Char Slurries as a Fuel for Developing Countries

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Declaration

The candidate confirms that the work submitted is his own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Publications

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Research produced for the article appears in chapters 3 and 4. Parts attributable to the thesis author are related to the chemical analysis of the samples collected and analysis of biomass supply and demand. Contributions by co-authors in this thesis are related to the selection and harvesting of samples.

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Abstract

The purpose of the thesis was to investigate if producing a slurry made from char particles could be used as a locally sourced alternative to diesel in developing countries for making electricity with engine generators. The lack of access to electricity in many areas of developing countries is seen as one of the biggest barriers to economic development.

The research investigated all aspects of char slurry fuels including sourcing suitable feedstocks, conversion to char, micronisation and combustion in an engine. A slurry fuel testing facility was built for the purpose encompassing a small diesel engine generator, typical of what is available in developing countries for producing electricity.

Analysis of a wide selection of chars made from several types of material showed that woody biomass was the most suitable for producing slurry fuels. The majority of chars made from agricultural residues were not suitable as the silicon content is likely to cause wear issues in engines. The grindability of chars made from biomass was good and the energy requirements to micronise to particle sizes suitable for an engine were small enough to make producing slurry fuels economically viable. It was recommended that low pyrolysis temperatures are used to make char for slurry fuels because they burn better in an engine whilst still having a high grindability.

Two 10%wt. char-diesel slurry fuels were tested, one using a pyrolysis char, the other using a hydrothermal carbonisation (HTC) char. It was found that the HTC char burned better, producing less CO, THC and soot than the pyrolysis char based fuel because the carbon was less recalcitrant. Issues were found with the engine when using slurry fuels, particularly the injector needle which would sieze. Investigating better injector design and engine construction materials is a priority to make slurry fuels viable for developing countries.

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Abbreviations

AAS	Atomic adsorption spectroscopy
cc	Cubic centimetre
CO	Carbon monoxide
CO_2	Carbon dioxide
CPMAS	Cross-polarisation magic angle spinning
CV	Calorific value
CWS	Coal-water slurries
DAF	Dry ash free
DB	Dry basis
DI	Deionised
DPMAS	Direct-polarisation magic angle spinning
EDL	Electrical double layer
EDM	Electrical discharge machining
EDX	Energy dispersive x-ray
FTIR	Fourier transform infrared spectroscopy
GDP	Gross Domestic Product
ICP-OES	Inductively coupled plasma- optical emission spectroscopy
HLB	Hydrophillic-lipohillic balance
kW(h)	Kilowatt (hour)
HTC	Hydrothermal carbonisation
MW	Megawatt
NMR	Nuclear magnetic resonance
NOx	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
OD	Outer diameter
PM	Particulate matter
PPM	Parts per million
RME	Rapeseed methyl ester
RPM	Revolutions per minute
SEM	Scanning electron microscopy
TGA	Thermal gravimetric analysis
THC	Total hydrocarbons
TPO	Temperature programmed oxidation
WCO	Waste cooking oil
WCOME	Waste cooking oil methyl ester
Wt.	Weight
XRF	X-ray fluorescence

Glossary

Amphoteric	Surfactant containing groups of positive and negative charge. Also known as zwitterionic.
Anionic	Surfactant with solely negatively charged ions.
Capacity factor	The average power produced divided by the rated peak power.
Cationic	Surfactant with solely positively charged ions.
Char	Carbonised material produced from a biomass material.
Cold gas efficiency	Ratio of energy in the feedstock used versus the energy in the syngas produced during gasification.
Dp	Diameter of particle.
Feedstock	Raw material used in manufacturing process.
Genset	Engine generator.
Hydrochar	A char produced via the thermochemical route of hydrothermal carbonisation.
Lignocellulosic	Containing lignin, cellulose and hemicellulose. Terrestrial plant matter.
Load	Resistance to the engine applied externally. Absorbs the power produced.
Pyrochar	A char produced by pyrolysis. Commonly known as charcoal.
Slurry	A mixture of fine particles suspended in a liquid matrix.
Specific emissions	Emissions produced normalised to the useful work performed by the engine.