ABE 30300 Homework 7 – Fall 2017 (Optional)

Problem 1 (20 marks)

A rheological test is carried out using a cone and plate geometry with a cone angle of 2° and a cone radius of 30mm. The following experimental data was obtained:

Ω (rad/sec)	Torque M (mN-m)
0.63	1.3
1.9	3
5.7	6.3
11	9
15	11
22	16
30	18

(a) Convert raw data into shear rate and shear stress
(b) Determine the rheological parameters of the liquid

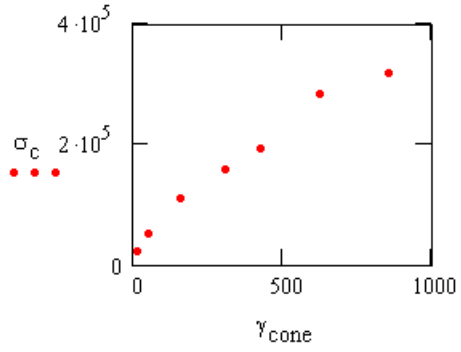
Data for this problem are given in the two vectors below:

$$\Omega := \begin{pmatrix} 0.63 \\ 1.9 \\ 5.7 \\ 11 \\ 15 \\ 22 \\ 30 \end{pmatrix} \qquad M := \begin{pmatrix} 1.3 \\ 3 \\ 6.3 \\ 9 \\ 11 \\ 16 \\ 18 \end{pmatrix} \qquad \theta := 2 \qquad R_{cone} := 30 \cdot 10^{-3}$$

(a)

$$\gamma_{cone} := \frac{\Omega}{\tan\left(\frac{\pi}{180} \cdot \theta\right)} \qquad \sigma_c := \frac{3 \cdot M}{2 \cdot \pi \cdot R_{cone}^{3}}$$

Units are mPa



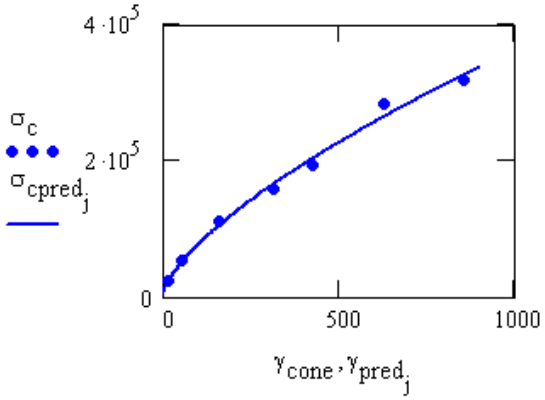
We can estimate the rheological properties of the liquid be either linear regression of the data after transforming the data in logarithmic coordinates

$LN\gamma_{cone} := \ln(\gamma_{cone})$ $LN\sigma c := \ln(\sigma_c)$ $n := slope(LN\gamma_{cone}, LN\sigma c)$ $K := e^{intercept(LN\gamma_{cone}, LN\sigma c)}$

$n = 0.677$ $K = 3.377 \times 10^3$ Units are mPa.s

$j := 1, 2 .. 300$ $\gamma_{pred_j} := 3 \cdot j$ $\sigma_{cpred_j} := K \cdot (\gamma_{pred_j})^n$

We can plot experimental and fitted values



Problem 2 (40 points)

(a) Explain in your own words **a relaxation experiment** and derive an expression to describe the stress relaxation behavior of a ***Maxwell model***.

(b) Explain in your words a **creep experiment** and derive an expression to describe the creep behavior of a ***Kelvin-Voigt*** model.

(c) Describe in a few sentences what methodology you will use to estimate the rheological properties of a viscoelastic food dessert.

(d) Find two (2) scientific articles in where viscoelastic tests are used to characterize the viscoelasticity of a biomaterial. In your answer include the complete reference and briefly (1 page each) discuss the experimental approach used and the main findings, include also criticisms if you have them. **Please try to work alone in this question**, it is important that you learn how to look for technical information, critically examine it and extract useful conclusions from that information. You can discuss that information with others including me, but the work has to be an individual work. You can use the tool Google Scholar linked to Purdue library to directly retrieve the articles.

