ENERGY FROM MUNICIPAL WASTE USING A GASIFIER

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CERTIFICATE

This is to certify that the project report on **"Energy from municipal waste using a gasifier" submitted by Sunil Yadav bearing Roll No.109CH0100** in partial fulfillment of the requirements for the prescribed curriculum of Bachelor of Technology in Chemical Engineering at the National Institute of Technology, Rourkela for the session 2009-2013 in an authentic work to the best of my Knowledge an belief.

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ABSTRACT

The municipal solid waste Gasification Technology has been carried out using a fluidized bed gasifies. This work focuses on the production of synthesis gas from municipal solid waste (agriculture waste, orange fruit waste, egg cover and household) the production of energy from municipal solid waste by combustion in fluidized bed gasifier and air discharge, and this energy also used for the power generation. Purpose of this study was to estimate the potential of gasification process an alternative to the combustion of municipal solid waste. Fluidized bed gasifier uses a relatively small amount of oxygen or water vapor to regenerate the organic compound into a combustible gas. The ratio of steam to biomass effects the composition of product gas. Silica sand and municipal wastes are used as bed material in fluidized bed gasifies.

Keyword: fluidized bed gasifier, energy production, and municipal solid waste.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

Today, the world requirement for renewable energy sources is the key factor in the consideration of the fluidized bed gasification system. An increment of municipal solid waste problem enforces to think for sustainable waste disposal. There are many methods of waste clearances. And gasification is one of the liberal promised technologies. Throughout gasification, the chemical energy inside municipal solid waste could be defensive through production of synthesis gas, and volume of solid waste can be quick decrease. Municipal waste was no more treated as the valueless garbage, the solid waste is rather perceived as resource in the present time. Associated waste management system attempt a pliability of waste analysis option base on different waste fraction like plastics, glass, organic waste. The gasification technology or approach could be analyzed by the environmental, social or environmental point of view. The old and more popular the fluidized bed gasification is the well proven Winkler process. Rheibraun was developed of the high temperature Winkler [1] biomass gasification; this is developed process different temperature and pressure below the ash melting point approximation (500-800ºC). there was here many solid waste could be described as any solid, semi-solid substance, and resulting from garbage waste , human or animal activities, damaged as useless or undesirable. This is a highly mixed mass of waste, which may be engender from household , commercial, industrial, agriculture animated. These are municipal [2] solid waste an extensive term, which an encompass all type of waste such as municipal solid waste, industrial waste, hazardous waste, bio-medical waste electronic waste depend on varies source and composition. This is applying of organic and inorganic combining which would or would not be biodegradable. It an economic molder with drying, fragment, gasification power generation and filigree connection module. There are three type of gasification system used fluidized bed, downdraft and updraft. It is three types of power generation system- internal combustion and steam turbine, gas turbine. it was appraised resulting in nine plant configuration arrangement. And fluidized bed gasifies an internal combustion engine plant and composition result the lowest cost of electricity at 15MK/h a micro-scale inaugurated capacity of 120Kwe and plant operating capacity at 82% with a report green waste process Expenditure has been the strongest effect on the lovelies cost of electricity under the configuration.

CHAPTER 2

LITERATURE REVIEW

2.1 Generation of Municipal Solid Waste

2.1.1 Municipal solid waste:

The municipal solid wastes are also called urban [3] solid waste, and many type of waste includes comprehensively household waste and sometime the addition of commercial waste construction and domestic waste. There are in either solid or semi-solid from and generally withdraw industrial hazardous waste. The municipal solid waste could be extensively categorized into five types.

Biodegradable waste: This is very simple bio-degradable[4] waste is by product which can be consist of natural material and it is defined as the bio-degradable garden and park waste vegetables flower, fruits, paper and food and kitchen waste from households.

Recyclable material: The recycling processes are to change waste material into new material, with the addition of many material paper, glass, bottles, etc.

Inert waste: This does not undergo any convincing physical and chemical transformation, and example construction and demolition waste, dirt, rocks, gypsum board and concrete.

Composite waste: waste clothing, tetra packs, waste plastics such as toys.

Domestic hazardous waste and toxic waste: the toxic waste are waste material that could be occasion death, injury to be living creatures, and some material are hazardous and toxic waste as well as medication, e-waste, paints, chemicals light bulbs, spray cane, fertilizer and pesticide containers. Some source of solid waste generators and solid waste content can be tabulated as bellow:

Table No.1 Source of solid waste Generation

S.No.	Source	Type of waste generator	Solid waste content
1.	Residential waste	Single and multifamily dwellings	Food waste, yard waste wood, textiles, paper, etc.
2.	Industrial waste	Light and heavy manufacturing, power and chemical plant.	Housekeeping wastes, packaging, construction and demolition
3	Commercial waste	Hotels, restaurants, markets office buildings.	Wood, food wastes, glass, etc.
4	Construction and demolition material	New construction sites, road repair, renovation sites	Wood, steel, concrete , dirt, etc.

