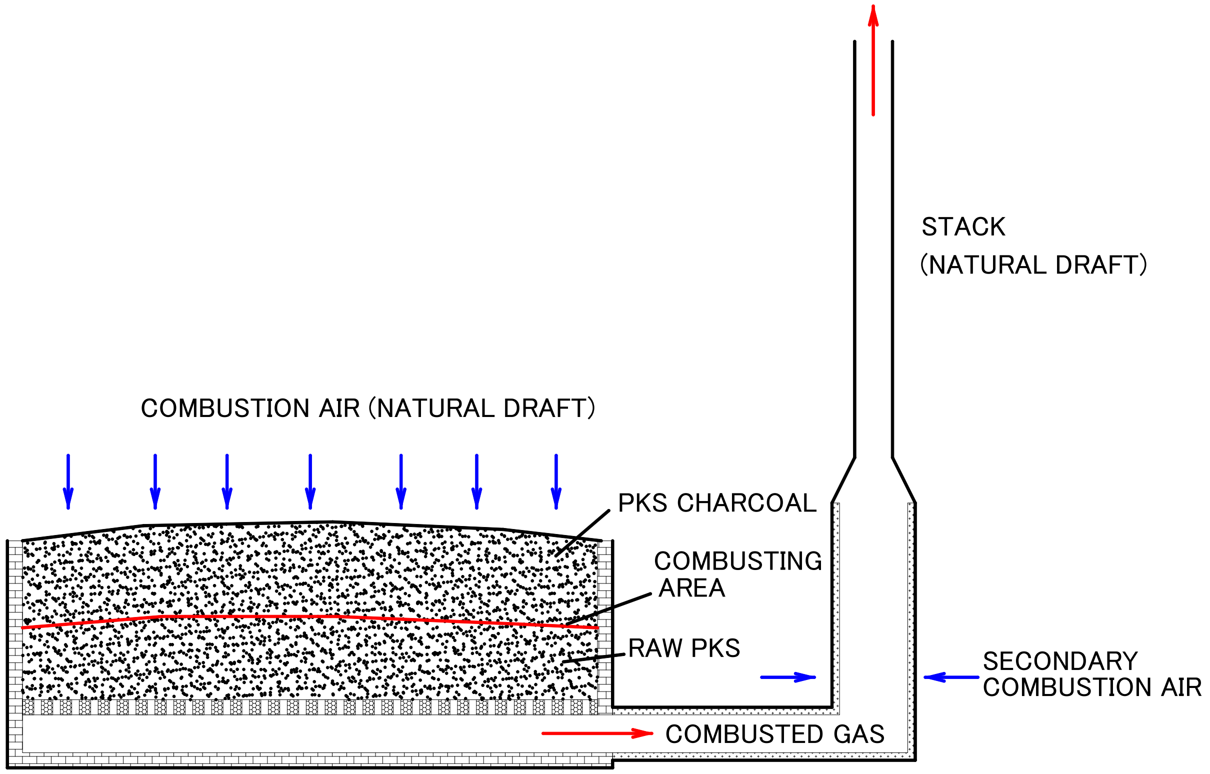


Fig. 2. Fixed bed batch furnace

(2) BC SDN. BHD.

Type of carbonizer : Rotary kiln for continuous process (Fig. 3.)

Site : Sarawak, Malaysia

Production capacity : 10,000 ton/y

Features

* Low and unstable quality inadequate for Japanese steel industry
  (fixed C 70-75 %, ash 9-11 %, and temporary high moisture)
* Complete combustion of exhaust gas, with few dust emission at the stable operation
* Continuous process suitable for production enlargement
* Rich and cheap PKS in Sarawak

