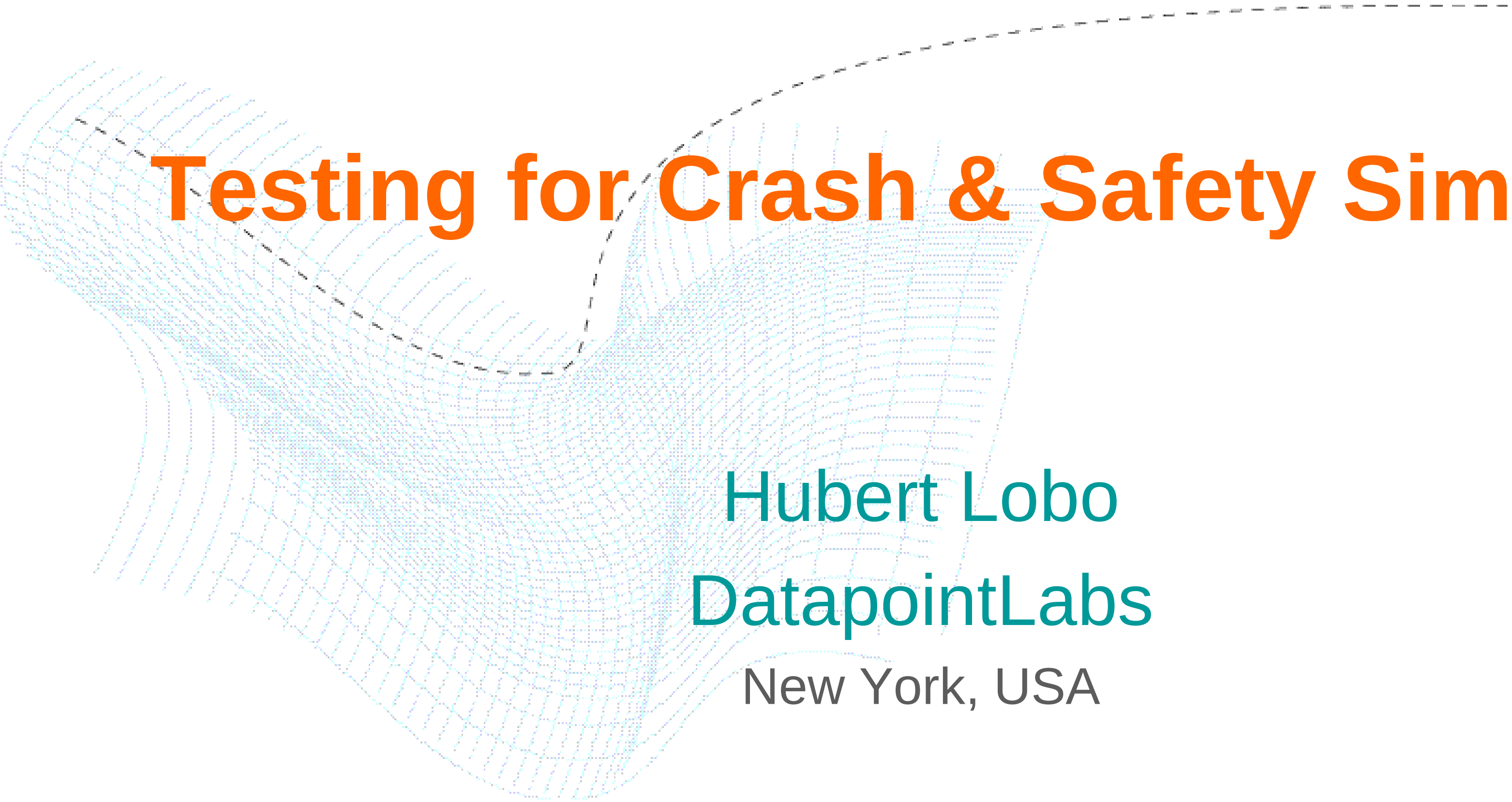
CAHRS Workshop



Testing for Crash & Safety Simulation

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DatapointLabs

New York, USA

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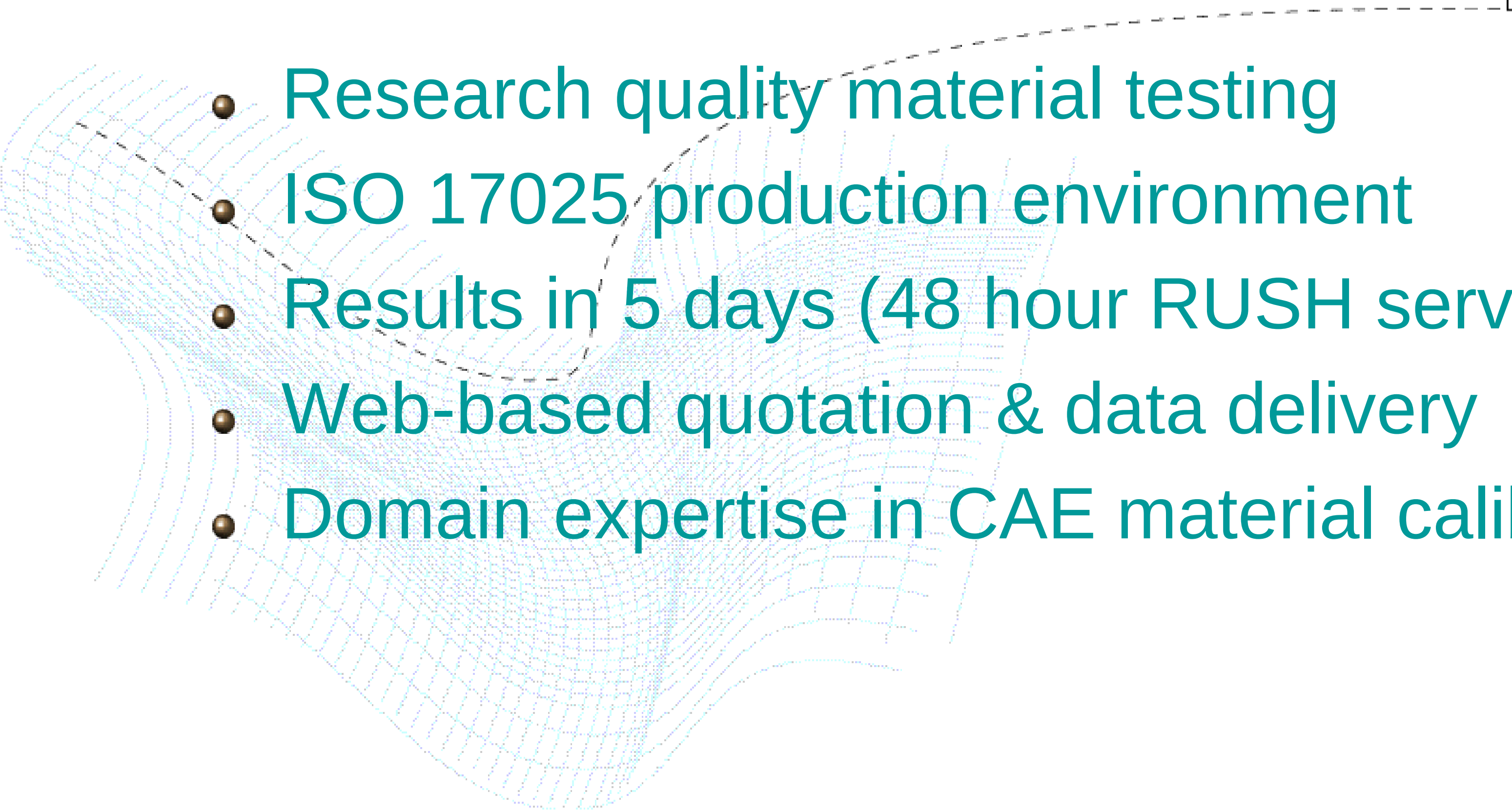
DatapointLabs

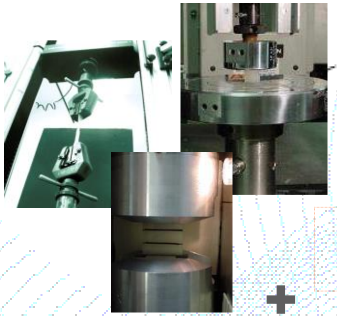
EST 1995
ISO
17025
Quality



- Research quality material testing
- ISO 17025 production environment
- Results in 5 days (48 hour RUSH service)
- Web-based quotation & data delivery
- Domain expertise in CAE material calibration

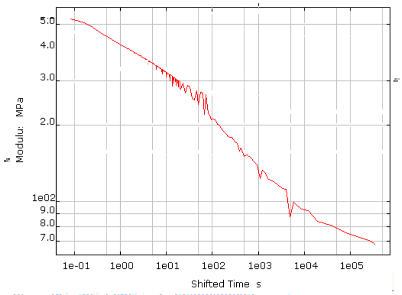
expert material testing

materials

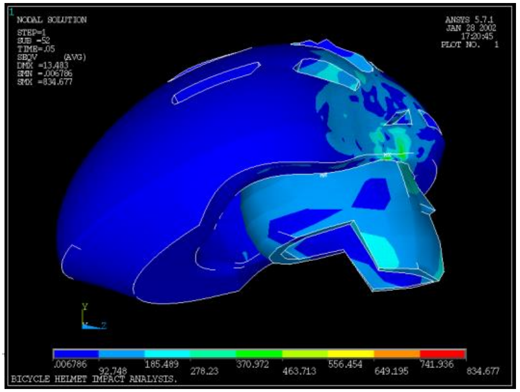


testing

+



data conversion



Your CAE

- *TestPaks*® = Materials testing + CAE material parameter conversion
  - metal, plastic, foam, rubber, composites…
  - over 20 CAE software codes

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Topics

- A test philosophy for representing rate dependency of materials
- Experimental technique including sampling and specimen geometries
- Assessment of crash material data quality, expected trends & validation
- Specific comments for unfilled and fiber-filled polymers, foams, rubber and metals.

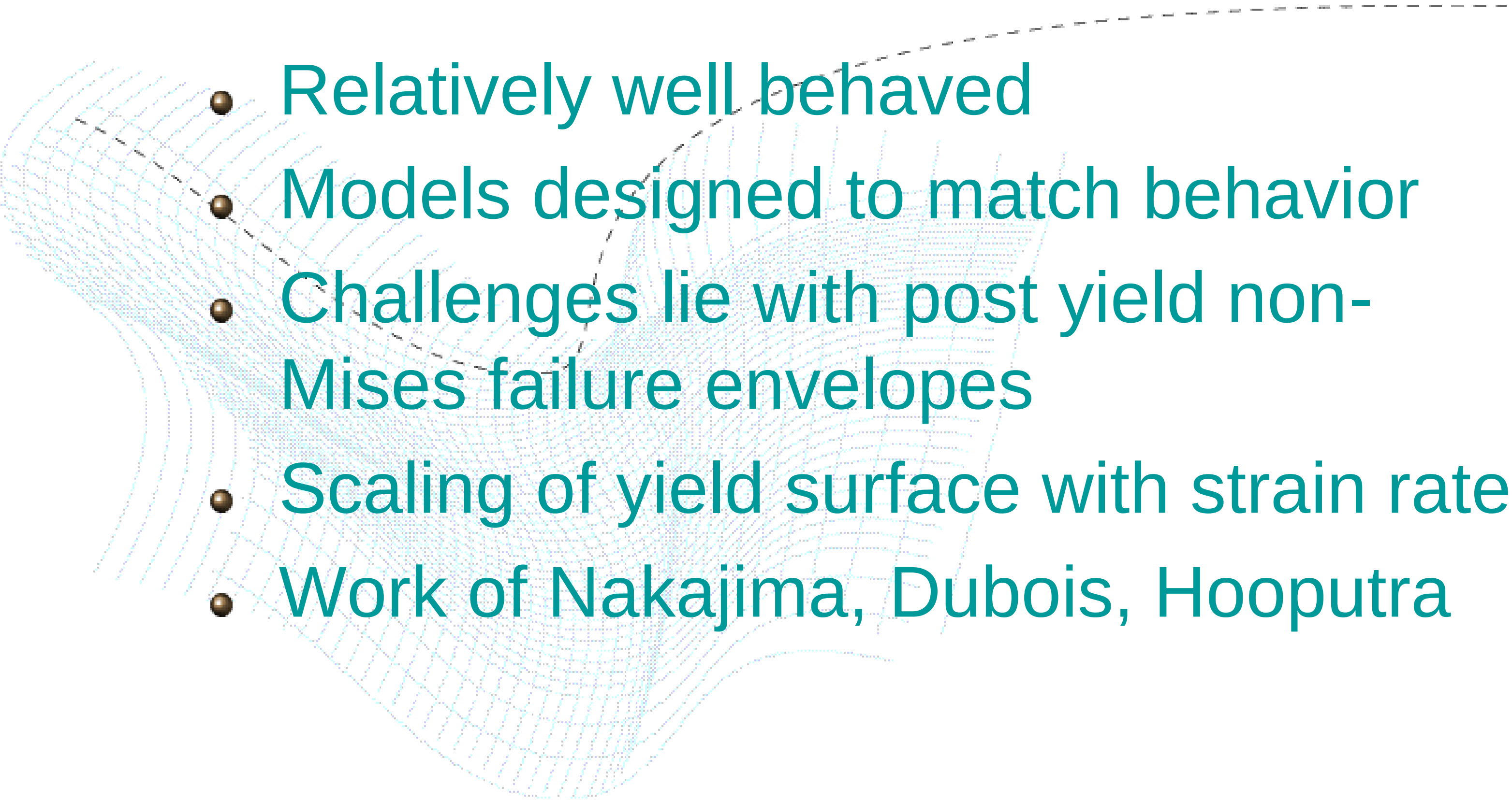
Getting pertinent properties

- Importance of measuring the right property
- Artifact free data
  - Properly designed experiments
  - eg. not using crosshead displacement to calculate strain
- Traceable data (ISO 17025)
  - NIST traceable instruments
  - Certified trained technicians

