Preparation of Biogas by Using Multiphase Flow Digester

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Abstract— Traditional anaerobic digestion technic has disadvantage of low gas production and long cycle of digestion. To maintain constant temperature during winter season and to improve the production rate of biogas a 3 m3 capacity a multiphase flow digester is developed in this study. Experiments were conducted on biogas production rate at different temperature of the system. 50 days trials on dynamic and static digestion shows that higher production rate of biogas in dynamic digestion compared to static digestion. It found that heat transfer rate and temperature of the digested slurry increased. The optimization of the system is depending on the slurry temperature and biogas production rate. The optimized digestion temperature is proposed and find in this study. Insulation thickness have effect on the digestion temperature. It is calculated in this study.

Keywords: Multiphase Flow Digester, Biogas, Slurry Temperature, Dynamic Digestion

I. Introduction

Due to increment in emission of livestock manure and straw production there is increase in environment pressure. The environment friendly technology for digestion is the anaerobic digestion which is used in many countries for the production of biogas [1]. There are certain disadvantages in case of without mixing like uneven material distribution less fluidity and low heat and mass transfer [2-5]. Digestion efficiency and bio gas production rate can be improved by dynamic digestion technic. Now, three different methods of mixing are present these are mechanical mixing, slurry recirculation and gas recirculation [7]. The quality of the biogas and production of bio gas can be improved by many different technologies. The success of an AD for more investments as the feedstock cost is low and varieties of biogas. Combination of methane which is 2/3rd and rest is carbon dioxide including hydrogen sulphide traces constitutes Biogas. From the produced biogas remaining slurry is used in agriculture as manure for crops which promotes sustainable biomass production throughout the world. For power supply application biogas can be used in rural and urban areas as it is beneficial for cost. Due to increasing demands of conventional fuels and greenhouse effect in the environment many researchers are working to produce fuel from bio source. Currently the demand of energy throughout the world is 88% is met by fossil fuel. As per the study up to 2050 the demand of fossil fuel is increased to 50%. In the environment the greenhouse gas amount is also increasing where the main contributor is carbon dioxide. In the Asian region developing countries such as Afghanistan, Nepal, Bangladesh, and Pakistan are energy stressed. Due to increasing population and gap between demand and supply led to load shedding session. Due to this increasing demand and less supply in last three decades there was stagnant economic growth [3]. Biogas produced by anaerobic digestion of organic materials which consists of methane and carbon dioxide. Some trace components such as water vapor, hydrogen sulphide, siloxanes, hydrocarbons, ammonia, oxygen, carbon monoxide, and nitrogen are present in biogas. To substitute for fossil fuel there is necessity of optimization of biogas production and to upgrade the biogas quality [4]. waste activated sludge (WAS) is the main by-product of any biological wastewater treatment. More amount of wastewater is treated thought the world results in increased amount of WAS. Hence, it is important to innovate new technic to manage the generated sludge. For stabilization of sludge anaerobic digestion is more common digestion technic it can reduces the number of volatile solid (VS) and increases the biogas production at a similar time. Digestion is the single stage process at conditions like mesophilic or thermophilic with limited efficiency. In 10 to 20 days retention time which is under mesophilic temperature organic matter content which are available in WAS is destroyed only up to 30% to 40% [4]. Cell bound organic matter is the single factor which affect the efficiency of the WAS anaerobic digestion. In anaerobic digestion process the rate of limiting stage is the hydrolysis of the organic matter [5]. In biogas plant or commonly it is known as biogas digester in which the digestion process takes place of organic matter and the resulting gas is known as biogas. To realize the maturity of the sector, developing the domestic biogas plant because it is important to check the current diffusion of the biogas. The actual diffusion of the biogas and its related information should be provided by government. Domestic biogas production is promoted in many countries and government implemented national programme to increase the biogas production. This programme includes the training campaigns and financial scheme and it is also providing the technical support. The main organization who are working throughout the world are German GIZ (Society for International Cooperation, formerly GTZ) and the Dutch SN. These two-organization helping in advancement of biogas production and they also provide technical service and necessary document on this issue. Some countries like India, Nepal, and China host much more domestic biogas plants than others. It is noted that 250,000 domestic biogas plants are developed in last 20 years in Nepal and 125,000 in Vietnam. Furthermore, 125,000 biogas plants are planned in various countries throughout the world.

