



Particle Size and Shape Distributions of New York City Municipal Solid Waste (NYC-MSW) and Residues for Combustion Chamber Design

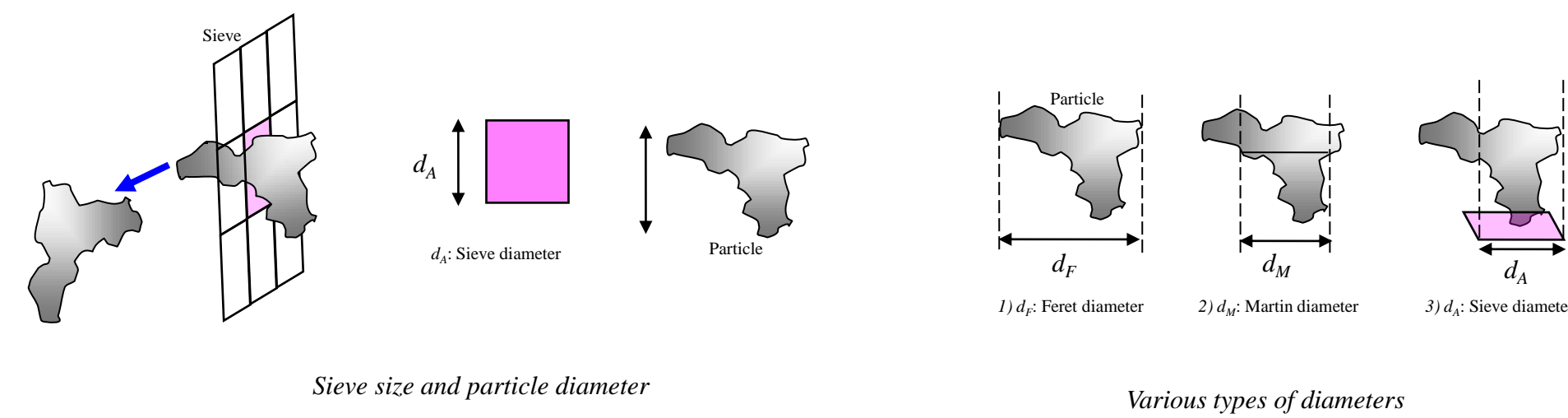


Jason Singh (student) and Masato R. Nakamura (advisor)

Department of Mechanical Engineering and Industrial Design Technology

New York City College of Technology (City Tech), City University of New York (CUNY), Brooklyn, 11201, NY

Background



The particle size and shape of MSW have not been successfully measured because

- Man-made items like MSW particles have complex shape,
- In sieving MSW particles do not move along sieve surface and difficult to handle,
- The projected particle area can vary depending on the forces acting on the area

Objectives

This study shows size and shape factor distributions of MSW and ash particles measured using image analysis. Image analysis has some advantages compared with sieve analysis.

- It is more accurate than sieve analysis since each particle can be outlined and measured.
- Not only are size distributions estimated; in addition, the shapes of particles are measured.
- The length, width, perimeter, and area of each particle are measured from camera images.

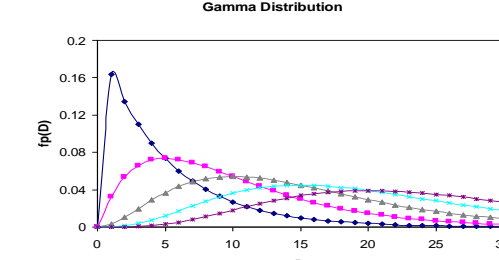
Applying image analysis for measuring MSW particles is a new approach.

