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New Perspective on Rupture and Fracture Behavior of Crosslinked Rubber

Asal Y Siavoshani, Ming-Chi Wang and Shi-Qing Wang
School of Polymer Science and Polymer Engineering, University of Akron, Akron, Ohio 44325

Background and Motivation

Origin of the rate and temperature effects

$$G_c(v_c, T) = G_0[1+g(v_c A_T)]$$

Fracture process → Viscoelastic effects

Temp & rate dependency Gc → Alterations in segmental mobility

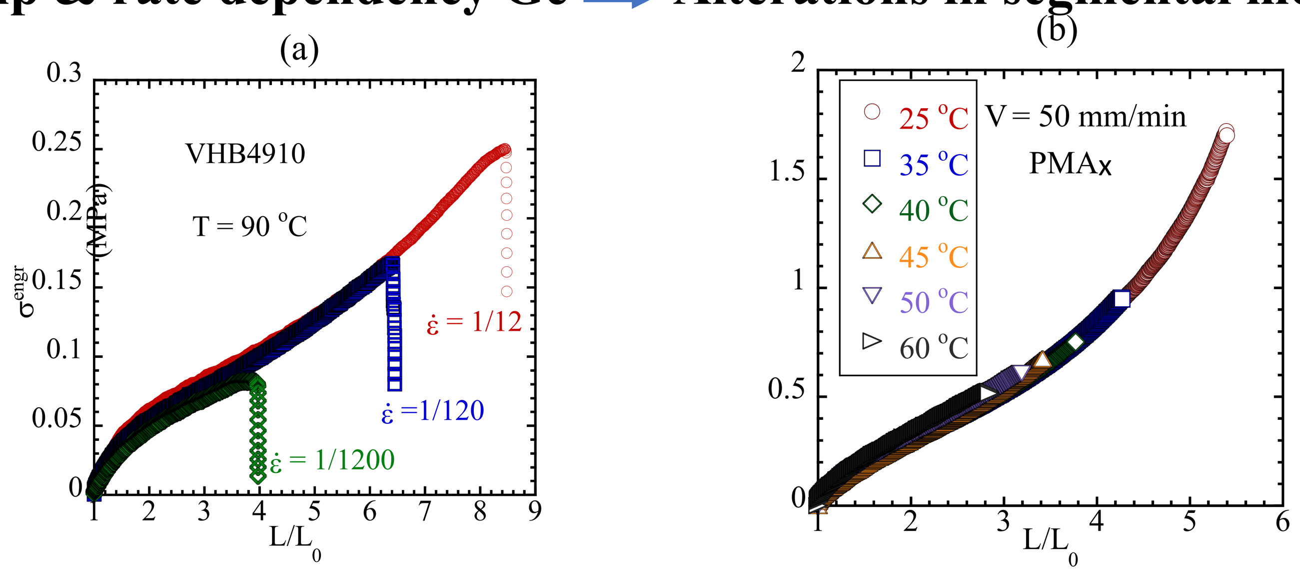

Fig.1 (a) Engineering stress vs. stretch ratio from uniaxial extension of VHB
(b) Engineering stress vs. stretch ratio at five temperatures at crosshead speed V = 50 mm/min

Elastomeric stretching is purely elastic

Theoretical result:

