Nonlinear viscoelastic properties of branched polyethylene

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BACKGROUND

- The Pom-Pom model developed by McLeish was designed to predict the nonlinear viscoelastic properties of branched polymers. However, Rubio, Wagner,[1] and Chodankar[2] showed this was not the case.
- The Kaye-Bernstein-Kearsley-Zapas (K-BKZ) theory, a special case of Doi-Edwards model that was originally expected to describe well the behavior of linear polymers, was proved to work well on branched polymers, not on linear polymers.[2-6]
- The torque and normal force responses in double-step strain flow can be predicted by K-BKZ theory in terms of the single-step relaxation responses:

Torque: $T(\gamma_1, \gamma_2, t, t_1) = T(\gamma_2 - \gamma_1, t) + T(\gamma_2, t+t_1) - T(\gamma_2 - \gamma_1, t+t_1)$

Normal force: $N(\gamma_1, \gamma_2, t, t_1) = N(\gamma_2 - \gamma_1, t) + N(\gamma_2, t+t_1) - N(\gamma_2 - \gamma_1, t+t_1)$

OBJECTIVES

- To investigate the nonlinear viscoelastic properties of branched polyethylenes in three types of reversing double-step flows.
- Apply the K-BKZ theory to the branched polymers to further test it's applicability for branched polymers.

EXPERIMENTAL

Materials

- Commercial low density and high density polyethylene

	M_w	M_n	PDI	MI	LCB/1000C
LD 103	230,067	42,787	5.38	1.0	12.3
LD 146	165,558	39,222	4.22	3.75	10.8
HDPE	125,000	-	-	0.25	-

- LD 103 and LD 146 are commercial low density polyethylene provided by ExxonMobil.
- HDPE is a commercial high density polyethylene from Sigma-Aldrich and the material characteristics are unknown.

Torsional testing

- There types of torsional tests:

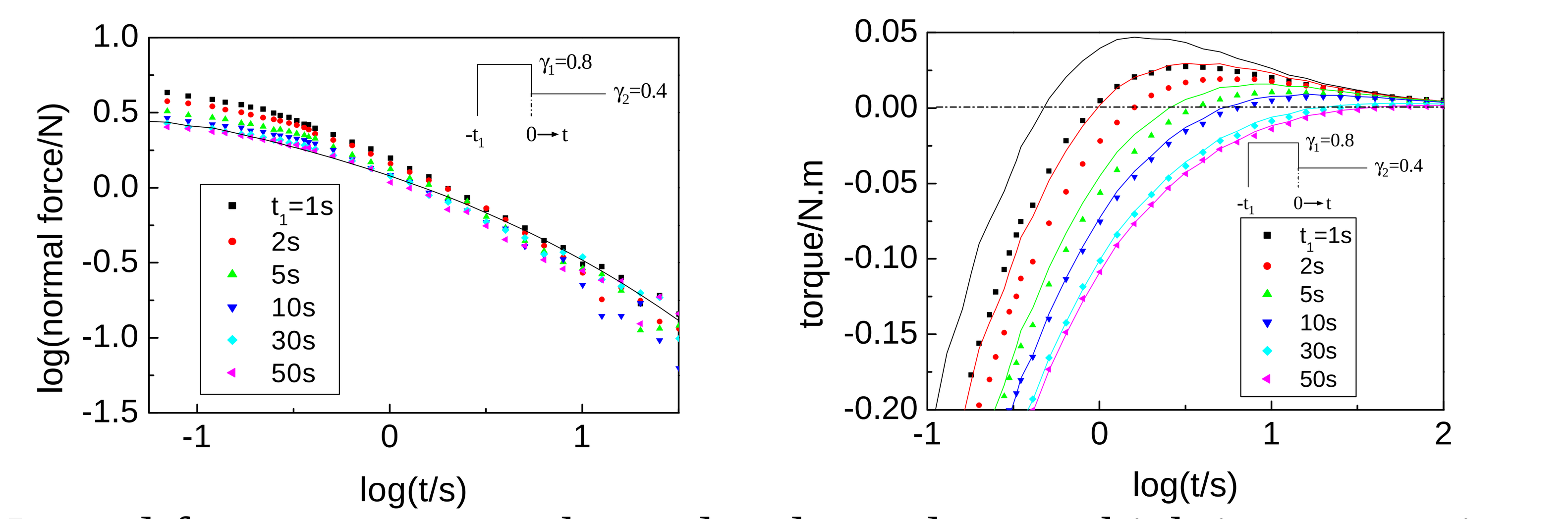
Deformation type	Strain	Strain history	Descriptions
Type B	$\gamma_2 = \gamma_1/2$	γ_1, $-t_1$, $0 \to t$, $\gamma_2=\gamma_1/2$	A half step strain history
Type C	$\gamma_2 = 0$	γ_1, $-t_1$, $0 \to t$, $\gamma_2=0$	A step back to zero
Type D	$\gamma_2 = -\gamma_1$	γ_1, $-t_1$, $0 \to t$, $\gamma_2=-\gamma_1$	A fully reversing strain history

