Strain Hardening Modulus and Natural Draw Ratio for PE Pressure Piping Applications

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POLYOLEFINS CONFERENCE
February 21 - 24, 2016
Houston, Texas

Overview

- Objectives
- Background on Slow Crack Growth (SCG)
- Definition of SHM and NDR
- Case Studies
  - 2001 – NDR versus NPT
  - 2005 – SHM versus Log ESCR
- ISO 18448
- Future Work
- Summary
- Conclusions

Objectives

- Discuss tensile properties of PE with a relationship to SCG and ESCR
- Examine an ISO test method for measurement of strain hardening modulus (SHM)
- Illustrate the promise of SHM to more quickly obtain useful information on SCG and ESCR
- Suggest some issues where SHM may provide value to the Plastic Pipe Industry
- Consider the next steps needed to realize the full promise of NDR and SHM in plastic pipe Industry

Background on SCG

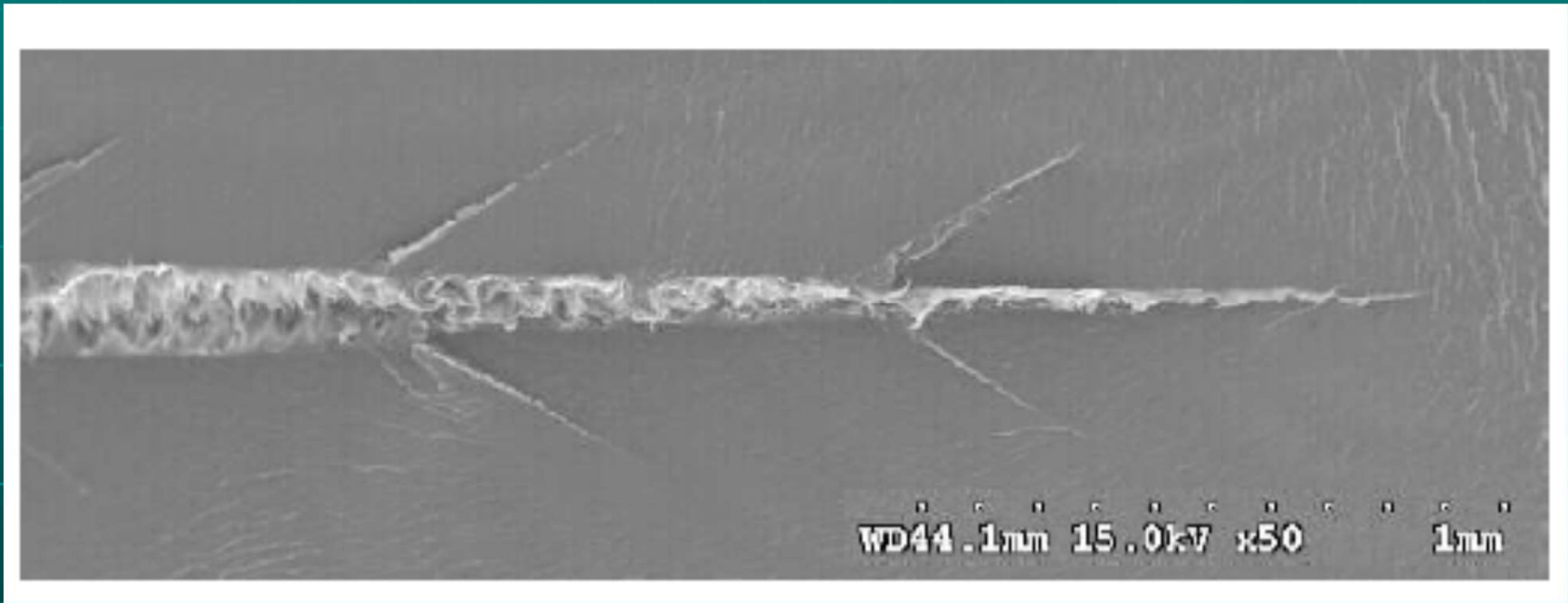
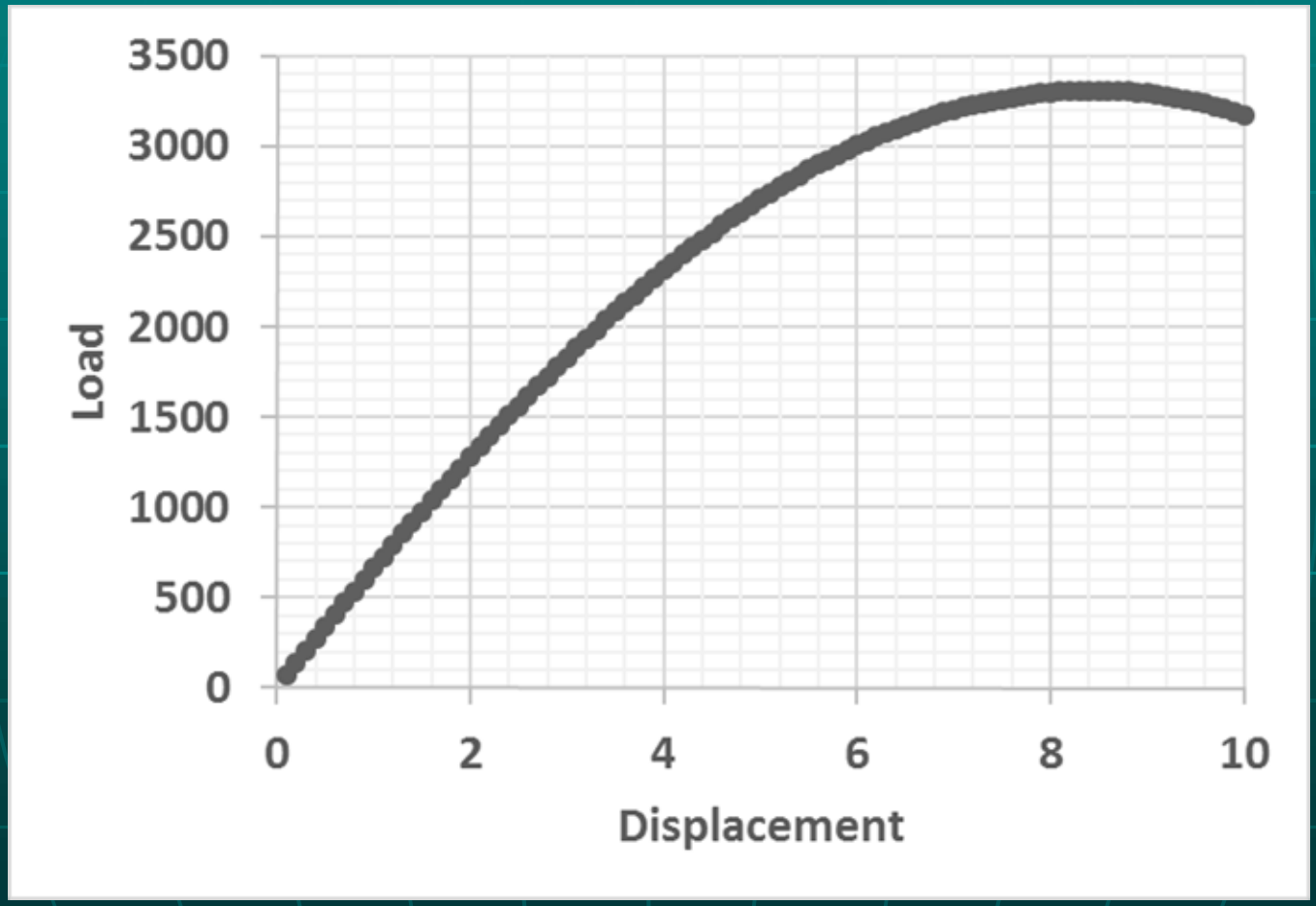
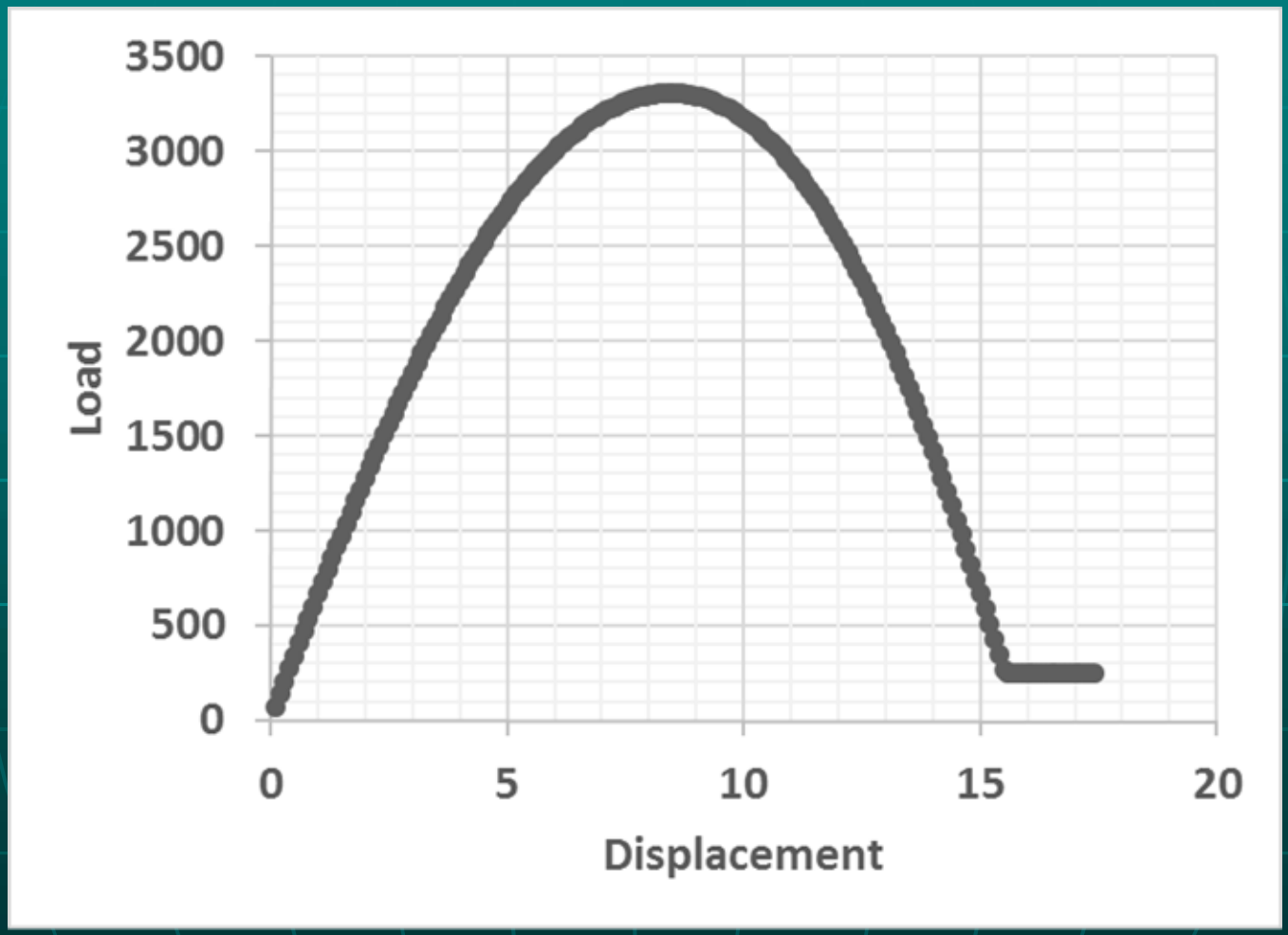


