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RESEARCH ARTICLE

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MANAGEMENT OF MUNICIPAL SOLID WASTE USING PYROLYSIS/GASIFICATION PROCESS IN FIXED BED REACTOR

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ABSTRACT

Pyrolysis is quickly emerging biomass thermal conversion technology and is getting consideration throughout the global due to its high effectiveness and its environmentally friendly characteristics. Pyrolysis technology can be also used for the conversion of urban solid wastes, agricultural Wastes, non-recyclable plastics, rubbers etc. into clean & green energy. It offers a clean way of converting the wastes into the clean energy in the form of heat energy, electrical energy, Hydrogen gas from Syn gas and other compounds.

Pyrolysis of Municipal Wastes

Pyrolysis is thermal conversion of carbon-rich organic materials when heated in a non-reactive chamber in very limiting/ absence of oxygen. It consists of both instantaneous and succeeding reaction. The thermal conversion process normally starts at 350°C–550°C and goes up to 700°C–800°C in the limiting / absence of oxygen.

For pyrolysis of municipal waste, the separation of municipal waste is done. The glass, metals & inert constituents are separated and the remaining are fed in a pyrolysis reactor. The heat at initial is provided externally by electrical or diesel burner for maintaining high temperature for pyrolysis process and after pyrolysis reaction the external heat source can be turned off. The normally used pyrolysis reactor are Fixed bed reactor & Rotary kiln reactor.

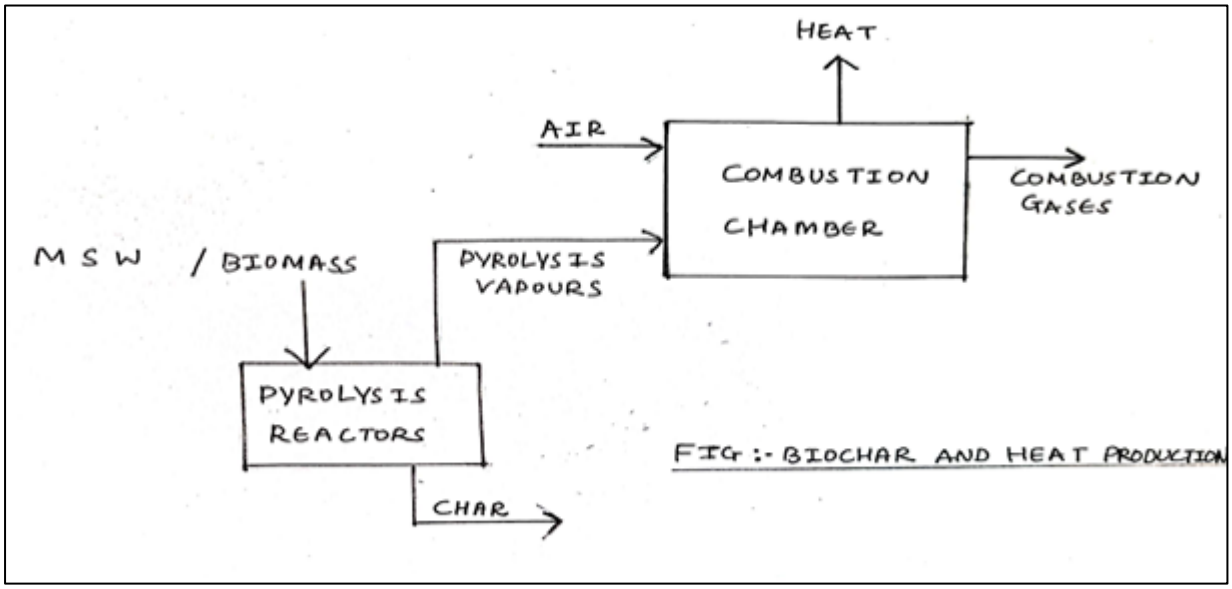


Fig 1: Bio char and Heat Production

Pyrolysis is generally done in small scale which will help to reduce the handling and transportation costs. Heat transfer is a critical area as the process includes endothermic reaction (Heat is absorbed from the surrounding and transfer to the system) and proper heat transferring area has to be given for the smooth and efficient result during the pyrolysis of Municipal solid waste (MSW).

High calorific value gas normally known as Synthetic / syn gas and Solid residue char are obtained from the pyrolysis of MSW. If the temperature is low i.e., less than 450^0C the solid residue is formed and if the temperature is high i.e., more than 800^0C high calorific gaseous are formed.

