Experimental Data (continues)

Unsteady shear flow

• Small strain - SAOS, step strain

linear polymers, material effects,
temperature effects

• Large strain - start-up, cessation, creep, large-amplitude step strain

later ...
Steady elongation
Unsteady elongation

Small-Amplitude Oscillatory Shear - Storage and Loss Moduli

Figure 6.30, p. 192 Plazek and O’Rourke; PS
Small-Amplitude Oscillatory Shear - Storage and Loss Moduli

Step Shear Strain - Relaxation Modulus
Ferry’s Summary of Viscoelastic properties of several classes of polymers

Figure 2-3 from Ferry, *Viscoelastic Properties of Polymers*, Wiley, 1980
© Faith A. Morrison, Michigan Tech U.

Key to Ferry’s plots

I. **Dilute polymer solutions**: atactic polystyrene, 0.015 g/ml in Aroclor 1248, a chlorinated diphenyl with viscosity 2.47 poise at 25°C. $M_n = 86,000$, $M_w/M_n$ near 1.

II. **Amorphous polymer of low molecular weight**: poly(vinyl acetate), $M = 10,500$, fractionated.

III. **Amorphous polymer of high molecular weight**: atactic polystyrene, narrow MW distribution, $M_w = 600,000$.

IV. **Amorphous polymer of high molecular weight with long side groups**: fractionated poly(n-octyl methacrylate), $M_w = 3.62 \times 10^6$.

V. **Amorphous polymer of high molecular weight below its glass transition temperature**: poly(methyl methacrylate).

VI. **Lightly cross-linked amorphous polymer**: lightly vulcanized Hevea rubber.

VII. **Very lightly cross-linked amorphous polymer**: styrene butadiene random copolymer, 23.5% styrene by weight.

VII. **Highly crystalline polymer**: linear polyethylene.
Ferry’s Summary of Viscoelastic properties of several classes of polymers

Loss modulus

Figure 2-4 from Ferry, Viscoelastic Properties of Polymers, Wiley, 1980

© Faith A. Morrison, Michigan Tech U.

Ferry’s Summary of Viscoelastic properties of several classes of polymers

Relaxation modulus

Figure 2-2 from Ferry, Viscoelastic Properties of Polymers, Wiley, 1980

© Faith A. Morrison, Michigan Tech U.
Ferry’s Summary of Viscoelastic properties of several classes of polymers

Figure 2-8 from Ferry, *Viscoelastic Properties of Polymers*, Wiley, 1980

Cox-Merz Rule

An empirical way to infer steady shear data from SAOS data.

\[ \eta(\dot{\gamma}) = \left| \eta^*(\omega) \right|_{\dot{\gamma}=\dot{\gamma}} \]

Figure 6.32, p. 193
Venkataraman et al.; LDPE

© Faith A. Morrison, Michigan Tech U.
Small-Amplitude Oscillatory Shear - $G'$
molecular weight dependence

All materials show terminal behavior

Breadth of plateau depends on MW

When MW is below $M_c$, there is no plateau.

---

Small-Amplitude Oscillatory Shear - $G''$
molecular weight dependence

All materials show terminal behavior

Breadth of minimum depends on MW; structure is more complex

When MW is below $M_c$, there is no minimum.
Small-Amplitude Oscillatory Shear - $G'$ as a function of temperature for copolymers

![Graph showing $G'$ as a function of temperature for different copolymers.](image)

Figure 6.39, p. 198 Cooper and Tobolsky: SIS block and SBS random copolymers

© Faith A. Morrison, Michigan Tech U.