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Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
A new model for gas radiative properties applicable to oxy-fuel combustion modelling

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Introduction
Radiation is the principal mode of heat transfer in furnaces. Modeling of radiation heat transfer in combustion systems is very complicated. There are two key issues, i.e., how to calculate radiation intensity at different locations along different directions from radiative transfer equations and how to evaluate radiation properties at different locations. Different combustion environments (air-fuel or oxy-fuel) make no difference to the 1st key issue; they will only affect the gaseous radiative properties.

Models for gaseous radiative properties have been well established for air combustion. However, there is uncertainty regarding their applicability to oxy-fuel conditions. The derivation, calibration, and implementation of the new model are given.

Result 1: Calibration of EWBM code
Based on “almost exact analytical expressions”, a computer code in c++ is developed to evaluate the emissivity of any gas mixture at any condition by using the exponential wide band model (EWBM), and the calculated results are calibrated in very details by data in literature.

Method
• First, a computer code is developed to evaluate the emissivity of any gas mixture at any condition by using the exponential wide band model (EWBM), and the calculated results are calibrated in very details by data in literature.
• Then, the calculated results are used to generate emissivity databases for representative air-firing and oxy-firing conditions, for each of which a new weighted-sum-of-gray-gases model (WSGGM) with new parameters is derived. The way to implement the new models into CFD simulations of combustion systems is given.
• Finally, as a demonstration, the new models are applied to CFD modeling of a 0.8MW oxy-natural gas flame furnace. The CFD results are compared with those based on the widely used WSGGMs in literature. Based on that, some useful guidelines on oxy-fuel modeling are recommended.

Result 2: The new models
The complete set of the new models consists of the following equations and new parameters for a number of representative air-fuel and oxy-fuel conditions, and the way to implement them into CFD modeling. Here, only the new WSGGM parameters for the representative oxy-fuel conditions are listed, as seen in Table 1.

\[
E = \sum_{i=0}^{l} a_i(T_f) \left(1 - e^{-k_i P L} \right)
\]

Result 3: Demonstration
The new models have been applied to CFD of a 0.8MW IFRF oxy-natural gas flame furnace.

Table 1. New parameters for the WSGGM, applicable to oxy-fuels

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of gray gases, (N)</td>
<td>6</td>
</tr>
<tr>
<td>Mean beam length, (L)</td>
<td>40 m</td>
</tr>
<tr>
<td>Partial pressures of all the participating gases, atm</td>
<td>(P)</td>
</tr>
</tbody>
</table>

Conclusions
The new WSGGMs need to be used in CFD modeling of large-scale oxy-fuel furnaces. For small-scale facilities, they do not make remarkable difference. Combustion chemistry also plays a key role in oxy-firing modelling.

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Acknowledgements
This work was financially supported by Grant ForsKEL 2009-1-0256, “Advanced modelling of oxy-fuel combustion of natural gas.”