Glass Engineering -- 150:312

Determination of Fulcher Coefficients Using Excel Solver

The Equation
The Fulcher Equation for the viscosity of glass is:

\[
\log_{10} \eta = A + \frac{B}{T - T_0}
\]

Where \( \eta \) is the viscosity of the glass in dPa's and \( T \) is the corresponding temperature in C.

Microsoft Excel
Open up a spreadsheet and pull down the TOOLS menu. If solver does not appear on your Excel Tools menu, click on add-ins and select it.

Set up three equations with three unknowns in the spreadsheet using three coordinate pairs of viscosity and temperature. Formulate the equations so they are in standard form, i.e.:

\[
F(x) = 0
\]

As an example, consider the following data:

<table>
<thead>
<tr>
<th>Point</th>
<th>Log_{10} Viscosity</th>
<th>Temperature, C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annealing Point</td>
<td>13</td>
<td>540</td>
</tr>
<tr>
<td>Softening Point</td>
<td>7.6</td>
<td>722</td>
</tr>
<tr>
<td>Gob Temperature</td>
<td>3</td>
<td>1185</td>
</tr>
</tbody>
</table>

Now you should have three equations, corresponding to the above data and three unknowns, \( A \), \( B \) and \( T_0 \). For starters, give the three constants all the initial value of one.

In cells adjacent to the cells containing the \( F(x) \) values, enter absolute values of the \( F(x) \) values using Excel built in functions. Sum these three absolute cells to a grand total. It is this total that we wish to minimize. Finally, in a isolated cell somewhere on the spreadsheet, enter an epsilon value [usually 0.0001]. This is the value that will determine when \( F(x) = 0 \), i.e. if \( F(x) < 0.0001 \).

Using Solver
Now you are ready to solve the equations. Click on TOOLS/SOLVER and enter the following:

Set target cell: make this the total sum of the absolute values of the three functions.
Equal to: Minimize

By Changing Cells: Enter the three cells that contain the A, B and T₀ values (all=1 to begin).

Subject to the Constraints: Set each function absolute value total <= the defined epsilon (0.0001). You will have three constraints.

Go to options and set the following:

- Max Time = 100
- Iterations = 100
- Precision = 10⁻⁵
- Tolerance = not applicable to real problems
- Convergence: 0.0001
- Do not check any of the boxes between Convergence and Estimates.
  - Estimate = tangent
  - Derivative = forward
  - Search = Newton

Now click OK on the options to return to the Solver Parameters screen and click Solve.

You should get a solution. If not, check your work, work the problem a bit, and if still no luck, check with me in class.