Spectroscopy in high-temperature industrial processes on Earth

Fateev, Alexander

Publication date: 2015

Document Version
Peer reviewed version

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Citation (APA):
Spectroscopy in high-temperature industrial processes on Earth

Senior Scientists Alexander Fateev
Spectroscopy in industrial processes | Outline

- **Background**
- **Large scale measurements**
- **Example/Case 1: NH3**
- **Example/Case 2: SO2/SO3**
- **Example/Case 3/UV: C6H6O and C10H8**
- **Conclusions**
Needs | **Large Scale Measurements**

- Boilers,
- Flames (oil, gas, bio-masses),

- Engines (ships, jets),
- Field campaigns (explosions)

VIS image grade flame (waste)

IR image wood dust flame (video fuel mixing)

DTU Chemical Engineering
Department of Chemical and Biochemical Engineering
Complexity:  
- get results first  
- trustful system  
- 1500°C is not uncommon  

Expensive:  
- access possibilities  
- man power  
- time  

Campaign at Blok 7 Fynsværket (Denmark)
Data analysis:  
- on-line  
- at home  

Source of reference data:  
- measurements in a cell with pre-mixed gases  
- databases (IR/UV)

NO measurements in exhaust duct of a large ship engine

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Department of Chemical and Biochemical Engineering
Example 1 | NH₃: experiment (500°C, 0.09 cm⁻¹) vs calculations (BYTe)

Can we use BYTe at 500°C for practical apps?

- in general a good agreement
- some difficulties with strong line intensities
- some frequency shifts in line positions

More work to do at even higher T (>500°C)

More details:
Emma J. Barton et al
“High-resolution absorption measurements of NH₃ at high temperatures: 500 - 2100 cm⁻¹”
(submitted to JQSRT)

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Department of Chemical and Biochemical Engineering
**Application case 1 | In Situ measurements on Pyroneer (6MW) gasifier**

**NH3: Q: Why to do measurements? A: NH3 contributes to NOx formation**

**Gas extraction (150°C):**

- 20-06-2014 (17:00-19:30): \( \text{NH3} = (0.4 \pm 0.02)\% \), \( \text{H2O} = (35 \pm 0.6)\% \), \( \text{CO2} = (14 \pm 0.45)\% \), \( \text{CO} = (10 \pm 0.21)\% \)
- 24-06-2014 (15:00-17:00): \( \text{NH3} = (0.42 \pm 0.02)\% \), \( \text{H2O} = (36 \pm 0.6)\% \), \( \text{CO2} = (13.5 \pm 0.45)\% \), \( \text{CO} = (10.3 \pm 0.21)\% \)

**In situ (547°C):**

- 24-06-2014 (20:00-21:00): \( \text{NH3} = (0.55 \pm 0.05)\% \), \( \text{H2O} = (36 \pm 1)\% \)
Application case 2 | SO2/SO3/NH3 in a hot flue gas

SO2/SO3/NH3: Q: Why to do measurements?
A: NOx reduction at SCR/NSCR units, NH3 slip/costs, corrosion/fouling
Example 2  |  **SO3: measurements at 25C and 400C**

**Good news:**
- Excellent agreement with PNNL data at 25C
- No need to use high-resolution at high T
- Simple to generate, but difficult to measure/quantify
- No databases (SO2/SO3) are available at T>100C
Example 2 | SO2/SO3 cross sections (0.5cm⁻¹)

PhD (Dan Underwood) with UCL:
- SO₂ and SO₃ line lists
- ready by the end 2015
- 2nd Power plant measurement campaign, fall 2015
Example 3/UV | Phenol/Naphthalene UV absorption cross-sections temperature effects

- Not too many reference data available even at low T (about 23C)
- An excellent agreement with published data at low T
- Significant changes in the fine structure of the cross-section spectra with T

Naphthalene abs cross-sections: from 23C to 500C
Phenol abs cross-sections: from 23C to 500C
Application case 3/UV  |  In Situ measurements on LT-CFB (100kW) gasifier

Phenol/Naphthalene: Q: Why to do measurements?
A: Phenol/Naphthalene – major trace gases from PAH’s in low temperature gasification

Few new challenges:
- Very strong UV light attenuation
- Very broad continuum-like abs structures
- Very small L for in situ measurements

DOAS approach: SO2 UV absorption as an example
Application case 3/UV | In Situ measurements on LT-CFB (100kW) gasifier

Comparison of the measurements

<table>
<thead>
<tr>
<th>Method</th>
<th>Time</th>
<th>Temperature</th>
<th>Phenol</th>
<th>Naphthalene</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC-MS</td>
<td>30 min</td>
<td>15°C</td>
<td>215 ppm</td>
<td>16 ppm</td>
</tr>
<tr>
<td>Extraction</td>
<td>3 min</td>
<td>150°C</td>
<td>360 ppm</td>
<td>31 ppm</td>
</tr>
<tr>
<td>In-situ</td>
<td>3 min</td>
<td>306°C</td>
<td>7700 ppm</td>
<td>1000 ppm</td>
</tr>
</tbody>
</table>
Conclusions

**Now**

**In general**
- You can find a lot inspirations for the work on the Earth
- Different research areas can have the same origin
- Scientists can make industry guys happy

**In particular:**
- Excellent experimental tools are available for (VUV) UV-FIR optical measurements
- Temperature range can be also negative (e.g. gases at low T)
- New data/lines for NH₃/SO₂/SO₃
- New data for phenol/naphthalene
- Try always In Situ and avoid any Ex Situ (extraction) measurements
Conclusions | Future

- Inspiration comes from industry (small, middle, large, ...)
- Possible spin offs: innovation (patents)
- New **gas components**: CH3Cl, KCl etc. (together with UCL)
- Combine several methods to obtain **multi-parameters**
- ... ?

- Contact: Alexander Fateev
  alfa@kt.dtu.dk
  +45 23652906
• To Energinet.dk: projects No. 2013-12027, 2011-1-10622, 2010-1-10422

• To MST.dk

• To DONG Energy and Vattenfall

• To UCL (Prof. Jonathan Tennyson’s group)
Thank you for your attention