

Techniques of Tar Removal from Producer Gas – A Review

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ABSTRACT:Energy utilization is a basic measure of economic growth of any country, Most of the countries are depending mainly on liquid fuels like petrol, diesel etc. ; Petroleum purely contains HC mixtures and carbon dioxide. Perfect combustion is not possible with petroleum. It will lead to the generation of CO like emissions. Also at high temperatures the formation of NOX takes place which may lead to the environmental pollution. Also, these fuels are supposed to be depleted in course of time. So there is the need to search for alternative fuels. Producer gas is one of the alternative fuels which can be obtained from the local available wastes by thermo-chemical biomass conversion processes, especially gasification and pyrolysis.

Gasification is the conversion of biomass into a combustible gas mixture by the partial oxidation of biomass at higher temperature typically in the range 800o–900oC.The low calorific value (CV) gas produced (about 4–6 MJ/N m3) can be burnt directly or used as a fuel for gas engines and gas turbines. The main constituents of the producer Gas are CH4, CO, CO2, and other HC’s. During gasification of biomass, however, a large amount of tar is also formed. Tar has all organic contaminants with a molecular weight larger than benzene. Tar formation is one of the major problems to deal with because of blocking and fouling process equipment such as pipes and valves in gas engine and turbines. Also the presence of tar will impose serious limitations in the use of producer gas due to engine wear and high maintenance costs. This work deals with various Tar removal techniques.

KEYWORDS:Bio-fuel, Producer gas, Tar removal.

I. INTRODUCTION

Biomass gasification is the thermo chemical conversion of biomass materials into a producer gas, which is a mixture of carbon monoxide, carbon dioxide, methane, hydrogen, nitrogen and water vapour.

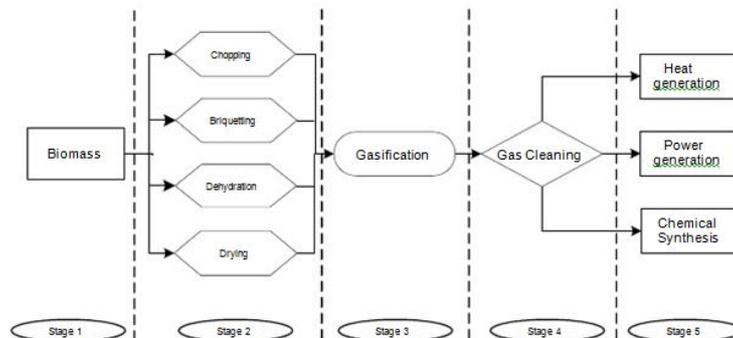


Fig 1: The process of gasification

The Fig 1 shows the process of gasificationGasification is a process of converting solid fuels into gaseous fuel. It is not simply pyrolysis, the pyrolysis is only one of steps in conversion process. The other steps are combustion with air and reduction of the product of combustion(water vapour and CO2) into combustible gases(carbon monoxide ,hydrogen ,methane ,some other hydro carbons) and inert (carbon dioxide and nitrogen). The process leads

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to the gas with some fine dust and condensable compounds termed tar, both of which must be restricted to low values if the gas is to be used in internal combustion engines

1.1. BIOMASS RESOURCES:-

The biomass resources include organic materials obtainable from forest, agriculture, aquaculture and organic waste residue from industrial and social activities.

Forests: Forests are source of fuel wood, charcoal and producer gas. Forest waste and residues from forest processing plants can be used as biomass. Certain plants produce seeds to yield vegetable oils which can be used in biofuels

Agriculture residues: Straw, rice husk, groundnut shell, coconut shell and sugarcane bagasse are crop residues which are the main biomass resources. The crop residues are generally gasified to obtain producer gas. The crop residues are also converted into fuel pellets to be used as solid fuels.

Energy crops: Energy crops are the cultivation which provide raw materials for biofuels. These include sugar plants to provide bioethanol, starch plants to produce bioethanol and oil producing plants to produce biodiesel.

Urban waste: Urban waste can be garbage or municipal solid waste and sewage or liquid waste. Garbage can be burnt to obtain biomass energy while sewage has to be processed to obtain biogas.

Aquatic plants : Certain aquatic or water plants are capable of growing extremely fast and supply organic raw materials for producing biogas. The fast growing water plants include water hyacinth, seaweed algae and kelp.

