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A Review of Coal Gasification Process, Byproducts and Its Environmental Impact

Devendra Kumar Gupta

[2]*Department of Mechanical Engineering, GLBIT, Greater Noida, India*

ABSTRACT

Coal is one of the abundant source of energy and has many possibilities in the energy sector fulfilling the demands of future generations when other resources are going to be depleted soon. Although as compared to other resources, coal costs more money for transport, storage and combustion, but there have been a continuous growth in the area of research to find the solution of these problems .Coal gasification is a method of producing Syngas- a mixture consisting primarily of methane (CH_4), Carbon Monoxide(CO), Hydrogen (H_2), Carbon Dioxide (CO_2) and water Vapor (H_2O) from coal and water, air or oxygen. Starting its use in earlier times from "town gas" now days coal is providing 70% of electricity in so many countries and much more [1]. This article is a brief study of gasification process of Coal, its byproducts and its environmental impact.

I INTRODUCTION

Coal as a fuel has been used in the earlier history as a fuel for street lightening and the coal gas was exactly produced by carbonization. In the 1850s every small medium sized town and city construct a gas plant so as to provide fuel for street lightening. Mond gas ,developed by Ludwig Mond, was producer gas made from coal instead of coke. Ammonia and coal tar were the byproducts and was processed to recover these valuable components. And as the time passed coal become one of the important fuel for the generation of electricity. Now a days so many countries are having power plants which uses coal as a fuel for different purposes and gasification is one of the best process to utilize this fuel efficiently.

II COAL AVAILABLE IN INDIA

Basically the quality of coal is classified into three sub categories according to the percentage of carbon present and the moisture content. These are Bituminous , Sub bituminous and Lignite. Indian coal is mainly a non coking coal. Coal when heated in absence of air produces a coherent bead, free from volatile with a strong is a potential solid fuel and is available in India in the states of Tamil Nadu, Pondicherry, Gujarat, Rajasthan and porous mass called as coke, is called Coking coal.[1].We have lignite coal also known as 'brown coal" that and Kashmir.

III PROCESS

During gasification, the coal is blown through Oxygen and steam (water vapor) while also being heated at a fixed temperature.The process is also divided into forms of heat sources used i.e.,if the external heat is used for heating coal, then the process is called "allothermal", while "autothermal" process assumes heating of the coal inside the gasifier itself via exothermal chemical reactions occurring inside the gasifier. One thing is kept to be under consideration that the oxidizer supplied should be insufficient so as to avoid the complete combustion.

When the reactions start, oxidation of coal is done by the molecules of oxygen and water and produce a gaseous mixture of carbon dioxide (CO_2), carbon monoxide (CO), water vapor (H_2O), and molecular hydrogen (H_2). For this process natural coal seems are used and hence the process is known as Underground coal gasification. The final product is usually syngas (H_2 + CO), but the produced coal gas may also be further refined to produce additional quantities of H_2.

$$3C \text{ (i.e., coal)} + O_2 + H_2O \rightarrow H_2 + 3CO$$

It is profitable to explain that the coal gas is collected and routed to a to a Fischer-Tropsch reactor for producing further alkanes ,gasoline, and diesel fuel.

IV TYPES OF GASIFIERS

The process of gasification is divided into two forms according to the method of blowing of the fuel and the type of gasifier.