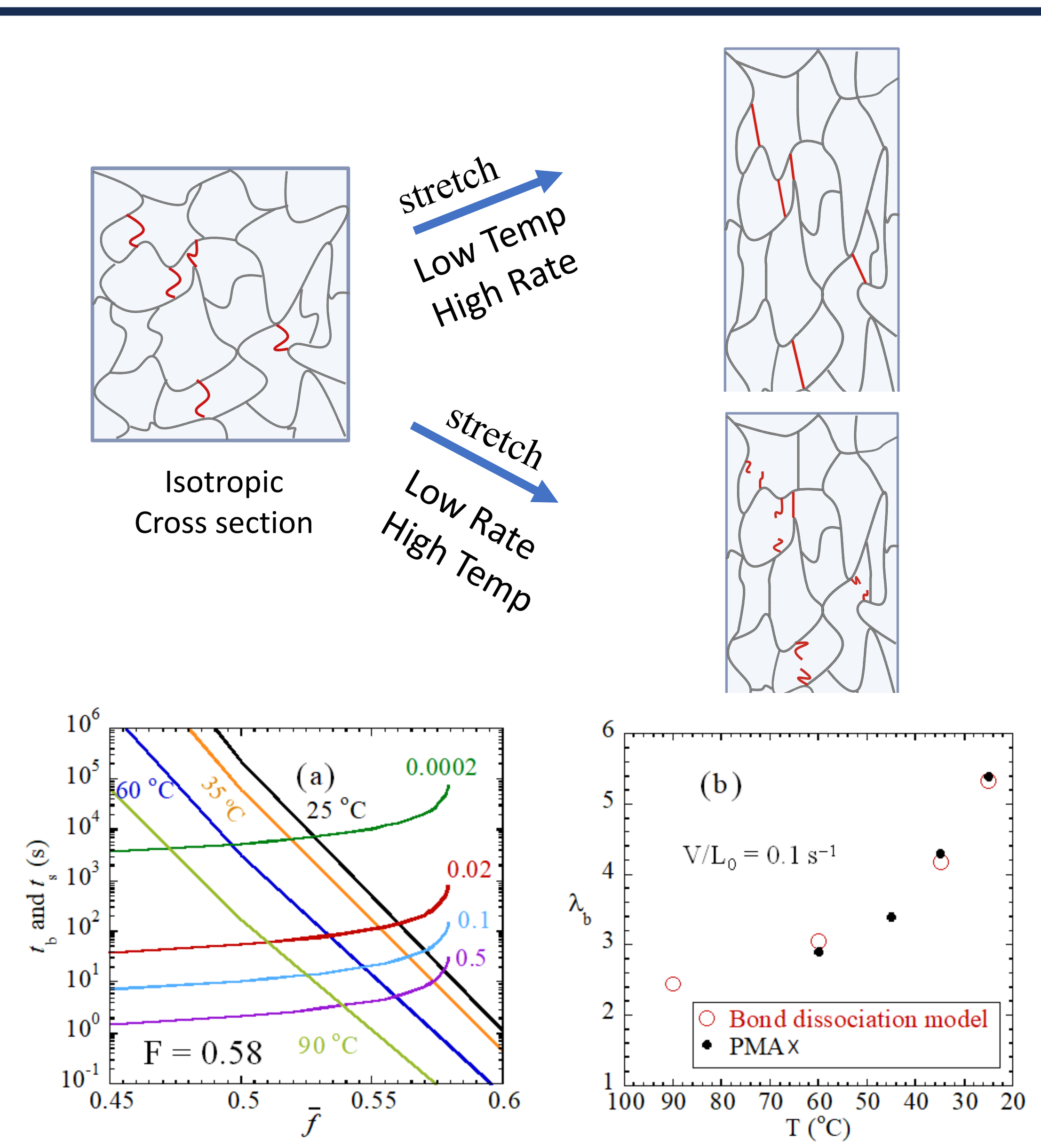

Fig.2 (a) Theoretical solution of nonlinear algebraic equation $\dot{\varepsilon} t_{0} e^{\frac{E_a(\bar{f})}{RT}} = [\lambda(\bar{f}) - 1]$ for $\bar{f}$. (b) Theoretical calculation of ultimate strain at rupture λ_b as a function of temperature, (c) Theoretical schematic explanation

