Characterization of Network Parameters for UHMWPE Using Plane Strain Compression

Eduardo Abreu, Terin Patel-Wilson, Hung Ngo, Anuj Bellare

Department of Orthopedic Surgery
Brigham & Women's Hospital
Harvard Medical School

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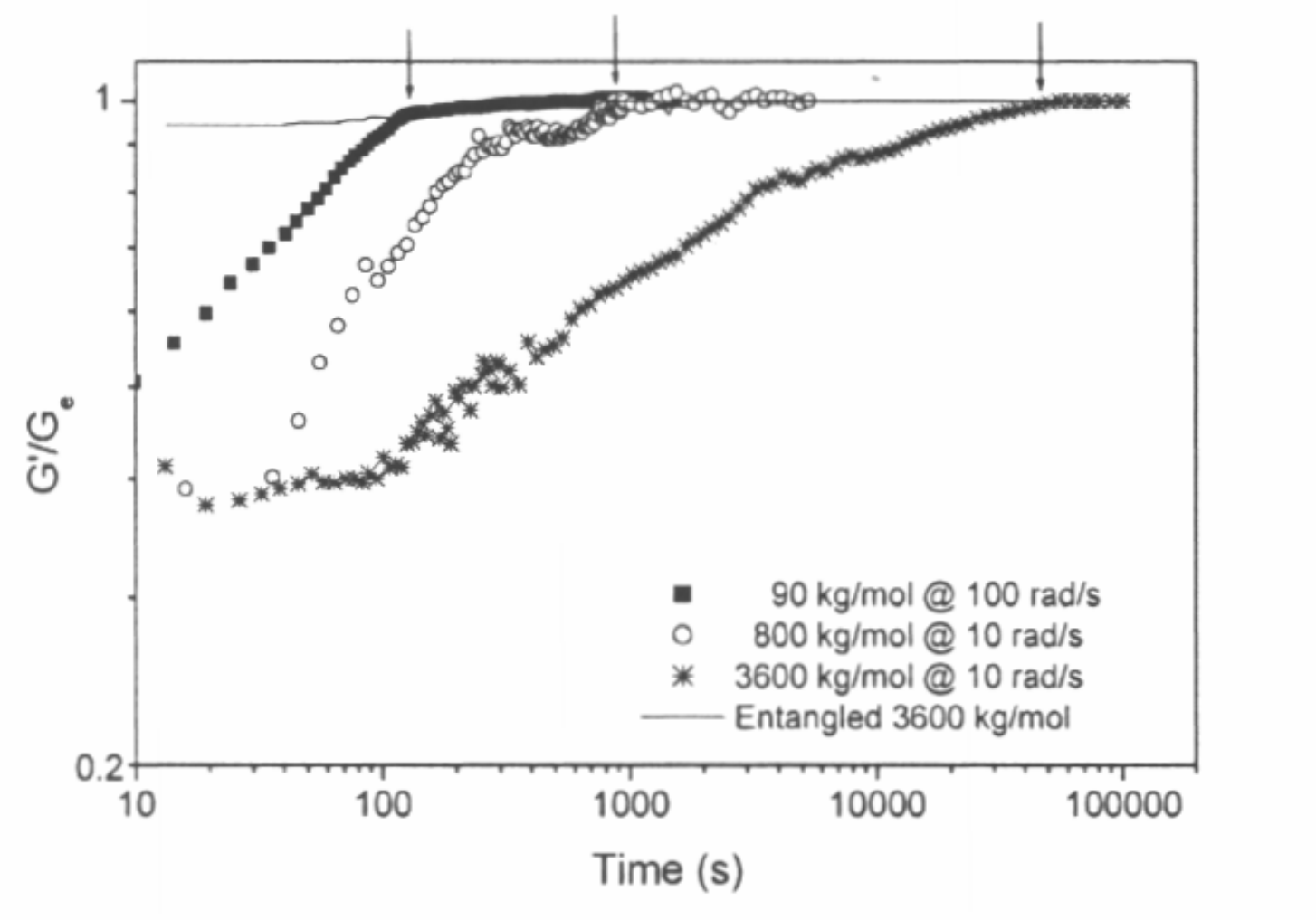
Introduction

- ***UHMWPE is a linear, highly entangled polymer***
- ***Radiation crosslinking makes it a network***
- ***Equilibrium Swelling: M_c~5,000-10,000 g/mole***
- ***At equilibrium entanglement density: M_e=1,240 g/mole (Pearson, 1994)***

Lippits, Macromolecules 2006



Materials and Methods

- *GUR 1050 Rod Stock*
- *γ radiation to a dose of 0, 50, 100 and 200 kGy*
- *maintained at 170ºC for 4 hours*
- *slow cooled to room temperature*