Image from Z. Zhou, et. al "Temperature Effects on Slow Crack Growth in Pipe Grade PE", SPE ANTEC Proceedings, 2010, p. 680.

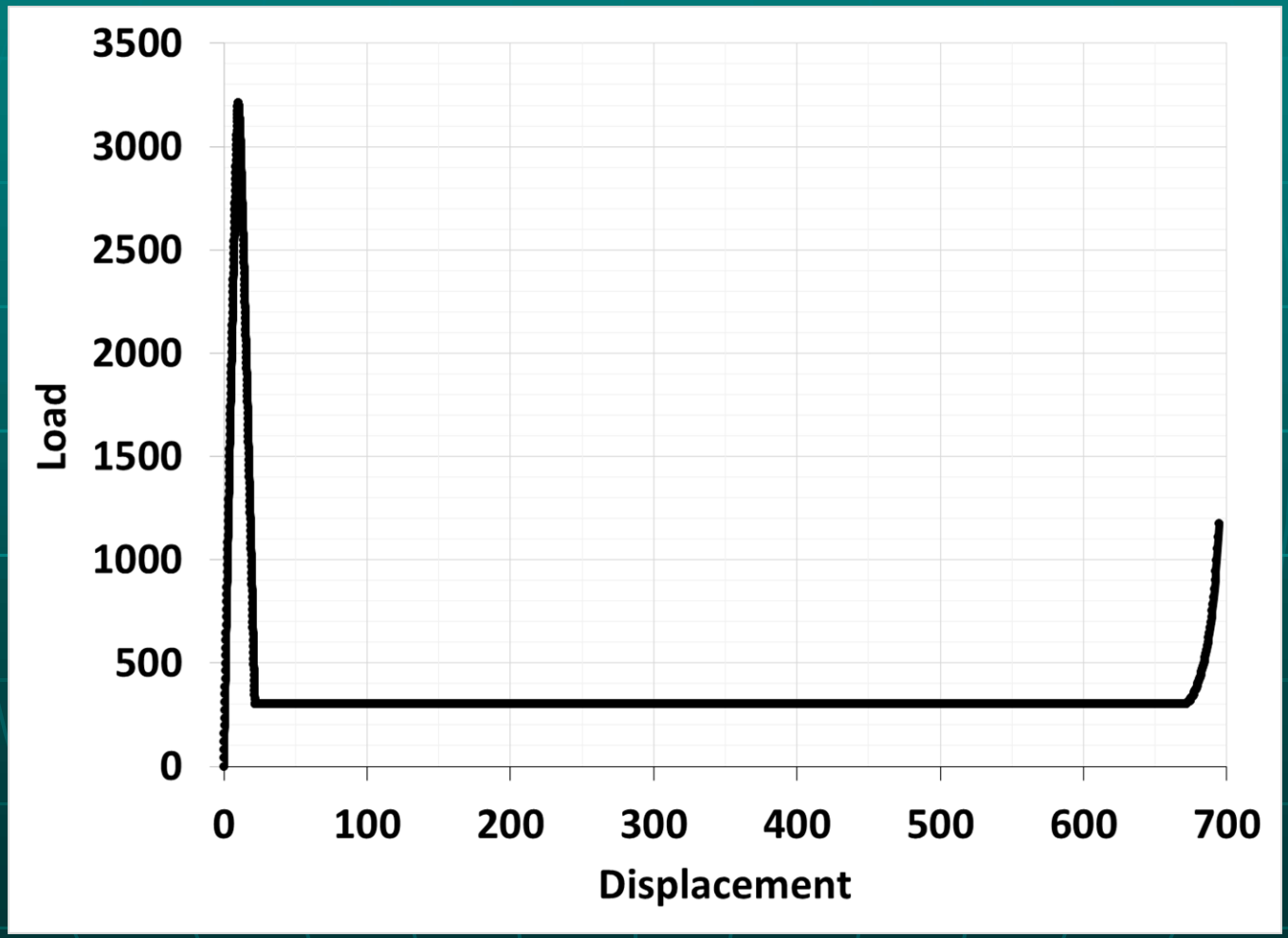
Stress Strain Curve for PE