Experimental Result

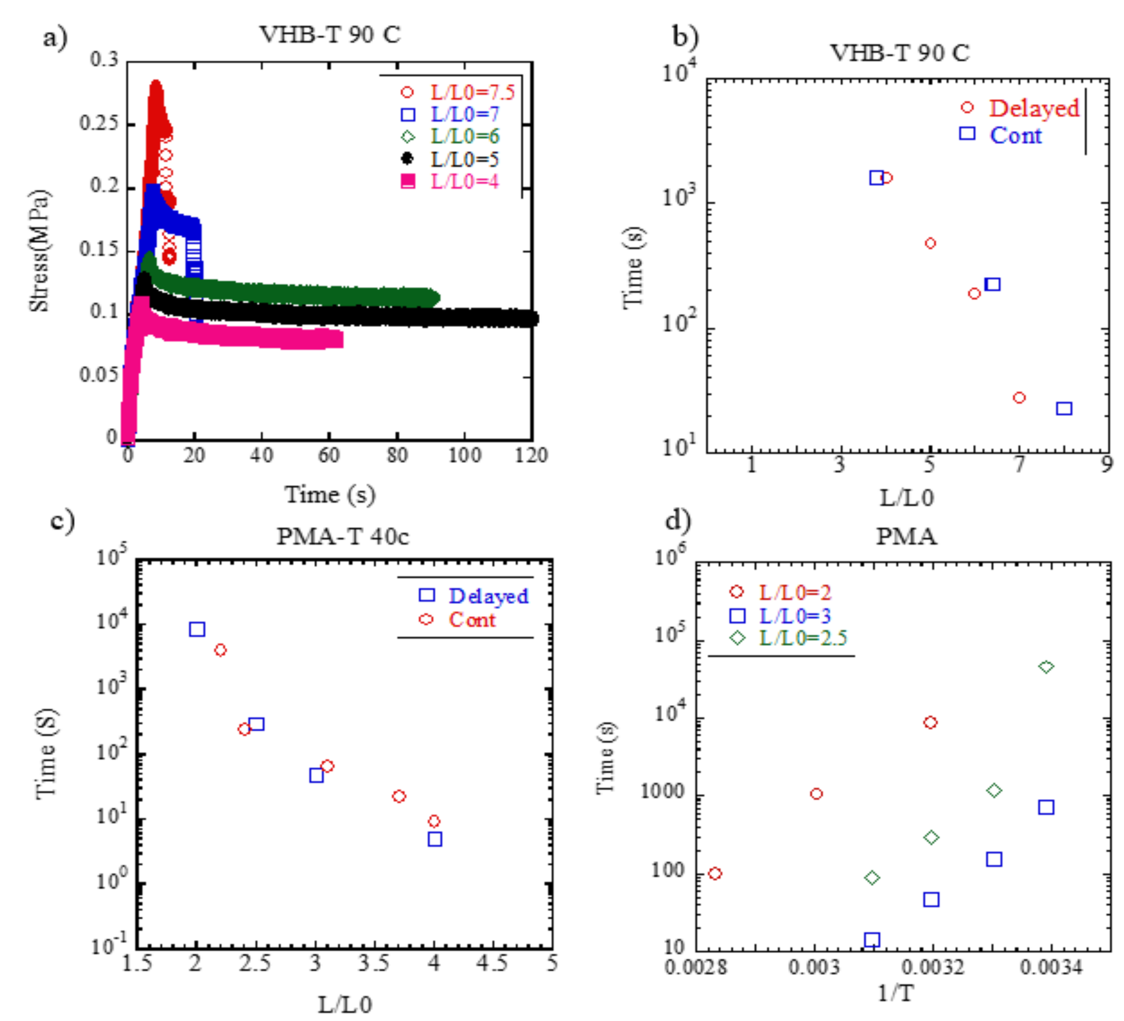

Fig.4 (a) Engineering stress vs. time curves from step stretching of VHB at 90°C.b) Delayed rupture time in step strain tests for various draw ratios, compared with continuous stretching, for VHB.(c) Delayed rupture time in step strain tests for various draw ratios, compared with continuous stretching, for PMA. (d) Delayed rupture time in step strain tests at various temperatures for PMA.

