GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

DESIGN AND FABRICATION OF BIOGAS DIGESTER FOR ANAEROBIC DRY FERMENTATION UNDER THERMOPHILIC CONDITION

Murulidhar K S*1 & Putta Bore Gowda B[2]
[*1]Assistant Professor, Mechanical Engineering Department, KSIT, India
[2] Professor, Mechanical Engineering Department, MSRIT, India

ABSTRACT

Big size digesters are in vogue for production of biogas from organic wastes. The products, methane and other hydrocarbon gases, can be used for cooking as well as for lighting. Such a system is ideally suited for poorer homes. However, while the poor people are aware of the uses and advantages of using methane gas, and would like biogas unit installation at their homes, the larger biogas units are unsuitable for the purpose. Bangalore is a thickly populated city, but domestic waste management has been a perennial problem. The twin issues – biogas availability for the poor and problem of management of domestic waste – can be solved by installation of smaller and economical biogas digesters. The paper presents a study involving development and analysis of the design of body shape of the biogas digester to increase its efficiency for production of methane gas under thermophilic conditions. The emphasis in this paper is on the economic aspects. Structural strength, durability, ergonomics, convenience and flexibility of usage in different weather conditions have also been considered in the design. The smaller biogas digester designed and developed using the knowledge and skills of industrial design, mechanical engineering and manufacturing technology, so as to be optimal in respect of materials usage and economical for operation.

KeyWords: *Anaerobic; Dry fermentation; Thermophilic; Bio gas; Digester*

I. INTRODUCTION

Biogas digester usually made from steel, zinc, rubber, mild steel, aluminum or combination with two or more between of them. The body of biogas digester commonly manufactured through casting process. Before humans use these types of materials to build the biogas digester, they use concrete to be the wall of the body structure. Nowadays, many improvements have been used in manufacture the body structure of biogas digester such as change the materials to build the structure of the digester and add some ways to make the digester be more efficient to produce methane gas. In nowadays, biogas digester is widely use among the countries in the world after humans know that the uses of methane gas which are for examples, methane gas can be used in generating electricity and also can be used to replace cooking gas. For example in India, the biogas digester widely uses at home to generate electricity and use as cooking gas.

By using biogas digester, methane gas can be produced throughout the fermentation process. Usually, the waste Product such as cow manure will be using back to be fermented to produce methane gas. From the digester, the methane gas will presently flow out through the gas outlet straight to container. The biogas digester must be built to be long lasting, has characteristic of corrosive resistance, high tensile strength and has technical stability.

Continuously increasing production of organic wastes remains to be one of the main environmental problems in recent times. Therefore, sustainable waste management and waste prevention, as well as reduction in waste generation have assumed major political priorities. Most countries are in the process of taking up common efforts to this end, which would result in the reduction of pollution and emissions of greenhouse

Gases which would ultimately result in mitigation of global climate changes. Since the environmental standards are being revised and upgraded on day-to-day basis, waste dumping landfill disposal and incineration of organic wastes are likely to become unacceptable options in the near future. As such, recycling of nutrients and organic matter in the energy option has to be aimed at.

II. METHODOLOGY

A. Planning

To identify all the information and requirement such as components, manufacturing process and cost planning must be done in the proper manner. The planning phase have two main elements namely data collection and components and software requirements.

Collection

Data collection is an important stage in any area of study. At this stage, the project resources and requirements are planned, literature survey made and for obtaining more information for the study. All the materials are collected from journal, texts book and research papers gathered from libraries and Internet.

Within the data collection period we have found the study about the importance of Digester in Biogas Technology and do some research about the project related.

While planning, we have done the research about the project related, which including with study about the types of Biogas plant digester, types of digesters and its importance. We also studied different digestion and fermentation processes in yielding of biogas

B. Component and software requirement

Component requirement

The following components are essential to design the biogas digester, Ball valves, Flexible pipes, Gas flow meter, Gas balloon Thermal insulation material, heating system.

Software requirement

For concept modeling and for preparation of the manufacturing drawings we have selected AutoCAD 2014 and Creo Parametric 2.0. The software used mainly for easier development of products. In engineering this CAD software are extremely important and widely used to design and develop products. It offers flexibility to draft and design in a digital format.

III. DESIGN AND FABRICATION

A. Design Of Biogas Digester and Base Frame

The digester was designed according to the organic loading rate and the hydraulic retention time. A single stage anaerobic digestion was operated at different organic loading rates to optimize the biogas production and to investigate operational parameters. The digester was cylindrical with double wall container to provide hot water bath in order to maintain the

Temperature inside the digester. For facilitating digestate disposal the digester was inclined at 35 degree and was also accommodated with valve outlet at bottom in order to prevent the intrusion of air inside the reactor during withdrawal.

