Physical and Stochastic Modeling of Mixing Phenomena of Municipal Solid Waste (MSW) Particles on a Traveling Grate

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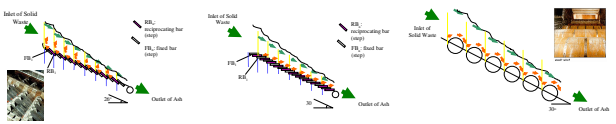
Background

The drying, volatilization, and combustion phenomena during the travel of the solid waste fuel over the grate depend on a large number of parameters

- The physical and chemical properties of the diverse particles in MSW that vary widely in size, shape, density, moisture, chemical composition, and calorific value; and also the design of the grate and combustion chamber.

Various types of traveling grate systems

- Drying process during MSW mixing by a traveling grate system
- Heat transfer in the MSW bed

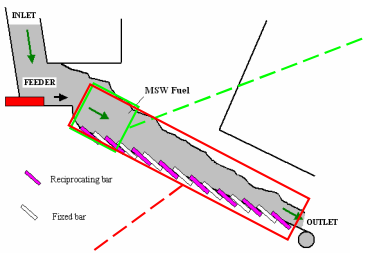


Reverse Acting Grate *Forward Acting Grate* *Roller Grate*

Objectives

Providing a better tool for understanding effects of solid flow and mixing by a traveling grate

- Developing a mathematical model to characterize and quantify flow and mixing processes of the highly non-homogeneous MSW.
- Simulating the behavior of solid waste particles with transport and combustion phenomena.

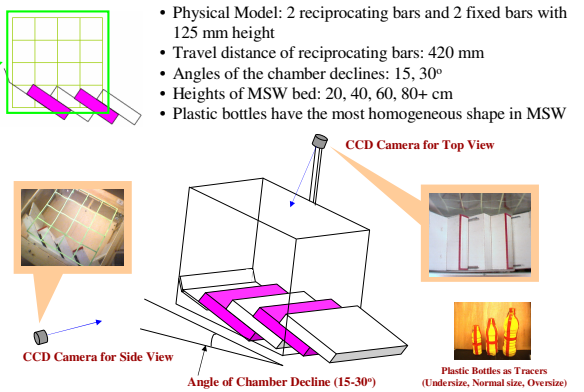


Reverse Acting Grate System in a Waste-to-energy Combustion Chamber

Physical Modeling

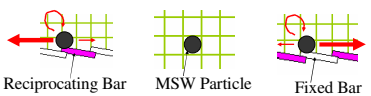
Full-scale Section Model

- Physical Model: 2 reciprocating bars and 2 fixed bars with 125 mm height
- Travel distance of reciprocating bars: 420 mm
- Angles of the chamber declines: 15, 30°
- Heights of MSW bed: 20, 40, 60, 80+ cm
- Plastic bottles have the most homogeneous shape in MSW

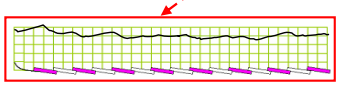


Stochastic Modeling

2-D Mixing Simulation

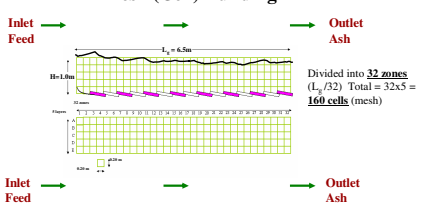


- Even Number Cells represent reciprocating bars
  $r_r < 1 - p_r - r_r < p_r$
- Odd Number Cells represent fixed bars
  $r_f < p_f < 1 - p_f - r_f$



- Reverse acting grate is divided into 32 zones (cells)
- Each cell represents either a reciprocating bar or a fixed bar.

Mesh (Cell) Building



- Each cell is divided into 5 layers (Layer A top of bed and Layer E next to the surface of grates)
- Interchange of particles between successive cells : the first cell of the model represents the inlet and the cell 32 represents the position next to the ash bin.

Transition Matrix

The rule governing the particle migration through the system is represented by a matrix:

Current Distribution = (Initial Distribution * n th power of Transition Matrix)

$$S(n) = S(0)\,P^n$$

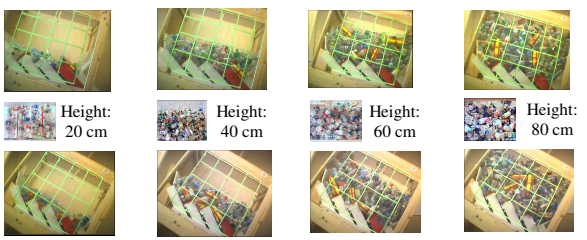
$$S(0) = [1 \;\; 0 \;\; \ldots\ldots\ldots\ldots \;\; 0] \quad (1 \times 162 \text{ cells})$$

Initial Distribution of MSW

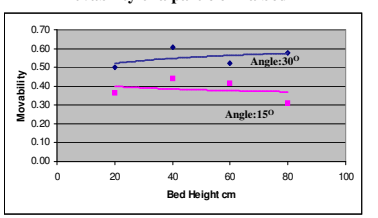
$$P = \begin{bmatrix} p_{11} & \cdots & \cdots & p_{1,162} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & p_{j,k} & \cdots \\ p_{162,1} & \cdots & \cdots & p_{162,162} \end{bmatrix} \quad (162 \times 162)$$

The Transition Matrix

Results and Discussion

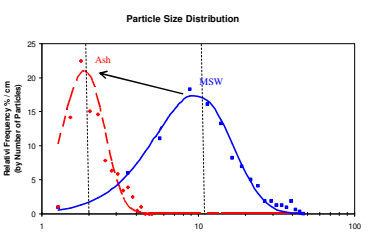


Movability of a particle in a bed



Future Work

Integration with Combustion Model



Particle size distributions (PSDs) by particle numbers of residential MSW and combined ashes in NYC: (lines: estimated gamma distributions, dots: experimental data)