Fixed bed reactor

Fix bed reactor is effective technology for the pyrolysis of MSW and production of Syn gas. Fixed bed reactor mostly contains Combustion chamber, Gas cooling Section and Cleaning section. In the combustion chamber the thermal cracking of MSW is occurred due to heat. The Syn gas is produced in this section. The cooling and cleaning section consists of cyclone chamber, calcination chamber, wet scrubber and dry scrubber followed by chimney.

The MSW is fed into the combustion chamber where it meets an upwardly moving current of gas stream product due to which heat transfer occurs between the newly Fed MSW & hot gas, causing thermal cracking followed by pyrolysis reaction. The reactor is made using high grade Mild steel and firebrick or fire clay for insulation to prevent heat loss to the environment and to protect Mild steel from being damage from high heat.

The reactor contains feeding unit for MSW, Initial Heating Unit (Burner), Ash removal unit and gas discharge unit. The general applications of fix bed reactor are:

1. Small scale – For minimizing material handling and transportation costs.
2. Has high ability to conserve carbon.
3. Has long operation time with high efficiency.
4. Low gas velocity with low ash carries over.
5. Less solid residue as the temperature maintained is more than more than 800^0C.
6. Ash removing can be done using screw conveyor or vacuum after cooling.

Process

The MSW (Municipal Solid Waste) is shredded into smaller, similar pieces so that the reaction time become less. The shredding is done by using shredder with 10HP motor. The shredded MSW is then taken to the screw feeder using the conveyor. The conveyor drops the MSW in the hopper of the screw feeder. The screw feeder feeds the MSW in the reactor.

The actual job is done inside the reactor as shredder, conveyor, screw feeder are accessories to decrease the human efforts. The major parts are Reactor, Retention chamber, Cyclone Chamber, Calcination Chamber, Wet Scrubber, Dry Scrubber & Chimney.

Reactor

Reactor is the chamber where the pyrolysis reaction takes place. The reactor is made of A 360 steel along with the 50 mm insulation with fire clay to make minimum heat loss to the environment.

There are 2 Blowers/fans to supply the oxygen inside the reactor and a diesel burner. The diesel burner is used to main the temperature so that the pyrolysis takes place. After certain temperature meets, the diesel burner is turn off. Out of two only one blower is used and other is kept as standby blower. All the electrical equipment are controlled by electrical control panel.

Inside the reactor after 350-degree centigrade is maintained, pyrolysis reaction takes place and the syn gas is produced.

Retention chamber

In the retention chamber the ash and smoke are stored. There is diesel burner installed at the opening end of the retention chamber to burn the unburned particles which may have entered in the chamber from reactor. This system plays vital role in pollution control.

Cyclone Chamber

In the cyclone chamber larger dust particles are separated. Cyclone separator is a cone shaped chamber which use the principle of inertia to remove particulate matter from the gases. They generally remove the matter with higher volume and density. The cyclone chamber is assisted with the induced draft fan (Centrifugal Fan) which creates a spiral vortex like tornado. The light particles in gases will have less inertia so they are influenced by the spiral vortex and flew upward. The large particles in gases will have more inertia are not influenced by spiral vortex so these particles fall down due to gravity. The gases from the cyclone chamber are then fed to cyclone chamber.

Calcination Chamber

In the calcination chamber limestone are filled. The main objectives of a calcination chamber are to drive off water that is present as absorbed moisture, to drive off volatile constituents such as Sulphur dioxide, or to oxidize part of, or the entire substance. The remaining smoke is then pulled to the wet scrubber using the blower.

Wet Scrubber

The fumes gases are brought in contact with water present in the wet scrubber. The gases are dipped into a pool of water so that the particulate matter in the gases is absorbed by water. The gases leave its particulate matter along with its temperature. From wet scrubber the gases are passed to dry scrubber.

Dry Scrubber

A dry scrubber is a device which is used to remove harmful materials from the gases before releasing to the environment. They are mostly used to eliminate the harmful impurities using filters such as clothes filter. They also help in passing the gases smoothly in the environment through chimney.

Chimney

Chimney is a system that allows venting of hot smoke and gases from furnace or any fireplace to the outer atmosphere freely or forcibly using fans.