2.2 Landfill Method

The disposal of solid waste and buried waste materials produce gases which are associated to the landfill. It is very a common exercise in most countries. The landfill [5] method was often an established method in eliminated or unutilized from which rock or mineral is extracted. An appropriately design and well managed landfill could be salubrious and relatively an economical method of distribute of waste material. The design of characteristics' a modern and landfill include method to contain leachier such as plastic undercoat material. Accumulated waste are normally compacted to increases the gas production. Many landfill methods have been used for landfill gas system and installed to extract the landfill gas. These are four types of solid waste landfill methods.

(1) Municipal solid waste landfill. (2) Bio-reactors/ Nuclear waste landfill. (3) demolition Debris landfill. (4) Industrial hazardous waste landfill.

The municipal solid waste has been measure from driveway and disposal at landfill method, and different composition with percentage show below.

Table No. 2 Landfill method by measure composition with percentage

Composition	Product gas (Vol.%)
CH_4	52
CO_2	37
CO	0.5
H_2	8.2
Another gas	4.3

Table No.3: Calorific value is obtained from different solid waste.

Material	Calorific Value(KJ/kg)
Paper Production	12763.207
Wood Waste	13013.06
Plastic Waste	21.837.76
Textile Waste	20721.03

2.3 High- Temperature Winkler Gasification of Municipal Solid Waste

High temperature Winkler process developed by Rheinbraun is a fluidized bed gasification process and suitable for various type of lignites. This is very reactive and ballast-rich biomass type, the biomasses are different types pre-treated and residuals waste. These are depending on some application and the high temperature Winkler process can be used for efficient conversion of these feed stocks and produce fuel gas or synthesis gas. Rheinbraun is father developer and licensor of advanced high temperature coal gasification, and Winkler processes work under pressure and temperature (800-1000^{0}C).

High temperature Winkler gasification used municipal solid waste (mixture of paper, wood, agriculture waste, and rice husk) and results on nitrogen free basis are shown below in the tabular form

Table No. 4 Winkler gasification of solid waste mixed measure composition with percentage.

Composition	Percentage (vol%)
CH_4	63
CO	18
CO_2	35
H_2	0.11
Another gas	3.6

2.4 Gasification of Municipal Solid Waste:

This is most important for the growing popularity and thermal process used for the analysis of solid waste. The municipal solid waste can be difficult to handle, the municipal solid wastes have a high disposition to fused ash deposit on internal surface of furnace and high temperature reactors. The different products have gained from the application on these process and different energy individual recovery system can be used to treat these. The gasification can be extensively assigned as the thermo chemical an exchange of solid or liquid carbon based feed stock into a combustible gaseous product into the supply a gasification agent. The thermo chemical modification change the chemical structure of the solid waste by mean of high temperature. The gasification an emissary allows the material to be fluently converted into gas by means different heterogonous reaction. The combustible gas are produce CO_2, CO, $CH_{4,}H_2$ and trace amount of higher hydrocarbons, and various impurity such as small char particle, ash and tars.

Generally, fluidized bed gasification system has three major steps : (1) Production of high calorific combustible syn-gas (2) The gas cleanup systems which are necessary to remove harmful compound from combustible syn-gas. (3) Energy recovery and conversion system. The total unit is suitable for controlling solid waste as an environmental impact.

Advantages of Gasification:

There are several solid waste gasification facilities under production throughout the word. The gasification has numerous advantages over acceptable combustion process for municipal solid waste analysis. This is take place in low oxygen environment and that limit the preparation of dioxin and very much quantities of SO_X and NO_X. Even, this is depends upon just a fraction the stoichiometric quantity of oxygen necessary for combustion. Show the result, Volume of process gas is very low, demanding the smaller and less gas an expansive gas cleaning apparatus. Lower gas segment also average higher partial pressure an impurity in the off gas, which is more favors and complete adsorption and particulate capture. In the end, gasification generates a fuel gas that has integrated with combined cycle turbines.

Disadvantages of Gasification:

Throughout gasification, tars heavy metals, halogens and alkaline compound is released within the product gas and can be foundation environmental and operational problem. Alkalis could be increase cluster in fluidized bed that is used in some gasification and also can ravage gas turbine during combustion. The heavy metal is toxic and deposits if it is release into the environment. The clean gas are recover from the municipal solid waste using fluidized bed gasification would be overcoming problems involved with the release and formation of these contaminant.

