Behavior-based Material Model Selection and Calibration of Plastics for Crash Simulation

Hubert Lobo
DatapointLabs

Automotive CAE Grand Challenge 2010
30th – 31st March, 2010

DatapointLabs: Expert material testing… since 1995

ISO 17025 Certified

Material properties for product development
- **Over 1,000 materials tested each year**
- **Wide variety of materials**
- **Over 200 types of physical properties**

CAE Material Model Calibration Services
- **25 CAE codes supported**
- **Abaqus, ANSYS, LS-Dyna, NX NASTRAN, Moldflow, Polyflow, in-house**

–Plastic
–Rubber
–Film
–Metal
–Foam
–Composite
–Cement
–Ceramic
–Paper
–Wire
–Fiber

Problem statement and needs

Many material models are available for crash simulation

Common models are not designed for plastics

Develop best practices for adapting common models to plastics

Develop best testing protocols for clean, accurate rate-dependent data

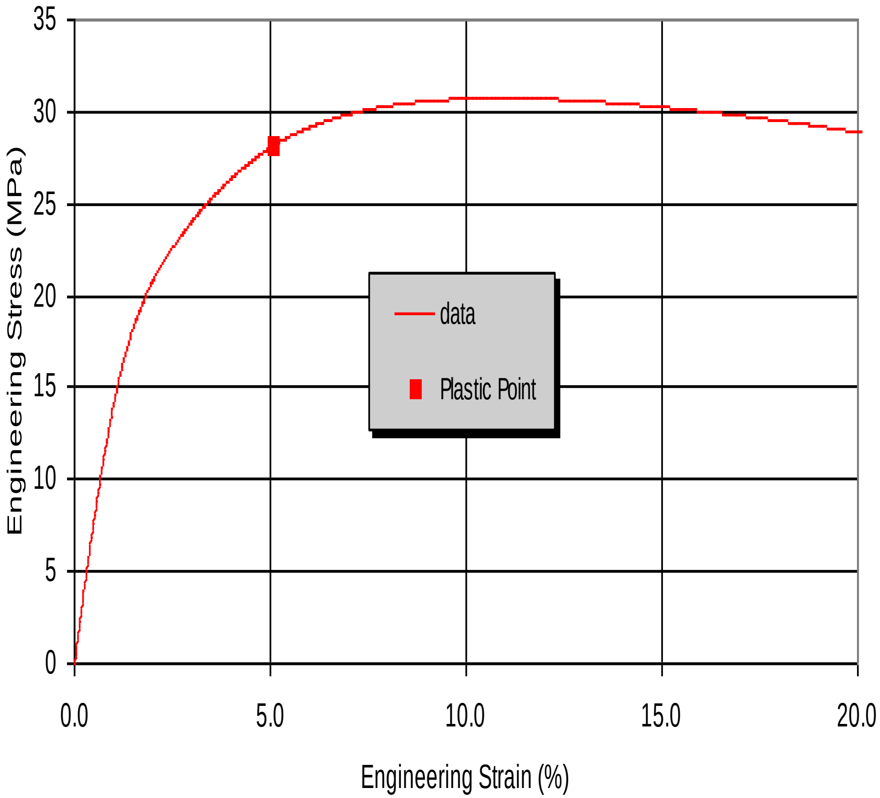
Develop streamlined process to convert raw data to LS-DYNA cards

Harmonized material datasets to use same raw data for

- Abaqus
- PAM
- RADIOSS..

