6.3 Gasification reactivity of HyperCoals from lignite, sub-bituminous and bituminous coals at 650°C under steam.

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SYNOPSIS: HyperCoal is an extremely clean coal with ash content <500 ppm. Mulia [MUL] (C=65.5%) a lignite coal and Pasir [PAS] (C=72%) a sub-bituminous coal were subjected to solvent extraction method to prepare Muria HyperCoal [MurHPC] and Pasir HyperCoal [PasHPC]. At 650°C, without catalyst both coals and HyperCoals prepared from them showed extremely slow rates. When 6 wt % K₂CO₃ was added as a catalyst to MUR, PAS, MurHPC and PasHPC, the gasification rates increased. Carbon conversion for MurHPC and PasHPC with catalyst was 99% and 85% in 60 min while for Mulia and Pasir coal with catalyst it was about 65% and 60%. These results show that addition of catalyst increased the reactivity of coals and Hypercoals in general but Hypercoals showed much higher reactivity increase than the coals with mineral. With addition of catalyst MurHPC and PasHPC showed dramatic increase in gas yield with gas composition as H₂: 55~63%; CO: 4~2%; CO₂: 40~37% indicating that H₂ rich gas was produced at as low as 650°C with high production rates. The results showed that high gasification rates and reduction in gasification temperature can be achieved by using HyperCoals from low rank coals as feedstock for H₂ production by catalytic steam gasification process.

INTRODUCTION
Gasification of coal is generally favored at temperatures above 1000°C. This is because commercially acceptable gasification rate can be achieved for most of the coals above this temperature. Low rank coals can be gasified at lower temperatures however, the cold gas efficiency is not high. Fluidized bed gasifiers are commonly operated around 850~950°C but suffer from agglomeration of bed. The gasification of coal at temperatures below 800°C has also been widely examined. The results concluded that except some low rank coals steam gasification rates of the most of the coals were very low for commercial application. Gasification rates may be increased by addition of catalyst but the catalyst is deactivated due to reaction with mineral matter in coals and is unrecoverable [1]. To overcome the problem of loss of catalyst due to deactivation, one approach is to remove the ash from the coal before gasification. Recently, our research group has developed a process to remove ash from coal by solvent extraction. The extracted coal named HyperCoal has less than 500 ppm of ash. Because of its almost ashless nature, a catalytic gasification process for coal may be developed by using HyperCoal as a feed material leading to low gasification temperature, recovery and recycling of catalyst [2, 3].

In this study experiments were carried out to investigate the suitability of HyperCoals prepared from low rank coals as a feedstock for catalytic gasification at <650°C with high gasification rates.

EXPERIMENTAL
A bituminous coal, Oaky Creek (OC) from Australia, a sub-bituminous coal, Pasir (PAS) and lignite, Mulia (MUL) both from Indonesia were selected for the investigation. HyperCoals (HPC) were produced by the extraction of the coal with 1-methylnaphthalene at 360°C. The HyperCoal production method has been described in detail elsewhere [2]. The properties of the coals and HyperCoals are shown in Table 1. The experimental set up consists of a HPLC pump, argon supply, steam generator, TG-DTA, cold trap, micro gas chromatograph (micro GC) and a film flow meter. About 15 mg of sample was prepared by mixing sample (Coal or HyperCoal) with 6 wt % of K₂CO₃ in an agate mortar. The particle size of sample was under 75 μm. Experiments were carried out in a thermogravimetric (TG-DTA 2020S, MAC) apparatus with purge gas flowing from bottom while steam/argon flowing down from top. The steam was generated at 250°C. The steam flowing from top comes into contact with the sample in the alumina crucible. The evolved gases flow out together with the purge gas from the side into an ice cooled tar trap to remove tar and moisture before injecting to the micro gas chromatograph. The gas evolution rate was measured by a film flow meter.

<table>
<thead>
<tr>
<th>Coal</th>
<th>Ash</th>
<th>Elemental analysis (wt % daf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(wt %)</td>
<td>C</td>
</tr>
<tr>
<td>Pasir coal</td>
<td>4.9</td>
<td>73.5</td>
</tr>
<tr>
<td>Pasir HPC</td>
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<td>79.4</td>
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<tr>
<td>Mulia coal</td>
<td>3.2</td>
<td>65.5</td>
</tr>
<tr>
<td>Mulia HPC</td>
<td>0.43</td>
<td>77.3</td>
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</tbody>
</table>
RESULTS AND DISCUSSION

Figure 1 compares steam gasification rates for OCHPC, PasHPC and MulHPC at 650 °C and 0.5 partial pressure of steam. The results show that gasification reactivity of HyperCoals produced from low rank coals was much higher than those produced from the high rank coals.

Figure 2 shows the gasification profile at 650 °C with steam. At 650 °C, both MUR and PAS with out catalyst show extremely slow rates. MurHPC with out catalyst also showed similar gasification rates as MUR. It can be concluded that the rates are extremely slow at 650 °C for all coals with out catalyst. When a catalyst, 6 wt % K2CO3 was added to MUR, PAS, MurHPC and PasHPC, the gasification rate of all samples increased.

At 650 °C the conversion in MurHPC with catalyst was 99 % in 60 min while for MUR coal with catalyst it was about 65 %. Similarly, for PasHPC with catalyst 100 % carbon conversion was achieved in 90 min while for PAS coal with catalyst it was about 60 %. These results show that addition of catalyst increased the reactivity of coals and Hypercoals in general but Hypercoals showed much higher reactivity increase than the coals with mineral.

Figure 1. Gasification rates of HyperCoals at 650 °C.

Figure 2. Gasification profiles at 650 °C.

CONCLUSIONS

A new approach for catalytic gasification of low rank coals has been proposed. High gasification rates for HyperCoals from lignite and sub-bituminous coals were achieved at 650 °C. H2: 65 % and CO2: 30 % make up 95 % of the produced gas. High concentration of CO2 in the product gas makes it very suitable for Carbon Capture and Storage (CCS) technology. The results show HyperCoal can be used as feedstock for low temperature catalytic gasification.

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REFERENCES