Bio-residue gasification – Science and Technology

Combustion, Gasification & Propulsion Laboratory

Department of Aerospace Engineering

The Presentation

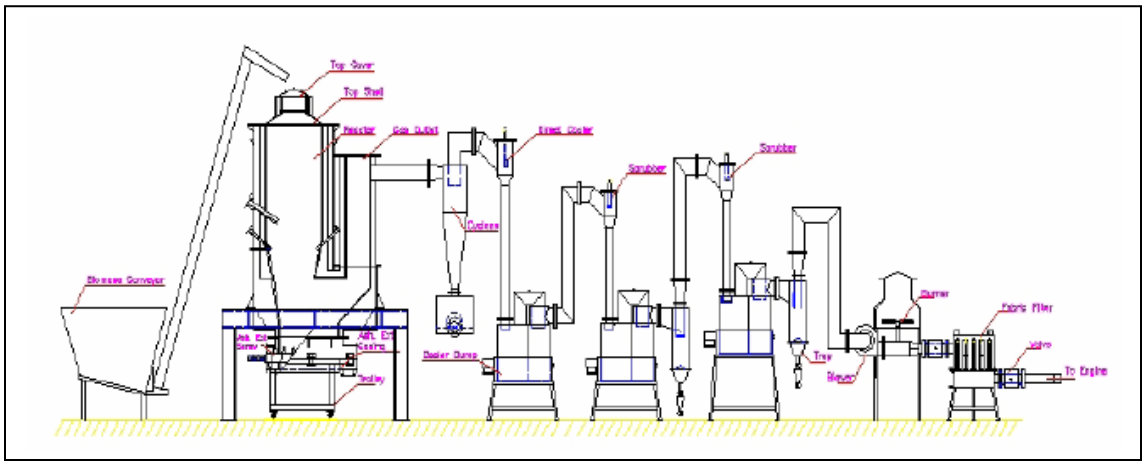
- The technology
  - System configuration and elements.
- Scientific input to the technology development
  - Results from basic studies and their use in design of the gasification system.

Gasification process

Process that converts solid fuel to gaseous fuel

- Used in an internal combustion engine for power generation to substitute fossil fuel
  - Diesel engine – for dual fuel application
  - Gas engine – for single fuel
- Used in heat application
  - Low temperature – drying, etc
  - High temperature – furnaces, kilns, etc

Technology elements

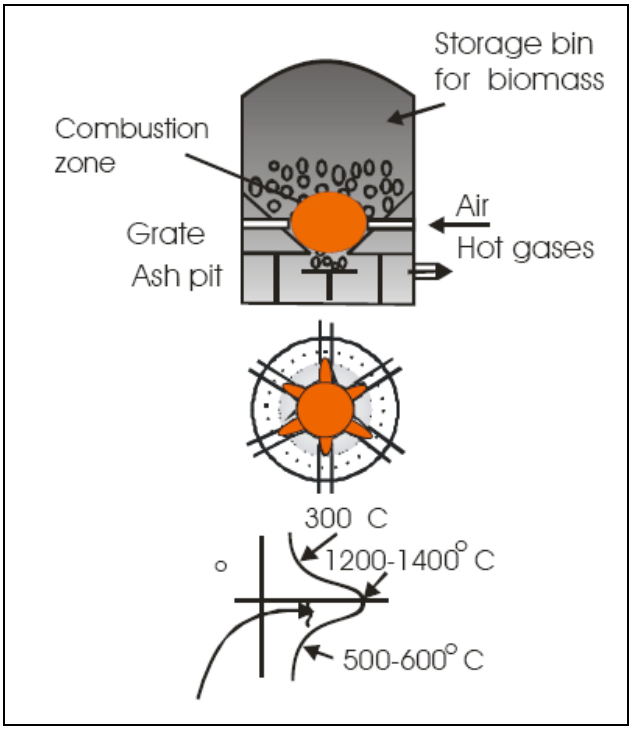


Salient features

- Well insulated reactor
    - Ceramics – to stand high temperature and meet industrial standards
    - No metal would stand the oxidizing and reducing environment
- Necessary cooling and cleaning system
    - to meet the end use requirements

