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"Production of CNG by using Nappier grass"

1.Mrs. Poonam Sagar Kadu 2.Mr.Shilbhadra Mahadev kadam 3.Mrs. Aditi Amol Deodhar,

1.**Assistant Professor, Department of Chemical Engineering, Pravara Rural Engineering College, Loni, Dist.: Ahmednagar 2.Assistant Professor, Department of Chemical Engineering.Sir vishveshwaraya institute of Technology Nashik 3. Assistant Professor, Department of chemistry, Sanjivani Arts,Commerce and Science college . kopargaon.**

ABSTRACT

Demand of gasoline and diesel is rising in India due to increase in vehicles and industries. All of these crude derivatives is imported in India which acts as burden on economy. Even the use of gasoline and diesel produces a high amount of toxic gases which creates pollution. India is also facing problem of global warming, climate change, pollution and greenhouse gas effect due to high quantities of CO2 in atmosphere. For both of these problems can be a solution. CNG is less costly and produces very less tail pipe emissions compared to conventional fuels. Currently necessary to find alternative source to produce CNG within country. Bio-CNG produced anaerobic digestion of Napier grass can be alternative to meet CNG demands in India. Although bio CNG is produced by purification of biogas which can produced by different materials among which from our study Napier grass was the best one. The yield of biogas can be increased by performing pre-treatment to Napier grass. Residue of Napier gas can also lead to formation of organic manure. Thus, by producing Bio-CNG from Napier grass can cause reduction import bills additional income to farmer..

Keywords – Napier grass, CNG, biogas, anaerobic digestion.

INTRODUCTION

The global energy demand is increasing rapidly and the impact of greenhouse gases on the environment created the concern in searching and exploring alternative sources. Due to limited supply of crude in our country we have to import crude from Arabian countries. Prices of crude also fluctuate highly due. In 1ndia's national biofuel policy supports CNG a lot and there are lots of incentives given for CNG based vehicles.

A recent decision of the central government which makes flex engine compulsory for upcoming vehicles will increase the demand for CNG. CNG is less costly and produces less tail pipe emissions compared to conventional fuels. Natural gas accounts for about 10of energy consumption in India and it is expected about 40in power, fertilizer and transportation sector. Bio-CNG produced by purification of Biogas is alternative to meet natural gas demands in India. Using Bio-CNG provides a non-Polluting and renewable source of energy, efficient way of energy conversion, leads to improvement in the environment, sanitation and hygiene. The technology is cheaper and much simpler than that for other bio-fuels.

The residue from Napier grass could be used as organic fertilizer and in this way household wastes, and bio-wastes can be disposed of usefully and in a healthy manner. Although under National biogas and manure management Program (NBMMP), India's bio gas mission is one of oldest in world but it does not get good success. Biogas is produced by anaerobic digestion. In these bacteria digest organic matter (biomass) in the absence of oxygen. This Bio-mass can be cow dung, human or animal waste, wheat and rice straw and by products sugarcane industry. Average biogas contains about 50-65 percent methane, 35-40 percent CO2 and 5-10 percent trace gases like hydrogen sulphides and nitrous oxides. Biogas needs to purified to remove other impurities from it. In India lots of Gobar gas plants were established but they failed because 1kg of cow dung produce 4000 kcal whereas gas created from 1kg of cow dung produced only 200 kcal. It also requires about 40-50 litres of water every day and extra farm labour which makes it difficult for handling small scale plants.

After bio-gas generation its conversion into Bio-CNG through separation is highly energy, cost and time consuming. Average biogas contains about 55-65 percent of methane, 35-40 percent of CO2 and 5-10 percent of trace gases like hydrogen sulphides and nitrous oxides. Biogas needs to purified for which pressurized water scrubbing, pressure swing adsorption, chemical absorption, membrane separation, cryogenic approach, physical absorption, and biological filtration methods are used to purify the biogas. Cleaned biogas containing more than 97 percent CH4 and less than 2 percent O2 Pure biogas then goes high compression pressure between 20 and 25MPa and converts into bio-CNG which occupies less than 1 percentage of its normal volume. The calorific value of BioCNG is about 52,000 kilojoules (kJ) per kg which is higher than natural gas produced in Gas fuel.

