Tensile Strain Hardening Test Indicator of Environmental Stress Cracking Resistance of High Density Polyethylene

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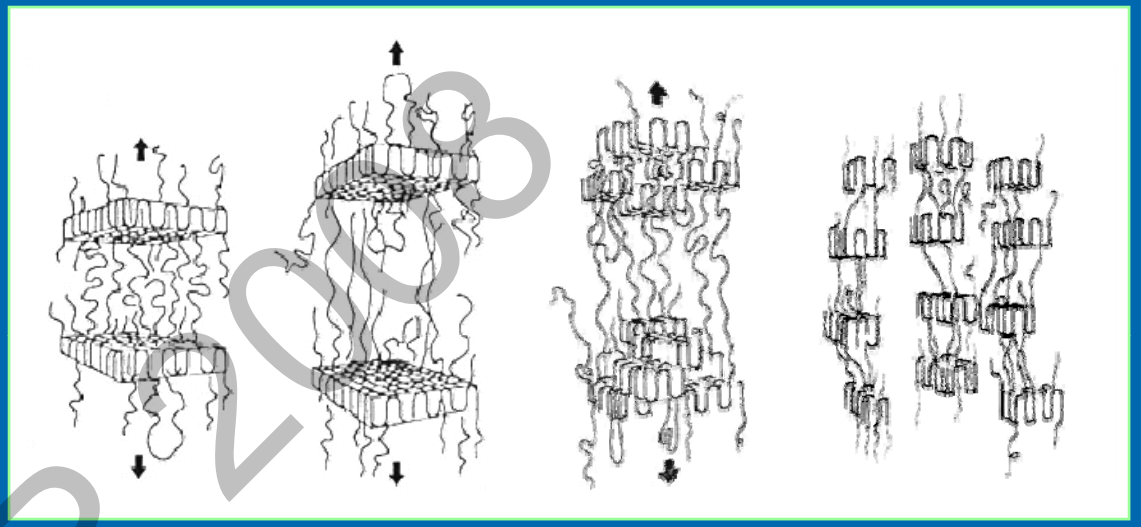
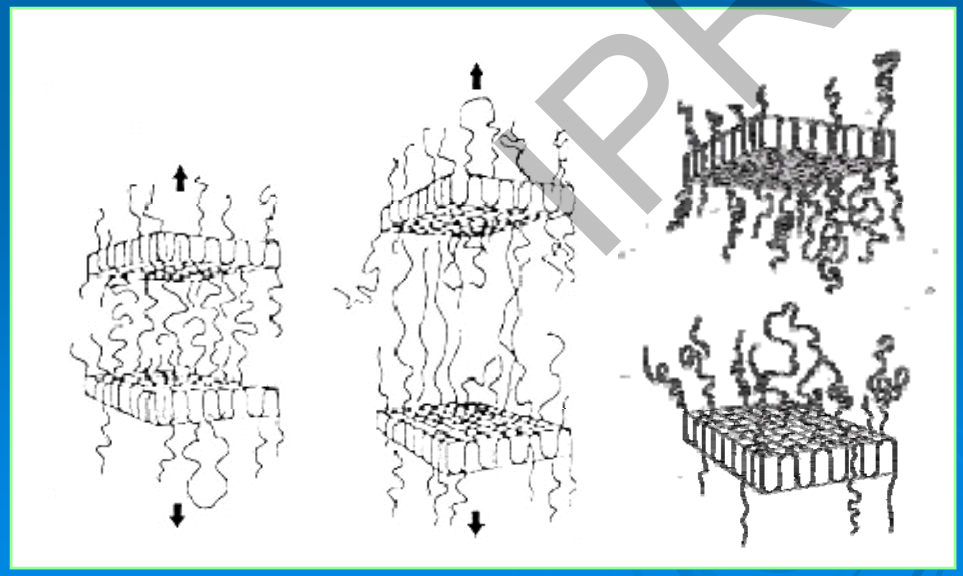
Failure Mechanisms

