THE USE OF CYCLONE COAL BURNER TO SUBSTITUTE OIL BURNER IN ALUMINUM SMELTER USING REVERBERATORY FURNACE

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ABSTRACT

The increasing of oil price forces the industries to alter their fuel from oil into a cheaper fuel. Undoubtedly, coal is a promising energy alternative in Indonesia. To save the cost, altering the fuel oil into coal in industries may be accomplished just by altering the oil burner with coal burner, therefore the existing equipment still can be used without much modification. The coal combustor employed should have nearly the same characteristic with the oil combustor, so that the performance of the kiln or other equipment served by the combustor is not change significantly.

R & D Centre for Mineral and Coal Technology (TekMIRA) has developed cyclone combustor for coal with particle size of less than 30 mesh. The combustion is stable at the rate of 50 – 180 kg/hr coal with excess combustion air of 22 – 26%. The length of cyclones is ranged from 120 up to 220 cm, the internal diameter is 60 up to 80 cm and the combustion temperature is 1200 up to 1325°C. This combustor characteristics are nearly the same with oil combustor such as: the combustion flame may be directed; high intensity combustion, long flame; and it is not difficult to match the energy output of previous oil combustor.

In this experiment the cyclone combustor was used to replace the oil combustor in a reverberatory furnace to refine aluminum from aluminum scrap by melting the material at 1000 – 1060°C. For 500 kg aluminum, the oil consumption was 47.5 litre for 2.5 hour or the average was 19 lt/hr and the energy efficiency was 29.2%. Using high ash bituminous coal with cyclone burner, the coal consumption was 129 kg for 1.8 hour or the average was 71.6 kg/hr and the energy efficiency was 17.9%. A higher efficiency was obtained by using low ash sub bituminous coal, that the coal consumption was 82 kg for 81 minutes or the average was 60 kg/hr and the energy efficiency was 29.0%.

Therefore it is a good opportunity for coal to substitute fuel oil in this reverberatory furnace and many other oil fuelled processes such as in boiler, lime calcination, mineral drying etc.

Keywords: Cyclone Coal Burner, Aluminum Smelter.

1. INTRODUCTION

The world oil price increases drastically which causes the domestic oil price increases significantly, especially the oil for industrial consumption which is not subsidized by the government. This makes the industries explore alternative energy to replace the fuel oil. Coal is undoubtedly a promising alternative energy as a huge amount of coal reserve is owned by Indonesia.

To replace fuel oil burner in industry, a coal combustor nearly the same characteristic with oil combustor is required. The combustion of fuel oil is relatively easier and more convenient than that of the coal. Fuel oil may be combusted in a wide range of conditions, in opened or closed system, easy to be stabilized, practically no ash. In the contrary combustion of coal is more complicated. Actually coal is not a single substance when it is heated in a combustion process. At least it contains water, gas, liquid, heavy liquid, solid combustible and ash (Elliot, MA 1981). Different combustion technique is required to combust coal at different capacity, combustion space, rate, coal particle size, rank, type and ash properties.

To replace the oil burner in industries with coal burner, some techniques are proposed such as using chain grate coal combustor (RBU 2005) and a fixed grate combustor. However decreases in the performance of the industrial facilities were experienced, as the heat output did not match of that generated by previous oil burner. Therefore, the coal combustion technique using cyclone burner is considered to be reliable. The cyclone coal combustor has some characteristics nearly resemble to that of the oil burner such as (HMSO 1963):

- Flame may be directed;
- High intensity combustion with long flame; and
- Combustion capacity may match the oil burner

Therefore the coal cyclone burner has opportunities to replace oil burner in many industrial processes such as in lime calcination, industrial boiler, mineral drying, metal smelter etc.

It is an effort to increase the role of coal in energy mix of energy consumption in Indonesia (Yusgiantoro 2007).

TekMIRA has developed the cyclone burner for coal (Sumaryono 1999). Normally cyclone burner combusts low melting point ash coal. The cyclone burner that was developed was used for combustion of high or low melting point ash coal. The particle size of the coal was less than 30 mesh. In this experiment the cyclone coal combustor will be used to replace the oil combustor in a reverberatory furnace for aluminum smelter. In this furnace heat transfer by radiation is important, therefore coal with high luminous flame is suitable for this purpose.

2. THEORETICAL BACKGROUND

2.1. The Cyclone Coal Combustor

Normally the combustion of coal in a cyclone combustor is carried out with coarser coal powder of -3 mm, especially with low melting point ash coal. The coal is fed in swirling motion within the furnace that a high turbulence condition is created to support a stable and intensive combustion (HMSO 1963). Figure 1 shows the schema of cyclone coal combustor and the photograph of simplified cyclone combustor developed by tekMIRA.

