PERFORMANCE STUDY ON CO-GASIFICATION OF COAL WITH SAWDUST AND SAWDUST PELLET IN DOWNDRAFT GASIFIER

FATIN ZAFIRAH BINTI MANSUR

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

____

(Supervisor's Signature)

Full Name : PM TS DR CHE KU MOHAMMAD FAIZAL BIN CHE KU YAHYA

Position : ASSOCIATE PROFESSOR

Date : 31 DECEMBER 2020

____

(Co-supervisor's Signature)

Full Name : DR NOOR ASMA FAZLI BIN ABDUL SAMAD

Position : SENIOR LECTURER

Date : 31 DECEMBER 2020

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : FATIN ZAFIRAH BINTI MANSUR

ID Number : PET17005

Date :

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FATIN ZAFIRAH BINTI MANSUR

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ABSTRAK

Pengegasan adalah teknologi perubahan termo-kimia dari bahan bakar organik kompleks ke singas yang digunakan untuk penghasilan tenaga di bawah kehadiran oksigen yang terhad dibekalkan oleh wap atau udara. Penurunan sumber arang batu dan kemerosotan persekitaran beserta kos pemprosesan yang tinggi dan pembentukan tar biasanya dikaitkan dengan pengegasan arang batu dan biojisim. Oleh itu, penggunaan pengegasan bersama biojisim dan arang batu adalah pendekatan alternatif yang memudahkan pertukaran antara sumber yang boleh diperbaharui dan yang tidak boleh diperbaharui. Walau bagaimanapun, ketumpatan yang rendah, kandungan lembapan yang tinggi, tingkah laku penguraian yang berbeza menjadi penghalang teknikal dalam pengegasan bersama. Oleh itu, tujuan kajian ini adalah untuk membandingkan biojisim mentah dan pra-rawatan biojisim bersama arang batu untuk menyiasat potensi pra-rawatan biojisim dalam meningkatkan prestasi pengegesan. Habuk kayu (SD) dan pelet habuk kayu (penguntilan habuk kayu, SDP) serta campuran kedua-dua bahan dengan arang batu (CL) telah disiasat. Dalam kajian ini, sifat bahan seperti analisis struktur, analisis proximat, analisis muktamad, nilai kalori, komposisi kimia dan lain-lain ditentukan bagi CL, SD, dan SDP serta campuran bahan tersebut pada nisbah yang berbeza (25%, 50% dan 75%). Sifat SD menunjukkan peningkatan ketika penguntilan SDP. Tambahan lagi, analisis termo-gravimetrik (TGA) dilakukan di persekitaran udara untuk mengkaji tingkah laku terma mengaplikasi kaedah Kissinger, Flynn-Wall-Ozawa dan Distribution Activation Energy Model untuk mengukur analisis kinetik. Hasil kajian menunjukkan bahawa tenaga pengaktifan, E_a yang lebih rendah (103.82 ± 4.39 kJ / mol) untuk CL/SD dan CL/SDP (88.79 ± 18.56 kJ / mol) didapati pada nisbah 75% arang batu. Terdapat juga sinergi positif untuk CL/SD dan CL/SDP yang menggunakan ketiga-tiga model tersebut. Penambahan CL meningkatkan degradasi SD dan SDP, meningkatkan ΔE_a, menurunkan E_a, menunjukkan reaksi reaktif. Didapati bahawa SD memiliki ΔE_a lebih tinggi daripada SDP dengan perbezaan purata 14%, 23% dan 38% masing-masing pada nisbah campuran 75%, 50% dan 25%. Selain itu, campuran CL dengan SD dan SDP di gasifikasi dalam gasifier tempat tidur tetap-draf untuk mengukur pengaruh nisbah arang batu, suhu pengegasan dan nisbah kesetaraan udara (ER_{air}) terhadap kepekatan gas (H_2, CO, CO_2 dan CH_4), nilai pemanasan singas yang lebih tinggi (HHV_{syngas}), penghasilan syngas (Y_{syngas}), kecekapan penukaran karbon (η_{CCE}), kecekapan pengegasan (η_{CGE}) dan kecekapan penukaran pepejal-gas (η_{SGC}). Penyiasatan parametrik serta keadaan optimum untuk memaksimumkan H_2 dan CO dinilai menggunakan Response Surface Methodology (RSM) dan analisis kepekaan dari model simulasi ASPEN Plus. Penemuan dari kedua pendekatan parametrik ini bertepatan menunjukkan bahawa dengan peningkatan suhu gasifikasi, pengeluaran komposisi gas terutama H_2 dan CO juga meningkat pada masa yang sama meningkatkan HHV_{syngas}, Y_{syngas}, η_{CCE} dan η_{CGE}. Selain itu, kandungan H_2, CO dan CH_4 tertinggi juga dikaitkan dengan ER_{air} yang lebih rendah lalu meningkatkan HHV_{syngas}. Sementara itu, untuk maksimum pengeluaran CO_2, Y_{syngas} dan η_{CCE}, ER_{air} yang tinggi diperlukan. Parameter optimum yang diserlahkan oleh RSM-CCD didapati jauh lebih spesifik berbanding model simulasi kerana andaian keadaan tetap dalam model simulasi mengabaikan pemindahan haba dan jisim di dalam pengegasan. Sebaliknya, kedua-dua parameter optimum berada dalam julat yang sama di mana bagi CL/SD memihak kepada nisbah arang batu tinggi (75%) dan CL/SDP pada nisbah arang batu (50 -61%) pada suhu pengegasan yang tinggi dan ER_{air} yang rendah untuk penghasilan H_2 (12.30 -14.07%), CO (14.63 -16.47%) dan HHV_{syngas} (5.74 hingga 6.66 MJ/kg) yang maksimum. Aplikasi teknik RSM-CCD mempunyai peratus ralat yang kecil (0.8-3.5%) berbanding model simulasi (8.0-12.57%) di dalam perbandingan dengan hasil kajian pada kondisi terpilih. Oleh itu, pengegasan bersama CL dan SDP berpotensi menjadi pengganti SD dengan jumlah minimum CL untuk prestasi pengegasan yang serupa.