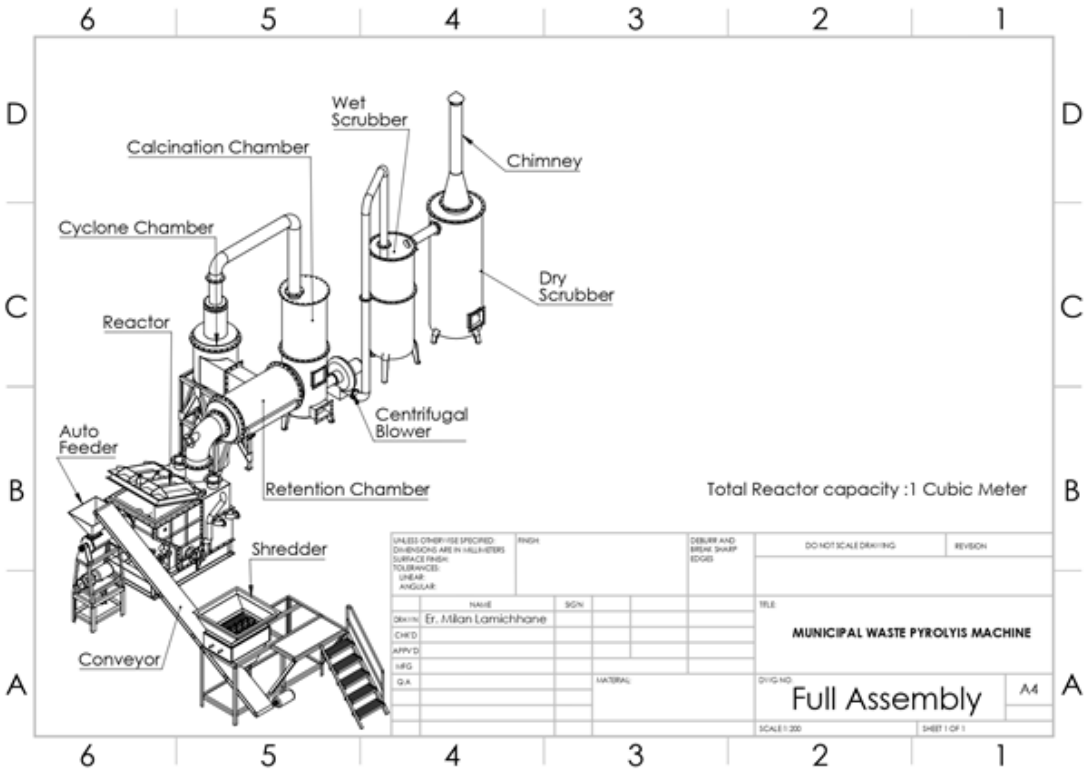


Fig.2: Assembly of Complete Set-up

Theory of pyrolysis

1. Pyrolysis is thermal Cracking Process.
2. It is carried out in closed chamber with limiting or absence of oxygen.
3. The process of pyrolysis is first drying using external heat, thermal cracking of material and then is changed to syn gas, which is composed of carbon monoxide (CO) and hydrogen (H_2) and few methane and low hydrocarbon.
4. Syn gas is $C + H_2O = CO + H_2$, and after catch fire by burner, the temperature goes up to over 800 degrees C. As many kinds of materials except pure carbon are actually included in the garbage, many kinds of gasses and ashes are generated, although the volume is few compared to the syn gas.

Description of Reactor:

