High spatial resolution monitoring of the temperature distribution from an operating SOFC

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High spatial resolution monitoring of the temperature distribution from an operating SOFC

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Abstract

In situ monitoring of cell temperature distribution of an operating SOFC is crucial to understand its performance and degradation. The available efforts recorded in literature are incapable of measuring the temperature from electrodes. Instead, they measure the gas channel temperature from a selected few points, mainly, by inserting thermocouples into the stack, which significantly limits the spatial resolution of measurements and introduces disturbance to the SOFC’s normal operation. To overcome these weaknesses, the authors developed a new temperature sensor architecture that shares the merits of thermocouple thermometry and measures temperature at \(N^2\) points with only \(2N\) number of thermoelements. This sensor is capable of measuring the electrode temperature distribution with greater spatial resolution than thermocouples. Using this sensor, authors are successful to measure the spatial cathode temperature distribution in high spatial resolution out of an SOFC test cell (50 mm x 50 mm, NextCell-5) under varying fuel flow rates (from 50 ml/min at A to 250 ml/min at F&G). The temperature measurements were validated with commercial thermocouples. Correlations between cell temperatures, flow rate and, OCV were observed and analysed.

High spatial resolution monitoring of the temperature distribution from an operating SOFC

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Department of Aeronautical & Automotive Engineering
Outline

- Importance & difficulties of temperature monitoring from SOFC
- Sensing method; sensor fabrication and apply
- Real-time temp. monitoring and validation/comparison
- Conclusions & Future works

5-8th July 2016, 12th European SOFC/SOE Forum
Here is the temperature distribution within a working SOFC stack.

Better stacks architectures.!

It helps me doing performance modelling.

wow… I can boost up degradation studies.

Should be good as a health monitoring tool.

5-8th July 2016, 12th European SOFC/SOE Forum
Present state of cell temperature identification

Cell temperature identification

Simulation

Experiments

5-8th July 2016, 12th European SOFC/SOE Forum
Present state of cell temperature identification

- Mathematical equations to model cell temperature gradient
- CFD modelling
- Software tools

Simulation

5-8\textsuperscript{th} July 2016, 12\textsuperscript{th} European SOFC/SOE Forum
Present state of cell temperature identification

- Gas inlet and outlet temperature has been measured using thermocouples.

No practical means of measuring cell surface temperature has been developed yet.

- Thin film sensor
- Reduce the required number of wires
- Signal processing software
New thermocouple architecture was developed

It requires only $2N$ thermo-elements for $N^2$ measuring points

Increases the spatial resolution of measurements

Patent App. No: GB1509690.2

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Sensing locations

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Test Rig

Cell holder

Anode chamber thermocouple

Anode chamber

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Anode reduction process

- Temperature (°C)
- Time (minutes)

Graph showing the reduction process with lines indicating different stages:

- N₂
- N₂ / H₂

- Flow rates: 300 cm³/min, 15 cm³/min
Anode Reduction

$N_2$ / $H_2$

$300 \text{cm}^3/\text{min : } 15 \text{cm}^3/\text{min}$

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Cell operation

<table>
<thead>
<tr>
<th>Setting</th>
<th>H₂ flow rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/ I</td>
<td>500 cm³/min</td>
</tr>
<tr>
<td>B/H</td>
<td>250 cm³/min</td>
</tr>
<tr>
<td>C/G</td>
<td>150 cm³/min</td>
</tr>
<tr>
<td>D/F</td>
<td>100 cm³/min</td>
</tr>
<tr>
<td>E</td>
<td>50 cm³/min</td>
</tr>
</tbody>
</table>

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OCV and temp comparison

S1 to S9: the 9 sensing points from THERMONO
TC-Si: The commercial thermocouple that touches the Cathode in close proximity to \(i\)th sensing point of THERMONO \((i = 1, 5, 7)\)
TC-Cathode: The commercial thermocouple kept about 2mm adjacent to cathode right above S5
### Cell Temperature vs Voltage

#### Change of OCV with temperature

<table>
<thead>
<tr>
<th>Furnace Temperature (°C)</th>
<th>700</th>
<th>750</th>
<th>800</th>
<th>850</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCV (V)</td>
<td>1.1256</td>
<td>1.1055</td>
<td>1.0963</td>
<td>1.0853</td>
</tr>
<tr>
<td>Average cell temperature (°C)</td>
<td>680.67</td>
<td>729.20</td>
<td>779.27</td>
<td>827.61</td>
</tr>
</tbody>
</table>

#### Change of cell voltage different temperature under 60 mA current

<table>
<thead>
<tr>
<th>Furnace Temperature (°C)</th>
<th>700</th>
<th>750</th>
<th>800</th>
<th>850</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell voltage ( @ I = 60 mA)</td>
<td>0.426</td>
<td>0.455</td>
<td>0.463</td>
<td>0.494</td>
</tr>
</tbody>
</table>

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Load-Temperature Relationship (850 °C)

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#InspiringWinners since 1909
Conclusions & Future works

- A new thermal sensor array has been applied to monitor a temp distribution from an operating cell.
- The monitored temp distribution was validated.
- Load driven cell temperature fluctuations has been observed.
- Local cell temperature could be used as a measure to identify normal/abnormal electrochemical behaviour of cells.
- Real-time detection of gas reforming, carbon deposition etc.
- Q: what temp. do you run your cells (stacks)? A: @ 750 °C
  
  Wrong Q&A..!!!
- Q: what range of temp. do you run yours? Model A: @ 750 °C ± 45 °C

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Acknowledgement

Modelling Accelerated Ageing and Degradation of Solid Oxide Fuel Cells (EP/I037059/1)

Novel diagnostic tools and techniques for monitoring and control of SOFC stacks - understanding mechanical and structural change (EP/M02346X/1)

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