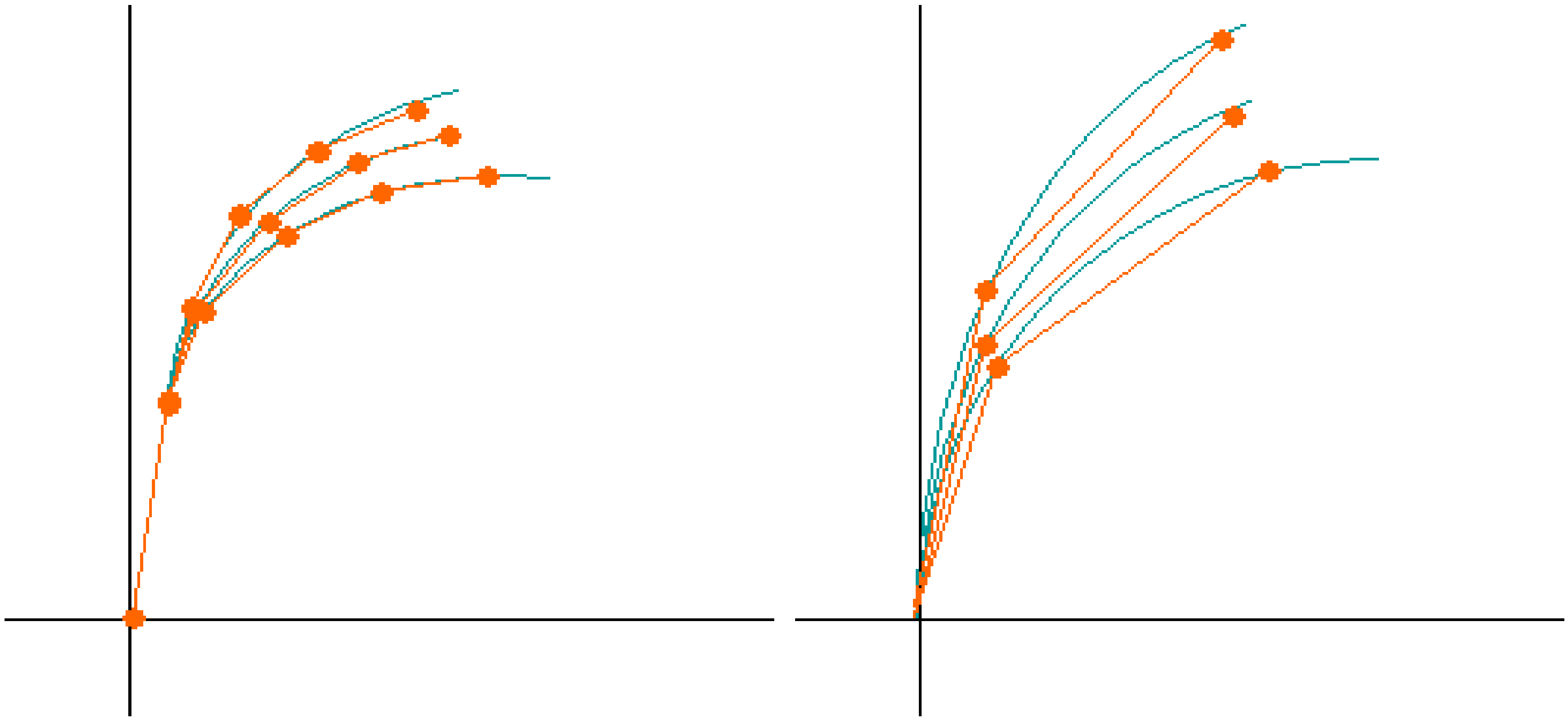
Plastics Behavior - Basics

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



Plastics Rate Effects

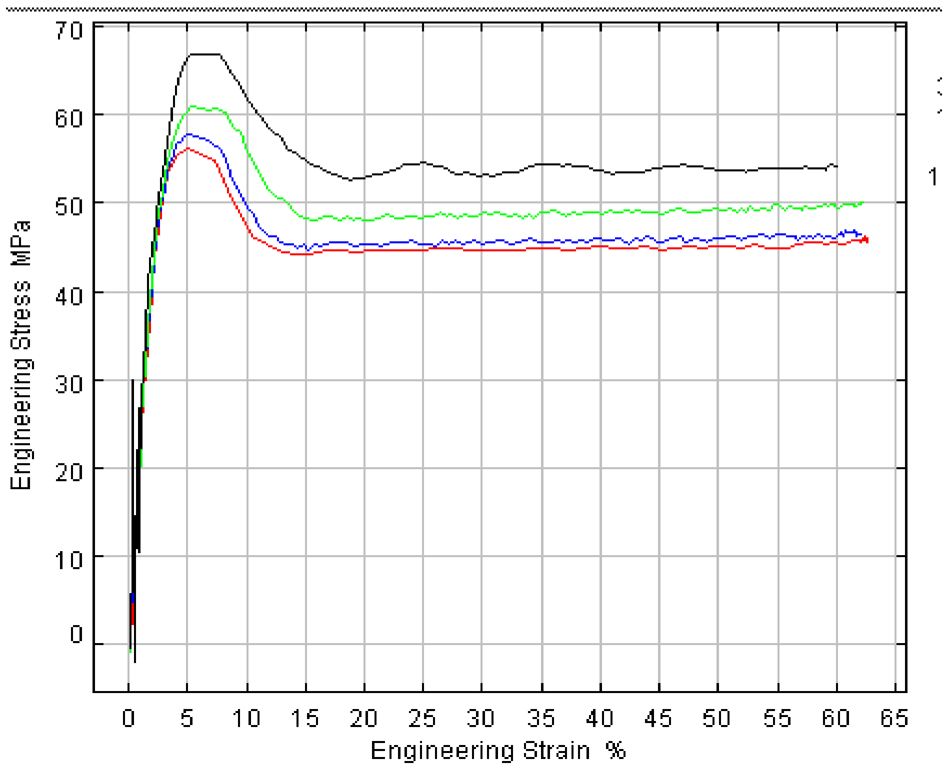
Modulus may depend on rate



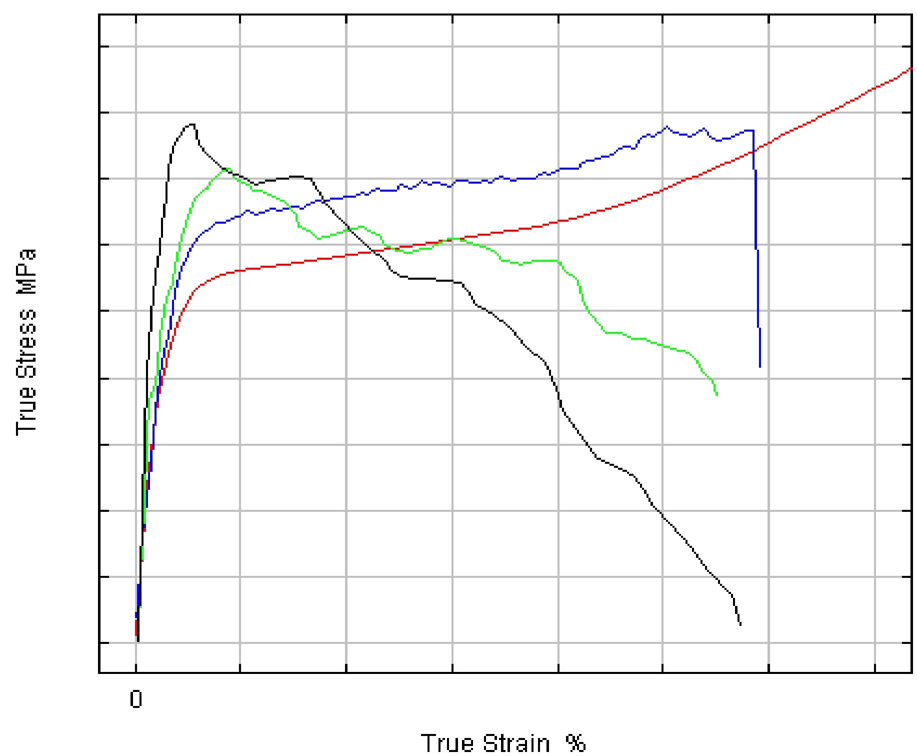
Plastics Rate Effects

