AN INDIRECT-FIRED ROTARY SUGARCANE BAGASSE TORREFYER: DESIGN AND PERFORMANCE

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Sugar mills basically require a lot of power for thermal as well as for electrical uses. Boilers, which are used in the production of sugar crystals, consume a lot of biomass fuel to boil water in order to produce steam which, in turn, vaporizes sugarcane juice. Sugar bagasse are also used to fuel steam turbine or gasifier to generate electricity to run electric motors that drive different machinery parts of the sugar mill. Sugar bagasse and cane trashes are two potential sources of biomass fuel that can be used to augment energy supply in the mill, particularly for heating application and for generating electrical power. Basically, 0.33 ton of sugar bagasse is produced per ton of raw sugar cane milled in the plant and around 5 tons of cane trash is available per hectare of sugarcane plantation. Despite their abundant supply, however, these biomass materials are not commonly utilized in sugar mill operations due to their high moisture content (more than 55%) and to their hygroscopic nature which makes them difficult to dry. To eradicate them, especially during preparation of the field for the next planting, the current practice is by spreading and burning them openly in the field producing heavy smoke pollution and emitting carbon dioxide to the atmosphere. To mitigate such problems, an indirect-fired rotary sugarcane bagasse torrefyer was designed and tested. The torrefied material, which is a good quality fuel, can be used as fuel for steam boilers making the production of heat and the generation of electrical power for the plant more efficient and reliable. In torrefaction, the moisture and parts of volatile matters in the materials are removed hence leaving higher amount of combustible solids and gases present in the material.

The indirect-fired rotary torrefyer, shown in Figures 1, 2, and 3, was designed to produce torrefied fuel from sugarcane bagasse. It consists of the following major components

Figure 1 The Sugar-Cane Bagasse Torrefyer (SCBT)

Figure 2. Left-Side View of SCBT.

Figure 3. Right-Side View of SCBT.

Figure 4. The Biomass Furnace.

Figure 5. The Belt Conveyor.

namely: (1) Rotary Torrefying Cylinder, (2) Belt Conveyor Feeder, (3) Biomass Furnace, (4) Hammer Mill, (5) Pneumatic Conveyor Cooler, and (6) Storage Bin. It was designed to torrefy dried sugar cane bagasse by conduction heating in a rotating cylinder using chopped sugar cane trash as fuel for the furnace.

The rotary torrefying machine is where sugar cane bagasse is subjected to conduction heating to remove moisture and a little of volatile matter. Table 1 gives the design specification of the machine. The rotating cylinder, which is made of 5mm-thick MS plate, has a diameter of 1.2 m and a length of 9.6 m rotating at a speed of 6.5 rpm. A RC 160 sprocket-and-chain drive with 5-hp gear motor (1:3) is used to rotate the cylinder. The cylinder is inclined at 2 degrees to allow

slow movement of the material from the inlet to the outlet end of the cylinder. Inside the rotating cylinder are 16 pcs of 10cm-wide straight baffles, with 1-cm stiffener for each baffle, that lifts and stirs the material while passing from one end to the other end of the cylinder. The rotating cylinder is heated by hot flue gas from the biomass furnace (Fig. 4) located radially at the inlet section of the cylinder. Flue gas enters and travels through the annular space between the rotating and the stationary cylinders and exits through the chimney located at the end section of the cylinder. Heat is transferred into the material by conduction heating in a rotating cylinder where moisture and some volatile matters are removed. Two belt conveyors (Fig. 5) feed the dry raw sugar cane bagasse into the rotating cylinder of the torrefyer. One belt conveyor has a 10-m length, 0.4-m width and 10-mm thickness made of rubber. The other has 8-m length and of the same width with the first conveyor. Both are driven by 2-hp gear motors, which are positioned in series perpendicularly with each other to facilitate movement of freshly dried sugar cane bagasse from the rotary dryer to the torrefyer. On the other hand, the biomass furnace supplies the needed heat by the torrefyer. It is a double inclined-grate furnace with induced-draft blower to supply the required amount of heat. It has a 1.2m-diameter by 2m-high combustion chamber insulated with locally-produced refractory cement. Sugar cane trashes are chopped into suitable size and are used as fuel for the furnace. A 20cm-diameter screw conveyor running at a speed of 24 rpm is used to feed the fuel into the furnace. Manual loading of cane trash is sometimes done to obtain sufficient amount of heat for the torrefyer. The torrefied sugar cane bagasse is immediately reduced in size in a fast rotating hammer located at the outlet end of the torrefying machine. A pneumatic conveyor, equipped with a backward-curved-blade blower, is used to cool and to deliver fine torrefied sugar cane bagasse into a rectangular storage bin. The storage bin is equipped with a 0.6m-diameter by 0.9m-long cyclone separator to minimize dust emission to the atmosphere during operation. Discharging of torrefied materials is accomplished with the use of a screw discharge feeder. Schematic drawing of the torrefying machine is shown in Figure 6.