Methodology

4.1 Material Selection: -

There are several feedstocks available for the production of CNG, but a low yield is a significant disadvantage. Napier grass is a great alternative when it comes to producing compressed natural gas (CNG). This fast-growing grass can be turned into CNG, which is an eco-friendly fuel. It's a sustainable option for generating CNG, making it a valuable choice for cleaner energy production.

Super Napier Grass, also known as elephant grass (scientifically termed Pennisetum purpureum), holds several potential benefits for the production of Compressed Natural Gas (CNG) through its use as a feedstock for biogas production. Here are some of the advantages:

1. High Biomass Yield: Super Napier Grass grows really well and can produce around 180 to 200 tons of grass per acre every year. The leaves of this grass are about 6 to 8 centimetre's wide. This means it's a type of grass that can give a lot of harvest from a piece of land and its leaves are fairly broad, providing plenty of material for use.

2. Calorific Value: Super Napier Grass has a high energy value, around 18.11 megajoules per kilogram (MJ/kg), which means it contains more energy compared to other usual materials used to make biogas. This high energy content makes it a very promising option for creating biogas. When this grass is used to produce biogas, it can generate more energy than many other commonly used materials in this process.

3. Renewable Energy Source: As a fast-growing perennial grass, Napier Grass is considered a renewable energy source. Using it for biogas production reduces dependency on finite fossil fuel resources, contributing to a more sustainable energy mix.

4. Utilization of Marginal Lands: It can be cultivated on marginal lands that might not be suitable for other crops, thereby not competing with food crops for agricultural space.

5. Soil Improvement: Napier Grass has the potential to improve soil health due to its extensive root system, which can help prevent soil erosion and improve soil structure.

6. Potential Economic Benefits: Cultivating Napier Grass for biogas production could offer economic benefits to farmers or agricultural communities by providing an additional income stream.

FIG: 4.1 SUPER NAPIER GRASS

Pretreatment of napier grass and anaerobic digestion:-

All the pretreatment methods can improve biogas production from napier grass in different method and indicates that high energy requirement is a disadvantage with all these methods. The facilities used in grass pretreatment are machinery which are persistent for other purposes than a high study is needed to optimize each application for the specific technique where it should be used. For biological and chemical treatments, novel compounds and enzymes need be study to increase the effectiveness and simultaneously decrease the toxicity and the time of pretreatment. For increase in biogas production from Napier grass, its thermal and alkaline pre-treatment's can be performed in batch mode. Literature survey results states that NaOH pretreated sample produced higher yield than biogas from raw, untreated and hot water pretreated napier grass. So here we decided to pre-treat the Napier grass first with hot water and then with NaOH and calculate yield from all this method. We are also thinking to perform pretreatment using ball mill and calculate the yield.

FIG: 4.2 FEED STOCK PREPARATION

4.3 Experimental setup and procedure: -

1) Preparation of Digester setup: -

I.Here we have taken 20L water storage jar as digester.

II.At top of digester, we attached a pipe crossing cap of jar which is sealed using M-seal.

III.In the pipe we attached a ball valve at the end for regulation of flow of gas.

IV.After pouring ingredients in it we closed the upper cap using an m-seal and went for anaerobic digestion process. Here we have taken 20L water storage jar as digester.

V.At top of digester, we attached a pipe crossing cap of jar which is sealed using M-seal.

VI.In the pipe we attached a ball valve at the end for regulation of flow of gas.

VII.After pouring ingredients in it we closed the upper cap using m-seal and went for anaerobic digestion process.