1.2. TYPES OF GASIFIERS:

Conventionally, gasifier can be classified as :Fluidized bed gasifier and Fixed bed gasifier

1.2.1. FIXED BED GASIFIERS:

Fixed bed gasifiers are classified depending upon the flow path of feedstock (biomass) and the generated gas (producer gas) as Updraft, Down draft and Cross draft systems

Updraft gasifiers:

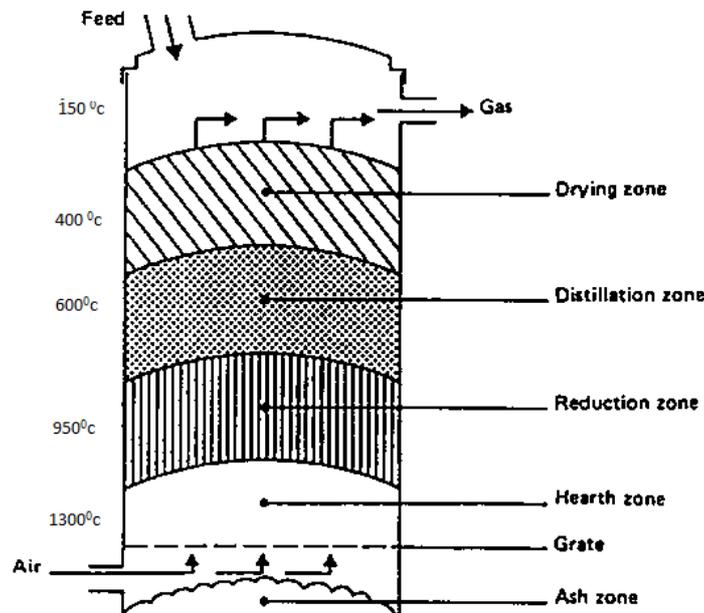


Fig2 : Updraft Gasifier

The start-up scheme would be built around a fire-on-grate over which the fuel bed rests; The Fig 2 shows, the Updraft Gasifier the hottest zone is created over the grate because of the exothermic reaction of air with char and biomass. This zone extends over a few particle depths through which the oxygen will get consumed. The products of combustion will percolate through the bed, heating up the biomass till volatiles are expelled from it. These volatiles are at temperatures of 300°C to 400°C. The gases with a mix of product gases and volatiles will move further in the bed,

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transferring the heat to dry the biomass till both temperatures are nearly same. By proper feeding process, this temperature can be maintained at 150oC to 200oC to ensure that the volatiles do not condense inside the reactor. The final product gas is composed of significant moisture, volatiles and product gases. The volatiles may condense into a viscous fluid.

II. PROBLEM DEFINITION

Gasification converts biomass into combustible gases, such as H₂, CO, CH₄ that can be used in boilers and in internal combustion engine or turbine to produce electricity generation [1]. The table 2.1 shows Gas quality requirements for power generation [2]

Constituent	units	IC engine	Gas turbine
Particles	mg/Nm ³	< 50	<30
Particle size	µm	<100	<5
Tar	mg/Nm ³	<10	n.d.*
Alkali metals	mg/Nm	n.d.*	<0.24

Table 2.1. Gas quality requirements for power generation

During gasification of biomass, however, a large amount of tar is also formed. Tar has all organic contaminants with a molecular weight larger than benzene [4]. Tar formation is one of the major problems to deal with because of blocking and fouling process equipment such as pipes and valves in gas engine and turbines [3] [4]. Also the presence of tar will impose serious limitations in the use of producer gas due to engine wear and high maintenance costs [5].

By far, tar removal is the most problematic. Thus the successful implementation of gasification technology for gas engine/turbine based power projects or for fuel cell applications depends much on the effective and efficient removal/conversion of tar from the producer gas. The aim of the research was to reduce tar content directly in the gasifier and to produce a producer gas with a high caloric value

2.1. CONVERSION METHODOLOGIES:

By far, tar removal is the most problematic. Thus the successful implementation of gasification technology for gas engine/turbine based power projects or for fuel cell applications depends much on the effective and efficient removal/conversion of tar from the producer gas. Several approaches are presently being investigated as a solution to address this problem.