Fail strain may be rate dependent

Engineering Tensile Stress-Strain Curves



True Tensile Stress-Strain Curves



Effect of fiber fillers

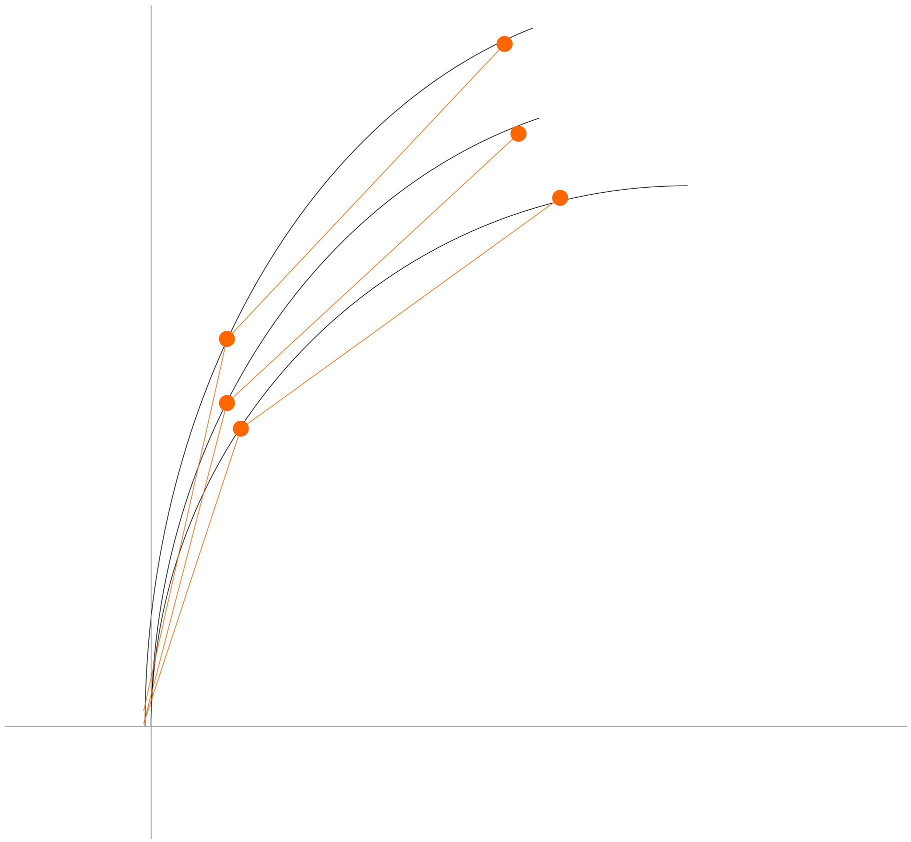
Higher modulus

Small strain to failure

Brittle failure

No post-yield behavior

Anisotropy



