3-2-3 Catalytic CO₂ gasification of a brown coal using biomass ash as a catalyst

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SUMMARY
In this paper, the gasification of the coal char that catalyzed by alkaline and alkaline earth metals (AAEMs) in the ash was studied. Two catalytic including calcium (Ca) and potassium (K) were used in the CO₂ gasification of Loy Yang brown coal (LY). The char conversion with the additional of CaO and K₂O at the temperature between 650 to 800°C were investigated utilizing Thermogravimetric analyzer (TGA). It was found that the char conversion has increased by increasing the gasification temperature. Moreover, the efficiency of char conversion and gasification rate using CaO and K₂O catalytic has significantly improved in CO₂ catalytic gasification.

[1] Introduction
The thermal conversion of coal has been studied for a long time and it is an important technology for the carbonaceous materials utilization and processing. Catalytic gasification is a key process of the thermal conversion that could enhance a coal conversion and reduce a reaction time. Nowadays, many extensive works had been performed to investigate the catalytic coal gasification with alkali and alkaline earth metals (AAEMs) due to their superior catalytic activity and low cost. The metal, particularly calcium (Ca) and potassium (K), on the char conversion are well known and has been subject in many recent publications.

In this work, the char conversion of coal mixed with different ashes including CaO and K₂O during the CO₂ gasification at 650 to 800°C was investigated.

[2] Experimental
Loy Yang brown coal (LY) from Australia with the size between 0.5 to 1.0 mm and 125 to 250 μm were used. The empty fruit bunch (EFB) from Malaysia and the chicken dropping compost (CC) from Japan with the size between 0.5 to 1.0 mm were used as a catalyst. The proximate and ultimate analysis of LY is shown in Table 1. The CC ash and EFB ash (hereafter referred as CCA and EFBA, respectively) were prepared by the Thermogravimetric analyzer (TGA) at the temperature of 500 to 815°C for 30 min. The composition of metal oxide in CCA is shown in Table 2. First, LY sample was mixed with CCA and EFBA. The preparation of coal char was performed by TGA in argon (Ar) gas ambient heated with the heating rate of 100°C/min until the reaction temperature has reached. After that, the temperature was maintained until the samples weight becomes stable. Subsequently, the inert gas was switched to the CO₂ reaction gas at the maintain reaction temperature.

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<th>Table 1 Proximate and ultimate analysis of LY coal.</th>
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<td>Proximate analysis</td>
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<td>(wt%, dry basis)</td>
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<td>Volatile matter Ash</td>
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<td>52.36</td>
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<th>Table 2 The composition of metal oxide in CCA.</th>
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<td>Type of ash</td>
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<td>CCA</td>
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<td>11.06</td>
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<td>EFBA</td>
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The gasification was considered to be started after introduced the CO₂ gas into the reactor. The reaction temperature was varied between 650 to 800°C for 2 hrs. The initial mass dry ash free (m₀) and the instantaneous of char mass (mₑ) can be measured by TGA. The char conversion (Xₜₚ) can be calculated by using the fraction of the weight loss and m₀ as followed:

\[ X_{ch} = \frac{(m_0 - m_e)}{m_0} \]  

(1)

[3] Results and discussion

Figure 1 shows the CO₂ gasification profiles of LY coal char. It was found that when the reaction temperature has increased from 650 to 800°C, the char conversion has slightly increased from 0.15 to 0.45.

![Fig. 1 CO₂ gasification of Loy Yang brown coal char.](image1)

The catalytic CO₂ gasification profile of LY coal after mixed with 10% of CCA at various reaction temperatures is shown in Fig. 2. It was found that by increasing the reaction temperature to 650°C and 700°C, the char conversion has increased. This char conversion is twice compared to the char conversion obtained from LY coal. Moreover, when the reaction temperature is 750°C and 800°C, the maximum char conversion of 1.0 was achieved. This might due to the calcium carbonate has broken down and converted to calcium oxide at high temperature as the chemical reaction shown below:

\[ \text{CaO} + \text{CO}_2 \leftrightarrow \text{CaCO}_3 \]  

(2)

The results in Fig. 3 show the catalytic gasification profile of LY coal mixed with 10% of EFBA at 650 to 800°C. It was found that the catalytic activity is strongly dependent on the reaction temperature. The char conversion of only LY coal was very slow whereas the char conversion of LY coal mixed with EFBA has significantly increased. The initial conversion rate has increased linearity and then exponential decreased until the end of the reaction. At the higher temperature than 650°C, the char conversion has increases to 1.0 (100%).

![Fig. 2 CO₂ gasification of LY coal mixed with CCA.](image2)

![Fig. 3 CO₂ gasification of LY coal mixed with EFBA.](image3)

When the reaction temperature is 700, 750, and 800°C, the time to reach 100% conversion is 120, 90, and 30 min, respectively. This means, the reaction rate is strongly depended on the process temperature.

[4] Conclusions

The alkali and alkaline earth metals (AAEMs) can improve the effectiveness of CO₂ catalytic coal gasification. The K₂O in EFBA has more effective than the CaO in CCA. However, both AAEMs has same conversion rate when the reaction temperature is higher than 750°C.

[References]