Equilibrium Swelling

$$q_s = \frac{V_f}{V_o}$$

$$\nu = \frac{-\ln(1-q_s^{-1}) + q_s^{-1} + \chi q_s^{-2}}{\phi_1 q_s^{-1/3}}$$

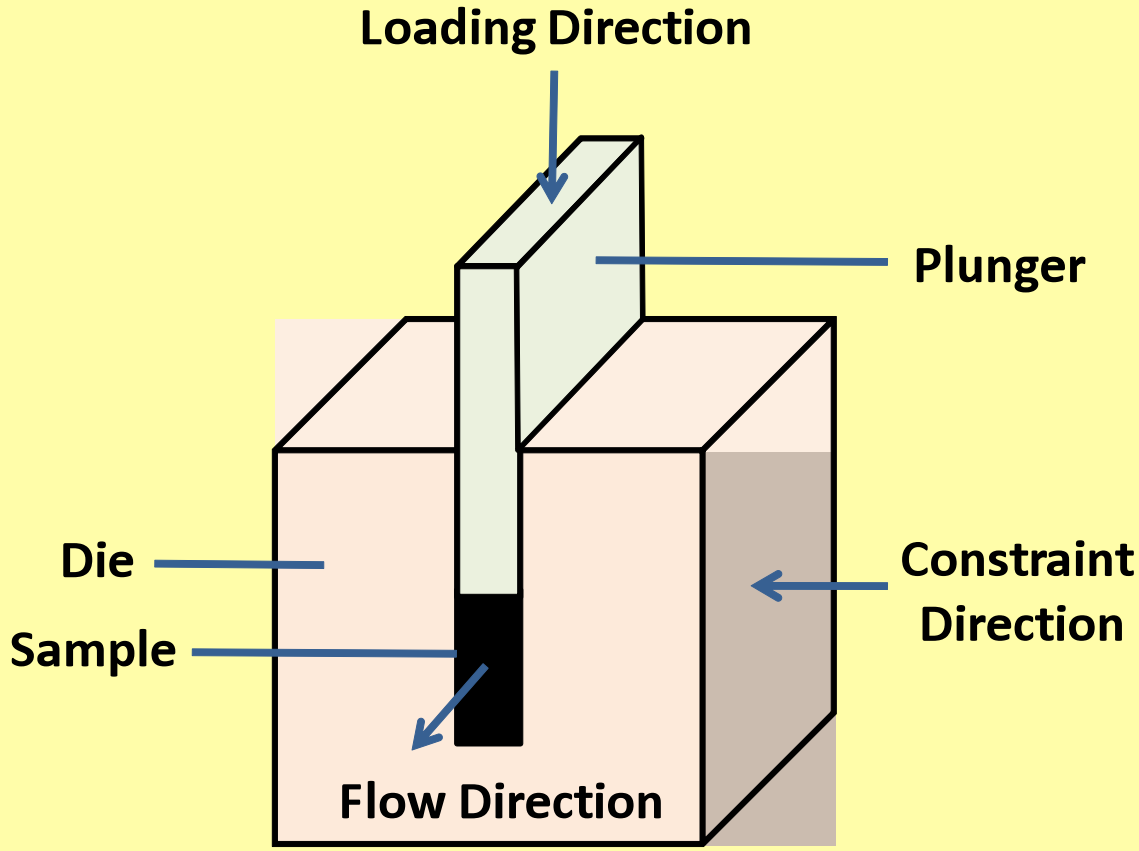
$$M_c = (\nu . \nu_d)^{-1}$$

where ϕ_1 = 136 cm^3/mol , χ = 0.33 + 0.55/q_s and ν_d^{-1}= 920 g/dm^3

Equilibrium Swelling

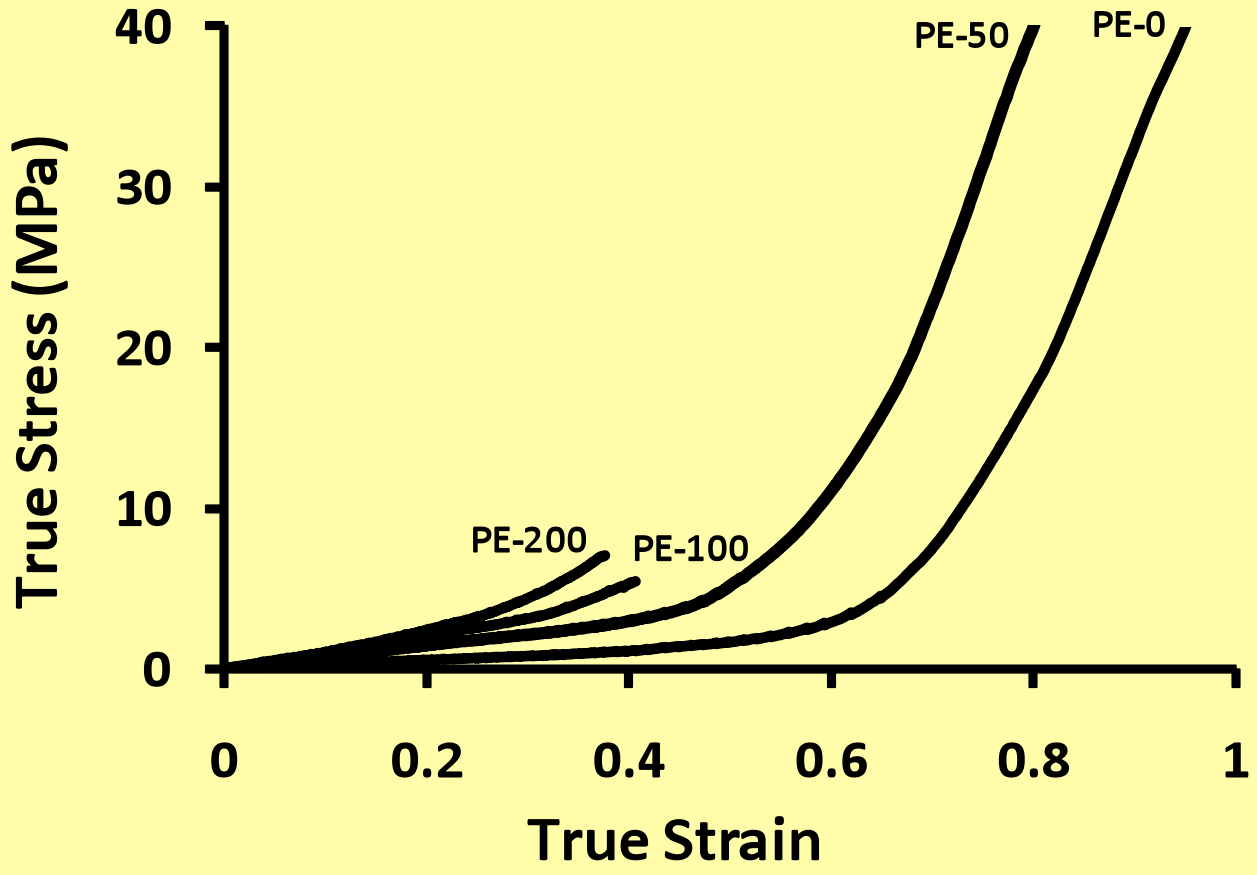
Sample	Swell Ratio	ν (mole.dm^{-3})	M_c (g/mole)
PE-0	Dissolved	-	-
PE-50	3.60 ± 0.46	0.154 ± 0.038	6255 ± 1472
PE-100	3.19 ± 0.63	0.207 ± 0.073	5000 ± 1904
PE-200	2.70 ± 0.65	0.325 ± 0.163	3580 ± 1860

Channel-die Compression (Bartczak, 2005)



- Sample geometry: 4 mm x 4 mm x 4.7 mm
- T= 150°C
- Crosshead speed: 0.25 mm/min

Results


40
30
20
10
0
True Stress (MPa)
PE-50
PE-0
PE-200
PE-100
0
0.2
0.4
0.6
0.8
1
True Strain