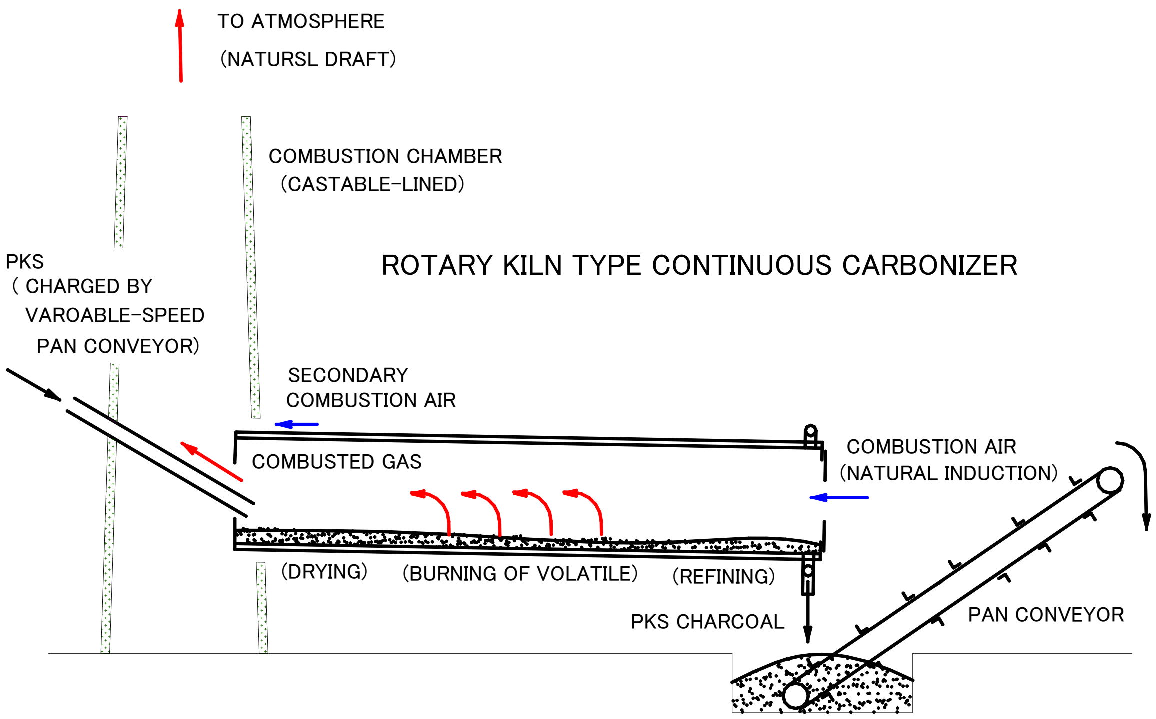


Fig. 3. Rotary kiln

5. Outline of the selected company

After comparing EC SDN. BHD. and BC SDN. BHD., BC was finally selected as a target company for the activity of "Service of Diagnosis and Renovation for Industrial Plants". Outline the selected company are as follows;

(1) Site

Head office is located in Kuching, capital city of Sarawak State of East Malaysia. It has one rotary kiln in Kuching and Two rotary kilns in Miri in Sarawak. for the production of PKS charcoal for activated carbon use. All kilns have the same dimension. Site map is shown in Fig. 4.

(2) Product

In addition to the charcoal and activated carbon from PKS, briquette of PKS and sew dust is produced for home use.

(3) Yearly production and turnover

10,000 ton/y PKS charcoal can be sold out. Total yearly turnover is about 2,500,000 US$.

(4) Type of rotary kiln

Direct heating without raw material pre-heater. Combustion air is induced with natural draft of stack, and dust collector is not equipped with.

(5) Features

* Simple facilities with small number of auxiliary equipment, easy operation
* Distillate gas seems to be almost completely burnt out in combustion chamber, emitted un-combusted gas and dust are not observed.
* In addition to the combustion of volatile matter, some of the fixed carbon is combusted in the kiln because of its direct heating process. This is a direct consequence of relatively high ash content in the product and 20 % lower yield than EC SDN. BHD. batch process.
* As the operating condition is not yet optimized, quality of product charcoal is unstable.
* Moisture content is the product charcoal is high, because of direct water-spray cooling.
* Hot gas energy from combustion chamber is not effectively used.