2.4.1 Gasifiers:

The gasification [6-8] technology is chosen on the basis of accessible fuel quality, capacity range, and gas quality condition. The major reactors used for gasification of municipal solid waste. The gasifies are the reactor in which the adaptation of material into the fuel gas take place. It is a three type of gasifies

(1) fixed bed (2) Fluidized bed (3) Indirect gasifies

2.4.1.1Fixed Bed Gasifiers:

The fixed bed gasifies typically have an enormous to keep up the feed material and maintain a motionless reaction zone. There are comparatively easy to design the operate, consequently useful for small and average scale for power and thermal energy used. It is a two type fixed bed gasifies are updraft and downdraft. Both are require fuel particle of small size (1-2cm) to make certain an unblocked passage of gas all the way through the bed. Therefore the chosen biomass from is pellet or briquettes. The fixed bed gasifies classically have a irritate to support the feed material and continue a stationary reaction zone.

Updraft gasifies: updraft counter current) gasifiers, in the organization air are injected from bottom and biomass enters the tops and moves down in the force of gravity. Since, this is gasified. These gasifiers have four sections; first biomass goes to drying phase and heat around (100-120^{0}C) follow by the distillation and reduction phase and finally the ignition of the ungasified solid fraction. The comparatively high energy efficiency is obtained of the system.

Downdraft gasifies: in the downdraft gasifiers, air introduced into a downward flowing packed bed or solid fuel stream and gas is drawn off at the bottom. The air and fuel go into the reaction zone from above decaying the ignition gases burning of the tars. The downdraft gasifiers are not ultimate for waste treatments because they are normally require a low ash fuel such as wood, keep away from clogging.

2.4.1.2 Fluidized bed gasifiers:

The fluidized [9] beds are a striking intention for the gasification of municipal solid waste. Fluidized bed in a boiler, the steam of gas has passed upward through a bed of solid fuel and material. The Gas acts as the fluidizing intermediate and as well provides the oxidant for an Ignition and tar cracking. The fluidized bed reactor is gasified types without different reaction zone. There are in addition isothermal beds in commission at temperature usually around (800 – 1000^{0}C) lower than maximum fixed bed gasifiers' temperature. The fluidized bed technologies are more suitable for generators with capacity more than 12 MW for the reason that it is used

different fuel, require moderately condensed combustion chamber and allow for good operational control.

2.4.2 Bed material:

In the gasification process is used bed material silica sand and also used bed material with catalytic activity like dolomite can be used. Therefore, the mechanical stability, thermal stability and chemical stability these are three main factors for usability of bed material. This bed material should have high adsorption capacity in order to transmit CO2 out of the gasification zone to give in a high quality product.

2.5 Gasification Reaction:

The gasification is development that converts organic or fossil based material which is rich carbon contents as well as carbon dioxide, carbon monoxide and hydrocarbon. It is achieved by reacting of material at high temperature 800^0C. And result in a char consisting of fixed carbon and oxygen the inorganic compound in the feed. After that second stage, the carbons in the chars are reacted with steam, air or pure oxygen. In the gasification system is exothermic reaction connecting carbon and oxygen provides the thermal energy required to drive the pyrolysis and char gasification [10] reaction. Basic gasification [8-10] reaction is moreover endothermic or exothermic and these are depending on temperature, pressure and oxygen concentration:

<u>The important reaction during biomass gasification:</u>

1- Primary devolatilization: (primary tar CHxOy)

Biomass = CO_2, CO, CH_4, H_2, C_2H_4, H_2O, cabon

Tar cracking and reforming:

Secondary tar

Primary Tar = CO, CO_2, CH_4, C_2H_4, H_2

2- Homogeneous gas phase-reactions:

Secondary tar = C, CO, H_2

(i)	$H_2 + 1/2O_2 =$	H_2O	- 242 kj/mol (1)
(ii)	$CO + 1/2O_2 =$	CO_2	-283 kj/mol (2)
(iii)	$CH_4 + 1/2O_2 =$	$CO + 2H_2$	- 110 kj/mol (3)
(iv)	$CH_4 + CO_2 =$	$2CO + 2H_2$	+ 247kj/mol (4)
(v)	$CH_4 + H_2O =$	$CO + 3H_2O$	+ 206 kj/mol (5)
(vi)	$CO + H_2O =$	$CO_2 + H_2$	- 409 kj/mol (6)

2.6 Electricity Generation:

Municipal solid waste gasification by generation of electricity [11-13], system is a technology which converts any kind of biomass energy with a low heat value such as solid waste from household waste, agriculture waste and fruits waste (orange) into combustible gas then feeds this gas to a generator for electricity generation.

