Integrated FLIC/FLUENT Modelling of Large Scale MSW Incineration Plants
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Summary
The combined simulation of FLIC and FLUENT was carried out for the combustion chamber of the municipal waste incinerator to predict the waste bed combustion and the gas flow field simultaneously. The combined simulation provided input conditions on both sides: the gas release from the waste bed for FLUENT and the radiative heat flux from the furnace for FLIC. After several updates of the two models, the heat and mass interaction reached a steady state. The ignition point of the waste combustion in the final solution was advanced by around 0.3m, compared to the initial result using an assumed constant radiation heat flux. The predicted results of waste combustion from FLIC was compared to the measured data within the bed using the novel ball instrument. The maximum bed temperature measured was 1000°C, 1138°C. Big fluctuations of less than 90°C were observed. This is due, among other reasons, a 10 cm combustion layer as predicted by the mathematical model where the thermocouples moved out and could not measure the boundary temperature. The model predicts that the upper and lower boundaries of both the temperature and O2 fluctuations in the gas flow field, the jet arrays of the secondary air dominate the flow pattern throughout the secondary combustion chamber. A high temperature and high velocity gas stream was created following the jet trajectories, improving the secondary air necessary for more efficient use of the furnace volume.

Conventional Flow Simulations

Major Phenomena in the Incinerator Combustion Chamber
- Waste combustion in the bed on the grate
- Gas flow region over the bed
- Close interaction of the two regions through heat and mass transfers
- Release of combustion gas from the bed to the gas flow region
- Radiative heat transfer between the furnace wall, the flame and the waste bed

Usual gas simulations for waste incinerators
- Based on simplification of waste combustion
  - The waste bed becomes the inlet of the gas plenum
  - The input conditions (temperature, velocity and gas concentrations) of the inlet are calculated from an assumed combustion profile
  - This method allows simple simulations of the incinerator, but limits the capability of usual gas flow simulation
- The gas flow simulations have provided useful information on the gas flow characteristics for various furnace shapes and on the effect of secondary air injections etc.

Combined Simulation Strategy

The objective – simultaneous simulation of waste combustion and gas flow field considering their heat and mass interaction

Calculation procedure: iterative calculation of FLIC and FLUENT
- FLIC = FLUENT: Gas properties leaving the bed as input conditions of the inlet
- FLUENT = FLIC: Radiation profile along the bed as boundary condition on the top of the bed
- Convergence criterion: change in radiation or in the gas temperature

Simulation Method for Waste Incinerator

MSW Incineration Plant
- Throughput of waste: 10t/h
- Total flow rate of combustion air: ~36,000Nm3/hr (60% excess air)
- grate: Marsh type: 3.76 m x 8 m
- Moisture: Variates Matter: Fixed Carbon: Ash content in waste
- Lower Calorific Value of waste: ~7500kJ/kg
- The secondary air is injected from 28 nozzles located on the front and rear walls between the primary and secondary combustion chambers.

FLIC for simulation of waste combustion
- Number of cells: 160 x 200
- Input conditions
  - Primary air flow rate: 15.32(25.18 m3/hr
  - Waste residence time: 80 min. Particle size: 45mm
- FLUENT for gas flow simulation
  - Flow Model: Turbulence Renormalised Group k-ω model
  - Radiation: Discrete Ordinates Method with the Weighted Sum of Grey Gases Model for gaseous emission by CO2 and H2O
  - Reaction: Eddy break-up rate model
  - Combined Simulation
  - 200 iterations for one input update from FLIC
  - The input update is repeated until the radiation profile from FLUENT becomes stable

Intermediate Results of Combined Simulation

Interaction between FLIC and FLUENT during the iterative calculation
- The radiation temperature was initially assumed to be constant at 1173K.
- The first radiation profile became similar with the temperature distribution of the combustion gas leaving the bed shown in the right graph, since the temperature on the furnace wall and gaseous emission is determined by the properties of combustion gas and the flow pattern.
- After 3 more updates, the changes in the profile of radiation were reduced significantly

Results: Waste Combustion

Comparison with measurements using the ball instrument
-Ball instrument: a unique instrument that can be introduced into the incinerator with the waste feed and tumbles along with the burning waste material while recording temperatures, gas composition and bed motion onto a thermally insulated electronic chip.
- The size of the instrument was about 130mm in diameter and 220mm in length.
- The waste feed was ignited at a position of 1.8 m to 2.0 m from the waste entrance. The maximum bed temperature measured was 1000°C, 1138°C. Big fluctuations of less than 90°C were observed. This is due, among other reasons, a 10 cm combustion layer as predicted by the mathematical model where the thermocouples moved out and could not measure the boundary temperature. The model predicts that the upper and lower boundaries of both the temperature and O2 fluctuations in the gas flow field, the jet arrays of the secondary air dominate the flow pattern throughout the secondary combustion chamber. A high temperature and high velocity gas stream was created following the jet trajectories, improving the secondary air necessary for more efficient use of the furnace volume.

Results: Gas Flow Field

Main features of the flow field
- The secondary air jets dominate the overall flow pattern
- A hot high-speed gas stream is formed following the jet trajectories
- The high speed stream may result in an increase of particle carry-over to the boiler tubes

Gaseous reaction
- The gaseous reactions occur by fresh oxygen from the secondary air in the main hot gas stream
- A long stretched flame is created over the bed

Conclusions

- FLUENT/FLIC Combined Simulation
- Simultaneously predicts the waste combustion and the gas flow field
- Allows investigation of the effect of various design and operational parameters in incinerators
- Combustion and Flow Characteristics of the Waste to Energy Plant
- Waste combustion ignited at x=2m and completed at x=7m
- Active mixing and reaction by the secondary air in the gas flow field
- The high speed hot gas streams increase the particle carry-over to the boiler
- Optimization of the injection method of the secondary air necessary to improve the flow pattern for better mixing and reaction efficiency

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