(6) Production capacity

400 kg-charcoal/h (2,000 kg/h PKS input) for one kiln

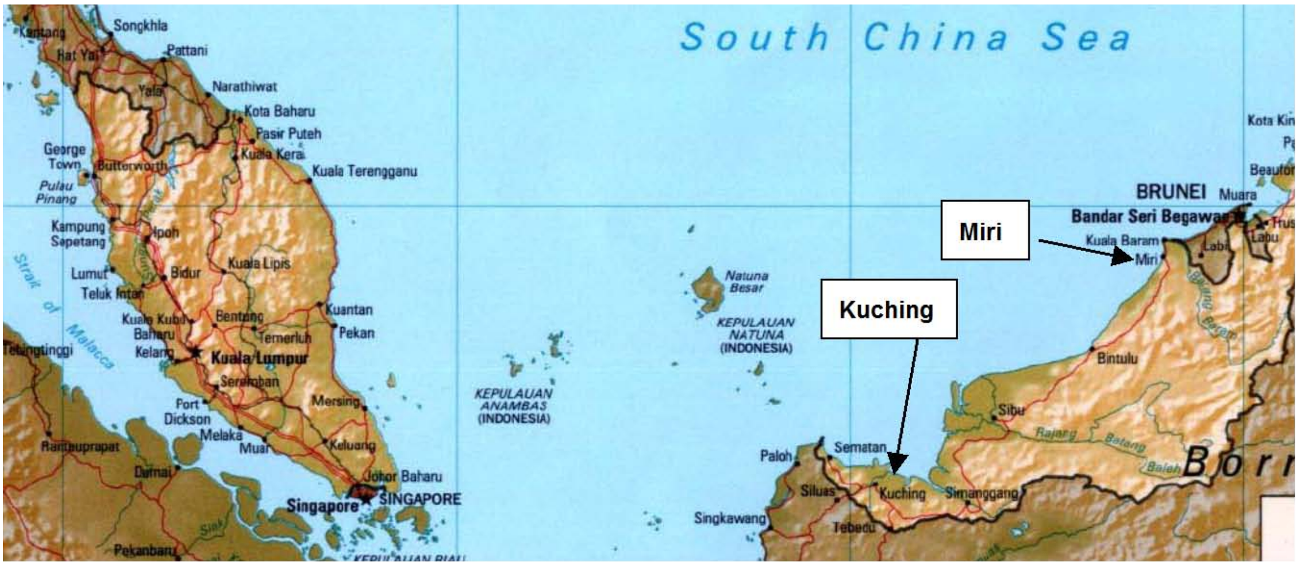


Fig. 4. Site map

6. Site survey

(1) First site survey

Visiting date : Sep. 6-12, 2009

Visiting member : JP Steel Plantech Co.　M. Nakayama, A. Kitamura, T. Ueda
JFE Shoji Trading Malaysia　Mr. Michael Wong

Host member : President of BC SDN. BHD.
President of BG SDN. BHD. (activated carbon manufacturer)

Services at site

* Observing kiln operation
* Discussion on measuring items and procedures for material balance and heat balance
* Main measured items

PKS supply rate and charcoal production rate (kg/h)

Flow rate and temperature of induced air and combustion gas
(SPCO carried in Pitot tube, anemometer, and thermocouples.)

Combustion gas content (CO, CO2, O2 were measured by a local company.)

Temperatures of kiln shell, kiln inner-brick surface, and combustion chamber surface (SPCO carried in an infrared radiation thermometer.)

Measuring work is shown in Photo 5., and measuring points are shown in Fig.5.