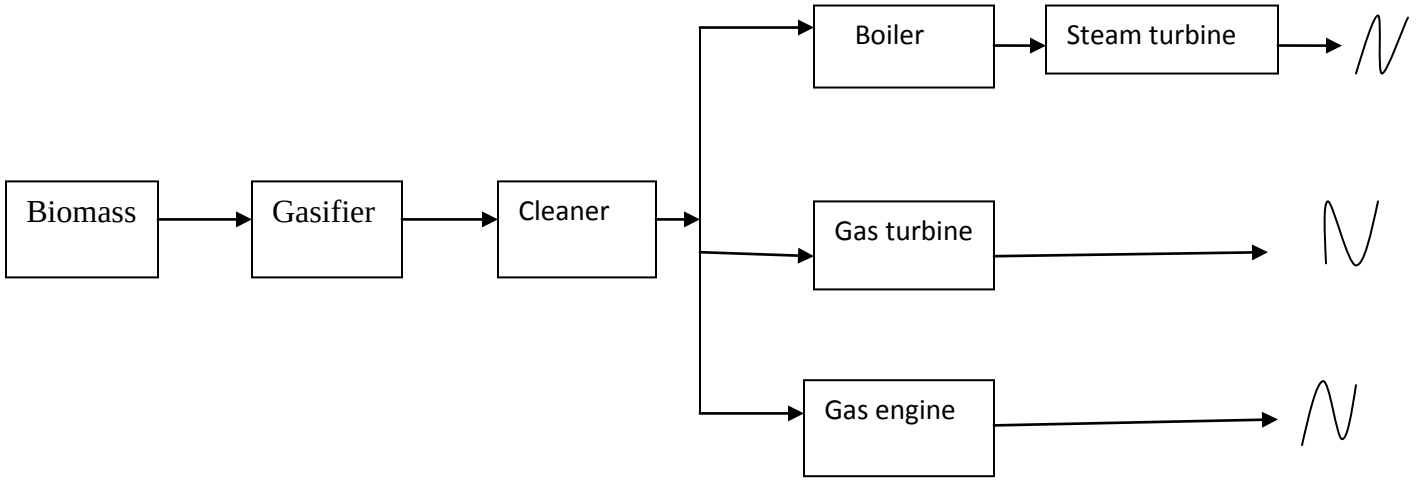
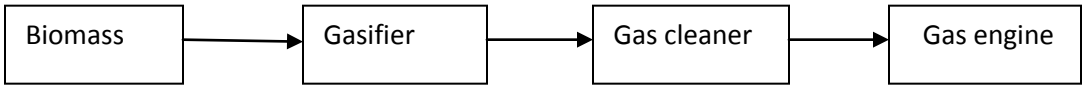


Fig.1- Block diagram for process of production of biomass energy

The biomass gasification for electricity generation can be solving both problem of effective use of renewable energy and environment population for organic waste. This reason, the

technology of biomass gasification for electricity generation attracts more and more research as well as application.

The gasifier is the system which converts solid waste into energy or combustible gas. The solid waste is combusted perfectly by way of controlling the flow of air into the gasifies to converted the solid stage by which a combustible gas mainly hydrogen, carbon dioxide, carbon monoxide and methane is obtained.



The gas temperature in the outlet of the gasifier is in the range 500-800^{0}C. These are depends on the type of gasifier. The gas contains impurity such as dust and untracked tar. This is in order to meet the demand of reliable gas engine operation over a long period of time. This is required to the clean gas at temperature below 40^{0}C such as reduce the content of dust plus tar below 50 mg/Nm^3. after cleaning, the gas is mixed with air, burns and drives the main shaft to rotate at high speed. The latter than drives the generator to generate electricity

CHAPTER 3

EXPERIMENTATION

3.1 Description of Experimental Setup:

In commercial scale fixed bed gasifier, the biomass is fed continuously at some high at a slow rate while steam and air is bed at the bottom. The biomass undergoes drying and devolatilization at the top gasifiers. The char descends slowly through the reactor. For the reason that the char in the bed are moving gradually. It is termed as fixed bed reactor. The gasification vessel is a 12 in. diameter, and 8 fit. Long cylindrical stainless steel tube. The vessel could be operated at temperature as high 1200^0C. And, this experiment was carried out by using solid waste and silica sand as bed material.

