Numerical Analysis of Flow and Mixing Phenomena of Municipal Solid Waste Particles on a Reverse Acting Grate

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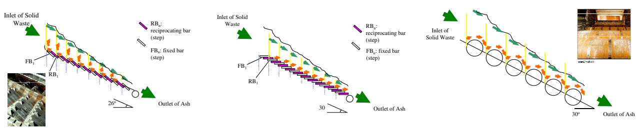
Background

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

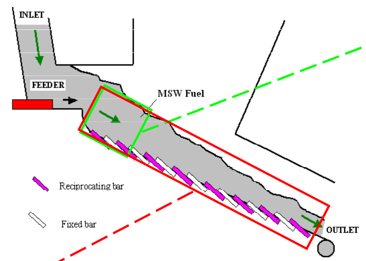


Reverse Acting Grate *Forward Acting Grate* *Roller Grate*

Objectives

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

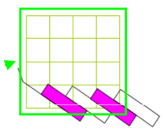
- Developing a mathematical model to characterize and quantify flow and mixing processes of the highly non-homogeneous MSW.
- Simulating the behavior of solid waste particles with transport and combustion phenomena.



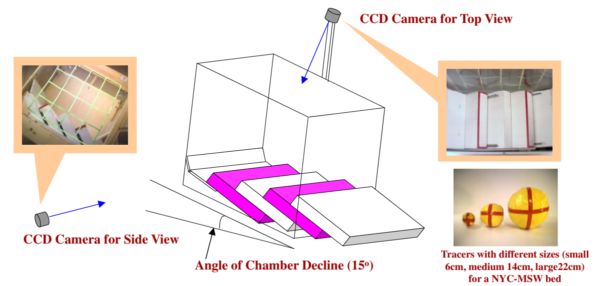
Reverse Acting Grate System in a Waste-to-energy Combustion Chamber

Physical Modeling

Full-scale Section Model

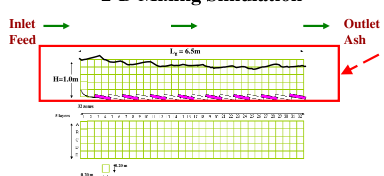


- Physical Model: 2 reciprocating bars and 2 fixed bars with 125 mm height
- Travel distance of reciprocating bars: 420 mm
- Angles of the chamber declines: 15°
- Heights of MSW bed: 80+ cm



Stochastic Modeling

2-D Mixing Simulation



- 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)

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

162 cells

$$S(0) = [1\ \ 0\ \ \ldots\ldots\ldots\ldots\ \ 0]$$

Initial Distribution of MSW

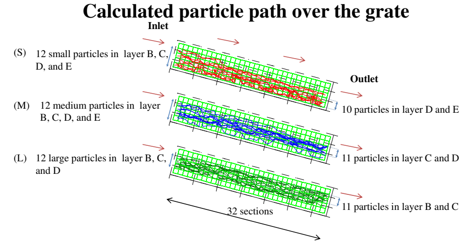
$$P = \begin{bmatrix} p_{11} & \cdots & \cdots & p_{1,162} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & p_{j,k} & \cdots \\ p_{162,1} & \cdots & \cdots & p_{162,162} \end{bmatrix}$$

162 × 162

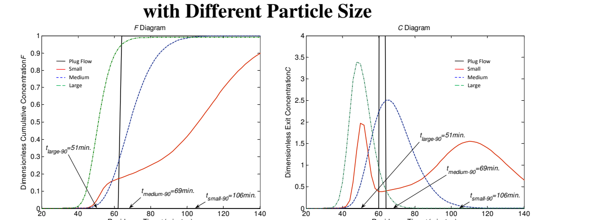
The Transition Matrix

Results and Discussion

Calculated particle path over the grate

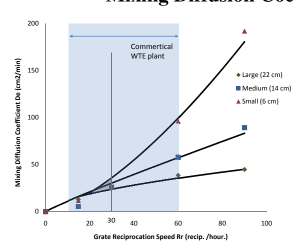


Residence Time Distributions - F and C Diagram – with Different Particle Size



Reciprocating speed : 90 reciprocations/ hour

Mixing Diffusion Coefficients, *De*

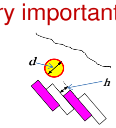


Mixing Diffusion Coefficients versus grate reciprocation speed for different particle sizes

$$D_e(R_r, d, h) = \begin{cases} a\left(\frac{d}{h}\right)^2 R_r^{\left(\frac{h}{d+b}\right)} & if\ d < h \\ a\left(\frac{d}{h}\right)^2 R_r^{\left(\frac{h}{d}\right)} & if\ d \geq h \end{cases}$$

a, b: constant
d: diameter of MSW particle (cm)
h: height of moving bars (cm)
De : mixing diffusion coefficient (cm^2/min)
R_r: reciprocation speed of moving bars (recip./hour)

The ratio *d/h* is very important



Conclusion

A 2-dimensional model of the flow and mixing of MSW fuel on the Martin reverse acting grate (RAG) was developed using a stochastic simulation and probabilities derived by means of a full-scale physical model of a section of the Martin RAG.

The study resulted in the following conclusions:

a) Different particle sizes result in different residence times according to the Brazil Nut Effect (BNE):

Larger particles rise to the surface while smaller particles migrate to lower depths of the bed where the reciprocating bars push them backwards against the main direction of flow due to the gravity force.

b) The motion of the reverse acting grate, at speeds ranging from 15 to 90 recip./hour, resulted in the net effect of increasing the mean residence time of small and medium sized particles by 68 % and 9%, respectively, while decreasing that of large particles by 17%.

c) Calculations of the mixing diffusion coefficient D_e showed that it was affected principally by the ratio of the height of reciprocating bars, *h*, to the diameter of the tracer particle, *d*.

Although the physical model tests were all carried out at one *h* value (13 cm), the results showed conclusively that the diffusion coefficient D_e for a given particle size distribution will increase with grate bar height.