FIG: 4.4 DIGESTER SETUP

2) Anaerobic digestion process:-

I. Here we have taken fresh Napier grass from farm near Ashoknagar Shrirampur.

II. We washed the cutted Napier grass with water to remove impurities like stones, bedding and forage grass from it.

III. We kept it dry for the next two days.

IV.We have taken Napier grass of 3.589 kg for anaerobic digestion.

V.Then we performed its size reduction using a chaff cutter and reduced the size of Napier grass from 6 feet height to 1.3 cm height with diameter of 1.2 cm having weight 2 gram.

VI.After this we prepared solution of 10 L 1N NaOH in a bucket. Here we add 400 grams of NaOH pallet in 10 L of water and allow it to sterilize properly. Its weight by volume ratio is 4.

VII.We kept our Napier grass submerged under 1N NaOH solution for the next 24 hours.

VIII.After completion of 24 hours, we take out all Napier grass and separate hydroxylate and solid fraction from it.

IX.After pouring the solution in NaOH solution its pH was increased so we washed its solid particles with water and checked the pH till it was coming in range of 6.9-7.4.

X.After this we have added 2.8 kg of cow dung into it which will act as bacterial solution for it. The ratio of addition was 1:1.3

XI.After this we put the mixture of Napier grass and cow dung in digester covering 90% volume (18L).

XII.Fermentation time for anaerobic digestion was 16 days.

Process parameters affecting anaerobic digestion:-

1. Hydraulic retention time:-

It tells how much time we have kept our material for digestion with increase in hydraulic retention time the biogas yield increases. We have kept out material for 16 days in digestion

2. Organic loading rate:-

It can be calculated as follow OLR= C/HRT Where, C= concentration (g/L) HRT= hydraulic retention time With increase in organic loading rate the biogas yield increases. Here the organic loading rate is 22.18 g/L day.

3. Total solids:-

It is basically dry weight of substrate . To know Total solid content the amount of substrate is weighted and dried at 150 C for 1 hour until water content becomes zero. Its optimum range is 10solids there is decrease in bio-gas formation

4. Volatile solids:-

Here the solid remained after 1hr at 150 C the solid is again burned at 600C for 30 minutes. With increase in volatile solids the bio-gas formation increases.

5. C to N ratio:-

lower carbon to nitrogen ratio higher will be biogas yield. Nitrogen content can be calculated by using nitrates in Palin test. Carbon content can be calculated by assuming 58 percent of volatile solids.

6. Surface are enhancement:-

With increase in surface area there is increase in viscosity leads to less floating and increase the biogas formation. In this case surface area has enhanced 1.89 times the original one.

7. Free ammonia:-

Free ammonia causes loss of stability in biogas generation because of excess in urea and protein related component. With increase in free ammonia there is decrease in biogas formation.

8. Temperature:-

In this mesophilic conditions (standard room temperature and pressure) is favoured as methanogen bacteria gives high yield during 19-25 C. But due to April month climate our anaerobic digestion has taken placed in thermophilic condition (temperature 30-42 C) and has lead to less biogas yield formation.

9.Feed composition:-

This plays an important role as if the feed has more cellulose andhemicellulose higher biogas will be formed and if more lignin then less biogas will be formed.

1) Renewable Energy Generation:

•Successful production of CNG from Napier grass contributes to the generation of renewable energy, reducing dependence on non-renewable fossil fuels.

2) Greenhouse Gas Emissions Reduction:

• Utilizing biogas from Napier grass helps reduce greenhouse gas emissions compared to traditional fossil fuels, as the grass captures carbon dioxide during its growth, and biogas combustion produces fewer emissions than conventional natural gas.

3) Sustainable Agriculture:

• Integration of Napier grass cultivation for biogas production promotes sustainable agriculture practices, providing an additional income source for farmers and utilizing marginal lands.

4) Energy Independence:

• The project contributes to local energy independence by providing a locally sourced and produced alternative fuel.

5) Waste Utilization:

• The project addresses organic waste management by using Napier grass as a biomass feedstock for biogas production, providing an environmentally friendly solution for agricultural residues.