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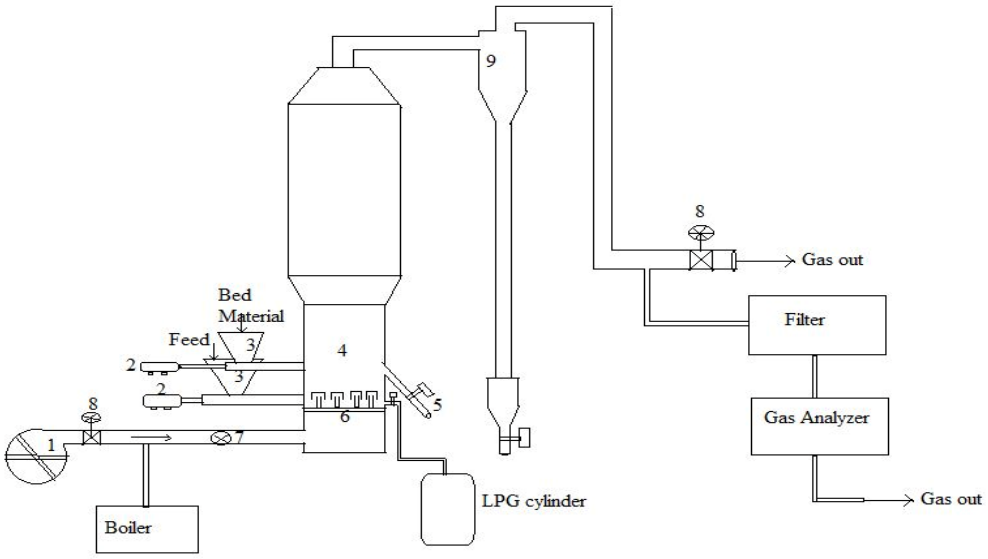

Fig. 2: Schematic diagram of the experimental setup

Table No. 5 Experimental setup

1	Air blower	6	Bubble cap
2	Motor	7	Orifice meter
3	Screw Feeder	8	Valve
4	Fluidized bed gasifier	9	Cyclone separator
5	Continuous cleaning system		

3.2 Experimental Procedure:

At the startup of each experiment, 2.5 kg of the bed material (silica sand) are fed to the fluidized bed reactor by the help of the screw feeder; the bed was fired using liquefied petroleum gas as a fuel at flow rate of 10-12 LPH. After the fluidized bed temperature increased a desired level, the flow of liquefied petroleum gas into the gasifier was stopped and the fruit waste, household was fed to the reactor by help of the attach feeder and the gasification start.

The filter was connected to outlet gas in which the solid particles are incarcerated by water and remaining particles captured by a filter of pore range0.01-0.04 micron. Earlier than going to an analyzer the moisture present in the gas were removed by passing it throughout silica gel transferable infrared coal gas analyzer was used to measure the concentration of hydrogen, carbon monoxide, methane and carbon dioxide in the outlet gas.

Operating parameters studied and their range.

Table No. 6 Experimental parameter rage

S.No.	Operating Parameter	Range
1	Temperature	500-800^{0}C
2	Bed material	3-4 kg.
3	Feed rate	10-15 kg/hr
4	Equivalence ratio	0.20-0.50

3.3 Experimental Analysis:

3.3.1 Effect of varying temperature on product gas composition at biomass agriculture waste

Bed material = Silica sand, biomass feed rate = 10 kg/hr

Table No. 7 Agriculture waste by product gas composition (vol.%) at different temperatures

Temperature ^{0}C	H_2(vol%)	CH_4(vol %)	CO_2 (vol %)	CO (vol %)
500	26.42	8.02	39.21	26.77

550	31.74	7.62	37.42	25.42
600	33.26	7.52	36.81	23.14
650	35.87	8.91	34.72	24.92
700	36.32	8.63	31.63	23.43
750	39.82	7.52	29.48	22.62
800	42.62	7.68	26.73	23.42

Effects of temperature on composition of syn-gas for agriculture waste are shown below