- Ductile failure
  - "Necking" of material
  - Rough fibrous surface

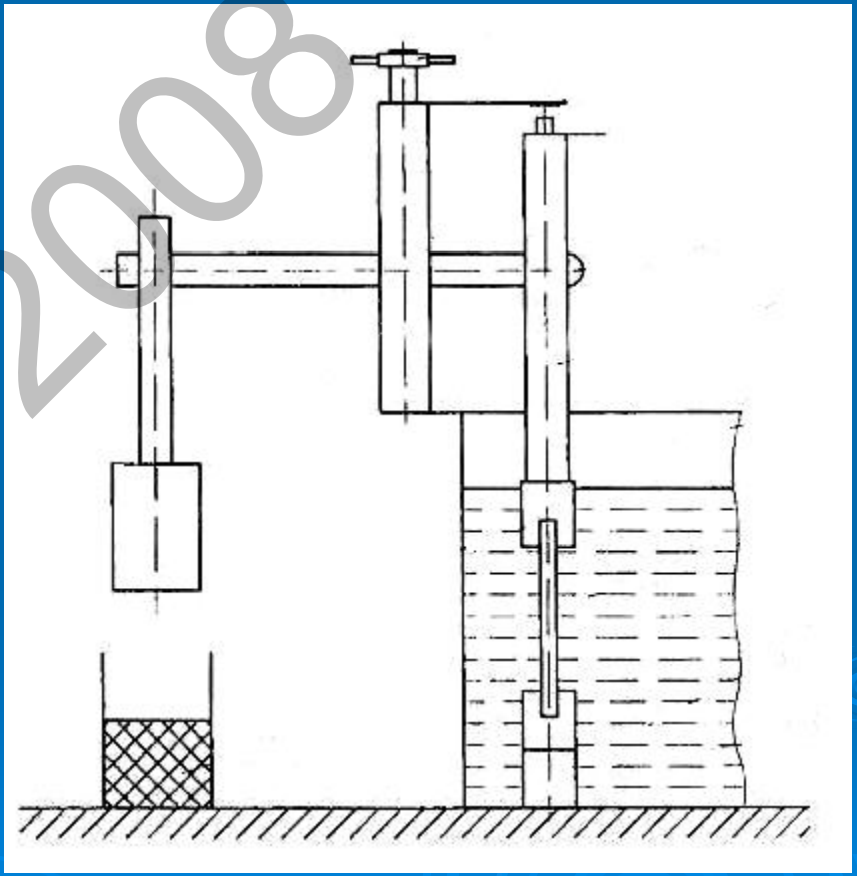




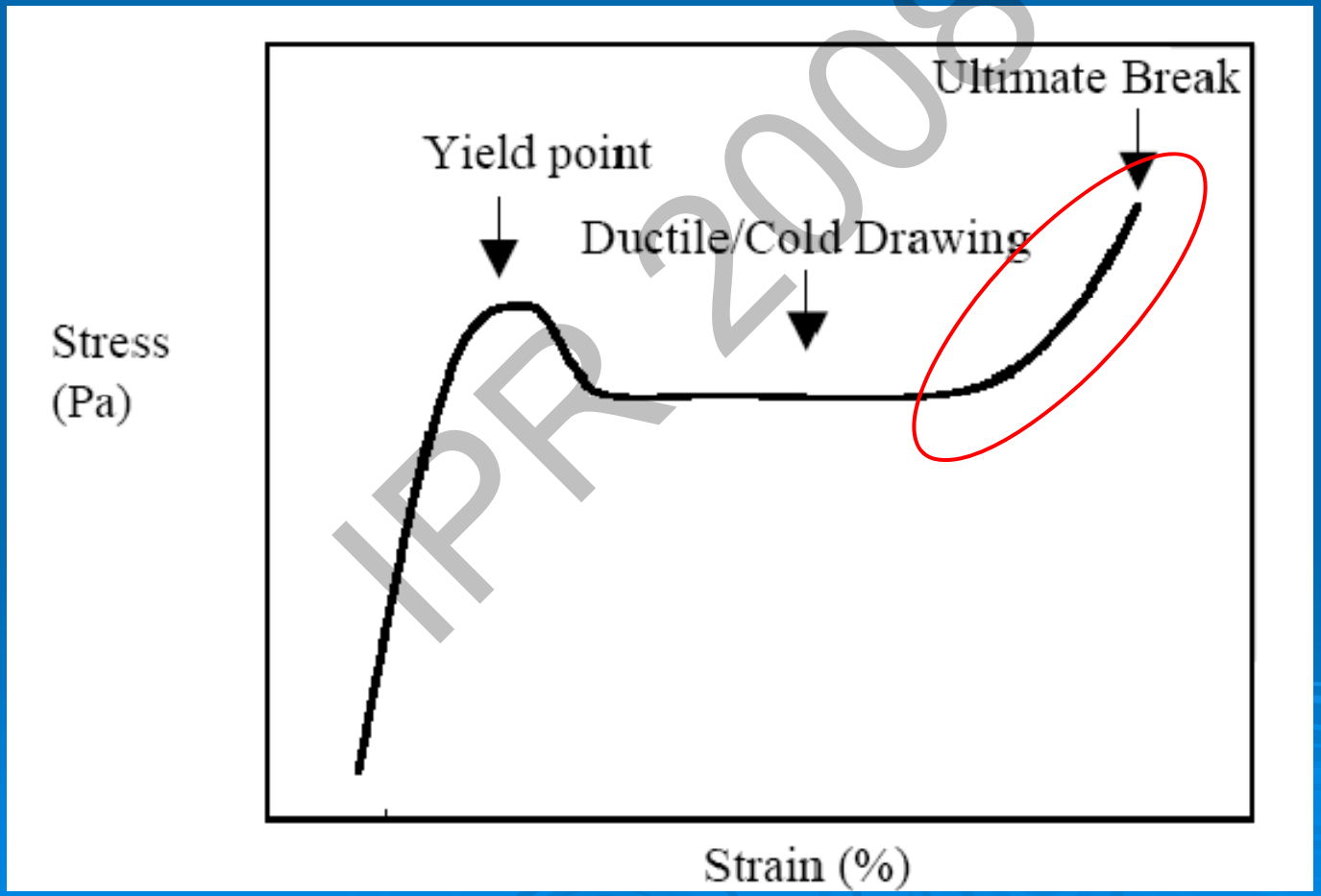
- Brittle failure
  - clean break with little material deformation
  - fracture surface appears smooth

Notch Constant Load Test

- Tensile creep test for ESCR
- Temperature and concentration controlled bath
- Long test duration
- Large variability in results

