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THE PREDICTION OF PARTICLE ATTENUATION COEFFICIENTS IN LUMINOUS FLAMES

M. Heap, T.M. Lowes

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On a développé un modèle mathématique, basé sur la série Mie, pour le calcul des coefficients d'émission/atténuation des flammes lumineuses. On a effectué des comparaisons entre des prédictions de modèle et des mesures faites pendant des essais récents de la F.R.I.P. Celles-ci indiquent que le modèle est satisfaisant pour des flammes de gaz, d'huile et de charbon pulvérisé, mais que son application reste limitée tant qu'une connaissance complète des caractéristiques des particules présentes dans les flammes ne sera pas obtenue.

A mathematical model is developed, based on the Mie series, for the calculation of emission/attenuation coefficients of luminous flames. Comparisons are made between model predictions and measurements made in recent I.F.R.F.-trials. These indicate that the model is satisfactory for gas, oil and pulverized fuel flames, but limited in its application until a complete knowledge of particle properties present in flames is available.

The accurate prediction of heat flux within a combustion chamber requires a simultaneous solution of fluid motion, chemical reaction and heat transfer. Two engineering methods of solution have been suggested \[1\] \[2\]. However, if these methods are to be successfully applied to systems involving luminous flames, particle attenuation coefficients must be known. A model has been developed based upon the Mie series \[3\] which predicts particle attenuation coefficients for the full range of particle sizes associated with luminous flames. The predicted values have been compared with those measured in large turbulent diffusion flames.

Two size fractions are of interest in luminous flames, which correspond to soot and pulverized fuel particles. Table 1 summarizes the predicted variation of attenuation coefficients of soot dispersions for possible ranges of particle properties. Fig. 1 shows experimental coefficients determined during recent trials at Ijmuiden \[4\]. It can be seen that the measured attenuation coefficients in a turbulent oil flame fall within the range predicted by the model.

The model developed shows that while the variation of optical properties and temperature have no effect on the particle attenuation coefficients of pulverized fuel, radiation scatter can be extremely significant. Fig. 2 illustrates how neglect of scattering leads to misinterpretation of measured attenuation coefficients in pulverized fuel flames. The discrepancy between the measured and calculated attenuation of unidirectional radiant intensity is due to scattering of radiation from the hot wall.

Conclusions
- A model has been developed which enables particle attenuation coefficients to be predicted for the range of particles present in luminous flames.
- The model has been used to predict particle attenuation coefficients of soot and pulverized fuel dispersions for the range of particle diameter, density and complex refractive index reported in the literature.
- Values of attenuation coefficients measured within luminous turbulent diffusion flames fall within this predicted range.
- The wide variation of particle attenuation coefficients emphasises that relationships predicting local particle properties are
Table 1.
Attenuation coefficients of soot dispersion \( (k_m) \)
Calculated at 1500°C, concentration 1x10^{-3} kg/m³, beam-length 0.5 m.

<table>
<thead>
<tr>
<th>Soot type</th>
<th>( k_m \times 10^{-3} )</th>
<th>( k_m \times 10^{-3} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>diameter: optimum for attenuation, density: 2.0x10^{3}</td>
<td>diameter: optimum for attenuation, density: 1.0x10^{3}</td>
</tr>
<tr>
<td></td>
<td>complex optical properties: room temperature increase in absorption index</td>
<td>complex optical properties: 50%</td>
</tr>
<tr>
<td>Sterling</td>
<td>0.87</td>
<td>2.49</td>
</tr>
<tr>
<td>Vulcan</td>
<td>1.25</td>
<td>3.58</td>
</tr>
<tr>
<td>Elf</td>
<td>0.86</td>
<td>2.46</td>
</tr>
<tr>
<td>Mogul</td>
<td>0.68</td>
<td>1.94</td>
</tr>
<tr>
<td>Acetylene</td>
<td>1.05</td>
<td>3.02</td>
</tr>
<tr>
<td>Propane</td>
<td>1.17</td>
<td>2.25</td>
</tr>
</tbody>
</table>

essential if accurate assessments of heat flux distributions are to be made within combustion chambers.

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