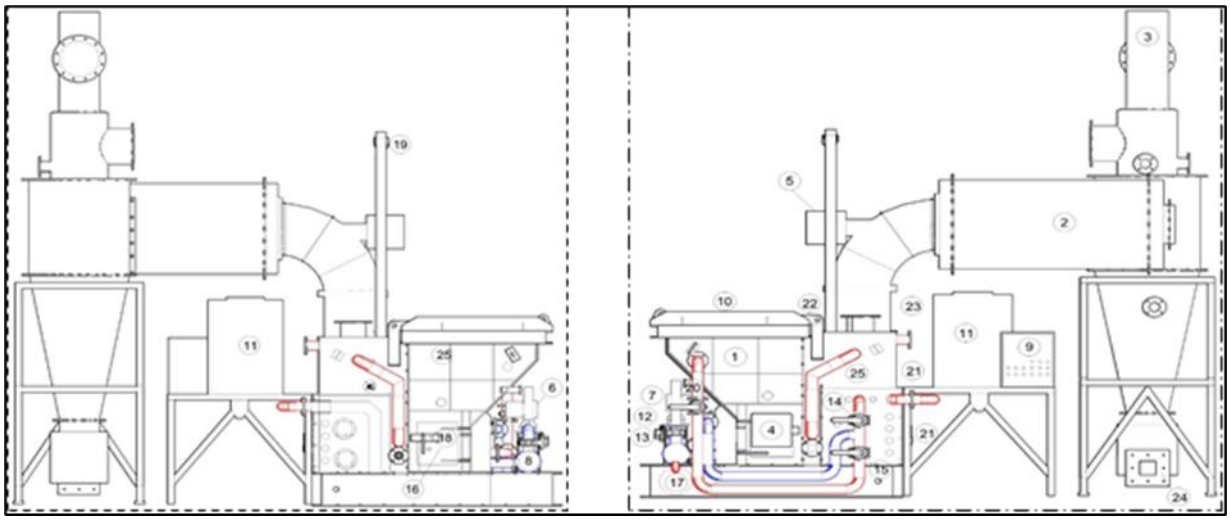


Fig 3: Reactor Right Side

Table 1: Description of Reactor

Part No.	Description
1	Reactor is a place to process waste pyrolysis.
2	Retention chamber is required for perfect combustion of exhaust gases.
3	Cyclone & Chimney function is to collect particle of exhaust gas and then be discharges at fly ash collector
4	Starting oil Burner is for initial warm up the reactor.
5	Burner 2 function is to complete combustion of the flue gas to avoid black smoke emerges to the chimney.
6	Fan 1 function is as provide air with sufficient capacity to complete combustion at first combustion chamber for gas product of pyrolysis /gasification process.
7	Fan 2 function as stand by spare for fan 1
8	Air Receiver function is air pressure stabilizer.
9	Control panel function is to operate and monitor the machine.
10	Reactor cover function is for waste input access.
11	Water Tank Function is to collect hot water from water heater tank

12	Valve 1 is to adjust air volume from air fan1 to the combustion chamber
13	Valve 2 is to adjust air volume from air fan2 to the combustion chamber
14	Air Valve 3 is to adjust air volume to the combustion chamber
15	Valve Air 4 to adjust air volume to the reactor
16	Bottom ash manhole.
17	Fuel Tank 1
18	Inspection glass is to monitor the flame in the reactor.
19	Electrical hoist is to open and close the reactor cover.
20	By pass Valve is to bypass the gas during start up
21	Hot water temperature sensor
22	Reactor cover openings sensor.
23	Crane manual control button.
24	Fly ash box is for fly ash removal

Operation procedure:

Cold Start Initial Waste Disposal Solution starts to cool.

1. First, make sure the water and fuel in the water tank are full and the electricity source is available,
2. Turn on the power on switch (ON position) on the panel.
3. Open the reactor cover (10) up to 75 degrees.
4. Fill in the waste into the reactor about half of it and it is recommended at first to be filled with organic waste in the form of pieces of wood or tree branches around 20% so that the start time is faster, then close the reactor cover (10).
5. Ensure that all air valves (14, 15 & 20) are fully closed.
6. Turn on the fan burner then turn on the fuel pump and press the lighter the burner flame, then make sure that the burner flame is on.
7. Turn on the fan over burner then turn on the fuel pump and press the lighter of the burner fire, then make sure that the burner flame is fully lit.
8. Turn on the main fan (6).
9. Whenever temperature at main chamber has higher than 250-degree C, then open air fan butterfly valves no (14 & 15) and turn off fuel oil pump, however burner fan should not be off, along in operation to avoid back fire to the burner and to avoid burner overheating.
10. If all the steps above are smooth, you will see the temperature in the combustion chamber 1 rises gradually and around 20 minutes the temperature can reach above 300-degree C if the garbage is dry.

Hot Operation or Continue full operation:

Operations in hot conditions or continuous waste refilling operations on a regular basis generally can be every 15 minutes to 30 minutes depending on the type of waste. Refilling garbage can be done if the garbage in the reactor is almost finish, this can be seen from the trend of temperatures to go down to 350.

1. Then we need to fill the waste into the reactor, but for that we need to ensure the combustion chamber temperature 1 is not less than 350-degree C for the purpose of saving fuel usage.
2. Turn off the main air fan (6).
3. Turn off all air valves (14, 15 & 20) in fully closed.