Size and Shape Distributions

The Gamma distribution is one of the common particle size distributions

$$f_p(D) = a \cdot \frac{1}{\beta^\alpha \Gamma(\alpha)} D^{\alpha-1} e^{-\frac{D}{\beta}}$$

$f_p(D)$: the Gamma distribution
 a : constant
 D : particle size
 α, β : positive parameters



- Aspect Ratio (AR) is described as *Length [L] / Breadth [B]* (Schneiderhohn 1954)
- Roundness (Circularity shape factor) is defined as $\frac{Perimeter [PM]^2}{4\pi \cdot Area[A]}$ (Cox 1927)
- Wadell defined Sphericity (Wadell 1932) as $\Phi = \frac{surface\ area\ of\ a\ sphere\ of\ the\ same\ volume\ as\ the\ particle}{actual\ surface\ area\ of\ the\ particle}$

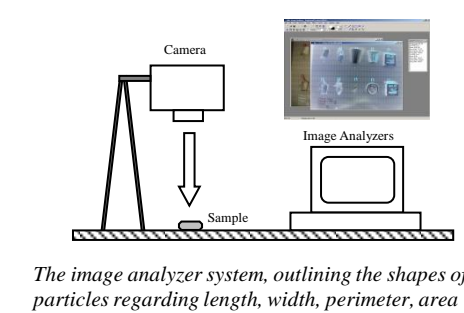
Methodology

• 350 particles of MSW in Black bags from five boroughs (Manhattan, Staten Island, Brooklyn, Queens and Bronx) of New York City

• 210 particles of combined ash (bottom ash + fly ash) Samples collected in the Covanta Union County facility that combusts a lot of MSW collected from New York City.

• Capturing particle images from the digital camera with color inversion

• Outlining the shapes of particles regarding length, width, perimeter, area



The image analyzer system, outlining the shapes of particles regarding length, width, perimeter, area

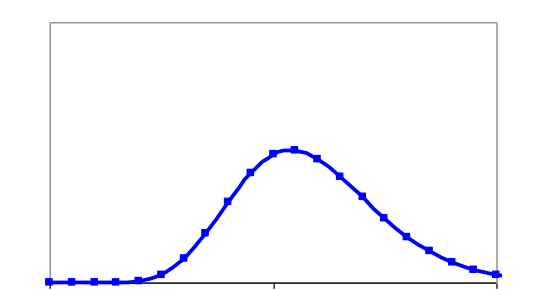


Digital camera images of MSW samples (left) and ash samples (right)