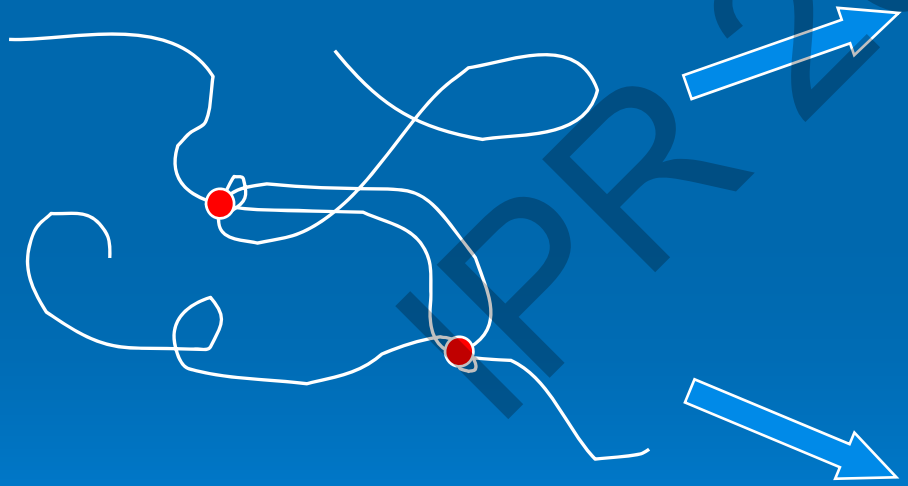


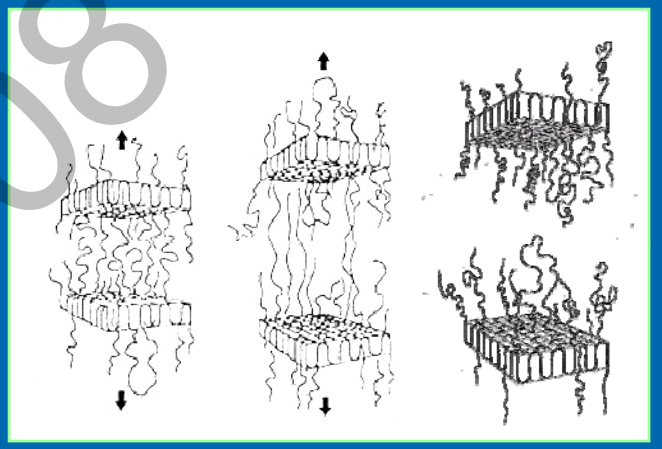
Strain Hardening

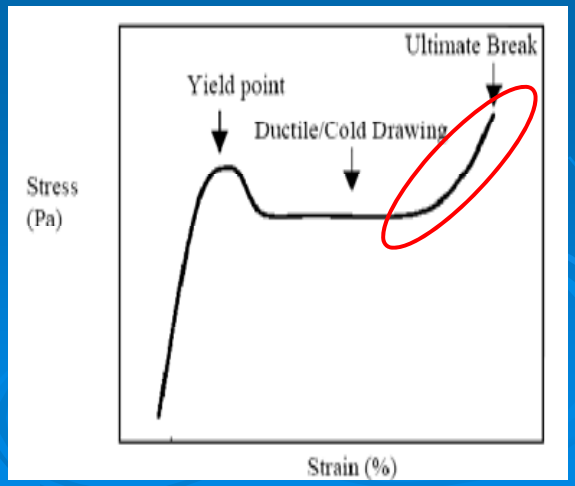


Strain Hardening and ESCR

- Chain entanglement effect



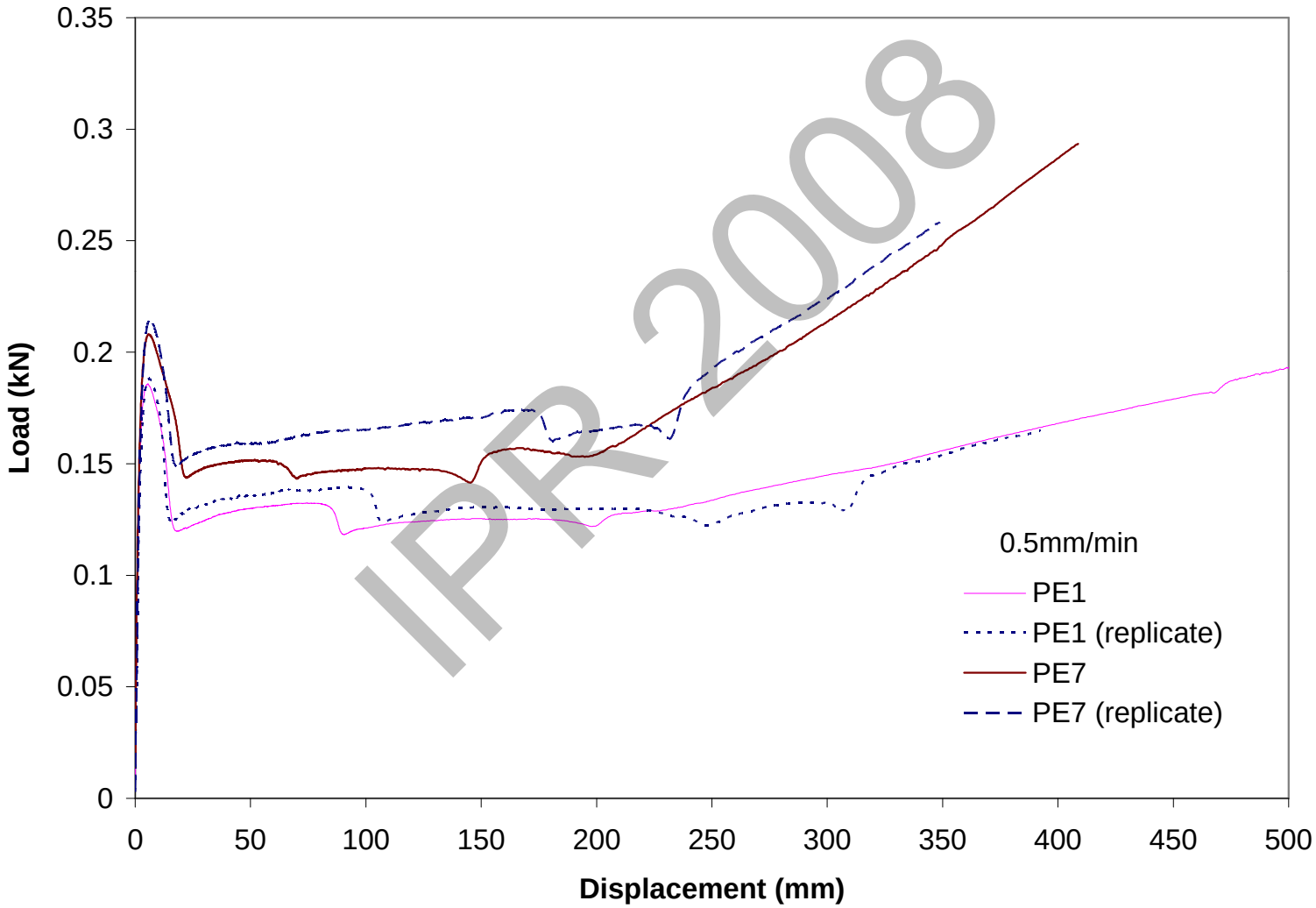