4. Open the reactor cover (10) up to 75 degrees and fill the waste into the reactor about 50%, then close the reactor cover (10).
5. Turn on the burner fan then turn on the fuel pump and press the igniter, then make sure the flame is on.
6. Turn on the fan above the burner then turn on the fuel pump and press the burner igniter (10), then make sure that the burner flame is fully lit.
7. Turn on the main fan (6).
8. If all the steps above are smooth, the temperature in combustion chamber 1 will rise again faster can reach above 300-degree C.
9. When the temperature at main combustion chamber 1 has higher than 250-degree C, then push the button, to operate the air main fan and open-air fan butterfly valves no (14 &15) and push button to off fuel oil pump, however don't switch off the burner fan along in operation to avoid back firing to the burner and it avoid burner on fire.

Turning off Machine:

To shut down the operation, it must not be in a hot condition, before the machine is turned off it must wait for the reactor waste empty and the temperature in combustion chamber 1 must be lower than 100-degree C after that,

1. Turn off the main fan.
2. Open all air valves (14, 15 & 20).
3. Turn off the top burner fan (9) if the temperature in the combustion chamber is lower than 100-degree Centigrade and there is no fire in the reactor, then the ash door can be opened and the ash can be taken manually.
4. Power sources can be turned off.

Control Panel

The main important physical quantities for the machine operation are temperature, pressure and the classification of incoming waste. To measure this parameter, the digital measuring devices are needed, located in the control panel. The instruments, indicators and push bottoms are installed on the local control panel which are located.

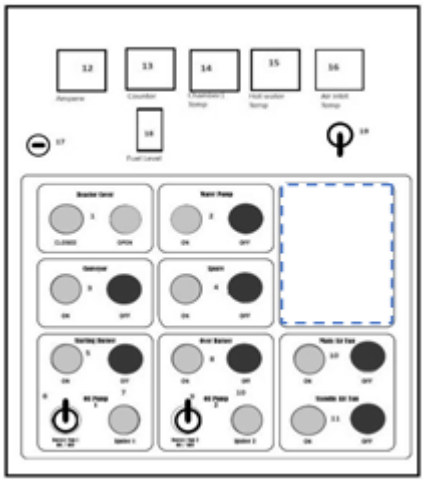


Fig 4: Control Panel

Table 2: Control Panel Description

Part No.	Description
1	Reactor feeding cover On-Off push button.
2	Water inlet pump- On-Off push button.
3	Conveyer On-Off push button.
4	Spare On-Off push button.
5	Starting burner fuel pump On-Off push button.
6	Starting burner fan On-Off switch.
7	Starting burner Igniter push button.
8	Over burner fuel pump On-Off push button.
9	Over burner fan On-Off switch.
10	Main air fan On-Off switch.
11	Stand by air fan On-Off switch.
12	Ampere Meter of electricity consumption.
13	Reactor feeding cover counter.
14	Combustion chamber 1 Temperature indicator.
15	Hot Water Temperature indicator.
16	Air inlet.
17	Panel cover lock.
18	Fuel level Indicator.
19	Machine on-off switch.

Temperature Curve:

As the Machine is initially burned with the help of diesel burner and later itself by self-generated syn gas through pyrolysis process, the temperature gradually increases with respect to time.

T1: Temperature of Coolant Water.

T2: Temperature of Reactor.

T3: Temperature of Fumes gases.

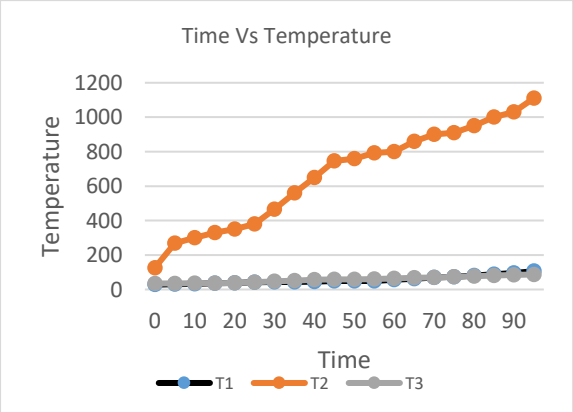


Fig 5: Time vs Temperatures

Emission Test

When the stack is tested, following emission data are found.

