METHANE ADSORPTION MICROCALORIMETRY BY ACTIVATED CARBON FIBRE DERIVED FROM EMPTY FRUIT BUNCH FIBRE

by

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LIST OF ABBREVIATIONS

AC	Activated Carbon
ACF	Activated Carbon Fibre
ANG	Adsorbed Natural Gas
BET	Brunauer–Emmett–Teller
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DA	Dubinin-Astakhov
DFT	Density Functional Theory
DOE	The US Department of Energy
DR	Dubinin-Radushkevich
EDX	Energy Dispersive X-ray
EFB	Empty Fruit Bunch
FTIR	Fourier Transform Infrared
GAC	Granular Activated Carbon
H_2SO_4	Sulphuric Acid
IUPAC	International Union of Pure and Applied Chemistry
KBr	Potassium Bromide
LNG	Liquefied Natural Gas
NGV	Natural GasFuelled Vehicle
PAC	Powdered Activated Carbon
PAN	Polyacrylonitrile
PSD	Pore Size Distribution

SEM	Scanning Electron Microscopy
SSA	Specific Surface Area
TG	Thermogravimetry
TGA	Thermogravimetric Analysis
XRD	X-ray Diffractometry

LIST OF SYMBOLS

°C	Unit of Temperature on the Celsius Scale
K	Unit of Temperature on the Kelvin Scale
Wt%	Weight Percent
%	Percent
g	Gram
kg	Kilogram
2θ	Angle of Incidence of the X-ray Beam
a.u.	Arbitary Unit
mmol	Millimole

MIKROKALORIMETRI PENJERAPAN METANA OLEHSERAT KARBON TERAKTIF TERBITANDARIPADA SERAT TANDAN BUAH KOSONG

ABSTRAK

Serat tandan buah kosong kelapa sawit ialah satu sisa pertanian yang boleh diperolehi dengan banyak dari industry pemprosesan minyak sawit. Dalam kajian ini, serat tandan kosong digunakan sebagai bahan pelopor bagi penyediaan serat karbon teraktif untuk aplikasi penjerapan gas asli. Serat karbon teraktif dihasilkan melalui pengkarbonan, diikuti oleh fizikokimia dan pengaktifan. Pengaktifan fizikokimia dijalankan dengan menggunakan rawatan asid sulfurik diikuti oleh aliran gas CO_2. Kesan suhu pembakaran dan pirolisis yang berbeza terhadap sintesis serat kosong aktif telah dikaji. Tambahan pula, kesan rawatan asid ke atas serat tandan kosong telah dikaji dengan penggunaan asid sulfurik dan penukaran jujukan rawatan asid sebelum dan selepas pembakaran dan pirolisis. Intekalasi dan reaksi pengelupasan ke atas serat tandan kosong yang dirawat dengan asid sulfurik telah mengakibatkan kadar penurunan haba lebih tinggi berbanding dengan serat tandan kosong mentah yang tanpa rawatan asid. Luas permukaan BET dan jumlah isipadu liang yang tertinggi diperolehi masing-masing pada1049 m^2/g dan 0.45 cm^3/g daripada sampel-sampel serat karbon teraktif yang dirawat dengan asid selepas pengoptimuman parameter pemprosesan. Serat karbon teraktif menunjukkan liang mikro sebagai liang utama dengan kelebaran liang 1.2 nm yang memenuhi salah satu syarat sebagai penjerap yang sempurna untuk aplikasi penjerapan gas asli. Penjerapan maksimum isipadu metana oleh serat karbon teraktif didapati mencapai 136 V/V pada 298 K and 3.5 MPa (memenuhi syarat-syarat ANG praktikal). Kapasiti penyimpanan metana bagi serat karbon teraktif terpilih ini standing dengan kapasiti karbon teraktif

komersil yang boleh didapati di pasaran, kebanyakan diperolehi daripada produk petroleum selepas merasionalisasi dengan ketumpatan pemadatan. Kemerosotan prestasi yang rendah dalam penyimpanan metana daripada penjerapan operasi kitaran berikutnya menunjukkan bahawa serat karbon teraktif yang diperolehi daripada serat tandan buah kosong mempunyai penggunaan semula yang baik dan sesuai untuk aplikasi penjerapan gas asli.

METHANE ADSORPTION MICROCALORIMETRY BY ACTIVATED CARBON FIBRE DERIVED FROM EMPTY FRUIT BUNCH FIBRE

ABSTRACT

Empty fruit bunch (EFB) fibre of oil palm is anagricultural waste available abundantly from palm oil processing industry. In present work, EFB fibre was utilised as a precursorfor preparation of activated carbon fibre (ACF) as an adsorbent for adsorbed natural gas (ANG) application. The ACFs were produced via carbonisation, followed by physicochemical and activation. Physicohemical activation was carried out using sulphuric acid treatment followed by CO_2 gas flow. The effects of different combustion and pyrolysis temperatures on the prepared ACFs were analysed. In addition, the effect of acid treatment on EFB fibres was further studied by switching the sequence of acid treatment before and after combustion and pyrolysis. Intercalation and exfoliation reactions on the acid-treated EFB fibre due to sulphuric acid resulted in a higher thermal degradation rate compared to raw EFB fibre without acid treatment. The highest BET surface area and total pore volume obtained amongst the ACF samples treated with acidwas found to achievevalues as high as 1049 m^2/g and 0.45 cm^3/g, respectively, after optimisation of the processing parameter. ACF exhibited predominantly micropore with pore width of 1.2 nm, which fulfil one of the requirements as an ideal adsorbent for ANG application.The maximum volumetric methane adsorption by the ACFs was observed to be 136 V/V at practical ANG conditions; viz. 298 K and 3.5 MPa. The volumetric storage capacities of these ACFs were comparable to the adsorptioncapacities of selected carbon materialscommercially available in the market, which are mainly derived from petroleum products after rationalising with packing density. Low deterioration in methane storage performance from subsequent adsorption cyclic operation indicated that the EFB fibre-derived ACF has good reusability, which is suitable for ANG application.

CHAPTER ONE

INTRODUCTION

1.1 Research background

Natural gas is a fossil fuel formed when layers of buried animals, plants, gases are exposed to severe heat and pressured underground over thousands of years (Agency, 2013). It is available abundantly in many countries. Natural gas composes more than 90% of methane (CH_4) which varies with locations and seasons of gas extraction (Arami-Niya et al., 2012). Another fuel which contains methane in its composition is biogas. Biogas is typically produced by anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal wastes, green wastes, plant materials and crops. Due to their eco-friendliness, enormous supply and costs effectiveness, both biogas and natural gas have attracted different interest from many researchers to use methane as an alternative fuel. These gases are by far the cleanest fuel because they produce sulphur dioxide, nitrogen oxide and carbon dioxide (CO_2) in minimal amounts compared to other fossil fuels such as gasoline, diesel and coal. Furthermore, they are cost effective and environmental friendly (Esteves et al., 2008, Guan et al., 2011, Zhang et al., 2010).

Natural gas and biogas are both highly promising clean energy in the automotive and other sectors. They are hydrocarbon gas mixtures consisting of primarily methane (Brady et al., 1996, Esteves et al., 2008). Biogas has the same characteristics as natural gas after the cleaning and upgrading purification processes (Esteves et al., 2008). Despite the advantages in using methane as a low cost and