

Establishing Auto Gasification of Sewage Sludge

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Abstract: The gasification is the process of thermo chemical conversion of biomass in to combustible gases, which can be used as a fuel. This paper gives an insight on gasification and establishing the auto gasification of sewage sludge. Auto Gasification is a thermo chemical process for converting solid combustible matter into gaseous fuel with the bio oxygen. The Bio oxygen is the oxygen content in the biomass. This process thus increases the specific calorific value of the producer gas.

Keywords: Auto gasification, Biomass, Gasification, TGA

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I. INTRODUCTION

All biomass release either inert gases such as CO₂ and N₂ or combustibles like CO, CH₄, and H₂ depending on the heating environment. The former happens in oxygen surplus environment and the later in oxygen-restricted environment. The gasification is the process of thermo chemical conversion of biomass in to combustible gases, which are burnt later for energy recovery. The biomass either be completely burnt to ash releasing the heat in combustion and incineration or be converted to combustible gases leaving behind ash in gasification. The produced gas approximately has the composition of 18-22% carbon monoxide, 8-12% hydrogen, 2-4% carbon-dioxide 45-50% methane and the rest is nitrogen.

The process of gasification, which involves four phases are explained here. The removal of moisture from biomass between 100 and 160°C is an endothermic reaction and is called *drying*. During drying, the moisture, which is 10 to 35% of biomass, is converted in to steam. After drying, continued heating beyond 250°C without supplying any oxygen to decompose the biomass in to non-condensable gases methane, hydrogen, carbon monoxide, carbon dioxide, condensable vapors (tar) and solid residue called coke is known as *pyrolysis*. After pyrolysis air is supplied and *oxidation* of coke or charcoal takes place at about 700–1,400 °C, which provides heat to all the other three phases of gasification. At higher temperature and restricted oxygen environment, *reduction* process of gasification occurs and the coke reacts with carbon dioxide and water vapor to form carbon monoxide, hydrogen and methane.

II. TYPES OF GASIFIERS

The gasifier is a reactor where partial combustion of biomass takes place at high temperature about 1000°C, which yields a gaseous mixture of combustibles called producer gas. The gasifiers are majorly classified as lean phase or dense phase gasifiers based on the ratio of the amount of fuel that can be burnt to its total volume available.

The lean phase reactors are further classified as entrained flow reactors and fluidized bed reactors. All reactions -drying, combustion, pyrolysis, and reduction occur in a sufficiently large chamber and no separate zones for each phase of gasification as compared with dense phase reactors.

The dense phase reactors are further classified as updraft, downdraft and cross draft gasifiers based on the direction of flow of reaction agent and the product gas.

2.1 Entrained flow gasifier

The fuel and air enters co-currently at the top of the gasifier. The operating pressure and temperature should be high about 20-80 bar and 1200–1600 °C respectively due to much smaller fuel residence time around 0.4 seconds. This type of gasifier can be used for any type of biomass as long as it is of low moisture and ash content.

The major advantages of entrained flow gasifier are fuel flexibility, low tar concentration, high carbon conversion and uniform temperature and high temperature slagging. The higher plant cost and maintenance cost are its major disadvantages.

2.2 Fluidized bed gasifier

A fluidized bed gasifier is a hot bed of sand particles, which are continuously agitated by air supplied through the nozzles at the bottom of the bed. These types of gasifiers produce more amount heat rapidly due to abrasive action between the bed material and the particles of biomass. The biomass is fed directly in to or over the bed according to the size and density of fuel. The bed is of inert material sand or char and maintained around 550–1000 °C for normal operation of gasifier. When the fuel is fed, it is dried first rapidly and followed by pyrolysis reaction which releases all volatile matter. The char is then oxidized within the bed to provide source of heat for drying and de-volatizing reactions to continue.

The major advantages of this type of gasifier are, no clinker formation due to high melting point of ash, accepts particle size variation, uniform temperature and compact construction. The major disadvantage of this type gasifier is that the product gas may contain fine particles of dust.

