Experimental And Numerical Modelling Of Thermal Stimulation In Geothermal Core Studies

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Thermal Stimulation for Geothermal Energy

• New Zealand Geothermal fields: Taupo Volcanic Zone (TVZ)

• Stimulated rock sourced from Rotokawa: Rotkawa Andesite

Siratovich et al., 2014
Thermal Stimulation Curve for Rotokawa Andesite

- **Slow heating**
- **Temperature Stabilisation**
- **Quenching**

**Graph Details:**
- **Y-axis:** Temperature (K)
  - Ranges from 273 to 673 K
- **X-axis:** Time (Hours)
  - Ranges from 0 to 7 hours
- **Sample Temperature Line**

The graph illustrates the temperature changes over time during thermal stimulation of Rotokawa Andesite.
Numerical Model of Rotokawa Andesite – Mineralogy and Texture

- Mechanical & Physical parameters +
  - Conductivity
  - Linear expansion
  - Specific heat
**Numerical Model of Rotokawa Andesite – Mechanical Calibration**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Laboratory</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCS (MPa)</td>
<td>105-126</td>
<td>102-108</td>
</tr>
<tr>
<td>Young’s Modulus (GPa)</td>
<td>31.2-38.9</td>
<td>69-71</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.19-0.23</td>
<td>0.33-0.36</td>
</tr>
</tbody>
</table>
Numerical Model of Rotokawa Andesite – Thermal Calibration

<table>
<thead>
<tr>
<th>Sample</th>
<th>Linear Thermal Expansion ($10^{-6}$ K$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>8.3 (Rotokawa Andesite average 9 at 300K)</td>
</tr>
<tr>
<td>Simulated (initial)</td>
<td>19</td>
</tr>
<tr>
<td>Simulated (final)</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Linear Expansion ($10^{-6}$ K$^{-1}$) for water:
Initial – 69
Final – $1 \times 10^{-7}$
Thermal Stimulation Model Results

Failed elements

Strain

Mineralogy + strain
Thermal Stimulation Model Results

Failed elements + strain

Mineralogy + strain
Thermal Stimulation Results

Siratovich et al., 2015
Thermal Stimulation Outcomes

- Can simulate strength and thermal stimulation behaviour
- Varying linear expansion for water simulates closed or open porosity
- Can observe the fracture patterns at the grain scale
- Can examine the development of the fractures with respect to element yield type, minerals, stress state, displacements, temperature variations, etc., all of which can be plotted, queried and output to spreadsheets for quantitative analysis

Siratovich et al., 2015
Thermal Stimulation Future Work - Input

- Incorporate strain-dependent stiffness to better simulate Young’s Modulus and Poisson’s ratio.
- Incorporate temperature-dependent thermal properties to better simulate fracture behaviour as sample is heated, then cooled.
- Derive more mineral-specific input parameters.

Siratovich, 2013
Thermal Stimulation Future Work - Input

- Derive function to determine changes in porosity
- Couple with water flow model (i.e. Tough2 - FLAC) for permeability

Villeneuve et al., 2019

Siratovich et al., 2015
References


