Gasification of Solid Waste

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Abstract

With an increasing demand for electrical energy, it is certain that the production will also increase, especially in rapid developing countries like Pakistan. Rapid industrialization is carving for more electrical energy, investment and suitable space for its infrastructure. But this development has to be sustainable keeping in mind the increasing global temperature due to pollution. Pakistan is the six largest populations in the world and hence produces a lot of waste daily. As of now, most of the waste goes to the landfills and gets burnt there or decomposed, either way releasing greenhouse gases in the process and degrading the environment. The municipal waste management is a challenging process in developing countries because of non-availability of proper infrastructure. There are some methods to manage this waste, such as scientific landfills, Incineration, Biomethanation, Gasification, Pyrolysis and Plasma Arc Gasification. By gasification the solid waste is converted into synthesis gas which can be used for chemical industries, power generation, transportation and industrial heating etc. This process shrinks the solid waste to slag or ash which can either be used to manufacture eco bricks or can be disposed of on landfill. Thus saving a lot of place from land filling and if used for power generation it does not release any considerable harmful gases into the environment making it a sustainable process and partially renewable source of energy. This project will estimate the cost and procedure to setup gasification plant. In the study, the generation, composition, treatment and energy potential of solid waste have been studied. The technologies for waste-to-energy conversion have also been studied and the feasibility comparison of two leading technologies has been done.

Keywords: Municipal Solid Waste, Gasification, Waste-to-Energy.

I. Introduction

Pervious concrete Combustion, gasification and pyrolysis are the thermal conversion processes available for the thermal treatment of solid wastes. As shown in Fig. 1, different products are gained from the application of these processes and different energy and matter recovery systems can be used to treat these. Gasification can be broadly defined as the thermochemical conversion of a solid or liquid carbon-based material (feedstock) into a combustible gaseous product (combustible gas) by the supply
of a gasification agent (another gaseous compound). The thermochemical conversion changes the chemical structure of the biomass by means of high temperature. Direct gasification occurs when an oxidant gasification agent is used to partially oxidise the feedstock. Pyrolysis is an indirect gasification process with inert gases as the gasification agent. As shown in Fig. 2, resulting from the gasification process and varying with the temperature at which the process is carried out, the three major output fractions are [I].

Figure 1: Thermal conversion process and products

1. A combustible gas
2. A liquid fraction (tars and oils); and
3. A char, consisting of almost pure carbon plus inert material originally present in the feedstock.

Figure 2: Gasification and pyrolysis Process
Due to the absence of nitrogen in the gasification agent, the indirect gasification process increases the volumetric efficiency and produces a gas with a higher heating value [II]. The lowering of gas production rate, typical of indirect gasification, reduces the cost of energy recovery and gas cleanup systems but is still complex and increases investment costs [III].

**Figure3:** Direct and Indirect Gasification Process

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**Solid waste and biomass:**

For a correct and efficient gasification process, a sufficiently homogeneous carbon-based material is required. Therefore many kinds of waste cannot be treated in the gasification process and for certain types an extensive pre-treatment is required (refuse derived fuel) (Fig. 4). Instead there are several types of waste that are directly suitable for the process; they are: paper mills waste, mixed plastic waste, forest industry waste and agricultural residues [IV].

In the gasification plant Thermie Energy Farm, one of the three IGCC projects selected for funding by the European Union, the sequence of treatment for tar-rich wastewater is [V] and [VI] precipitation of sulphur by iron sulphate addition; recovery of sulphur and dust by filtering; disposal of filter cake; stripping off gases dissolved in the water and the major part of the hydrocarbons; partial evaporation of water and usage of condensate as scrubber make-up; discharge of evaporator blow down to conventional bio-treatment. The salt recovered has a very low polluting potential, and is conveyed to a sanitary landfill. Hydrocarbons and other stripper
gases are recycled in the combustor for destruction, so that the tar energy content is recovered [VII]

II. Waste Gasification & Waste Combustion

Gasification produces an intermediate product, which is suitable for use in a wide range of applications, such as energy generation or liquid fuels and chemicals manufacturing processes. On the contrary, conventional WTE units directly combust waste feedstock. There is a potential for higher efficiency conversion when the fuel gas is burned in gas reciprocating engines or gas turbines or, better, integrated gasifier combined cycles, compared with conventional Rankine steam cycle power systems. Operating temperatures typically lower than those of direct combustion reduce potential for alkali volatilization, fouling, slagging, heavy metal volatilization and (for fluidized bed reactors) bed agglomeration. Application for power generation at a smaller scale (typically lower than 120 kt/y), for which the conventional direct combustion system could be not convenient, since gas cleaning (that is primary concern and expense) could be less relevant. Gasification plants are often modular (and this allows the possibility to modify the capacity of solid waste treatment) and are also quicker to build. Except for fly ash and some volatile components, most of the inert, non-combustible material is collected at the bottom of the reactor, with metals mainly in a non-oxidized form. Due to the reducing atmosphere, emission of dioxins and furans are strongly limited. Pre-mixed flames can yield substantial reduction of NOX emissions. In the case of heat gasifier configuration, between the gasifier and the combustor, raw syngas may undergo cooling and some sort of treatment. Cleaning of the product gas from gasification prior, for instance, to firing the gas in a boiler means that high temperature corrosion of the metal of the super heater is so reduced that higher steam temperatures can be tolerated and thus higher electric efficiencies can be achieved. However, syngas treatment is generally mild (typically, removal of coarse particular matter) because the homogeneous combustion process downstream can easily handle high contents of acid gas, impurities, tar, etc [VIII].