ABSTRACT

Gasification is a thermochemical conversion technology in which complex organic fuels are converted into syngas that are used to generate energy in the presence of limited oxygen supplied by steam or air. A decline in coal resources and environmental deterioration coupled with a high pre-processing cost and tar formation are usually associated with coal and biomass gasification. Thus, the co-gasification of biomass and coal is an alternative approach that facilitates a trade-off between renewable and non-renewable resources. However, low energy density, high moisture content and different decomposition behaviours serve as technical barriers to co-gasification. This study aimed to compare raw biomass and pre-treated biomass co-gasified with coal to investigate pre-treated biomass's reliability in enhancing gasification performance. Sawdust (SD) and sawdust pellets (SDP) as well as the blends of these two feedstocks with sub-bituminous coal (CL) were investigated. Feedstock properties, like structural analysis, proximate analysis, ultimate analysis, higher heating value, chemical composition etc. were determined for CL, SD, and SDP and coal-biomass mixtures at different ratios (20%, 50% and 75%). Properties of the sawdust showed improvement as the feedstock was pelletized. Moreover, the thermogravimetric analysis (TGA) was performed in an air environment to study thermal behaviour and this study adopted the Kissinger, Flynn-Wall-Ozawa and Distribution Activation Energy Model methods to measure the kinetic analysis. Results show that lower activation energy (E_a) for CL/SD (103.82 ± 4.39 kJ/mol) and CL/SDP (88.79 ± 18.56 kJ/mol) was found at 75% coal ratio. There is also positive synergy for both CL/SD and CL/SDP employed by the three models. The addition of CL enhances the degradation of SD and SDP, increase the ΔE_a, lower the E_a and indicates a reactive reaction. It was found that SD possessed a higher ΔE_a than SDP, with an average difference of 14%, 23% and 38% at blending ratios of 75%, 50% and 25%, respectively. Furthermore, mixtures of CL with SD and SDP were gasified in a down-draft fixed bed gasifier to quantify the effect of coal ratio, gasification temperature and equivalence ratio of the air (ER_{air}) on the gaseous concentration (H_2, CO, CO_2 and CH_4), syngas higher heating value (HHV_{syngas}), syngas yield (Y_{syngas}), carbon conversion efficiency (η_{CCE}), cold gas efficiency (η_{CGE}) and solid-gas conversion efficiency (η_{SGC}). The parametric investigation as well as the optimum condition for maximizing H_2 and CO were evaluated by adopting the Response Surface Methodology (RSM) method and sensitivity analysis using the ASPEN Plus model. Findings from both parametric approaches are similar, indicating that with an increase in gasification temperature, the production of gaseous composition, mainly the H_2 and CO, also increases while enhancing the HHV_{syngas}, Y_{syngas}, η_{CCE} and η_{CGE}. Moreover, the highest content of H_2, CO and CH_4 is also associated with a lower ER_{air}, thus, improving the HHV_{syngas}. Meanwhile, for the maximum production of CO_2, Y_{syngas} and η_{CCE}, a higher ER_{air} is favourable. It was found that the best conditions determined by RSM-CCD are much more specific than that indicated by the simulation model due to steady-state assumption in the simulation model and neglecting the heat and mass transfer inside the gasifiers. Instead, both the optimum parameters are within the range in which CL/SD favours a high coal ratio (75 %) and CL/SDP favours a lesser coal ratio (50-61 %) at a high gasification temperature and low ER_{air} for the maximum production of H_2 (12.30 -14.07 %), CO (14.63 -16.47 %) and HHV_{syngas} (5.74 to 6.66 MJ/kg). The RSM-CCD method resulted lesser percentage error (0.8-3.5%) than the simulation model (8.0-12.57%) when compared with the experimental study under the most conducive conditions. Therefore, co-gasified CL with SDP can potentially be a substitute for SD with the minimum amount of CL for similar gasification performances.

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