Table no 3: Emission Table

S.No	Interval	Time Taken	Oxygen Present (O_2) %	H_2S ppm	CO ppm
1	-	0	20.9	4	200
2	2	2	20	2	180
3	2	4	20	2	100
4	2	6	20	0	102
5	2	8	20.9	0	100
6	2	10	21	0	98
7	2	12	20	0	90
8	2	14	20	0	100
9	2	16	20	0	100
10	2	18	20	0	83
11	2	20	20	2	243
12	2	22	20	1	192
13	2	24	20.8	0	100

14	2	26	20	0	100
15	2	28	20.9	0	103
16	2	30	20	0	114
17	2	32	20	0	100
18	2	34	20.9	0	90
19	2	36	20.9	0	91
20	2	38	20	0	90

Syn Gas Generator:

Syn gas, or synthesis gas, is a gas mixture consisting mainly of hydrogen, carbon monoxide, and some carbon dioxide. Syngas is flammable and can be used as a fuel of internal combustion engine. The electricity is produced using the alternator due to reciprocating of internal combustion engine.

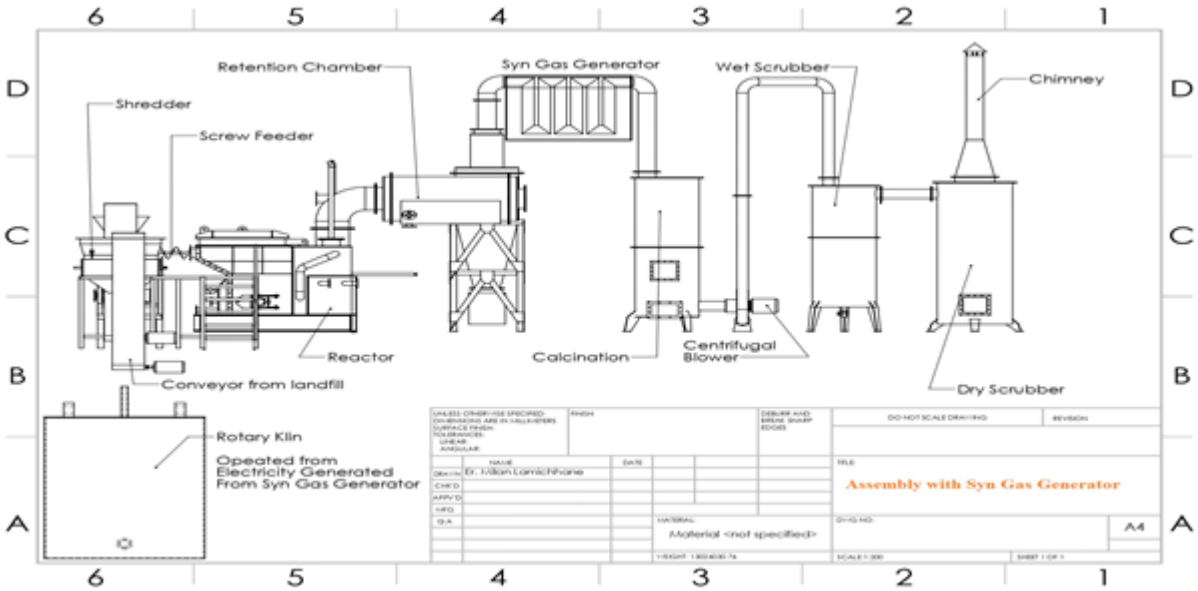
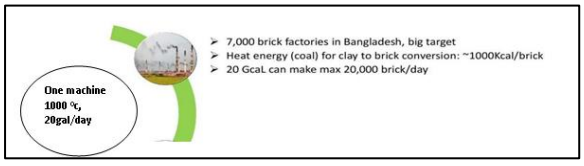


Fig 6: Assembly of Machine with Syn Gas Generator

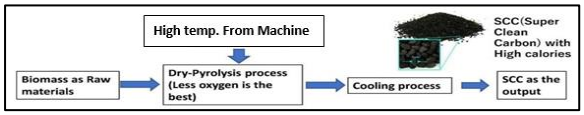
Utilization of Output Heat

As during pyrolysis process, large amount of energy is generated in the form of heat energy. These heat energies can be utilized by the following ways.

1. Using in the Bricks factory to heat the bricks.



2. Utilizing the heat to make SCC (Coal) from the torrefaction process from biomass.



Conclusion

This machine on proper use not only solve the problem of plastic throughout the world, this can also be used to do useful work utilizing the by-products. The heat can be used to heat up different sources like discussed above. The residue (ash) left over after burning can be used as bio-cement which can be used to pitch the road and also be used to stop the soil liquidation. The generated syn-gas can be fed into the Syn gas generator (Genset) and produce the electricity.

As Syn gas from the gasifier is key source to generate Hydrogen gas. We can furthermore research on extraction of hydrogen in cheapest and efficiently way as $C + H_2O = CO + H_2$.

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