Table 1. Design Specification of SCBT.

Type	Indirect Rotary Cylinder
Diameter and Length	1.2 m D x 9.6 m L
Inclination	2 deg
Baffles	16 pcs straight 10-cm wide
Speed of Rotation	6.5 rpm
Power Source	5-hp gear motor
Heat Source	Biomass Furnace
Fuel	Chopped Sugar Cane Trash
Feeding Method	Screw Feeder and Manual
Air Supply	
Primary Air	½-hp centrifugal blower
Secondary Air	3-in. electric blower
Size-Reduction Equipment	Hammer Mill
Power Source	3-hp Electric Motor
Conveyor	Pneumatic
Air-Moving Device	Centrifugal Fan at 3,600 rpm, 3.7 kW
Duct	20 cm D x 50 m L
Cyclone Separator	0.6 m D x 0.9 m L
Bin	
Size	1.8 m x 1.8 m x 3.2 m
Discharge Mechanism	20-cm screw

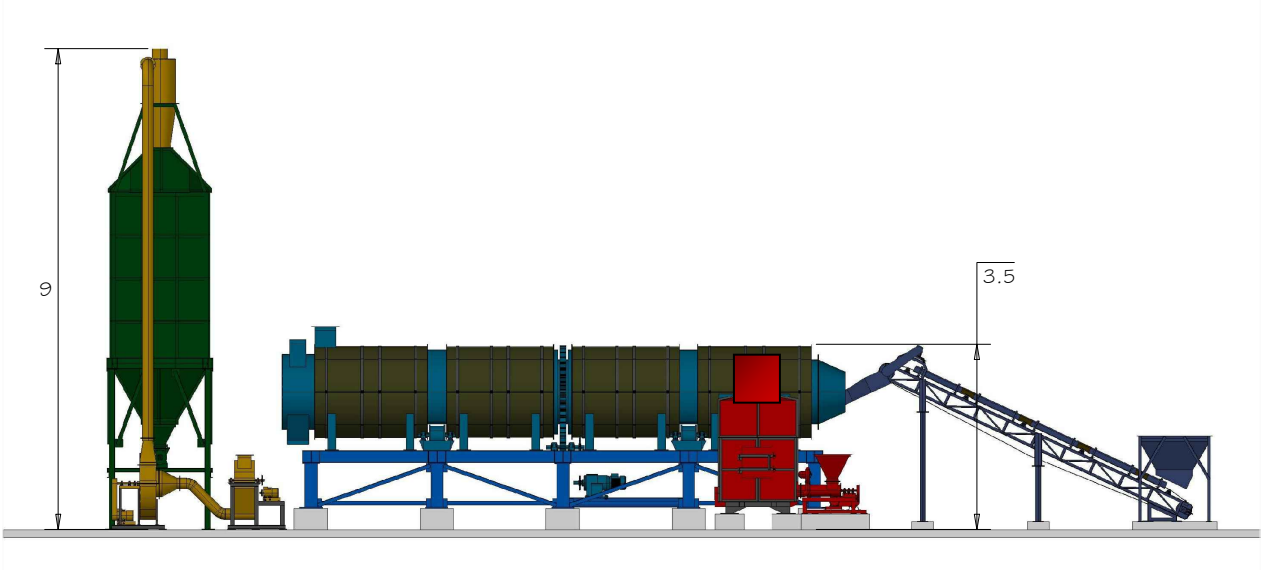

Figure 6. Schematic Drawing of the Torrefying Machine.