- The test specimens were pre-molded with radius of 25 mm, 6.35 mm and thickness of approximately 3 mm and 2 mm from pellets by using a hydraulic platen press at 160 °C.
- Torsional testing was performed on a modified Rheometrics RMS-7200 with a digitally controlled servomotor in a N_2 gas environment.
- Parallel plate fixtures of 50 mm and 12.7 mm diameter were used.

RESULTS

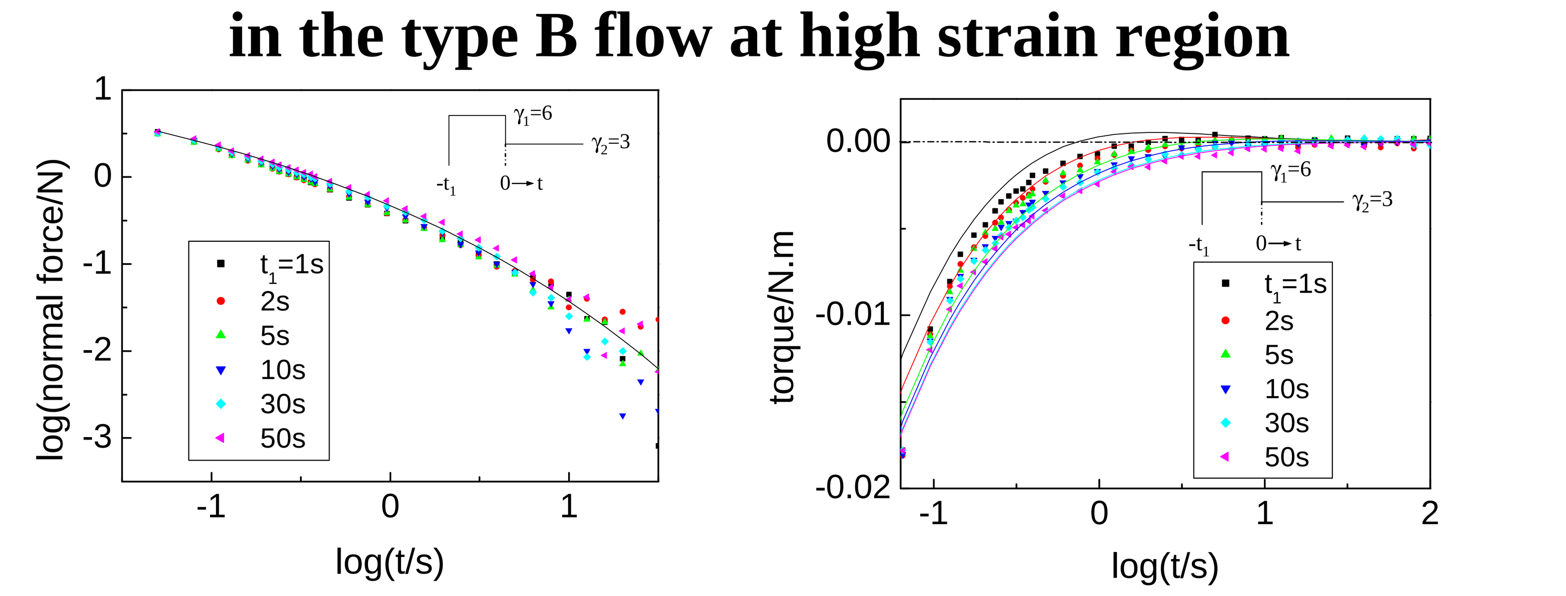
- Symbols: experimental data. Lines: the K-BKZ predictions for all the figures.
- Good agreement between observed and predicted behaviors for both LD103 and LD146 was obtained.

