DESIGN AND ANALYSIS OF SCRUBBER FOR A BIOGAS PLANT

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Abstract
In recent times Biogas is one of the widely used and rapidly growing renewable sources of energy. The raw biogas is constituted of various gases – Methane (50- 65%), Carbon Dioxide (35-50%), few traces of Hydrogen Sulphide and water vapour. The presence of Carbon Dioxide and Hydrogen Sulphide hinders the effective usage of Biogas as a fuel. So it becomes necessary to purify the biogas in order to enrich its methane content up to the level of natural gas thereby resulting in high calorific value of the biogas. This process of purifying the biogas is done by a physical device known as Scrubber.
Keywords: Scrubber, Flow analysis, packed bed, Vectorflow.

1. Introduction:

Energy is an essential prerequisite for accelerated economic development and improved quality of life for citizens of any country. Due to rapid industrialization and urbanization in last few years, there is a huge pressure on crude oil, coal and other fossil fuels. This resulted into need for finding some alternative sources of energy. Biogas is a renewable source of energy, produced by anaerobic digestion of biomass such as cattle dung, vegetable wastes, poultry droppings and solid waste etc. Anaerobic Digestion is a biochemical degradation process, in which biodegradable organic matters are decomposed by bacteria forming gaseous by- product. It usually consists of Methane(50-70%), Carbon dioxide(30-45%), traces of Hydrogen Sulphide (about 2%), Ammonia and Water vapour.

2. LiteratureReview:

The current literature survey is about the information concerning the topics of our research. In the following survey, the information on biogas has been given along with the mechanism of anaerobic digestion of converting biomass into biogas. Different methods of removing CO_2 and H_2S have also been discussed. A packed bed scrubber, a device for upgradation of biogas has also been discussed. CO_2 are H_2S are some of the major Green House Gases (GHG).

Divyang R. Shah, Prof. (Dr.) Hemant J. Nagarsheth(2015) proposed a low cost biogas purification system using water scrubbing and using this system raw biogas can be converted into bio CNG and can be used as a vehicular fuel. It is the cheapest and easiest method of biogas up gradation in which pressurized water is used as absorbent. Water scrubbing involves physical absorption of CO2 and H2S in water at high pressure and regeneration by a release in pressure with very little change in temperature.

A.A. Adamu (2014) investigated about the various components of the biogas and the amount of those produced from various kinds of wastes generated.**Wiley Barbour, Roy Oommen, GunseliSagunShareef(1995)** investigated on the various types of wet scrubbers used to remove acid gases. His work mainly concentrated on packed bed scrubbers. The various packing materials and the factors affecting them were alsodiscovered.

Temilola T Olugasa, Oluwafemi A Oyesile (2015) discussed the results of studies conducted on raw biogas produced from a prototypic biogas production plant located at the Teaching and Research Farm, University of Ibadan, Ibadan. He also proposed construction of an effective and efficient technology used in purifying raw biogas generated from the prototypic biogas productionplant.

VinayakR.Gaikwad, Dr.P.K.Katti (2014) summarizes an idea that can be carried out for effective biogas compression and bottling process and it also includes 3D model of the proposed method developed in Solid works software.**Q. Zhao, E. Leonhardt, C. MacConnell (2010)** carried out a review of existing technical solutions for scrubbing CO2 and/or H2S to identify the most promising options for application to farm scale anaerobic digesters. The strengths and weaknesses of the various scrubbing technologies were identified.

3. ExperimentalDesign:

There are many packing materials which can be used in the scrubber. Packing section in the absorption process plays important role providing surface area for the gas and liquid phases to contact upon. Mainly, two different types of packing materials are available for gas absorption; Random packing (Pall ring, IMTP, Raschig rings) and Structured packing (Flexipac, Mellapak, Gempak, BX). The overall mass transfer coefficient is high in structured packing compared to the random packing.

