BWP Modeling

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AMS Users’ Meeting
Oct. 10, 2004
Gaussian Assumption

\[
\gamma_p = \frac{\kappa_{\phi} \gamma_{\phi} \delta_{\phi}}{I} \left[ \frac{\gamma_{\phi} \delta_{\phi} \delta_{\phi}^2}{I(x-x_0)^2 + \gamma_{\phi} \delta_{\phi}} + \gamma_{\phi} \delta_{\phi} \delta_{\phi} \right]
\]
• Beam Width Probe (BWP):
  – Collection Efficiency (CE)
  – Surrogate particle non-sphericity
Transmission Curves

For $d = 0.56$ mm:
- $c_{w} = 0.01$: 1.0, $8.64 \times 10^{-7}$
- $c_{w} = 0.25$: 1.0, $5.43 \times 10^{-4}$
- $c_{w} = 0.5$: 1.0, $3.88 \times 10^{-4}$
- $c_{w} = 1$: 0.84, $1.55 \times 10^{-3}$
- $c_{w} = 2$: 0.37, $6.21 \times 10^{-3}$

For $d = 1.51$ mm:
- $c_{w} = 0.01$: 1.0, $8.64 \times 10^{-7}$
- $c_{w} = 0.25$: 1.0, $5.43 \times 10^{-4}$
- $c_{w} = 0.5$: 1.0, $3.88 \times 10^{-4}$
- $c_{w} = 1$: 0.94, $1.55 \times 10^{-3}$
- $c_{w} = 2$: 0.37, $6.21 \times 10^{-3}$
Soot Data

![Graph of Soot Data with wire position and transmission values. The graph shows data points and fits for fractal soot and Gaussian distributions.](image)
CE_s Plot

Oleic Acid:
\[ \sigma_z = 0.25 \text{ mm}, \ CE = 1.0 \]
"Well-focused" beam

Soot:
\[ \sigma_z = 0.75 \text{ mm}, \ CE = 0.96 \]
"Poorly-focused" beam

Standard 45 cm Chamber

35 cm Chamber
Definition of $\psi$

- Lift shape factor (surrogate non-sphericity parameter):
  \[
  \psi = \frac{\sigma_p^{d_{va}}}{\sigma_{sph}^{d_{va}}}
  \]
- $\sigma$ is the standard deviation of Gaussian
- Beam width for sphere of given $d_{va}$: $\sigma_{sph}^{d_{va}}$
- Beam width of particle of same $d_{va}$: $\sigma_p^{d_{va}}$
### Summary Table

<table>
<thead>
<tr>
<th></th>
<th>Beam Width (mm)</th>
<th>CEs</th>
<th>Lift Shape Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oleic Acid</strong></td>
<td>0.25</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ammonium Nitrate</strong></td>
<td>0.47</td>
<td>1</td>
<td>1.88</td>
</tr>
<tr>
<td><strong>Ammonium Sulfate</strong></td>
<td>0.68</td>
<td>0.98</td>
<td>2.72</td>
</tr>
<tr>
<td><strong>Fractal Soot (Jay)</strong></td>
<td>0.77</td>
<td>0.95</td>
<td>3.08</td>
</tr>
</tbody>
</table>
BWP Optimization
BWP Current Conclusions

• $CE_s$ (due to shape) is 1.0 in most cases
  – Bounce is much more important for CE (Tim)
• BWP still provides information about:
  – $CE_s$ when important (fractal, etc.)
  – Surrogate shape factor ($\psi$) achieved easily (to be tested in lab for what it means)
  – Phase related to focusing (Yasmine)
• Optimal BWP $\sim 1.0$ mm
Trans. vs sigma

Oleic Acid, $\sigma_s = 0.25$ mm

$\text{NH}_4\text{NO}_3$, $\sigma_s = 0.47$ mm

$\text{(NH}_4\text{)}_2\text{SO}_4$, $\sigma_s = 0.68$ mm

Wire Position
(Step Number)
- Center
- $\frac{1}{2}$
- 1
- $\frac{1}{2}$
- 2
TCE Summary

- Ambient distribution
- Ambient distribution after cyclone
- Distribution at AMS vaporizer for spheres that do not bounce
- Distribution at AMS after accounting for $CE_a$
- Distribution at AMS after accounting for $CE_b$

Graph showing data with axes $d_{ve} (\text{nm})$ and $\frac{dM}{d\log d_{ve}} (\mu g/m^3)$.
Gaussian Volume Integration Table

<table>
<thead>
<tr>
<th></th>
<th>1-D</th>
<th>2-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1\sigma$</td>
<td>68.2</td>
<td>60.7</td>
</tr>
<tr>
<td>$2\sigma$</td>
<td>95.5</td>
<td>88.3</td>
</tr>
<tr>
<td>$2.36\sigma$</td>
<td>-</td>
<td>93.8</td>
</tr>
<tr>
<td>$3\sigma$</td>
<td>99.7</td>
<td>95.6</td>
</tr>
</tbody>
</table>
Aerodynamic Lens

- Forces act to broaden beam only during nozzle expansion

Brownian motion
Lift forces (irregular particles)

2.4 Torr inlet

Axial Coordinate (m)

Radial Coordinate (m)

10^{-3} torr Exit