The molten ash from low melting point coal ash covers the inner surface of the cyclone and the coarser coal particles adhere on this sticky surface. The result is that the relative velocity of the combustion air towards these adhering coal particles is higher, rendering a more intensive combustion of these coal particles. The molten ash flows out of the cyclone cylindre.

TekMIRA has developed a simplified cyclone combustor using higher melting point ash coal. To get stable combustion the coal should be crushed and pulverized into -30 mesh so that it was different with the pulverized coal combustion, in which the coal was pulverized into -200 mesh. The combustor developed by tekMIRA had inner diameter of 60 – 80 cm and the length was 120 – 240 cm, may combust 50 up to 180 kg/hr coal with excess combustion air 22 – 26% and the temperature within the furnace is 1200 – 1320°C. A larger capacity combustor will be developed.

This combustor may be operated horizontally or vertically. The horizontal cyclone was implemented in:

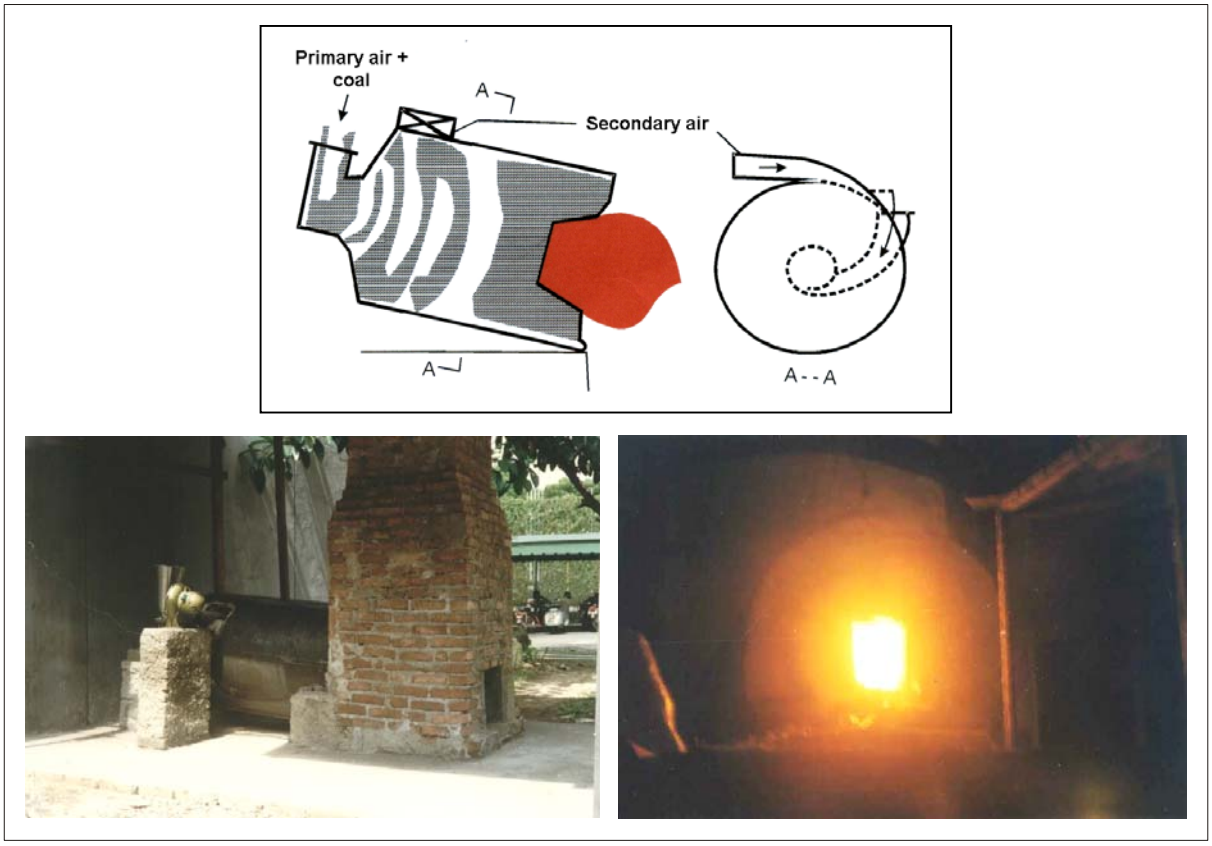

Figure 1. The schema of cyclone combustor and the photograph of simplified cyclone combustor

- Continuous lime calcination kiln to substitute oil burner and firewood (Sumaryono and Suripto 2004).
- Steam boiler to substitute oil burner (Sumaryono et. al 2005).

The vertical cyclone has been implemented in periodical system lime calcination to substitute firewood.