Photo 5. Kiln measuring work

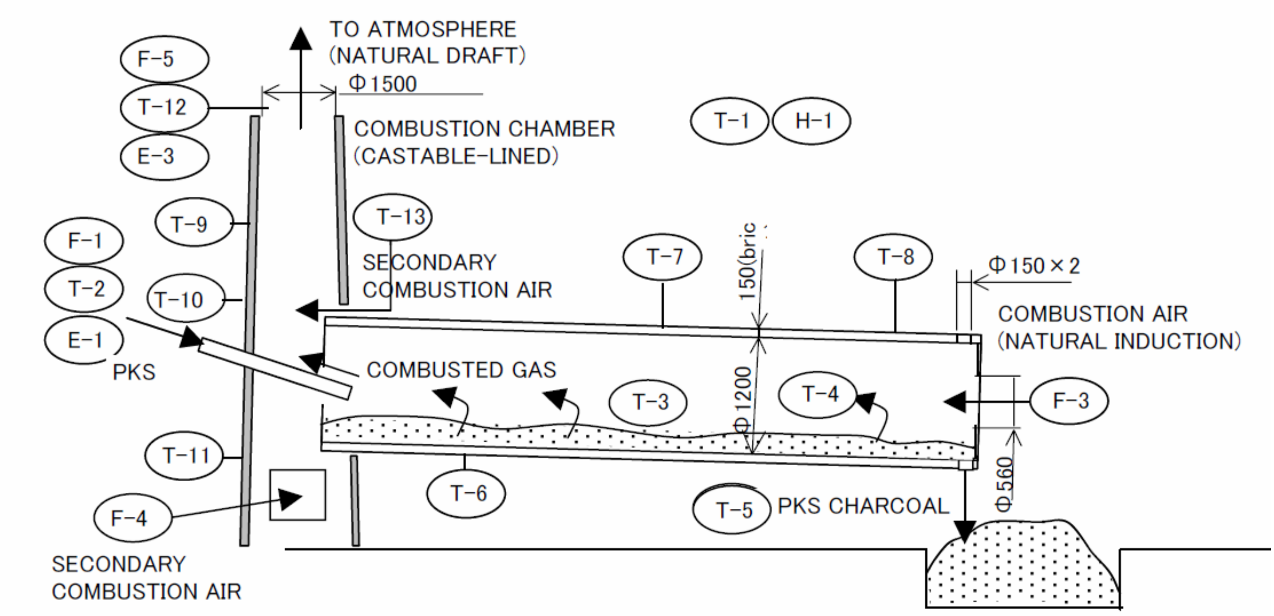


Fig. 5. Measuring points

(2) Second site survey

Visiting date : Feb. 1-4, 2010

Visiting member : JP Steel Plantech Co.

M. Nakayama, A. Kitamura, T. Ueda, T. Ushioda

JFE Shoji Trading Tokyo Mr. R. Takahashi

JFE Shoji Trading Malaysia Mr. Michael Wong

Host member : Same as the first site survey

Services at site

* Reviewing the measured and analyzed data of first site survey
* Explanation and evaluation of the results of laboratory carbonizing test data executed by Hokkaido University
* Discussion on the modification of operating kiln facilities
* Discussion on the collaboration work in future

7. Laboratory carbonizing test by Hokkaido University

In order to establish the effects of such factors as carbonizing time, temperature, and atmosphere in the kiln which affect the quality and the yield of charcoal quantitatively, laboratory carbonizing test was executed by Hokkaido University, Laboratory of Forest Chemistry. Followings are the outline of the test and its data.

(1) Experimental arrangement and conditions

Experimental arrangement is shown in Fig. 6. 10 cm-DIA x 20 cm-LN sealed stainless canister was installed in an electrically heated muffle furnace. 50 g PKS was put on a stainless tray in the canister and heated indirectly from outside. Nitrogen was continuously fed into the canister as a carrier gas and collected at the outlet as a mixture of nitrogen and generated gas, then ingredients and flow rate were analyzed. This arrangement was also used to measure the simulated decrease in volatile matter during the holding time and the burn-off of fixed carbon in the kiln after carbonization. Industrial analysis of the generated charcoal (moisture, volatile matter, fixed carbon, ash, calorific value) at the various stages was executed.