The digestate from the digester was collected into the digestate collection container with progress screw pump and part of it was re-circulated. The total volume of the digester was approximately 170 L with working volume of 200 L and the inside diameter of the cylindrical digester was 450 mm. The digester was also accommodated with other accessories such as geyser for maintaining temperature of water bath and biogas flow meter to measure the biogas production.

For the post treatment of the digestate, Fig.-1 below indicates the detail design aspects of pilot scale system along with the supporting equipments such as heater, pump, biogas gas flow meter, temperature control, and pipe lines.

Input calculations

1. Volume requirement for the digester

Density of water = 1000 kg/m^3
Density of kitchen waste = 514 kg/m^3
Density of cow dung = 405 kg/m^3
Density of chicken litter = 330 kg/m^3
Drum volume = π/4 x 4522 x 850
Total volume = 136.39 x 106 mm^3 For 10 liters water, volume required 1 liter = 1/1000 m^3 = 1000cm^3
10 liters = 1/1000 x 10 m3 = 10 x 10 mm^3
Weight of water = 10kg
Remaining volume:
= (136.39 x 106) – (10 x 106)
= 126.39 x 106 mm^3

Divide by 3 = 42.13 x 106 mm^3

Kitchen waste (weight) = volume x density
= (42.13 x 106) x (314 x 10^{-9})
=21.65 kg

dung (weight) = volume x density
= (42.13 x 106) x (405 x 10^{-9})
= 7.06 kg

Chicken litter (weight) = volume x density
= (42.13 x 106) x (330 x 10^{-9})
= 13.90 kg

Total input weight = 13.90 + 17.60 + 21.65 +10 = 62.61 kg
Weight of empty drum = 46.2 kg

Total weight of drum including input
= 62.61 + 46.2
= 108.6 kg

Based on this calculation the digester was designed.

2. Digester drum calculations

- **Inner cylinder**
  D1 = 456 mm
  D2 = 452 mm

Volume = π/4 x (4562 – 4522) x 850
= 2.42 x 10^6 m^3
Weight = volume x density
(Density of mild steel = 7.859 x 10^{-6} kg/mm^3)
= 2.42 x 10^6 x 7.859 x 10^{-6}
= 19.01 kg

- **Outer cylinder**

D3 = 500 mm
D4 = 496 mm
Volume = π/4 x (5002 – 4962) x 850
=2.65×10^6 mm^3
Weight = volume x density
=$2.65 \times 10^6 \times 7.859 \times 10^{-6}$
=20.9 kg

- **Side plate**

D = 505 mm
Area = π/4 x D2= π/4 x 5052
=200.2×10^3 mm^2
Volume = area x length
=200.2 x 103 x 2
=400.59×10^3 mm^3

Weight = volume x density
= (400.59 x 103) x (7.859 x 10-6)
=3.14 kg
For two plates, weight = 3.14 x 2 =6.28 kg
Total weight of the drum:
= 19.01 + 20.1 + 6.28 = 46.2 kg
Base channel length:
= (850 x 5) + 555 + 920 + (810 x 2) + (1200 x 2)
=9745 mm
Thickness of channel = 3mm
Box channel size = 50 mm x 30 mm Area of channel = BH – bh
= (50 x 30) – (44 x 24)
=444 mm^2
Volume = area x length
=444 x 9745
=4.326×10^6 mm^3
Weight = density x volume
= $(7.859 \times 10^{-6}) \times (4.326 \times 10^6)$
=34 kg

- **Support plate**

Area = 850 x 50 = 42500 mm2
Volume = 42500 x 3 = 0.127×10^6 mm^3
Weight = density x volume
= $(7.859 \times 10^{-6}) \times (0.127 \times 10^6)$
= 1 kg
For three plates = 1 x 3 = 3 kg

3. Determination of Safe stress of the drum

Condition for thin cylinder theory t/di ≤0.07 (From DDHB)
t – Thickness of cylinder in mm = 2 mm

di – inner diameter of cylinder in mm = 452 mm The circumferential stress in thin cylinder with internal pressure (Pi di)/2t ----------- (eq. 11.2, DDHB)

