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POLLUTION FREE CHEMICAL REACTIONS IN A FLUIDIZED BED

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ABSTRACT

Emission of Green House Gases (GHG) and other industrial pollutants like CO_2, SO_2 , NO_x is one of the major issues in industrial sectors.This analysis report concludes that control of these gases is especially important using gasification technology to reduce both CO_2 and non-CO_2 greenhouse gases. Coal gasification found to have some environmental benefits relative to conventional mining including like reduced sulfur emissions, reduced discharge of ash, H_g and tar, and the additional benefit of carbon capture and sequestration. Gasification of carbonaceous industrial residues will contribute to both electricity and thermal applications in gas and oil industry. Fluidized bed gasification system facilitates Gas-solids reactions, catalytic and non-catalytic reactions, drying and in petroleum industries for hydrocarbon cracking and reforming. The objective of present work is to make a note on the critical importance of gasification techniques and gaseous product with controlled emission to safeguard the atmosphere.

Keywords: Pollution, Atmosphere, Gasification, Emission, Fluidized bed, Chemical reaction, Pyrolysis.

Contribution/ Originality

This study originates an environment-friendly and sustainable solution to power crisis. This paper contributes the analysis of reduction of atmospheric pollutants when gasifying fossil fuels rather than direct combustion. The Papers primary contribution focus to prevent the emission of GHG, other industrial pollutants like CO_2, NO_x into atmosphere. This study is one of very few studies which have investigated the gaseous emission using different fuels.

1. INTRODUCTION

Fluidization is a process in which solids are caused to behave like a fluid by blowing air (or) gas through a bed of solid-filled reactor.In FBG silica sand filled at the bottom bed of the gasifier is brought to a fluidized state by the primary air which is supplied uniformly through a distributor plate. Gasification is primarily a thermo-chemical conversion of organic materials at elevated temperature with partial oxidation. It converts carbonaceous materials to a combustible

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or synthetic gas contains (H_2, CO, CO_2, CH_4). Combustible components include Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane and other products like tar and dust. The production of these gases is by reaction of water vapor and CO_2 through a glowing layer of charcoal. Gasification process produces a fuel gas that can be combusted for generating heat or can be used in an engine or turbine for generating electricity. The fast pyrolysis process produces a liquid fuel that can substitute for fuel oil in any static heating or electricity generation application Bridgwater and Peacocke [1]. Circulating Fluidized bed (CFB) gasification is considered to be the most advanced method for thermo chemical conversion. Gasification is a thermal degradation process occurs in a limited oxidizing environment at different operating temperatures. Gases released from the gasification process can be utilized for firing up furnaces in industrial combustion and also for generating power using diesel generators Lim and Alimuddin [2]. The producer gas leaves the gasifier with pollutants and therefore, requires cleaning to satisfy requirements for engines. Mixed with air, the cleaned producer gas can be used in gasturbines (in large scale plants), gas engines, gasoline or diesel engines.

2. THERMAL GASIFICATION OF BIOMASS

Gasification is a form of pyrolysis, carried out at high temperatures in order to optimize the gas production. In gasification, biomass is subjected to partial Pyrolysis under sub-stoichiometric conditions with the air quantity being limited to 1.5 to 1.8 kg of air per kg of biomass. The resulting gas, known as producer gas, is a mixture of CO, H_2, CH_4, CO_2 and N_2.Gasification yields combustible gases such as hydrogen, carbon monoxide, and methane through a series of reactions Basu [3]. The following are four major gasification reactions.

$C + H_2O= CO + H_2$ Eq.(A.1)

$CO_2 + C = 2CO$ Eq. (A.2)

$CO + H_2O = CO_2 + H_2$ Eq. (A.3)

$C + 2H_2= CH_4$ Eq.(A.4)

Water- gas reaction Eq.(A.1) is the partial oxidation of carbon by using a fluidizing Medium (Air, Steam etc.). Air reacts with the hot carbon to form Carbon monoxide & Hydrogen. Then carbon dioxide present in the gasifier reacts with char to produce CO, which is known as the Boudouard reaction Eq(A.2). Shift conversion reaction Eq(A.3) is a highly desirable reaction for production of hydrogen. This endothermic reaction occurs by thereaction of steam with CO resulting in increase in ration H_2 to CO. It is widely used forthe manufacture of synthesis gas. Formation of CH_4 in the gasifier is due to the Methanation reaction Eq(A.4).