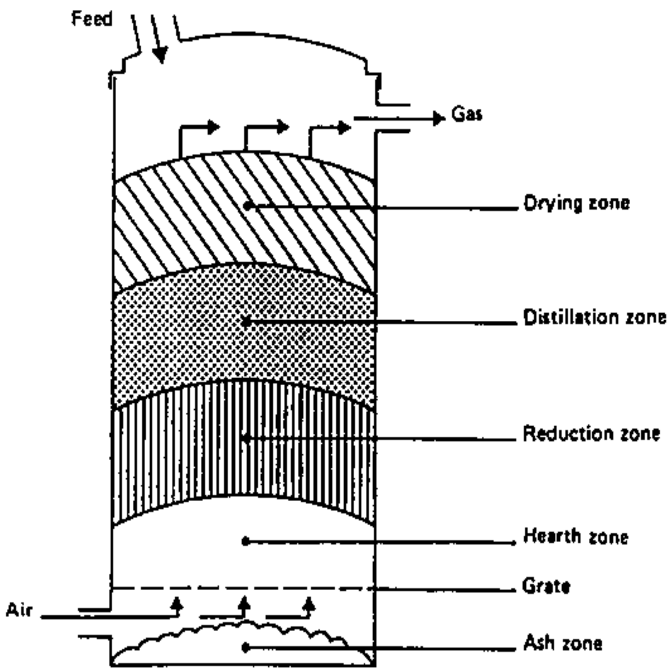
4.1 Updraught or counter current gasifier

The oldest and simplest type of gasifier is the counter current or updraught gasifier shown schematically in Fig4.1

The air inlet is kept at the bottom and the gas leaves at the top of the gasifier.The bottom zone is the combustion zone near the grate after which reduction reactions occur. In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones. The tars and volatiles produced during this process will be carried in the gas stream. Ashes are removed from the bottom of the gasifier.

The main advantages of this type of gasifier is its simple design, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high equipment efficiency.

Figure 4.1Updraught or counter current gasifier



Major drawbacks result from the possibility of **"channelling"** in the equipment, which can lead to oxygen break-through and dangerous, explosive situations and therefore there is a necessity to install automatic moving grates, as well as from the problems associated with disposal of the tar-containing condensates that result from the gas cleaning operations.[2]

4.2Downdraught or co-current gasifiers

A solution to the problem of tar entrainment in the gas stream is removed in co-current or downdraught gasifiers, in which primary gasification air is introduced at or above the oxidation zone in the gasifier. The Syngas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction, as schematically shown in Fig. 4.2

The fuel is passed through a glowing bed of charcoal on its way, due to this the distillation products and acid is converted into permanent gases hydrogen, carbon dioxide, carbon monoxide and methane. The temperature of the hot zone and the residence time of tarry vapors decides the breakdown of the tars, more or less.

Down draught gasifiers produce a tar free gas which is the most important advantage of this type of gasifiers.In practice, however, a tar-free gas is seldom if ever achieved over the whole operating range of the equipment,tar-free

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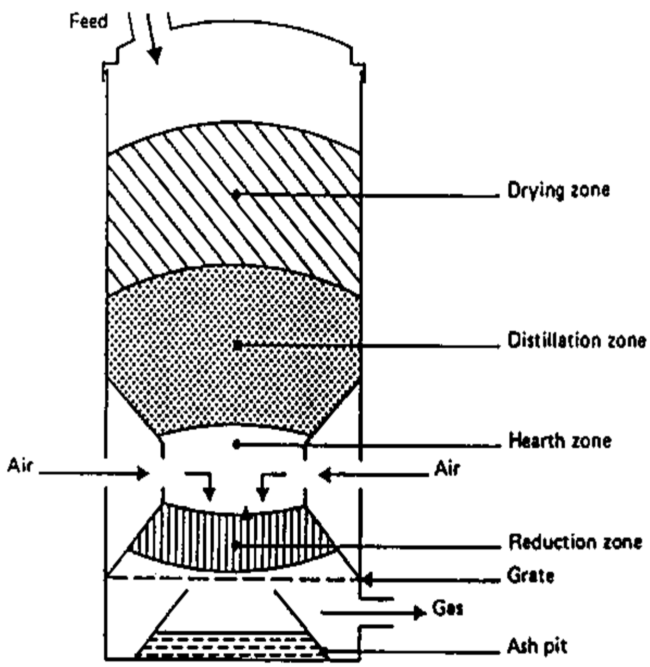
operating turn-down ratios of a factor 3 are considered as standard; a factor 5-6 is considered excellent.It should be noted that as compared to updraught gasifiers a less amount of organic components are present in the condensate and hence less environmental problems are present.