2.3 Downdraft or co-current gasifier

In this type of gasifier, there are four distinct zones of reactions, the order of which depends on the direction of air and gas flow. The air and gas flow downwards through the oxidation and reduction zones in the downdraft gasifier. The combustion zone is in between pyrolysis and reduction zone. Hence, the tar produced in the pyrolysis zone has to pass through the combustion zone where it is completely burnt leaving mixture of clean gaseous product with low tar content.

The major advantage is that the product gas is with low tar content and suitable for power applications such as fuel for IC engines. The product gas contains high amount of ash and dust and high amount of tar production at low temperature are the major disadvantages of downdraft gasifier.

2.4 Updraft or counter-current gasifier

In updraft gasifier, the reaction agent air flows upwards and fuel flows in downward direction. This gasifier has four distinct zones of reactions drying, pyrolysis, reduction and combustion in order from top to bottom. The heat generated in the exothermic combustion reaction is the heat source necessary for the remaining three endothermic reactions of gasification. The product gas contains both gaseous products of reduction zone and the steam from drying zone. Hence, the product gas is rich in hydrocarbons of high calorific value, which is more suitable for heating applications such as fuel for industrial furnaces.

The gasifier is simple in design, accepts fuel with different particle size and high moisture content and high charcoal burnout are the major advantages. The major drawback is, it needs cleaning operation if the product gas is used for power applications.

2.5 Cross-draft gasifier

The air enters from one side of the gasifier and gas leaves from the other side. It needs no grate and the ash is collected at the bottom of the gasifier. The operating temperature is higher than 1500 °C. It is highly suitable for smaller power (below 10kw) applications. The major disadvantage of this type of gasifier is its low tar converting capabilities.

III. AUTO-GASIFICATION – A MYTH OR REAL?

Recent studies on auto-gasification by Recently Jarvinen, et. al., (2002) it is evident that up to 40% char conversion of a bio fuel such as black liquor is possible through auto-gasification. Saastamoinen (1996) has suggested a detailed combustion model for simultaneous pyrolysis and char conversion.

The reactivity of char, which ensures complete gasification, depends on reaction surface area and catalytic inorganic constituents in the form of ash [Jarvinen, et. al., (2002)]. The particle size influences residence time in direct proportion. The larger particles contribute to higher residence time, which is good for CO₂ and H₂O to react with char. Jarvinen, et. al., (2002) reported that increase in particle size and hence the residence time results in increased percentage of char conversion and it is dominated during de-volatilization process by H₂O.

From the above investigators studies, it is evident that auto-gasification of biomass is feasible. The water formation during de-volatilization dictates the amount of char conversion in the process of bio-gasification and in-turn the water formation depends on the amount of oxygen and hydrogen in the biomass. Hence, it is clear that the composition of biomass is the key factor for the auto-gasification process.

IV. EXPERIMENTATION

Thermo Gravimetric Analyzer (TGA) is used to record weight loss with respect to time or temperature. TGA has been operated both in inert / oxidization environment. Around 200 kg of sewage sludge from was collected and dried in the shadow to achieve a constant weight. The dried sludge was stored in double polythene

bag and sealed to prevent the moisture entering the system. Several samples were analyzed to get an average composition for proximate and ultimate analysis and same is reported here.

Table 1. Proximate Analysis of sewage sludge

Moisture	Volatile matter	Ash	Fixed carbon
3.7	44.2	49.2	2.9

Table 2. Ultimate Analysis of sewage sludge

Carbon (C)	Hydrogen(H)	Nitrogen	sulphur	Oxygen (O)	C/H	C/O	Heating value MJ/kg
34.2	5.8	3.9	0.5	24.2	5.9	1.4	15.8

TGA experiment has been carried out using Nitrogen as well as Oxygen environment and reported in Fig.1.

