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Tin Smelting using Carbonized Palm Kernel Shell as Reductant

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Abstract. PT Timah Tbk has a vision to become a leading environmentally friendly mining company. To achieve this, efforts are being made to use biomass, specifically palm kernel shells, as a reductant in the smelting process, aiming to reduce carbon emissions associated with smelting. Palm kernel shells are selected due to their abundant availability in the Bangka Belitung Islands Province, the operational area of PT Timah Tbk. Before being utilized in the smelting process, palm kernel shells undergo carbonization at a temperature of 400°C for 15 minutes to increase the content of fixed carbon, which plays a crucial role in tin reduction. Carbonized palm kernel shells consist of 51.4% fixed carbon, 27% volatile matter, 14.54% ash, and 7.06% inherent moisture. The smelting process using carbonized palm kernel shells takes place in a Reverberatory Furnace and serves as the initial stage of the tin smelting process. In this stage, tin concentrate is smelted to produce crude tin and slag 1, with a slag 1 assay typically ranging from 15% to 20%. After three cycles of smelting, the average formation of crude tin is 83.31%, the Sn slag assay is 18.70%, and the smelting capacity reaches 50 tons per day. These results align with the standards set for stage 1 of tin smelting at PT Timah Tbk, which traditionally uses coal as a reductant. Therefore, smelting tin with carbonized palm kernel shell as a reductant is a viable and feasible option.

Key Word: tin smelting, reductant, carbonized palm kernel shell

1. Introduction

As part of its efforts to achieve net-zero emissions by 2060, Indonesia has developed a roadmap along with a series of programs to reach this target. One of the programs launched by the Indonesian government involves the application of biodiesel, which is a mixture of diesel fuel and vegetable oil – in this case, palm oil. This program was initiated in 2006 as B2.5, then progressed to B7.5 in 2010, and as of 2023, it has reached B35, meaning it consists of 35% vegetable oil and 65% diesel. The B35 program is projected to increase the demand for palm oil by 3% compared to the previous year.[1] The B35 program was also able to reduce greenhouse gas emissions by 34.9 million tonnes of CO2e.[2]

An increase in the demand for palm oil will encourage a rise in palm oil production, consequently leading to an increase in palm waste production. The processing of palm oil generates solid, liquid, and gas waste.[3] Solid waste comprises empty bunches, fibers, boiler ash, solid decanter, and shells. The liquid waste takes the form of POME (palm oil mills effluent), while the gas waste consists of exhaust gas from the processing of palm oil into CPO (crude palm oil).[4] For every 1 ton of fresh fruit bunches of oil palm, the production breakdown of waste is as follows: 23% empty fruit bunches, 6.5% palm kernel shell, 4% wet decanter solid, 13% fiber, 50% liquid waste.[5]

In 2022, the Bangka Belitung Province, which falls within the operational area of PT Timah Tbk, is projected to produce 862,300 tons of palm oil.[6] This production amount will result in 56,049 tons of palm kernel shells.

Indeed, palm kernel shell possesses a high-calorie content and net calorific value, making it an excellent source of energy that generates substantial heat during the combustion process. Considering these factors, palm kernel shell holds great potential as an alternative energy source to replace coal.[7] Palm kernel shell can be converted into charcoal, functioning as a reducing agent, similar to coal and coke. Through specific treatments, palm shell charcoal can become an even more efficient reducing agent than coke.[8]

In this study, two major stages were conducted, namely the preparation of carbonized palm kernel shell as a reducing agent and the utilization of carbonized palm kernel shell as a reducing agent in the tin smelting process within a reverberatory furnace.

2. Materials & Method

Palm kernel shell was sourced from one of the palm oil mills on Bangka Island. The waste consists of dry fragments of palm fruit shells measuring 1-2 cm. Before carbonization, the palm kernel shell underwent proximate analysis following the ASTM D3172 standard. The palm kernel shell was subjected to carbonization at a temperature of 400°C for 15 minutes before being utilized as a reducing agent in the tin smelting process. During the carbonization process, the palm kernel shells were heated to a high temperature, 400°C, in the absence of air. This process drove off volatile components, leaving behind carbon-rich material, which was used as a reducing agent in metallurgical processes. The subsequent use of the carbonized palm kernel shells served to facilitate the reduction of tin ore, typically cassiterite (SnO_2), to obtain metallic tin.

Figure 1. Palm Kernel Shell

On a lab scale, the carbonization process was conducted using a muffle furnace. Following carbonization, proximate analysis was performed on the palm kernel shell, using the same method as before carbonization. This was done to assess the characteristics of the palm kernel shell used.

The carbonized palm kernel shell served as a substitute for coal as a reducing agent, with characteristics specified in Table 1.

Figure 2. Muffle Furnace

Table 1. Coal Proximate Analysis

No	Parameter	ADB
1	Fixed Carbon (%)	50,51
2	Volatile Matter (%)	35,54
3	Ash (%)	4,50
4	Moisture (%)	9,45

Carbonized palm kernel shell can be utilized if its characteristics, based on proximate analysis, are similar to those of coal, as indicated in Table 1.

On a larger scale, the carbonization process is performed by harnessing heat loss from a flame oven, using the same operating parameters as the lab scale – namely, a carbonization temperature of 400°C with a process time of 15 minutes.

