Possibilities of Producing Biogas/CBG from Filter Cake

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Abstract— Conventionally, handling of the filter cake in the sugar industry is considered to be a troublesome area and whatever utilization is made is in making the bio-compost. However, in pursuit of generating higher revenues, the unharnessed potential of filter cake may be exploited by utilizing for generating bio-gas or Compressed Bio-gas (CBG). Filter cake contains appreciable proportion of biodegradable organic matter which has very good potential for the production of bio-gas from it. The Government of India has also made certain policy interventions to encourage production of CBG/Bio-CNG utilizing filter cake and other waste streams of the sugar industry. The paper discusses potential of Bio-CNG/CBG production utilizing filter cake from sugar industry, technology, opportunities and challenges.

Keywords: CBG (Compressed Bio-Gas), Filter Cake, Scrubbing, Reactor

I. Introduction

The Indian sugar industry is faced with a reality that sugar, molasses and bagasse can no longer be regarded as final product from sugar industry and thus, value additions, diversifications and transformations to be vigorously investigated as possible routes to new market and making sugar industry less dependent on single commodity i.e. sugar. The future of the sugar industry, as a whole, lies in development of sugarcane bio-refineries i.e. bio-electricity, bio-ethanol, bio-gas/ bio-CNG, bio-manure and chemicals etc.

The sugar industry across the globe is also required to work on the mandate developing "Wealth from Waste" or converting "Waste to Resource" utilizing anything which is available with sugarcane or is generated in one or other form of processing. Thus, for sustainability of the Indian sugar industry or sugar industry as a whole, it includes improvement in the sugarcane and sugar productivities, conversion from single-product to multi-product factory, optimizing cost of sugarcane processing, integration with food processing industry, utilization of huge infrastructure during off-season, adoption of hybrid system for power generation i.e. biomass: solar: wind power and finally conversion of existing sugar factories to bio-refineries.

In terms of bio-energy, the major sugarcane energy chains are;

- Bagasse for heat & bio-electricity generation.
- Molasses for conversion to bio-ethanol.
- Filter Cake and spent wash for conversion to methane/ biogas/ bio-CNG.

Sugar mills in India crush about 300 million tonnes of sugar cane every year. Indian sugar factories producing plantation white sugar produce filter cake @ 3.0-3.5% on cane per year. The quantity of filter cake is thus about 10 million tonnes per year. At present filter cake is used primarily for bio-composting and in many cases disposal is a problem. This is because of the fact that due to advent of Incineration technology only limited molasses based distilleries are undertaking bio-composting. The sugar industry in India is focusing on clean and green form of energy and value additions. Thus, utilization of filter cake for production of biogas/compressed biogas may prove to be a tool for producing green energy and adding value to the revenue pot of the sugar factories. Thus, with the availability of filter cake @10 MMT, the total CBG production is estimated as 0.1 MMT.

II. About Bio Gas & Market Potential

Biogas, a clean and renewable fuel, has vast potential in India and can be a supplement to petroleum products. Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic conditions. It consists of a varying proportion of CH4 (methane) and CO2 (carbon dioxide) and traces of H2S, N, CO, O, etc. The content of CH4 and CO2 is a function of the matter digested and the process conditions like temperature, C/N ratio, etc. Methane is the most valuable component under the aspect of using biogas as a fuel; the other components do not contribute to the calorific ("heating") value and are often "washed out" in purification plants in order to obtain a gas with highest possible CH4 content.

The global CNG and LPG vehicle market size is projected to grow from 2,135 thousand units' sales in 2021 to 4,389 thousand units' sales by 2026, at a CAGR of 15.5%. Factors such as growing demand for low emission commuting and governments supporting CNG and LPG vehicles through subsidies & tax rebates have compelled the manufacturers to provide CNG and LPG vehicles around the world.

III. Compressed Biogas vs Compressed Natural Gas

The table no. 1 below gives the characteristics of CBG, CNG and Raw Biogas.