Figure 4: Heat Gasifier
Methodology

The most current

The biomass gasification process consists in the conversion of a solid/liquid organic compound in a gas/vapor phase and a solid phase. The gas phase, usually called "syngas", has a high heating power and can be used for power generation or biofuel production. The solid phase, called "char", includes the organic unconverted fraction and the inert material present in the treated biomass. This conversion represents a partial oxidation of the carbon in the feeding material and is generally carried out in the presence of a gasifying carrier, such as air, oxygen, steam or carbon dioxide. Biomass gasification is considered as a way to increase the use of biomass for energy production allowing widespread biomass utilization. The development of biomass gasification processes is pushed up by the growing awareness of the possible effects of fossil fuels on the climate and by the continuous increase in oil prices. The syngas produced is a gas mixture of carbon monoxide (CO), hydrogen (H2), methane (CH4) and carbon dioxide (CO2) as well as light hydrocarbons, such as ethane and propane, and heavier hydrocarbons, such as tars, that condense at temperatures between 250 and 300 °C. Undesirable gases, such as sulphidric (H2S) and chloridric acid (HCl), or inert gases, such as nitrogen (N2), can also be present in the syngas. Their presence depends on the biomass treated and on the operational conditions of the gasification process. The lowest heating value (LHV) of the syngas ranges from 4 to 13 MJ/Nm3, depending on the feedstock, the gasification technology and the operational conditions [VI]. The char produced is a mixture of unconverted organic fraction, largely carbon, and ash. The amount of unconverted organic fraction mainly depends on the gasification technology and the operational conditions. On the other hand, the amount of ash depends on the biomass treated. The LHV of the char ranges from 25 to 30 MJ/kg, depending on the amount of unconverted organic fraction. The principal reactions of the gasification are endothermic and the necessary energy for their occurrence is, generally, granted by the oxidation of part of the biomass, through an alloy-thermal or an auto thermal phase. In the auto-thermal process, the gasifier is internally heated through partial combustion, while in the allo-thermal process the energy required for the gasification is supplied externally [VII]. Considering the auto-thermal system, gasification can be seen as a sequence of several stages. A simplified schematic representation of the gasification is reported in Fig. 1. The main steps of the gasification process are:

1. Oxidation (exothermic stage).
2. Drying (endothermic stage).
3. Pyrolysis (endothermic stage).
4. Reduction (endothermic stage).

This paper is a literature study directing a viability study of MSW gasification plant. Lot of scientific articles were collected and studied, to come up with a technical, economical and legal feasibility study. The procedure to setup such plants was also studied and summarized. An additional step, consisting in tar decomposition, can be also
included in order to account for the formation of light hydrocarbons due to the decomposition of large tar molecules

III a. Oxidation

The oxidation of part of the biomass is necessary to obtain the thermal energy required for the endothermic processes, to maintain the operative temperature at the required value. The oxidation is carried out in conditions of lack of oxygen with respect to the stoichiometric ratio in order to oxidize only part of the fuel. Despite the partial oxidation involving all carbonaceous species (tars included), it is possible to simplify the system considering that only char and the hydrogen contained in the syngas participate in the partial oxidation reactions [X].

III b. Drying

Drying consists in the evaporation of the moisture contained in the feedstock. The amount of heat required in this stage is proportional to the feedstock moisture content. Generally, the heat required derives from the other stages of the process. Drying can be considered complete when a biomass temperature of 150 °C is achieved [IX].

III c. Pyrolysis

This phase consists in the thermochemical decomposition of the matrix carbonaceous materials; in particular, the cracking of chemical bonds takes place with the formation of molecules with a lower molecular weight. By pyrolysis it is possible to obtain different fractions: a solid, a liquid/condensed and a gaseous fraction [X].

III d. Reduction

The reduction step involves all the products of the preceding stages of pyrolysis and oxidation: the gas mixture and the char react with each other resulting in the formation of the final syngas. The main reactions occurring in the reduction step are:
\[ C + CO_2 \leftrightarrow 2CO \quad H = 172 \text{ kJ/mole} \] Boudouard reaction (1)
\[ C + H_2O \leftrightarrow CO + H_2 \quad H = 131 \text{ kJ/mole} \] Reforming of the char (2)
\[ CO + H_2O \leftrightarrow CO_2 + H_2 \quad H = -41 \text{ kJ/mole} \] Water gas shift reaction (3)
\[ C + 2H_2 \leftrightarrow CH_4 \quad H = -75 \text{ kJ/mole} \] Methanation (4)

IV. Conclusion

Gasification technology can be a good solution for energy production from renewables. Efforts are necessary to eliminate the causes that hinder its development on a large scale. Several technological problems exist, first of all the compatibility between the engines and syngas. The optimal operation of engines coupled with gasification plants requires a high quality standard fuel, but due to the high concentration of pollutants, such as tar, ammonia, chloridric acids, the syngas quality is often insufficient. Further more, gasification companies provide little information about the cleaning section of plants and the engine is not guaranteed for a long period of time. Moreover, economic profitability strongly depends on the biomass market price. Even if gasification plants often obtain considerable financial incentives from governments. Due to the high syngas purity, required to save the catalyst in the biofuel synthesis, only few pilot or industrial plants for the production of liquid biofuels from syngas are functioning at present. In several gasification plants, in order to increase the cleaning efficiency, syngas depuration is performed at atmospheric conditions, with consequent losses in terms of gasification process efficiency and power production, especially when the gasifiers are coupled with high energetic conversion devices that require syngas at high temperature, such as high temperature fuel cells a gas turbines.

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