Design of Fermentation

The liquid portion of the slurry has 8-12% ethanol by weight. The whole process requires 48-72 hours. The Batch and Continuous fermentation systems can be used and out of both batch process is more popular. By using material balance, we get the volume of fermenter for 1 KL ethanol production. With help of volume and design equations we can calculate Length, Height, Thickness, I.D., O.D., Weight of Vessel, Head thickness and cost of Fermenter.

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Stepwise Procedure for Fermenter Design

1. Calculate the volume of ethanol produce from 1 or 2 L of ferment by lab based experimental analysis.
2. Ferment means the medium and biomass mixture which produce the ethanol.
3. Convert that volume for 1 T/Day ethanol production i.e., by calculation we get volume of ferment requires to produce 1 T/day ethanol.
4. By considering volume we can calculate internal diameter and length of fermenter.
5. Then using design equation we can also calculate the outer diameter and thickness of vessel.
6. With help of outer diameter and thickness next, we can calculate the weight of heads and vessel.
7. Finally we can calculate the cost of vessel requires. (Total cost for vessel = Material cost and Fabrication Cost)
8. Then add cost of agitator, motor, supports, gas Spurger etc.

Design of Fermenter for Continuous Operation

Feed Conditions

Temperature – 35 ^{O}C and 40 oC (For both Temp.)

Pressure – 101.325 KPa

Fermentation Time – 72 hrs.

Feed –

Elephant grass (20 gm)

Water (1 L or 1 Kg)

Aspergillums Niger (2 gm)

Brewer's Yeast (5 gm)

$MgSO_4$ (1 gm)

$(NH_4)\ H_2PO_4$ (2 gm)

Output from Fermenter

Fermented Biomass -97-99 gm

Non-fermented Biomass- 931-933 gm

Here, fermented biomass in filtrate is 99 kg but maximum recovery of ethanol will be 98%. Hence, the distillate will be 0.98 * 99 = 98 gm. Volume of ethanol produce can be calculated by using density of ethanol (0.875 gm/ml). As density is the ratio of mass / volume. Volume of Ethanol (ml) = 97/0.875 = 110 ml/L of Ferment.

Volume of Fermenter

Total Feed (Composition) for Fermenter or Reactor = 1030 gm/Day

Total Mass of Ethanol produce = 99 gm (110 ml)

1.030 L (1030 gm) Feed ferment = 110 ml Ethanol

Ethanol contains in slurry or ferment = (110/1030) * 100 = 10.6 %

Design based on 1 Ton per day Production.

Density of Ethanol = 785 kg/m^3 at room temperature.

Using, Density = Mass/ Volume

Volume of Ethanol for 1T (1000 kg) Production = 1000/785 = 1.27 m^3

1.27*1000 = 1270 L

Volume of Ethanol per produce batch = 1.27 m^3 (1270 L)

Volume of ferment can be calculated,

1L Ferment = 0.110 L Ethanol

X liter ferment = 1270 liter

X = 11545.45 L

For production of 1 T/Day requires 11545.45 L (11.55 $m^{3)}$ ferment medium.

Volume of Fermenter (Reactor) (20% Extra) = 13855 liter (13.85 $m^{3)}$

Diameter and Length of Reactor (Fermenter)

Fermenter cylindrical vessel can be design from process & mechanical design, Volume =13.85 m^3

$V = \text{Area} * \text{Length} = \pi/4 * Di * L$

$L = 1.5\ Di$

$V = \pi/4 * Di * 1.5 * Di$

$13.85 = \pi/4 * Di^2 * 1.5$

By solving we get,

Di = 3.42 m = 4 m

L = 4 * 1.5 = 6 m

Di = 4 m and L = 6 m

Thickness and Outer Diameter of Fermenter

Shell Thickness ($t_{s)}$ = P Di / (2 f j – P) + C = 101325 * 4 / (2* 138 *10^6 * 0.85 – 101325) + 1 mm = 0.001727 m + 1 mm = 0.001727*1000 + 1 mm = 1.727 mm + 1 mm

t_s = 3 mm

Outer Diameter (Do)