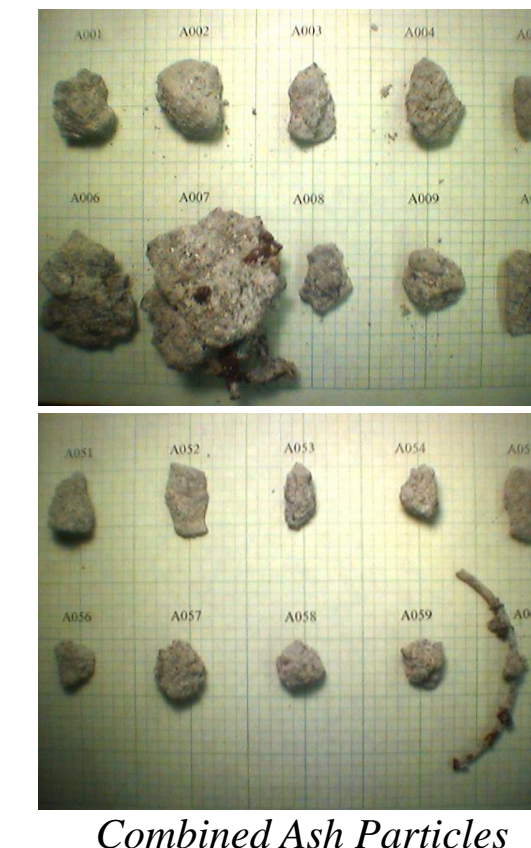
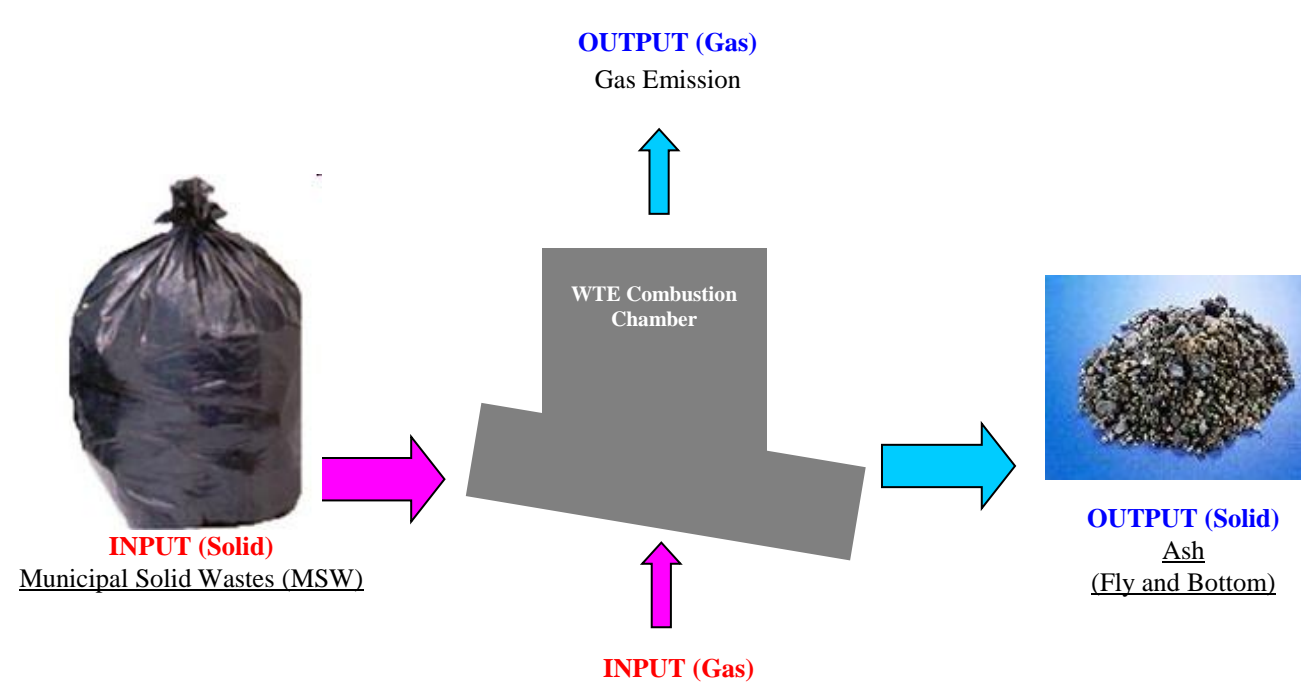
New York City generates 15,000 tons/day of MSW



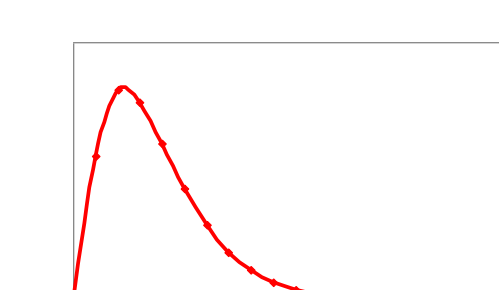
MSW Particles



MSW particle size distribution



Combined Ash Particles



Ash particle size distribution

Combustion and transport phenomena of one particle in a MSW bed on the traveling grate

