UTILISATION OF SAWDUST IN CYCLONE GASIFIER FOR ELECTRICAL GENERATION

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ABSTRACT

A great amount of sawdust produced everyday from sawmills and wood-based industries. Sawdust generally considered as a timber industry waste can seriously affect the environment and becomes a potential health problem. About 303 tons of sawdust produced per day in Malaysia from sawmills and wood-based industries and the sawdust are dumped at landfill as a waste. With the existing gasification technology, sawdust can be used as a source of energy produced that can generate power for internal consumption. Currently, cyclone separators have been one of the most popularly used industrial devices for separating sawdust from their carrying fluid. With cyclone gasifier, we can apply a new gasification technology in utilizing sawdust as a fuel which can enhance the separation process of sawdust to gasification process. The advantage with this technique is the temperature of the fuel might keep at a level where ash vaporization will not occur and then the corrosive ashes would remain solid in the char particles. In this paper, the design processes for cyclone gasifier are described in detail. The required fuel flow rate is 60 kg/h corresponds to desired thermal output of 200 kW_T (considering gasifier efficiency of about 70%).

Keywords: Sawdust, Cyclone, Gasifier.

1 INTRODUCTION

The utilisation of biomass is a very important source of energy in many parts of the world, especially for areas remote from supply of high-quality fossil fuels. There is a wide range of processes available for converting biomass into more valuable fuels. The conversion technologies especially pyrolysis and gasification have been substantially studied to promote renewable energy utilisation. Therefore, various types of gasification systems have been developed and commercialised. Since, Malaysia produced about 303 tons of sawdust daily from sawmills and wood-based industries, the utilisation of this fuel for power generation is substantial than easily dumped this waste at landfill. Currently, cyclones were studied to be an alternative gasifier to gasify smaller particle of biomass fuels.

Syred et al. (2004) have studied the inverted cyclone gasifier coupled to a cyclone combustor in series for indirect firing of a small-scale gas turbine. The experimental studies were carried out on Commercial Austrian sawdust and Commercial Swedish wood powder with the size distributions were between 0.063 and 2 mm. Gabra et al., (2001) discussed the comparison of alkali retention using bagasse in a fluidized bed and cyclone gasifier. The alkali retention in the fluidised bed gasifier was 12-4% whereas in the cyclone gasifier was about 70%. Gabra et al. (2001) also have studied the performance of cyclone gasifier using two different biomass fuel. The first experiment is gasification of crushed bagasse in a two-stage combustor at atmospheric pressure, where the first stage is a cyclone gasifier. In this experiment, the crushed bagasse palletized and then ground to improve the characteristics of the fuel and to eliminate the feeding problems. The second experiment is gasification of cane trash in the same cyclone gasifier. The overall assessment shows that the cane trash appears more problematic fuel than bagasse. The operation of a cyclone gasifier should be smooth and continuous, for this purpose, Gabra et al. (1998) demonstrated the sugar cane residue feeding system for a cyclone gasifier that designed to operate without interruption or large fluctuations. It was found that to eliminate the blockage in the downcomer channels, the powder should be more homogeneous. Hassan et al., 2000 discussed the possibility of using the steam-jet ejector to inject wood powder and sawdust into the pressurized cyclone gasifier.

A cyclone gasifier has been developed at University Science Malaysia using sawdust from furniture industries as a fuel produced 200 kW thermal output with combustion rate of 60kg/hr. In the present paper, the detail design of the cyclone gasification system are presented and discussed.

2 COMPLETE SYSTEM OF CYCLONE GASIFIER

The gasifier consists of air supply component, the feeding port, the ignition port and removing compartment. Figure 1 show the schematic diagram of a cyclone gasifier system.