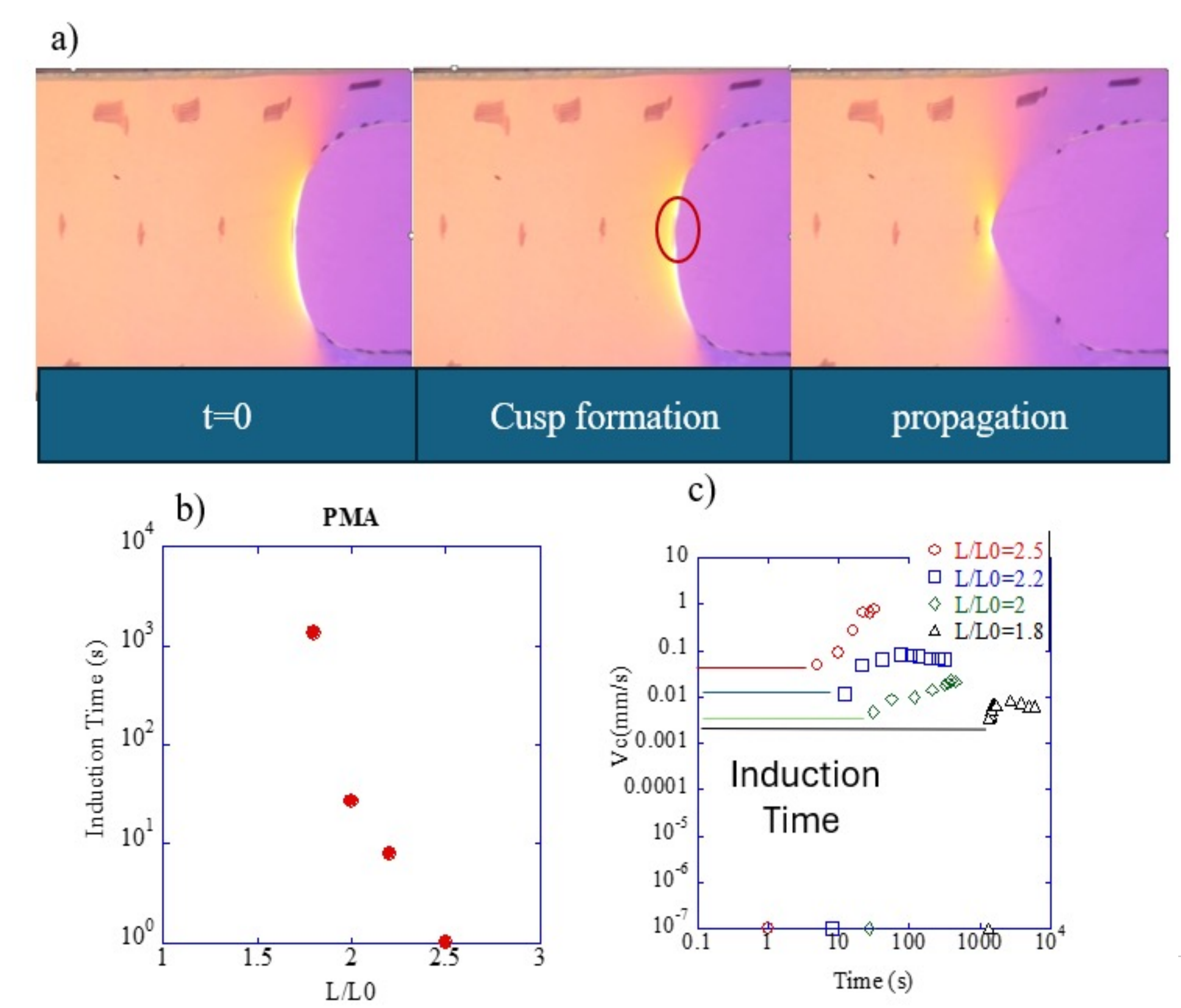

Fig.5 a) Frames showing blunt-cut delayed fracture. (b) Induction time before fracture versus different draw ratios for PMA.(c) Change in crack propagation velocity for different draw ratios.

