Fixed bed Combustion of Segregated wastes

Anh N Phan, Changkook Ryu, Yao-bin Yang, Vida N Sharifi and Jim Swithenbank

Sheffield University Waste Incineration Centre (SUWIC), Sheffield University

Summary

The combustible materials in municipal wastes are mostly bio-derived. Energy recovery of wastes that cannot be economically recycled is a key part of sustainable energy policy as well as of waste management.

The combustion characteristics of waste materials and their mixtures in a fixed bed are presented as a fundamental investigation for energy recovery from municipal wastes. Key combustion parameters including the ignition and burning rates are derived from experimental results at different air flow rates in order to evaluate their combustion performance. The visual observation of combustion using a glass tube reactor provides clear understanding on the propagation of the ignition front.

Cardboard and waste wood had typical combustion characteristics showing two successive stages of combustion: the ignition propagation stage and the char gasification stage. As the air velocity or the amount of oxygen increased, the ignition and burning rates linearly increased until they were balanced by convective heat loss.

Textile residues had very irregular ignition rate, low burning rate and high unburned carbon content of bottom ash, compared to other materials. Co-combustion of textile residues with other waste materials investigates a way to achieve more controllable and efficient combustion of textile residues.

Experimental and Numerical Methods

Materials: Cardboard, Waste wood and Textile residues

Properties	Waste wood	Cardboard	Textile Residues
Moisture (%wt)	6.9	2.7	3.6
Volatile matter (%wt)	71.7	80.4	89.0
Fixed carbon (%wt)	18.5	11.2	6.9
Ash (%wt)	2.9	5.7	0.5
Carbon (%wt)	44.9	41.7	43.3
Hydrogen (%wt)	6.7	6.4	6.2
Oxygen*(%wt)	38.6	43.5	46.4
Gross calorific value (MJ/kg)	16.0	15.7	16.0
Particle size and shape	20mm cube	5x20x20mm	30x50mm
Bulk density of bed (kg/m^3)	308	76	90

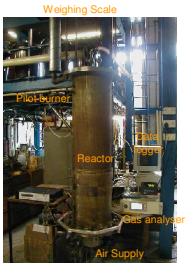

Waste wood

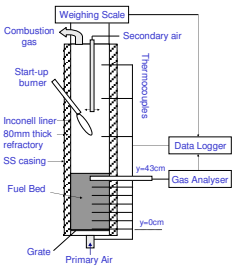

Cardboard


Textile residues (cotton ~95%, polyester ~5%)

Fixed Bed Reactor

- Reactor size: ID 20cm x H 150cm
- Weighing scale for mass loss
- Gas analyser: CO/CO2/O2
- K-type thermocouples





Test Conditions

- Air flowrate: 117~2106 kg/m^{2}hr
- Bed height: 33~52 cm
- Textile fraction in co-combustion: 0~100 wt%

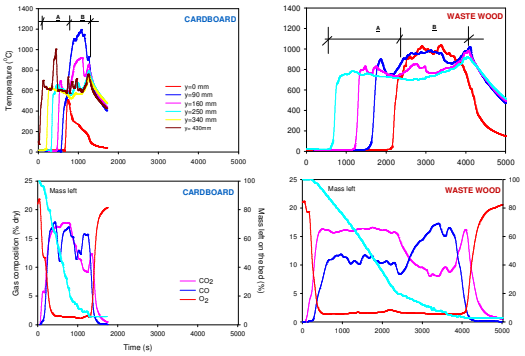
Mathematical Modelling (FLIC)

- FLIC: Unsteady 1-dimensional calculation of a two phase (fuel and gas) reacting bed
- Combustion process: moisture evaporation, devolatilisation and char gasification
- Number of cells: 200
- Time step: 2 seconds

Combustion of Cardboard and Waste Wood

Combustion of Cardboard and Waste Wood

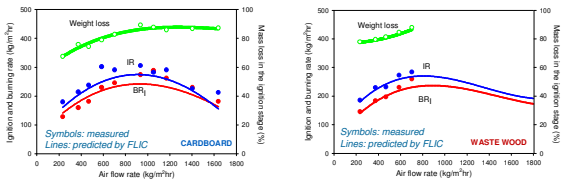
- Two successive stages of combustion: Ignition propagation ('A') and char gasification ('B')



Temperature profiles and gas composition at air flow rate of 234 kg/m^{2}hr

Ignition and Burning Rates

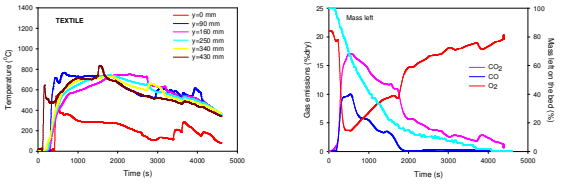
- Ignition rate (IR): Mass rate swept by ignition front
- Burning rate (BR): Mass rate converted to gas
- BR close to IR at high air flows: All mass ignited was converted to gas, short char gasification stage