The equation of longitudinal stress:
= (Pi di)/4t ----------- (eq. 11.3, DDHB) Pressure inside the cylinder
P= W/A
W = load applied
=136 kg
=136 x 9.81
=1334.16 N
Area = πdl
=π x 452 x 850
=1.20 x 10^6 mm^2
Pressure (Pi) = 1334.16/ (1.20 x 10^6)
= 3.47 x 10^{-3}Mpa

Circumferential Stress:
= (Pi di)/2t = (3.47 X 10^{-3} X 452)/ (2 X 2)
=0.392 Mpa

Longitudinal Stress:
= (Pi di)/4t
= (3.47 X 10^{-3} X 452)/ (4 X 2)
=0.196 Mpa

Yield strength of mild steel = 400 Mpa
Assuming FOS = 2

Working stress = (Yield stress)/FOS = 400/2
= 200 Mpa

Since compressive strength and longitudinal stress is less than yield stress, the design is safe.

4. Determination of Safe stress of the frame:

Drum weight = 46.2 kg
Total weight of the drum including input = 46.2 + 136 = 182.2 kg

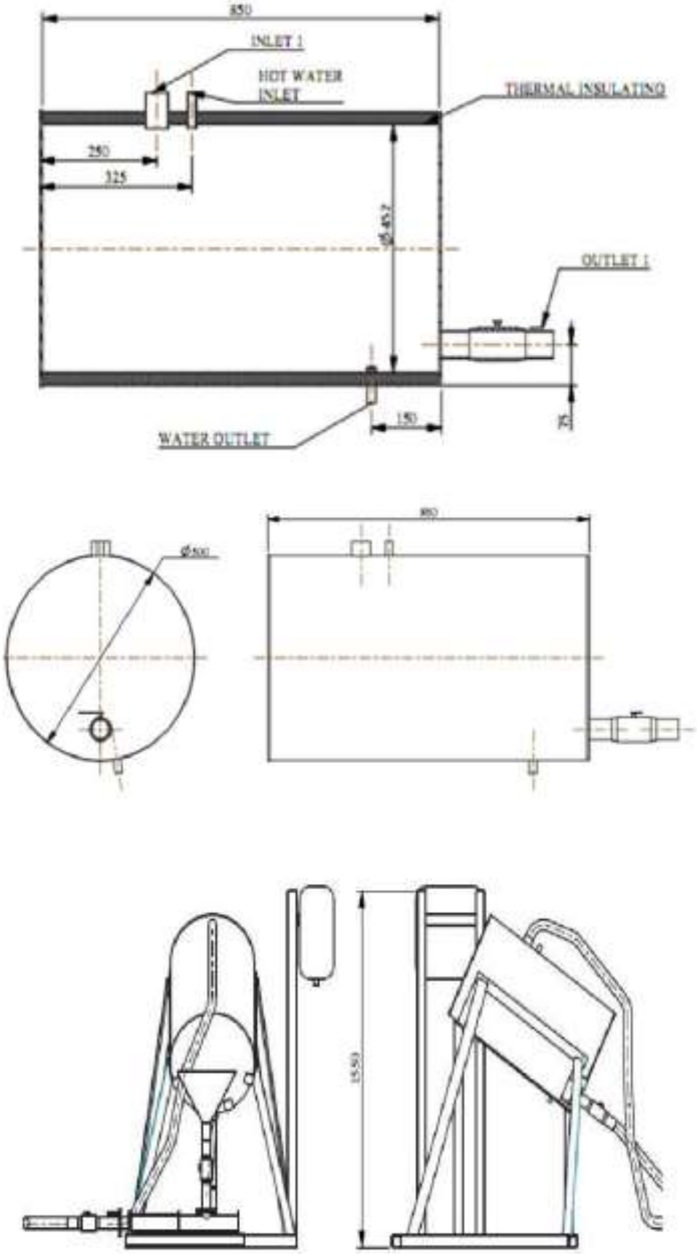

Fig 1.Two Dimensional Diagram for Digester

Area of the channel = 444 mm^2

Stress (σ) = force/area

Force = 182.2 x 9.81

= 1787.38 N

Total no. of columns=6

Force per each column = 1787.38/6

= 297.897 N

σ= 297.897/444 = 0.670 Mpa
Compressive strength of mild steel = 247 Mpa Assuming FOS = 2
Working stress = 247/2 = 123.5 Mpa
Since theoretical stress is less than the working stress the frame design is safe.