3. FLUIDIZED BEDS GASIFICATION SYSTEM

The production of generator gas (producer gas) called gasification, is partial combustion of solid fuel (biomass) and takes place at temperatures of about 1000°C. The reactor is called a gasifier. The system consists of centrifugal blower, gasifier, cyclone separator, dust filter and gas cooler. The layout diagram of the gasification system is shown in Figure 1.

The produced gas enters the inertial separator and the cyclone separator to remove ash, and then passes through two parallel Venturi tubes and two parallel water scrubbers, where the gas cleaning process takes place. The gas can be cooled to room temperature after the gas cleaning process and then sent to a gas storage tank using a Roots blower. The gas leaving the gas tank can be burned in the combustion chambers of the gas engines, The gasification system can be used later to drive an engine Chuang-Zhi, et al. [4].

4. RESULTS AND DISCUSSION

FBG technologies will be efficient for extracting combustible gases like CO, H_2 and CH_4 and other by products in petroleum and power industries. Biomass gasification in fluidized bed offers a particular advantage for renewable energy. Experimental investigation by expert's shows that the calorific values of bio-oils obtained from pyrolysis is comparatively higher. Whereas havingdiesel fuel has a higher calorific value of 42.151 MJ/kg. Calorific value of bio-oils increases when blended with Diesel to form a rich carbonaceous fuel "Bio-diesel".The application of gasification process is shown in Figure.1 and Figure.2. Katyal, et al. [5]. The first commercial-scale plant using our coal gasification technology started up in 1993 at the integrated gasification combined cycle power plant in Buggenum, the Netherlands. Coal gasification also creates useful by-products such as fly ash for cement industries, sulphur for fertilizer manufacture and for chemical applications, and slag for building materials and for roads (gasification combined cycle power plant in Buggenum).

Coal extraction by the underground coal gasification (UGCG) process appears to be both technically and economically feasible and exhibits many potential advantages over the conventional mining methods. Kapusta and Krzysztof [6]; Shuqin, et al. [7]. The UGCG process occurs when un-mined coal seams are reacted underground to create syngas. An oxidant (usually air, oxygen, or steam) is injected into the coal seam and reacts with the coal and water present in the seam to produce syngas that is extracted through a production well Bell David, et al. [8]; Solcova, et al. [9]. The gasification process creates synthesis gas that can be used as fuel or feed stock for further chemical processes such as NH_3 production or liquid fuels. As the gasification process proceeds, the cavity grows radially outward and upward from the injection well Perkins and Sahajwalla [10]. Contaminants can be introduced into the groundwater during the UGCG process, at termination, and after termination. The contamination mechanism involves simultaneous diffusion and penetration of contaminants generated in the UCG process with the gas that escaped to the surrounding underground formations [6]. Contaminants from the UCG process can affect water quality making sources unfit for human and wildlife consumption [8].

UGCG has some environmental benefits relative to conventional mining including (1) no discharge of tailings, (2) reduced sulfur emissions (3) reduced discharge of ash, Hg and tar, and (4) the additional benefit of carbon capture and sequestration. Hydraulic control is the most important feature of UCG. It controls the gasification process and prevents groundwater contamination [11]. Coal resources that are not suitable for conventional mining are ideally suited for UCG Van Der Riet [12]. Ultimately, UCG will compete in the marketplace with conventional and innovative gasification technologies to provide syngas for fuel and power applications, which will in turn compete against other fuels such as biodiesel and gasoline. In the coming years, these technologies will likely be competitive in the market place not just on an economic basis but also on the costs and difficulties of managing CO_2 emissions to the atmosphere Friedmann Julio, et al. [13].

Wisa [14] investigated the conversion of waste lube oil into petrochemical liquid Fuels by Pyrolysis process in a stainless steel reactor at an operating temperature of 200ºC – 500ºC. The study showed that the waste lube oil, containing C11 – C30 hydrocarbon, was thermally cracked to oil products comprising mainly of C10 – C30 hydrocarbons. Their experimental results support their concept as a promising alternative to pyrolysis oils comprising valuable light aliphatic and aromatic hydrocarbons, which could be treat and used as either an energy source or valuable chemical feedstock.