Primary methods:

Tar formation results from the incomplete conversion of the liquid products in the gasification. This is caused by the limitations on account of the physical or geometrical design of the gasifier coupled with the limitations in the chemical reactivity [6]. Apart from overcoming the limitations in the gasifier design, various catalysts are being investigated to enhance the chemical reactivity [7].

Secondary methods

One of the challenges related to primary measures is a particular design would apply to one type of a gasification fuel. In secondary gas cleaning system, the gas contaminated with tars, particulates and other components acts as the input to such a system. The gas cleaning systems should meet the requirements of the end-use or the downstream applications. Removal of tars can be done by two approaches:

a) **Physical removal** [2]: The gas cleaning is mainly done by means of scrubbers, i.e. by condensing tars. The aerosols formed are later removed by means of wet ESP's. Newer methods also proposes to recycle the scrubbed tars in to the gasifier [8].

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b) **Chemical removal** [9]: In this approach a chemical conversion of tars is achieved, i.e. by means of thermal (by partial oxidation) or catalytic cracking (by dolomite, or nickel catalyst).

To extract thermal energy from the biomass following methods are available. Conversion of biomass to energy is undertaken using two main process technologies:

- A. Thermo-chemical
- B. Bio-chemical / biological.
- C. Mechanical extraction.

Within thermo-chemical conversion four process options are available:

- i. combustion
- ii. gasification
- iii. Liquefaction and
- iv. pyrolysis

Combustion: The burning of biomass in air, i.e. combustion, is used over a wide range of outputs to convert the chemical energy stored in biomass into heat, mechanical power, or electricity using various items of process equipment, e.g. stoves, furnaces, boilers, steam turbines, etc. Combustion of biomass produces hot gases at temperatures around 800–1000°C. It is possible to burn any type of biomass but in practice combustion is feasible only for biomass with a moisture content <50%, unless the biomass is pre dried.

Gasification: Gasification is the conversion of biomass into a combustible gas mixture by the partial oxidation of biomass at higher temperature typically in the range 800^o–900^oC. It is a combination of oxidative pyrolysis and hot-char caused reduction reactions. The low calorific value (CV) gas produced (about 4–6 MJ/N m³) can be burnt directly or used as a fuel for gas engines and gas turbines.

Liquefaction: Liquefaction is the conversion of biomass into a stable liquid hydrocarbon using low temperatures and high hydrogen pressures. This process is more complex and more expensive than pyrolysis process.

Pyrolysis: Pyrolysis is a process in which the solid fuel will be converted at high temperatures to vapour and gases in the absence of any oxidant. The output can be condensed to ambient temperature to lead to water and some complex oxygenated hydrocarbons in the form of liquids and permanent gases like CO, H₂, CO₂ and CH₄. There is also residual solid in the form of char. The fraction of solids, liquids and gases will depend on the rate of temperature rise and actual temperature to which it is raised. Typically, volatiles begin to evolve at about 300°C to 500°C depending on the actual biomass considered. At a low end, drums built to carry petroleum tar and other crude oils are often used to produce char by burning away the volatiles leading to 20% to 30% char.

Bio-chemical conversion encompasses two process:

- i. Digestion (production of biogas, a mixture of mainly CH₄ and CO₂)
- ii. Fermentation (production of ethanol)

Fermentation: It is used commercially on a large scale in various countries to produce ethanol from sugar crop and starch crops. The biomass is ground down and the starch converted by enzymes to sugars, with yeast then converting the sugars to ethanol

Anaerobic digestion: AD is the conversion of organic material directly to a gas, termed biogas, a mixture of mainly methane and carbon dioxide with small quantities of other gases such as hydrogen sulphide.

Producer gas can either be used in mono or dual fuel mode in reciprocating engines. In case of mono fuel mode of operation, the gas is fuelled to a SI engine, whereas in the dual fuel mode it is operated along with small quantity of liquid fuel in a compression ignition (CI) engine. The choice of mode of operation is entirely dictated by the economics of the operation, and of course on availability of appropriate engines.