A. Fabrication of Biogas Digester

Specifications

Particulars	Dimensions/material
Diameter of the digester	450 mm
Length of digester	850mm
Material using for digester	Mild steel
Outer jacket of digester	Mild steel
Thermal insulation	Glass wool
Thickness of sheet metal	1mm

Fabrication details of the equipment

1. Digester

Rolling

The digester consists of an inner tank made up of mild steel rolled to a diameter of 450 mm with cylinder length 850 mm. A cylindrical shaped product from plate or steel metal is produced by roll bending. The 2mm thin sheet metal is rolled to form a cylinder. Two sheet metal is rolled to form two cylinders one of diameter 452mm and another of 456mm.

Welding

Oxy-fuel welding (commonly called oxyacetylene welding, oxy welding, or gas welding) and oxy-fuel cutting are processes that use fuel gases and oxygen to weld and cut metals, respectively. Pure oxygen, instead of air, is used to increase the flame temperature to allow localized melting of the work piece material (e.g. steel) in a room environment.

In oxy-fuel welding, a welding torch is used to weld metals. Welding metal results when two pieces are heated to temperature which produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material depends upon the metals to be welded.

Fig. 3 Welding of Digester Tank

In oxy-fuel cutting, a torch is used to heat metal to its kindling temperature. A stream of oxygen is then trained on the metal, burning it into a metal oxide that flows out of the kerf as slag.

Spiral rolling of steel pipes

In order to maintain the inner side of the tank at thermophilic conditions steel tubing is coiled throughout the length as shown in figure. A half inch diameter pipe is spirally rolled and certain distance is given along the length so that it is not closely attached.

Fig. 4 Spiral rolling of steel pipes

Welding of steel pipe to the drum

The spirally rolled pipe is inserted into the drum, and welded along the circumference of the inner face of the drum as shown in the figure.

Fig. 5 Welding of Steel Pipe to the Drum

Preparation of hole in the side plate of the drum

Two three inch holes are drilled on the side plate of the drum on opposite sides, for the inlet and outlet of slurry the digester is provided with an outlet pipe at the bottom to remove the waste from the digester without air intrusion. An inlet pipe is provided for input of waste on top of the digester tank and a gas outlet pipe for the removal of the biogas.

Fig. 6 Holes for inlet and outlet of slurry

2. Base Frame

The digester assembly is supported on a rigid stand made up of mild steel channel which is designed in such a way that the digester rests on stand at an inclination of about 35^0.

Fig. 7 Base Frame

3. Glass wool

The inner tank is jacketed by an outer jacket of mild steel between them there is a thermal insulation provided using a layer of glass wool of thickness 2.5 cm as shown in figure. Glass wool is an insulating material made from fibers of glass arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in the thermal insulation properties.

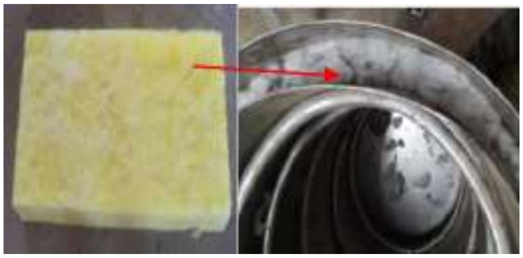

Fig. 8 Filling of Glass wool

4. **Final assembly of the component**

Fig. 9 Final assembly of the component

IV. RESULT & DISCUSSION

Table i. Comparison of biogas plant

Property	BHARC biogas plant	Conventional biogas plant	Thermophilic Plant
Typed of waste processed	Kitchen waste, dry leaves, green grass, animal remains, paper etc.	Mainly gobar	Kitchen dry waste, chicken litter
Pre-digester	Included	Not included	Not included
Waste feed	After making a slurry in a mixer	Direct	Direct
Handling of waste	Needs segregation`	Direct	Direct
Power consumption	5 HP motor for about 1 hour to run mixer	No power	Less power
Use of hot water	Solar heater is used for getting hot water, which is mixed in	No usage of hot water	Temperature of hot water is maintained at 55^0C with the

	pre-digester		help of geyser
Type of bacteria	Thermophilic in pre-digester and Methanogenic bacteria in main tank	Methanogenic	Thermophilic in pre digester
Digestion	Aerobic and anaerobic	Anaerobic	Anaerobic
Type of manure	High quality, weed less and odorless manure is obtained which can be used as soil conditioner	Manure is more fibrous and less consistent and may have bad odour.	Manure is rich fibrous and average odour.
Processing time	About 10-12 days	About 30 days	About 6 – 7 days
Gas composition	Methane 70-75%	Methane 50-55%	Methane 55-60%
Scope	Urban and rural	Rural	Urban and Rural
Design	Suitable for larger community	Small scale	Small and medium scale
Advantage	1. Save on transporting of waste 2. Complete digestion of waste is possible 3. More environmental friendly	1. Do but lesser extent 2. Incomplete digestion	1. Good yield of Biogas 2. Portable 3.Environmental friendly