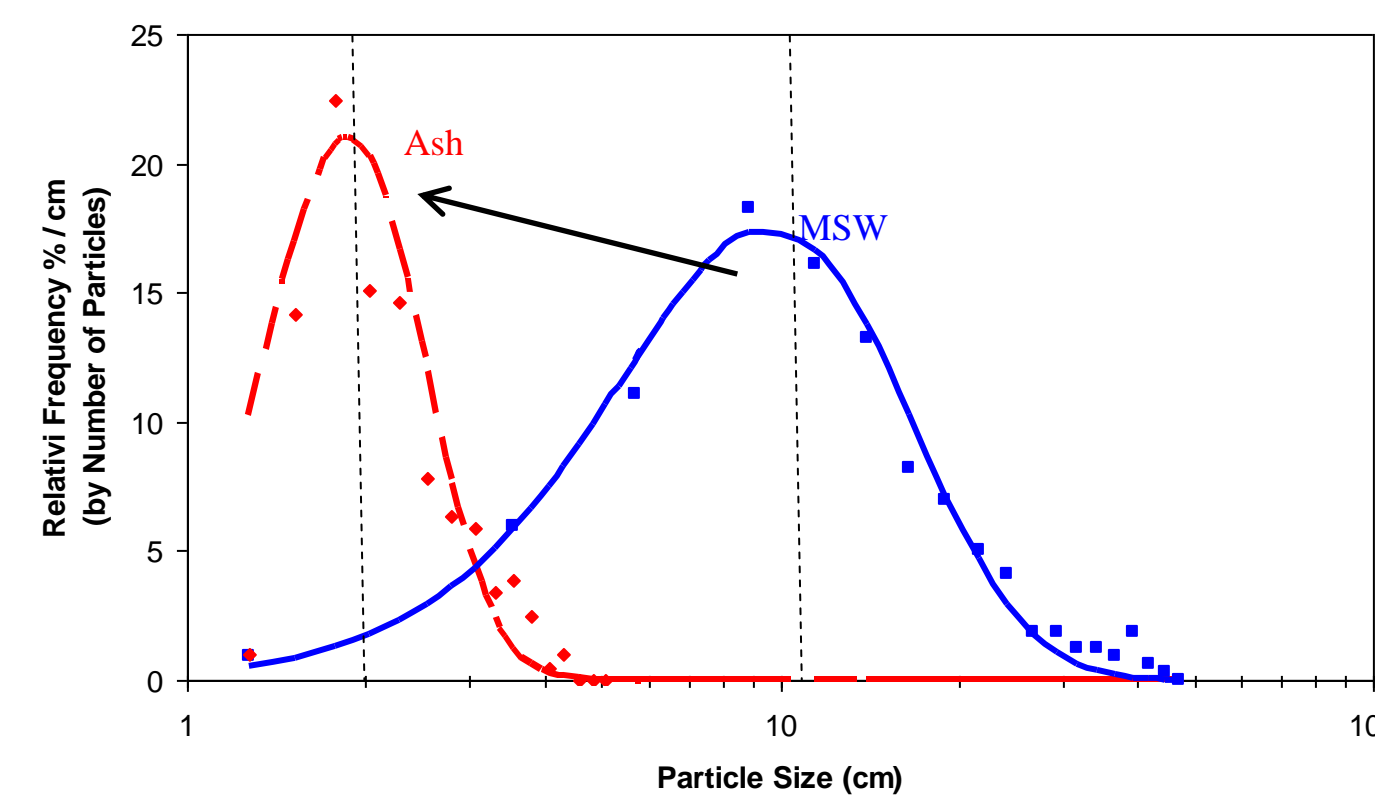
Results

Ash particle size distribution

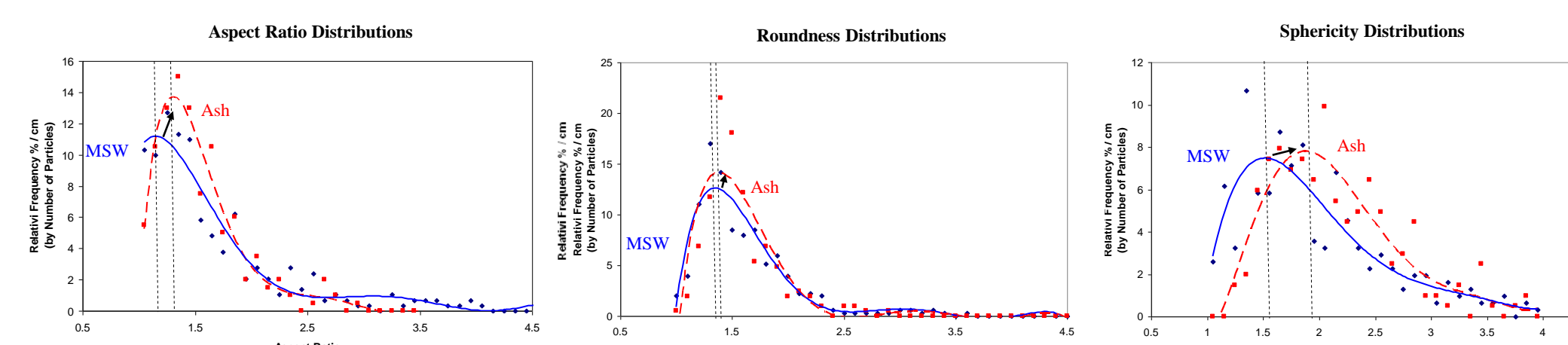
constant $a = 30$
 parameter $\alpha = 12$
 parameter $\beta = 0.17$
 mean $\mu = 2.04$
 standard deviation $\sigma = 0.5889$
 covariance $CV = 3.46$