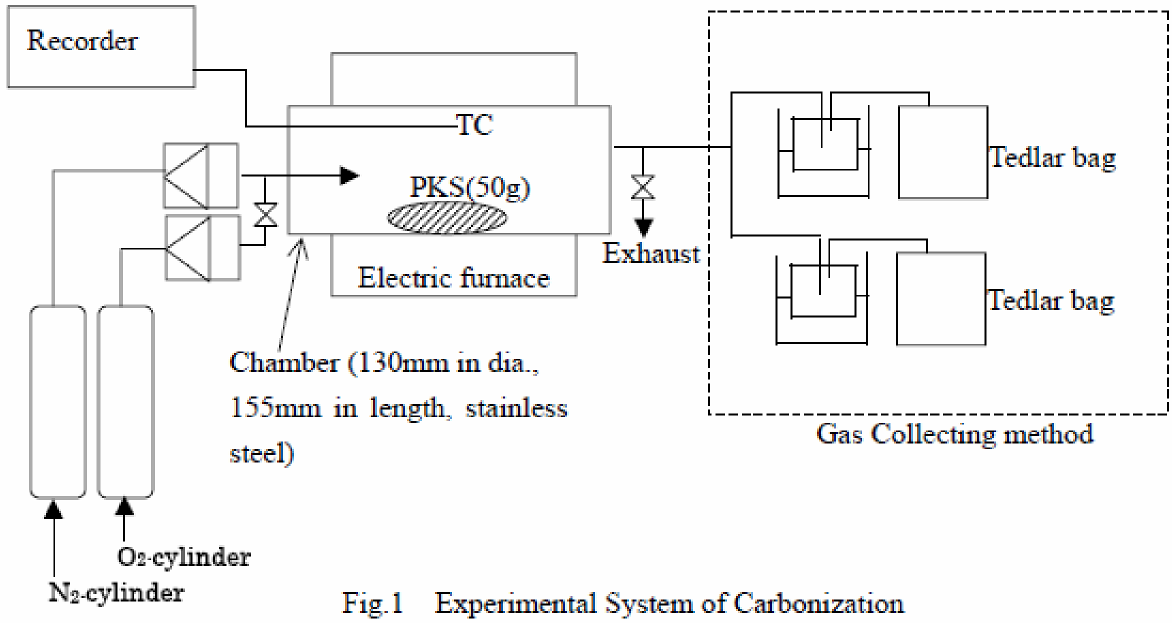


Fig.1 Experimental System of Carbonization

Photo.1 Chamber

Photo.2 Electric furnace

Photo.3 Accessoies for N2,O2gas injection

Fig. 6. Experimental arrangement

(2) Results of laboratory carbonizing test

1) Volume and ingredients of the volatile matter generated during carbonization

Fig. 7. shows the data of generated volatile matter. At the relatively low temperature CO+CO2 generate, then hydrocarbon at the middle stage, hydrogen at the later high temperature stage.

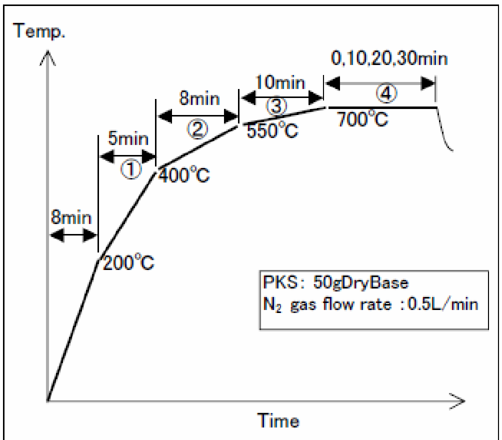


Fig 1-2 Heating Pattern

Table 1 Generated gas during carbonization (for PKS 50g, DryBase)

Pyrolytic gases measured	Volume of pyrolytic gases measured at the increasing temperature stages						
	① 200℃ ~400℃	② 400℃ ~550℃	③ 550℃ ~700℃	④ 700 ℃ holding 0min holding	10min holding	20min holding	30min holding
total volume of pyrolytic gas [L]	2.11	3.57	2.90	0.00	1.82	1.10	2.12
H_2	trace	trace	0.02	n.d.	0.16	0.54	0.60
CO	trace	0.91	0.51	n.d.	trace	0.01	trace
CH_4	n.d.	trace	0.48	n.d.	trace	trace	trace
CO_2	trace	2.24	0.06	n.d.	n.d.	trace	n.d.