Do = Di + t_s = 4 + 2 * 3 * 10^{-3} = 4.06 m

Here,

f = Permissible stress for SS-316 = 138 MPa = 138 * 10^6 Pa (20000 psi)

J = Joint Efficiency = 0.85 (85%)

C = Corrosion Allowance

t_s = 3 mm and Do = 4.06 m

Weight of Cylindrical Shell & Head

Weight of Cylindrical Shell = $\pi/4 * (Do^2 - Di^2) * L * \rho$ (Density)

ρ = 7950 kg/ m3 (Density of Stainless Steel-316)

Weight of cylindrical shell = $\pi/4 * (4.06^2 - 4^{2)} * 6 * 7950$ = 18117 kg

Weight of Head = $\pi/4 * (Do^2 - Di^2) * \rho = \pi/4 * (4.06^2 - 4^{2)} * 7950$

Weight of tori spherical head = 3019 kg

Weight of Top and Bottom head = 2 * 3019.5 = 6039 kg

Total Weight of Vessel = Weight of Vessel + Weight of Head = 18117 + 6039 = 24156 kg

Fermenter Costing

As per design total weight of material = 24156 kg.

Material cost = 250 Rs / kg

Total Material cost = 24156*250 = 60, 39,000 Rs

Fabrication Cost (45-60 Rs / kg) = 60 * 24156 = 1449360 Rs

Agitator with motor and assembly cost = 2 Lac

Spurger cost = 0.5 Lac

Support cost is 15% of total material cost = 0.15 * 6039000 Rs = 9, 05,850 Rs

Jacket cost is 15% of Total Material Cost = = 9, 05,850 Rs

Total Fermenter Cost with Design Structure = 9550060 Rs

For complete fermentation of elephant grass required time is 72 hrs. i.e., is 3 days so, for this operation in case of continuous operation we need to install 4 No. of fermenter 3 fermenter for 3 days operation and one as stand by. According to fermentation time we feed material in 1st, 2nd and 3rd as randomly 1st, 2nd and 3rd day will get output as 4th, 5th and 6th day. After it will continuous in manner. Actually, process is batch but operation can operate at continuous in manner.

Hence as per operation requirement,

Total cost of fermenter 4 no. of fermenter will be equal to 4* 9550060 = Rs. 3, 82, 00240

CONCLUSION

Napier grass or others of lignocellulose biomass has to hydrolyze cellulose into fermentable sugars by enzyme and then these sugars are converted into products by microorganism. Chemical methods for Napier grass biomass pretreatment involve the use of sodium hydroxide, liquid ammonia, dilute sulfuric acid, and dilute acetic acid and hydrogen peroxide. Two-stage pretreatment processes have often been used. Biomass of Napier grass presoaked with 5 % H_2SO_4 or 5 % NaOH. For continuous operation, for complete fermentation of elephant grass required time is 72 hrs. i.e., is 3 days so, in case of continuous operation we need to install 4 No. of fermenter 3 fermenter for 3 days operation and one as stand by. According to fermentation time we feed material in 1st, 2nd and 3rd as randomly 1st, 2nd and 3rd day will get output as 4th, 5th and 6th day. After it will continuous in manner. Actually, process is batch but operation can operate at continuous in manner. For this system we design fermenter for 13.85 m^3 volume get internal and outer diameter as 4 and 4.06 m resp., Thickness and length 3mm and 6 m resp. We need four fermenter of volume 13.85 cubic meter each and need of total cost for both fermenters will be 2,80,89,080 Rs.

According to the cost view the batch operation is economical and requires low maintenance, labor cost and less time consuming and needs two fermenters. For continuous operation need high cost than the batch need four fermenters. In view of continuous is suitable operation than the batch in which regular feeding of fermenter and regular output. Also, one fermenter is in standby operation

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