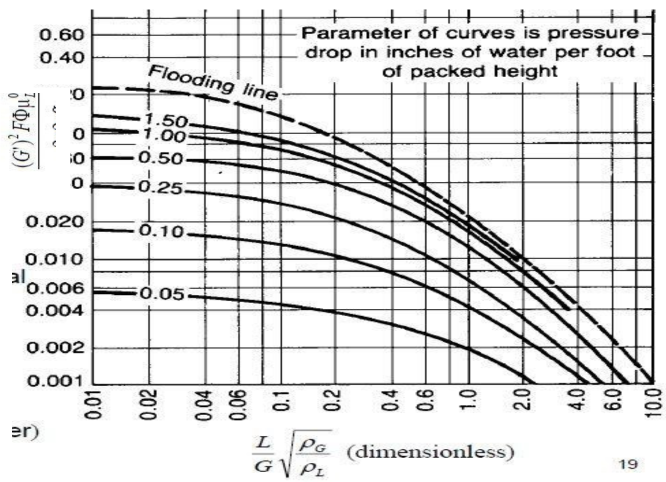


Fig.1 Sherwood flooding and pressure drop correlation graph

where,

L = mass flow rate of liquid (L/m^3)

G = mass flow rate of gas (lb/s) ρ_g = gas density (lb/ft^3)

ρ_L = liquid density (lb/ft^3)

G' = mass flux of gas per cross sectional area of column (lb/ft^{3}s)

F_p= Packing factor

Φ = specific gravity of the scrubbing liquid(lb/ft^3) μ_L= liquid viscosity (in cP; **0.8centipoise** for water)

a. Calculating the flooding pressuredrop:

$$\Delta P_{flood} = 0.115\ (F_p)^{0.7}$$

The value of G' for Raschig rings is found to be 0.612lb/ft3s and for Pall rings is found to be 1.2112lb/ft3s.

b. Calculate actual gas flow rate per unit area as a fraction of the gas flow rate atflooding:

$$G_{operating} = G'\ f$$

The actual gas flow rate per unit area of the gas $G_{operating}$ is found to be

Raschigrings=**0.4591lb/ft^{2}s or 2.242kg/m^{2}s** and Pall rings=**0.9084lb/ft^{2}sor 4.435kg/m^{2}s.**

c. Collector Efficiency of the packed bed towers:

η= 1-Pt

where,η= Collector , Pt= Penetration

Penetration can be found out using the graph which relates penetration (Pt), the parameter for Liquid-Gas ratio (B) and inertial parameter for mass-median diameter (K_{pg}). For Geometric standard median of σ_{gm}=5.0, the following graph is used:

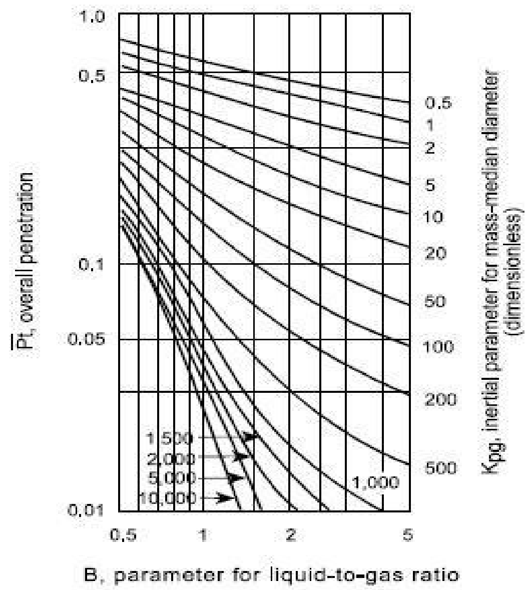


Fig2 Graph relating Pt, K_{pg} and L/G parameter

4. 3D MODELING

Based on the calculation made as per our requirements the designhas been made using themodelling software and the sectional view of the scrubber design with packed bed is given below in fig 3.3.

