THERMOCHEMICAL COAL GASIFICATION WITH CO_2 USING A SOLAR FURNACE SIMULATOR

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ABSTRACT

The conversion of solar energy to chemical fuels enables solar energy storage and transportation. Direct thermochemical conversion of solar high-temperature heat to chemical fuels is desired. The goal is an industrially important endothermic process that can be driven by high-temperature heat. Gasification of coal is one of the most attractive candidates for solar thermochemical conversion process and in recent years solar coal gasification processes have been studied extensively. The conversion of coal to synthesis gas (syngas) provides a chemical pathway for the production of synthetic liquid fuels such as methanol. Steam or CO_2 gasification of coal is highly endothermic, being strongly high-temperature-dependent and energy-dependent process:

CHn (coal) + H2O $B"* (B CO + (n/2+1)H2
CHn (coal) + CO2 $B"* (B 2CO + n/2H2

Gasification of coal has been widely studied and is presently practiced at an industrial scale, but in the conventional coal gasification, coal itself is burned with oxygen or air internally in the gasifier to supply the process heat, which releases large amounts of CO_2. In solar coal-gasification processes, about 26-30% of CO_2 emission can be ideally reduced in comparison to the conventional coal gasification because the process heat is supplied from a clean renewable solar energy.

In the present work, thermochemical CO_2 gasification of coal was performed in the packed-bed or fluidized-bed reactor using a solar furnace simulator. Coal in the reactor was directly irradiated using the concentrated Xe-lamp beam to 973-1373 K and CO_2 was fed to the reactor. The gaseous contents in the outlet gases from the reactor were estimated from the data of the gas chromatography.

20% of coal (0.1g) in the packed-bed reactor was converted to CO in 10 min-irradiation. It was found that the CO_2 gasification was much catalyzed with In_2O_3 or ZnO catalysts. About 8-16wt% of metal content in the mixture of coal and catalyst was enough to catalyze the reaction. The coal conversion to CO was improved to 50-80% in the presence of In_2O_3 or ZnO catalyst. Similar results are obtained when using a fluidized-bed reactor instead of the packed-bed reactor.

The catalysts such as In_2O_3 and ZnO can improve the kinetics and chemical conversion, and reduce the operating temperature requirements for the solar coal-gasification process, but their use is subjected to the feasibility of recovering catalysts from the remaining coal ash. Indium oxide may be separated from the ash by In_2O evaporation. The vapor pressure of $In_2O(g)$ is very high at high temperatures and exceeds 1 atm above 1373 K. It is reported that at high temperatures volatile oxide of $In_2O(g)$ is formed by a process corresponding to the reaction:

$$In_2O_3(c) + 4In(l) \rightarrow 3In_2O(g)$$

Zinc oxide will be separated from ash by Zn evaporation above 1200 K.

In order to estimate the energy and exergy balance, we proposed the

system model for the solar coal-gasification process. The idealized thermal efficiency of the system model was estimated to be about 0.64.