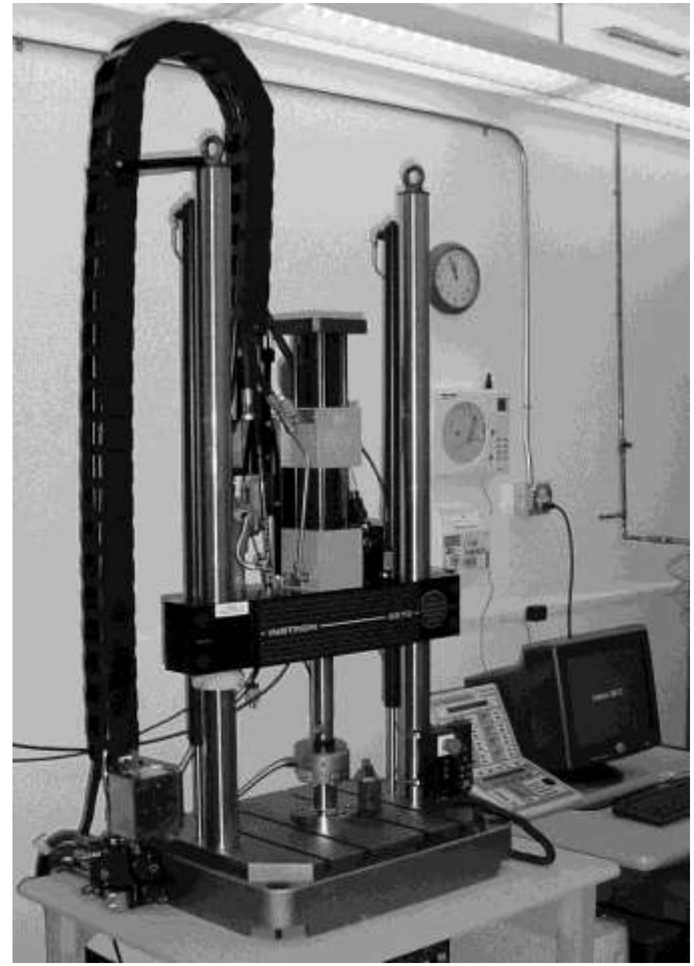
Material Testing

Instron servo-hydraulic UTM

- **Dynamic load cell**
- **-40 to 150C**

•Testing Protocol

- **ASTM D638**
- **Tensile Stress strain data**
- **5 decades of strain rate**
  - *0.01/s*
  - *0.1/s*
  - *1/s*
  - *10/s*
  - *100/s*



carhs.