Reactor design: II WW - Closed top design

Initial development activity began using a closed top design



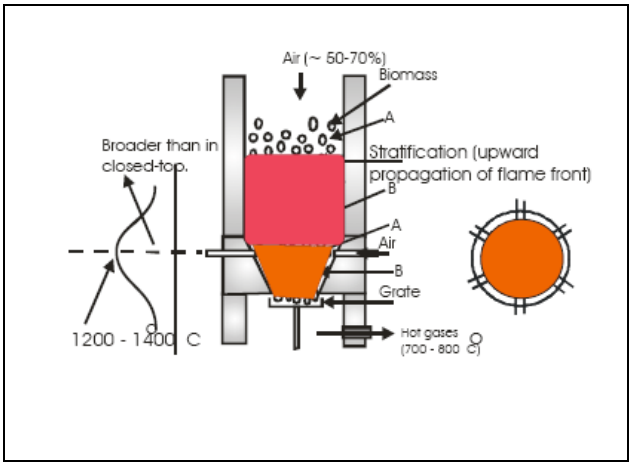
Findings

- Combustion zone confined to a small region
- Regions of low temperature
- Can handle only woody biomass
- Turn down ratio limited
- Problem of consistent gas quality

Reactor design - IISc design – open top

Novel reactor design

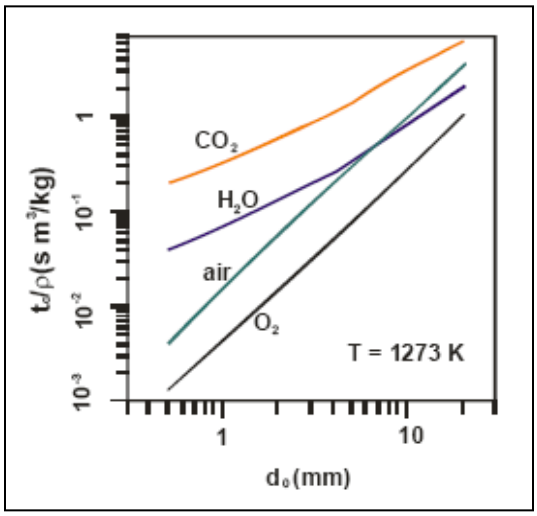
- Biomass + air -> volatiles + char with CO_2 + H_2O -> 0.2 CO, 0.2H_2, 0.12CO_2, 0.02 CH_4 + rest N_2
- Air is drawn from the top and from the air nozzles –
    - Uniform distribution
- Broader high temperature zone



- Consistent high quality gas over the turn down ratio
- Varying biomass quality – can accept all agro residues

The ratio of air flow rate from the nozzle to the top depends on the fuel properties – size, density; the char consumption rate, etc

Basic Research – Single particle



Reactants: (a) CO2 (b) H2O (c) air (d) O_2

$t_b \sim d_0^{1.03}$	CO_2	Kinetic and diffusion dependence
$t_b \sim d_0^{1.2\text{-}1.3}$	H^2O	Kinetic and diffusion dependence
$t_b \sim d_0^{1.9}$	air	diffusion limited
$t_b \sim d_0^{2}$	O_2	diffusion limited