Getting the right samples

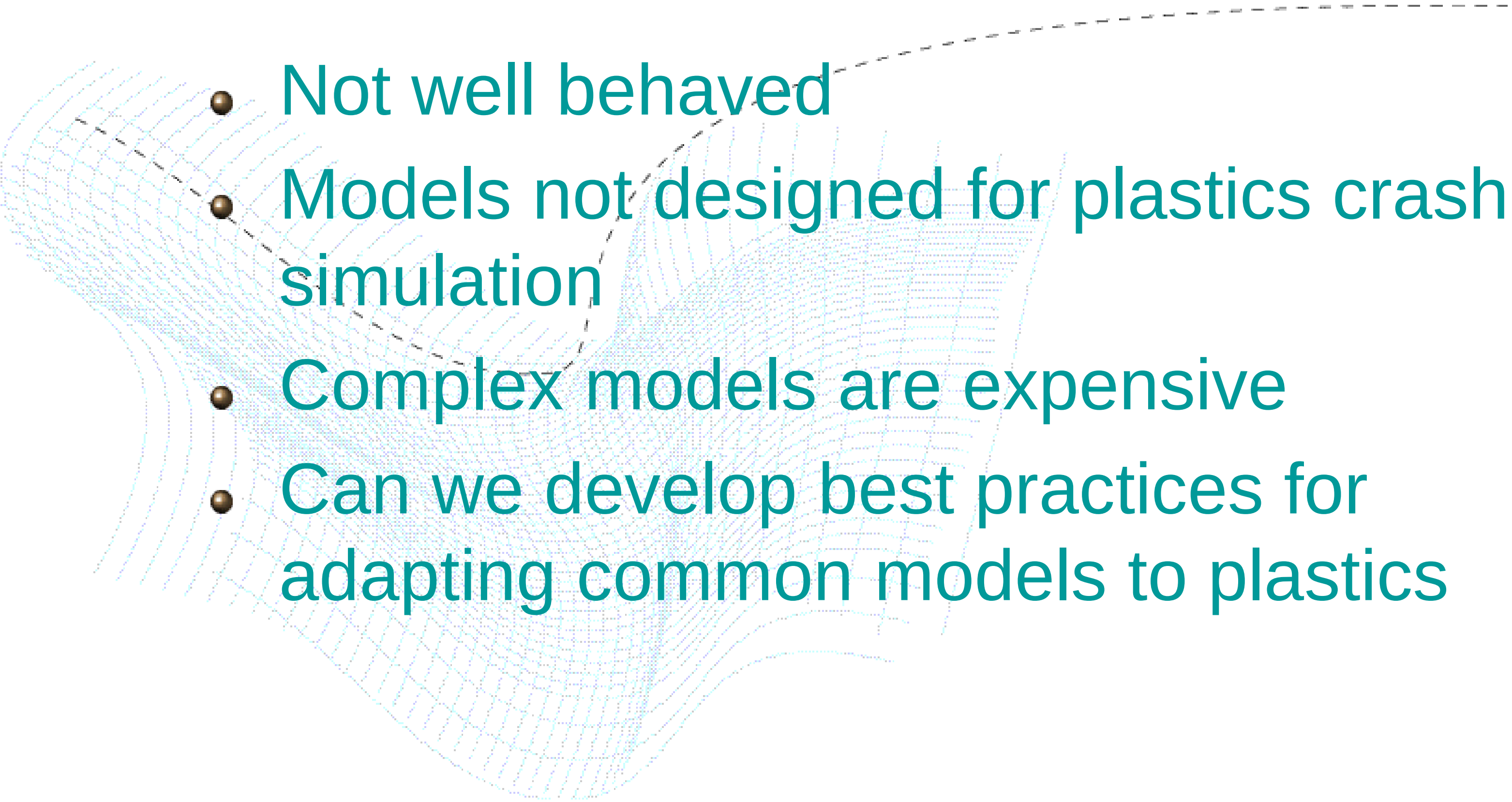
- Spatial variation
  - Properties vary with location
  - Forming, stretching, molding…
- Environmental variation
  - Ageing and conditioning
- Process variation
  - Degradation from processing
  - Recycled materials

Metals



- Relatively well behaved
- Models designed to match behavior
- Challenges lie with post yield non-Mises failure envelopes
- Scaling of yield surface with strain rate
- Work of Nakajima, Dubois, Hooputra

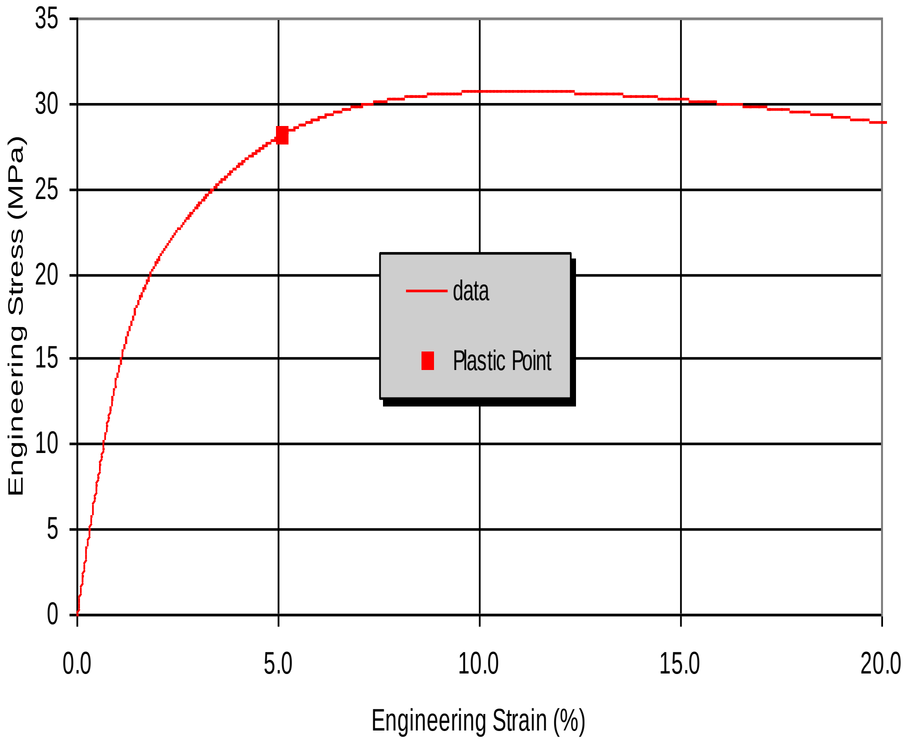
Plastics



- Not well behaved
- Models not designed for plastics crash simulation
- Complex models are expensive
- Can we develop best practices for adapting common models to plastics

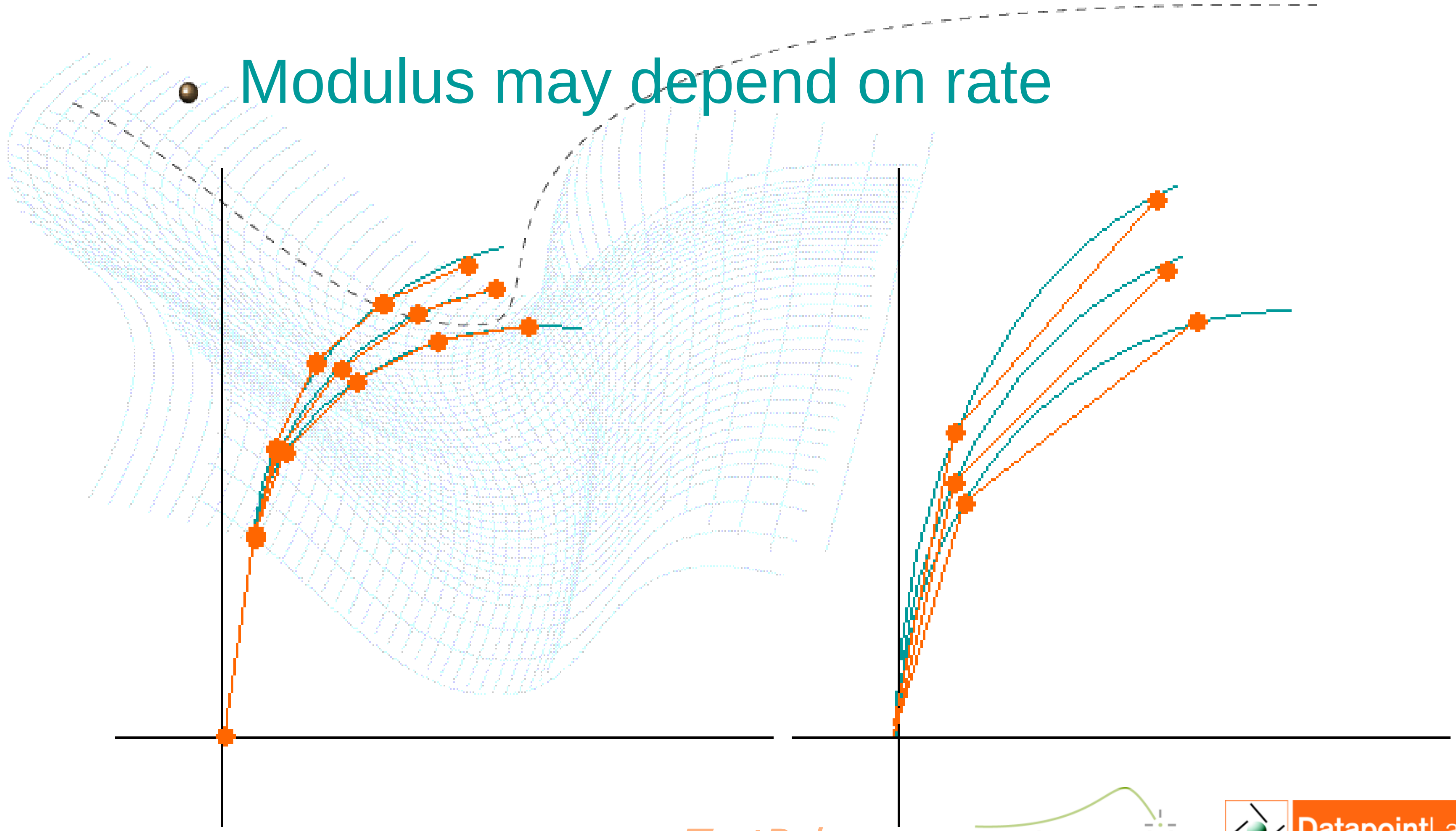
Plastics Behavior - Basics

- Non-linear elasticity
- Elastic limit well below classical yield point
- Significant plastic strains prior to yield
- Post-yield with necking behavior



