Product Gas Analysis and Effect of Partial Pressure on the Gasification Behavior of Jhama Coal

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ABSTRACT

Coal gasification technology has been widely used in the world because of efficient utilization of coal by reducing CO_2 and other pollutant emissions in the environment. Gasification Performance depends on the selection of suitable gasification technology which should be matched with coal properties and operating conditions. Therefore, Studies on coal gasification reactivity are essential in order to obtain maximum gasification rate. Coal gasification is affected by number of operating parameters. There is wide range of coal available, on which gasification data are available in the literature. In the present paper, experiments were performed to study the effect of gasifying agent on the product gas composition after gasification. Jhama coal has been used in the present investigation because limited data has been available on Jhama Coal. Gasifying agents taken into account are CO_2 and mixture of CO_2 and steam. Effect of partial pressure of CO_2 on the gasification reaction rate is also investigated.

Keyword: - *Jhama coal, product gas, partial pressure, gasification.*

1. Introduction

Coal is the world's most abundant and broadly distributed fossil fuel. According to International Energy Agency (IEA), coal is the second source of primary energy (roughly 30%) and it is generally used for the generation of power (over 40% of worldwide electricity produced from coal). Global energy demand is increasing worldwide due to the increasing world population and standards of living. Future demand of energy is manly coal dependent because of continuous depletion of oil and natural gas. Coal is the most essential and abundant fossil fuel in India. India has the third-largest hard coal reserves (roughly 12% of the world total) [1]. According to Ministry of coal, Government of India coal accounts for 55% of the country's energy requirement. Conventional utilization of coal for power generation offers drawbacks such as lower efficiency and carbon dioxide emission, which promotes global warming. Therefore, clean coal utilization for the power generation is essential. Coal gasification is a way to utilize coal more efficiently in order to meet the environmental regulations. Coal gasification is the thermo-chemical conversion of carbonaceous feedstock into carbon dioxide (CO_2), carbon monoxide (CO), and hydrogen (H_2) and other by products [2]. Coal pyrolysis is the first step of gasification which produces char and volatiles. Char gasification is the second and final step of converting solid char to gaseous products. Char is usually gasified in the presence of gasifying agents like oxygen, steam, carbon dioxide, or mixture of these gases. O_2 and Steam are frequently used as gasifying agent in industrial coal gasification. Usually excessive steam is introduced into the gasifiers in order to prevent the formation of slag during the process of coal gasification [3]. But there might be some consequence of flow of excessive heat such as lots of heat takes away by excessive steam, and the amounts of energy consumption and waste water emission enhance [3]. The gasification kinetics of char using various gasification agents comprising steam, O_2, H_2, CO_2 or their mixtures have been Investigated from different aspects

[4-8]. The gasification process in the gasifier is very complex which includes pyrolysis of coal as temperature exceeds 400^{o}C. Products of pyrolysis are tar, phenol as liquid and hydrogen rich volatile hydrocarbon gases. Gasification of carbon rich residue of pyrolysis known as char starts after achieving 700^{o}C, gasification is the controlling step because of its low gasification rate [9]. The gasification rate of chars using CO_2 is much slower than the steam gasification rate, so char gasification rate using CO_2 is considered as the rate determining step in practical process of gasification [10]. Present study investigates the effect of partial pressure on the gasification rate of India Jhama coal and experiments were also performed to study the product gas analysis by using pure CO_2 and mixture of CO_2 and steam as gasifying medium.

2. Experimental

2.1 Coal Sample

For the present study, Jhama coal has been chosen. Jhama coal is an Indian special low volatile coal. Jhama coal is also known as Natural coke. Jhama coal can also be used as substitute for coke.

2.2 Char Preparation

Approximately 100 gram Jhama coal sample of size -212 mm has been taken into a crucible and kept inside thermogravimetric analyzer. Then the temperature has been raised in N_2 flow upto the desired temperature the flow of N_2 was stooped as the loss in weight due to pyrolysis was constant and CO_2 was allowed to flow. Experiments were performed to determine the progress of gasification reaction with flow rate of pure CO_2 and mixture of CO_2 and steam at the temperature of 1373 K for 40 minutes residence time. Gasification temperature of 1373 K for 40 min residence time was chosen because this value of temperature gives the maximum rate of gasification. Flow rate of pure CO_2 and CO_2 and Steam mixture was chosen as 1.5 lit/min because gasification rate increases with flow rate upto 1.5 lit/min, after that rate of gasification remains constant.

3. Results and Discussion

3.1 Product Gas Analysis

In the present investigation experiments were performed to study the effect of gasifying medium on the product gas composition after gasification. Char was gasified at 1373K using 100% CO_2 and mixture of 80% CO_2 and 20 % steam as a gasifying medium and the product gas was collected in the container. Composition of product gas in CO_2 and mixture of CO_2 and steam is tabulated in Table 1 and Table 2, respectively. From the tabulated results, it is reported that product gas composition after gasification is affected by medium of gasification. Considerable effect of gasifying medium is found on CO, H_2 and CH_4 composition. Percentage of CO is more in CO_2 gasification and percentage of H_2 and CH_4 is more in mixture of CO_2 and steam gasification. Effect of gasification medium over CO_2 and N_2 is negligible as compare to other three products of gasification.