Figure 4.2 Downdraught or co-current gasifier



A major drawback of downdraught equipment is that the cannot processed fluffy, or low density materials and give rise to flow problems and excessive pressure drops,also solid fuel should be briquetted before the use.[2] Downdraught gasifiers also suffer from the problems associated with high ash content fuels (slagging) to a larger extent than updraught gasifiers. The efficiency is also lower resulting from lack of internal heat exchanger and lower heating value of the gas.

4.3. Cross-draught gasifier

Cross-draught gasifiers,mainly based on the use of charcoal During the gasification of charcoal the temperature goes to 1500^{0}C or more in the oxidation zone leading to material problems. Hence, thereforein cross draught gasifier insulation is provided for this high temperature problems by the fuel(charcoal) itself.
Advantages of the system is that it is a small scale process having installations below 10 kW (shaft power) can under certain conditions be economically feasible.

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A disadvantage of cross-draught gasifiers is their minimal tar-converting capabilities and the consequent need for high quality (low volatile content) charcoal.

It is because of the uncertainty of charcoal quality that a number of charcoal gasifiers employ the downdraught principle, in order to maintain at least a minimal tar-cracking capability.

4.4 Fluidized bed gasifier

In keeping consideration ,the problems occurring in down draught gasifier such as loss in bunkerflow, slagging etc., fluidized bed gasifiers are introduced.

A design approach aiming at the removal of the above difficulties is the fluidized bed gasifier illustrated schematically in Fig.4.4

A bed of solid particles is used through which the air at a sufficient velocity is blown through. The bed is originally heated by an external source and the feedstock is introduced as soon as a sufficiently high temperature is reached. The fuel particles are introduced at the bottom of the reactor and get mixed with the bed material and almost reach the temperature of the bed. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further gasification and tar-conversion reactions occur in the gas phase. Most systems are equipped with an internal cyclone in order to minimize char blow-out as much as possible. Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications[2].

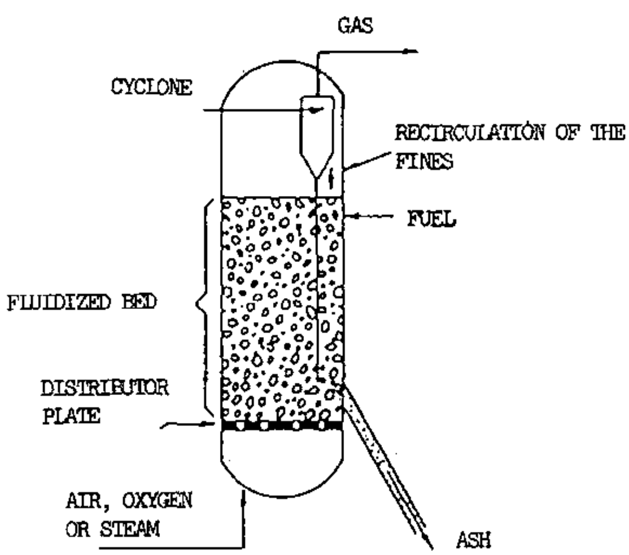
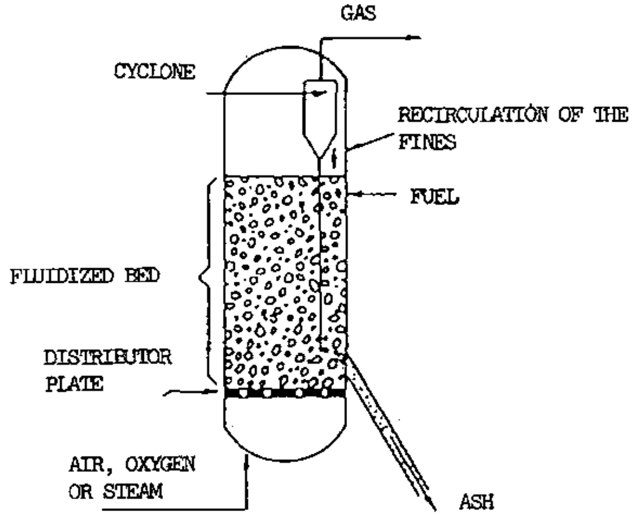


Figure 4.4 Fluidized bed gasifi



V. BYPRODUCTS AND THEIR PROPERTIES

The by-products of coal gas manufacture included coke, coal tar, sulfer and ammonia; all are very useful products. Dyes, medicines ,including sulfa drugs, saccharin and many organic compounds are therefore derived from coal gas. After the distillation of coal tar various products are recovered such as:

Tar: Tar made from coal or petroleum is considered toxic and carcinogenic because of its high benzene content.