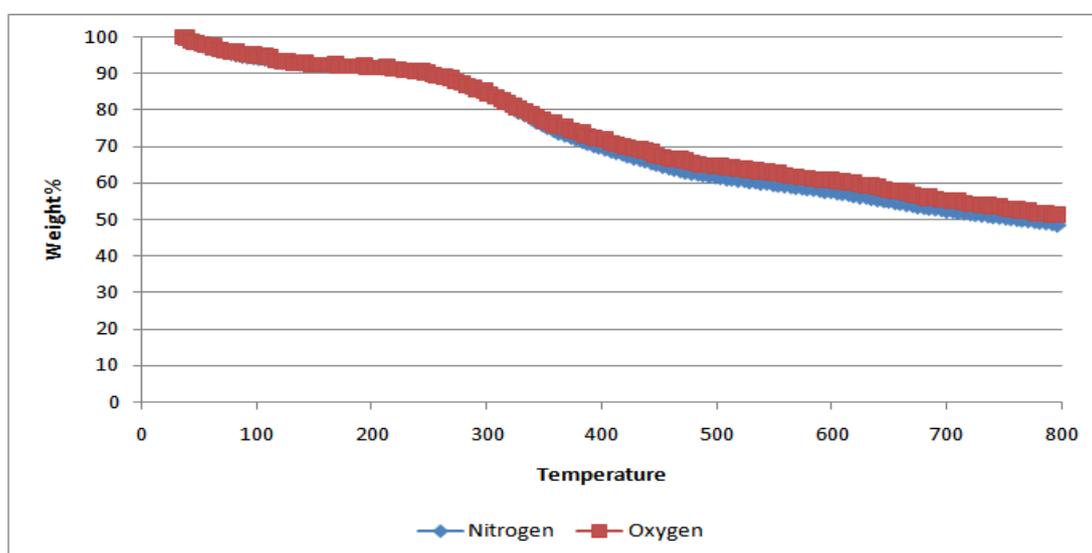


Fig.1. TGA of Sewage Sludge with Nitrogen and Oxygen Environment

V. RESULT AND DISCUSSION

Thermo gravimetric analysis throws light on thermal degradation characteristics of biomass. From the above result it reflects that for both Nitrogen and Oxygen Environment the sample degrades at the same manner. This establish the auto gasification of sewage sludge. Further on the interpretation of ultimate analysis also reveals the same.

VI. CONCLUSION

From the investigation it has been established the auto gasification of sewage sludge is possible. Even in the nitrogen environment the sample degrades on the same manner as that of oxygen environment. This is the influence of bio oxygen present in the sample. Further investigation is needed on the influence of catalysis on the reaction.

REFERENCES

- [1]. Agrawal, R.K.,1998,“Compositional analysis of solid waste and refuse derived fuels by Thermogravimetry method D 997”.Annual book of ASTM standards, (Ed.C.M.Earnest), ASTM, Philadelphia, pp 259.
- [2]. Agrawal, R.K. and Sivasubramanian, M.S., 1987, “Integral approximation for non isothermal kinetics”, AIChE Journal, 33, pp 1212-1214.
- [3]. Bridgwater, A.V., 1995, “The technical and economic feasibility of biomass gasification for power generation”,Fuel, 74, pp 631-657.
- [4]. Chern, S.M., Walawender, W.P. and Fan, L.T., 1989,“Mass and Energy balance analyses of a downdraft gasifier”,Biomass, 18, pp 127-151.