Stress Strain Curve for PE



Stress Strain Curve for PE

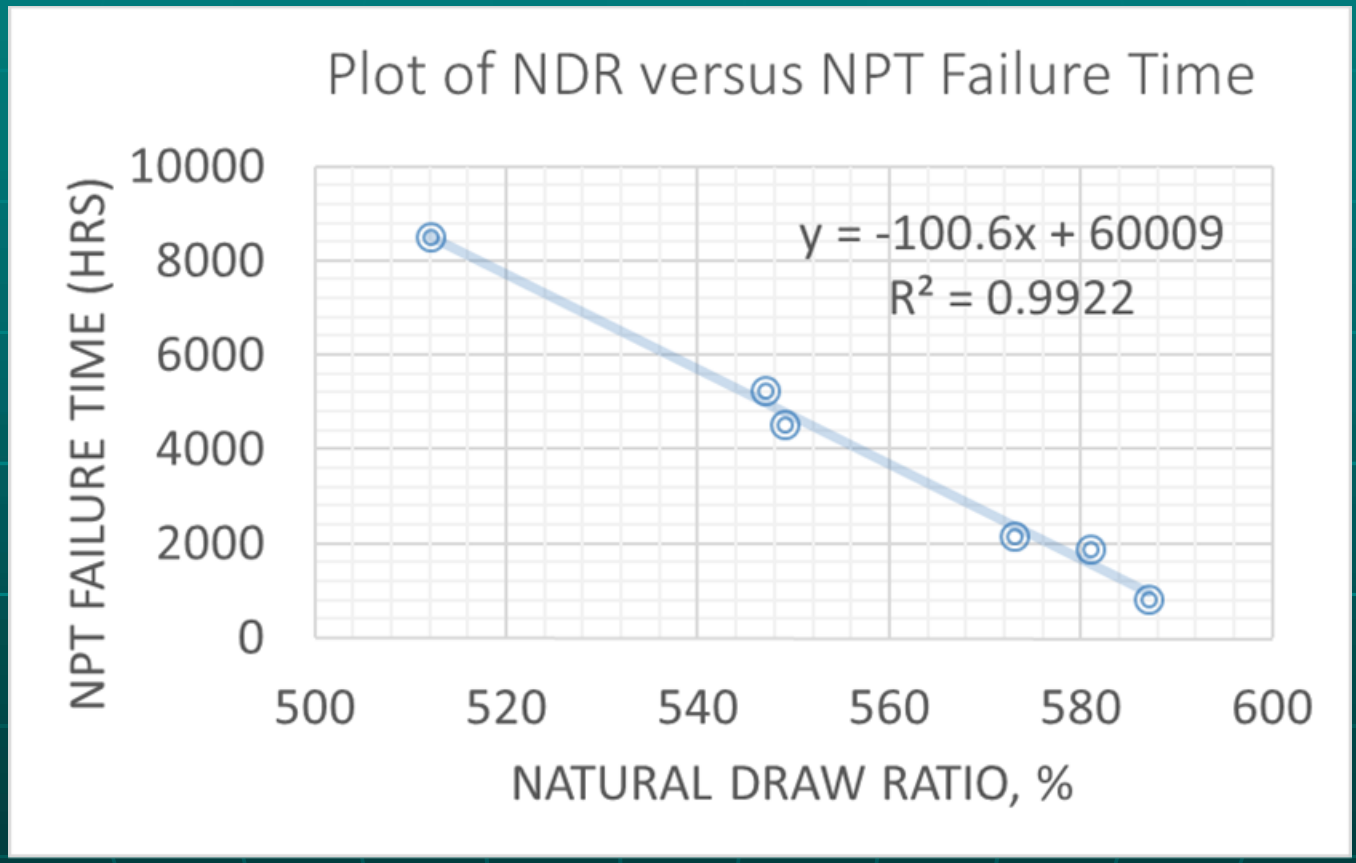


2001 Case Study - NDR versus NPT

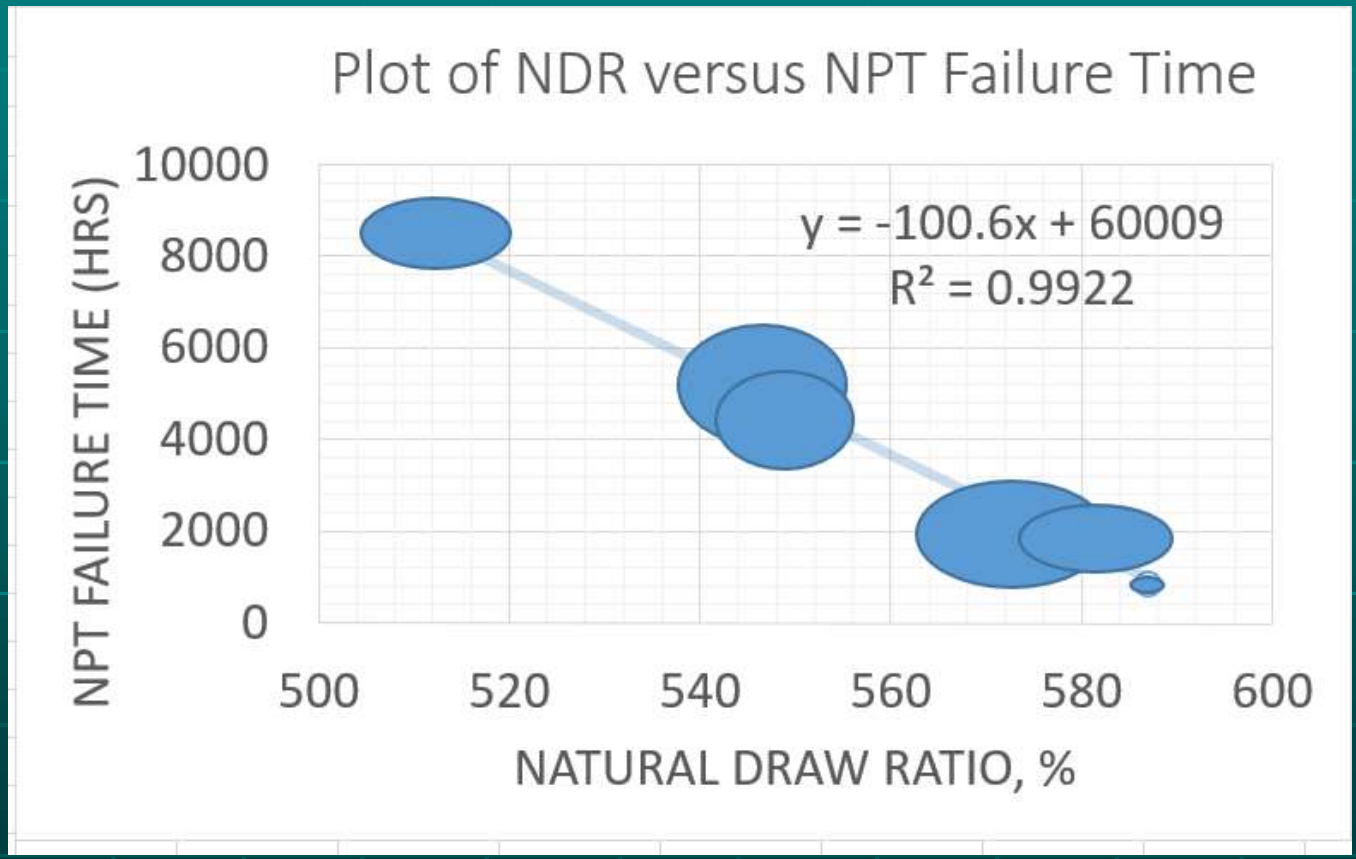
- "Comprehensive Evaluation of the Long-Term Mechanical Properties of PE100 Resins", Plastics Pipes XI, Munich, Germany.
- Bimodal pipe resins were subjected to both Notched Pipe Testing by ISO 13479 and ASTM D638 tensile on Type IV tensile bars at RT.