III. TAR REMOVAL TECHNIQUES

There are different methods to remove the tars from the producer gas. The following Fig 3 shows some of them

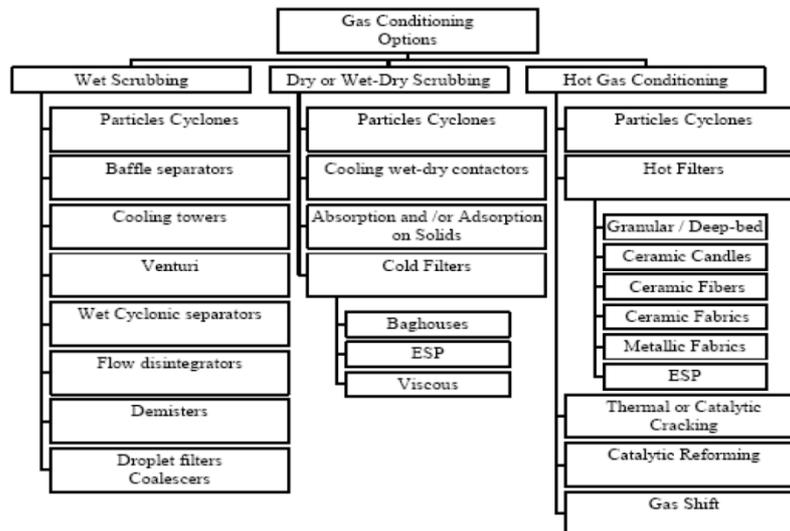


Fig 3: The techniques of Tar removal

Cooling Towers and Venturi Scrubbers

Cooling/scrubbing towers are usually used after cyclones as the first wet scrubbing units. All heavy tar” components condense there. In venturi scrubber a throat section is built into the duct. As the gas enters the venturi throat, both gas velocity and turbulence increase. The scrubbing liquid is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the throat and droplet-particle interaction is increased. After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles have been captured by the liquid, the wetted particulate matter and excess liquid droplets are separated from the gas stream by an entrainment section which usually consists of a cyclonic separator or mist eliminator [10]

Thermal Cracking of Tars

Thermal processes raise the temperature of the producer gas to the levels that “crack” the heavy aromatic tar species into lighter and less problematic species, such as hydrogen, carbon monoxide and methane. For this process, it is suggested that temperatures exceed 1000oC in order to reduce tars effectively[10]

Partial Oxidation

When oxygen is added selectively to different stages, such as in secondary zones of a pyrolysis-cracker reactor, tars can be preferentially oxidized[10]

Catalytic Cracking of Tars

The research on catalytic, hot-gas cleanup has involved (a) incorporating or mixing the catalyst with the feed biomass to achieve so-called catalytic gasification or pyrolysis; and (b) treatment of gasifier raw gas in a second bed or beds[10]

Syngas Sampling

The structure of the gas sampling process is shown in Fig 4.

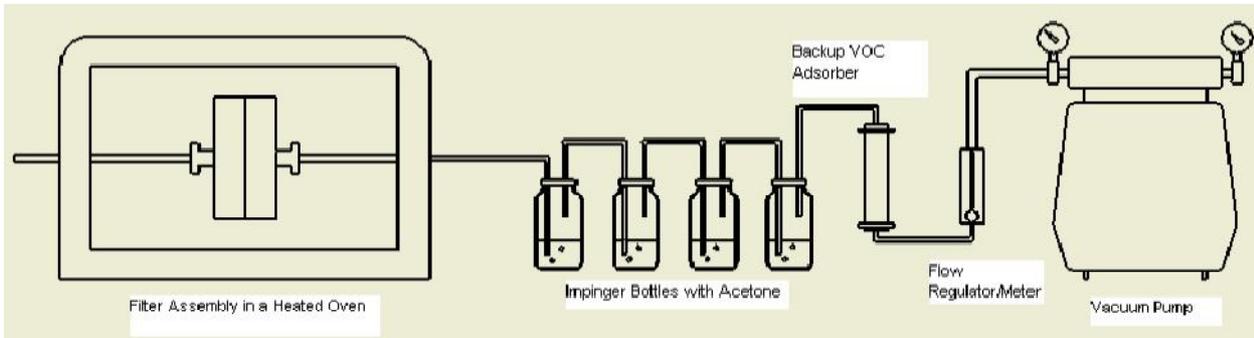


Fig 4: The structure of the gas sampling process

Gas traveled through copper connection tubing to the filter assembly where the particulates are collected. At temperatures around 250°C, most of the tar contained in the gas passed through the connection tubing to a series of impinger bottles containing acetone in which it was dissolved. The vacuum pump generated suction for the process and the flow regulator controlled and measured the volume of gas sampled.