Performance testing of SCBT torrefyer showed that sugar cane bagasse can be successfully torrefied in the machine using sugar cane trash as fuel for the furnace. The machine can be simply operated by switching ON the motors that drive the various parts of the torrefyer. The use of a frequency inverter for the motors facilitates the changing of speed of the cylinder and of the other machine parts. Sugar cane trash with energy content of about 16,260 kJ/kg and is used as fuel for the furnace to supply the needed heat by the torrefyer, can be easily ignited in starting up the furnace. Spontaneous combustion of sugar cane trash fuel in the furnace is achieved within a minute. Once the blower at the furnace is switched ON, tremendous burning of fuel is observed and flame moves directly towards the rotating cylinder. As shown in Table 2, sugar cane bagasse is fed into the heated rotating cylinder at a rate of 60 kg per hour using a spring scale for the recorded time of 1.2 hours, and its moisture immediately drops from 13% to 0% after passing the torrefyer. Moisture measurement was taken using a probe-type moisture meter. The burning rate of sugar cane

Table 2. Performance of SCBT.

Biomass	Sugar Cane Bagasse
Moisture Content Initial	13%
Moisture Content Final	0%
Throughput Capacity	60 kg per hour
Fuel Used	Sugar Cane Trash
Consumption Rate	45 kg per hour
Fuel-to-Material Ratio	0.75 kg fuel/kg material
Temperature	
Furnace	640° to 805°C
Duct	468° to 674°C
Chimney	95° to 150°C
Surface Temperature	
Cylinder Inlet	299° to 440°C
Cylinder Outlet	53° to 70°C
Color of Torrefied Biomass	Light to Pale Brown

trash in the furnace is 45.3 kg per hour with material-to-fuel ratio of 0.75. Measurement of temperature showed that at the furnace combustion chamber the reading obtained ranges from 640° to 805°C, that at the duct between the furnace and the rotating cylinder ranges from 468° to 674°C and that at the chimney outlet ranges from 95° to 150°C. Surface temperature taken at the inlet section of the stationary cylinder using infrared thermometer ranges from 299° to 440°C and that at the outlet end of the cylinder ranges from 53° to 70°C. It was observed that torrefied sugar cane bagasse, shown in Figure 5, have light-to-pale=brown color which is lighter as compared with that of raw sugar cane bagasse. Exposing torrefied sugar cane bagasse in the atmosphere for 6 hours slightly increased its moisture adsorption from 0 to 6.8% for non-hammer-milled samples while 0 to 8.4% for hammer-milled samples.

Figure 7. Samples of (a) Raw and (b) Torrefied Sugar Cane Bagasse.

Based on the performance tests, it can be concluded that the sugar cane bagasse can be torrefied simply in a indirect-fired rotary torrefyer using sugar cane trash as fuel for the furnace. Torrefied materials leaving the heated rotating cylinder of the torrefyer can be effectively reduced in size using a hammer mill and conveyed into the storage bin while, at the same time, cooled to the level required for storage.

To further improve the performance of the machine particularly in terms of throughput capacity, the following courses of action are recommended: (1) Enlarge the opening of the torrefying machine and of the biomass furnace to increase its throughput capacity; (2) Seal the gaps in various connections in the torrefying machine and provide it with rock-wool insulation to minimize heat losses; (3) Conduct actual and long-term operation of the machine to further see the parts that need to be adjusted and replaced.

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