Table 1: Product gas analysis after gasification with CO_2

Gas	Composition
CO	76.9%
H2	10.8%

CO2	9%
N2	1.5%
CH4	1.8%

Table 2: Product gas analysis after gasification with 80% CO_2 + 20% steam

Gas	Composition
CO	63.2%
H2	23.7%
CO2	8.4%
N2	1.2%
CH4	3.5%

3.2 Partial Pressure Variation

Gasification reaction can be affected by changing the reactant partial pressure, while keeping total pressure of the system constant. Partial pressure variation was achieved using CO_2/N_2 mixtures. For gasification, sample was exposed to CO_2/N_2 mixture at total pressure of 1 atm, temperature of 1373K, 40 min residence time and 1.5 lit/min flow rate. Variation in rate of gasification with change in partial pressure of CO_2 is tabulated in Table 3 and plotted in Fig 1. From the tabulated results, it is reported that gasification rate increases with the increase in partial pressure of CO_2 at a particular residence time. Obtained results are in good agreement with the data available in the literature [9,11].

Table 3: Partial pressure variation of CO_2 by mixing N_2 Gas at 1373K, 40 min residence time and 1.5 lit/min flow rate

% CO_2 in CO_2/N_2 mixture	% Gasification
100	94.2
80	90.6
60	83.5
40	69.3
20	40.6

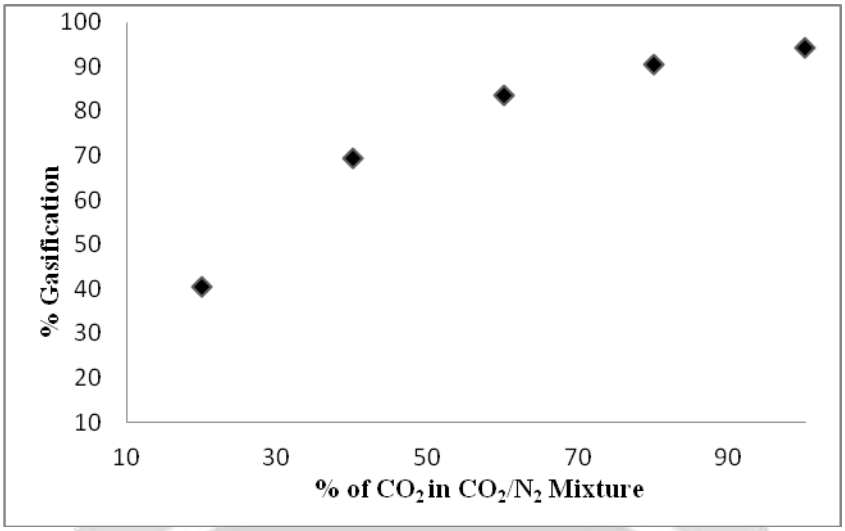

Fig 1: Variation in rate of gasification with variation in partial pressure of CO_2 at 1373K, 40 min residence time and 1.5 lit/min flow rate.

4. Conclusions

Present Investigation is useful in understanding the behaviour of Indian Jhama coal under certain operating conditions. Product gas analysis of Jhama coal after gasification in different gasification medium (pure CO_2 and mixture of 80% CO_2 and 20 % steam) identifies the composition of product gas. By varying the partial pressure of CO_2 in the mixture of CO_2 and nitrogen shows the effect of partial pressure of CO_2 on the gasification of Jhama coal. Rate of gasification is increased by increasing the partial pressure of CO_2.

5. References

[1] https://www.iea.org/publications/freepublications/publication/IndiaEnergyOutlook_WEO2015.pdf

[2] A. Gomez and N. Mahinpey, A new model to estimate CO2 coal gasification kinetics based only on parent coal characterization properties, Applied Energy 137 (2015) 126–133.

[3] F. Li, Q. Yan, J. Huang, J. Zhao, Y. Fang and J. Wang, Lignite-char gasification mechanism in mixed atmospheres of steam and CO_2 at different pressures, Fuel Processing Technology 138 (2015) 555–563.

[4] L. Shufen and S. Ruizheng, Kinetic studies of a lignite char pressurized gasification with CO_2, H_2 and steam, Fuel 73 (3) (1994) 413-416.

[5] M. Weeda, H.H. Abcouwer, F. Kapteijn and J.A. Moulijn, Steam gasification kinetics and burn-off behaviour for a bituminous coal derived char in the presence of H2, Fuel Processing Technology 36 (1993) 235-242.

[6] A-G Collot, Matching gasification technologies to coal properties, International Journal of Coal Geology 65 (2006) 191– 212.

[7] D. G. Roberts and D. J. Harris, Char Gasification with O_2, CO_2, and H_2O: Effects of Pressure on Intrinsic Reaction Kinetics, *Energy & Fuels 14*(2000) 483-489.

[8] D.G. Roberts and D.J. Harris, Char gasification in mixtures of CO_2 and H_2O: Competition, Fuel 86 (2007) 2672–2678.

[9] S. Saha, Study on physical properties of Indian coals and its effect on coal gasification kinetics, Indian School of Mines, Dhanbad, India, Ph.D thesis, April, 2013.

[10] G. Wang, J. Zhang, X. Hou, J. Shao and W. Geng, Study on CO_2 gasification properties and kinetics of biomass chars and anthracite char, Bioresource Technology 177 (2015) 66–73.

[11] L. Zhang, J. Huang, Y. Fang and Y. Wang, Gasification reactivity and kinetics of typical Chinese anthracite chars with steam and CO_2, Energy & Fuels 20 (2006) 1201-1210.