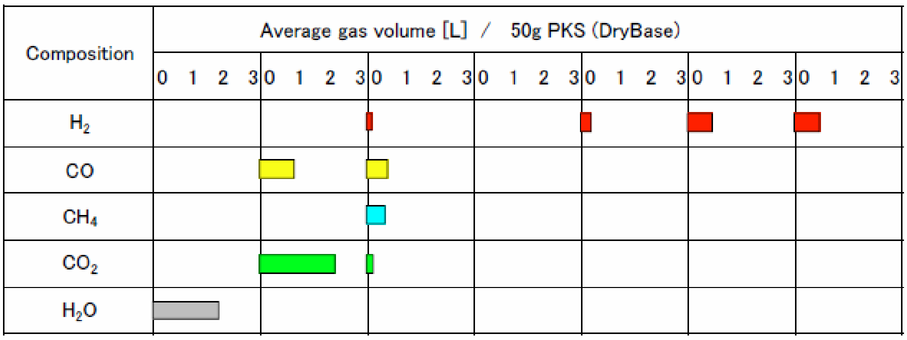


Fig.7. Volatile matter generated during carbonization

2) Decrease in volatile matter after the holding at high temperature

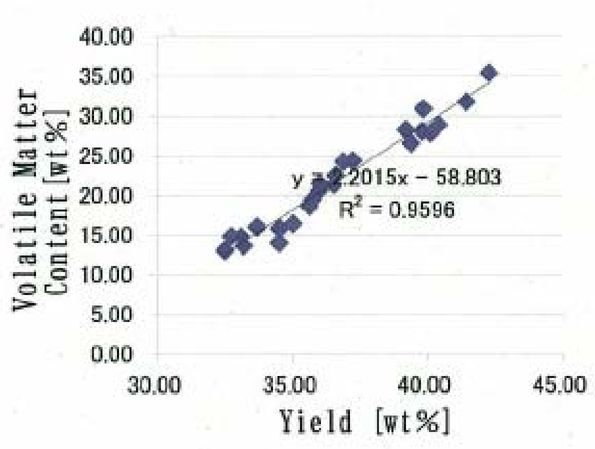
The feature of the BC carbonizing process is the fast heating in the rotary kiln followed by the decrease in volatile matter with the holding. The results of the simulation of this process is shown in Table 2. and Fig. 8. Although the yields are larger than targeted value 25 %, Targeted volatile matter content 8 % and fixed carbon 85 % are not achieved with such carbonization conditions. Actual furnace temperature seems to be a little higher than 700 degC, about 800 degc from the extrapolation of Fig. 8 graphs.

Table 2. Decrease in volatile matter by the holding at hot temperature

sample	Yield [wt%]	Ms* [wt%]	VM* [wt%]	FC* [wt%]	Ash [wt%]	C [%]	H [%]	N [%]	O [%]
Palm Kernel Shell		13.37	80.51	17.40	5.62(2.C	47.36	5.33	0.83	44.39
700 ℃-30 min	32.62	0.90	14.02	81.43	3.44(4.56	89.29	2.14	0.73	3.29
700 ℃-20 min	33.13	0.86	14.29	80.66	5.05	87.32	2.27	0.67	4.71
700 ℃-10 min	34.09	1.04	16.01	80.10	3.89	88.26	2.53	0.68	4.64
700 ℃-0 min	34.76	0.90	15.29	80.14	0.98(4.57	86.09	2.54	0.64	6.17
600 ℃-30 min	36.29	1.20	22.07	74.03	3.90	85.18	3.16	0.79	6.97
600 ℃-20 min	35.80	0.84	19.69	76.00	4.58(4.32	83.79	3.05	0.71	8.14
600 ℃-10 min	36.12	0.72	20.47	77.15	2.39	84.52	3.09	0.65	9.36
600 ℃-0 min	37.04	0.52	24.37	71.26	3.04(4.37	82.42	3.16	0.71	9.35
500 ℃-30 min	39.74	0.92	27.29	69.58	3.13	79.01	3.73	0.75	13.39
500 ℃-20 min	39.49	0.38	28.23	69.48	2.29	78.85	3.45	0.68	14.74
500 ℃-10 min	40.11	0.38	29.95	66.81	2.06(3.24	78.94	3.56	0.68	13.59
500 ℃-0min	41.84	0.83	33.65	62.89	2.91(3.46	76.51	3.98	0.74	15.32

*Ms: moisture content, VM: volatile matter content, FC: fixed carbon content

After heating up to prescribed carbonizing temperature, hot samples were held in 30, 20, 10 and zero minutes at that carbonizing temperature. Industrial analysis and elements analysis were done for the samples. Higher carbonizing temperature brings about lower yield, lower volatile matter, and higher fixed carbon.