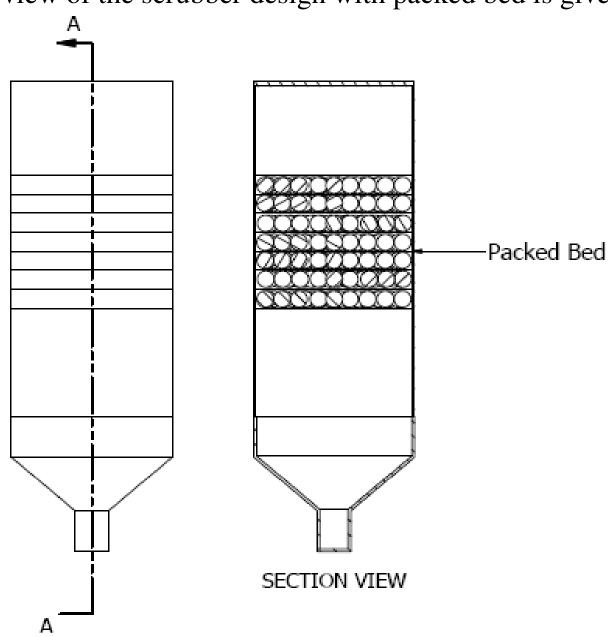


Fig3. Sectional view of the designed Scrubber

5. FLOW ANALYSIS OF SCRUBBER

The complete scrubber is analyzed using ANSYS 17.2. ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. Version 15 of ANSYS was released in 2014. It added new features for composites, bolted connections, and better meshing tools. In February 2015,version 16 introduced the AIM physics engine and Electronics Desktop, which is for semiconductor design.

Discretization methods:
Further information: Discretization of Navier–Stokes equations. The stability of the selected discretization is generally established numerically rather than analytically as with simple linear problems. Special care must also be taken to ensure that the discretization handles discontinuous solutions gracefully. The Euler equations and Navier–Stokes equations both admit shocks, and contact surfaces.
Some of the discretization methods being used are:

Finite volume method:
The finite volume method (FVM) is a common approach used in CFD codes, as it has an advantage in memory usage and solution speed, especially for large problems, high Reynolds number turbulent flows, and source term dominated flows (like combustion).
The finite volume equation yields governing equations in theform,
∂/ ∂ t□Q dV+□FdA=0 ,

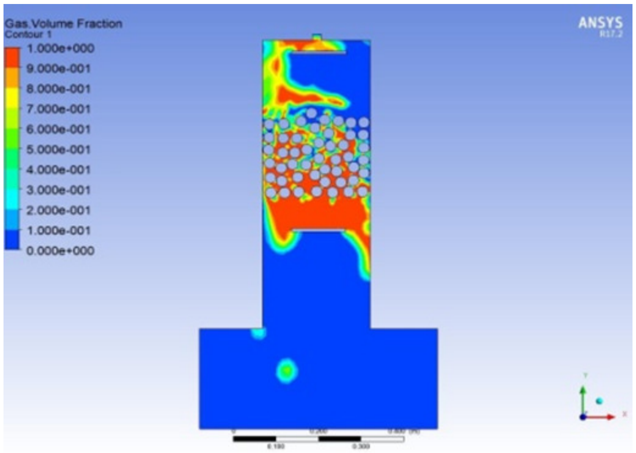
Where,
Q is the vector of conserved variables,
F is the vector of fluxes (see Euler equations or Navier–Stokes equations), V is the volume of the control volume element,and
A is the surface area of the control volumeelement.