Plastics Rate Effects

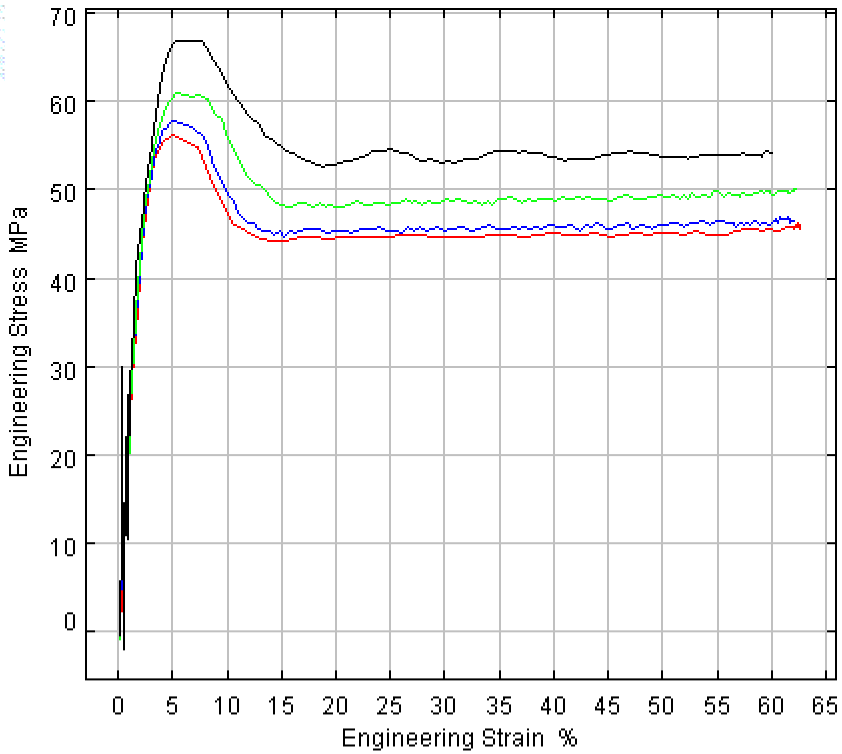
- Modulus may depend on rate



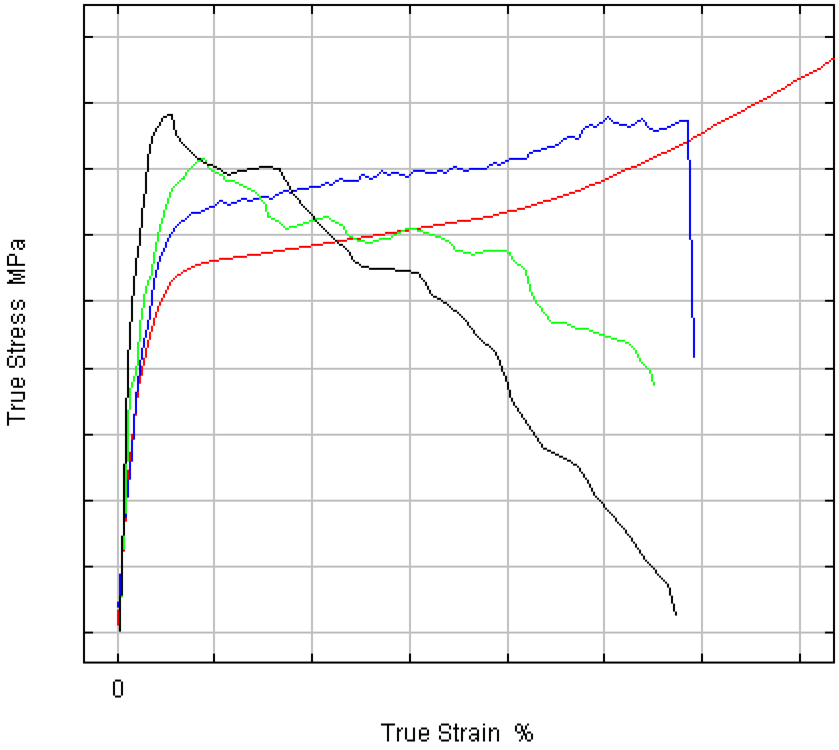
Plastics Rate Effects

- Fail strain may be rate dependent

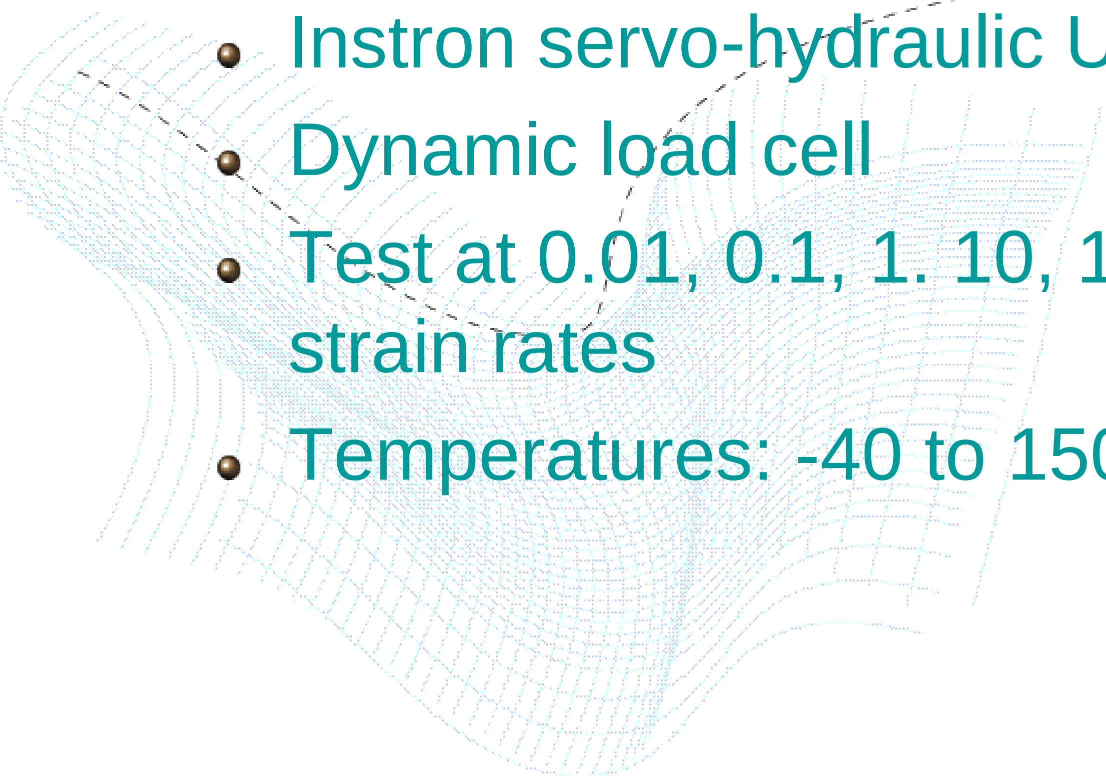
Engineering Tensile Stress-Strain Curves



True Tensile Stress-Strain Curves



Material Testing



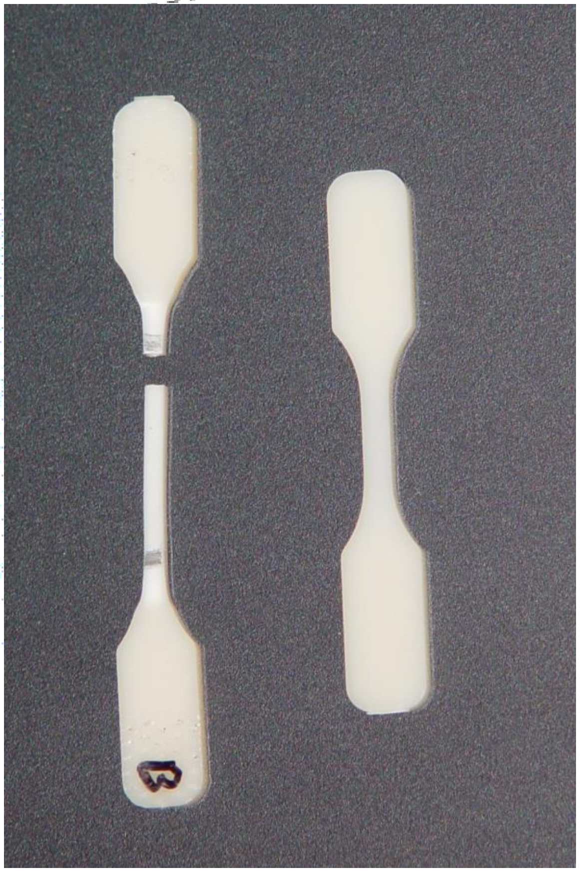
- Instron servo-hydraulic UTM
- Dynamic load cell
- Test at 0.01, 0.1, 1. 10, 100/s strain rates
- Temperatures: -40 to 150C

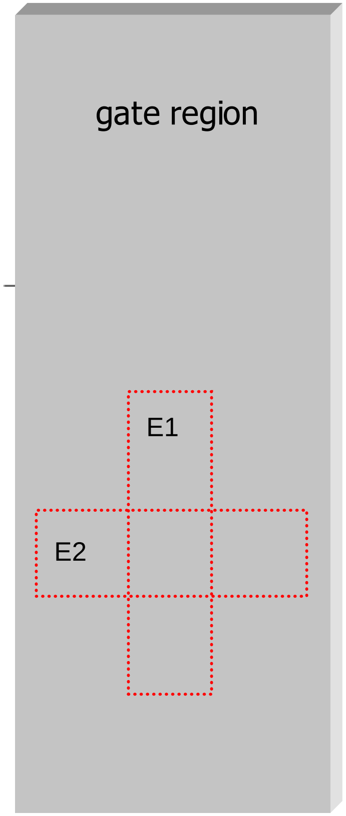
tens_slow.mpg

Tens.mpg

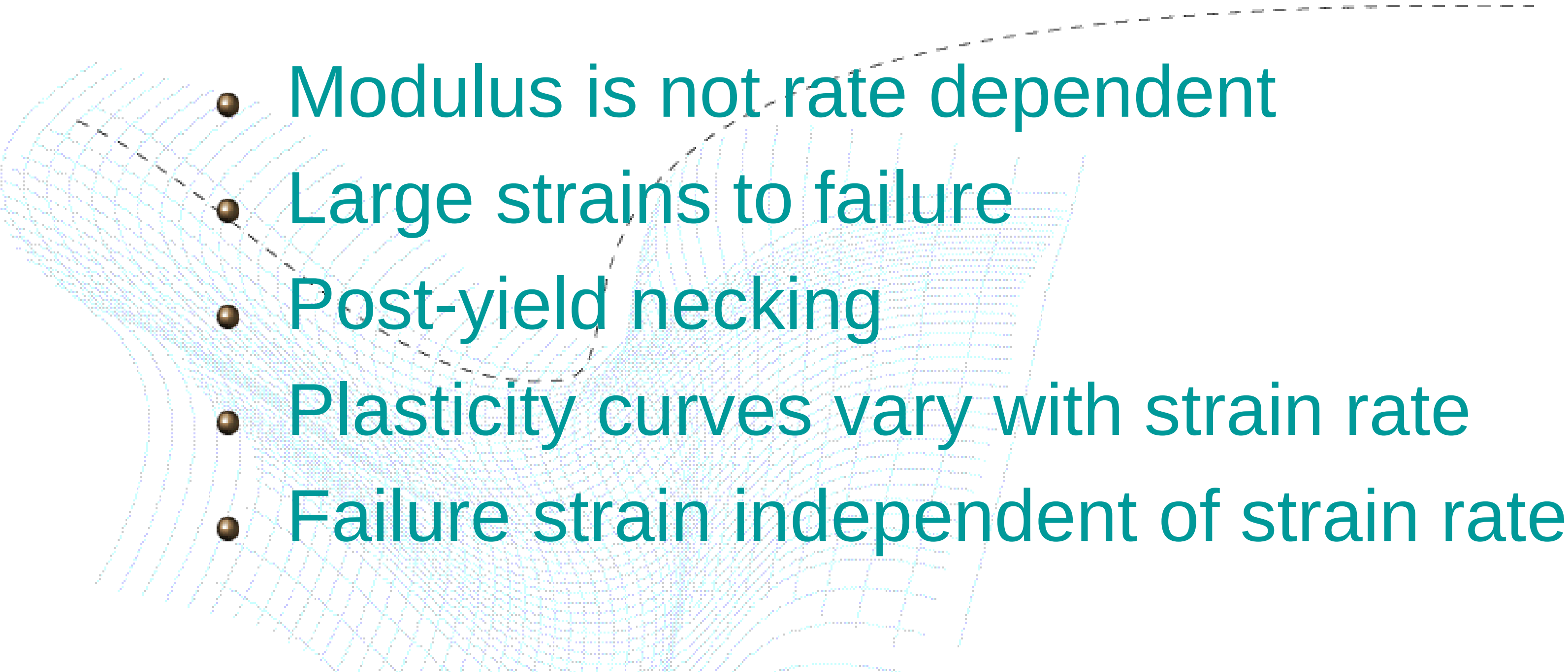
Test Specimens

- ASTM D638Type V
- Preparation
  - CNC from plaque
  - CNC from part
  - Molded
- Variability
  - processing
  - orientation
  - thickness





