Modelling of Catalytic Biomass Flash Pyrolysis with Artificial Neural Networks and Hybrid Models

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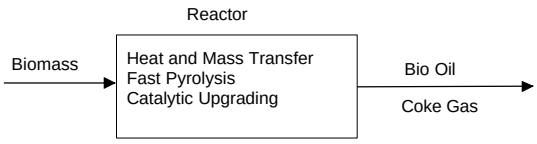
Project Goals

This project is part of a European research project working to optimise the yield and quality of bio oil produced by catalytic flash pyrolysis. The objective of our work is to develop computer models describing the overall processes in different reactors used for biomass flash pyrolysis. The major aspect of this goal is the development of kinetic models using data-based approaches and models including both a priori knowledge and data-based estimations.



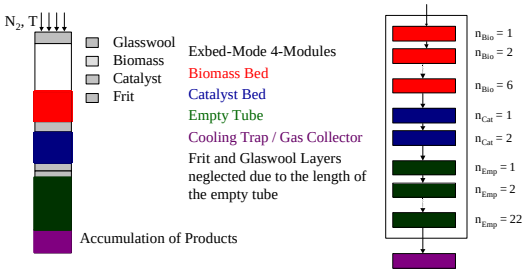
Project Strategies

Traditional kinetics models are hardly applicable for the prediction of the bio oil composition, since not enough information about the pyrolysis mechanisms is available. Thus, databased strategies may offer advantages for the description of this complex reaction mechanism. One possibility is the usage of artificial neural networks (ANN) or a combination of artificial neural networks with traditional knowledge based models (Hybrid Models).
The following four steps will be taken to complete this goal.

1. Reactor Modeling of the involved reactors
   - Fixed bed reactor
   - Fluidized bed reactor
   - Circulating fluidized bed reactor
   - Rotating cone reactor
2. Isolation of kinetic information from experimental data
3. Kinetic modelling using traditional models, ANN and hybrid models
4. Implementation of kinetic models in reactor models

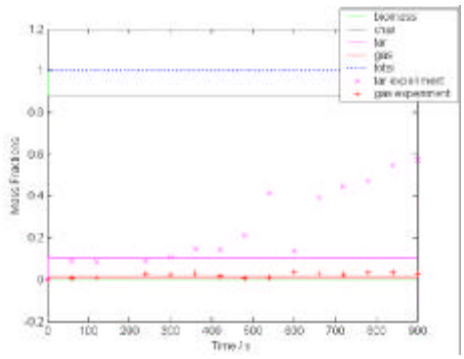
Fixed Bed Reactor

This reactor was planned to be the primary reactor, to gather necessary data for step 2 and 3 processing 1.5 g biomass (wood or crop) per run.
For all modes of operation (non-catalytic, inbed or exbed) a transient 1-d model has been completed using a series of well mixed zones as approximation.



Schematic Representation of the fixed bed reactor operated by CPERI

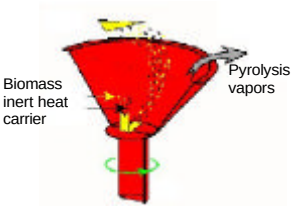
Comparing experimental data with simulation results predicted using a model proposed by Di Blasi et al. it could be shown that the kinetic information in the experimental results is not sufficient for the estimation of kinetic parameters (most likely due to condensation of heavier compounds).



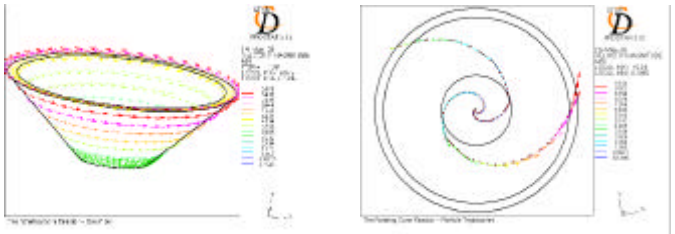
=> New strategy:
- Further experiments to analyze the influences of primary, secondary and secondary catalytic pyrolysis reactions
- Determination of reaction rate ratios for simplified literature models
- Evaluation of catalytic reactions of selected primary pyrolysis products

Rotating Cone Reactor

This reactor type was specifically developed for the bio oil production. A rotating outer conus induces a fast gas movement leading to a short dwell time of the pyrolysis gases and high heating rates. The unit processes up to 5 ton of biomass per day and is modeled using the CFD-software-package Star - CD(R).



http://www.btgworld.com/technologies/pyrolysis.html



Predicted Gas and Solid Flow without Consideration of Pyrolysis Reaction

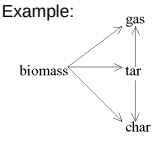
Kinetic Modeling

Traditional Approach

$$R_i = \sum_j \nu_{ij} r_j(\bar{c}, T)$$

+ extrapolative
- mechanism has to be determined
  => difficult for complex reaction systems

Example:

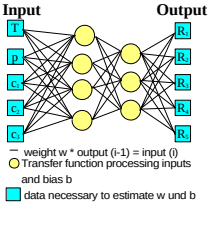


DiBlasi - Mechanism

Hybrid Approach

Traditional approaches for known mechanisms of the system
+
ANN - Estimation for unknown parts
=
Approaches for systems hardly describable with traditional methods and more extrapolative results than ANN

ANN Approach



+ no a priori knowledge needed
- hardly extrapolative
- a lot of experimental data needed