Test Specimens

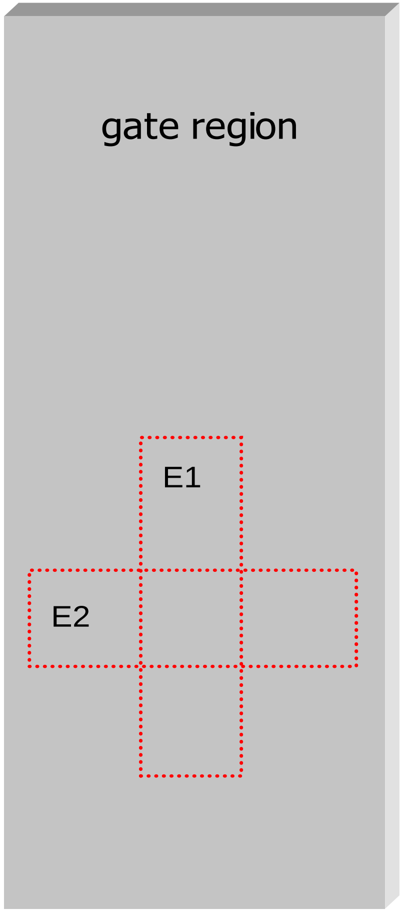
ASTM D638Type V

Preparation

- **CNC from plaque**
- **CNC from part**
- **Molded**

Variability

- **processing**
- **orientation**
- **thickness**



Creating Harmonized Pedigreed Datasets

Matereality datasets comprise

- all stress strain curves (each replicate)
- all strain rates
- all test parameters
- data source and traceability
- statistical data

Data in full digital form ready for post-processing and export into

- LS-Dyna
- Abaqus/Explicit
- ANSYS Autodyn

Material Dataset loaded to Matereality

Home | Help | Logout

Confidential Demo Purposes's Matereality

- my account
- my data
- data center
- my users
- contact us

Home > MyData > DataSummary

Makrolon 7435 > Tensile Properties

Unit system: --System Default--

Click on the property titles below to view data

Summarized Results

Engineering Tensile Stress-Strain Curves	Effect of strain rate
Eyring Plot	(strain rate : 0.0692899615250087 /s) (strain rate : 0.266526757607555 /s) (strain rate : 2.66526757607555 /s) (strain rate : 26.6526757607555 /s)
Tensile Modulus	Effect of strain rate