$$f_p(D) = a \cdot \frac{1}{\beta^\alpha \Gamma(\alpha)} D^{\alpha-1} e^{-\frac{D}{\beta}}$$

Particle Size Distribution

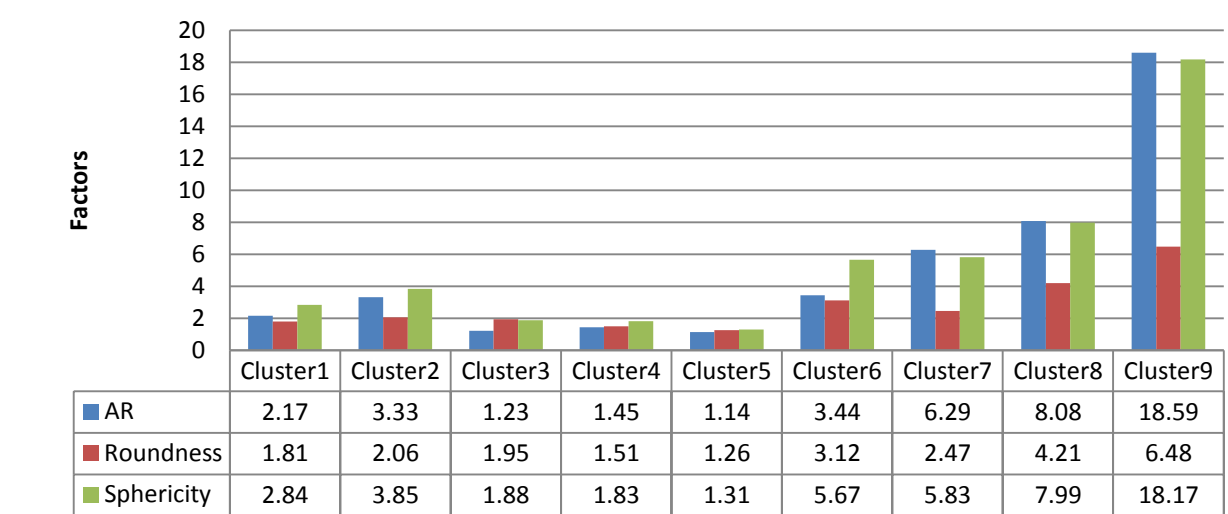


Particle size distributions (PSDs) by particle numbers of residential MSW and combined ashes in NYC: (lines: estimated gamma distributions, dots: experimental data)