Information is in lectures

Problem 3 (20 points)

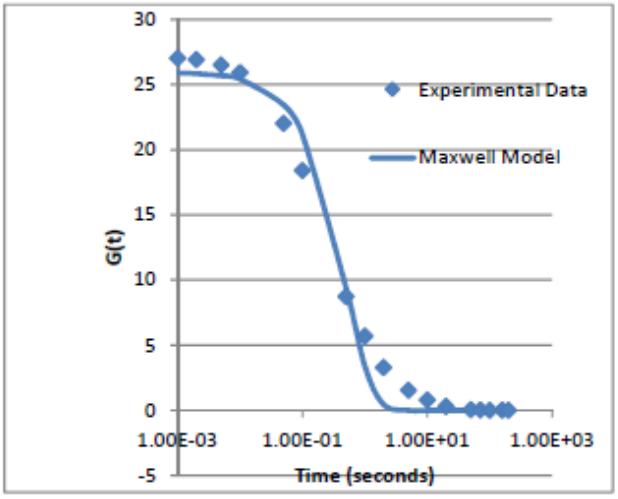
You need to estimate a relaxation time t_R to scale a mixer to be used to mix a viscoelastic material. The table below gives data from a relaxation test as *G(t)* versus *t*. *G(t)* is known as the relaxation modulus estimated as $\sigma(t)/\gamma_0$, where γ_0 is the value of the strain applied in the text. From the data estimate the value of t_R.

t, seconds	*G(t), MPa*
1E-3	27.0
2E-3	26.9
5E-3	26.5
1E-2	25.9
5E-2	22.0
1E-1	18.4
5E-1	8.75
1	5.68
2	3.29
5	1.53
10	0.795
20	0.30
50	0.045
70.8	0.015
100	3.4E-3
158	1.81E-4
200	2.32E-5

From the plot in next page, t_R = 0.49 seconds, a small relaxation time so material is a very liquid

Parameters Go= 25.94164061
tR= 0.49246918

Time (seconds)	G(t)	Model	(Exp-model)^2
1.00E-03	27	25.89	1.234282392
2.00E-03	26.9	25.84	1.131030356
5.00E-03	26.5	25.68	0.673072966
1.00E-02	25.9	25.42	0.230221448
5.00E-02	22	23.44	2.065255738
1.00E-01	18.4	21.17	7.69707517
5.00E-01	8.75	9.40	0.420641961
1	5.68	3.41	5.175306477
2	3.29	0.45	8.082958405
5	1.53	0.00	2.33780815
10	0.795	0.00	0.632024937
20	0.3	0.00	0.09
50	0.045	0.00	0.002025
70.8	0.015	0.00	0.000225
100	3.40E-03	0.00	0.00001156
158	1.81E-04	0.00	3.2761E-08
200	2.32E-05	0.00	5.3824E-10
		Sum Square=	29.77193959



Problem 4 (20 points)

G’ was calculated and the fitting was done with the G’ versus Frequency data

Number		1	2	3		
	G=	6.76E+05	1.00E+04	6.39E+04		
	$t_{R=}$	1.5958862	0.01	0.140074345		
Frequency		G*	tan Delta	G'	Model	(Exp-Model)^2
9.40E-03		9.81E+03	47.2	2.08E+02	1.52E+02	3075.37779
1.40E-02		1.49E+04	29.3	5.08E+02	3.38E+02	29041.92669
3.30E-02		3.44E+04	14	2.45E+03	1.87E+03	334294.9199
2.18E-01		1.91E+05	2.77	6.49E+04	7.31E+04	68230906.14
8.44E-01		5.94E+05	0.88	4.46E+05	4.38E+05	68807382.03
2.33E+00		6.67E+05	0.41	6.17E+05	6.43E+05	692949107.8
3.92E+00		7.46E+05	0.28	7.18E+05	6.93E+05	625887521.4
8.30E+00		8.00E+05	0.15	7.91E+05	7.95E+05	18800699.81
					Sum =	1.48E+09