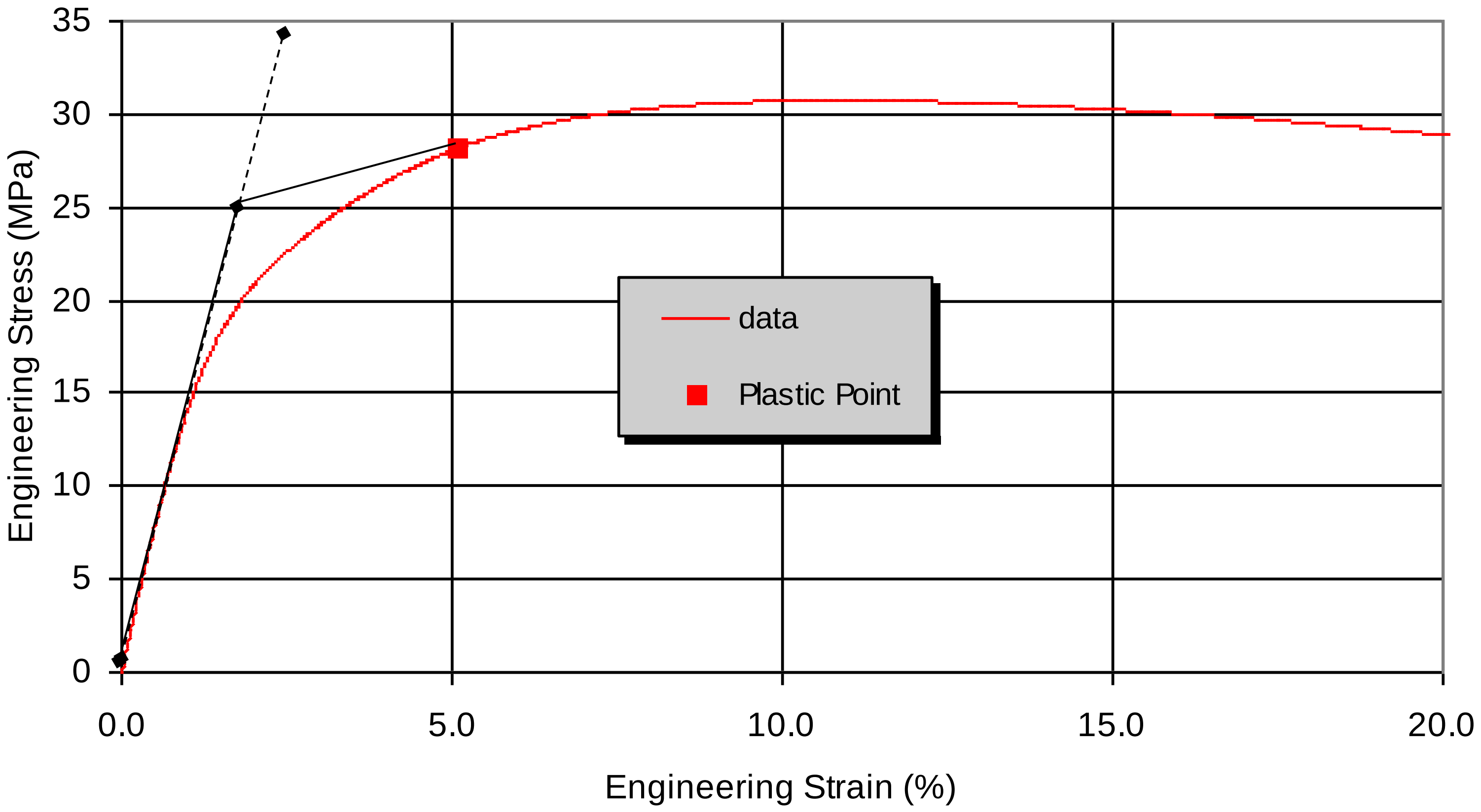
Modeling simple ductile plastics



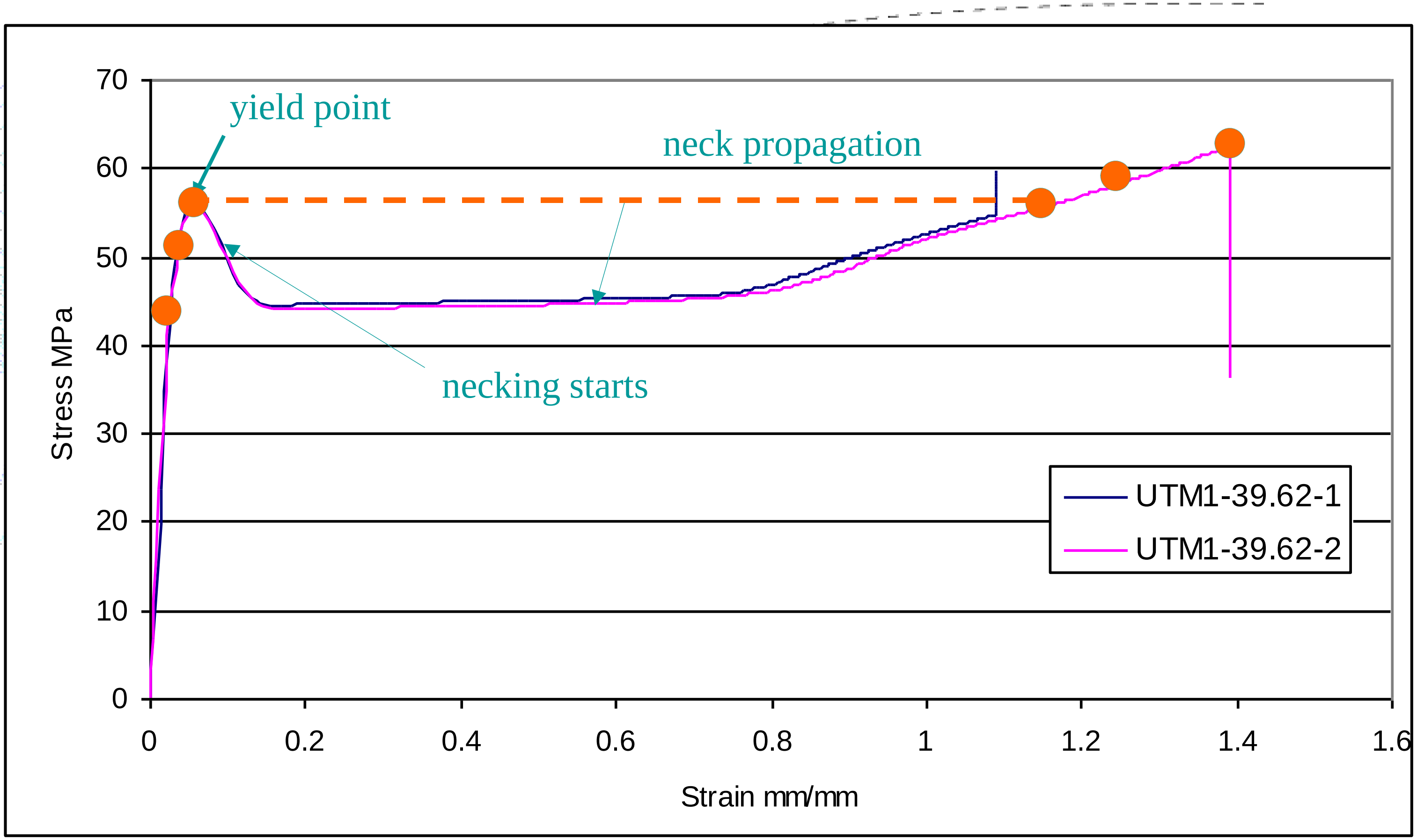
- Modulus is not rate dependent
- Large strains to failure
- Post-yield necking
- Plasticity curves vary with strain rate
- Failure strain independent of strain rate

- LS-DYNA, ANSYS, ABAQUS, PAMCRASH

Choosing EMOD



Post-yield with necking (Deihl)



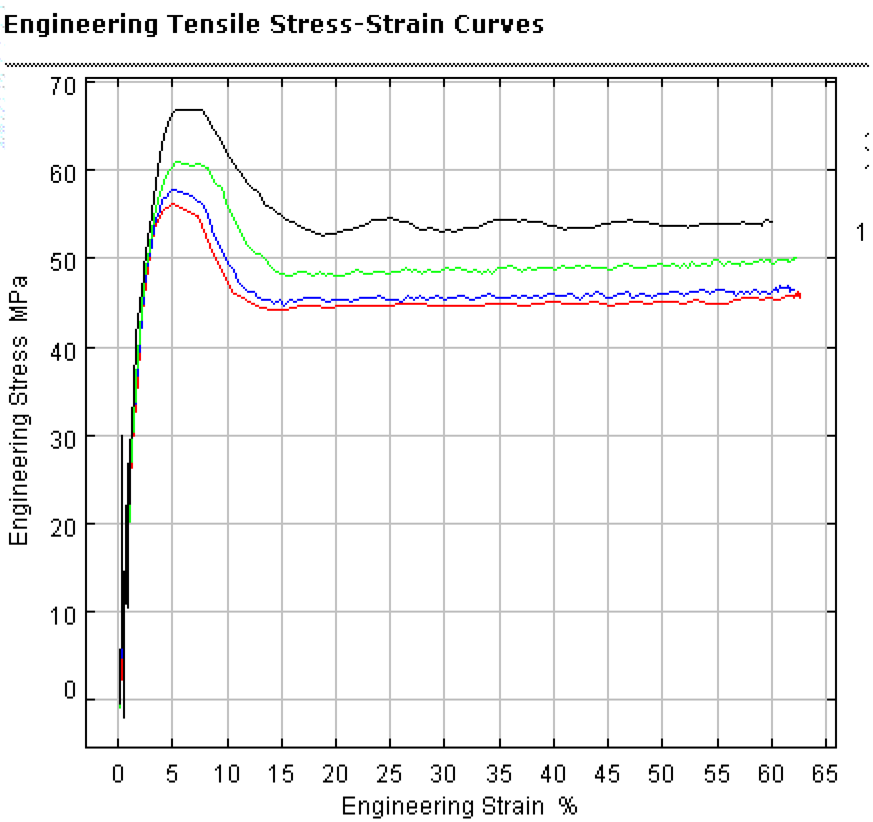
yield point

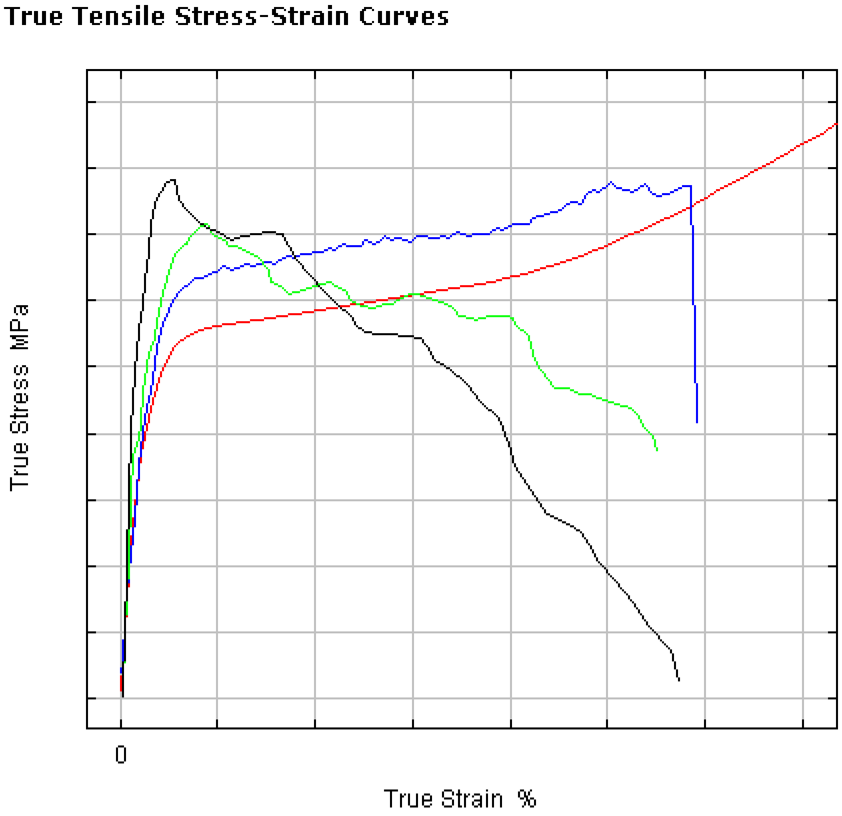
neck propagation

necking starts

Fail Limitations

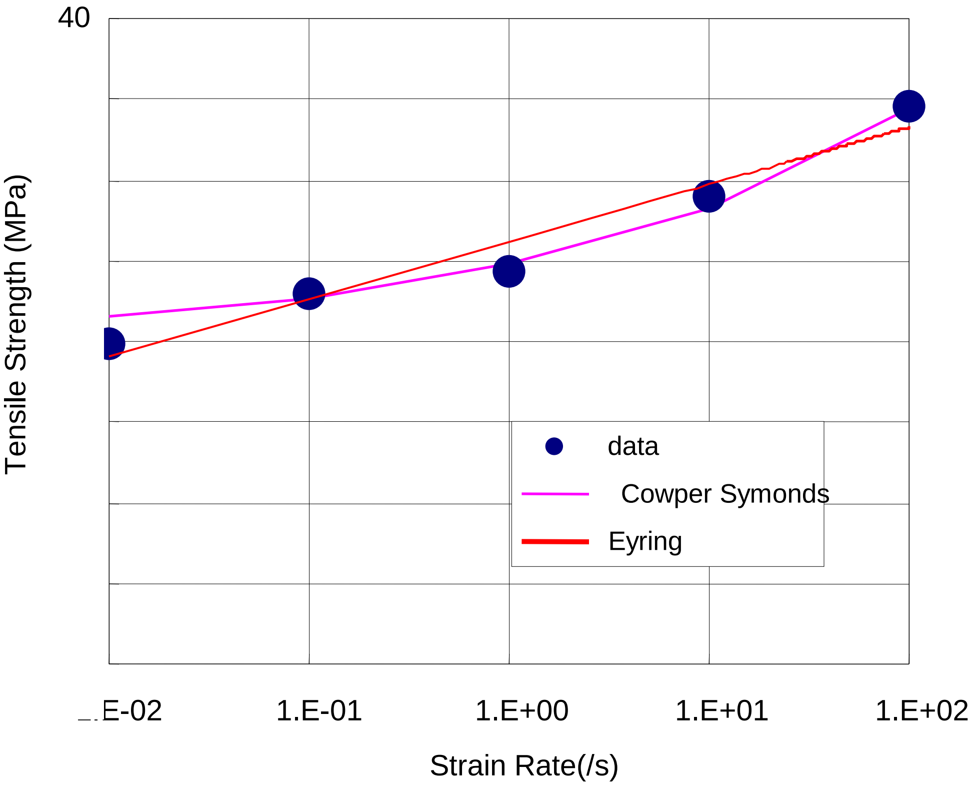
- When FAIL f(strain rate)





Modeling Rate Dependency

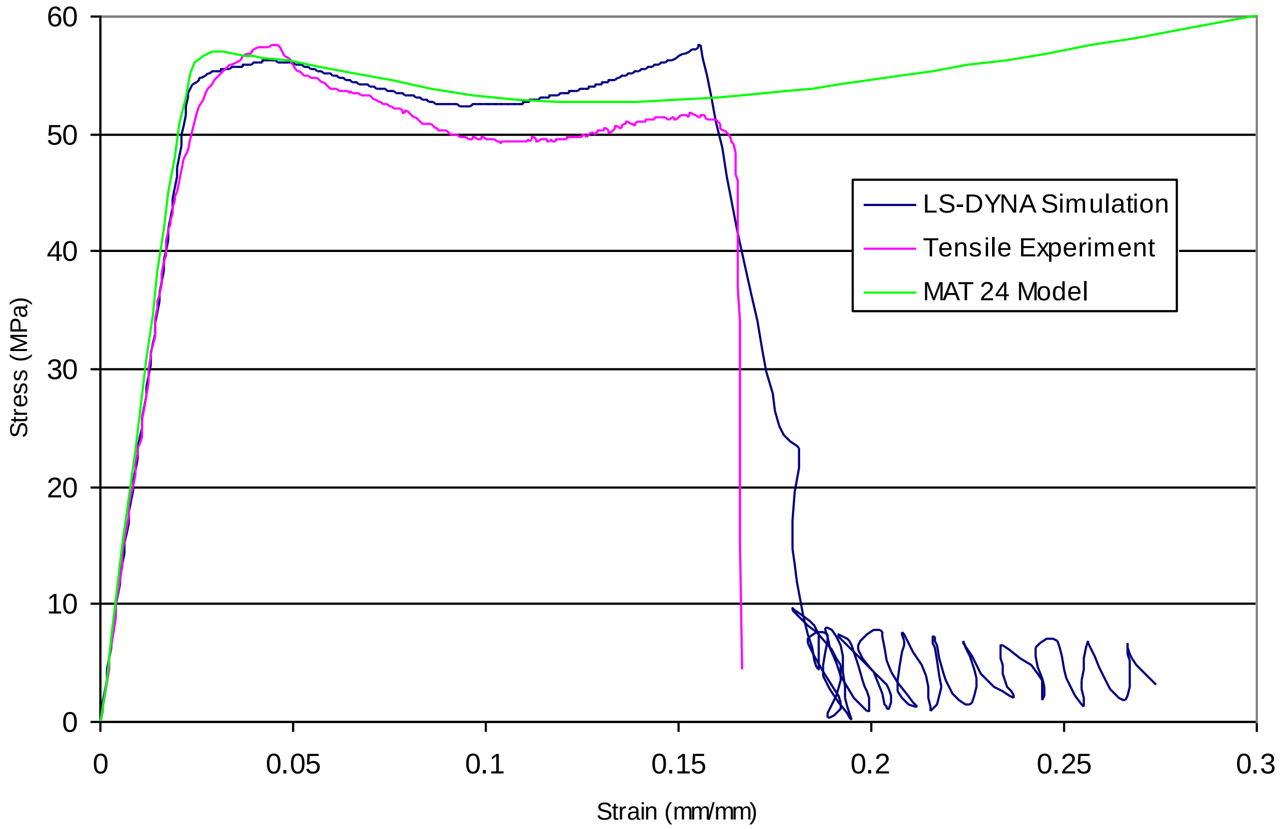
- Cowper Symonds
  - Does not correlate well with plastics rate dependency
- LCSR
  - Capture model independent behavior