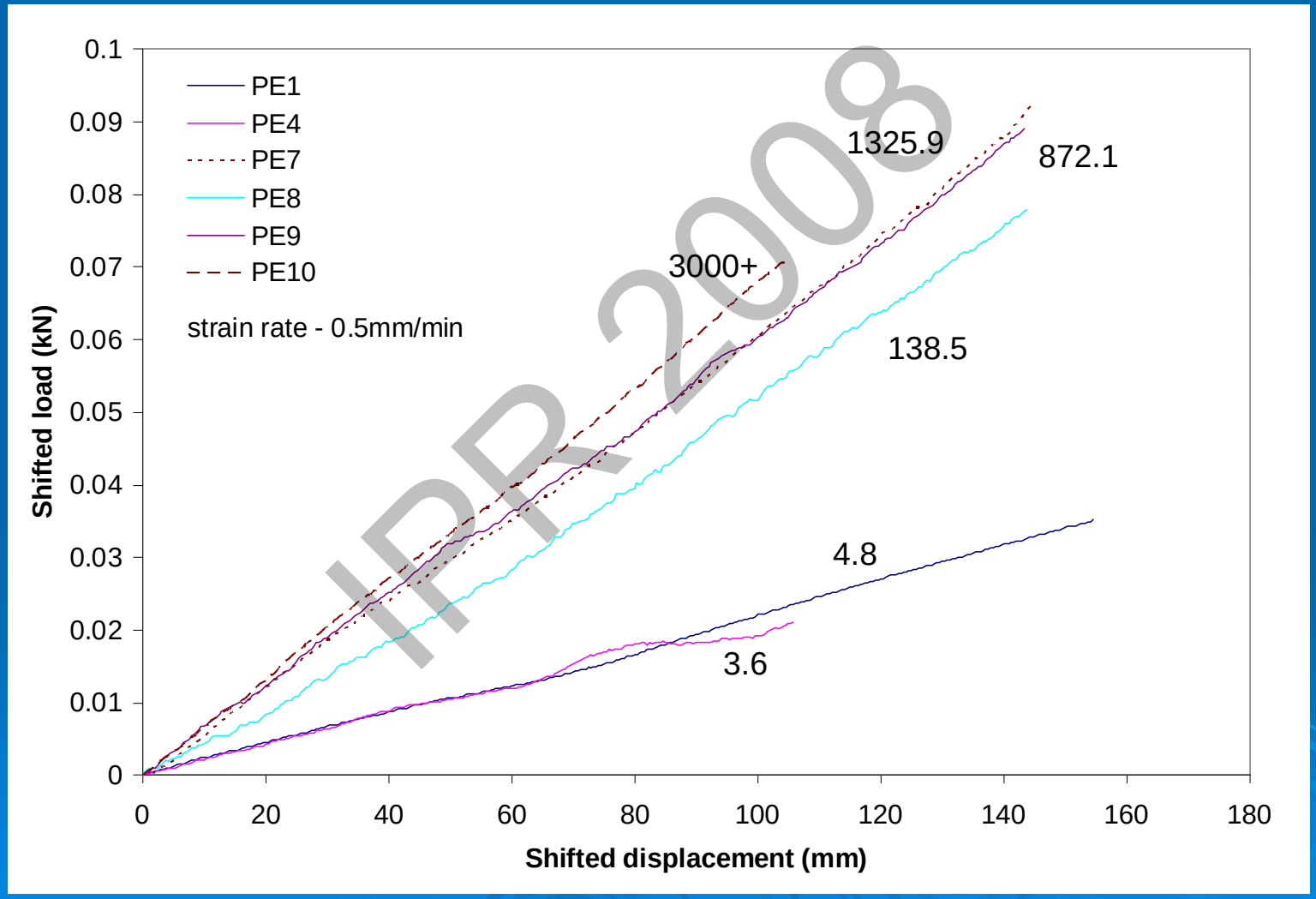
Strain Hardening Test

- Previous method
  - 80°C test temperature
  - Optical extensiometer
  - True stress-strain measurements
- Proposed method
  - Ambient conditions
  - Standard tensile tester
  - Load-displacement measurements