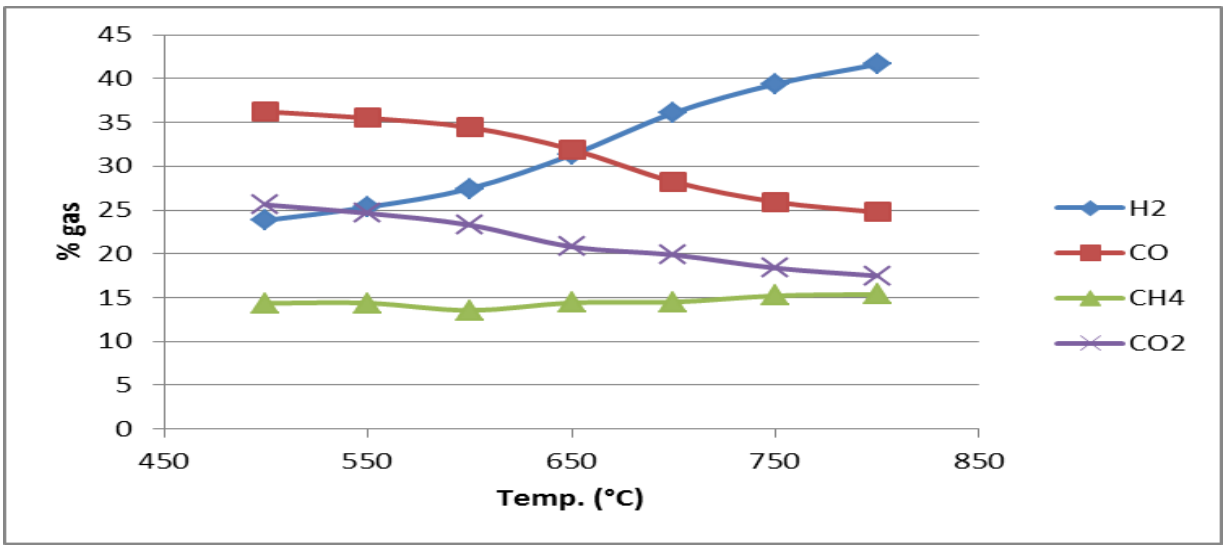

Figure -3 Temperature Vs product gas composition (vol. %)

Experimental Analysis

3.3.2 Effect of varying temperature on product gas composition at household waste.

Bed material = silica sand, feed rate = 10 kg/hr

Product gas composition on nitrogen free basis

Table No. 8 Household waste by product gas composition (vol.%) at different temperatures

Temperature ^{0}C	H_2 (vol %)	CH_4 (vol %)	CO_2 (vol %)	CO (vol %)
500	22.83	13.37	25.49	36.23
550	25.35	13.17	24.63	35.36
600	27.45	12.95	23.29	34.43
650	31.30	13.42	20.81	31.92
700	36.09	13.50	19.88	28.23
750	39.38	14.21	18.38	25.93
800	41.64	14.37	17.38	24.75

Effects of temperature on composition of syn-gas for household waste are shown below

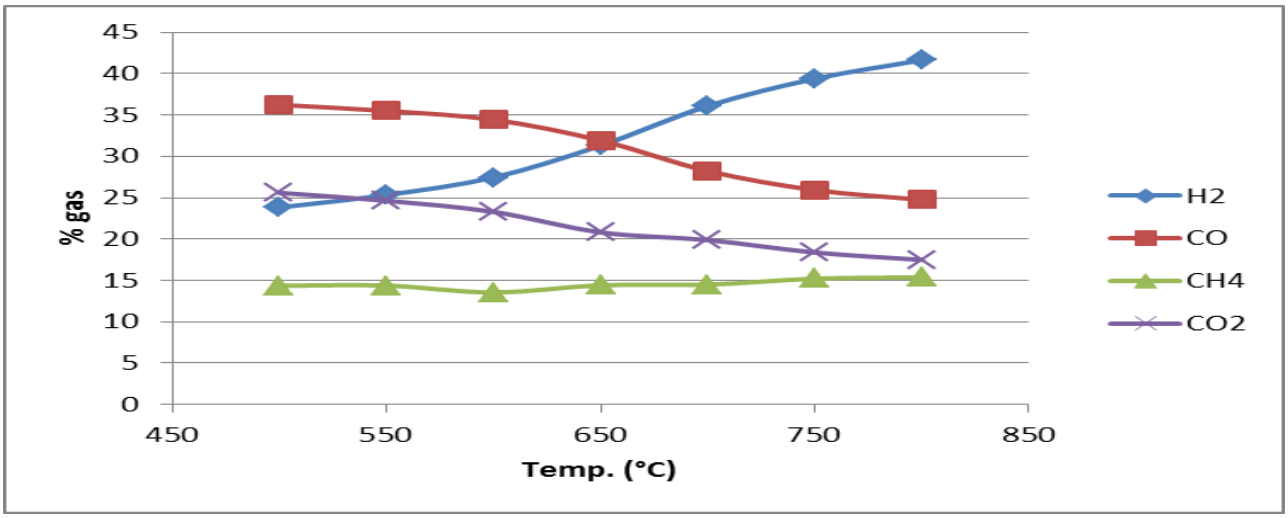

Figure- 4 Temperature Vs product gas composition

Experimental Analysis

3.3.3 Effect of varying temperature on product gas composition at fruit waste (orange).

Bed material = silica sand, feed rate = 10 kg/hr.