II. Literature review

The emission caused due to the livestock manure and straw production hence, environmental pressure is increases to avoid this the environment friendly technology is needed for the anaerobic digestion. Without mixing technic has some disadvantages such as low heat transfer less fluidity and distribution of material is not proper. As, we know bio gas is produced from pig manure, cow dunk kitchen waste etc. many researchers work on this produce the bio gas. Some of the researchers find out the optimum condition for product of bio gas by using various biogas model. The benefit of mechanical mixing is high rate of heat and mass transfer and decreases hydraulic dead state. It maintains the reproduction and metabolism of anaerobic bacteria. By using viscous fluid De Jesus et al. evaluated the hydrodynamic mass transfer of four bioreactors. It was found in the experiment that higher mass transfer coefficient occurs due to mechanical mixing and better homogeneity of the content of the digester [9]. All the three mixing levels are compared by Trad et al. and concluded that for mechanical mixing the mixing energy level (MEL) was higher. In case of non-Newtonian fluid along with high (OLR) organic loading rate fast mass transfer and low mixing rate are promotes homogeneity in mechanical mixing [10]. Hence, this mechanical mixing technic is used in many European countries [11]. The main limitation of recirculation of slurry and gas are high costing Equipments, dead zone easily formed and clogging at high concentration [12]. It was found that blockages are easily formed about 3 mm. For straw granules an anaerobic slurry recirculation digester was designed by Huang et al. [13]. According to Xiong et al. in case of straw digestion recirculation of gas carries straw particle towards the liquid surface and it will deposit on that surface [14]. In large digestion system there is limited enhancement of the three technologies [15]. Due to this reason, they do not change the static digestion mechanism or they do not solve the defect in traditional digester. At high production rate of biogas there is need of significant temperature as we know Anaerobic digestion is dependent on temperature [16,17]. There is requirement of large heat transfer rate for reproduction of anaerobic bacteria. The thermal energy is transfer to the digester by means of hot water in static heating method, which can be done installing heat exchanger coil in the digester. The factor that affects biogas production is static heating because it is non-uniform heating method and it has low thermal efficiency. It will affect the stability of the production rate of the biogas. Large temperature gradient is observed by Liu et al. who developed static heating system of digestion in which he uses polyethylene helical coil. This was nonconductive in case of digestion [18]. In the dynamic heating method, the circulating slurry was heated which results the rapid transfer of heat and it helps to maintain the temperature uniform throughout. The structure of dynamic digestion system is more complex as compared to static digestion. In many fields such as power, petrochemical and metallurgical multiphase flow technic is used compared to other as it is mature technic [20,21]. By using this multiphase flow technic, the problem of fluidity is solved. the solid particles are transforms to the "quasi-fluids". The heat and mass transfer rate are comparatively high as, its boundary layer is thin [22].

III. MATERIALS AND METHODOLOGY

A. Experimental System

The experiment system consists of MFD i.e. Multiphase Flow Digester, biogas boiler, biogas pump and tank which contain the biogas. It is mounted as shown in fig. 3.1 with the help of slurry pump slurry is pumped in to the Multiphase Flow Digester (MFD) from low part of the digester and it is pumped out from the upper part of the digester of the digester. The fig. 3.1 shows the experimental set up i.e., schematic of multiphase flow digestion system.

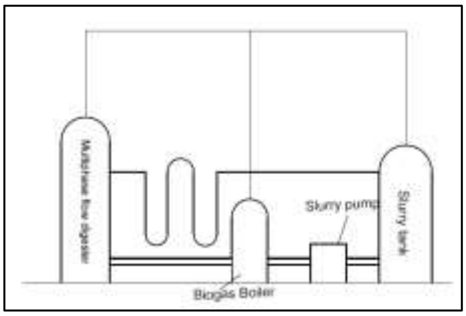

Fig. 3.1: Schematic of Multiphase Flow Digestion System.

B. Multiphase Flow Digester (MFD)

3 m^3 (400X150 mm) volume of the multiphase flow digester (Figure 3.2) was used in the experiment. From enamel steel plate this multiphase flow digester (MFD) was made and the walls thickness was 1 mm. The 9 mm thickness polystyrene insulation layer was wrapped around the MFD. There was foundation about 100 mm thickness for easy installation of the MFD i.e., Multiphase Flow Digester. The main device in the Multiphase Flow Digester (MFD) is the slurry distribution plate and it has thickness of 5mm. The slurry distribution plate has 21 holes and each hole has diameter 2 mm. The multiphase flow digester (MFD) and slurry distributor plate is shown in fig. 3.2

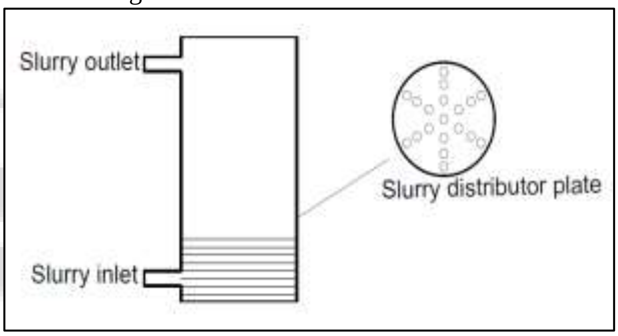

Fig. 3.2: MFD and Slurry Distributor Plate

C. Biogas Boiler

A biogas boiler was selected in the system as the heat source for heating, and biogas produced in the experiment was used as the fuel. The maximum power of the biogas boiler was 50 W. The temperature control function of the biogas boiler regulated the slurry temperature in the MFD through the setting of the digestion target temperature. Similar to the MFD. The biogas boiler was placed on a concrete foundation with a thickness of 100 mm.