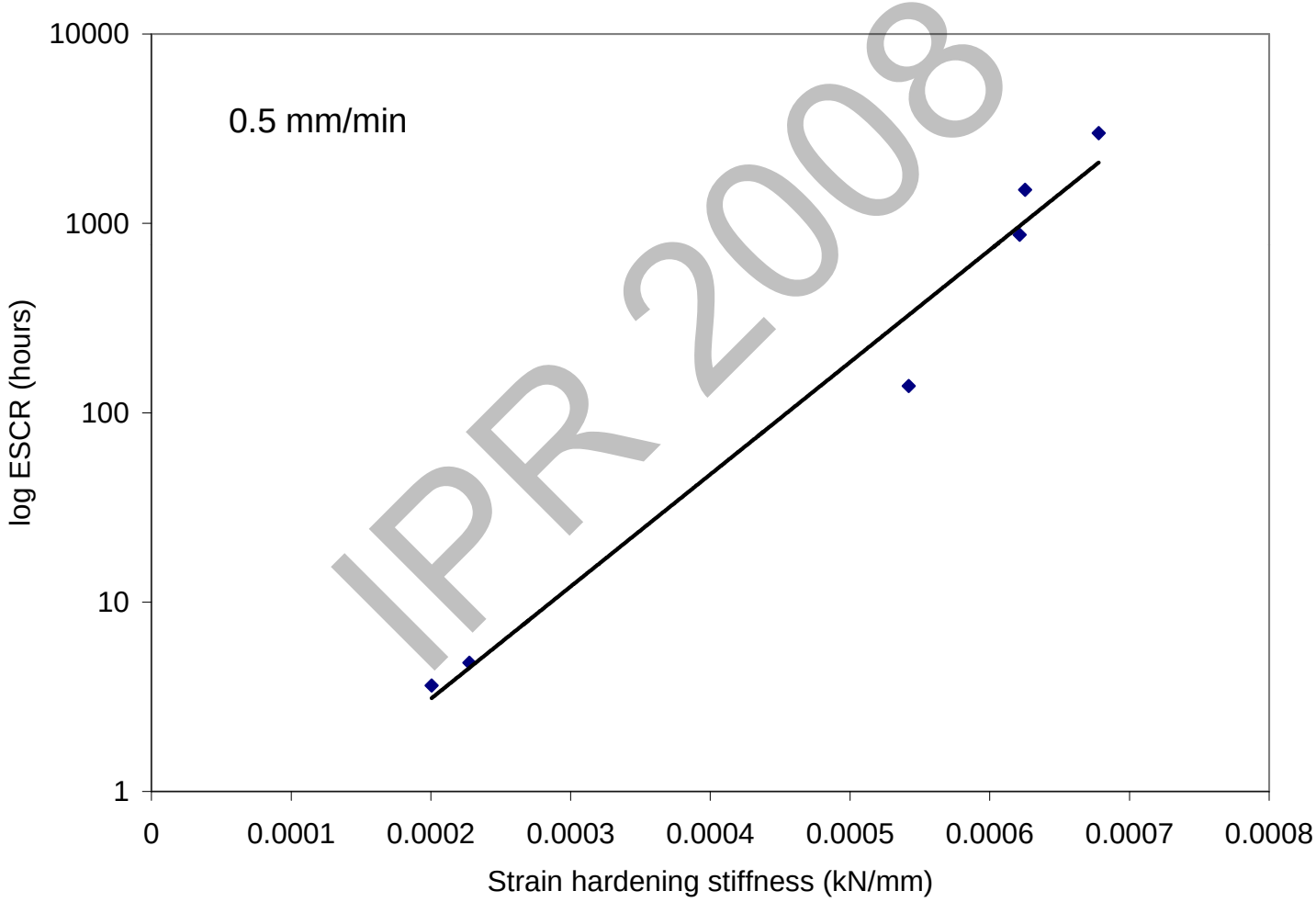
Tensile Experiment



Strain Hardening

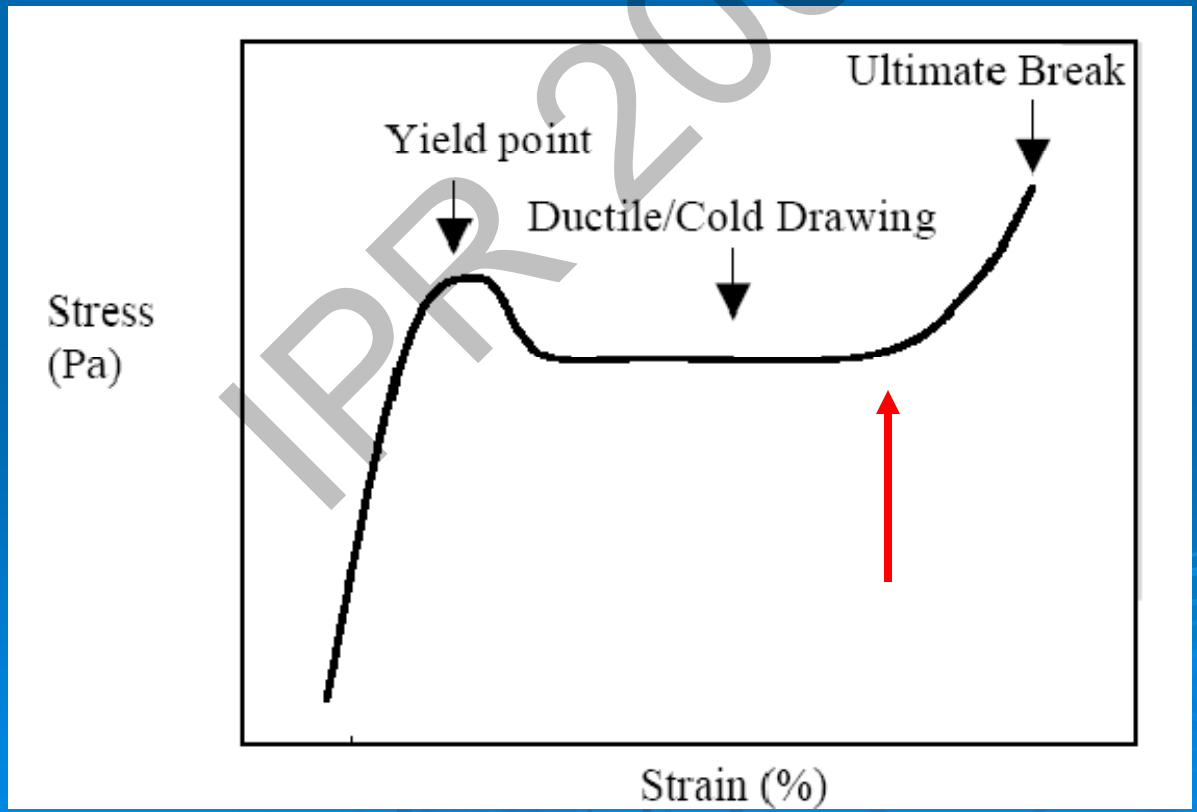


