

Module 4: Gaseous Fuel

Lecture 27: Producer Gas

Keywords: Calorific value, solid fuel gasification, air blast, gas producer

4.2 Producer gas

Producer gas is a low calorific value fuel gas comprising of mainly carbon monoxide and nitrogen. It is produced by passing air or a mixture of air and steam through a burning bed of solid fuel such as, coal, coke, wood or biomass. Hydrogen is also present in a significant amount in the producer gas if air-steam blast is used. The exact composition of producer gas depends on the type of fuel, composition of the blast and operating condition. Producer gas is formed in a gasifier, called gas producer.

The reactions involved in gas producer are as follows:

1) When only air is used as blast through the fuel bed (air-blast),



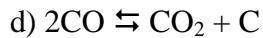
Reaction (a) is highly exothermic and occurs at temperature above 500^0C . Due to heat generation by this reaction, the fuel bed temperature increases. CO_2 formed in that reaction reacts with carbon of fuel to form CO. This reaction is named as Boudouard reaction and this reaction is important in the sense that the main component of producer gas, CO, is obtained in this reaction. This reaction is endothermic in nature and is favoured at temperatures above 500^0C . As a whole the net process is exothermic.

The overall reaction is



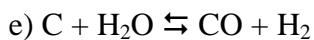
The favourable condition for reaction is high temperature, sufficient time of reaction and reactive fuel. If the fuel contains ash of low fusion point, such as below 1100°C , it melts and resolidifies into the cooler part of the fuel bed. This is called clinker and it disturbs the uniform burning of fuel and thus the overall efficiency decreases. The coals having big lumps are also not suitable as a good fuel due to non-uniformity of the bed. The lumps must be broken into small pieces for getting higher efficiency.

After producer gas is formed in the bed, an opposite reaction to the Boudouard reaction may occur, which is called Neumann reversal reaction, to form CO_2 and C.



2) When steam is used in admixture of air (steam blast)

At this condition, the above reactions occur (reactions a, b, c, d) and along with those, some other reactions also occur. Carbon reacts with steam to form carbon monoxide and carbon dioxide by the following reactions,



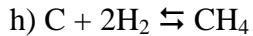
and f) $\text{C} + 2\text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 2\text{H}_2$

Both the reactions (c) and (f) are endothermic. The reaction (e) is active at or above the temperature 1000°C but reaction (f) occurs at the temperature range of 500 to 600°C . The later reaction (f) is not desirable as it produces CO_2 , which is not a component of producer gas, hence, always the fuel bed temperature is kept high to avoid this reaction.

The excess steam may also react with CO to form CO_2 and H_2 in water gas shift reaction as shown below. This is also an undesired side reaction.



Methanation or methane formation is another side reaction observed.



The above reaction is not favoured at high temperature.

There are several advantages of using steam blast over air blast. In steam blast, hydrogen and methane are the two gaseous components formed which add more calorific value to producer gas. The endothermic reactions (e) and (f), which occur in steam blast do not allow the fuel bed temperature to shoot up very high, and this way they prevent clinkering of bed to a great extent. Clinkering reduces overall efficiency.

The optimum temperature required for producer gas manufacture is within the range 1100 – 1300⁰C. There is some restriction on the amount of steam also. The endothermic reactions, (e) and (f) occur at a faster rate using large amount of steam, which thereby reduces the fuel bed temperature below 1100⁰C. Lower temperature of fuel bed encourages the carbon dioxide formation by the reactions (a), (f).

Steam blast is formed either by injecting steam to the air or passing air through water. The first process is more convenient to use. The temperature of the air is raised by blowing steam into it upto a desired temperature. This temperature is called 'blast saturation' temperature.

Gas producer

In the gas producer, the fuel bed is set on a metallic grate. Fig 1. depicts a fuel bed in a gas producer with different reaction zones. The zones are ash zone, oxidation zone, primary reduction zone, secondary reduction zone and drying zone. Different reactions occur at different zones of the bed. In a countercurrent movement of air-steam blast and solid fuel, the blast gets preheated at the ash zone. In the oxidation zone, carbon dioxide is formed by the reaction of carbon and oxygen of air. In the primary reduction zone, several reactions occur which produce carbon monoxide, carbon dioxide and hydrogen (reactions b, e and f). At this stage carbon monoxide formation is quite high. After this, secondary reduction zone starts where steam reacts with carbon monoxide to produce carbon dioxide.