D. Slurry Pump

To ensure the stability of slurry fluidized digestion, the slurry pump should be kept running all day. The rated power, rated flow, head, and rotating speed of the slurry pump were 1.0 kW, 5 m3/h1, 12.5 m, and 1000 rpm, respectively. The slurry pump was placed on a concrete foundation with a thickness of 100 mm.

E. Slurry Tank

To reduce the backflow of slurry, a slurry tank was placed near the biogas boiler, and the volume, height, and inner diameter were 5 m3, 2.0 m, and 1.8 m, respectively. The slurry tank was made of 304 stainless steels with a thickness of 5 mm, and the polystyrene insulation layer with a thickness of 9 mm was wrapped around the slurry tank. The thickness of concrete foundation was 100 mm.

IV. EXPERIMENTATION

Kitchen waste cow dunk manure is the digestion materials of the experiments near to the experimental system. The experiment is divided into two groups such as dynamic group and static group and process of pre-treatment for both the group is kept similar. For determination of relationship between the production rate of the biogas and slurry temperature the continuous feeding digestion was done and the experiment is conducted for many months. Using two batch feeding system scheme for 50 days experiment was conducted, for dynamic digestion the inlet slurry temperature in winter is found to be 20 °C and for static digestion it is 12 °C. From pre-treatment tank the digestion material with the help of slurry pump is pumped to the Multiphase Flow Digester (MFD) before starting of digestion. For separation of solid and liquid the digestion material is pumped into centrifuge decanter after the digestion. Slurry temperature, slurry flow rate ambient air temperature and biogas production these are the main parameters. For measurement of inlet and outlet temperature of slurry platinum resistance temperature sensors (pt100) are used. An electrical temperature controller is also used to regulate the temperature having range 0 - 400 °C. To monitor slurry flow, rate an electromagnetic flowmeter is used having 100m^3/hr capacity. Ambient temperature is measured with the help of testo temperature logger. Gas meter is used to measure the gas produced. Vacuum pump is also used to extract the gas from the gas bags and daily produced gas is measured with the gas meter.

V. RESULT AND DISCUSSION

A. The Relationship between Temperature and Biogas Production Rate

AN important indicator of Multiphase flow digester is the production rate of the biogas. Experiments were conducted by continuous feeding the digestion material in the digester. To generate the scatter diagram average production of biogas of 5 days and its relation between slurry temperature as shown in fig. 5.1 below. The minimum temperature in the month of February was noted as 7.6 °C. At that time the biogas production rate was 0.101 m^3 m^{-3} d^{-1}. The maximum temperature was 41 °C in July, at this stage the production rate was observed 0.346 m^3 m^{-3} d^{-1}. As the temperature of slurry increases the biogas production rate also increases, it was found in the throughout range of all test temperatures (7.6-42°C). This also shows that at low digestion temperature multiphase flow digester achieve high biogas production rate.

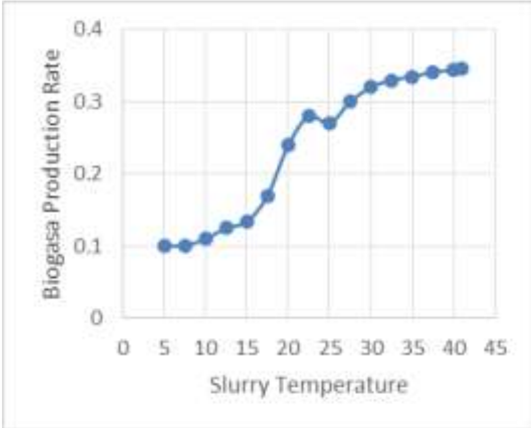

Fig. 5.1: Biogas Production Rate vs Slurry temperature.

