UNIVERSITI TEKNOLOGI MARA

CO-GASIFICATION OF PRETREATED PALM KERNEL SHELL AND MUKAH BALINGIAN COAL

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ABSTRACT

Abundant of biomass in Malaysia such as palm waste has a great potential as renewable energy resource. Utilization of low rank coal offers a good prospective to replace high rank coal in gasification. However, there are restriction in individual gasification and limitation of biomass and low rank coal due to poor characteristics. Therefore, samples pretreatment prior to co-gasification are desirable to overcome the problems. In this research, co-gasification of palm kernel shell (PKS) and Mukah Balingian (MB) low rank coal was carried out in a fixed bed reactor with steam as co-gasification agent. In the first objective, PKS and MB were subjected to two different pretreatments i.e. torrefaction and microwave irradiation. The results showed that the properties of both pretreated PKS and MB were improved, where the mass and energy yield, volatile matter, moisture and oxygen content reduced, while the energy density, calorific value, fixed carbon and carbon content increased with increasing pretreatment temperature and microwave power. Torrefied PKS (PKS_{To}) at 270 °C, preheated MB (MB_{Pr}) at 250 °C and microwave irradiated PKS (PKS_{Mi}) and MB (MB_{Mi}) at 450 W demonstrated a good quality feedstock to be used in co-gasification. Moreover, at preferred parameters, the kinetic analysis displays low activation energy of 96.11 and 119.6 kJ/mol for PKS_{To} and MB_{Pr}, respectively. In the second objective, the co-gasification parameters were optimized to maximize the gas production using response surface methodology (RSM). The results verified that the effect of the independent variables, i.e. gasification temperature, biomass blending ratio and steam flow rate on response variables i.e. gas, tar and char yield were significant due to p-value of less than 0.05. The optimum conditions for gasification temperature, biomass blending ratio and steam flow rate were at 767 °C, 52 % and 54 ml/min, correspondingly. These optimum conditions produced maximum gas yield of 67.3 % with minimum char and tar yield of 20.8 % and 11.9 %, respectively. In the third objective, the comparison between co-gasification of both untreated (PKS_{Un}/MB_{Un}), PKS_{To} and untreated MB (PKS_{To}/MB_{Un}) and pretreated (PKS_{To}/MB_{Pr}) blending were evaluated on product yields and gases composition via optimize conditions. The outcomes revealed that, co-gasification of both pretreated samples produced high gas yield due to characteristic enhancement of pretreated samples. The PKS_{To}/MB_{Pr} sample improved the H_2 production by 63.9 % than PKS_{Un}/MB_{Un} at 45 min reaction time. High H_2 production is in accordance with the high quantity of carbon content in PKS_{To}/MB_{Pr} compared to the PKS_{Un}/MB_{Un}. In the fourth objective, the optimization parameters of catalytic co-gasification was explored. The gasification temperature of 735 °C, catalyst ratio of 12 % and steam flow rate of 51 ml/min produced maximum gas yield of 67.5 %. The catalytic co-gasification shows minor enhancement of 4 % on H_2 composition. As a conclusion, the pretreatment approaches on PKS and MB prior to co-gasification is a promising method in enhancing product distribution, specifically on the hydrogen production. Accordingly, the pretreatment on both biomass and low rank coal prior to co-gasification without the catalyst addition that contributed to positive synergy on gas yield and hydrogen production was a novelty and new contribution in this study.

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Finally, it is hope that the ideas, outcomes and findings from the research work will be benefited and contributes to knowledge.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

1.1.1 Energy Scenario

Worldwide energy consumption has been greatly increased over the last several decades, due to global growth in industrialization, economy and population. As a result, the global energy demand increases exponentially and the increasing rate will become more rapid in the future. Global primary energy consumption growth averaged 2.2 % in 2017, up from 1.2 % in 2016 and the fastest since 2013. Rapid growth and improving prosperity mean growth in energy demand is increasingly coming from developing economies, particularly within Asia, rather than from traditional markets [1]. Figure 1.1 shows the world energy consumption by energy source from 1990 to 2040. The consumption of all fuels except coal (from 2025 to 2040) grows throughout the entire history and projection. Renewable energy is the world's fastest growing forms of energy and the fossil fuels are expected to continue to meet much of world's energy demand. Outstandingly, the extensive use of fossil fuels has contributed to climate change due to greenhouse gas emissions.

In recent years, the increasing emission of carbon dioxide (CO_2), sulphur oxide (SO_x) and nitrogen oxide (NO_x) has become a concern on the utilization of the world energy [2]. In the midst of limited availability of fossil fuels and high level of air pollution, energy efficient technologies are gaining importance and gasification being highly efficient technology, has received significant attention [3], [4]. The energy mix is shifting towards clean, low carbon fuels, driven by environmental needs and technological advances. Currently, coal is the main feedstock in gasification and is expected to be applied as the energy resource for many decades ahead. However, this direction is difficult to achieve due to the increasing in energy demand that has caused the shortage of supply and reduction of high rank coal [5]–[7]. Consequently, one of the approaches is to utilise the abundant low rank coal and biomass in gasification.