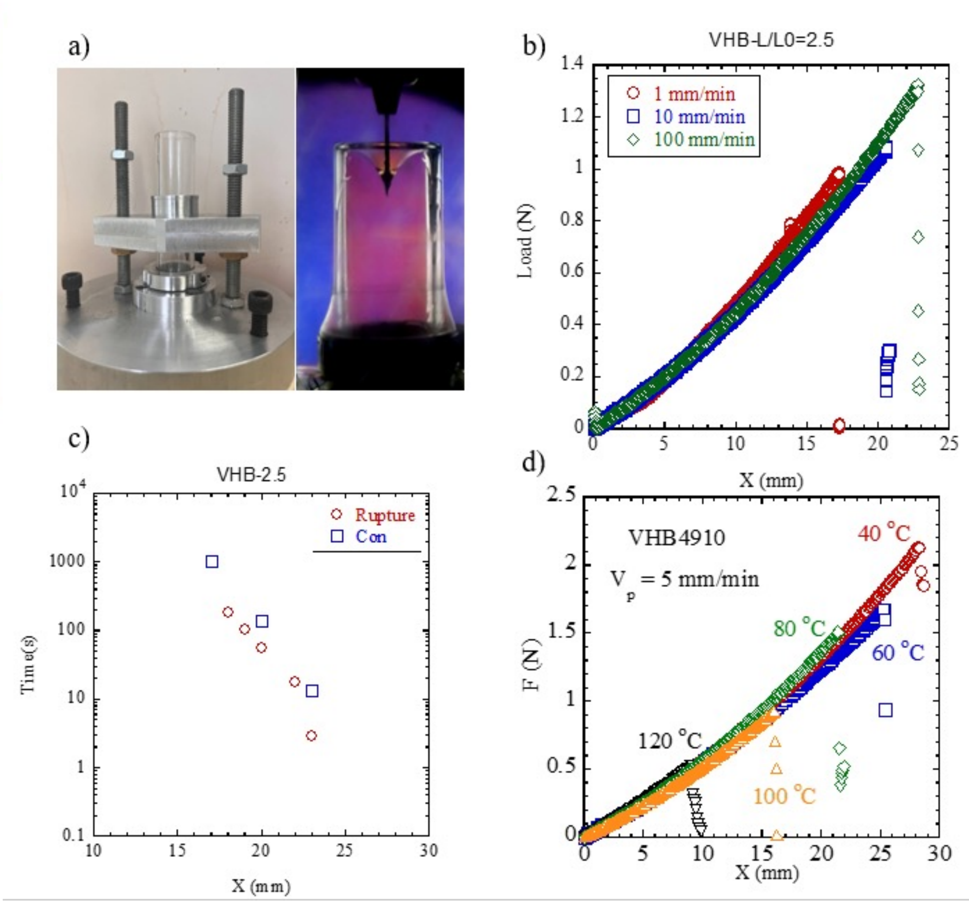

Fig.6 (a) Puncture device and frame illustrating the test procedure.(b) Rate dependence of puncture. (c) Delayed puncture time from step strain tests, compared with continuous stretching. (d) Temperature dependence of the puncture test for pre stretched VHB

Conclusions

- Elastomeric rupture inevitably involves covalent bond dissociation
- When an elastomer is subject to stretching to a particular strain (stretch ratio), a notable level of bond tension may arise in backbones of network strands. Rupture occurs when the bond tension has risen to reduce the bond lifetime to the experimental timescale prescribed by stretching rate.
- At a lower rate, the elastomer would have undergone rupture at a stretch ratio because network strands have spent enough time to undergo chain scission.
- The delayed induction times observed in both puncture and rupture tests align closely with the time scales of continuous stretching. This consistency leads to the key conclusion that the system is primarily governed by the amount of tension built up, regardless of the loading path or test conditions.

Acknowledgements

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References

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2. Wang, S.-Q.; Fan, Z. Investigating the dependence of elastomeric fracture on temperature and rate. *Rubber Chem. Technol.* **2023,** 96, (4), 530-550