Computer code for calculation of the L factors

The code requires that both R and OpenBUGS be installed, both are free to download. R can be obtained at [http://www.R-project.org/](http://www.R-project.org/)

1. Click on “download R” this will appear:

![R download page](image1)

2. Scroll down to USA and pick one of the sites:

![R mirrors](image2)

3. Download the R version appropriate for your system.
4. Click “install R for the first time and follow instructions.

OpenBUGS can be obtained at [http://www.openbugs.net/w/Downloads](http://www.openbugs.net/w/Downloads).

1. Click on the download for your system

2. Run the installer.
To run the program:

1. Start the R program, get this:

   ![R Program Screenshot](image)

2. The only input to the program that is needed are the values $N$ and $\Gamma$, and the sample size $n$. In the program below $x = N$ in rad/s, and $y = \Gamma$ in $\mu$Nm.

For example, SRM 2497 with spiral concrete paste data:

<table>
<thead>
<tr>
<th>SR (1/s)</th>
<th>Viscosity (Pa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.5105</td>
<td>0.052329</td>
</tr>
<tr>
<td>7.5642</td>
<td>0.054203</td>
</tr>
<tr>
<td>5.4411</td>
<td>0.056974</td>
</tr>
<tr>
<td>3.91545</td>
<td>0.061296</td>
</tr>
<tr>
<td>2.8182</td>
<td>0.067419</td>
</tr>
<tr>
<td>2.0223</td>
<td>0.074173</td>
</tr>
<tr>
<td>1.4595</td>
<td>0.08222</td>
</tr>
<tr>
<td>1.05105</td>
<td>0.095143</td>
</tr>
<tr>
<td>0.756</td>
<td>0.10582</td>
</tr>
<tr>
<td>0.5439</td>
<td>0.1287</td>
</tr>
<tr>
<td>0.39165</td>
<td>0.153198</td>
</tr>
<tr>
<td>0.2814</td>
<td>0.177683</td>
</tr>
<tr>
<td>0.20265</td>
<td>0.197385</td>
</tr>
<tr>
<td>0.14595</td>
<td>0.274066</td>
</tr>
<tr>
<td>0.105</td>
<td>0.380952</td>
</tr>
<tr>
<td>0.0756</td>
<td>0.396825</td>
</tr>
<tr>
<td>0.0546</td>
<td>0.549451</td>
</tr>
<tr>
<td>0.03885</td>
<td>0.772201</td>
</tr>
</tbody>
</table>
3. Paste the entire program below into a notepad window:

```r
library(R2OpenBUGS)

############## type data X (in rad/s), Y (in µNm), n here:
linedata<-linedata=
list(y=c(0.0523,0.0542,0.0613,0.0674,0.0742,0.0822,0.0951,0.1058,0.1287,0.1532, 0.1777,0.1974,0.2741,0.3810,0.3968,0.5495,0.7722,1.0582,1.5038,2.0408,2.8860), x=c(10.5105,7.5642,5.4411,3.9155,2.8182,2.0223,1.4595,1.0511,0.7560,0.5439,0.3917, 0.2814,0.2027,0.1460,0.1050,0.0756,0.0546,0.0389,0.0284,0.0200,0.0147,0.0104), n=22)

SRM 2497 curve for comparison to see the fit
visc97<-c(88.1,89.5,90.1,92.1,93.7,95.8,98.6,99.9,101.6,103.5,104.1,104.7,105.3,106.0,106.8,107.7, 108.7,109.8,111.1,112.7,114.4,116.6,119.2,122.1,122.8,127.5,134.5,146.3,171.5,182.1,191.4, 203.5,219.8,230.3,243.1,279.1,342.8,397.5,487.1,662.4,833.8,1168.9,1415.3,1589.3)
sr97<-c(250.0,125.0,100.0,55.0,37.5,25.0,16.3,13.8,11.3,9.1,8.7,8.2,7.7,7.2,6.8,6.3,5.8,5.3,4.8,4.3,3.9, 3.4,2.9,2.5,2.4,1.9,1.5,1.0,0.50,0.43,0.38,0.33,0.28,0.25,0.23,0.18,0.13,0.10,0.08,0.05,0.04,0.03, 0.02,0.02)

OpenBUGS code and inits

lineinits<-function(){list(sig=1)}
linemodel <- function() {sig~dgamma(1.0E-5,1.0E-5)
Lg~dunif(0.5,10)
Lm~dunif(0.4)
Lmu<-1/Lm
Ltau<-Lg/Lm

a<--4
```
\[
\begin{align*}
a2n &< -8.89 \\
a2sig &< -1/(0.18*0.18) \\
b2n &< -0.53 \\
b2sig &< -1/(0.06*0.06) \\
c2n &< -5.94 \\
c2sig &< -1/(0.24*0.24) \\
a1n &< -8.62 \\
a1sig &< -1/(1.18*1.18) \\
b1n &< -0.94 \\
b1sig &< -1/(0.05*0.05) \\
c1n &< -7.49 \\
c1sig &< -1/(0.35*0.35) \\
a2 &\sim \text{dnorm}(a2n, a2sig) \\
b2 &\sim \text{dnorm}(b2n, b2sig) \\
c2 &\sim \text{dnorm}(c2n, c2sig) \\
a1 &\sim \text{dnorm}(a1n, a1sig) \\
b1 &\sim \text{dnorm}(b1n, b1sig) \\
c1 &\sim \text{dnorm}(c1n, c1sig) \\
\end{align*}
\]

\[
\begin{align*}
&\text{for } (i \text{ in 1:n}) \{ \\
&srd[i] <- x[i]*Lg \\
&\text{num}[i] <- a*srd[i] \\
&\text{top}[i] <- a*(srd[i]-1) \\
&\text{mu}[i] <- Lm*(c2*exp(a)+c1*exp(num[i])+a1*exp(num[i])/pow(srd[i],b1)+a2*exp(a)/pow(srd[i],b2))/(exp(a)+exp(num[i])) \\
&y[i] \sim \text{dnorm}(\mu[i], \sigma) \\
&\} \\
\]

# run the OpenBUGS
lineout <- bugs(data=linedata, inits=lineinits, parameters=c("Lg", "Lmu", "Ltau"), model.file=linemodel, n.chains=1, n.iter=100000, n.burnin=50000, n.thin=10)

# print the values of the L factors
print(lineout, digits=7)

# compute the calibrated curve
Lg <- lineout$mean["Lg"]
Lmu <- lineout$mean["Lmu"]
viscnew <- linedata$y*Lmu*Lmu*14.3
srnew <- linedata$x*Lg*Lg*0.25

### plot the SRM 2497 curve and the calibrated curve
plot(visc97~sr97,type="p", col="blue", lwd=3, xlab="shear rate (1/s)", ylab="viscosity (Pa s)", log="x")
title("Viscosity vs. Shear rate ", sub="blue points are SRM 2497 paste, cyan line new material")
lines(viscnew~srnew, type="l", col="Cyan", log="x")

4. Edit the X and Y lists to input your own data.
5. Paste the entire edited file into the R window.
6. This will run the code and produce the estimates of the $L$ factors as well as a plot which shows the fit to the SRM 2497 function.

7. Read the $L$ factors as: $L_\gamma$ (Lg in the output)  
   $L_\mu$ in Pa s / N m s (1000000 Lmu in output),  
   $L_\tau$ Pa/N m (1000000 Ltau in output).