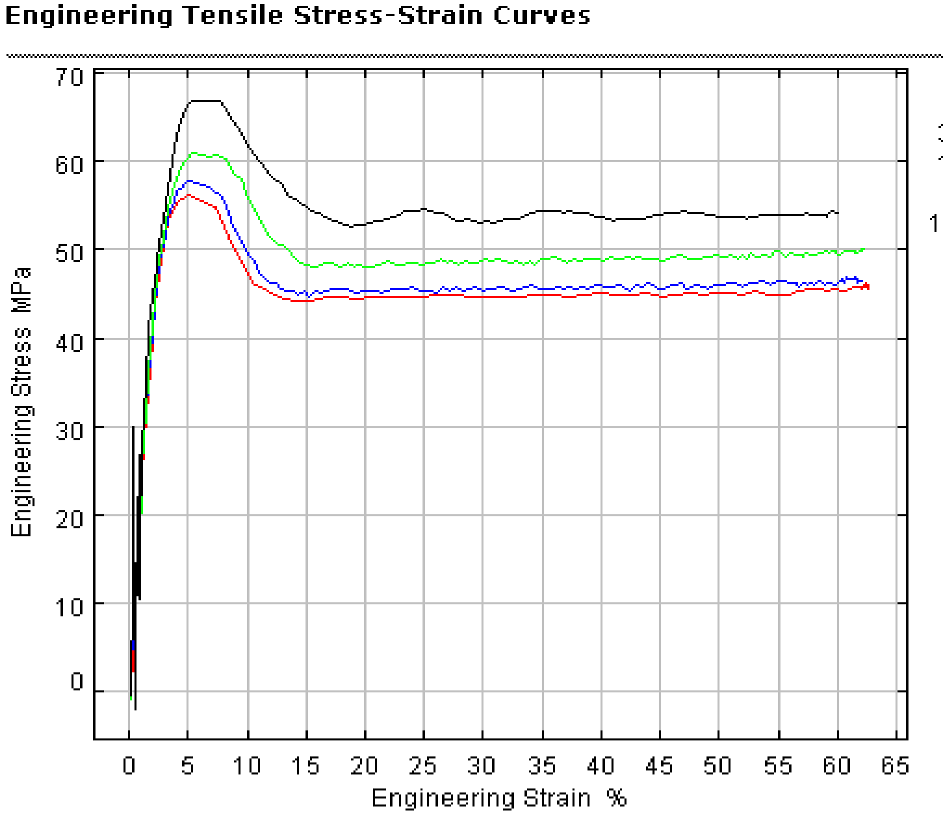
Individual Results

Poissons Ratio Tensile Modulus Tensile Modulus - Secant True Tensile Stress-Strain Data Plasticity Data Engineering Tensile Stress-Strain Curves	strain rate : 0.0692899615250087 /s
Tensile Modulus Engineering Tensile Stress-Strain Curves	strain rate : 0.266526757607555 /s
Tensile Modulus Engineering Tensile Stress-Strain Curves	strain rate : 2.66526757607555 /s
Tensile Modulus Engineering Tensile Stress-Strain Curves	strain rate : 26.6526757607555 /s

Share | Modify Access | Request Review | Discard | Transfer Owner

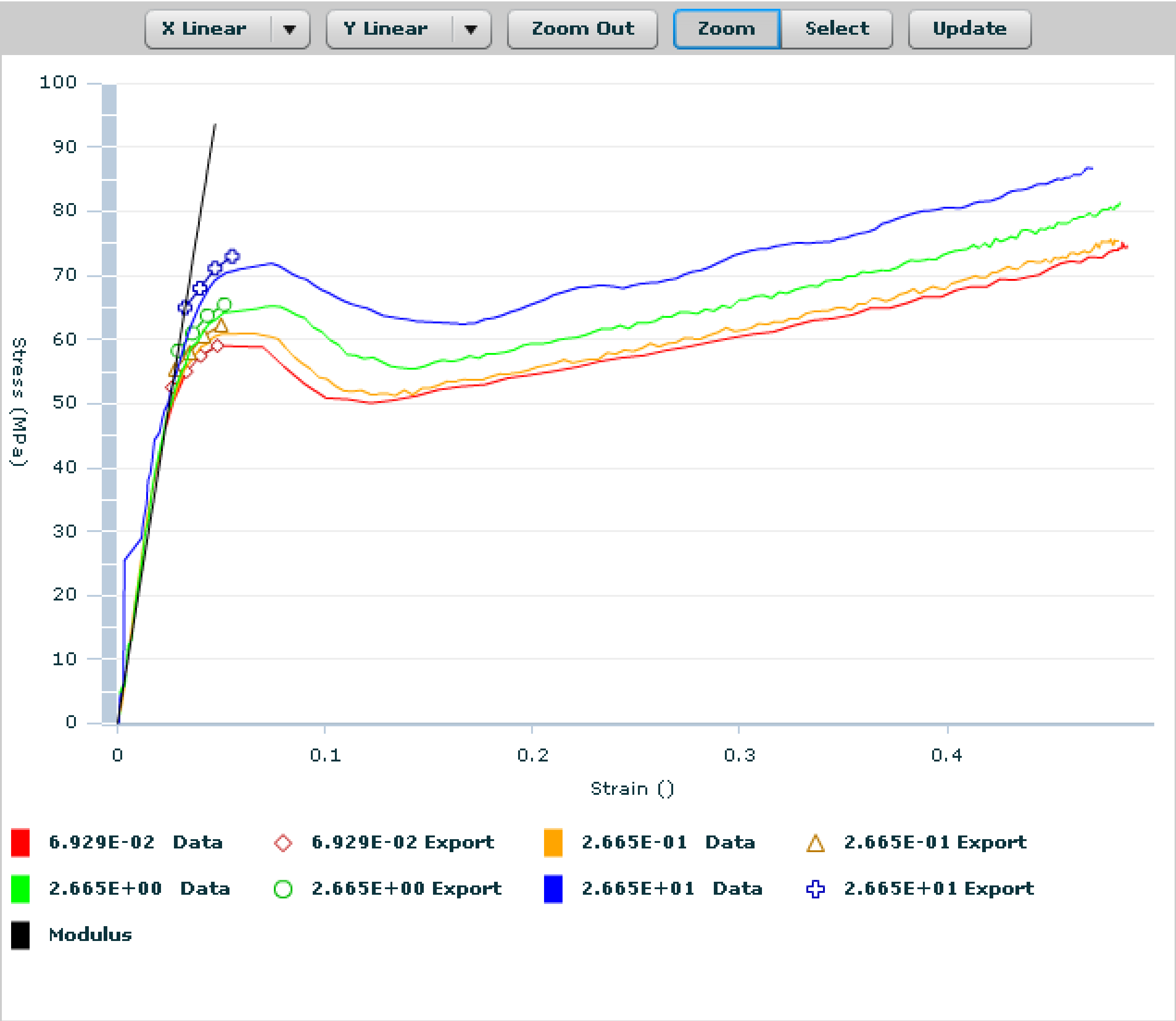
MAT 24 – Ductile plastics

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



carhs.

