POWER LAW CORRELATION MODELS FOR THE WHOLE DATA BASE

MODEL 1.1: Power Law Correlations

- If \( \frac{Re_{sl}}{\lambda_L} \leq 500 \) then:

\[
f_M = 13.9796 \left( \frac{Re_{sl}}{\lambda_L} \right)^{-0.9501}
\]  

Points | Ave. relative error [%] | Standard deviation [%] | Min. relative error [%] | Max. relative error [%]  
--- | --- | --- | --- | ---  
135 | 11.01 | 7.77 | 0.02 | 34.88  

- If \( \frac{Re_{sl}}{\lambda_L} > 500 \) then:

\[
f_M = 0.0925 \left( \frac{Re_{sl}}{\lambda_L} \right)^{-0.2534}
\]  

Points | Ave. relative error [%] | Standard deviation [%] | Min. relative error [%] | Max. relative error [%]  
--- | --- | --- | --- | ---  
1966 | 21.10 | 25.54 | 0.01 | 184.21  

The 2101 points include all transitions. The equations for each region are shown one in the Figure 1.

MODEL 1.2: Logistic dose response curve for whole region and all flow patterns

\[
f_M = F_2 + \frac{(F_1 - F_2)}{1 + \left( \frac{Re_{sl}}{293\lambda_L} \right)^{4.8638}^{0.1972}}
\]  

Where \( F_1 \) y \( F_2 \) are defined as:

\[
F_1 = 13.9796 \left( \frac{Re_{sl}}{\lambda_L} \right)^{-0.9501}
\]  

\[
F_2 = 0.0925 \left( \frac{Re_{sl}}{\lambda_L} \right)^{-0.2534}
\]  

Points | Ave. relative error [%] | Standard deviation [%] | Min. Relative error [%] | Max. relative error [%]  
--- | --- | --- | --- | ---  
2060 | 20.27 | 20.78 | 0.003 | 183.954  

Figure 2 shows the logistic dose response curve for whole region.
Figure 1.- Power law correlations for $\text{ReSL}/\lambda L>500$ and $\text{ReSL}/\lambda L<500$

$y = 13.98x^{-0.9501}$

$y = 0.0925x^{-0.2534}$

Figure 2.- Logistic dose response curve for the whole region
MODEL 1.3 Logistic dose response curves for segregated and not segregated flow for the whole region

a) Logistic dose response curve for not segregated flow (slug and dispersed bubbles flow)

\[
f_M = F_2 + \frac{(F_1 - F_2)}{1 + \left( \frac{\text{Re}_{SL}}{293\lambda_L} \right)^{3.614^{0.201}}} \tag{6}
\]

Where \( F_1 \) and \( F_2 \) are defined as:

\[
F_1 = 13.9796 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.9501} \tag{7}
\]

\[
F_2 = 0.1067 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.2629} \tag{8}
\]

<table>
<thead>
<tr>
<th>Points</th>
<th>Ave. relative error [%]</th>
<th>Standard deviation [%]</th>
<th>Min. Relative error [%]</th>
<th>Max. Relative error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1356</td>
<td>11.99</td>
<td>11.47</td>
<td>0.01</td>
<td>71.749</td>
</tr>
</tbody>
</table>

b) Logistic dose response curve for segregated flow (annular and stratified flow)

\[
f_M = F_2 + \frac{(F_1 - F_2)}{1 + \left( \frac{\text{Re}_{SL}}{300\lambda_L} \right)^{11.6984^{0.0217}}} \tag{9}
\]

Where \( F_1 \) and \( F_2 \) are defined as:

\[
F_1 = 13.9796 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.9501} \tag{10}
\]

\[
F_2 = 0.0978 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.2457} \tag{11}
\]

<table>
<thead>
<tr>
<th>Points</th>
<th>Ave. relative error [%]</th>
<th>Standard deviation [%]</th>
<th>Min. Relative error [%]</th>
<th>Max. relative error [%]</th>
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</thead>
<tbody>
<tr>
<td>704</td>
<td>33.27</td>
<td>23.15</td>
<td>0.02</td>
<td>180.42</td>
</tr>
</tbody>
</table>

