Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 1; October, 2014 pp. 1-3

http://www.krishisanskriti.org/jbaer.html

Effect of Char Structure on Coal Gasification

Akanksha Mishra[1], Shalini Gautam[2], Tripurari Sharma[3]

[1]*Mechanical & Automobile Engineering Department,*
Sharda University, Greater Noida, India
6akanksha2@gmail.com
[2]*Department of Fuel & Mineral Engineering, Indian School of Mines, Dhanbad, India*
shalini_ism@rediffmail.com
[3]*Department of Fuel & Mineral Engineering, Indian School of Mines, Dhanbad, India*
hodfmeism@yahoo.co.in

Abstract: **The Worldwide increasing population gives rise to energy demand-supply chain in different sectors such as commercial sector, industrial sector, residential sector and transportation sector. After the oil crises, coal becomes a major source of energy supply worldwide. In India coal is a primary energy source. Most of the conventional coal based power plants are the major source of carbon emissions which causes environmental pollution. So there is a need to adopt clean coal technology for power generation. Coal gasification is one of the essential clean coal technologies, because coal gasification is a mean to utilize coal more efficiently by reduction of CO_2 and other pollutant emissions in to the environment. Integrated gasification combustion cycle (IGCC) with possibility of cogeneration of electricity, chemicals and H_2, is another attraction of coal gasification technology. Coal gasification is affected by several parameters such as operating conditions like pressure, temperature and medium during pyrolysis and gasification, rank of coal, and char structure. Among all parameters char structure: porosity and surface area plays an important role during coal gasification. In this paper an attempt has been made to compile the investigations carried out by various researchers on effect of char structure on coal gasification.**

1. INTRODUCTION

Coal is playing an important role in achieving the world's energy requirement for the current energy demand and also for the next few decades. However energy production from coal via a conventional combustion process causes CO_2 emission which is badly affecting global warming. Therefore the development and operation of clean coal technologies with higher efficiency is essential to reduce CO_2 emissions and another environmental pollutions cause by the use of coal [1]. Coal gasification is used as a clean coal technology in the world. Coal gasification is a well-known method for coal utilization for power production [1, 2, 3]. Number of technologies such as pressurized fluidized-bed combustion (PFBC) and integrated gasification combined cycle (IGCC) are found to be most feasible alternative for the utilization of coal as a clean fuel because of their use of combined cycles and by reduction of CO_2 emissions [3]. Advantages of IGCC power plant brought it into commercialization process in United State and Europe.

Gasification is an effective and clean way of conversion of solid coal to gaseous products. Gasification of coal occurs in two steps: (a) pyrolysis and (b) gasification. Coal pyrolysis process is reliant on the organic properties of the coal. Coal structure is complex because of that coal pyrolysis consists of series of complex reactions. Coal structure becomes more organized and simplified with the increase in rank of coal. If after coal pyrolysis carbon rich solid residue is in powder form, is known as char and if the same is in agglomerated form, is known as coke. Coal gasification is defined as the coal reaction at elevated temperature (exceeding 700^oC) with steam, air, carbon dioxide and oxygen to yield gaseous products, theses gaseous products are suitable to use as a gaseous fuel [1]. Coal gasification reactivity is affected by several parameters such as rank of coal, pyrolysis operating conditions, structure of char obtained from pyrolysis and gasification operating conditions. For the design and modeling of gasifiers understanding of kinetics and structure of char is essential. In literature structure of coal studied broadly due to its importance in char combustion and gasification. In this paper an attempt has been made to compile the outcome of several researchers [1-12] on char structure and effect of char structure on char gasification.

2. CHAR STRUCTURE: POROSITY AND SURFACE AREA

Coal is made up of aromatic and hydroaromatic structural blocks. There are various type of cross linkages between them and heteroatom functional groups at their periphery. Amount of porosity in coal is decided by extent of cross links between the building blocks. There are three types of structures which are present in coals [4]:

Open structure

This structure is generally found in lower rank coals (upto 85% carbon). This type of coals is generally highly porous.

Liquid structure:

This type of structure is found in coals ranging from 85 to 91% carbon. This range of coals is less porous.

Anthracite structure:

This structure is found in higher rank coals (over 91% carbon). This type of coal structure also leads to porous coals.

Char particles obtained from coal pyrolysis contained large number of pores with radii range from one length of nanometer to tens of micrometers [5]. Generally char pores are different in size as well as randomly orientated. Pores in char are classified as micropores and feeder pores (mesopores and macropores). Mainly micropores determine the reactivity of char while feeder pores provide channel to the reactant gas to pass through carbon active site in the micropores [5, 6]. There are two competing phenomena to determine the evolution of pore structure: coalescence of neighboring pores and growth of individual pores [5]. The gasification rate of char in any medium of gasification such as steam, carbon dioxide and oxygen is governed by its structure. Bhatia and gupta [7] reviewed several types of pore structure models existing in literature and suggested that normally pore structure models consider that gasification reaction occurs on the surface of the micropores, which is responsible for the main part of char surface area. Generally gasification reaction is considered to occur on the active surface area, this active surface area is a part of total surface area or importantly on reactive surface area which is a part of active surface area [8]. Reaction rate normalization by reactive surface area and active surface area are reported to be more successful than total surface area [8]. On the other side Hurt et al. [9] reported that gasification reaction occurs on the surface of macropores i.e. outside the micropores. Hurt et al. [9] explained that micropores may be composed of basal planes, which are less reactive and macropores may come into sight in crystallite edges or sites in contact with catalytic active inorganic impurities. Both porosity and surface area of coal is rank dependent. Due to the structural changes during coalification. Porosity and surface area decreases with increase in rank, pass through flat minimum and then again increases with rank [1].