Eyring Model

- Eyring Model
  - Yield stress v. log strain rate is linear
  - Best form for plastics
- Fit yield stress v. log strain rate data to Eyring equation
- Can submit to LSDYNA MAT24 as table using LCSR

MAT24 validation



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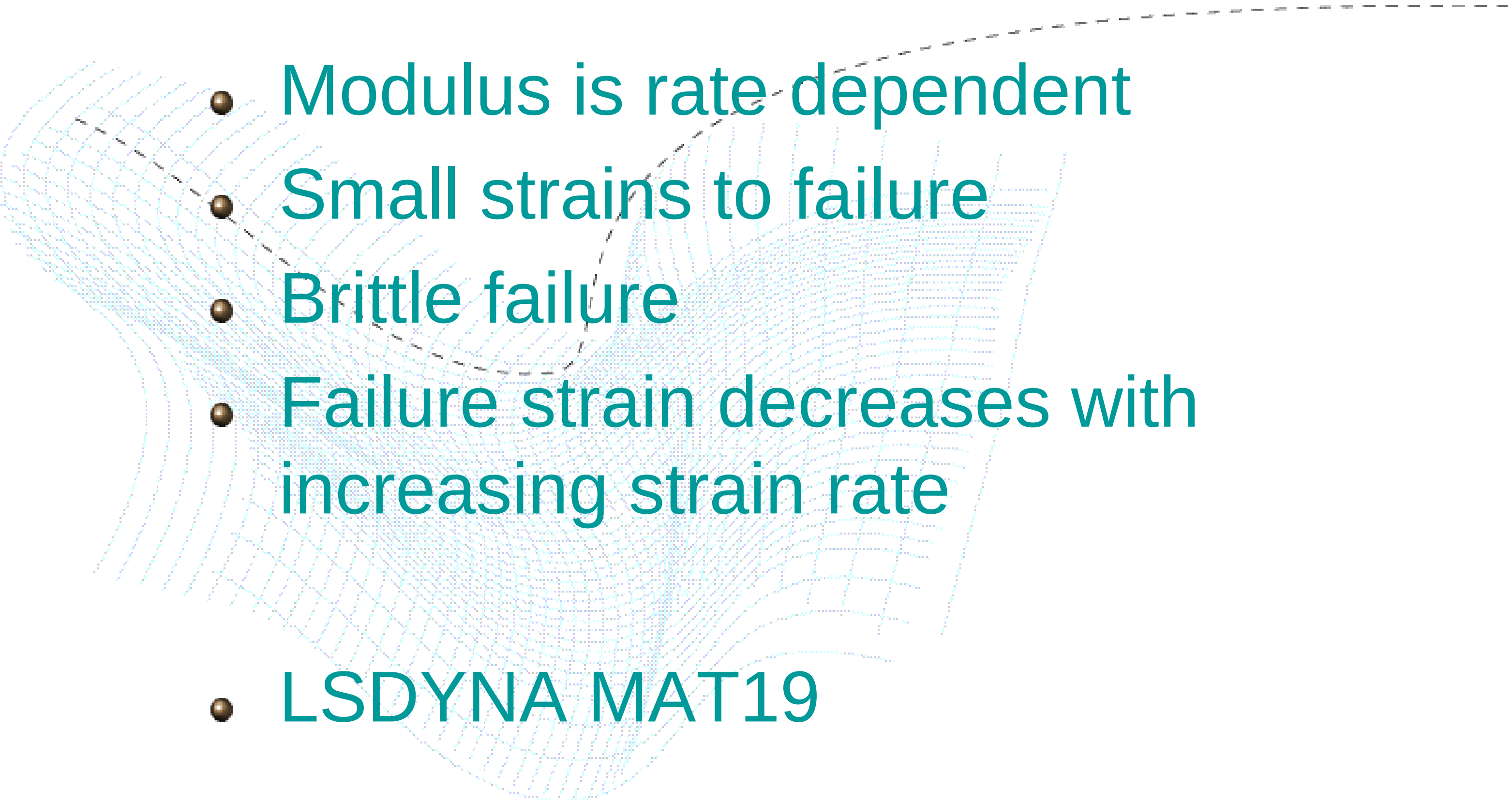
Brittle plastics

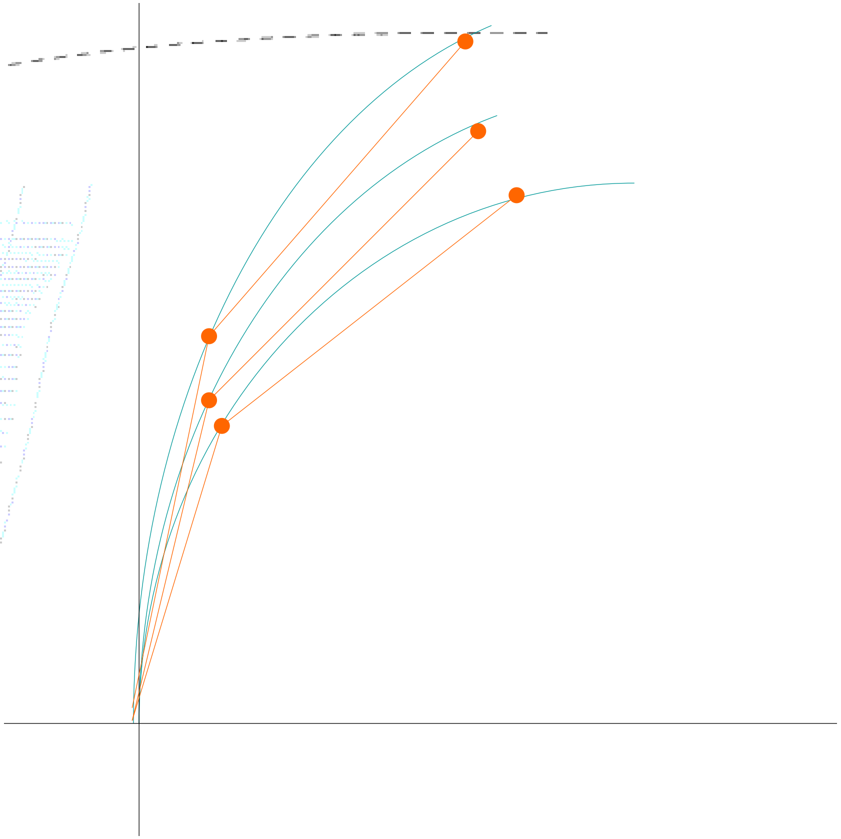


- Modulus is rate dependent
- Small strains to failure
- Brittle failure
- Failure strain decreases with increasing strain rate

- LSDYNA MAT19

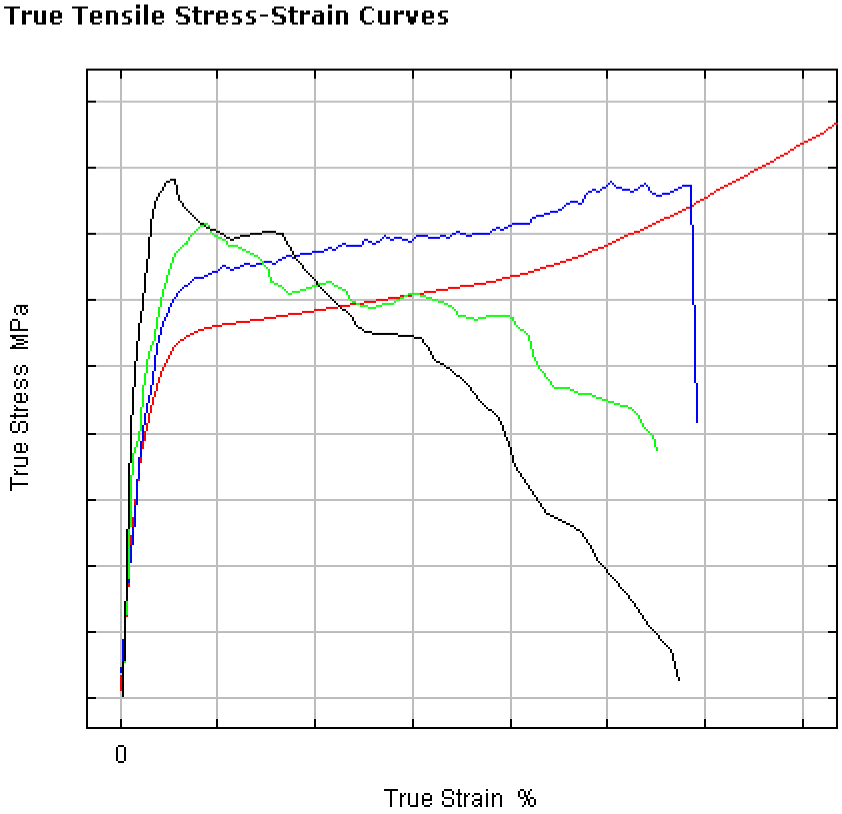
Methodology for MAT 19

- Determine elastic limit at quasi-static strain rate
- Use elastic limit for von-Mises yield
- Define failure
  - failure stress v. strain rate table

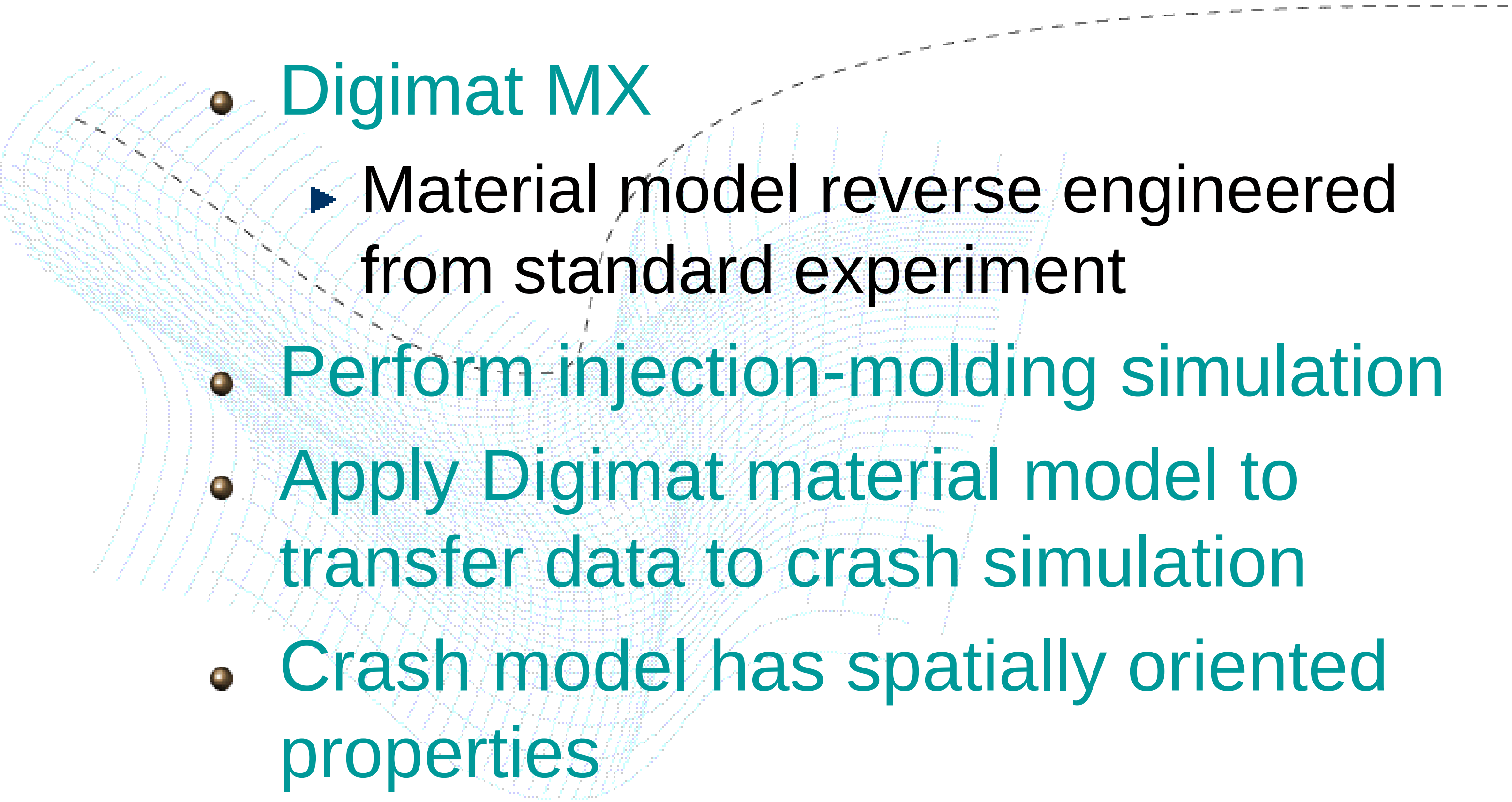


Ductile-brittle transitions

- Non-linear behavior
- Failure depends on strain rate
- Models
  - LS-DYNA MAT89
  - PAMCRASH 103
  - Abaqus *ELASTIC *PLASTIC,Rate