Properties	Compressed Natural Gas (As per IS 15958:2012)	Upgraded Biogas (As per IS 16087:2016)	Raw Biogas
Composition % (v/v)	CH_4 – 89.14% CO_2 – 4.38% H_2 – 0.01% N_2 – 0.11%	CH_4 – 90%* CO2 – 4% $CO_2+N_2+O_2$ - 0.5% TS (including H_2S) -20 mg/m^3 Moisture < 5 mg * Technologies can provide up to 97% gradation	CH_4 – 55-65% CO_2 – 35-45% H_2 – 0.02% N_2 – 1.98% H_2S – 500 ppm
Lower Heating Value	44.39 MJ/kg	42.62 MJ/kg	20.5 MJ/kg
Relative Density	0.765	0.714	1.014

Table 1: Properties of CBG, CNG & Raw Biogas

IV. USE OF FILTER CAKE FOR PRODUCING BIO-GAS

Filter cake a solid residue which is obtained from rotary vacuum filters after the extraction of residual sugarcane juice from the precipitates. It is usually used as a manure but can be used as raw material for the production of biogas. It generally consists of 70 to 75% moisture, 8-10% of ash and 15-20 % of volatile solids along with 70-75% of organic matter on solids [1].

Biogas is formed by anaerobic digestion using bacteria formed due to biodegradation of organic waste material. It consists of methane, carbon dioxide and small amounts of H2S, N, CO, O. Methane is the most important thing in the aspect of the formation of biogas fuel.

After the process of decomposition (fermentation) the main products are:

$$C_6H_{12}O_6 \longrightarrow 3CO_2+3CH_4$$

Using Hydrolysis, the organic materials are broken into simpler elements and the solid waste is liquefied and hydrolyzed into small solid molecules like cellulose and it is transformed into soluble sugar. [2].

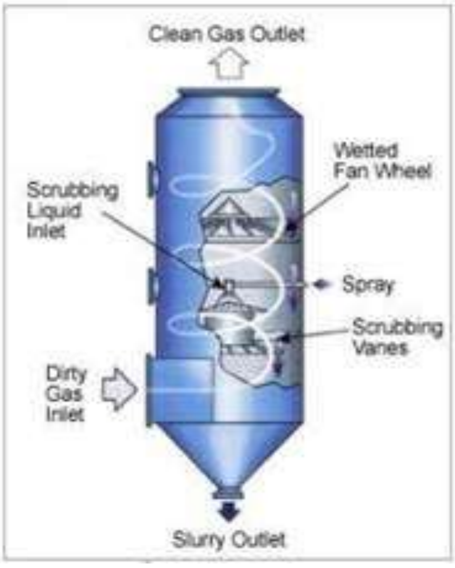

Fig. 1: Generalized Bio-gas Plant

V. TECHNIQUE OF PRODUCTION OF BIO GAS FROM FILTER CAKE

Production of biogas by anaerobic digestion of filter cake can be represented by Fig. 2 [3].

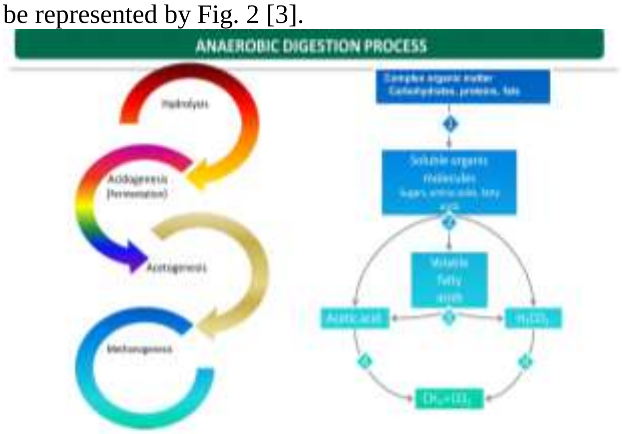

Fig. 2: Anaerobic Digestion of Filter Cake to produce Biogas

VI. FILTER CAKE DIGESTER: CSTR REACTOR

In the process, Filter cake is guided into the digester with the help of a pump, several times per day. Additionally, recycled and treated water from the same plant is pumped into these digesters. The treated sludge is pumped to the two digesters when indicators show a certain level within the digesters is reached this is set via the control philosophy and is generally guided by the PLC. The digester is fully mixed by high quality submersible agitators and is operated in a mesophilic (40°C) temperature range. This combination leads to a stable process with good homogenization results and a minimized effort as far as area requirements and digester volume are concerned. On the other hand, it aims at maximum gas yield which results in maximum greenhouse gas reduction.