NDR (%)	NPT failure, hours
512 ± 8	8507 ± 273
530 ± 5	>5000
547 ± 9	5250 ± 421
549 ± 7	4512 ± 296
573 ± 10	2158 ± 313
581 ± 8	1890 ± 155
587 ± 2	830 ± 5

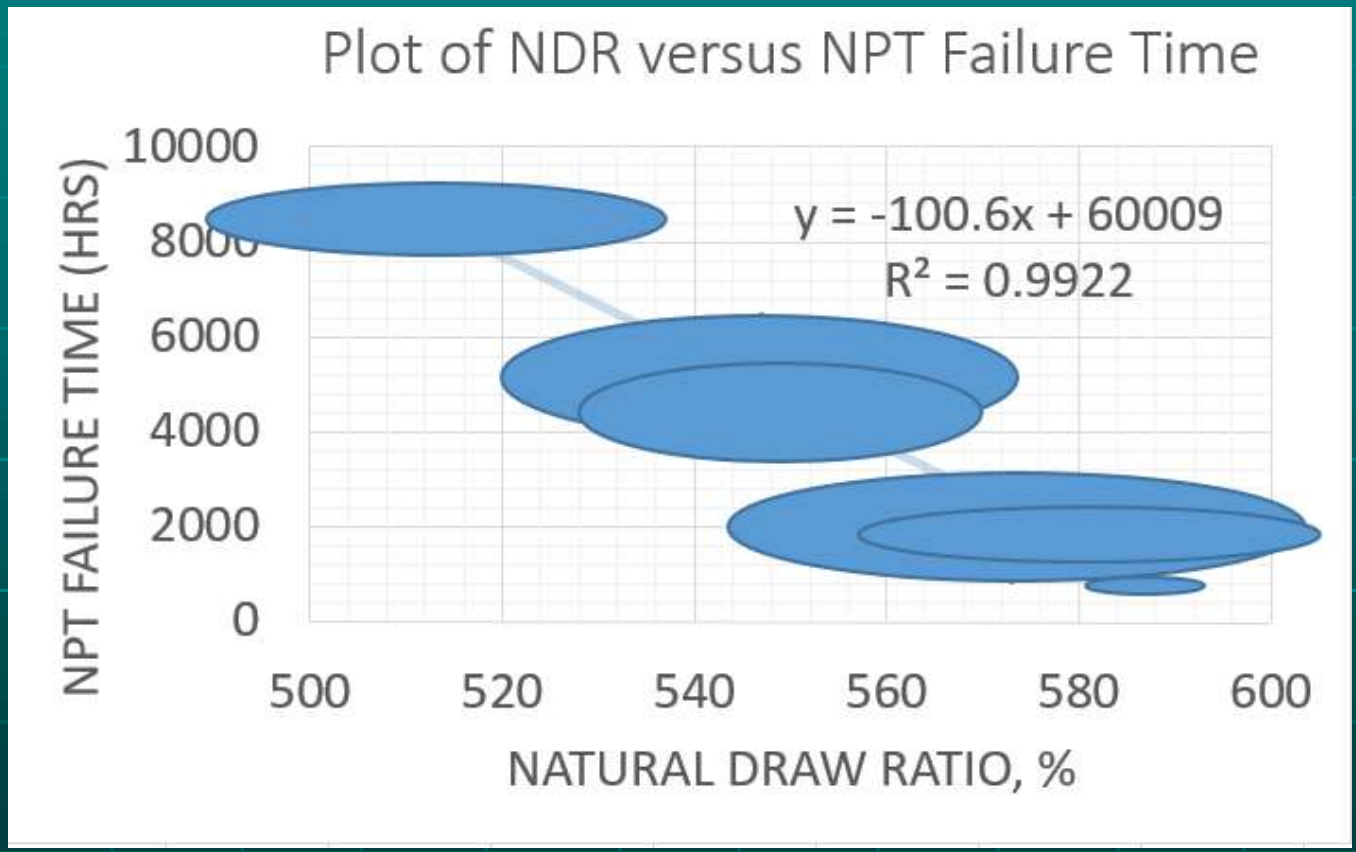
2001 Case Study - NDR versus NPT



2001 Case Study - NDR versus NPT XY error bars



2001 Case Study - NDR versus NPT
3 sigma xy error bars



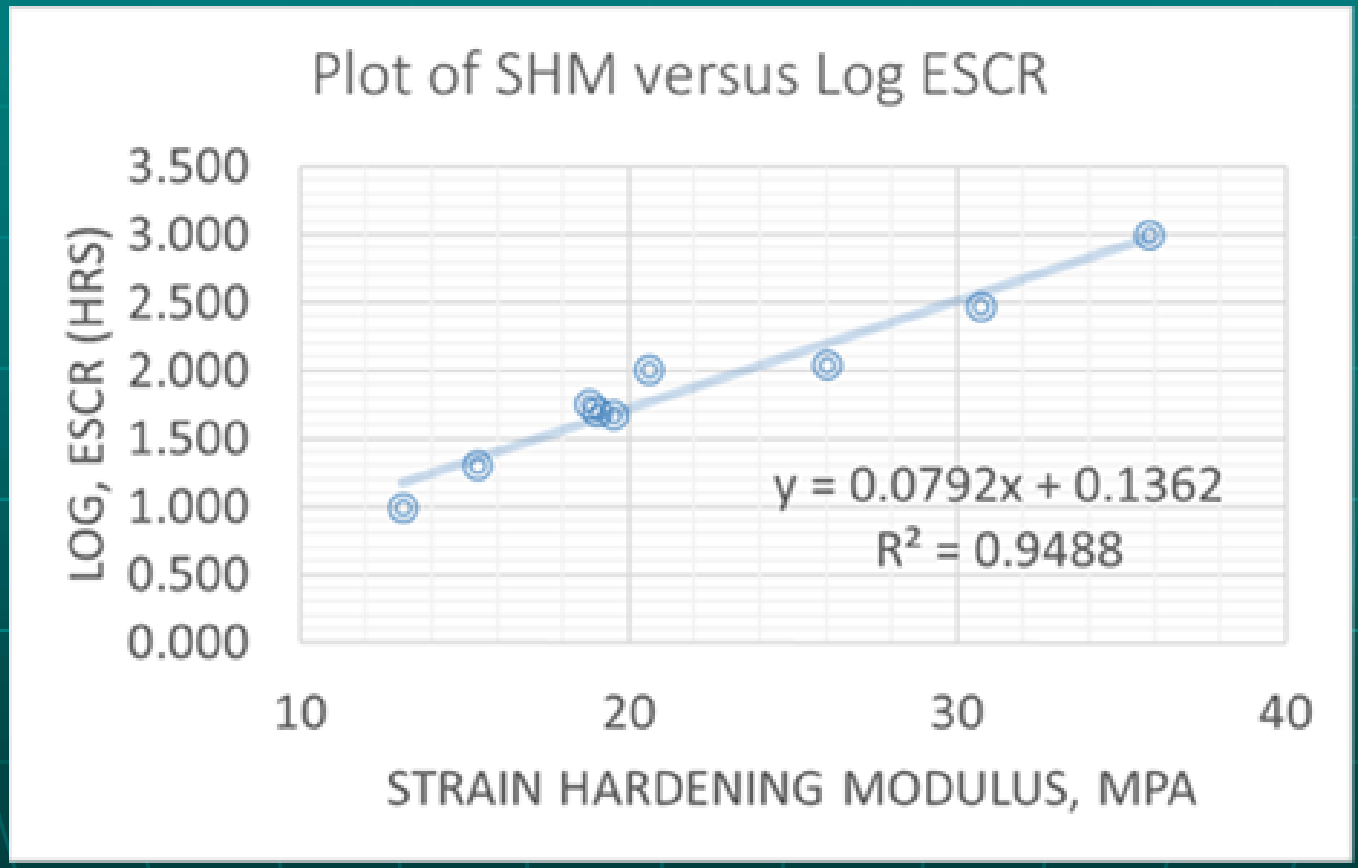
2005 Case Study - SHM versus Log ESCR

- "Strain Hardening Modulus As a Measure of Environmental Stress Crack Resistance of High Density Polyethylene" Polymer, 46, (2005), 6369-6379.
- Blow molding and pipe resins were subjected to both "standard tensile ESCR test" at 75C and an ISO37 type 3 tensile bar at 80C and elongation at 10 mm/min using an optical extensometer

2005 Case Study - SHM versus Log ESCR

ESCR (hrs)	SHM	Log ESCR
10	13.1	1.000
20	15.4	1.301
47	19.5	1.672
50	19	1.699
58	18.8	1.763
103	20.6	2.013
112	26	2.049
300	30.7	2.477
1000	35.8	3.000
>2000	47.2	NA

2005 Case Study - SHM versus Log ESCR



2005 Case Study - SHM versus Log ESCR

- The materials are pressed at 160C to a sheet with a thickness of about 300 mm by;
  - heating for 5 minutes at 0 kN load then
  - 3 min at 10 kN load followed by
  - 3 min at 50 kN load and finally
  - cooling to RT at a load of 180 kN
- The sheet is annealed for 1 h at 120C and then
- Slowly cooled to RT by switching off the heat to the temperature chamber.
- Test specimens (ISO37 type 3) are punched from the pressed sheets.

ISO 18488 Molding

- The materials are pressed at 180C to a sheet with a thickness of about 300 mm of 1000 mm by;
  - heating for 5 to 15 minutes at 0 kN load then
  - 5 +/- 1 min at 5 Mpa load followed by
  - cooling to RT under load at 15 +/- 2C