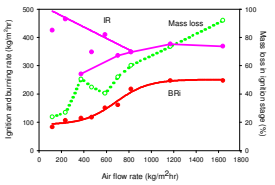
Combustion and Co-combustion of Textile Residues

Combustion of Textile Residues

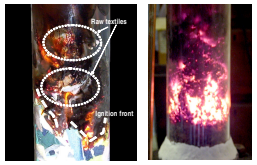
- At low air flow rates (<1200 kg/m2hr): Irregular propagation of the ignition front due to development of random air channels along the chunks of textiles
- Very long burn-out stage due to the large amount of unburned materials above the ignition front
- At high air flow rates (>1200 kg/m2hr): Less irregular ignition front
- Lower burning rates than waste wood and cardboard



Temperature profile and gas composition of textile residues at air flow rate of 234 kg/m^{2}hr



Ignition rate (IR), burning rate (BR) and mass loss in the bed

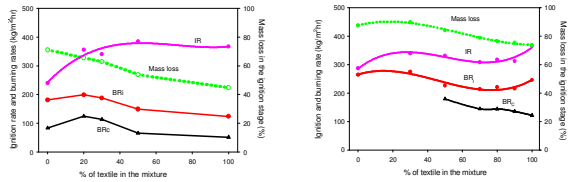


(a) (b)

Glass tube tests: (a) textile residues (b) refuse-derived fuel as an example of flat ignition front

Co-combustion of Textile Residues with Cardboard

- Two materials had similar ignition front speeds: combustion of cardboard particles increased the ignition front speed and burning rate.
- For textile residue fraction up to 30%, burning rate increased and the burn-out stage was shortened.
- Wider range (up to 1700 kg/m^{2}hr) of air flow rate for stable combustion: the mixture (textile 30%+cardboard 70%) was more resistant to convective cooling by primary air

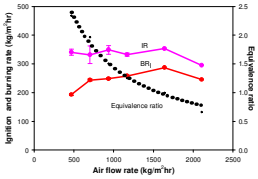


(a) Air flow rate: 468 kg/m^{2}hr (a) Air flow rate: 1170 kg/m^{2}hr

Ignition rate (IR), burning rates (BRI: in the ignition stage; BRC: in the char gasification stage) and mass loss on the bed for the combustion of textile/cardboard mixtures

(a) (b) 1 min after (a)

Cardboard particles ('C') burning at the ignition front: Textile 50% + Cardboard 50%, air: 280 kg/m^{2}hr



Wider range of air flow rate for stable combustion: Textile 30% + Cardboard 70%

Co-combustion of Textile Residues with Waste wood

- Ignition front speed (IFS) and overall combustion behaviour dominated by textile residues even for smaller particle size (5mm) of wood

Materials	Weight loss in the ignition propagation stage (%)	IFS (m/hr)	IR (kg/m^{2}hr)	BR_I (kg/m^{2}hr)	BR_C (kg/m^{2}hr)
Waste wood (20mm) 100%	74.1	0.77	227.9	197.9	138.5
Waste wood (20mm) 70% / Textile residues 30%	36.4	3.44	688.0	217.1	59.0
Waste wood (5mm) 70% / Textile residues 30%	49.7	3.71	574.9	197.0	99.1
Textile residues 100%	47.5	3.33	299.7	117.8	63.8

Conclusions

- Waste wood and cardboard showed typical combustion characteristics in a fixed bed: uniform propagation of the ignition front followed by char gasification
- Cardboard was less resistant to convective cooling with a peak of IR and BR at air flow rate of 936 kg/m^{2}hr.
- Textile residues had poor combustion performance: irregular ignition front, low burning rate and high unburned carbon content
- Co-combustion of textile residues with cardboard for the textile fraction of up to 30% had synergy of increased burning rates and a wider range of air flow rate ideal for stable combustion.
- Co-combustion of textile residues should be performed with materials having similar ignition front speed so that the combustion of the target materials contributes to faster burn-out of textile residues.

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More Information on SUWIC can be found at our websites: http://www.suwic.group.shef.ac.uk/

Contact: Professor V N Sharifi,
Dept. of Chemical & Process Engineering, Sheffield University
Mappin Street, Sheffield S1 3JD, UK
Tel: +44-114-222 7518 E-mail: v.n.sharifi@sheffield.ac.uk