Hardening Stiffness

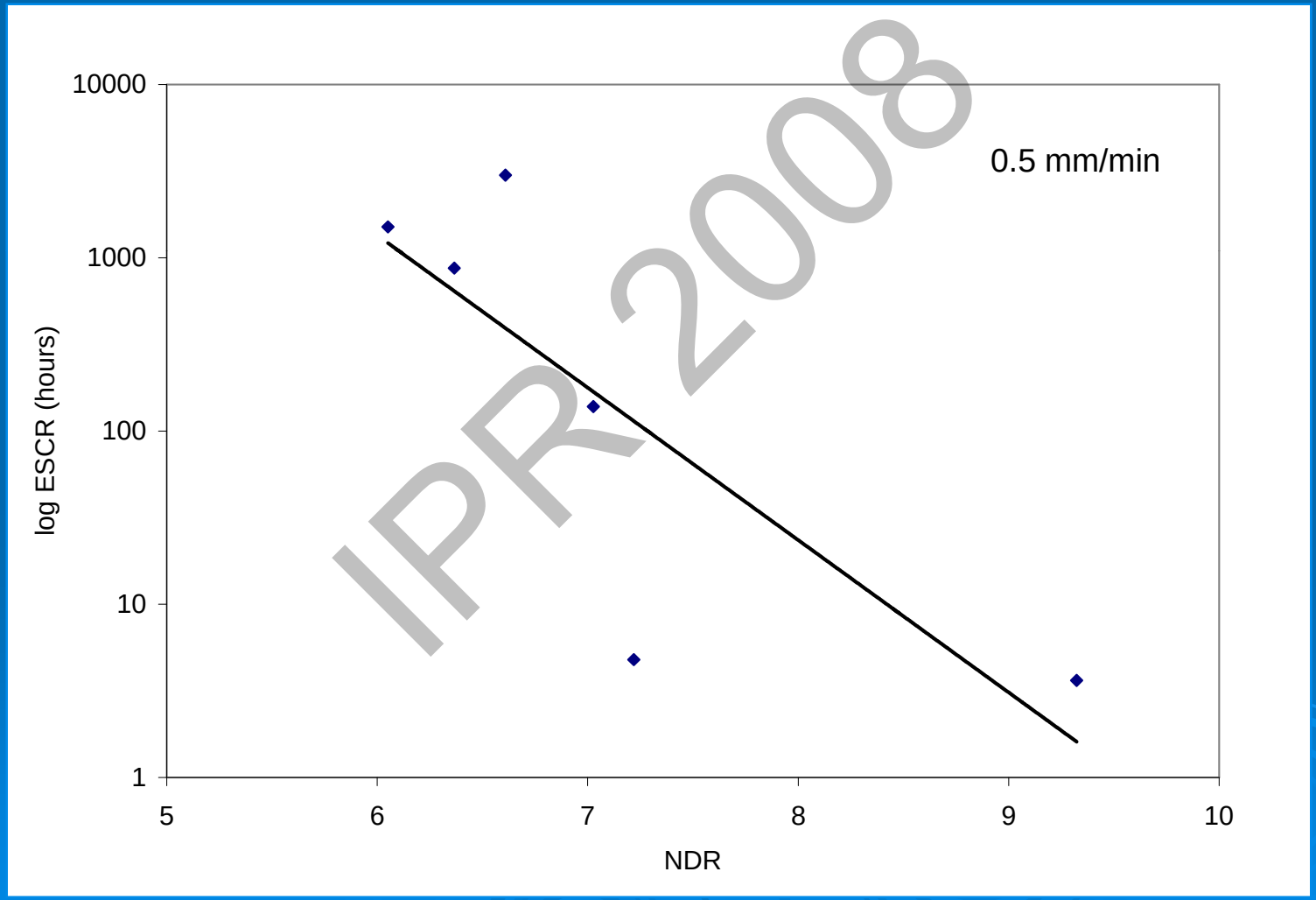


NRD – Natural Drawing Ratio

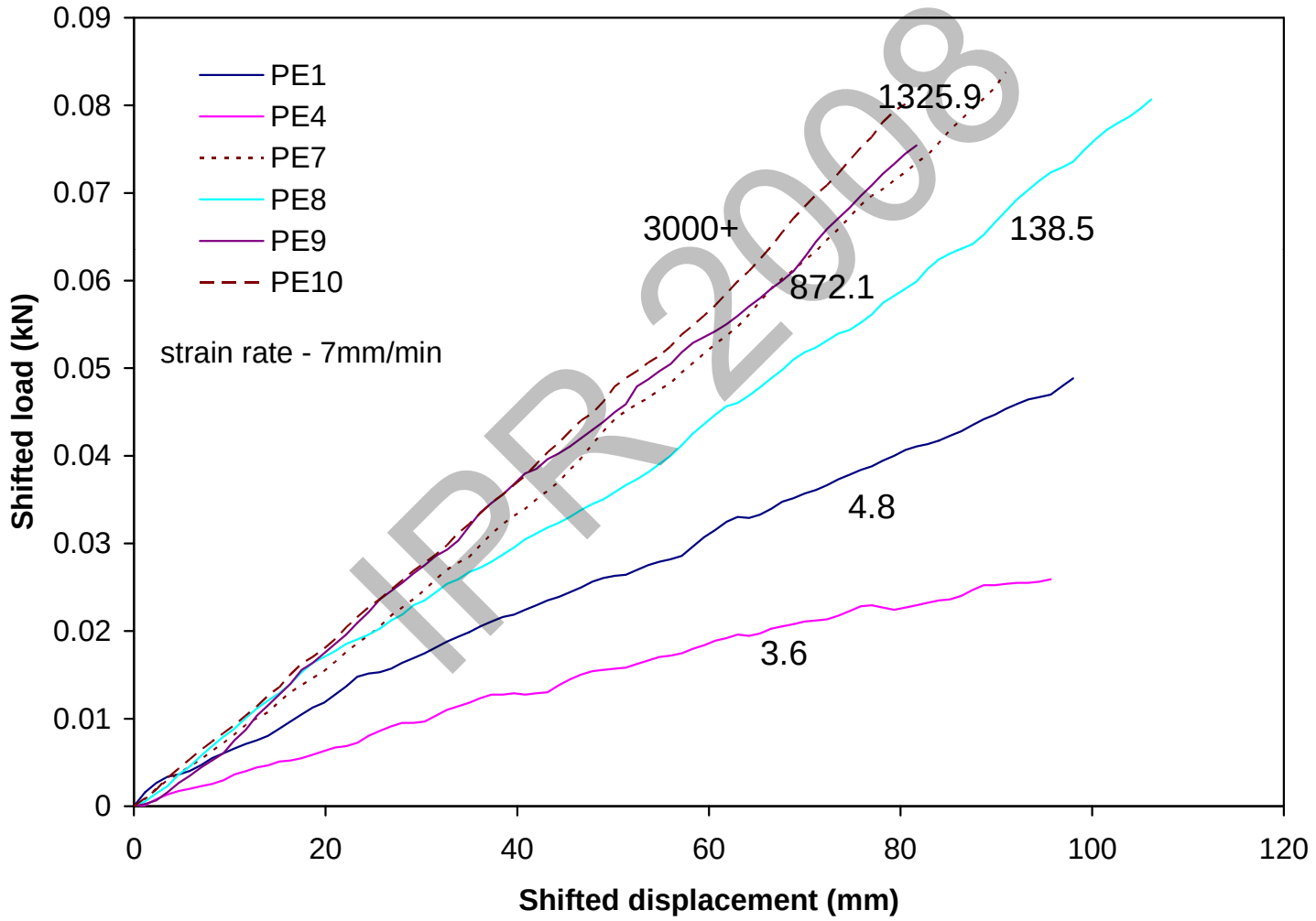
$$NRD = \frac{sample\ displacement\ at\ onset\ of\ \ strain\ hardening}{initial\ \ sample\ length}$$