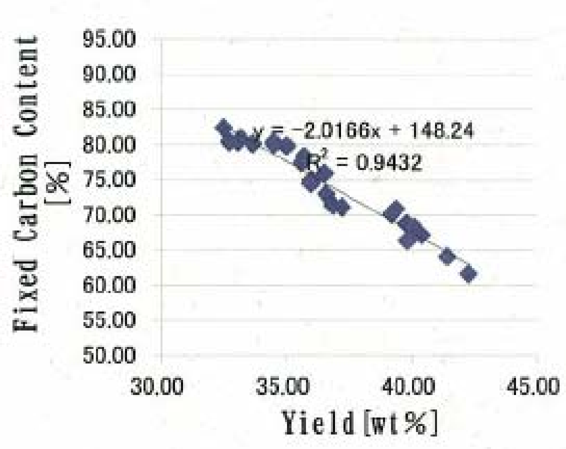


Fig. 8. Yields vs volatile matter and fixed carbon

3) Oxidation and weight loss of charcoal in the kiln

PKS charcoal which is currently produced by BC SDN.BHD. has the property of higher ash content and lower yield compared to the products of batch furnace of other companies. The reason was assumed to be the combustion of fixed carbon in the kiln caused by excess air. In order to verify this hypotheses, oxidation test of the carbonized charcoal was executed. The charcoal was kept at the temperature levels of 500, 600, 700 degC in the atmosphere of 21 %, 10 %, and 5 % oxygen in 10 minutes. Change of ingredients in those charcoals were analyzed and shown in Table 3. The conclusion is that the oxygen content has little effect on the change of ingredients, but temperature affects considerably. Not fixed carbon, but remaining volatile matter was oxidized at first. The results of above 2) and this testing leads to the possibility to achieve 8 % volatile matter and 85 % fixed carbon.

Table 3. Oxidation and weight loss of charcoal in the kiln

	Temperature [℃]	O2 content	Yield [%]	Moisure [%]	Volatile [%]	Ash [%]	Fix C [%]
PKS				13.37	80.5	2.09	17.40
1	700	21	33.28	1.30	8.53	5.79	85.93
2	700	10	32.73	1.04	8.67	7.16	84.16
3	700	5	33.37	1.18	7.54	6.39	86.07
4	600	21	35.64	0.88	14.44	7.11	78.47
5	600	10	34.32	1.29	13.22	6.78	79.99
6	600	5	35.96	1.09	14.66	5.97	79.37
7	500	21	38.65	0.67	22.72	4.78	72.49
8	500	10	39.27	0.93	23.18	5.85	70.97
9	500	5	40.61	0.55	21.90	6.11	72.00

8. Discussion on equipment modification

From the results of laboratory test, it was concluded that effective modification should be directed to control the combustion air volume and to keep the hot charcoal in an insulated sealed chamber for several hours. That may be effective to suppress excess oxidation of fixed carbon and to remove remaining volatile matter without reducing most of the fixed carbon. And in order to reduce the moisture content in product charcoal, direct water spray should be avoided. JP Steel Plantech made a drawing of this idea and discussed.

9. Future plan

(1) Cost sharing of equipment modification

BC SDN. BHD. expected that Japan side could owe some of the cost of equipment modification. JP Steel Plantech answered that they could owe some of the cost, but compensation from the benefit should be shared. Expense from JP Steel Plantech is assumed from the research and development budget of next fiscal year. It was concluded that the “Collaboration Agreement” among three companies was needed before the work.

(2) Agreed items for future collaboration work

1) Modification for remaining two kilns of BC SDN. BHD. in Miri
2) Sales activity of PKS charcoal making equipment and process technology for palm oil mills in Malaysia and Indonesia
3) Such further technology developments as effective waste heat utilization, stable charging of raw material (PKS) into kiln, establishment of optimum charcoal specification for EAF use.
4) Sales promotion of PKS charcoal for Asian and Japanese EAF steel companies

(3) Discussion on the forecast demand of PKS charcoal for metallurgical use

BC SDN. BHD. liked to know the demand in the future, and JFE Shoji Trading answered as below.

1) Future market is huge enough for good quality and cost competitive charcoal.
2) JFE Shoji has been promoting the use of charcoal for Japanese steel companies, and they highly evaluate its utility.
3) Price of metallurgical coke is estimated to escalate from this April, and it is advantageous for PKS charcoal business.
4) Japanese government is strongly promoting the plan of Green House Gas emission reduction. If governmental policy becomes concrete, it is a tail wind.
5) In all cases, important points are quality improvement, cost competitiveness, and stable supply.