Normal force and torque responses of HDPE in the type B flow at low strain region



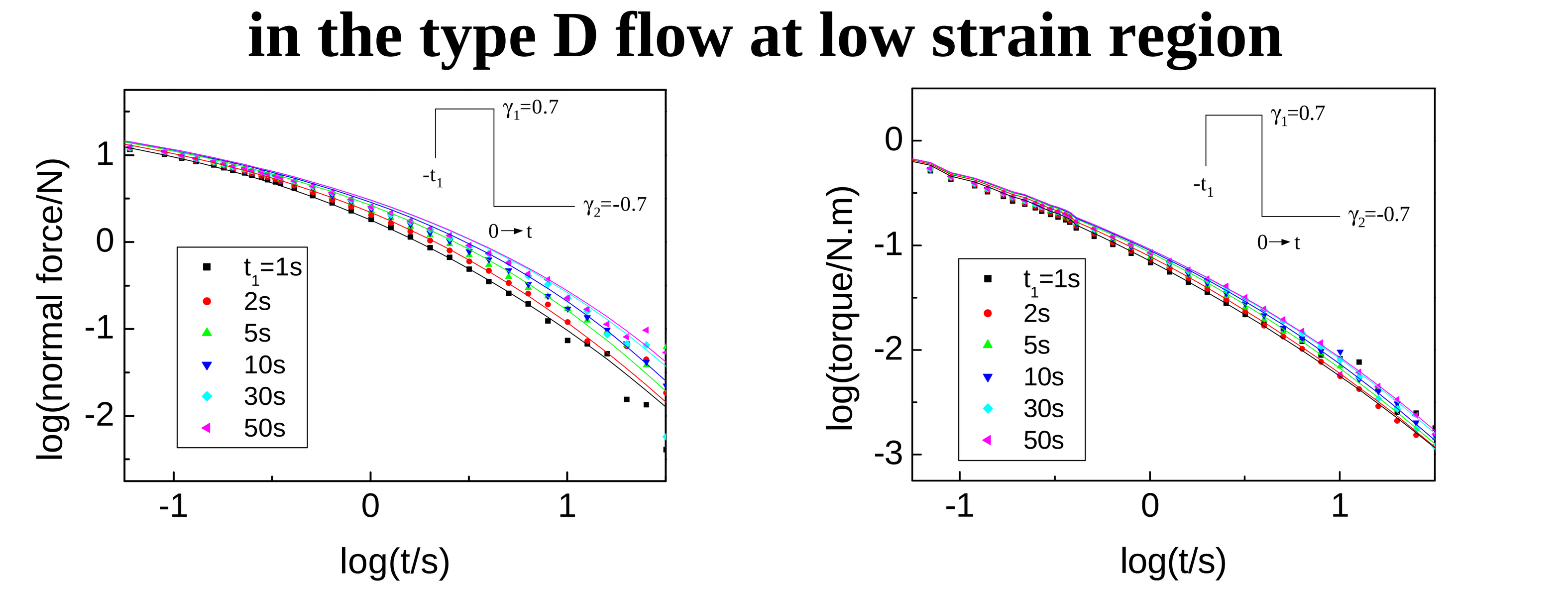
- Normal force responses showed t_1 dependence which is not consistent with K-BKZ theory.
- K-BKZ over–predicted the torque responses at small values of t_1.

Normal force and torque responses of LD 146 in the type B flow at high strain region



- Normal force response is not t_1 dependent and is equal to the single-step response which is in good agreement with the K-BKZ prediction.
- Torque responses change sign from negative to positive and levels off at zero which is the same as the behavior of linear polymers. K-BKZ theory also provided good predictions for torque responses except for the data at t_1=1 s.

Normal force and torque responses of LD 146 in the type D flow at low strain region



- Both normal force and torque responses are well predicted by K-BKZ theory for all values of t_1.

CONCLUSIONS

- Our results showed that K-BKZ theory does not work on linear polymers, which further confirms the previous findings.
- The K-BKZ theory provides good predictions for branched polymers in the type B and C (not shown here) flow.
- In the type D flow, very good agreement between experimental data and theory predictions were found for all values of t_1.

REFERENCES

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