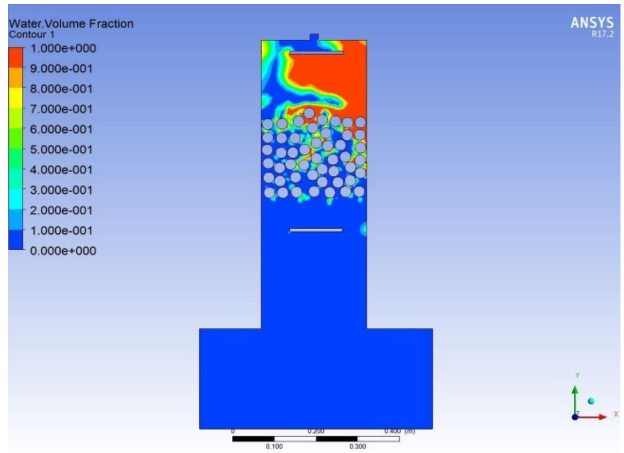
Finite element method:
The finite element method (FEM) is used in structural analysis of solids, but is also applicable to fluids. However, the FEM formulation requires special care to ensure a conservative solution. The FEM formulation has been adapted for use with fluid dynamics governing equations.[citation needed] Although FEM must be carefully formulated to be conservative, it is much more stable than the finite volume approach. However, FEM can require more memory and has slower solution times than theFVM.

In this method, a weighted residual equation is formed:

$$\mathbf{R_i = \iint W_i\, Q\, d\, V_e}$$

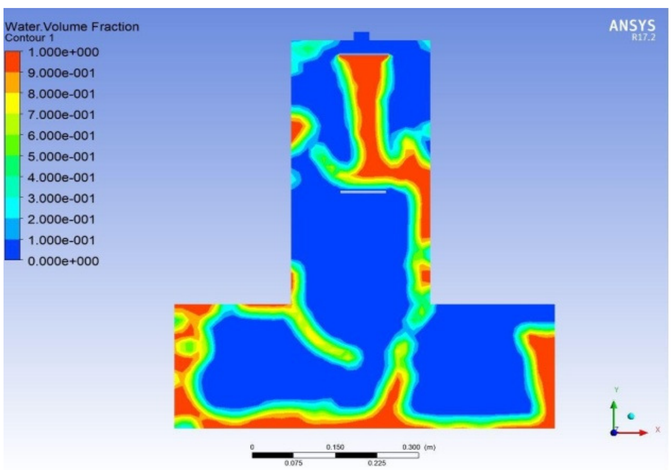
The following set of flow analysis on various condition is varied out and the results are shown below.

