Fuel Conversion and CO₂ Selectivity Improvement by Adding Other Oxygen Carrier for Syngas Chemical Looping Combustor at High Temperature Condition

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Abstract

Carbon dioxide, a major greenhouse gas, is produced in large quantities from combustion of fossil fuels, much of this related to electric power generation. In a conventional power generation system, fuel and air are directly mixed and burned; therefore it is not easy to separate CO₂ from flue gas because CO₂ is diluted by N₂ in air. Chemical-looping combustion (CLC) is a novel combustion technology with inherent separation of the greenhouse gas CO₂ and no NOx emission. The chemical-looping combustor consists of two reactors, an oxidation reactor and a reduction reactor. A fuel and an air go through the different reactors. In the reduction reactor, gaseous fuel (CH₄, H₂, CO or CₙH₂n+2) reacts with metal oxide and release water vapor and carbon dioxide. The solid products, metal particles, are transported to the oxidation reactor and react with oxygen in the air and produce high-temperature flue gas and metal oxide particles. Metal oxide particles at high temperature are again introduced to the reduction reactor and supply the heat required for the reduction reaction. Between the two reactors, metal (or metal oxide) particles play an important role in transportation of oxygen and heat, therefore the looping material between the two reactors is named as an oxygen carrier particle. It is important that the exhaust gas from the reduction reactor contains only highly concentrated CO₂ and water vapor. Therefore, CO₂ can be easily recovered by cooling the exhaust gas without any extra energy consumption (energy penalty) for CO₂ separation. Another advantage of CLC is that NOx formation can be thoroughly eliminated because the oxidation reaction occurs at a considerably lower temperature (~900°C) without a flame; therefore there is no thermal NOx formation¹². Moreover, the efficiency of chemical-looping combustion system is very high. There are many reports on the reactivity of oxygen carriers with methane and hydrogen for chemical-looping combustor. The fuel conversion and the CO₂ selectivity decreased with increasing reaction temperature within high temperature range (>900°C) due to the increment of exhaust CO concentration from reduction reactor. In this study, the applicable metal oxide component was selected by calculation of the equilibrium CO concentration of metal oxide components such as Fe₂O₃, NiO, Co₃O₄, CuO, Cu₂O, MnO₂ to improve reduction reactivity at high temperature. After that, feasibility of reduction reactivity improvement at high temperature was checked by using solid mixture of the selected metal oxide particle (Co₃O₄/CoAl₂O₄, metal oxide content 70%, bulk density 1.087 g/cm³) and NiO based oxygen carrier (OCN706-1100, metal oxide content 70%, bulk density 1.651 g/cm³). The reactivity was measured and investigated using batch type fluidized bed reactor (0.054 m I.D. and 1.64 m high). The reaction temperature varied from 900°C to 1000°C. The concentration of inlet and outlet CO, CO₂, H₂, CH₄ concentration were measured by on-line gas analyzer (ABB, Advance Optima, A0 2000, NDIR type). The solid mixture of Co₃O₄/CoAl₂O₄(10%) and OCN706-1100(90%) showed higher fuel conversion, higher CO₂ selectivity and lower CO concentration than OCN706-1100 (100%) cases. Consequently, we could
conclude that improvement of reduction reactivity at high temperature range by adding some Co$_2$O$_4$ based oxygen carrier was feasible.