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Kinetic Studies on CO_2 Gasification of Low and High Ash Indian Coals in Context of Underground Coal Gasification

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Abstract : Underground coal gasification (UCG) technology is an efficient and an economic in-situ clean coal technology, which converts unmineable coals into calorific valuable gases. This technology avoids ash disposal, coal mining, and storage problems. CO_2 gas can be a potential gasifying medium for UCG. CO_2 is a greenhouse gas and, the liberation of this gas to the atmosphere from thermal power plant industries leads to global warming. Hence, the capture and reutilization of CO_2 gas are crucial for clean energy production. However, the reactivity of high ash Indian coals with CO_2 needs to be assessed. In the present study, two varieties of Indian coals (low ash and high ash) are used for thermogravimetric analyses (TGA). Two low ash north east Indian coals (LAC) and a typical high ash Indian coal (HAC) are procured from the coal mines of India. Low ash coal with 9% ash (LAC-1) and 4% ash (LAC-2) and high ash coal (HAC) with 42% ash are used for the study. TGA studies are carried out to evaluate the activation energy for pyrolysis and gasification of coal under N_2 and CO_2 atmosphere. Coats and Redfern method is used to estimate the activation energy of coal under different temperature regimes. Volumetric model is assumed for the estimation of the activation energy. The activation energy estimated under different temperature range. The inherent properties of coals play a major role in their reactivity. The results show that the activation energy decreases with the decrease in the inherent percentage of coal ash due to the ash layer hindrance. A reverse trend was observed with volatile matter. High volatile matter of coal leads to the estimation of low activation energy. It was observed that the activation energy under CO_2 atmosphere at 400-600°C is less as compared to N_2 inert atmosphere. At this temperature range, it is estimated that 15-23% reduction in the activation energy under CO_2 atmosphere. This shows the reactivity of CO_2 gas with higher hydrocarbons of the coal volatile matters. The reactivity of CO_2 with the volatile matter of coal might occur through dry reforming reaction in which CO_2 reacts with higher hydrocarbon, aromatics of the tar content. The observed trend of Ea in the temperature range of 150-200˚C and 400-600˚C is HAC > LAC-1 >LAC-2 in both N_2 and CO_2 atmosphere. At the temperature range of 850-1000˚C, higher activation energy is estimated when compared to those values in the temperature range of 400-600°C. Above 800°C, char gasification through Boudouard reaction progressed under CO_2 atmosphere. It was observed that 8-20 kJ/mol of activation energy is increased during char gasification above 800°C compared to volatile matter pyrolysis between the temperature ranges of 400-600°C. The overall activation energy of the coals in the temperature range of 30-1000˚C is higher in N_2 atmosphere than CO_2 atmosphere. It can be concluded that higher hydrocarbons such as tar effectively undergoes cracking and reforming reactions in presence of CO_2. Thus, CO_2 gas is beneficial for the production of high calorific value syngas using high ash Indian coals.

Keywords : clean coal technology, CO_2 gasification, activation energy, underground coal gasification
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