Ademiluyi [15] evaluated fuel gas production from pyrolysis of waste polyethylene (pure water sachets) at low and high temperatures. Results shows that pyrolysis of the waste for 300secs at temperatures of 25°C -140°C produced 2.53% ethane, 21.67% propane and 75.82 % propylene. The volume of the gaseous products at this low temperature is reported to be far less than the initial volume of the waste resulting into over 80% reduction in the volume of waste generated by discarding the polyethylene waste. Fresh samples of the waste were pyrolysed at higher temperature and cooled in a condenser. The non-condensable gas produced were collected and analyzed with Shimadzu gas chromatography. The gaseous products being 75.82% propylene at low temperatures and 48.6% (normal and Iso) butane at higher temperatures. The flame test carried out shows that the gaseous products burns with a blue flame at lower temperature range. Above 300°C the flame becomes more luminous and production of fuel gases stops at 550°C. The gaseous products can serve as feedstock and as fuel gas.

Experiments carried out by expert's shows that the gasification yields rich producer gas .Producer gas is a mixture of combustible and non-combustible gases. Experts reported that the heating value of producer gas may vary between 4.5 to 6 MJ/m^3 depending upon the proportion of its constituents. Vander Drift, et al. [16] successfully tested a total of ten different fuels in a circulating fluidized bed gasifier called BIVKIN having 500-kWth capacity. Raskin, et al. [17] presented the operating experience of Kymijarvi power plant located at Lahti in Southern Finland jointly owned by Laden and Lampovoima. The gasifier produced a product gas equivalent of 35-55 MWth depending on the gasifier fuel moisture content reporting the gas heating value in the range of 1.6-2.4 MJ/Nm3. Li, et al. [18] reported the results of pyrolysis behaviour of seven typical ingredients of municipal solid wastes (MSW) in China using double-dipleg FB incinerator. The typical ingredients were wood paper, food, textile, straw, plastic and rubber. Petersen and Werther [19] conducted experiments on sewage sludge gasification in a 0.1m diameter and 15 m height circulating fluidized bed pilot plant. In their study the air ratio was chosen as 0.3 and 0.6 and the temperature was maintained in the range of 750°C to 850°C. The influence of the air ratio, superficial gas velocity, temperature, and feeding height on the product gas composition was examined. The general composition of producer gas obtained by gasification as reported by experts) on volumetric basis presented in Table 1.

A number of operating parameters should be considered, such as concentration, properties of fuel slurry, reaction temperature, pressures, O^2/ fuel ratio, physical and chemical properties of fuels. And also those parameters have strong influence to output from gasifier ; syngas compositions, heating values, carbon conversion and fluidity of molten slag. Especially the slagging behaviour in the gasifier is observed one of the most important considerations for gasifier design and operation.

6. CONCLUSION

The gasification technology carries an environment-friendly and sustainable solution to the power crisis. It can reduce the pollutions when gasifying fossil fuels rather than combustion. The technology can recycle industrial-waste, be localized, and made available on demand without the need for separate storage. The fluidized bed technique (FBT) can be used for diversified industrial applications temperatures ranging from 300 - 1200°C. Most commonly used for facilitating Gas/solids reactions, catalytic and non-catalytic reactions, drying and in petroleum industries for hydrocarbon cracking and reforming. The other features of FBT includes good gas solid contact, excellent heat transfer short residence times, compact space requirement and Minimum energy requirements from low calorific value fuels.

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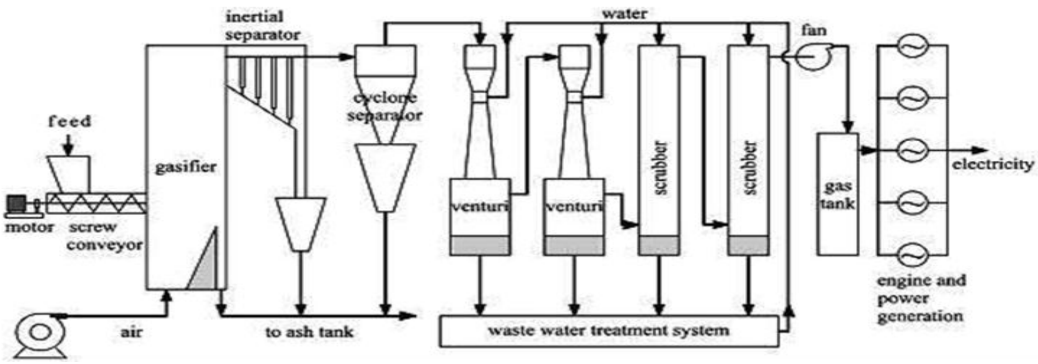

Figure-1. Fluidized beds gasification process.