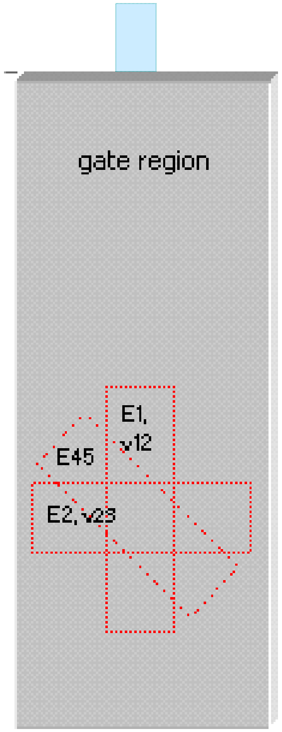


Fiber Filled Plastics



- Digimat MX
  - Material model reverse engineered from standard experiment
- Perform injection-molding simulation
- Apply Digimat material model to transfer data to crash simulation
- Crash model has spatially oriented properties

Basic Digimat *TestPak* Protocol



- Mold 100X300X3.16mm plaques
    - Edge gated on 100 mm end
    - Long flow length
    - Fully developed flow
    - Highly fiber orientation
- Cut test specimens by CNC
- 5 specimens each (0°, 90°)
- Obtain true stress-strain data

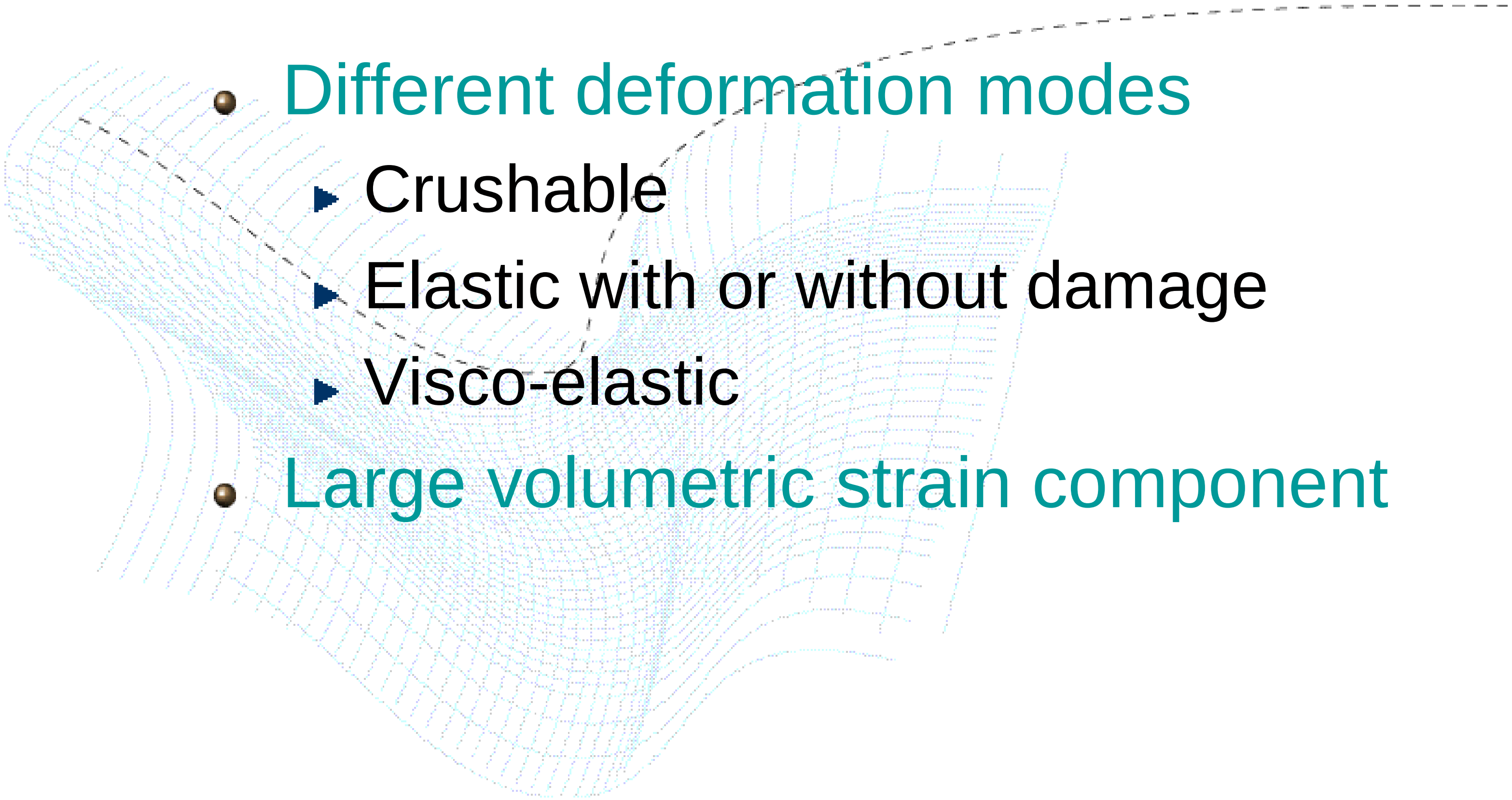
Advanced Models

- MATSAMP (LS-DYNA)
- Standard rate dependent model
- Add non-mises failure envelope
  - Compression
  - Shear
- Add triaxiality
  - Post yield transverse strain
- Add unloading

Pros and Cons

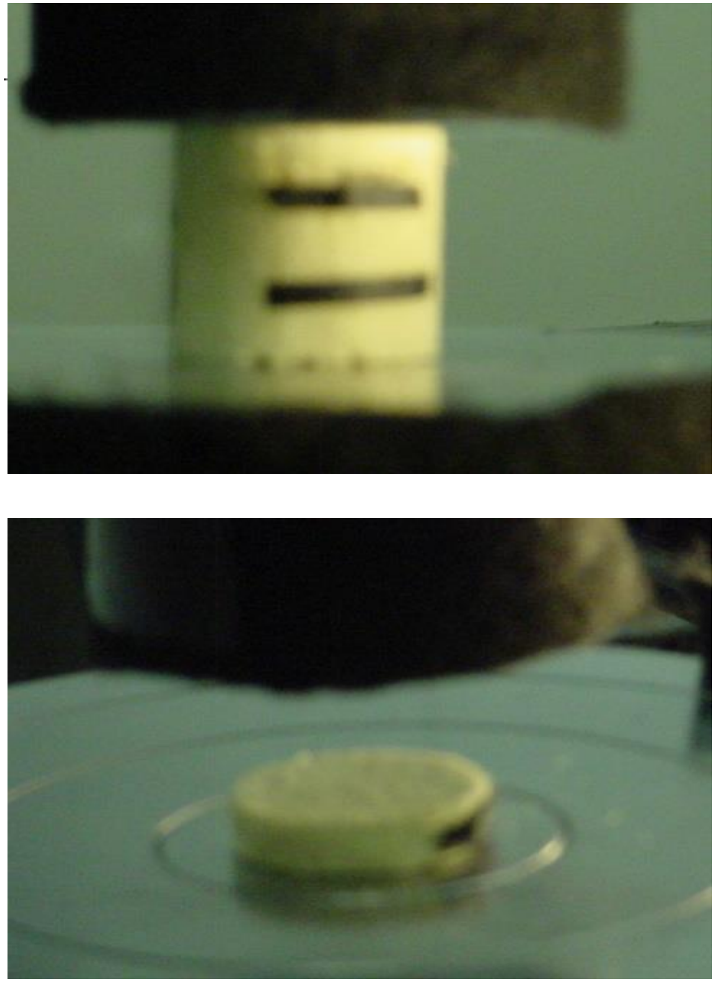
- Better failure envelope modeling
- Greater cost
- More complex model
- Greater simulation accuracy in difficult cases
- Cost-benefit not certain for general use

Foams



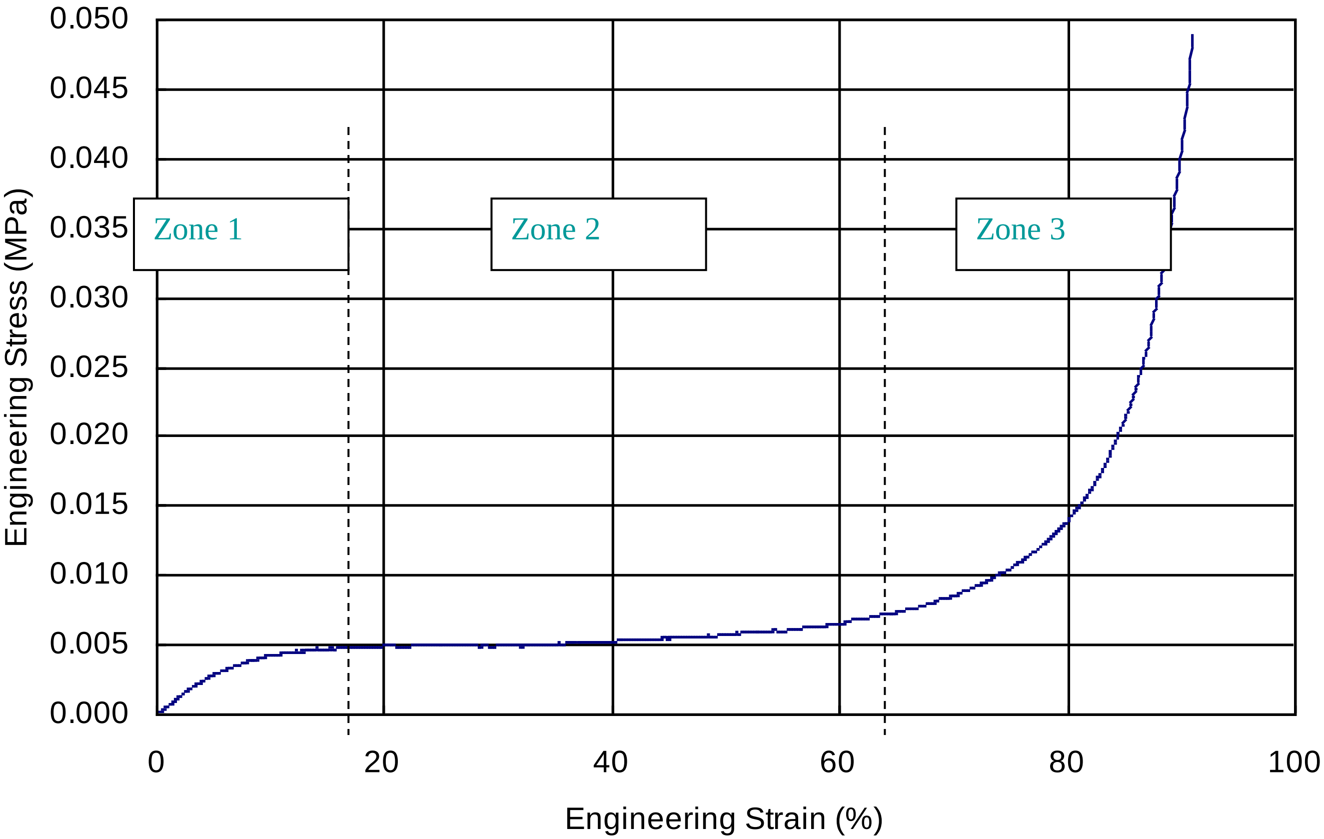
- Different deformation modes
  - Crushable
  - Elastic with or without damage
  - Visco-elastic
- Large volumetric strain component

Effect of Poisson’s Ratio = 0



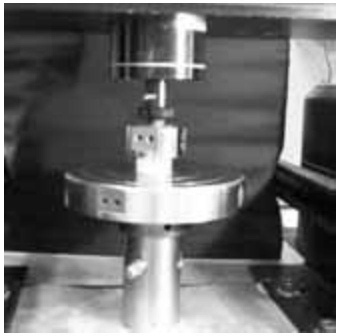
- Material compacts by eliminating air
- No lateral deformation
- Poisson’s Ratio -> 0
- Axial strain ≅ volumetric strain
- True for
  - open cell foams
  - crushable foams
- May not be true for
  - closed cell foams
  - elastomeric foams

Typical Stress-Strain Data



Test Strategy

- Compressive stress-strain
  - 5 decades of strain rate
    - .01, .1, 1, 10, 100 /s
  - Temperatures
    - -100 to 150C
- Optional tests
  - Tensile (for cut-off stress)
  - Shear (as required)