The digesters are standing cylindrical tanks made of reinforced concrete and are equipped with a wall heating system. The digesters are covered with a double membrane. The anaerobic digester system includes a fixed vertical anaerobic digester with fixed dome and a biogas storage system. The fixed digester has a waste inlet which is coupled up with a waste fed buffer tank. The buffer tank acts as a homogenizer as well as a blending tank for mixing the raw material with the re-circulated water. From these buffer tanks the liquid goes to the anaerobic digester. The specially designed stirring mechanism inside the digester makes sure that no clogging, no froth and no scum formation inside the digester occur. The stirring mechanism is designed in such a way that it can be suited for any kind of biodegradable substrate. The heat and temperature maintenance system inside the feeding buffer tank takes care of a stable temperature inside the digester.

Further a digester effluent outlet is connected to the substrate buffer tank and via the re-circulation system and the substrate manifold it is again pumped in the required amount to hydrolyze the feeding material. The generated biogas is collected in the biogas storage system after removing the condensate through the condensate remover/moisture trap. The biogas plant is designed for minimum manual operation. Since the volume of daily waste to be processed is known, the plant is designed low on automation. The daily operations, emergency shut down and adjustment to change operating conditions are carried out manually with the help of an electric control panel provided along with the biogas plant.

VII. BIOGAS UPGRADING

The use of a biogas upgrading or purification process in which the raw biogas stream like CO_2, H_2S and moisture are absorbed or scrubbed off, leaving above 90% methane per unit volume of gas.

Presence of CO_2 in biogas poses following problems:

1) It lowers the power output from the engine;
2) It takes up space when biogas is compressed and stored in cylinder;
3) It can cause freezing problems at valves and metering points where the compressed gas undergoes expansion during engine running.
4) The traces of H_2S produces H_2SO_4 which corrode the internals of pipes, fittings etc.
5) Moisture causes corrosion and decreases heating value of the fuel.
6) As per IS 16087:2016 and the OMC requirement decides the units
7) Elemental Sulphur is produced as byproduct from the H_2S scrubbing System
8) Carbon Di Oxide can be liquefied and marketed.

VIII. DIFFERENT TECHNOLOGIES FOR UPGRADATION

Parameters	High pressure water scrubbing	Chemical absorption	Pressure swing absorption	Membrane separation	Cryogenic
Gas Pre Cleaning Requirement	No	Yes	Yes	Yes	Yes
Working Pressure	9-10 Bar	1 Bar	4 – 7 bar	4-7 bar	40 bar
Methane Loss	1– 2 %	1-2 %	1-9 %	10 - 15 %	1-2%
% purity attained of upgraded Biogas	95-98 %	Up to 99 %	95 - 99 %	Up to 90 %	Up to 99 %
Heat requirement	-	Required	-	-	-
Operating Cost	Low	Moderate	Moderate	Low	High
Initial Cost	Low	Moderate	Moderate	Moderate	High
Process Handling	Easy	Complex	Easy	Easy	Complex

IX. BIOGAS COMPRESSION & STORAGE

- Biogas compressors are readily available in the local market in the range of 2.5 bar up to 200 bars.
- Depending on the application a suitable compressor can be chosen.
  - High Pressure compressor,
  - Cascade of storage cylinders
- Compressed and stored in Cylinders
- The compressed and stored biogas in cylinders can be used for various purposes.

X. COMPOSITION OF BIO-SLURRY

The remains of fermentation after biogas formation are called slurry. Since it is obtained biologically, it is also called bio-slurry. The slurry contains the largest composition by mass with water, which are around 93% and rest of it which contains 4.5% of dry matter and 2.5% of inorganic matter. Slurry contains scum, liquid effluent, sludge and many other organic and inorganic substances. Scum is the fluid present above the surface of solid slurry. Liquid effluents contain some of the macro and the micro nutrients. The macro nutrients which is present in them are nitrogen, phosphorous, potassium and other micro nutrients present in them are calcium, magnesium, iron, manganese and zinc. Sludge is the substances present as a residue in a biogas. The sludge materials can also be used as fertilizer for the plants. It contains very high amount of nutrients and it can be settled in the bottom of the digester for many years. Nutrients in different organic substances are as shown in Table No. 2.