2.2. The Reverberatory Furnace for Aluminum Smelter

The reverberatory furnace in the form of a cube is covered with a silica brick roof and vertical walls with the inner dimension is the length x width x height = 1 x 1 x 1.3 m. A shallow refractory hearth at the bottom for holding the molten charge and heated it. The fuel combustion proceeds above the bath and the surrounding refractory walls and roof receive radiant heat from the combustion product, then reradiate this heat to the surface of the bath. Figure 2 shows the scheme of the reverberatory furnace for this experiment.

The cyclne combustor was positioned at the corner adjacent to the furnace door and the chimney's opening.

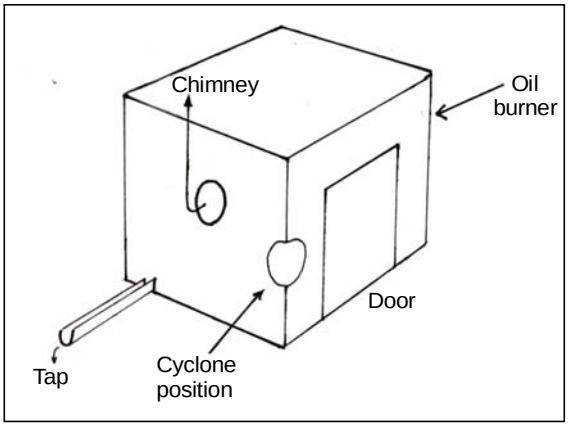

Figure 2. The schema of reverberatory furnace for aluminum smelter

3. EXPERIMENTAL AND RESULTS

To substitute the oil burner with cyclone burner, the works performed are:

1. Connect the cyclone burner in the position in balance with the oil burner that the energy output is effectively heat up the reverberatory furnace. The waste heat from the flue gas is recovered by the same system previously used in the burning with fuel oil burner.

2. Perform the aluminum smelting process using the cyclone burner with coal. Follow the procedure of material feeding as usual and calculate the energy efficiency using different coals.

3. Observe the performance of the smelting process and compare the results using fuel oil and coals.

3.1. The Attachment Of Cyclone To The Reverberatory Furnace

The inner diameter of the cyclone combustor is 55 cm and the length is 120 cm. It is made of firebricks SK 34 cemented by refractory cement. There is a silica seal between the steel outer plate and the firebricks setting.

At the bottom of the cyclone there is an opening of 15 x 20 cm for the ash outlet. The powdered coal was fed by a screw-feeder, then it is blown with an air blower through a steel tube of 12.5 cm diameter, entering the cyclone tangentially. A secondary combustion air was passed through the cyclone via the same steel tube. The combustion capacity of the cyclone was 60 – 70 kg/hr sub bituminous coal.

The oil burner was attached at the right corner of the furnace while the cyclone combustor was attached at the left corner. So that the fire propagates straight away then it turned back to follow the draught produced by the chimney at the right side adjacent to the cyclone. The cyclone was connected with the reverberatory furnace by a cylindrical refractory made of firebrick and castable cement. The inner diameter of the cylinder was 30 cm and the length was 22 cm.

3.2. Aluminum Smelting Process

The smelting process is simply by heating up the furnace to a temperature of about 1000°C. The aluminum scrap is fed into the furnace at 125 kg increment. After this increment has been melted, fed another increment of 125 kg and so further that the total amount of the material containing 500 kg aluminum has been melted. Continue to heat up the molten aluminum until a temperature of 750 – 800°C is reached that the molten aluminum is ready to tap.

It needs 2.5 hour to melt 500 kg aluminum with diesel oil to consume 47.5 litre fuel. The final temperature of the melt is 760°C. The energy efficiency with diesel oil is 29.2%

3.3. The Smelting Process With Coal

The coals used were characterized according to their proximate analysis and calorific value results (Table 1).

Table 1. The Proximate Analysis and Calorific Value of A, B and C Coals (Air Dried Basis)

	A Coal	B Coal	C Coal
Moisture, %	23.0	3.72	14.5
Ash, %	9.0	23.0	0.6
Volatile Matter, %	34.4	32.11	43.9
Fixed Carbon, %	33.6	41.17	41.0
Calorific Value, kcal/kg	4830	5764	5587

A Coal

A Coal of -30 mesh was burned in the cyclone combustor at a rate of 90 kg/hr. After the furnace temperature reaches 855°C in 1 hour heating, the aluminum scrap was fed into the furnace at 125 kg increment. Totally 500 kg aluminum was melted at a temperature of 760°C in 3.5 hour to consume 310 kg coal.

The energy efficiency attained was 8.9%. Compared with the use of diesel oil, this coal is considered to be less affective. It needs longer time for furnace heating up and aluminum melting process.