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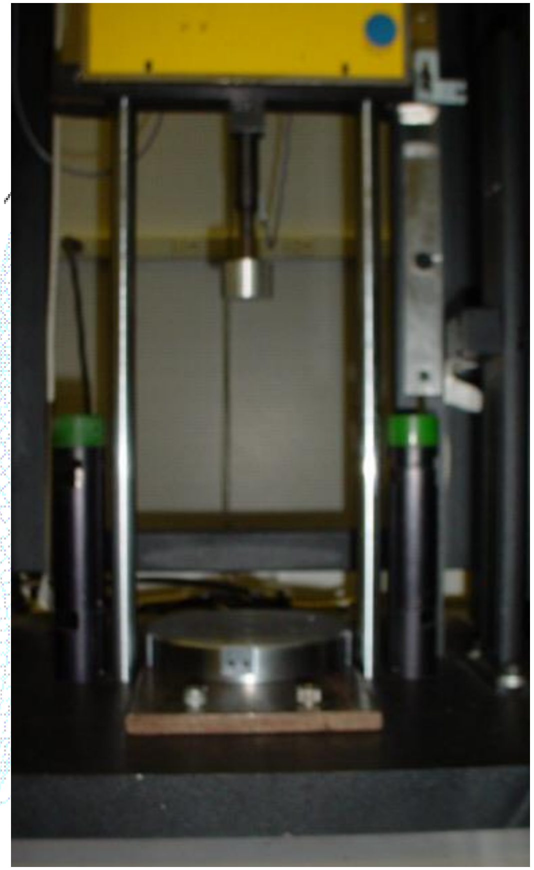
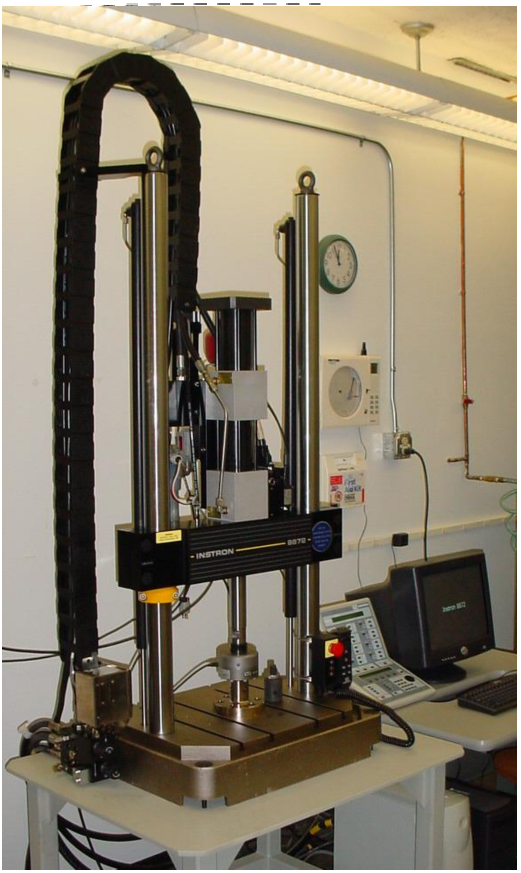
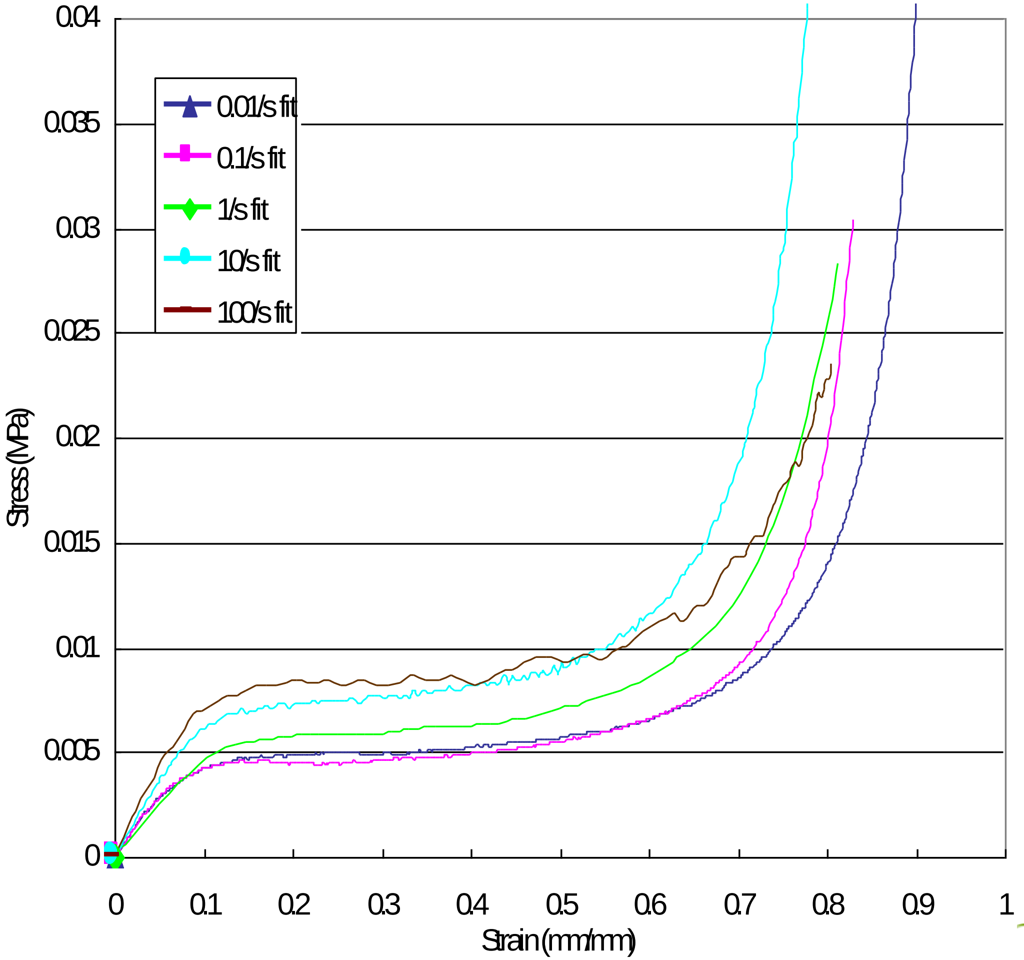
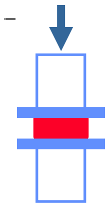
Test Instruments





PU Foam-stress strain





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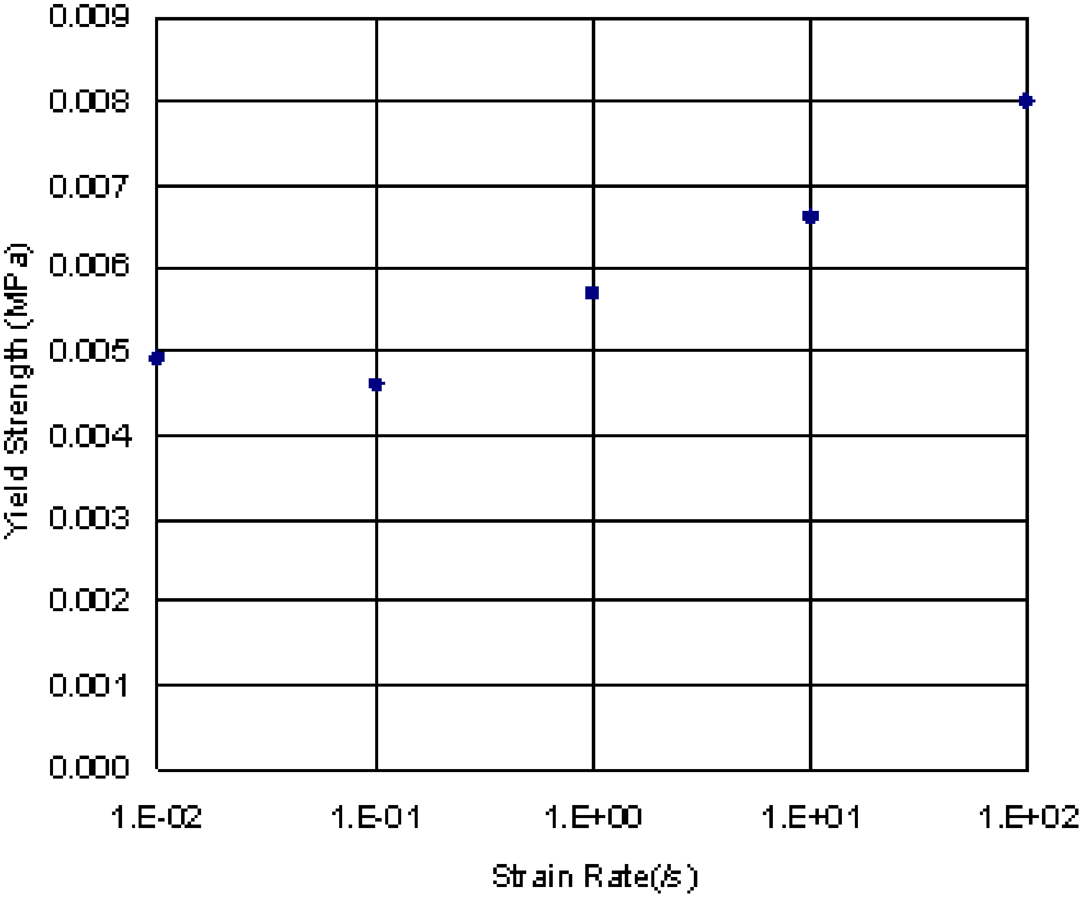
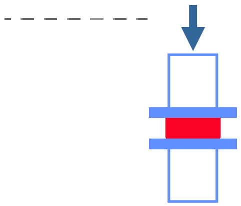
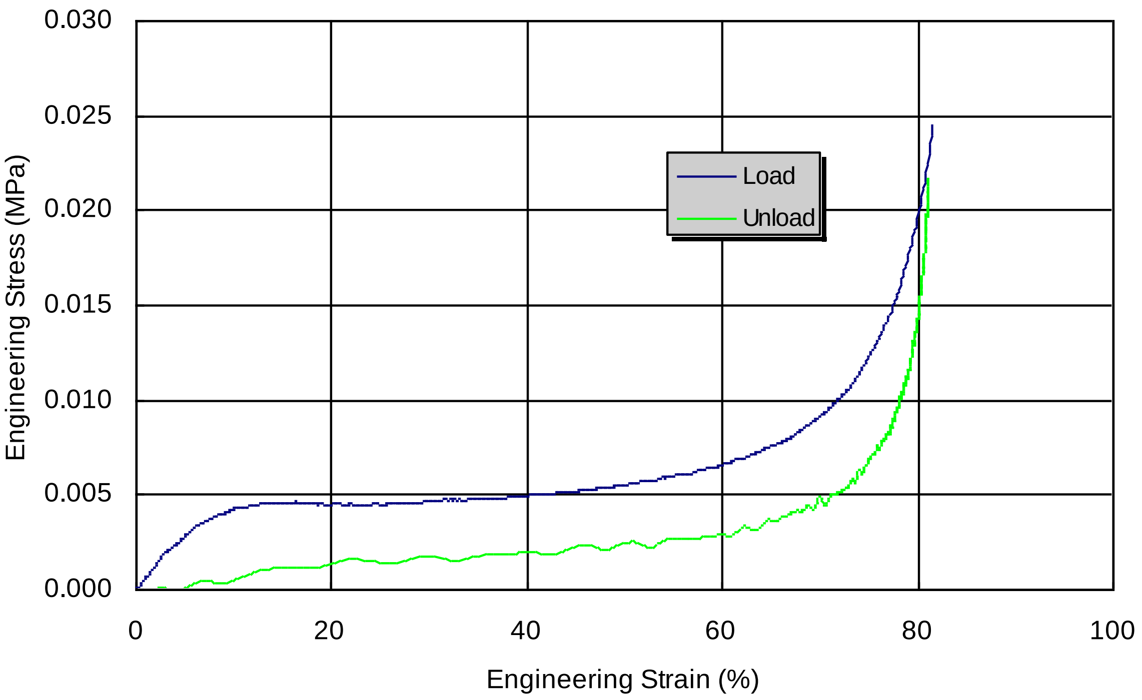
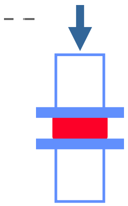
PU Foam- rate effects