- The sheet is annealed for 1 h at 120 +/- 2 C and then slow cooled with a cooling rate less than 2 C / minute

ISO 18488 Testing

- Test specimens are slightly modified in Geometry
- 80C tensile testing
- Strain rate is 20 mm / minute

Future Work

- Publish a test report that includes error bars
- Include Precision and bias testing
- Document if pigments and carbon black are tolerated
- Documents how blended systems respond
- Log ESCR versus Strain Hardening Modulus is of interest
- Log PENT versus Strain Hardening Modulus is also of interest
- Extend the range of pipe resins to include high performing materials and take them to failure

Potential Needs

- Development Accelerator – New generations of materials can be developed more quickly and easily based on a rapid screening slow crack growth (SCG) test
- Time Machine – the equivalent of thousands or tens of thousands of hours of SCG information in dozens of hours
- Lie Detector – the detection of the presence of low cost low SCG materials into higher cost highly qualified high SCG materials

Future Work


ISO 18488
Industry Interest
PENT Study
Pipe Standards
Code Adoption

Summary

- The viability of using tensile testing to obtain SCG information on PE resins has been documented in literature.
- ISO 18488 has been published as a test method which should assist future efforts.
- The lack of a larger round robin study with statistical values attached to measurements is a barrier to further industry use and regulatory acceptance.

Conclusions

- The relationship between tensile test data and slow crack growth performance has support in literature.
- The publication of ISO 18488 may form the basis of further studies.
- The promise of a rapid and low cost method to obtain SCG information will support continued activity.

Questions