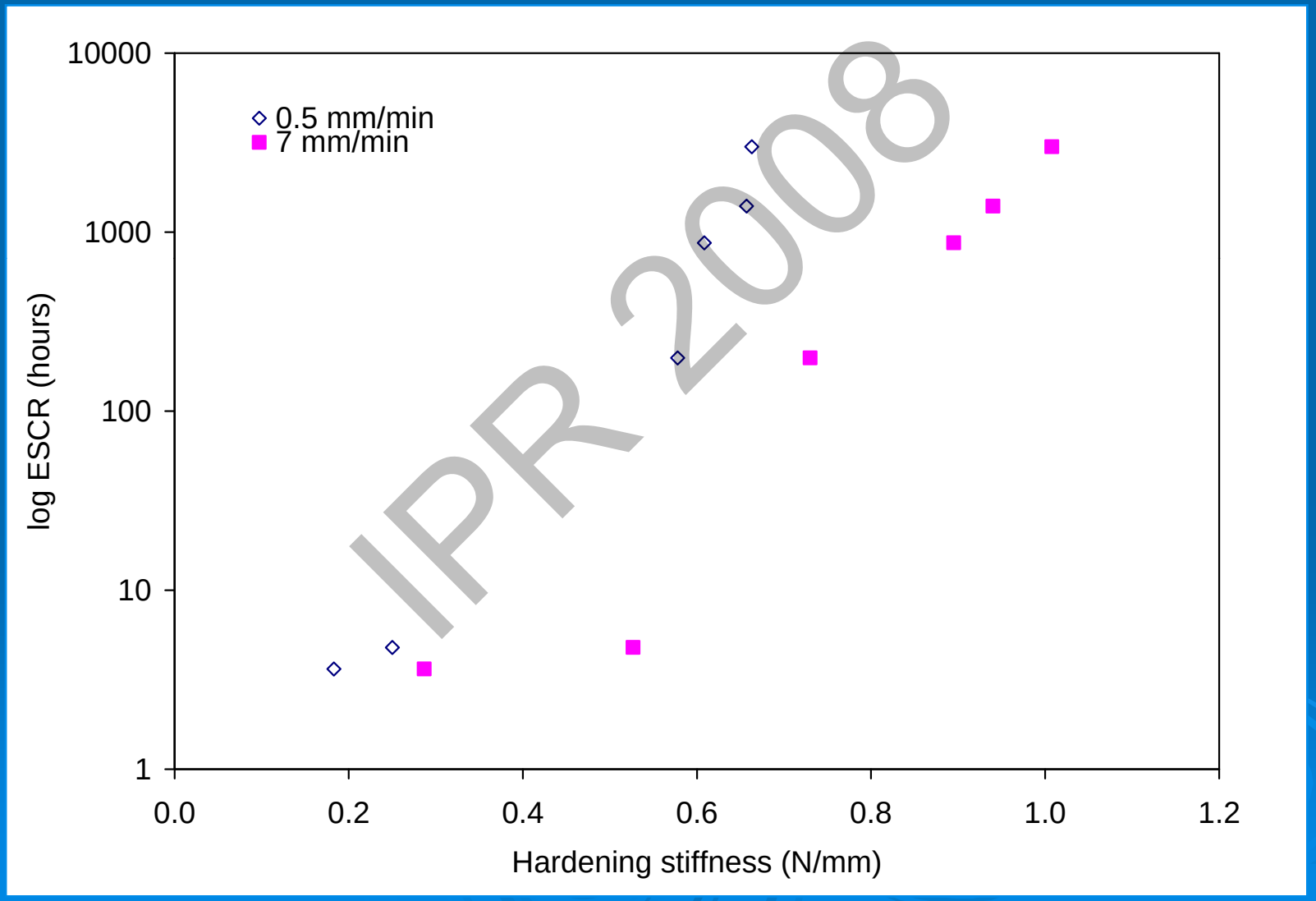
Natural Drawing Ratio



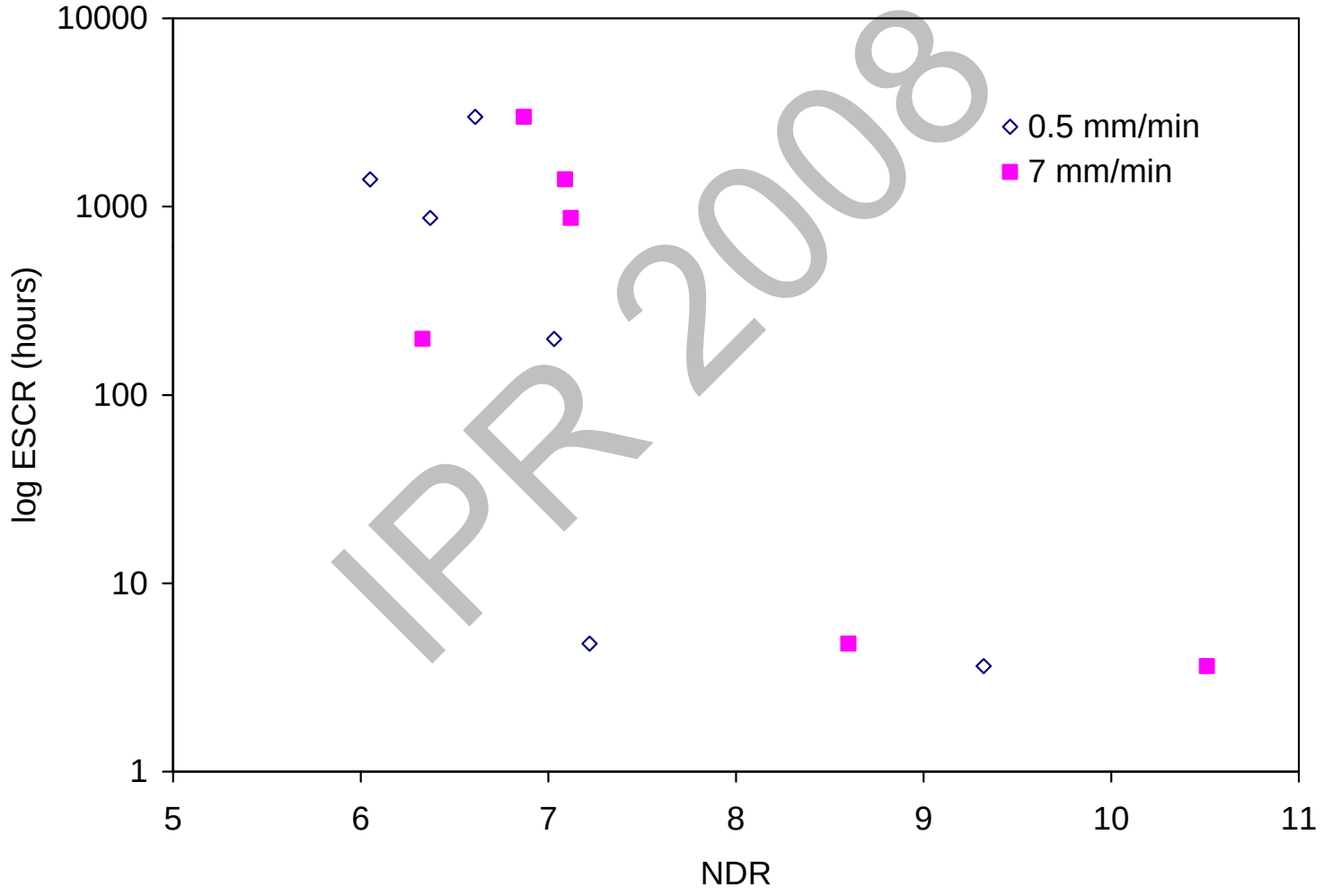
Strain Rate Effect



Strain Rate Effect: Stiffness



Strain Rate Effect: NDR



Test Method Comparison

Tensile strain hardening	•Short test time •Easy test method •Average coefficient of variation 0.05
NCLT	•Long test duration •More test variables •Average coefficient of variation 0.20

Concluding Remarks

- Strain hardening stiffness allows clear ranking of resins for ESCR
- NDR strain-rate independent indication of ESCR trend
- Strain hardening test has better reproducibility than NCLT
- Potential to replace NCLT as ESCR test method (discussion with industry in progress)

Acknowledgements

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