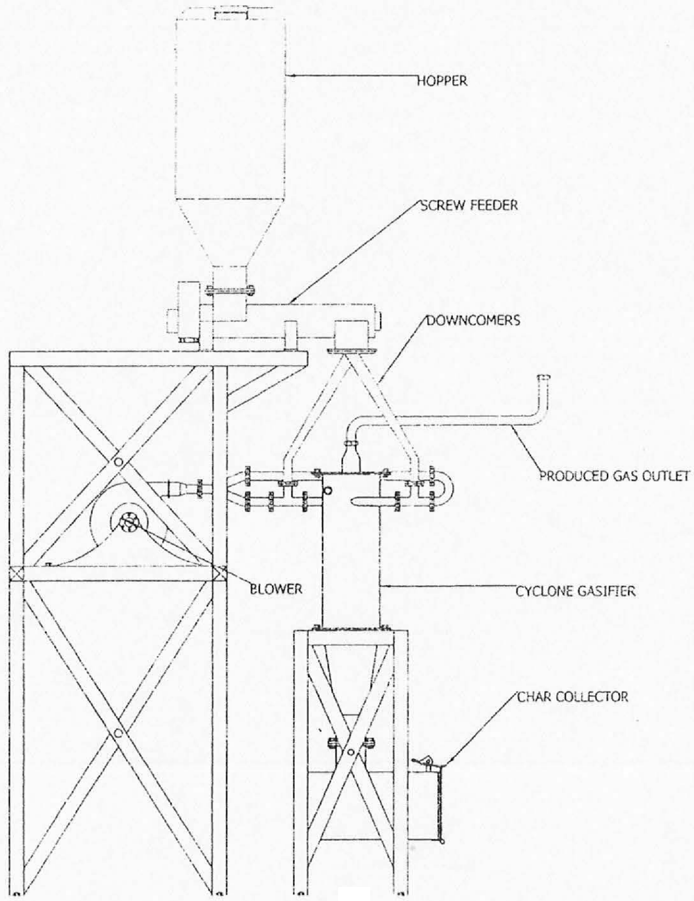

FIGURE 1. Schematic diagram of a cyclone gasifier system

3 FUEL FEED RATE AND VOLUME OF HOPPER

To produced 200 kW_T thermal power output with assumption of 70% cyclone efficiency, the thermal power input is:

$$\eta = \frac{\text{Power thermal output}}{\text{Power thermal input}} \qquad (1)$$

$$0.7 = \frac{200\ kW_T}{P_i}$$

$$P_i = 286\ kW_T$$

The High Heating Value (HHV) of dry wood (moisture 10%) is 17.06 MJ/kg. So the sawdust should be fed at minimum mass flow rate:

$$\text{Thermal input} = (HHV)_{sawdust} \times m_f \qquad (2)$$

$$Q_i = (HHV)_{sawdust} \times m_f$$

$$286\ kW_T = 17.06\ \frac{MJ}{kg} \times m_f$$

$$m_f = 0.016\ 76\ \frac{kg}{s}$$

$$= 60.4\ \frac{kg}{hr}$$

So, for $286kW_T$ thermal input, sawdust should be feed at minimum rate of about 60 kg/hr.

The hopper designed applied funnel flow where the fuel flows through the core. The degree of inclination of the tapered side should not less than 45° from vertical wall to make sure the hopper provide mass flow effect properly. The hopper volume is:

$$V_{hopper} = \frac{W_{sawdust}}{\rho_{sawdust}}\ m^3 \qquad (3)$$

The minimum fuel feed rate is 60 kg/hr and the mass density of dry sawdust (10% moisture) is 267 kg/m^3.

$$V_{hopper} = \frac{60}{267} = 0.225\ m^3$$

The minimum hopper volume is 0.225 m^3 for 1-hour operation time.

4 CYCLONE CHAMBER VOLUME

The size of cyclone chamber is determined by the rate of heat release. Combustion intensity, C.I can be used to scale the combustor volume when the heat release rate and the pressure are given.

$$C.I. = \frac{\text{heat release rate}}{\text{combustor volume x pressure}}\ kW/m^3.atm \qquad (4)$$

Fredriksson (2004) have studied a cyclone gasifier using wood powder as a fuel with minimum fuel flow rate 10 kg/hr was found that to achieved a good performance, the Combustion Intensity, C.I. is 5.0 MW/m^3.atm. Therefore, the cyclone volume is:

$$V_{combustor} = \frac{Q}{C.I. \times P} = \frac{286}{5000 \times 1} = 0.0572\ m^3$$

Perry and Green (1984) have considered the separation efficiency of the cyclone designed as same as standard cyclone separator. The standard cyclone separator designed gives the relationships between cyclone dimensions. The typical values are:

$$D_e = D/2,\quad H = 4 * D,\quad h = 2 * D,\quad S \approx D/2$$

The total volume of the cyclone designed can be separated into two portions. The first one is a cylinder (V_1) and the second is a cone (V_2).