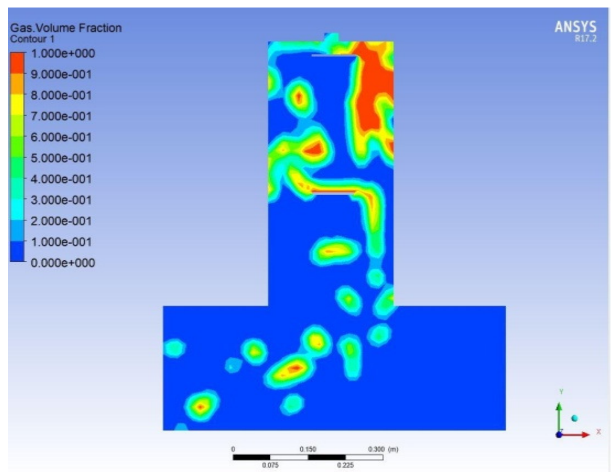




GAS VOLUME FRACTION WITH PACKED

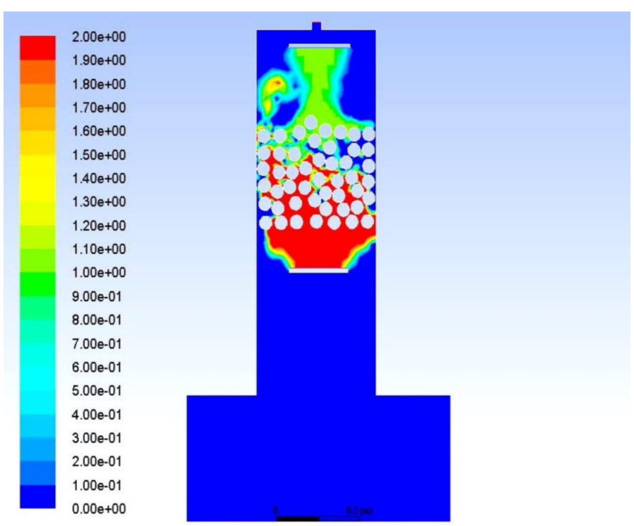
WATER VOLUME FRACTION WITH PACKED

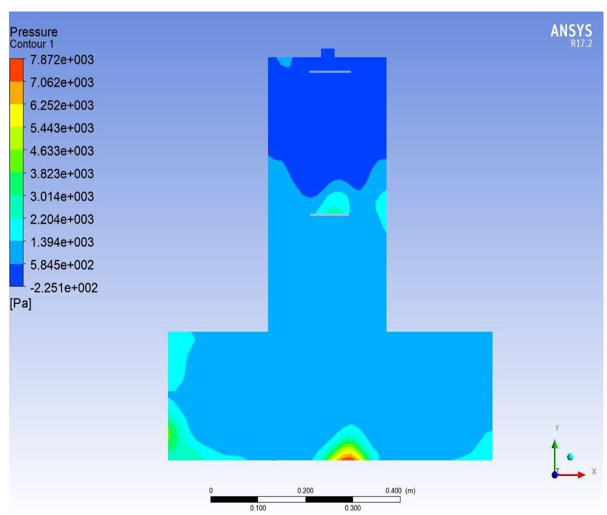




GAS VOLUME FRACTION WITHOUT PACKED

WATER VOLUME FRACTION WITHOUT PACKED





PRESSURE DIFFERENCE WITH PACKED PRESSURE DIFFERENCE WITHOUT PACKED

Fig4. Flow and pressure analysis of various packing conditions

A flow formalizes the idea of the motion of particles in a fluid. Flows are ubiquitous in science, including engineering and physics. The notion of flow is basic to the study of ordinary differential equations. Informally, a flow may be viewed as a continuous motion of points over time. More formally, a flow is a groupaction of the real numbers on aset. The idea of a vector flow, that is, the flow determined by a vector field, occurs in the areas of differential topology, Riemannian geometry and Lie groups. Specific examples of vector flows include the geodesic flow, the Hamiltonian flow, the Ricci flow, the mean curvature flow, and the Anosov flow. Flows may also be defined for systems of random variables and stochastic processes, and occur in the study of erotic dynamical systems.

6. CONCLUSION

The design of a vertical packed column scrubber was done by analytical formulas andstandarddataandfurthermodeledusingAutodeskandexportedtoANSYS18.1 for further analysis. The design data were used to fabricate the real model. The model is now capable of removing CO_2 and H_2S from biogas efficiently. The packed bed was proposed with two materials i.e., Raschig rings and Pall rings. Using the design procedure, it was found that, for this proposed design; Pall rings are more suitable at this application, with a packing bed efficiency of 89%. The by- product of the water scrubbing process is fairly easy to dispose unlike the products of chemical scrubbing process because it contains very weak carbonic acid. This shows that water scrubbing with the use of a Pall ring packed bed is quite effective in the removal of CO_2 and H_2S from biogas. Using the Material/ mass balance equation, the Ergun equation, the flow rate equation, the relationship between volume, area and height of a packed bed; the following design specifications of a waterscrubberwithPallringspackedbedwereobtained:Asuperficialvelocityof4.35 m/s was obtained; the packed bed area of; a diameter of $0.2706m^2$ and a packed bed height of 0.59m. ANSYS Fluent software has been used to investigate the gas distribution within a counter-flow wet scrubber system based on airflow velocity and pressure fields. The velocity flow contours and vectors at the inlet, across the scrubbing chamber and the outlet shows a distributed flow and the velocity profiles have fully conformed to the recommended profile for turbulent and vector flows in cylindrical pipes. It is thus advisable to verify which effects predominated in both the Raschig ring and Pall rings. The next logical step would then also be to find ways in which to combat the effects and to adapt the models to take these effects into account. The result will then be accurate predictions of flow through any packed bed and anycolumn.

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