B Coal

The combustion with B coal attained higher temperatures (1220 – 1280°C) than the combustion

with A coal (1180 – 1230°C). Figure 3 shows the attachment of the cyclone combustor to the reverberatory furnace.

Figure 3. The attachment of cyclone to the reverberatory furnace

B Coal was burned at a rate of 72 kg/hr. After the furnace temperature reaches 1040°C in 32 minutes, the aluminum scrap was fed. The total of 500 kg aluminum was melted and heated up to 760°C in 108 minutes consuming 129 kg B coal.

The energy efficiency attained was 17.9%. Although the energy efficiency was lower than the use of diesel oil, this coal is considered to be an effective fuel as a shorter time is required for the process.

C Coal

The combustion temperature of the C coal in the cyclone was nearly the same with B coal, i.e. 1230 – 1280°C. C Coal was burned at a rate of 60 kg/hr. After the furnace temperature reached 1060°C in 30 minutes, the aluminum scrap was fed. The total of 500 kg aluminum was melted and heated up to 760 – 850°C in 81 minutes consumed 82 kg coal. At a higher temperature the melting aluminum flows more easily for tapping. The energy efficiency attained was 29.0%, or it is nearly the same as the use of fuel oil.

4. DISCUSSION

As a convenient fuel, fuel oil may be used in a reverberatory furnace simply by burning the fuel oil within the furnace, where a stable combustion process may be attained easily. With this condition a high efficiency process may be obtained since there will be lower heat loss from the process. In the contrary as a more complicated fuel, it is not easy to obtain a stable combustion of coal within the reverberatory furnace, especially that the temperature within the furnace fluctuates widely during smelting process. To overcome this situation, coal should be combusted in other place, then the heat released may be transferred into the furnace. The consequence is that the energy efficiency may be reduced. It is one of the reason that fuel oil gains higher energy efficiency than the use of coal in this case.

The coals used in this experiment, A coal is a low calorific coal with high water content and a fairly high ash too. B Coal is a high ash coal, although it is a bituminous coal. C Coal is a high water content but it has a low ash content, that the calorific value is higher than A coal. A and C Coals are sub-bituminous coals. Among these coals, A coal performs the worst as its specification is the worst especially with the respect of its water content, calorific value and ash content. Therefore it may be understood its combustion properties is objectionable. B Coal is better than A coal, besides of its higher calorific value this bituminous coal flame has higher radiative properties that the furnace temperature increases in a shorter time. The energy efficiency of melting process with B coal is higher than it is with A coal, i.e. 17.9% compared with 8.9%. C Coal performs the best compared with A and B coals. Although the calorific value of C coal is close to the calorific value of B coal, but the ash content of C coal is lower than that of B coal. The ash melting point of B coal is not proper for this cyclone burner that the ash adhering on the cyclone wall and accumulates to form thick deposition. This deposit obstructs the travel of coal along the cylinder wall that the combustion process is disturbed.

The use of C coal shows that low ash coal heats up the furnace more quickly, more effective than the use of fuel oil. It may be explained by the facts that,

a. Low ash coal keeps the cylindrical joint clean, that there is no bottle neck in the supply of heat into the reverberatory furnace.
b. The energy supply rate using coal is higher. The combustion rate using coal C is 60 kg/hr, it means an energy output of 60 x 5587 kcal = 335.220 kcal/hr. On the other hand, the energy output using 19 lt/hr fuel oil is 19 x 9600

kcal = 182400 kcal/hr or about 54% that of the energy output using coal C, therefore the use of fuel oil in this case is less effective.

Coal combustion stabilization by reverberatory furnace was revealed in this experiment. The reverberatory furnace used in this experiment is characterized by a shallow hearth, surrounded by four vertical wall surfaces and a refractory roof. Therefore there is 7 m^2 surface area facilitating radiation on the hearth. At temperature of higher than 1000°C, the radiation is strengthened by the high emissivity of the surface. Therefore it is clear that the combustion of coal carried out within the cyclone is then supported by the combustion process out of the cyclone in the highly radiated space, to combust the rest combustible material produced by the cyclone.

5. CONCLUSION

1. Coal with a cyclone combustor may alter the function of oil burner in a reverberatory furnace for aluminum smelter by attaching the cyclone and joining it with the furnace. The effectiveness and efficiency is comparable or better than the use of fuel oil.

2. There are some parameters in the coal specification that affect the combustion properties in the cyclone burner. The observation with those three coals, the parameters are calorific value, rank, ash content and its melting point. A high rank coal has higher radiative flame and the ash melting point should not close to the operational temperature of the cyclone combustor.

3. The parameters increase the effectiveness of coal are:
   - Higher energy output of coal combustion using the cyclone combustor.
   - Radiation surfaces in the reverberatory furnace stabilize the combustion of coal.

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