Generally with the increase in the heat treatment temperature, porosity and surface area of coal increases, passes through the maximum and then decreases. This happens because of volatile matter release due to change in structure during heating [1]. Fermoso et al. [10] reported liner correlation between reactivity index of char prepared under different microporoe surface areas and pyrolysis pressure. Arenilllas et al. [11] reported that char samples prepared at different temperature shows slower gasification reactivity with the decrease in porosity and surface area. Highly porous char surface area decreased linearly with increase in conversion, so gasification rate is linearly proportion to the surface area during gasification [12]. Adschiri et al. [12] reported that the initial surface area was measured for various chars which produced in the fluidized bed and surface area was correlated with the carbon content in the parent coal. Correlation is shown in Fig 1.

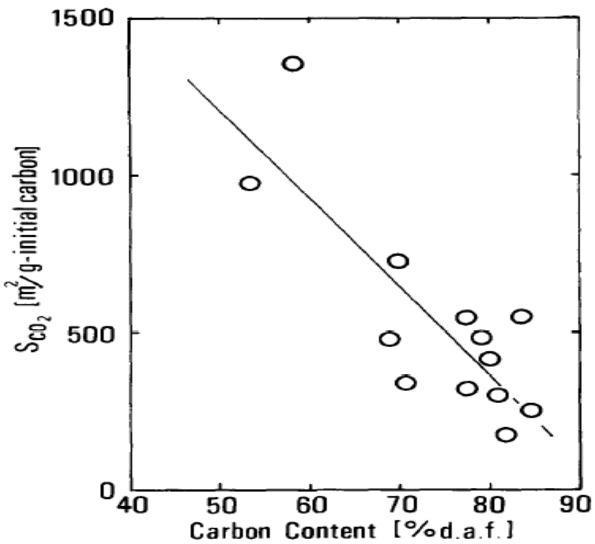

Figure 1: The corelation between the initial surface area of char produced in the fluidized bed and coal carbon content [12].

Ng et al. [6] reported the relationship between total pore volume of the coal and gasification rate. It is concluded from the Figure (2) that the reactivity of the coal remains constant at total pore volume less than 0.070 ml g - [1], above this rise in reactivity is rapid. This turning point occurs at about carbon content of 80 wt% where micropore volume predominant over the feeder pore volume (meso and macro pores) [6].

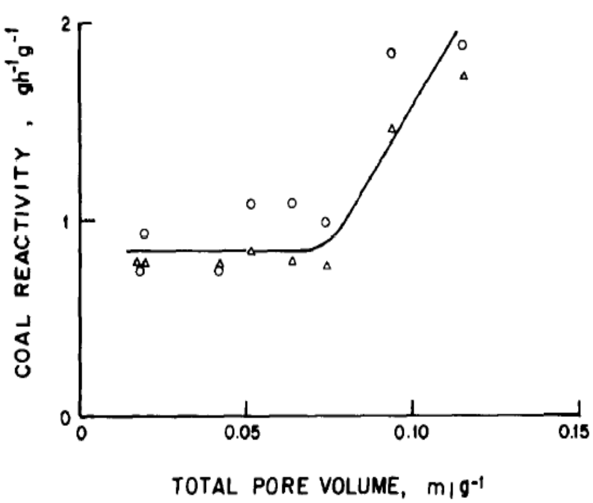

Figure 2: Relationship between gasification reactivity and total pore volume of coal; Δ:steam gasification, o: No steam [6].

Ng et al. [6] also reported that the reactivity of coal decreases with decrease in surface area

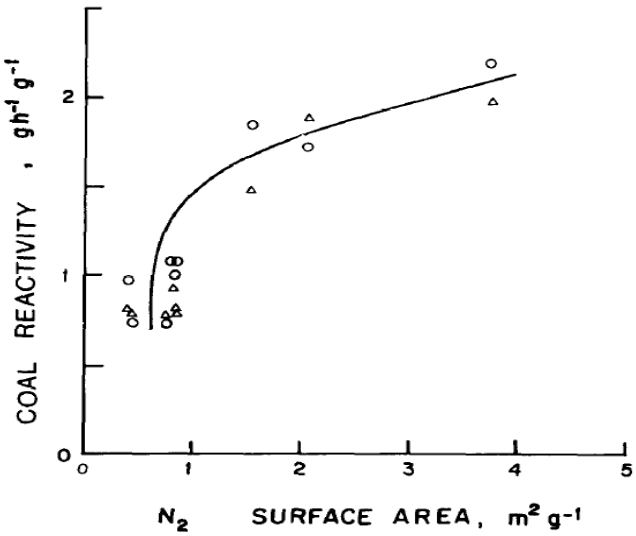

Figure 3: Correlation between gasification reactivity and surface area of coal; ∆: steam gasification, o: No steam [6].

3. CONCLUSION

On the basis of outcome of various researchers reviewed and discussed in the papers it is concluded that char structure plays very important role in determining the gasification behavior of coal. Micropores and feeder pores developed during pyolysis and surface area of char are responsible for controlling the gasification behavior of char.

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