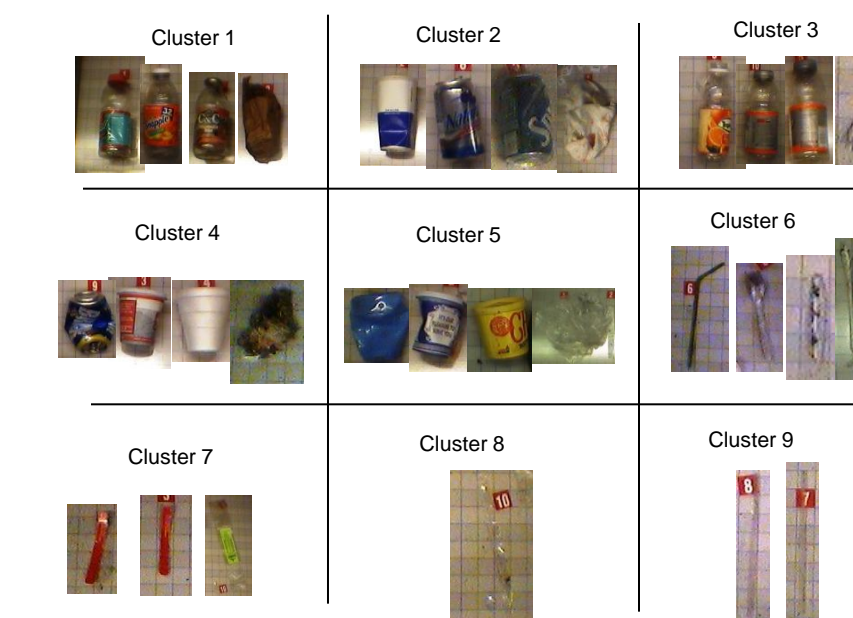


Discussion - Cluster Analysis -

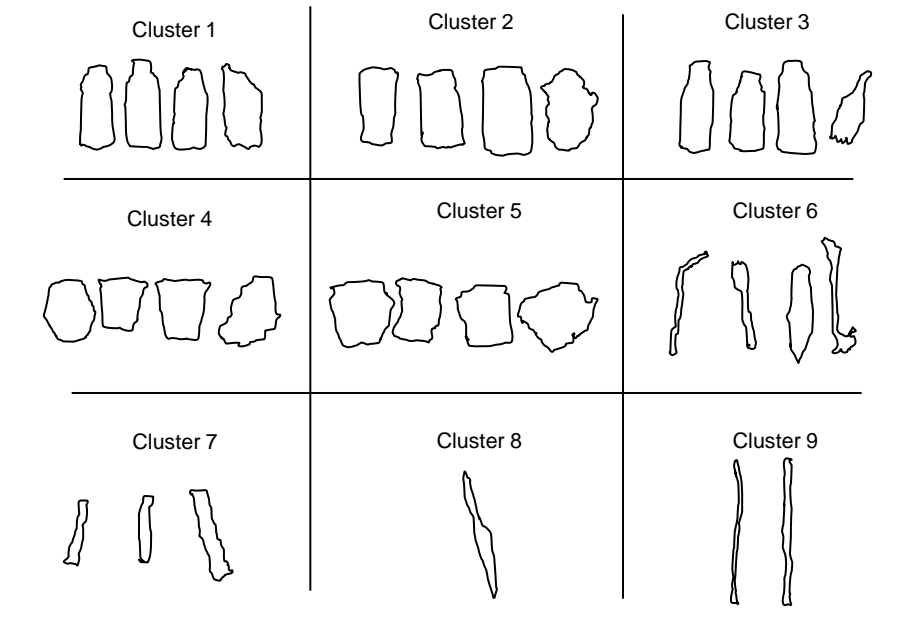
Shape Factors of MSW Particles



Mean Values of Aspect Ratio, Roundness and Sphericity in 9 Clusters (MSW Particles)