$$V_1 = \frac{\eta D^3}{2} \quad (5)$$

$$V_2 = \frac{\eta D^3}{6} \quad (6)$$

Therefore, the inner diameter, D of the cyclone is:

$$V_{combustor} = \frac{2}{3}\eta D^3 \quad (7)$$

$$0.0572 = \frac{2}{3}(3.142)\,D^3$$

$$D = 300 \text{ mm}$$

The dimension of inlet diameter, D_i is determined by:

$$S_{gT} = \frac{D_e.D}{n.D_i^2} \times \frac{T_{inlet}}{T_{outlet}} \quad (8)$$

Fredriksson (1999) had recommend that the Swirl number is 12 as the temperature at inlet and outlet are 473 K and 1073 K to keep the corrosive ashes would remain solid in the char particles. Therefore, D_i of the cyclone is:

$$12 = \frac{150x300}{2.D_i} \times \frac{473}{1073}$$

$$D_i = 28.75 \text{ mm}$$

4.1 SCREW FEEDER

4.1.1 Screw Feeder Nominal Diameter And Pitch

The volume flow rate is:

$$I_V = \frac{I_m}{\rho} = \frac{60 \text{ kg/hr}}{267 \text{ kg/m}^3} = 0.225 \text{ m}^3/\text{hr} \quad (9)$$

Therefore, the value of nominal screw diameter D is:

$$I_V = 60\varphi\frac{\eta}{4}D^2 S_n \quad (10)$$

$$0.305 = (60)(0.3)(\frac{\eta}{4})(D^2)(0.7D)(30)$$

$$D = 0.101 \text{ m} = 101 \text{ mm}$$

where, S = 0.7D and trough filling coefficient, φ is 0.3.

4.1.2 Drive Power Of Loaded Screw Feeder

The drive power of the loaded screw is given by the formula:

$$P = P_H + P_N + P_{St} \quad (11)$$

where, P_H is power necessary for the progress of the material, P_N is drive power of the screw conveyor at no load and P_{St} is power due to inclination.

$$P_H = \frac{I_M L\lambda}{367} = \frac{(0.060\ \text{ton/h})(1)(1.9)}{367} = 3.12\times10^{-4}\text{kW} \quad (12)$$

$$P_N = \frac{DL}{20} = \frac{(0.1)(1)}{20} = 5\times10^{-3}\ \text{kW} \quad (13)$$

$$P_{St} = \frac{I_M H}{367} = 0 \quad (14)$$

L = length of conveyor [m] → 0.1 m, λ = artificial friction coefficient or progress resistance coefficient → 1.9, *H* = lifting height of screw; for this case *H* is zero. [m] → 0, I_M = mass flow rate [t/h] → 0.060 ton/h.

Therefore, the minimum power required to drive the sawdust into the screw feeder is 5.312 W.

4.1.3 Size Of Screw Plating

The size of screw plating is:

$$D_{plat/inside} = \frac{\sqrt{S^2+(\eta D)^2}}{\eta} \quad (15)$$

$$D_{plat/inside} = \frac{\sqrt{70^2\times(\eta\times42.4)^2}}{\eta}$$
$$= 47.89\ \text{mm}$$

where, the nominal outer diameter for this conveyor, D is 100mm with a pitch of 70mm (S). Nominal outside diameter of tubular shaft, C is 42.4mm base on data given in BS4409 Part 1.

$$D_{plat/outside} = \frac{\sqrt{S^2+(\eta D)^2}}{\eta} \quad (16)$$

$$D_{plat\ outside} = \frac{\sqrt{70^2\times(\eta\times100)^2}}{\eta}$$
$$= 102.5\ \text{mm}$$

5 CONCLUSIONS

The cyclone gasifier was design base on combustion intensity, C.I and geometrical swirl number, S_g in order to determine the suitable dimensions. The cyclone gasifier dimension can be summarized in the Table 1 while Table 2 show the screw feeder specification.

In conclusion, to developed cyclone gasifier using sawdust as the fuel, a few considerations have been taken in order to select and determine the appropriate parameters as discussed earlier.

TABLE 1. Cyclone's dimensions

Dimension	Value
D.	28.75 mm (two inlet)
D	300 mm
D.	150 mm
H	1200 mm
Cyclone's volume, V.	0.0572 m^3
Fuel power	286 kW
Combustion intensity	5 MW/m^3atm

TABLE 2. Summary of screw feeder specification

Specification	Description
Sawdust bulk density	267 kg/m^3
Max lump size (commercial sawdust)	1mm (45%)
Required capacity	Minimum 60kg/h
Required speed of rotation	30 rpm
Power required	1 hp (minimum)
Torque	3200 inch-pounds
Nominal outside diameter of tubular shaft	42.4 mm
Nominal diameter of helical screw	160 mm
Pitch	70 mm
Nominal thickness of helical screw blade	5 mm (root), 2.5 mm (tip)
Motor type	AC, Class E, Single Phase; max 1400rpm
Reducer	1:40
Gear ratio controlling device	1Hp variable speed pulley

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