Gasification and combustion of biomass and acid hydrolysis residues (AHR)

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DIBANET

OBJECTIVES

- Characterisation of biomass feedstocks: miscanthus, sugarcane bagasse and sugarcane trash
- Characterisation of acid hydrolysis residues from miscanthus and bagasse
- Evaluation of miscanthus and acid hydrolysis residue from miscanthus as gasification feedstock
- Evaluation of kinetic parameters for combustion of miscanthus, sugarcane bagasse, sugarcane trash and their acid hydrolysis residues

INTRODUCTION

Biomass from either energy crops or agricultural residues can be thermally and/or chemically treated under different conditions to obtain varying yields of liquids or gases according to the desired application. The decomposition of the cellulose and hemicellulose contained in biomass into sugars, and their further transformation into relevant chemicals is possible through a chemical treatment known as acid hydrolysis. In this process, almost 50% of the biomass feedstock is transformed into a solid residue consisting of mainly lignin and containing some of the carbohydrate degradation products. Since this residue has a greater heating value than the original biomass, it is necessary to recover and use the energy contained in the acid hydrolysis residue (AHR).

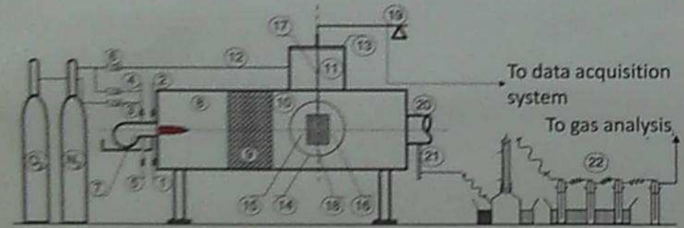
The present work was developed within the scope of the Work Package 4 of the Dibanet Project, with the aim of recovering the energy from acid hydrolysis residues and biomass by gasification and combustion.

BATCH GASIFICATION

Experimental setup

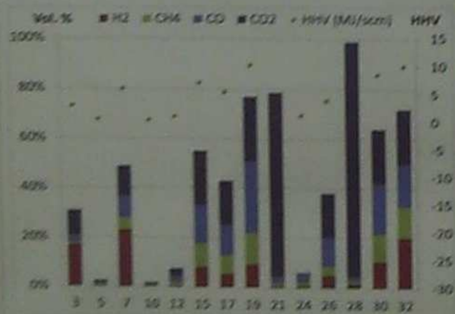
Experiments carried out at KTH in Sweden in a batch gasifier under the following conditions:

- Initial temperatures of 700, 800 and 900 °C
- Atmospheric pressure
- Agents: oxygen, nitrogen, air, steam, carbon dioxide and combinations



1-5. Gas inlets
6. Mass flow meters
7. Methane burner
8. Gas chamber
9. Flow straightener
10. Gasification chamber
11. Cooling chamber
12. Nitrogen purge
13. Inlet flange
14. Sample holder
15-17. Thermocouple
18. Sample
19. Mass measurement
20. Exhaust pipe
21. Sampling probe
22. Sampling train

Results



Exp.	Feedstock	Gas
3	AHR	Steam
5	AHR	N_2
7	AHR	Steam
10	AHR	10% O_2 in N_2
12	AHR	5% O_2 in N_2
15	AHR	Steam and air
17	AHR	Steam + air
19	Miscanthus	Steam + air
21	AHR	CO_2
24	Miscanthus	Steam
26	AHR	Steam
28	AHR	Steam
30	50% AHR	Steam
32	75% AHR	Steam

- Steam improves production of methane, hydrogen and carbon monoxide
- Carbon dioxide has no effect on carbon monoxide production
- Heating value of the product gas can be improved by mixing the AHR with untreated feedstock

FEEDSTOCK CHARACTERISATION

Structural composition of untreated biomass

Determination of structural carbohydrates and lignin by the method of Ona.

Structural CH and Lignin Content (dry, ash-free basis).			
Fraction	Miscanthus	Bagasse	Trash
Extractives	7.7%	7.3%	16.3%
Lignin	22.0%	18.4%	16.6%
α - Cellulose	40.8%	45.1%	32.9%
Hemicellulose	29.6%	29.2%	34.2%

Proximal and ultimate analysis of biomass and structural fractions

Determination of elemental composition and ash content by ASTM methods.

Feedstock	Fraction	C	H	N	O	Ash	HHV (kJ/g)
Miscanthus	Untreated	46.0%	6.0%	0.5%	47.5%	2.6%	18.18
	Cellulose	45.1%	6.2%	0.2%	48.5%	2.7%	17.93
	Klason lignin	59.7%	5.2%	0.7%	34.5%	6.8%	23.22
Sugarcane bagasse	Untreated	47.7%	6.1%	0.4%	45.9%	2.1%	18.99
	Cellulose	46.3%	6.5%	0.1%	47.1%	1.7%	18.88
	Klason lignin	60.9%	5.0%	0.6%	33.6%	3.1%	23.58
Sugarcane trash	Untreated	45.2%	5.9%	0.7%	48.2%	4.6%	17.61
	Cellulose	45.7%	6.2%	0.5%	47.6%	2.1%	18.31
	Klason lignin	53.5%	4.9%	1.0%	40.6%	11.7%	19.98

Proximal and ultimate analysis of biomass and AHR

Determination of elemental composition and ash content by ASTM methods.
Char, volatiles and fixed carbon determined by thermogravimetric analysis.

Feedstock		Miscanthus		Bagasse	
Property		Untreated	AHR	Untreated	AHR
Composition	C (wt%)	46.0	66.2	47.7	64.6
	H (wt%)	6.0	4.7	6.1	4.6
	N (wt%)	0.5	0.2	0.4	0.4
	O (wt%)	47.5	28.9	45.9	30.4
	Ash (wt%)	2.6	1.9	2.1	6.0
High heating value (kJ/g)		18.2	25.6	19.0	24.7
Char content (wt%)		26.2	59.9	16.5	63.8
Volatiles content (wt%)		68.3	40.0	78.1	36.2
Fixed carbon (wt%)		23.6	58.2	14.4	56.8

COMBUSTION KINETICS

Methodology

- Calculate activation energy by model-free isoconversional methods (Coats and Redfern, Doyle, Vyazovkin)
- Determine best fitting reaction model for each feedstock using the Malek method
- Calculate frequency factor using the best fitting model

Results

Feedstock	$Ea_{Vyazovkin}$ (kJ/mol)	Reaction model	A (min^{-1})
Miscanthus	133	Contracting volume	3.12E+11
Miscanthus AHR	137	Contracting volume	2.11E+09
Sugarcane bagasse	150	Contracting volume	6.93E+13
Sugarcane bagasse AHR	191	Contracting volume	9.05E+15
Sugarcane trash	136	Order 1	4.68E+11

CONCLUSIONS

- Gasification of AHR and untreated feedstocks gives low heating value gases suitable for engines..
- Combustion of AHR and untreated feedstocks has been modelled through kinetics and the process is feasible in most conventional combustors.

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