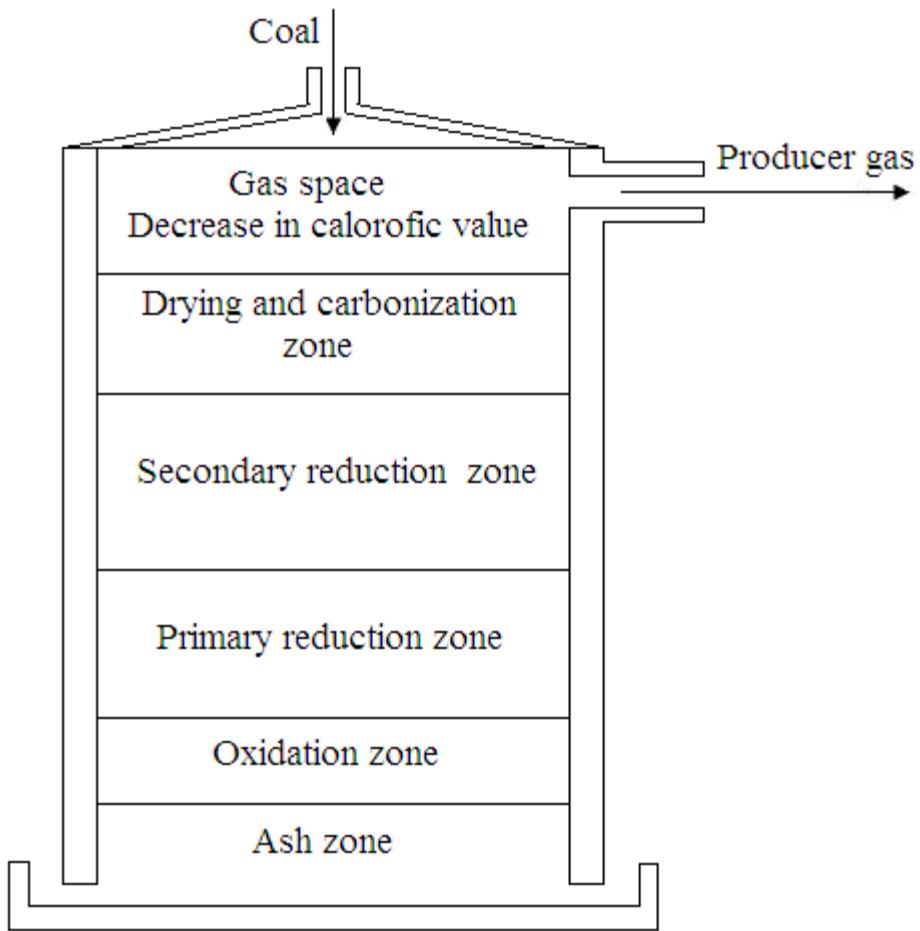


Fig 1. Different reaction zones in a gas producer

The topmost zone is drying zone where water vapour and volatile matter of the fuel are added to the gas. Hence, it is observed that, as the gas travels through the bed, its composition goes on changing at each point. The addition of volatile matter increases the calorific value of the exit gas. After the gas leaves the bed, it comes to the gas space above the bed. Here, water gas shift reaction (g) and Neumann reaction (d) occur, where, amount of carbon monoxide decreases. Hence, the composition of the producer gas is changed and a decrease in calorific value of the gas is observed.

Different types of gas producers are used in industry. Depending on the direction of fuel and blast movement, the producers are broadly classified as, up-draft, down-draft and cross draft producers. In these types of producers, the fuels move either countercurrent or concurrent to the flow of gasification medium (steam, air or oxygen) as the fuel is converted to fuel gas. They are relatively simple to operate in a fixed bed process.

In an updraft fixed bed producer, the flows of the fuel and gases are countercurrent to each other. The reactive agent, i.e air-steam blast is injected at the bottom of the reactor and ascends to the top while the fuel is introduced at the top and descends to the bottom through zones of progressively increasing temperatures (drying, secondary reduction, primary reduction and oxidation). Heat from the primary reduction and oxidation zones rises upward to provide energy for the next zones. Gases, tar and other volatile compounds are distributed at the top of the reactor and increase the calorific value of producer gas, while ash is removed from the bottom.

In case of downdraft producers, the locations of the zones are reversed. The fuel is introduced at the top, and the reactive agent is introduced through a set of nozzles on the side of the reactor. Producer gas leaves from the bottom of the producer.

Cross-draft producers exhibit many of the operating characteristics of downdraft gasifiers. Air or air/steam mixtures are introduced into the side of the gasifier near the bottom, while the producer gas is drawn off on the opposite side.

Producer gas has a very low calorific value in the range of 1000 to 1200 Kcal/Nm³. Applications include the use of it as fuel for industrial kilns and heat treatment furnaces, such as those found in steel plants. Producer gas is also usable in plants that melt zinc for use in galvanizing processes and for melting metals, such as aluminum and copper. It is used for heating open

hearth furnaces in the manufacture of steel and glass. It is used for heating muffle furnaces and retorts in the manufacture of coke and coal gas.

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