Product gas composition on nitrogen free basis

Table No. 9 Fruit waste by product gas composition (vol.%) at different temperatures.

Temperature ^{0}C	H_2 (vol %)	CH_4 (vol %)	CO_2(vol %)	CO (vol %)
500	21.56	17.31	33.48	26.68
550	23.08	18.03	32.75	24.79
600	25.86	18.35	30.9	22.31
650	28.34	19.51	29.84	20.73
700	31.93	18.50	28.32	19.10
750	34.79	18.65	27.63	18.37
800	37.65	17.85	26.39	17.85

Effects of temperature on composition of syn-gas for fruit waste are shown below

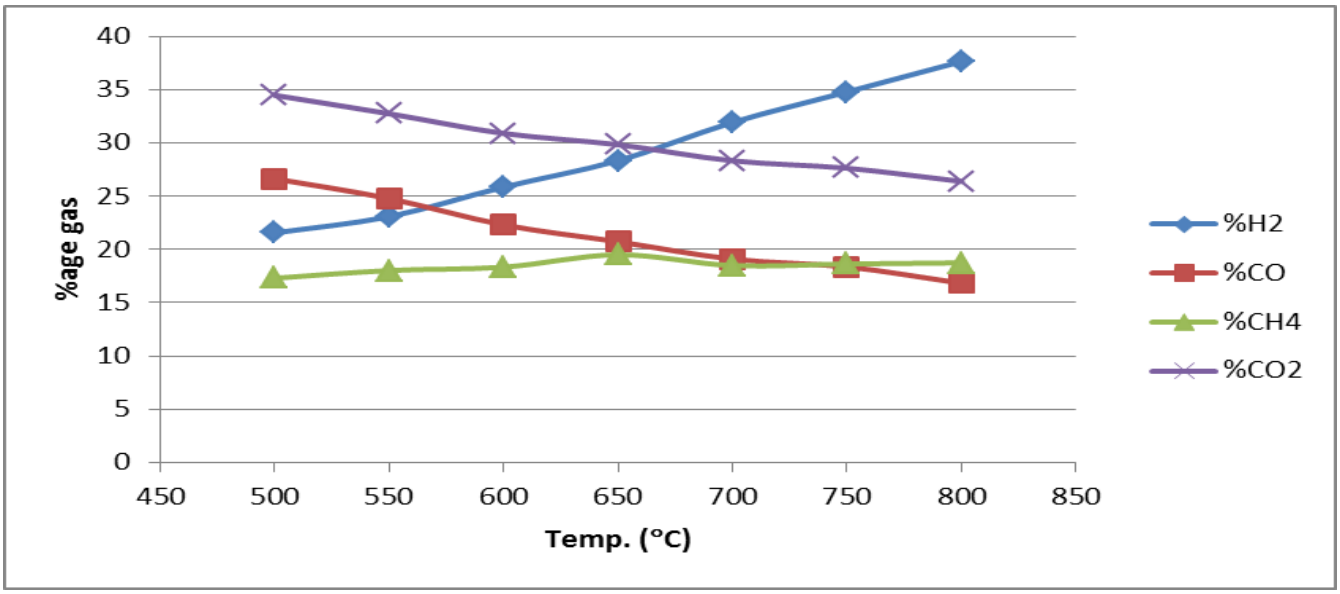

Figure-5 Temperature Vs product gas composition

Experimental Analysis:

3.3.4 Effect of varying temperature on product gas composition at egg cover waste.

Bed material = Silica Sand, feed material = 10 kg/hr.

Product gas composition on nitrogen free basis.

Table No. 10 Egg cover by product gas composition (vol.%) at different temperatures

Temperature ^{0}C	H_2 (vol %)	CH_4 (vol %)	CO_2 (vol %)	CO (vol %)
500	20.84	10.53	36.62	31.02
550	24.61	10.01	35.31	28.94
600	30.60	9.84	31.53	25.43
650	32.84	10.34	29.50	24.61
700	36.71	9.31	28.91	23.84
750	38.84	8.91	27.84	22.43
800	42.83	9.10	25.72	21.30

Effects of temperature on composition of syn-gas for egg cover waste are shown below