Figure 3. Flame Oven

The carbonized palm kernel shell served as a reducing agent in the tin concentrate smelting process with the composition specified in Table 2, divided into 3 batches. The characteristics of the concentrate to be melted were presented in Table 3. The smelting process was carried out in a reverberatory furnace.

Table 2. Tin Smelting Composition

No	Material	Weight (kg)
1	Concentrate	25.000
2	Coal	5.000
3	Limestone	300

Table 3. Tin Concentrate Characteristics

No	Element	Assay (%)
1	Sn	65,22
2	Fe	3,21
3	SiO2	1,18

The parameters assessed to determine the performance of carbonized palm kernel shell as a reducing agent include crude tin formation, Sn assay on slag, and smelting capacity.

3. Results & Discussion

The results of the proximate analysis of palm kernel shells before carbonization are shown in Table 4.

Table 4. Palm Kernel Shell Proximate Analysis

No	Parameter	ADB
1	Fixed Carbon (%)	18,29
2	Volatile Matter (%)	71,63
3	Ash (%)	7,28
4	Moisture (%)	2,80

After the carbonization process was carried out at a temperature of 400°C for 15 minutes, the proximate analysis of palm kernel shell was obtained in Table 5.

Table 5. Carbonized Palm Kernel Shell Proximate Analysis

No	Parameter	ADB
1	Fixed Carbon (%)	51,40
2	Volatile Matter (%)	27,00
3	Ash (%)	14,54
4	Moisture (%)	7,06

Based on the comparison of Tables 4 and 5, significant changes occur in the fixed carbon and volatile matter parameters. The data shows a decrease in volatile matter after the carbonization process, accompanied by an increase in fixed carbon. This change happens because the constituent compounds of the volatile matter transform carbon, as observed in reaction 1.

$$CH_4 = C + 2H_2(g) \text{ ………. (1)}$$

When comparing the fixed carbon content of carbonized palm kernel shells in Table 5 with the fixed carbon content from coal in Table 1, it becomes evident that the fixed carbon content from carbonized palm shell waste closely resembles that of coal. Consequently, carbonized palm kernel shells can be effectively utilized as a reducing agent in the tin smelting process.

In the selection of a material for use as a reducing agent in the tin smelting process, the crucial parameter to be considered is the fixed carbon content, as mentioned in point number 2. As stated earlier, fixed carbon plays a significant role in the tin smelting process.

$$C + O2(g) = CO2(g)$$
$$C + CO2(g) = 2CO(g)$$
$$SnO2 + 2CO(g) = Sn + 2CO2(g)$$
………. (2)

Furthermore, the tin smelting process was conducted using carbonized palm kernel shells in the Reverberatory Furnace in 3 batches. Table 6 presents the results of tin smelting using carbonized palm shell waste. Table 7 provides the standards for tin smelting set by PT Timah Tbk, which employs coal as a reducing agent.

Table 6. Tin Smelting using Carbonized Palm Kernel Shell

No	Parameter	Unit	1	2	3	All
1	Concentrate	*Ton*	25,00	25,00	25,00	75,00
2	Concentrate Assay	*%Sn*	65,22	65,22	65,22	65,22
3	Sn Input	*Ton Sn*	16,31	16,31	16,31	48,92
4	Smelting Hour	*hour*	12,00	12,00	12,00	36,00
5	Capacity	*Ton/Day*	50,00	50,00	50,00	**50,00**
6	Crude Tin Ouput	*Ton Sn*	12,40	14,25	14,10	40,75
7	Crude Tin Formation	*%*	76,05	87,40	86,48	**83,31**
8	Slag Ouput	*Ton*	5,40	6,70	7,20	19,30
9	Slag Output	*Ton Sn*	1,25	1,26	1,1	3,61
10	Slag Assay	*%Sn*	23,15	18,81	15,28	**18,70**

Table 7. PT Timah Tbk First Stage Tin Smelting Standard

No	Parameter	Unit	Value
1	Capacity	*Ton/Day*	50
2	Crude Tin Formation	*%*	80-85
3	Sn Slag Assay	*%*	15-20

When comparing the data in Tables 6 and 7, it becomes evident that the melting parameter values between the coal-reducing agent and the carbonized palm shell-reducing agent are nearly identical. This similarity can be attributed to the fact that the fixed carbon values of coal and carbonized palm shells are not significantly different. As seen in reaction number 2, the amount of carbon in the reducing agent will affect the reduction reaction in the tin smelting process. An insufficient carbon content will lead to an imperfect reduction reaction, resulting in low crude tin formation and high Sn Assay in slag. Conversely, an excess of carbon will cause over-reduction, leading to high crude tin formation, low Sn assay, and higher Fe content in the crude tin. Therefore, the amount of carbon the reducing agent supplies must be appropriate for a specific quantity to achieve optimal results.

4. Conclusion

In certain carbonization treatments, it is possible to enhance the characteristics of palm kernel shells to make them resemble coal. Among the similar characteristics between carbonized palm kernel shells and coal, one notable similarity is their ability to effectively reduce tin. Based on the trial results, the tin concentrate smelting process using carbonized palm kernel shells achieves a melting capacity of 50 tpd, crude tin formation of 83.30%, and Sn slag assay of 18.7%.

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