Hydrogen and Synthesis Gas Production from Rapeseed Residue For Use in Solid Oxide Fuel Cells

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Introduction

Biomass has historically been a very important source of energy and to this day, continues to play a vital role in peoples lives in the less developed world. Recently, it has been making a comeback in the developed world as fears over energy security and resource depletion grow with every passing year. Biomass is able to offer abundant availability thereby reducing future geopolitical tensions over energy resources. Equally as important, is its ability to act as a substitute for petroleum products ensuring that some of the most important industrial chemicals can still be synthesised once crude oil and its derivatives become financially unviable. Waste biomass is particularly attractive as it is cheap and does not compete for valuable farmland. To obtain such products, advanced thermochemical conversion technologies such as pyrolysis and gasification are being developed.

Rapeseed

Rapeseed is an important agricultural commodity. Between 2012 -2013, 60.93 million tonnes of rapeseed oil were produced worldwide. [1] Around 40% of the rapeseed is oil, the rest of the seeds (and plant) must be utilised in other ways. One potential method is to pyrolyse the waste for energy production. Pyrolysis is able to convert biomass matter into useful oils and gases that can be used to generate electricity or for transport purposes

Biochar Production

Biochar is a by-product of pyrolysis. Intermediate pyrolysis is a promising process that is carried out in a Pyroformer [Fig. 1] at 400–500ºC. Biomass is fed in at the inlet, it falls onto the screw which is continuously being rotated by the motor. The speed of the rotation controls the resident time the biomass spends within the reactor. High quality pyrolysis vapours and gases escape through the outlet whilst the remains, mainly biochar exits at the coke outlet.

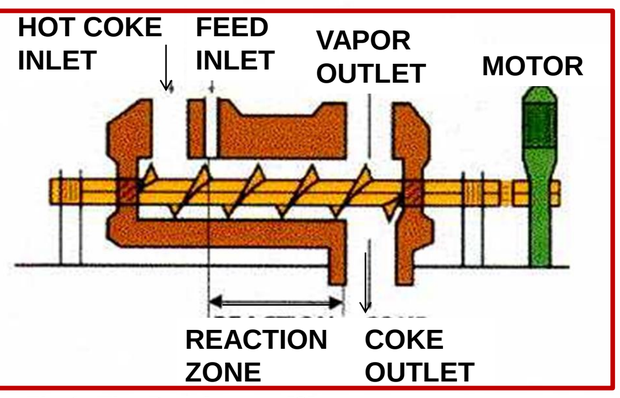

Fig.1: The Pyroformer [2]

Biochar Uses

Biochar can be added to soil to improve its fertility

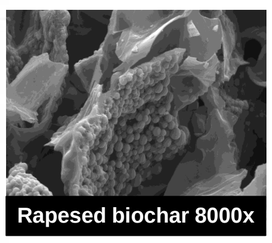

Fig.2 Rapeseed biochar

Fig.3 biochar [3]

Solid Oxide Fuel Cells

Solid Oxide Fuel Cells (SOFC) are the most efficient devices known to man. They operate at high temperatures of 800ºC and are perfect for combined heat and power (CHP) applications. They can give an overall efficiency of ~85%.

SOFCs are able to utilise synthesis gas to produce electricity, however, pure synthesis gas must be used. Conventional biomass produces a range of gases that must be upgraded before they can be used in a SOFC. Biochar gasification is able to produce a high quality syn' gas that can be used in a SOFC with little treatment.

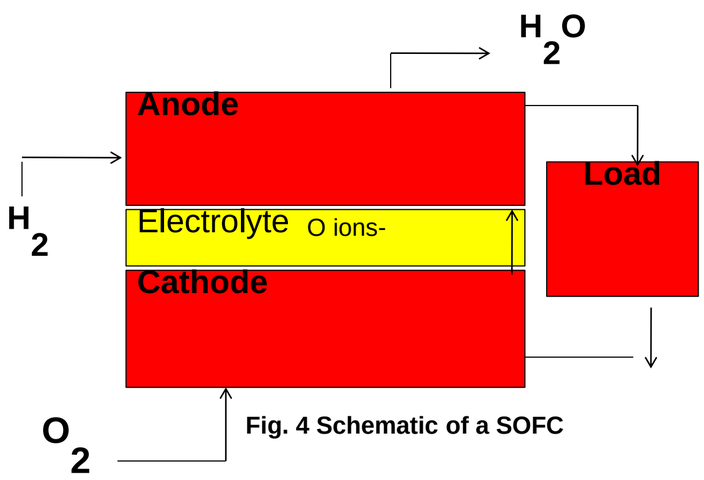

Fig. 4 Schematic of a SOFC

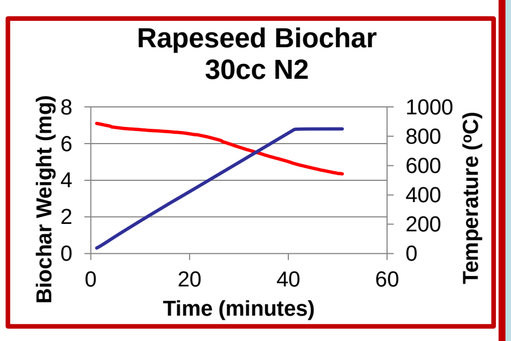

Fig.5 TGA Analysis: Rapeseed biochar

Table 1 Showing BET Surface Areas of the biochars

Biochar	BET SA (m^2 /g)
Rapeseed	0.51

Table 2 Showing the Elemental Analysis of the rapeseed biochar

Biochar	C %	H %	N %	S %	Ash %	O % *	HHV (MJ/kg)
Rapeseed	60.25	4.03	4.19	0.1	4.2	27.61	24.04

Experimental Set Up

The gasification rig consists of a novel, quartz tubular reactor, a preheater, a furnace, a trace heating rig and a condenser. The reactor has the following specifications; L = 750mm, d = 60mm on one side and 20mm on the other.