V. CONCLUSIONS

Depletion of the limited resources of fossil fuels, increase in global energy demand and concerns about environment has given fillip to the development of alternative energy sources as replacement for non renewable sources. In this context, use of biogas as an alternative has become more attractive owing to the fact that it can be designed as an integrated system with multiple benefits. Different uses of energy {cooking, lighting)reduced emission of local pollutants, decrease in level of deforestation which would otherwise be caused by logging for wood as fuel; in addition secondary benefits like improvement in air quality, better sanitation and increase of crop yield because of the sequestered carbon in soils (loaded with digested organic waste).

The processes of digestion in biogas digesters are well understood and various designs for economical digesters have become operational. Therefore, the problem is not for the development of smaller digesters. The challenge is to make these digesters available to common public, who may have little or no extra disposable income. Thus translational research for developing safe, affordable and effective methodology for usage of smaller digesters for household purposes while at the same time improving sanitation to obtain optimum benefits in respect of economic and environmental factors.

VI. ACKNOWLEDGEMENTS

- We are thankful to our institute KSIT and MSRIT for providing the support, guidance and flat form to work. I express my gratitude to my guide
- Dr. Puttboregowda B and I extend my thanks to Dr. C Chandra shekar for his constant guidances.
- My sincere thanks to my parents and friend Mr. Nareasha K

REFERENCES

1) *D.Thyagarajan, M.Barathi, R.Sakthivadivu, "Scope of Poultry Waste Utilization", IOSR Journal of Agriculture and Veterinary Science, Vol. 6, pp 29-35, 2013.*
2) *Baba Shehu Umar Ibn Abubakar and Nasir Ismail, "Anaerobic Digestion of Cow Dung for Biogas Production", ARPN Journal of Engineering and Applied Sciences, Vol. 7, pp 169-172, 2012.*
3) *Kamoru Akanni Adeniran, Isiguzo Edwin Ahaneku, Isaac Nataniel Itodo, Habeeb Ajibola Rohjy, "Relative Effectiveness of Biogas Production Using Poultry Wastes and Cow Dung", CIGR Journal, Vol. 16, pp 126-132, 2014.*
4) *Md. Forhad Ibne Al Imam, M. Z. H. Khan, M. A. R. Sarkar, S. M. Ali, "Development of Biogas Processing from Cow Dung, Poultry waste, and Water Hyacinth" International Journal of Natural and Applied Science, Vol. 2, pp 13-17, 2013.*
5) *Doug Hamilton, Waste Management Specialist, "Yes you can produce biogas from swine manure", Oklahoma Pork Council Magazine, Vol.13, pp 4-6, 2012.*
6) *Karan Sehgal, "Flexi Biogas systems: Inexpensive, Renewable Energy for Developing Countries", Journal of Quality and*
7) *Technology Management, Vol. 8, pp 107-118, 2012.*
8) *Ukpai, P. A and Nnabuchi, M. N, "Comparitive Study of Biogas Production from Cow Dung, Cow Peel and Cassava Peeling Using 45 Litres Biogas Digester", Advances in Applied Science Research, Vol. 3, pp 1864-1869, 2012.*
9) *E. Salminen and J. Rintala, "Anaerobic Digestion of Organic Solid Poultry Slaughterhouse Waste – A Review", Bioresource Technology, Vol. 8, pp 13–26, 2002.*
10) *Rose M. Stenglein, Charles J. Clanton, David R. Schmidt, Larry D. Jacobson, Kevin A. Janni, "Impermeable Covers for Odor and Air Pollution Mitigation in Animal Agriculture: A Technical Guide" Air quality education in animal agriculture, Vol. 2, pp 1-12, 2011.*
11) *B.V Umesh and C.V Seshadri, "Jwala- The low cost biogas plant", Invention Intelligence, Vol. 19, pp 64-68, 1984.*
12) *A.R.T.I. (www.arti.org)*
13) *Book: By. G D Rai [Khanna Publisher and printed] Non Conventional Energy Resources [2004]*
14) *Book: By. Dublein D and Steinhauser [Published by WILEY-VCH] A Biogas from waste and renewable sources[2008]*
15) *: By. Kothari.D.P & Singal.K.C & Rajan R. Renewable energy source & emerging technologies*
16) *Data Hand book: K.Lingaiah Machine Design Hand Book [Second Indian Edition][2010]*