All condensed tar particles were washed from the transfer lines (e.g. copper tubing) using the high purity acetone and combined with the tar collected in the impinger bottles. The mass of gravimetric tar was determined through solvent evaporation. The results were calculated using the following equation:

$$C_t = \frac{W_t}{V_g}$$

Where: C_t = Concentration of tar in syngas (g/m^3)

W_t = Weight of tar (g)

V_g = Volume of sampled gas (m^3) [10]

III. BIOMASS PYROLYSIS

A schematic representation of the experimental setup shown in fig 5. the feed stock was prepared from Japanese cedar, crushed and sieved with a mesh size of 0.71-1.00mm. the feedstock was dried at a temperature of 105°C overnight in an oven, before it was packed in the feeder, to remove moisture.

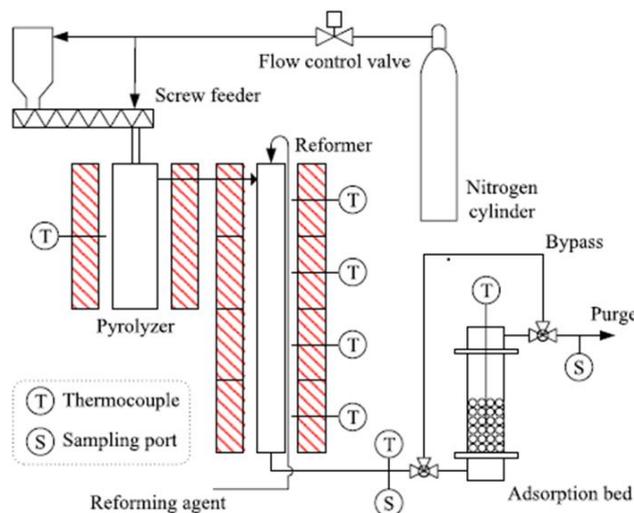


Fig 5 : Diagram of the experimental equipment

The proximate and ultimate analysis result of the feedstock are summarized. The feedstock was introduced into the pyrolyzer by a controlled screw feeder with a Continuous feed rate of 0.6 g/min. the pyrolyzer reactor was made of stainless steel with an inner diameter of 30 mm and length of 280 mm, and was surrounded by an electric heater. in

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each experiment, the pyrolyzer was heated up to a temperature of 6000c and kept at this temperature for 30 min before starting the feeder, in order to ensure that pyrolyzer tar production should be done under a steady –state operation. When the feedstock was introduced into the pyrolyzer, the feedstock released its volatiles in the form of syngas and tar aerosols, which was carried out of the pyrolyzer by nitrogen, used as a carrier gas, and entered the gas cleaning equipment with the flow rate of 1.51/min. the product Of the pyrolysis process was sampled at the exit of the reformer, which was kept at 4000c, in order to avoid tar decomposition or condensation.

4.1 TAR DECOMPOSITION:

Pyrolysis tar decomposition experiments under different reforming agents were carried out in an externally heated reactor. The reactor called as the reformer was made of stainless steel with an inner diameter of 25mm and a length of 1300mm. The entire pyrolysis product in the form of gas was supplied directly in to the reformer in the tar decomposition experiment. The effect of each reforming condition was investigated on the basis of the changing gravimetric tar mass and concentration of tar compounds ,and their changes were compared with the result of the pyrolysis condition. All experimental conditions of tar decomposition are summarized. In the studies of steam and air reforming, water and fresh air were heated up to the temperature of reforming, before being supplied in to the reformer for supporting the tar decomposition reaction. The parameters of steam and air reforming used to observe the effect on tar decomposition are given by the steam to biomass(S/B)ratio and the equivalent ratio (ER),respectively, where the S/B ratio is defined as the steam mass flowrate divided by the feedstock mass flowrate on the dry basis.while the the ER is defined as the actual amount of air supplied to the reformer divided by the stoichiometric amount of air for complete combustion of the feed.