B. Effect of Dynamic Digestion

Generally, in an anaerobic digestion gas production peaks are two types medium temperature (30-38°C) and high temperature (50-55°C). In medium temperature gas production peak, the optimum temperature is 35 °C, and this is used in small biogas engineering projects. To evaluate the effect of dynamic digestion the digestion temperature is considered as 35 °C according to the literature. In figure (5.2 and 5.3) 50 days experiments are shown for both the cumulative biogas production rate for dynamic (fig. 5.2) and static digestion (fig.5.3). By comparing (fig.5.2 and 5.3) we can see that under 35 °C digestion temperature both groups are operating, and there is no any effect of ambient temperature on it. From both the figures it is clearly seen that the cumulative biogas production rate for SD group is smaller than DD group. After 50 days the DD group reached end of digestion whereas in SD group the maintains the sudden growth as compared to DD group. It has been seen that for SD group digestion period is large as compared to DD group. As there was a slow mass transfer rate in SD group many substrates were not completely degraded. biogas production for DD and SD group. The rate of production of biogas in DD group is higher as compared to the SD group. At day 22, the rate of production of biogas reaches the peak value for DD group and it is increases rapidly at the beginning of the digestion. But in case of SD group there is no such increment found in digestion it is not increases until 9th day and the peak of SD group is observed at 24-day. Form, this result we can say that the time required for hydrolysis in DD group is less as compared to SD group and ultimately rate of production of biogas increases in DD group.

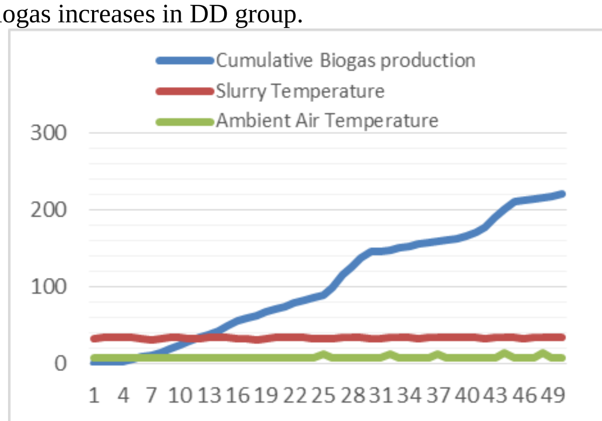

Fig. 5.2: Rate of biogas production for DD Group.

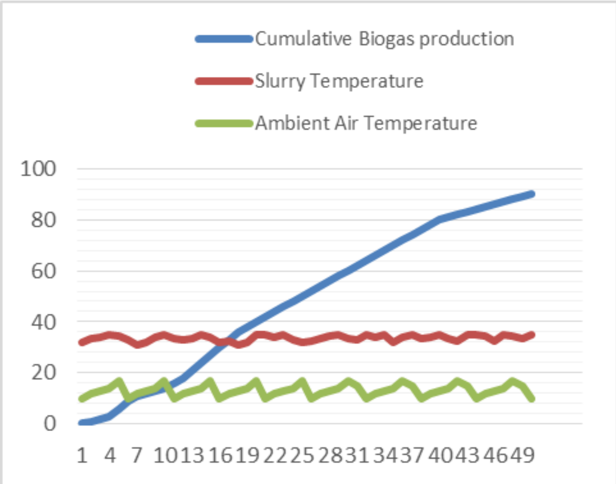

Fig. 5.3: Rate of Biogas Production for SD Group.

Figure 5.2 and 5.3 Respectively represents the rate of *Heat Transfer Performance of MFD*

There was an influence on the digestion process i.e. bacterial digestion process due to variation in temperature and this temperature should not exceed 2-3 $^{\circ}$C per hour. Within short period as the variation in temperature exceed up to 5 $^{\circ}$C, there was changes observed in rate of production of biogas. Therefore, it is necessary the digestion temperature should be constant. To avoid this change in digestion temperature the slurry temperature should be controlled. Before the start of digestion ambient temperature was noted as 10°C and initial temperature of slurry was 30°C and initial volume of slurry was 2 m^3. After, some time in the morning the new slurry of 1 m^3 volume was added which has temperature 12 $^{\circ}$C. Digested sludge in equal amount of added slurry was removed and at this stage the slurry temperature immediately drops to 26°C. After 6 hours there was decrease in slurry temperature and it was 26.3°C after mixture was completed. It shows that in static digestion to reach uniform slurry temperature need more time and hence it is not conductive for stable biogas production.

VI. Conclusion

In this study MFD is used for digestion and dynamic anaerobic digestion system is proposed. Additionally, the experiment was carried out on this system. From this study it is found that the biogas production rate for dynamic digestion group is increased by 90% as compared to static digestion group. The gas production of the DD group is 3 m^3 per day and for 50 days trial it was 148.85 m^3. The DD group reduces the cycle of digestion and rate of production of biogas is found 0.346 $m^3\,m^{-3}\,d^{-1}$ where the digestion temperature is 35 $^{\circ}$C. On the basis of kinetic calculations, for DD group the time lag is noted 9.44 days whereas for SD group the time lag is noted as 11.25 days. From this we can conclude that for SD group the time lag is more as compared to DD group. In multiphase flow digester the temperature of the slurry is suddenly increases and the heat transfer rate is increases significantly due to dynamic heating experiment.

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