Gasification and thermal radiation

by

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Introduction

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### Project description

“Heat transfer connecting to hydrogen and bio fuel production and use for heat- and power production”

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<th>Heat and Power</th>
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Lund University / Faculty of Engineering, LTH / Energy Sciences / Heat transfer / 091007
Literature survey

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In depth literature survey on gasification

Gasification is conversion of carbonaceous materials into a gas with a usable heating value

Synthetic gas (syngas): CO+H$_2$

The carbon is oxidized either by air or steam or both

Air react as partial combustion: C+0.5O$_2$ → CO (exothermic)
Steam with carbon: C+H$_2$O → CO + H$_2$ (endothermic)
In depth pilot study of gasification

There exist a large variety of gasifiers. The majority is some kind of:

Fluidized bed

Entrained flow
Numerical modeling of gasifiers

With the gasification process we have many similarities with process of combustion:
- Chemical reaction, Kinetics modeling
- Fluid flow, turbulence
- Heat transfer, conduction, convection and radiation

The major difference for the gasification process is the instead high content of CO and low content of CO$_2$. 
Numerical modeling of gasification

The CO$_2$ molecule is considered as a strong radiating molecule and the CO a not so strong.

Radiation in participating media:
- Strong temperature gradients
- Strong concentration gradient

Most present models focus on
- chemical reactions and/or fluid flow
- use a simple approach for radiation
- neglects it
Numerical modeling of gasification

\[ \frac{dI_v(r, s)}{ds} = -\beta_v(r)I_v(r, s) + \kappa_v(r)I_{by}(r) + \frac{\sigma_{sv}(r)}{4\pi} \int_{4\pi} I_v(r, s^*)\Phi(s^*, s) d\Omega^* \]

Emittance and absorption
- Rotational and vibrational modes of the molecule
- Creates bands with specific band center at distinct wave number
- Mixture molecules + adding contributions throughout the entire electromagnetic spectra
Numerical modeling of gasification

Line-by-line calculations divides the electromagnetic spectra into millions of lines.

Narrow band model having smoothens the actual emissivity for a group of lines.

Wide band model having even larger intervals where the entire bands are approximated.

Gray assumption is constant emissivity throughout the entire spectra.
Narrow band model and FAST NB model

FAST NB model (Zhenghua Yan)

RADCAL (Grosshandler)
- non-homogeneous
- non-isothermal

RADCAL uses molecular models and tabulated values for the calculation of the absorption and emittance of gases
Narrow band model and FAST NB model

“Once and for all database”
  – Temperature steps of 10 degrees C
  – 20 times faster
  – 1 percent in loss of accuracy

My work:
  – add carbon monoxide and methane and
  – possibly particulate matter
  – verify the expanded model
Narrow band model and FAST NB model

Verification against: Natural gas diffusion flame 0.6 meters from burner
Narrow band model and FAST NB model
Narrow band model and FAST NB model

Spectral Intensity at distance 0.6 m from burner

- 2.7 μm
- 4.3 μm
- 6.3 μm
- 4.7 μm
Narrow band model and FAST NB model

Verification against: Natural gas diffusion flame 0.6 meters from burner

Comparing the radiation intensity at the end of the path:

Experimentally: Intensity= 24.22 kW/m\(^2\)/sr
FAST NB model: Intensity= 23.47 kW/m\(^2\)/sr
Correlated k-gas method: Intensity= 23.18 kW/m\(^2\)/sr

Without CO the intensity lessens with approximately 1 %
Narrow band model and FAST NB model
Narrow band model and FAST NB model
Further work on gasification

Aim:
Implement the FAST NB model into a full scale model of a gasifier together with models for:

– Fluid flow
– Chemical reactions, kinetics
– Conduction, Convection and Radiation

Simtec, Fluent, Open Foam…
Future papers

Conference paper for:

The Sixth International Symposium on Radiative Transfer
Radiative Transfer, RAD-10
Antalya, Turkey
June 13 – 19, 2010
Questions!?! 

Thanks for listening!