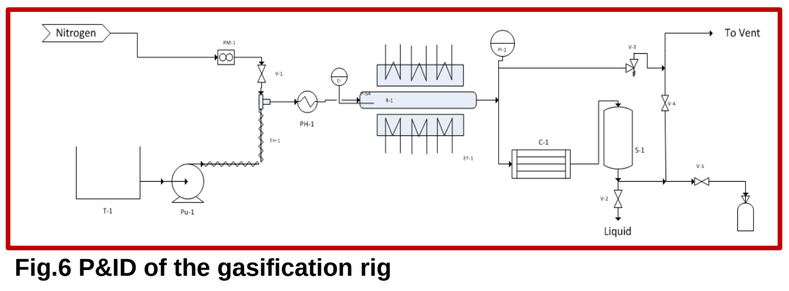

Fig.6 P&ID of the gasification rig

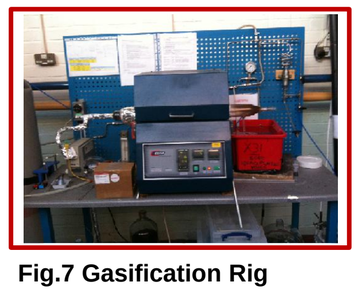

Fig.7 Gasification Rig

The rig works as follows; a pump is used to pump water into a trace heating rig which generates steam, the steam is then superheated in a preheater before entering the reactor where it flows over the biochar and reacts. The products leave and enter a condenser where the tars are condensed out. 50 ml of Gas is collected every 1.5 mins for a total time of 30 minutes.

Results

The following results were obtained

Table 3: Gas composition from Biochar, steam flow in g/min/g biochar

Steam Flow	H_2	CO	CO_2	CH_4
0.054	59.49	21.38	17.78	1.33
0.112	65.27	17.13	16.32	1.28
0.172	64.32	13.94	20.71	1.03
0.217	65.66	11.35	22.27	0.72

Table 3: Showing conversion of rapeseed biochar with steam flow

Steam Flow g/min/g biochar	Conversion Wt%
0.054	62.57
0.112	68.87
0.172	72.18
0.217	71.47

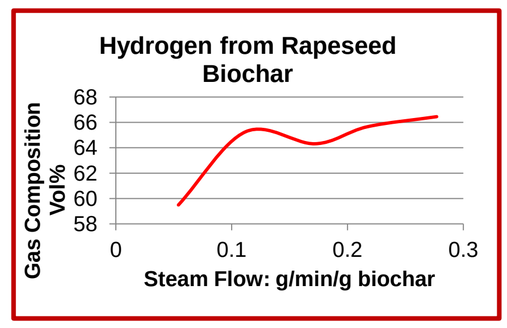

Figure 8: Hydrogen at steam flow: 0.172 g/min/g biochar

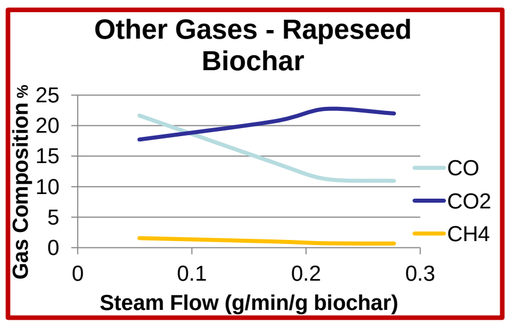

Figure 9: Gas compositions at conditions: 850ºC

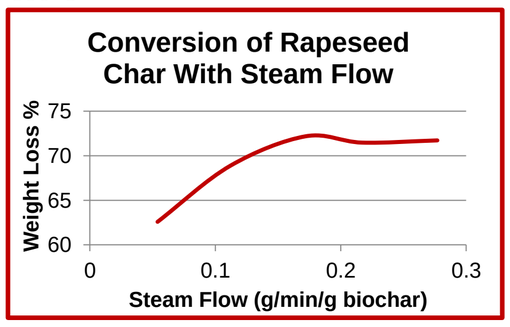

Figure 10: Conversion at 850ºC

Discussions

The results show that with increasing steam flow, the volume of Hydrogen produced increases and the volume of CO decreases. The conversion also increases as there is more steam to react with the biochar.

Conclusions

Rapeseed biochar was gasified with steam to produce a high quality synthesis gas. The syn' gas was very low in tar and hydrocarbon contentmaking it ideal for use in SOFCs.

Future Work

- ❑ Continue experiments to obtain optimum conditions
- ❑ The condensate is a clear liquid [Fig' 11] – investigate whether or not it has any fertiliser value
- ❑ Investigate co-blending with other biochars to further optimise the process
- ❑ Integrate process with SOFC and investigate its behaviour

Figure 11: Condensate from rapeseed biochar gasification

References

[1] US Dept' of Agriculture. Foreign Agricultural Service. Major Oil Seeds, Worldwide Supply and Distribution
[2] A. Hornung et al. Thermal Treatment of Biomass . Great Britain Patent Application Number: GB 0808739.7 2009. World Patent Applied (WO 138757; Nov' 19 2007).
[3] Biochar picture taken from: http://novotera.ca/?page_id=10

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