Sulphur: Sulfur burns with a blue flame concomitant with formation of sulfur dioxide, notable for its peculiar suffocating odor. Sulfur is insoluble in water but soluble in carbon disulfide and, to a lesser extent, in other nonpolar organic solvents, such as benzene and toluene.

Ammonia: It is a colourless gas with a characteristic pungent smell. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers.

VI. ENVIRONMENTAL IMPACT OF MODERN COAL GASIFICATION

Coal gasification processes require controls and pollution prevention measures to mitigate pollutant emissions. Pollutants or emissions related to the coal gasification include primarily.

- **Ash & slag**

Non-slagging gasifiers produce dry ash similar to that produced by conventional coal combustion, which can be an environmental liability if the ash (typically containing heavy metals) is leachable or caustic, and if the ash must be stored in ash ponds. Slagging gasifiers, which are utilized at many of the major coal gasification applications worldwide, have considerable advantage in that ash components are fused into a glassy slag, capturing trace heavy metals in the non-leachable glassy matrix, rendering the material non-toxic. This non-hazardous slag has multiple beneficial uses such as aggregate in concrete, aggregate in asphalt for road construction, grit in abrasive blasting, roofing granules, etc. [3].

- Carbon dioxide (CO_2)

CO_2 is of paramount importance in global climate change.

- Mercury
- Arsenic
- Particulate matter (PM)

Ash is formed in gasification from inorganic impurities in the coal. Some of these impurities react to form microscopic solids which can be suspended in the syngas produced by gasification.

- **Sulfur dioxide (SO_2)**

Typically coal contains anywhere from 0.2 to 5 percent sulfur by dry weight, which converts to H_2S and COS in the gasifiers due to the high temperatures and low oxygen levels. These "acid gases" are removed from the syngas produced by the gasifiers by acid gas removal equipment prior to the syngas being burned in the gas turbine to produce electricity, or prior to its use in fuels synthesis.

- **Nitrogen oxides (NO_x)**

(NO_x) refers to nitric oxide (NO) and nitrogen dioxide (NO_2). Coal usually contains between 0.5 and 3 percent nitrogen on a dry weight basis, most of which is converted to harmless nitrogen gas. Small levels of ammonia and hydrogen cyanide are produced, and must be removed during the syngas cooling process. In the case of power generation, NO_x also can be formed downstream by the combustion of syngas in turbines.

During the gasification of wood and/or agricultural residues, ashes (from the gasifier and from the cleaning section) and condensate (mainly water) are produced. The latter can be polluted by phenolics and tar.

The ashes do not constitute an environmental hazard and can be disposed of in the normal way. For the tar-containing condensate the situation is different, and disposal of those from a large number of gasifiers can have undesirable environmental effects. No hard data are available on the bio-degradation of the phenolic and tarry constituents of the condensates, and the problem of disposal needs careful study.

The properties of exhaust emissions from engines run on producer gas are generally considered to be acceptable, compared to those of diesel engines.

VII. SUMMARY

Coal covers a major part of energy sector, although there are some problems such as transportation, installation etc.,but as soon as the other natural resource will be diminished, coal will become a major fuel for future demands.The high ash content and poor quality of coal sometimes creates problems in industries, but it should be consider before the application that the right technology should be used so as to produce an efficient result.However to use a better technology it should be clear that one has to study all the important points to use and to configure, analyze different options to remove the problems related from the environmental effects such as by carbon capture technology.

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