4.2. TAR ADSORPTION:

Adsorption studies were carried out using a fixed-bed type adsorbed, which was installed downstream of the reformer. The entire reformer product was supplied directly into the adsorption bed through a high temperature resistance tube connector. The reformed gas was cooled down to the temperature of 25–30C by natural convection without any heat exchanger device. Before starting the tar adsorption experiments there formed gas was by- passed from the adsorption bed for 30min in order to ensure that the upstream reactions were under a steady-state condition. Wood chip, as the same type of feedstock and synthetic porous cordierite were selected to study the adsorption ability of tar compound to compare them with the adsorption ability of activated carbon, which has a good adsorption performance to adsorb hydrocarbons. In case of wood chip, it was dried in a controlled oven at a temperature of 1050c Over night before using as an adsorbent .The characteristics of each adsorbent are summarized.

Adsorbent characteristics

Adsorbent	Activated carbon	Wood chip	Synthetic porous
Shape mean particle	Granular 4	Chip 1.0-	Pellet
Volume of adsorbent (cm ³)	200	200	200
Weight of adsorbent (g)	85.1	37.9	109.4
Advantage	Good adsorption	Low cost	Re-usable

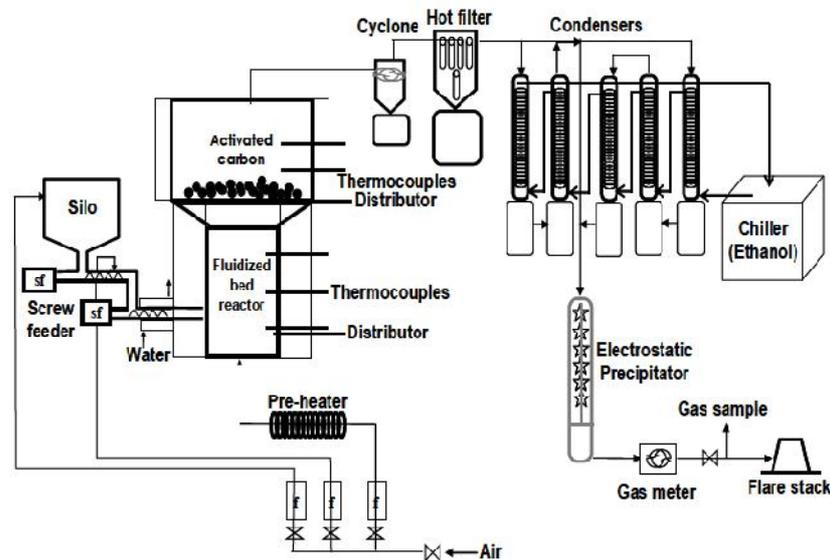


Fig 5 : Tar removal

In the experiments activated carbon was applied to reduce tar components in producer gas. In experiments, the total amount of tar in producer gas was reduced six fold when activated carbon was used in the upper reactor of the gasifier (11)

The plant has two reactors made of STS - 316 are in series, which were heated indirectly with electricity and. The bottom reactor was filled with silica sand and the upper reactor was filled with activated carbon for tar - cracking. The two reactors were separated by a distributor. Air, a fluidizing medium, was heated by a pre - heater to reduce heat loss of bottom reactor and then entered in the bottom reactor. Immediately after the gasification, producer gas passes through a char separation system consisting of a cyclone and a hot filter. After that liquid was collected condensers. Finally, electrostatic precipitator (EP) captured particles and aerosols in producer gas.

IV. CONCLUSION

As the reactor temperature increased, H₂ concentration strongly increased up to 16.6 vol.%. With respect to the influence on equivalence ratio, it was found that increase in equivalence ratio led to the higher production of CO₂,

Activated carbon played a significant role in tar - cracking and H₂ production. Total tar content consisting of tar on apparatus and in condensate liquid reduced from 24 g to 4 g, when activated carbon is used. [11]

Liquid fuels like petrol, diesel etc, which are supposed to be depleted in course of time. So there is the need to search for alternative fuels. biomass are cheap compared to the other alternative fuels and these are abundantly available.

Tar elimination efficiencies of the removal of tar decomposition combined with physical tar adsorption were investigated by using a reformer as the first step and a fixed bed adsorber as the second step. Thermal tar decomposition was carried out at a temperature of 8000c. High temperature had a strong influence on tar decomposition. removal of tar aerosols in producer gas may be block the engine.

The non-condensable tar could be combusted in the downstream combustion equipment, three different adsorbents were conducted to study their performance of light tar removal. activated carbon showed the best adsorption performance for both light aromatic hydrocarbon tar and light tar among other adsorbents.

As inert co₂ we have to remove co₂ from the producer gas from the mentioned techniques..

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