Gaussian and Eight Chain Models

Gaussian

$$\sigma_R = G_N(\lambda^2-\lambda^{-2})$$

$$\nu = G_N kT$$

Eight Chain

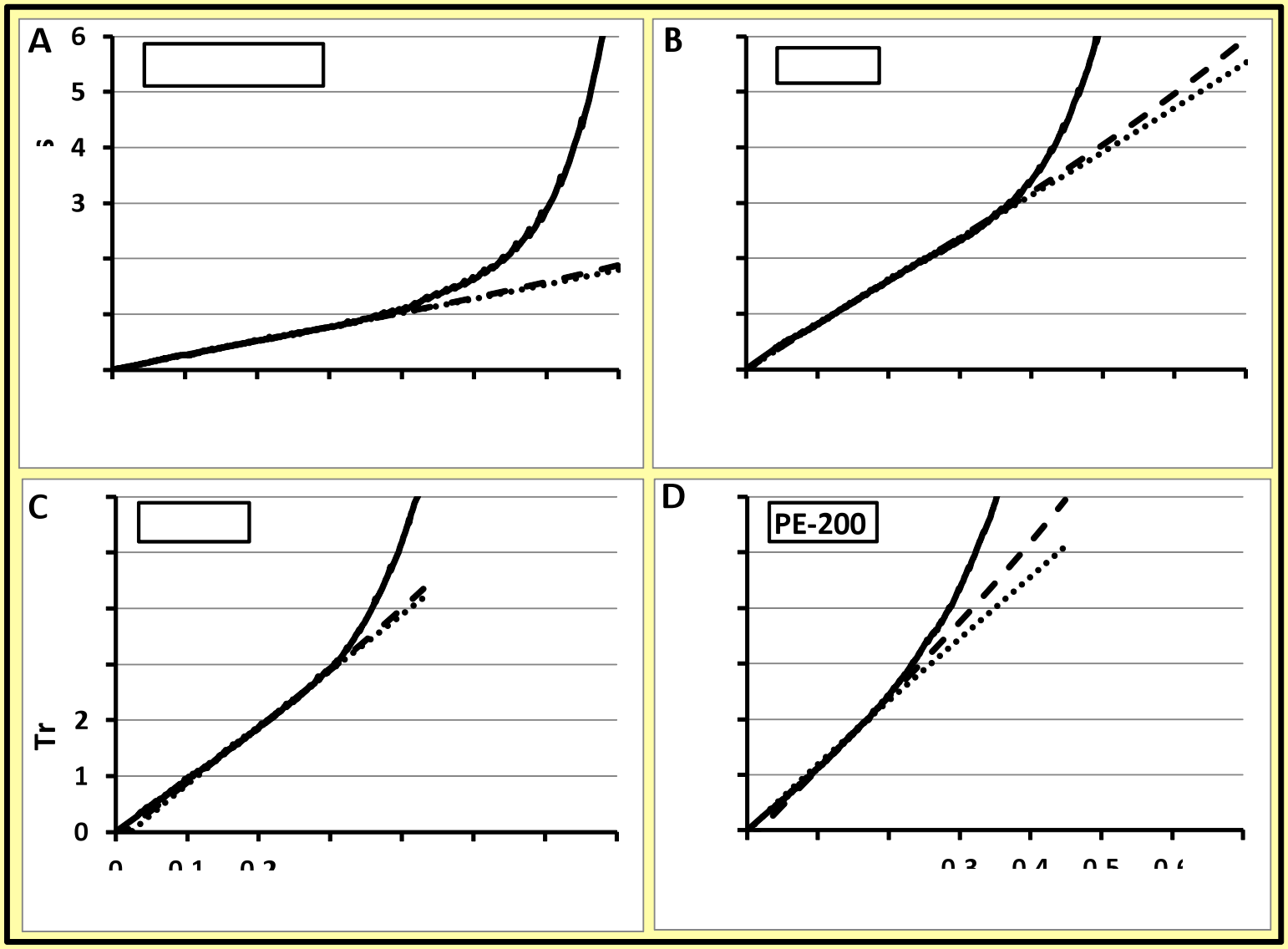
$$\sigma_R = \frac{G_N}{3} n^{1/2}\left(\frac{1}{\lambda_{chain}}\right) L^{-1}\left(\frac{\lambda_{chain}}{n^{1/2}}\right)(\lambda^2-\lambda^{-2})$$

(Arruda and Boyce, 1993)

$$\lambda_{chain} = \frac{[\lambda^2 + 1 + \lambda^{-2}]^{-1/2}}{3}$$

$$L^{-1}(x) = \frac{x(3-x^2)}{1-x^2}$$

Model fits to Experimental Curve



Molecular Parameters

Gaussian Model			
Sample	G_N (MPa)	ν (mole.dm^{-3})	M_e (g/mole)
PE-0	0.566 ± 0.213	0.156 ± 0.064	6767 ± 2677
PE-50	2.072 ± 0.087	0.589 ± 0.025	1565 ± 66
PE-100	3.053 ± 0.261	0.868 ± 0.974	1066 ± 86
PE-200	3.538 ± 0.190	1.006 ± 0.054	917 ± 51
Eight-Chain Model			
Sample	G_N (MPa) $^{\xi}$	ν (mole.dm^{-3})	M_e (g/mole)
PE-0	0.478 ± 0.182	0.132 ± 0.055	8073 ± 3338
PE-50	1.617 ± 0.112	0.460 ± 0.032	2010 ± 140
PE-100	2.086 ± 0.222	0.593 ± 0.063	1566 ± 157
PE-200	2.432 ± 0.125	0.691 ± 0.036	1334 ± 70

Summary

- ***Fitting models to deformation of PE provided molecular weight between entanglements***

- ***Crosslink densities obtained from models were much higher than from swelling***

- ***<u>Limitations</u>***

- ***Strain rate effects were ignored***

- ***Molecular relaxation ignored***

Acknowledgements

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