Conversion time for char reaction with

1. CO_2 is 3-4 times that of H_2O
2. H_2O is comparable to air at dp > 8 mm

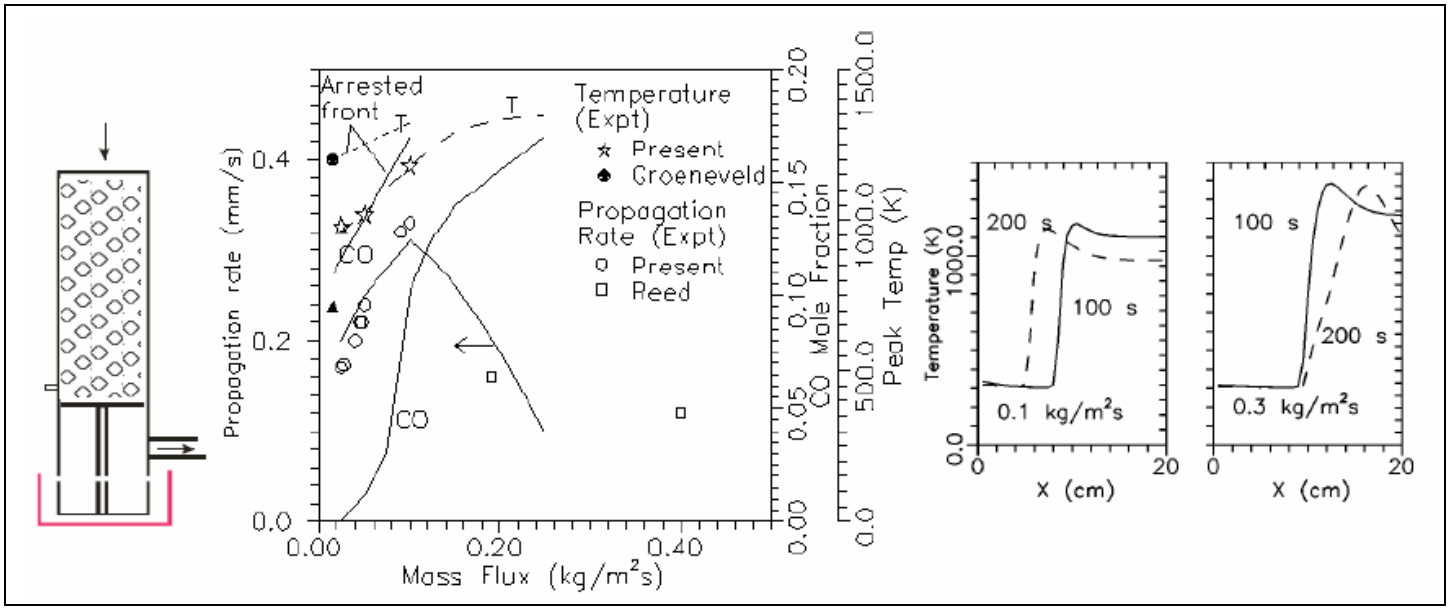
Time for conversion depends on the particle density and diameter

Basic studies has helped in assessing

- Char consumption rate
    - Depends on the concentration of O2, H2O and CO2
        - Has helped to use high density briquettes, coconut shell and other agro residues as fuels
- Char quality
    - For activated carbon
        - The reactions that occur in the gasifier produces high surface area; evident from single particle studies

Air flow rate through the nozzles decides the consumption of char – fixes air nozzle area

Basic Research – packed bed



With increase in mass flux the front velocity initially increases and then reduces

- This fixes the turn down ratio of the gasification system
- Superficial mass flux and ash properties are used as design parameters

Gas cleaning - process

- Gas has to be cooled and cleaned for end use application
    - Cooling by spraying water in scrubbers
    - Cleaning is achieved using chilled scrubbers.

With this gas cleaning process it is possible to restrict the contaminants to ppb levels

Gas cleaning

- After cooling
    - Gas is saturated with moisture
    - Contains fine dust and condensable (~ 25 ppm) even after filtering – not acceptable to turbo charged engines
- Use the principle of condensation of moisture over nuclei of particulate matter
    - Scrub the gas using cold water (< 10 C)

- Dries the gas by condensing the water vapor
- This happens over the particles – thus removing the particulate in sub microns levels
- The gas is dry and clean to ppb level Chilled scrubbers are currently being used in all the systems

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