Parameter	Composition of Nutrients (%)		
	Nitrogen	Phosphorous	Potassium
Cow dung	2.5	0.2	0.5
Sludge	3.5	4	0.6
Neem cake	5.2	1	1.8
Compost	1.8	1	1.4
Groundnut Cake	7.3	2.5	2
Castor cake	4.3	2.4	2.3

Table 2: Nutrients in different organic substances

Bio slurry being fully fermented, it is odourless and it does not attract flies. It also repels the termites and pests that are attracted to raw dung. Bio slurry reduces weed growth. Application of bio slurry has proved to reduce weed growth up to 50%. Bio-slurry is an excellent soil conditioner, adds humus, and enhances the soil's capacity to retain water. Bio- slurry is pathogen free. The fermentation of dung in the reactor kills organisms that cause plant disease. Synthetic fertilizers increase the soil's nutrients more than organic fertilizers but they could only provide specific nutrients to the crops. If only synthetic chemical fertilizers are used it reduces the soil productivity. Synthetic fertilizers are expensive and not affordable for small scale farmers.

XI. UTILIZATION OF BIO SLURRY OBTAINED FROM BIO-REACTOR

A. Slurry being used as a fertilizer.

Usage of Bio slurry as a fertilizer uses the optimum usage of bio resources that is used for the production of bio gas and the leftovers are used as fertilizer. Bio slurry acts as an organic fertilizer that facilitates plant growth without any type of contamination. It also enriches the soil and thus improves the fertility of the soil. Synthetic fertilizers cause many ill effects to the land. Bio slurry is safe to use as it is a natural product. The necessary nutrients required for plant growth such as Potassium, Nitrogen and phosphorous are abundantly present in bio slurry.

B. Slurry used for organic farming.

Organic farming is being practiced in almost all parts of India where there is cultivation of oranges, pepper, pineapples, ginger, turmeric, etc. Many macro and micro nutrients are present in the slurry obtained from the BGP. The nutrients include 'N' which comprises 1.8%, P2O5 with an average content of 1.0%, 0.90% of K2O and also manganese (MN), zinc (Zn), iron (Fe) and copper (Cu) with average content of 188ppm, 144ppm, 3550ppm and 28ppm respectively. It also contains organic matter of 65% and the C/N ratio is about 10–15. The compost produced will always contain other metals in trace amount that serve as a vital role in the growth of organisms [4].

XII. Advantages and Benefits of Biogas/Compressed Biogas

1) Biogas is eco-friendly fuel which provides a non-Polluting and renewable source of energy.
2) It has a calorific value of around 6kWh/m3—this is equivalent to half a liter of diesel. It can be thus a prime choice for automotive industry.
3) Larger biogas plants can also generate and feed electricity into mainstream power grids.
4) It may be considered efficient way of energy conversion.
5) Saves women and children from drudgery of collection and carrying of firewood, exposure to smoke in the kitchen, and time consumed for cooking and cleaning of utensils.
6) The digested sludge is high quality organic manure, completely natural and free from harmful synthetic chemicals. It can supplement or even replace chemical fertilizers.
7) Leads to improvement in the environment, sanitation and hygiene.
8) Provides a source for decentralized power generation.
9) Leads to employment generation in the rural areas.
10) Household wastes and bio-wastes can be disposed of usefully and in a healthy manner.
11) The technology is cheaper and much simpler than those for other bio-fuels.
12) Any biodegradable matter can be used as substrate.
13) Anaerobic digestion inactivates pathogens and parasites, and is quite effective in reducing the incidence of water borne diseases.
14) Environmental benefits on a global scale: Biogas plant significantly lower the greenhouse effects on the earth's atmosphere. The plant lowers methane emissions by entrapping and using it as fuel.

XIII. Challenges

Although production of Bio-gas/CBG from filter cake is being looked into, but the subject matter requires in-depth study for the following reasons:

1) Optimization of process parameters keeping in view varying composition of filter cake and ambient temperatures.
2) Deterioration of organic matter in filter cake with the passage of time which adversely affects the bio-gas production.
3) Scrubbing technology and cost for removing carbon di-oxide and hydrogen sulphide from the producer gas.
4) Disposal of residual slurry as bio-fertilizer.
5) Cost economics as a whole.

XIV. Conclusion

Production of Biogas/Compressed Biogas using filter cake from sugar industry with a blend of other potential feed stocks can be a source of producing clean and green energy. It can also become a source of value addition for the sugar industry as at present filter cake is not being used for deriving economic benefits out of it. The efforts are more on disposal rather than value addition. Bagasse based co-generation and production of ethanol using various feed stocks from the sugar industry already been in practice, utilization of filter cake for production of Biogas/Compressed Biogas shall be a step forward towards converting sugar factories into a hub of Bio-energy.

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