- [5]. Coats, A.W. and Redfern, J.P., 1964, "Kinetic parameters from thermogravimetric data", *Nature*, 201, pp 68 – 69.
- [6]. Cumming J.W., 1984, "Reactivity assessment of coals via a weighted mean activation energy", *Fuel*, 63, pp 1436-1440.
- [7]. Cumming J.W. and MC Langhlin.J., 1982, "The Thermogravimetric behavior of coal", *Thermochemica Acta*, 57, pp 253-272.
- [8]. Davalos, J.Z., Maria Victoria Roux and Pilar Jimenez, 2002, "Evaluation of poultry litter as a feasible fuel", *Thermochemica Acta*, 394, pp 261 – 266.
- [9]. Diebold, J.P., 1994, "A unified global model for the pyrolysis of cellulose", *Biomass and Bioenergy*, 7, pp 75 – 85.
- [10]. Fletcher D.F., Haynes,B.S., Christo, F.C. and Joseph, F.D., 2000, "A CFD based combustion model of an entrained flow biomass gasifier", *Applied Mathematical Modelling*, 24, pp 165-182
- [11]. Gronli, M.G., Varhegyi,G. and Blasi C.D., 2002, "Thermo gravimetric analysis and devolatilization kinetics of wood", *IND.Engg.Chem.Res.*, 41, pp 4201 – 4208.
- [12]. Henihan, A.M., Leahy,M.J., Leahy, J.J., Cummins, E. and Kellehar, B.P., 2003, "Emissions modeling of fluidized bed co-combustion of poultry litter and peat", *Bioresource Technology*, 87, pp 289 – 294.
- [13]. Jarvinen, M.P., Zenvenhoven, R. and Vakkilainen, K., 2002, "Auto-gasification of biofuel" *Combustion and flame*, 131, pp 357 – 370.
- [14]. Kandasamy, K., Natarajan, E. and Reganarayanan, S., 2003, "Comparative analysis of biomass gasifiers for thermal and power application", *Proceedings of 17th FBC conference, 17th International (ASME) fluidized bed combustion conference, Jacksonville, Florida*, pp 5 – 6.
- [15]. V.Kirubakaran, V.Sivaramkrishnan, R.Nalini, T.Sekar, M.Premalatha and P.Subramanian, "A review on gasification of Biomass" *Renewable and Sustainable Energy Reviews* Vol. 13(1) 2009pp 179-186
- [16]. V.Kirubakaran, V.Sivaramkrishnan, R.Nalini, T.Sekar, M.Premalatha and P.Subramanian, "Studies on Auto-Gasification of Bio-Residues", *Energy Sources – Part A*, Vol.31, 2009, pp 967-973
- [17]. V.Kirubakaran, V.Sivaramkrishnan, M.Premalatha and P.Subramanian, "Kinetics of Auto-Gasification of poultry litter" , *International Journal of Green Energy* , V 4, 2007pp 519-534
- [18]. Lawrence A., 1999, "Studies on Combustion Characteristics of biomass fuels", Ph.D Thesis, Bharathidasan University, Tamilnadu, India, pp 81-90.
- [19]. Munoz Guillena, M.J., Linares-Solano,A.and Salinas-Martinez de Lecea, 1992, "Determination of calorific value of coals by differential thermal analysis", *Fuel*, 71, pp 579-583.
- [20]. Patel, B., K. McQuigg and Toerne, R "Integration of poultry litter gasification with conventional pulverized coal fired power plant" <http://bioproducts-bioenergy.gov/pdfs/bcota/abstracts/11/z176.pdf>, pp 1-2.
- [21]. Piloyan, G.O. and Novikova. D.S., 1960, *Russian Journal of Inorganic Chemistry*, 12, pp 313
- [22]. Rasool, S., Sial, M.A., Ahsan-UI-Haq and Ameth Jamil, 1998, "Chemical changes during ensiling of sudax fodder with broiler litter", *Animal Feed Science and Technology*, 72 pp 347-354.
- [23]. Raveendran, K., Anuradda Ganesh and Kartic C. Khilar, 1995, "Influence of mineral matter on biomass pyrolysis characteristics", *Fuels*, 74, pp 1812 – 1822.
- [24]. Raveendran, K., Ganesh, A., and Khilar, K.C., 1996, "Pyrolysis characteristics of biomass and biomass components", *Fuel*, 75, pp 987 – 998.
- [25]. Reed, T.B. and Gaur Siddhartha., 2000, "A survey of Biomass Gasification 2000" *The National Renewable Energy Laboratory and The Biomass Energy Foundation, Inc., Golden,Co. 80401. ISBN 1-890607-13-4*, pp-112-116.
- [26]. Sarkar Samir., 1988, "Fuels and combustion", 2nd Edition, Orient longaman, pp 189.
- [27]. Tomita.A., Mahajan,O.P. and Walker,P.L., 1977, "Reactivity of heat-treated coals in hydrogen" *Fuel* 56, pp 137-144.
- [28]. Wagoner, C.L. and Duzy, A.F., 1976, "Burning Profile of solid fuels", *ASME 67-WA/FU3*.
- [29]. Williams, P.T. and Besler, S., 1993, "The pyrolysis of rice husks in a thermo gravimetric analyzer and static batch reactor", *Fuel*, 72, pp 151 – 159.
- [30]. Williams, P.T. and Besler, S., 1996, "The influence of temperature and heating rate on the slow pyrolysis of biomass", *Renewable Energy*, 7, pp 233 – 250.

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