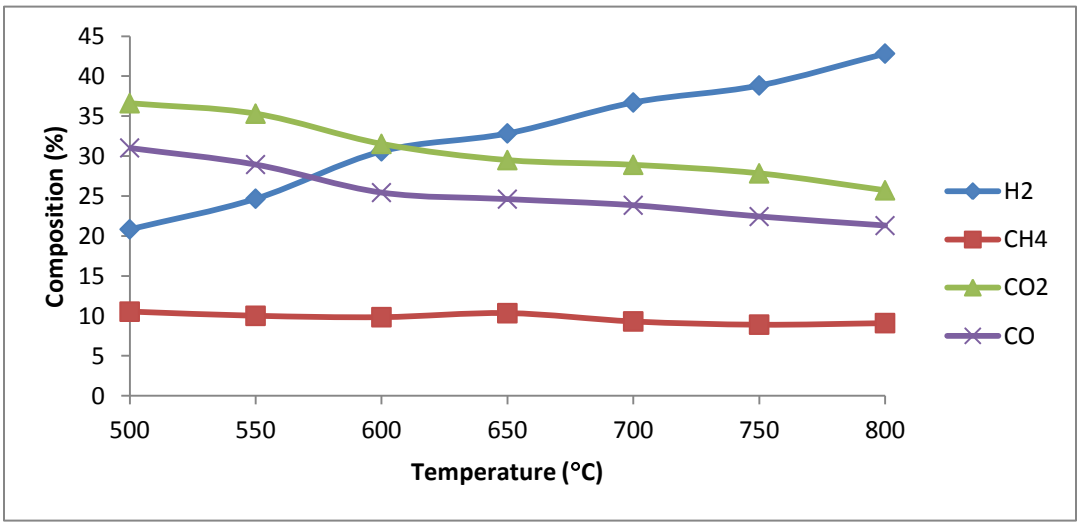

Figure-6 Temperature Vs product gas composition

CHAPTER 4

DISCUSSIONS

Discussions:

All experiments have been carried out under equivalent condition concerning fuel load and fluidization settings. The temperatures in the gasification zone, which are characterize the operating point at around 800^0C in all experiments. The report is show that fluidization behaviors of rice husk, household waste, egg cover and fruit waste (orange) are summarized in four experimental data. The convenience of comparison, all the report value have been converted to SI unit and air flow rate has been converted to corresponding equivalence ratio, which is defined the ratio of actual to stoichiometric mass of air supply per kg of fuel. In the deficiency of stoichiometric air or elemental composition in the reports. Therefore, a value of 10 kg/hr of dry household waste, egg cover, rice husk and orange waste taken.

Since, the fluidized bed gasifier is an endothermic reaction; the product gas composition is responsive towards temperature change. It was observed that the concentration of hydrogen increased with increased temperature, and the concentration of carbon monoxide remain constant over the range of temperature. As a result with increase in temperature and concentration of methane decreases in the product gas and this is approach to increases concentration of hydrogen. The carbon dioxide is concentration decrease with increase in temperature since higher temperature favors endothermic formation of carbon monoxide and carbon dioxide vie boudoirs reaction.

The gasification uses a relatively small amount of oxygen or water vapor to convert to organic compounds into a combustible gas. The volume of process gas per unit that could be integrated with combined cycle turbine or reciprocating engine and therefore synthesis gas converted to electricity more efficiently than the steam boilers used in combustion of municipal solid waste. Disadvantages are need for complicated pre- processing of the municipal solid waste to refuse derived fuel and formation of the inorganic compounds and that must be removes from the product gas prior to using in a turbine.

CHAPTER 5

CONCLUSION

Conclusion:

The gasification process offers extensive energy recovery and reduces the emission of potential pollutants. It is consider an integrating and alternative to the conventional technology for the thermal treatment of solid waste. The principal difficulty of solid waste gasification, in particular for municipal solid waste, furthermore an experimental analysis of solid waste gasification waste conducted to using fluidized bed gasifies. In any case gasification, particularly suitable for homogenous agricultural, industrial waste household waste and fruits waste. And volume percentage of hydrogen, carbon monoxide, carbon dioxide and methane was calculated on dry, inert free basis and neglecting other gases, which are very low concentrations. The results explain that the hydrogen concentration increase with increases temperature (500-800^{0}C). Some solid wastes have also comparison as well as, egg cover, household waste, agricultural waste and fruit waste. These are comparison fruit waste more suitable than other. And higher energy source fruit waste. This leads to better yield of hydrogen but much higher steam flow rates will have a contrasting effect on gasification rate because it reduces the reactor temperature.

Future Work:

(i) Using a gas engine electricity can be produced from synthesis gas.

(ii) Composition of different solid wastes can be studied in detail for maximum energy production.

(iii) CFD simulation can be carried out for electricity generation.

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