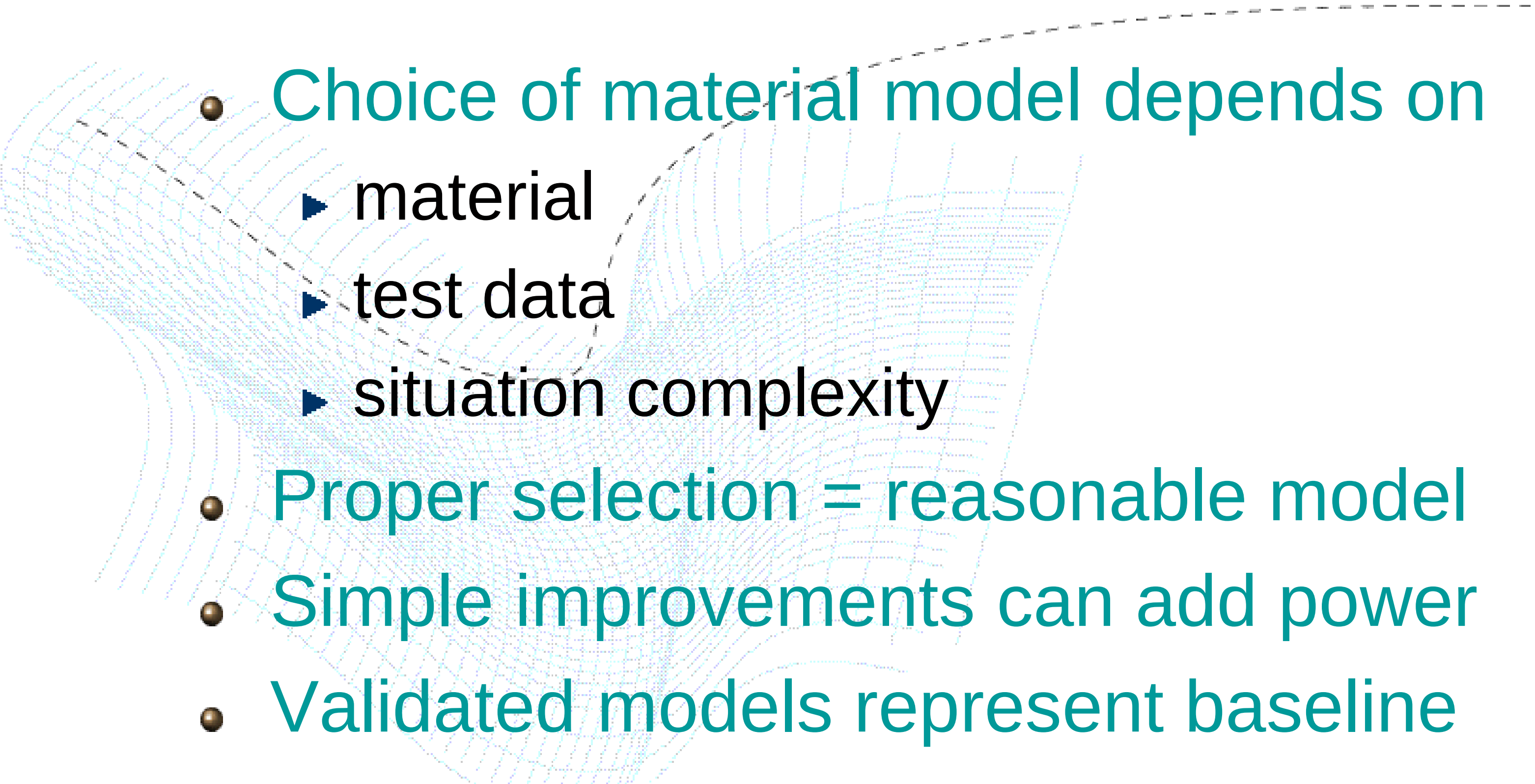


PU Foam recovery

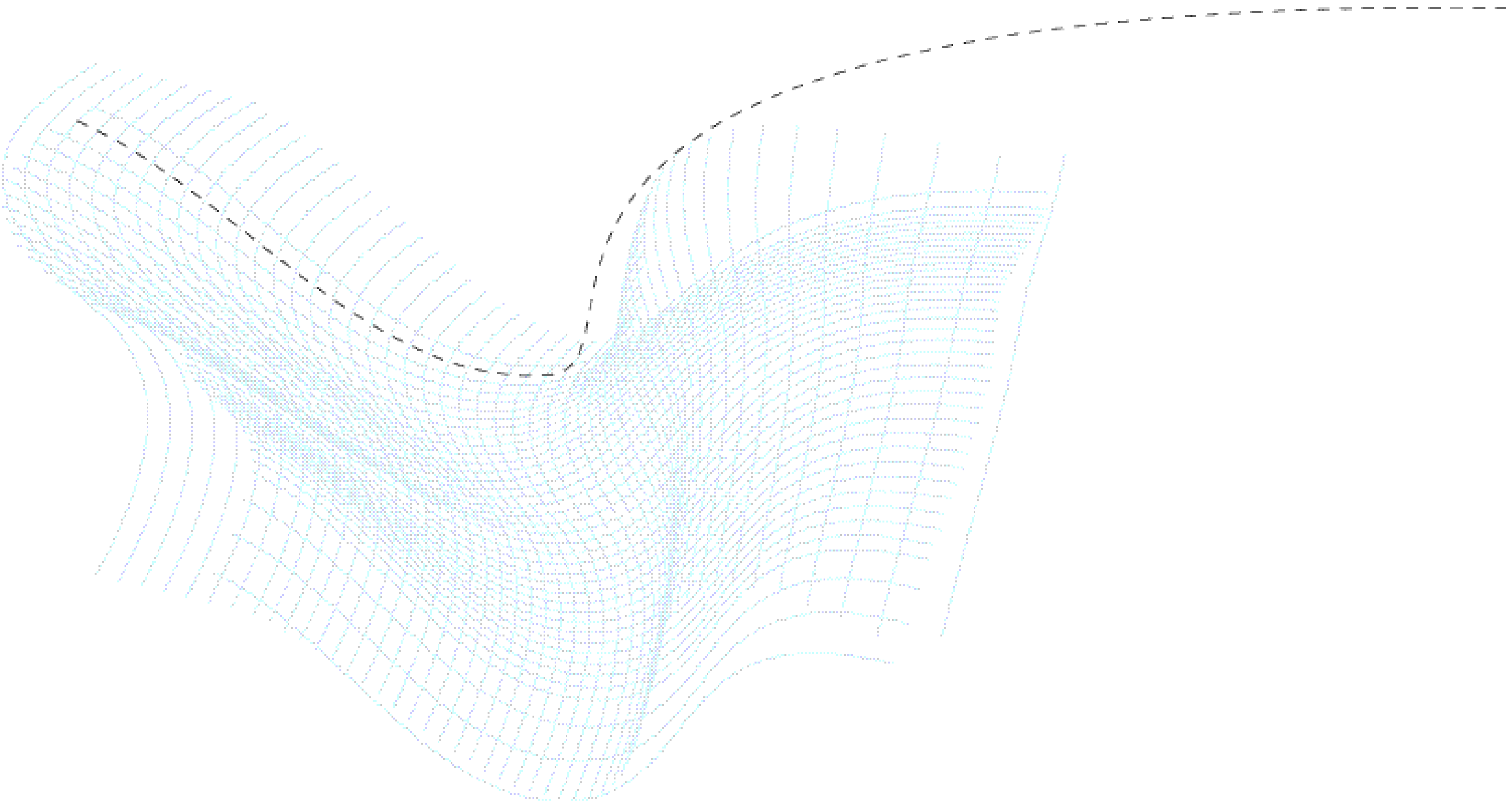


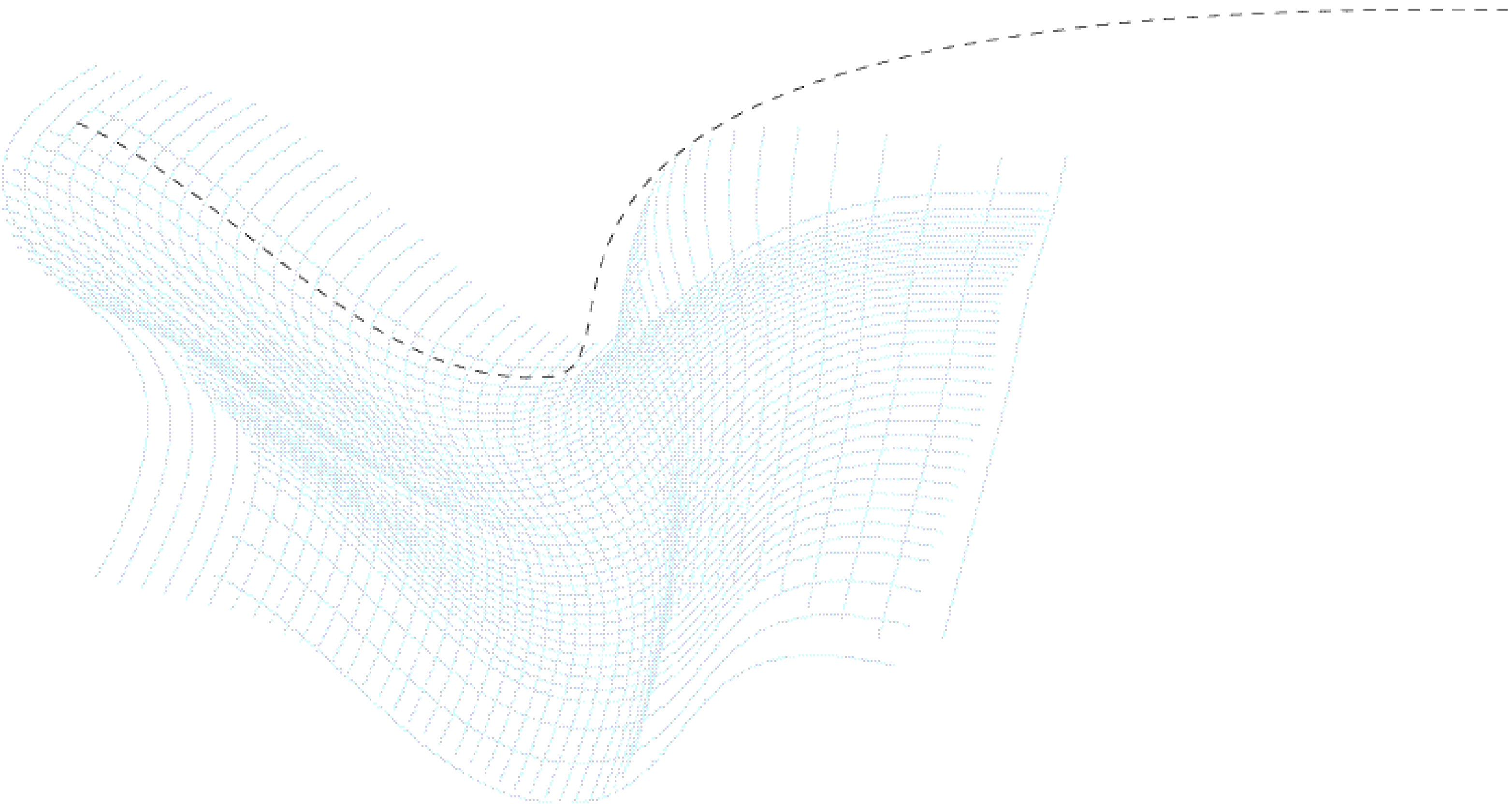


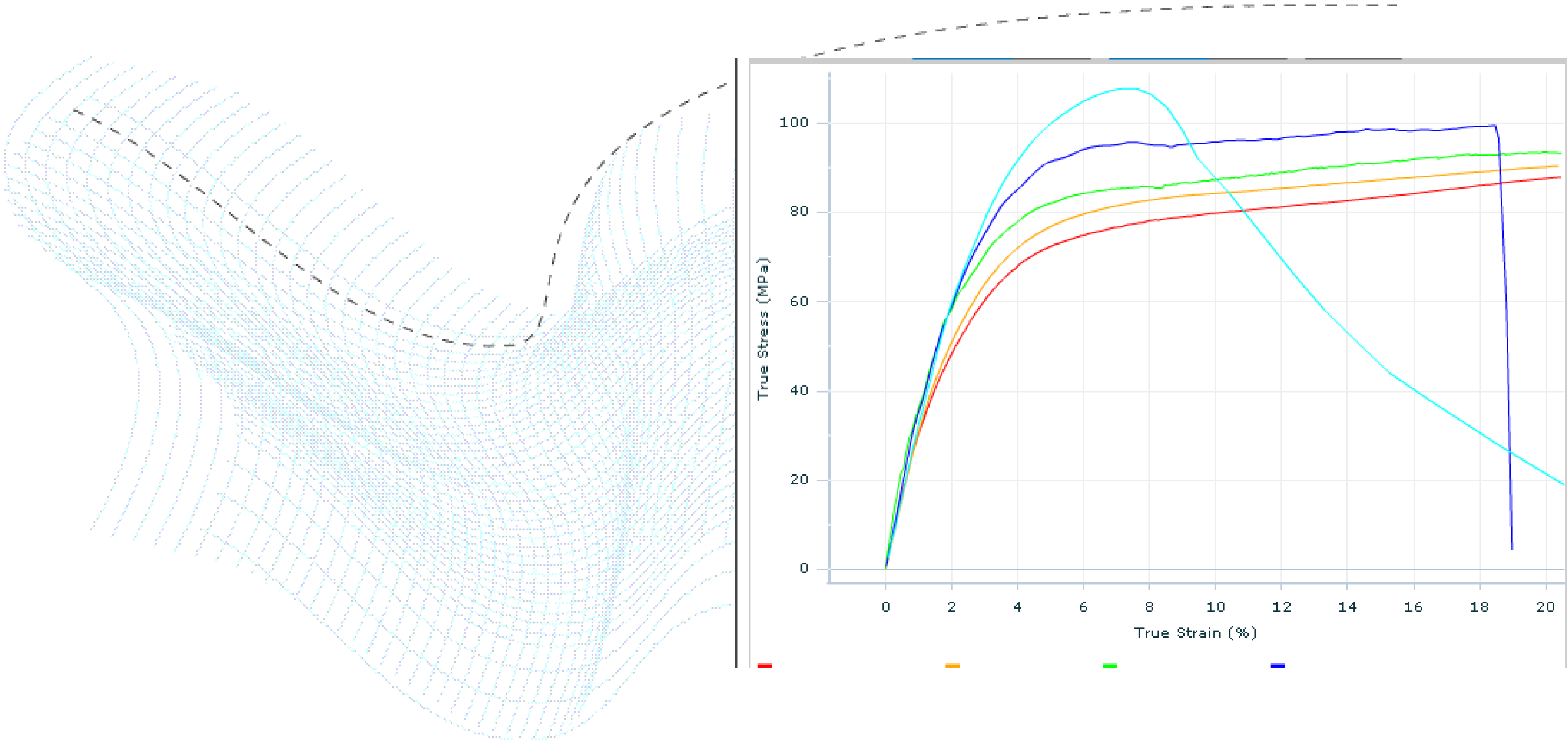
Conclusions



- Choice of material model depends on
  - material
  - test data
  - situation complexity
- Proper selection = reasonable model
- Simple improvements can add power
- Validated models represent baseline
- Models can be tuned for multi-axial loadings







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