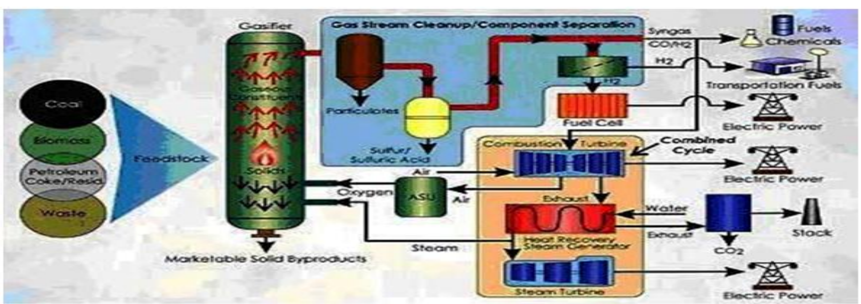

Figure-2. Gasification Applications.

Table-1. Composition of Producer Gas derived from gasification process.

Authors	Fuel	CO%	CO_2%	H_2%	CH_4%
Chuang-Zhi, et al. [4]	Rice husk	16-21	15-16	5.0-8.0	4.0-6.0
Vander Drift, et al. [16]	Residual biomass	5.34-11.65	13.94-17.10	1.80-9.02	1.24-3.30
Garcia-Ibanez [20]	Olive oil waste	6.9-8.6	19-21.7	5.4-9.3	1.8-3.0
Sheeba, et al. [21]	Coir pith and coal powders	30-48	38-55	6.0-12	6.0-7.7
Park, et al. [22]	Cyprus coal	29 – 32	43 – 58	18-27	0.7 -1.38
Park, et al. [23]	Alaska coal	39	42	21-41	0.02-1.21
Samir Deshmukh, et al. [24]	wood	18-22	-	15-19	1-5%
Li, et al. [25]	saw dust	6.9-21.4	15-18.3	3.0-7.3	1.4-4.6
Kersten, et al. [26]	Willow - pine wood	33	19	1.9	8
Xiao, et al. [27]	Animal waste	7.0-15	20-25	39-47	4.0-8

BIOGRAPHY

Prof. Nagaraja Mohan obtained his B.Engg in Mechanical from Anna University; Chennai. He had worked as a Plant Engineer in Sri Ariyanachi Rice Mills Food processing & Boilers division. Also as an Engineer in Lakshmi Krishna Textiles ltd. He had also been as an engineer trainee at Rajshree Sugars and Chemicals (RSCL). Latter he served as JRF from 2008 to July 2011 in the DST,Newdelhi sponsored R&D project in VIT University,Vellore. He pursued Masters of Sciences ., MS (By Research) for 5 years as per DST norms. He is the first MS alumni in Mechanical Engineering.He had successfully completed a funded project supported by DST and VIT University along with Dr. R. Sundaresan and Dr. R. Natarajan. He is continuing the research from 2008 is his association with VIT universty ,Vellore and also a Ph.d.,Research fellow of Ballsbridge University. He had published 28 research papers in reputed journals and in conferences held in BITS Pilani, BITS Hyderabad, BIT Sathy, AMACE and NIT Calicut with outstanding awards. He had filed an Indian Patent and also granted with an Indian Copyright certification from Government of India. His research interest includes Biomass energy, Biofuels, Fluidized Bed gasification, Pyrolysis, CFD ,Educational management and administration.He render his profesional service as a Lead editor and reviewer in reputed science, engineering and management journals.

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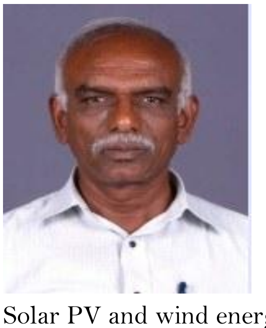
Dr. R. Sundaresan had his education in Salem taking his B.E. in Mechanical Engineering Degree at Government College of Engineering and M.E. Thermal Power Engineering at Annamalai University and Ph.D from IIT Madras, Chennai. He is having more than 25 years of experience in teaching and Research. He also had executed four funded project supported by UGC, DST and BRNS in VIT University. He has published research papers in reputed Journals and conferences. He also supervised Ph.D & M.S., (by research) candidates. Presently he is a Director in Galgotias College of Engineering & Technology at Greater Noida. His research interest includes Biomass gasification, Heat Transfer in Fluidized Bed and Renewable Energy. He is also a life member of ISTE, ISHMT, SESI and FIE.



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