Regression analysis of the results (Table 3.4 and Fig. 3.28) yields a statistically acceptable fit to the experimental data as

$$\sigma = 7.64(\dot{\gamma})^{.303}$$

where K = 7.64 Pa s^n and n = 0.303. These results are different than those found in Example Problem 3.8.9 when evaluating Kraft French salad dressing using the infinite cup assumption with a concentric cylinder viscometer. Differences may be due to various factors such as analytical assumptions, natural biological variability, and differences in shear rate coverage. More experimental data would be required to resolve these issues.

3.8.13. Parallel Plate - Methylcellulose Solution

Data for a 3% hydroxypropyl methylcellulose solution have been collected using a parallel plate viscometer (Table 3.5). Generate a rheogram for this material.

Table 3.5. Parallel Plate Data (R=25mm; h=0.70mm) for a 3% Aqueous Solution of Hydroxypropyl Methylcellulose (Methocel K4M, Dow Chemical Co.) at 24.2 °C

M N m	$\dot{\gamma}_R$ 1/s	ln M	ln $\dot{\gamma}_R$	σ_R Pa
0.116E-4	0.0127	-11.36	-4.37	0.5
0.211E-4	0.0198	-10.77	-3.92	0.8
0.334E-4	0.0317	-10.31	-3.45	1.3
0.442E-4	0.0503	-10.03	-2.99	1.7
0.807E-4	0.0797	-9.42	-2.53	3.2
1.259E-4	0.1262	-8.98	-2.07	4.9
2.029E-4	0.1999	-8.50	-1.61	7.9
2.979E-4	0.3166	-8.12	-1.15	11.7
4.536E-4	0.5016	-7.70	-0.69	17.8
6.687E-4	0.7945	-7.31	-0.23	26.2
9.343E-4	1.258	-6.98	0.23	36.6
12.900E-4	1.994	-6.65	0.69	50.5
17.270E-4	3.158	-6.36	1.15	67.6
22.700E-4	5.003	-6.09	1.61	88.8
29.260E-4	7.925	-5.83	2.07	114.5
37.320E-4	12.55	-5.59	2.53	146.0

The shear rate at the rim of the plate was determined, by considering angular velocity and geometry, from Eq. [3.59] as

$$\dot{\gamma}_R = \frac{\Omega R}{h}$$

and shear stress was calculated with Eq. [3.66]:

$$\sigma_R = f(\dot{\gamma}_R) = \frac{M}{2\pi R^3}\left[3 + \frac{d\ln(M)}{d\ln(\dot{\gamma}_R)}\right]$$

Using linear regression, the following relationship was determined from the torque and shear rate data (Fig. 3.29):

$$\ln(M) = -7.12 + .934\ln(\dot{\gamma}_R)$$

which identifies the slope term as

$$\frac{d\ln(M)}{d\ln(\dot{\gamma}_R)} = .934$$

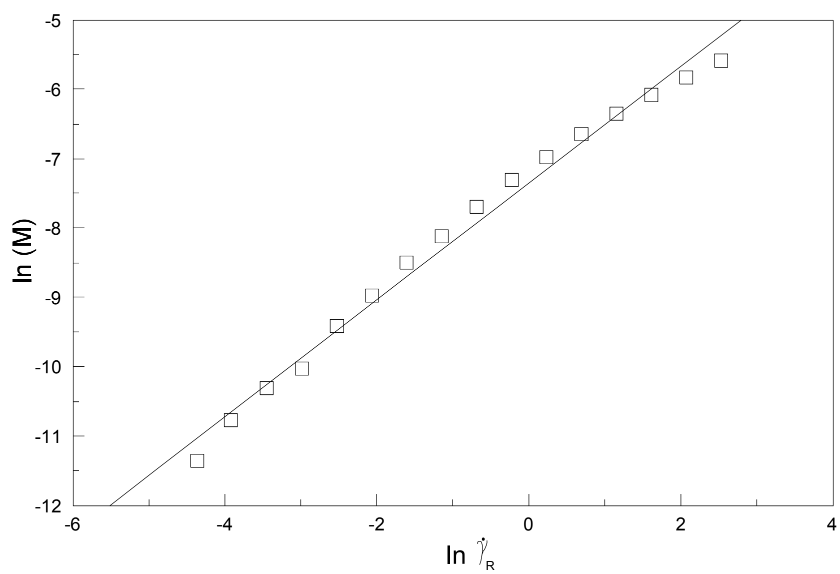

Figure 3.29. Torque versus shear rate for 3% aqueous solution of hydroxypropyl methylcellulose at 24.2 °C.

This result can be used to evaluate the shear stress at the rim for each torque value:

$$\sigma_R = \frac{M}{2\pi R^3}[3 + .934]$$

Shear stress values calculated from this equation are presented in Table 3.5 and plotted in Fig. 3.30. Using the power law model, values of the consistency coefficient and the flow behavior index were determined: K = 25.3 Pa s^n and n = 0.83.

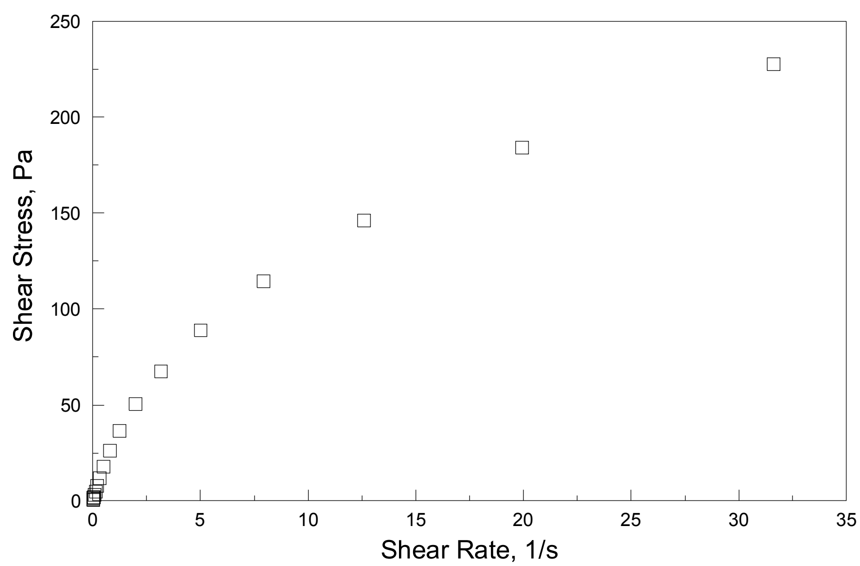

Figure 3.30. Flow behavior of a 3% aqueous solution of hydroxypropyl methylcellulose (Methocel K4M, Dow Chemical Co.) at 24.2 °C.

3.8.14. End Effect Calculation for a Cylindrical Bob

Determine the bottom end effect (h_o) for the bob (R_b = 1.95 cm) and cup (R_c = 2.00 cm) combination illustrated in Fig. 3.31.