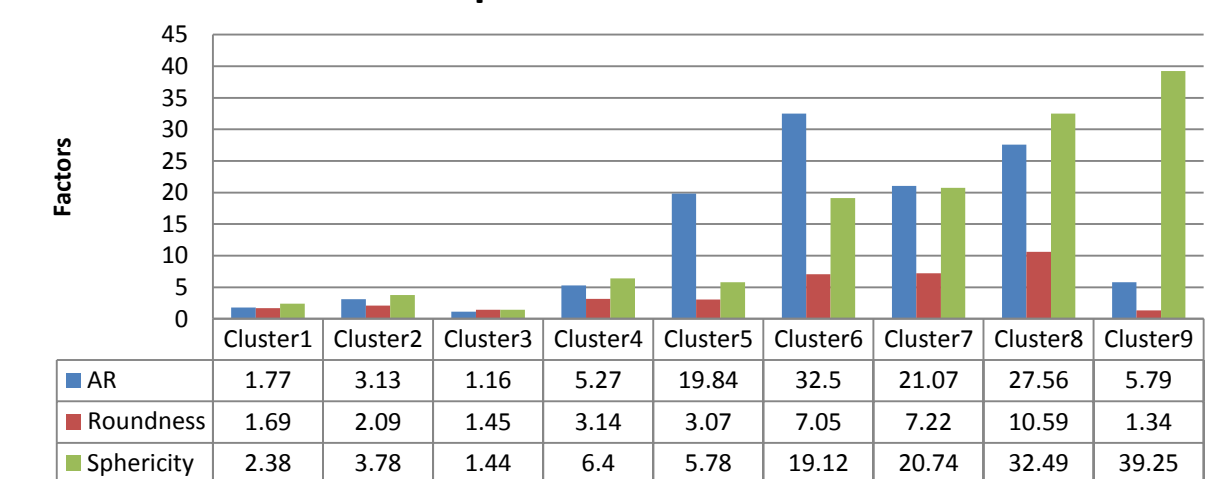


Particle Pictures Representing 9 Clusters (MSW particles)



Particle Outlines Representing 9 Clusters (MSW particles)

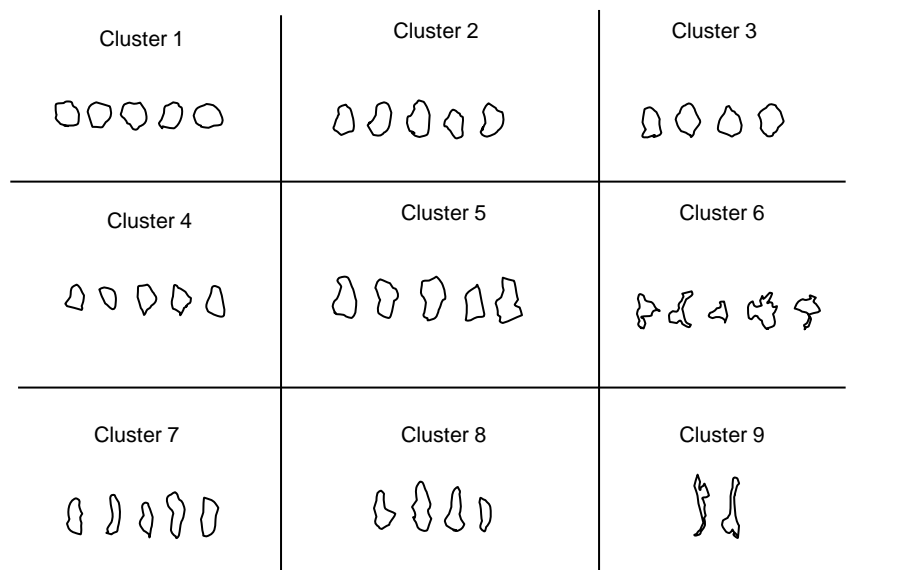
Shape Factors of Ash Particles



Mean Values of Aspect Ratio, Roundness and Shape Factor in 9 Clusters (Ash Particles)



Particle Pictures Representing 9 Clusters (Ash particles)



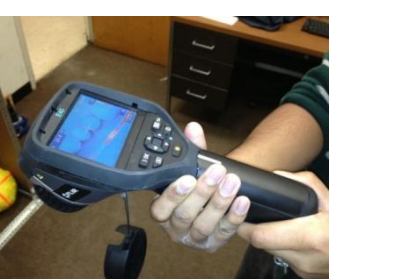
Particle Outlines Representing 9 Clusters (Ash particles)

Summary and Future Work

- Black bags were collected in New York City and MSW particles from the bags were sampled for obtaining its particle size distribution and shape distributions.
- Image analysis for measuring particle size and shape are carried out accurately more than sieving.
- Gamma function with $a = 250, \alpha = 4, \beta = 3.2$ matches the particle size distribution of MSW collected in New York City.
- Also this function with $a = 30, \alpha = 12, \beta = 0.17$ matches the particle size distribution of residues (ash) from a WTE combustion chamber.
- The cluster analysis based on the three shape factor definitions (AR, Roundness, Sphericity) provides characteristics of the particle shapes that can be divided into 9 categories.



Oversized and mean-sized tracers with different weights



Infrared Camera for Heat Transfer Analysis