Figures 3 and 4 show the logistic dose response curves for not segregated and segregated flow, respectively.
Figure 3.- Logistic dose response curve for not segregated flow

Figure 4.- Logistic dose response curve for segregated flow
MODEL 1.4 Logistic dose response curves for the whole region per flow pattern

a) Logistic dose response curve for slug flow.

\[ f_M = F_2 + \left( F_1 - F_2 \right) \frac{\left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{3.5678}}{1 + \left( \frac{\text{Re}_{SL}}{293\lambda_L} \right)^{0.2025}} \]  \hspace{1cm} (12)

Where \( F_1 \) and \( F_2 \) are defined as:

\[ F_1 = 13.9796 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.9501} \]  \hspace{1cm} (13)

\[ F_2 = 0.1076 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.2637} \]  \hspace{1cm} (14)

<table>
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<tr>
<th>Points</th>
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<th>Min. Relative error [%]</th>
<th>Max. relative error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1316</td>
<td>11.99</td>
<td>11.46</td>
<td>0.00</td>
<td>71.65</td>
</tr>
</tbody>
</table>

b) Logistic dose response curve for dispersed bubble flow.

\[ f_M = F_2 + \left( F_1 - F_2 \right) \frac{\left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{3.1935}}{1 + \left( \frac{\text{Re}_{SL}}{293\lambda_L} \right)^{0.1888}} \]  \hspace{1cm} (15)

Where \( F_1 \) and \( F_2 \) are defined as:

\[ F_1 = 13.9796 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.9501} \]  \hspace{1cm} (16)

\[ F_2 = 0.0866 \left( \frac{\text{Re}_{SL}}{\lambda_L} \right)^{-0.2422} \]  \hspace{1cm} (17)

<table>
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<tr>
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<th>Max. relative error [%]</th>
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<tbody>
<tr>
<td>40</td>
<td>8.67</td>
<td>9.47</td>
<td>0.03</td>
<td>43.19</td>
</tr>
</tbody>
</table>

Figures 5 and 6 show the logistic dose response curves for slug flow and dispersed bubble flow, respectively.
c) Logistic dose response curve for stratified flow.

\[
f_M = F_2 + \frac{(F_1 - F_2)}{1 + \left(\frac{\text{Re}_{SL}}{300\lambda_L}ight)^{0.0324}}^{9.2749}
\]

Where \( F_1 \) and \( F_2 \) are defined as:

\[
F_1 = 13.9796\left(\frac{\text{Re}_{SL}}{\lambda_L}\right)^{-0.9501}
\]

\[\text{(19)}\]

\[
F_2 = 0.0445\left(\frac{\text{Re}_{SL}}{\lambda_L}\right)^{-0.1874}
\]

\[\text{(20)}\]

<table>
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<th>Max. relative error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>528</td>
<td>30.42</td>
<td>23.29</td>
<td>0.00</td>
<td>186.18</td>
</tr>
</tbody>
</table>

d) Logistic dose response curve for annular flow.

\[
f_M = F_2 + \frac{(F_1 - F_2)}{1 + \left(\frac{\text{Re}_{SL}}{10000\lambda_L}\right)^{-0.3072}}^{2.1909}
\]

Where \( F_1 \) and \( F_2 \) are defined as:

\[
F_1 = 3.6709\left(\frac{\text{Re}_{SL}}{\lambda_L}\right)^{-0.6257}
\]

\[\text{(22)}\]

\[
F_2 = 0.027\left(\frac{\text{Re}_{SL}}{\lambda_L}\right)^{-0.1225}
\]

\[\text{(23)}\]

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<th>Max. relative error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>176</td>
<td>29.59</td>
<td>17.73</td>
<td>0.00</td>
<td>77.12</td>
</tr>
</tbody>
</table>

Figures 7 and 8 show the logistic dose response curves for stratified flow and annular flow, respectively.
Figure 5.- Logistic dose response curve for slug flow

Figure 6.- Logistic dose response curve for dispersed bubble flow
Figure 7.- Logistic dose response curve for stratified flow

Figure 8.- Logistic dose response curve for annular flow