MAT 24 Automated data conversion

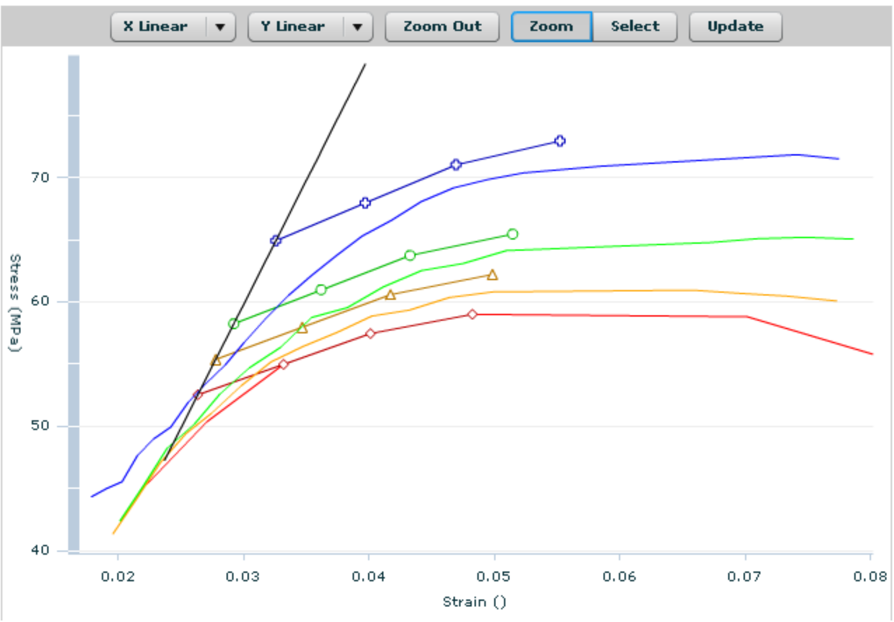


Rate Dependency Tuning

LCSR

Strain Rate (/s)	Stress Ratio
0.06929	1
0.2665	1.0545454545454545
2.665	1.1090909090909091
26.65	1.2363636363636363

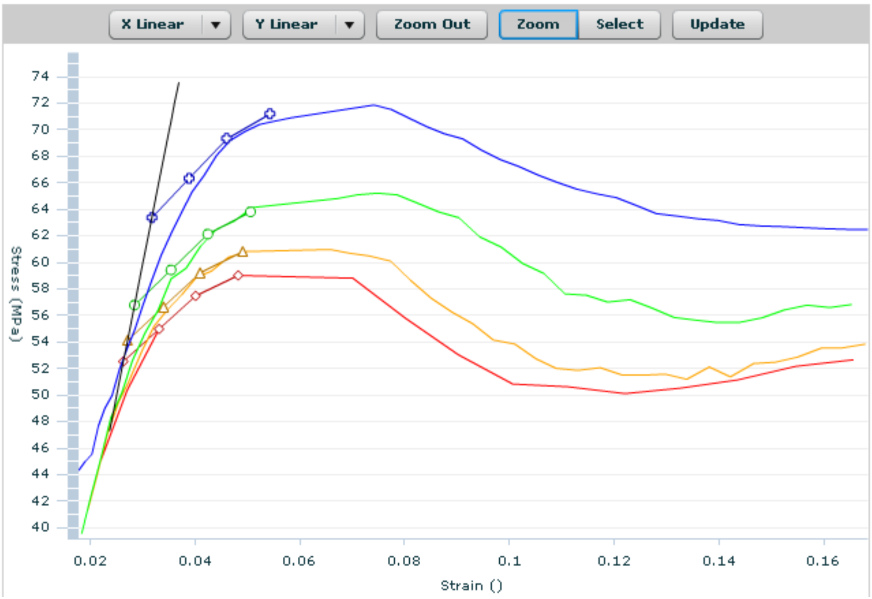
lcsr



LCSR

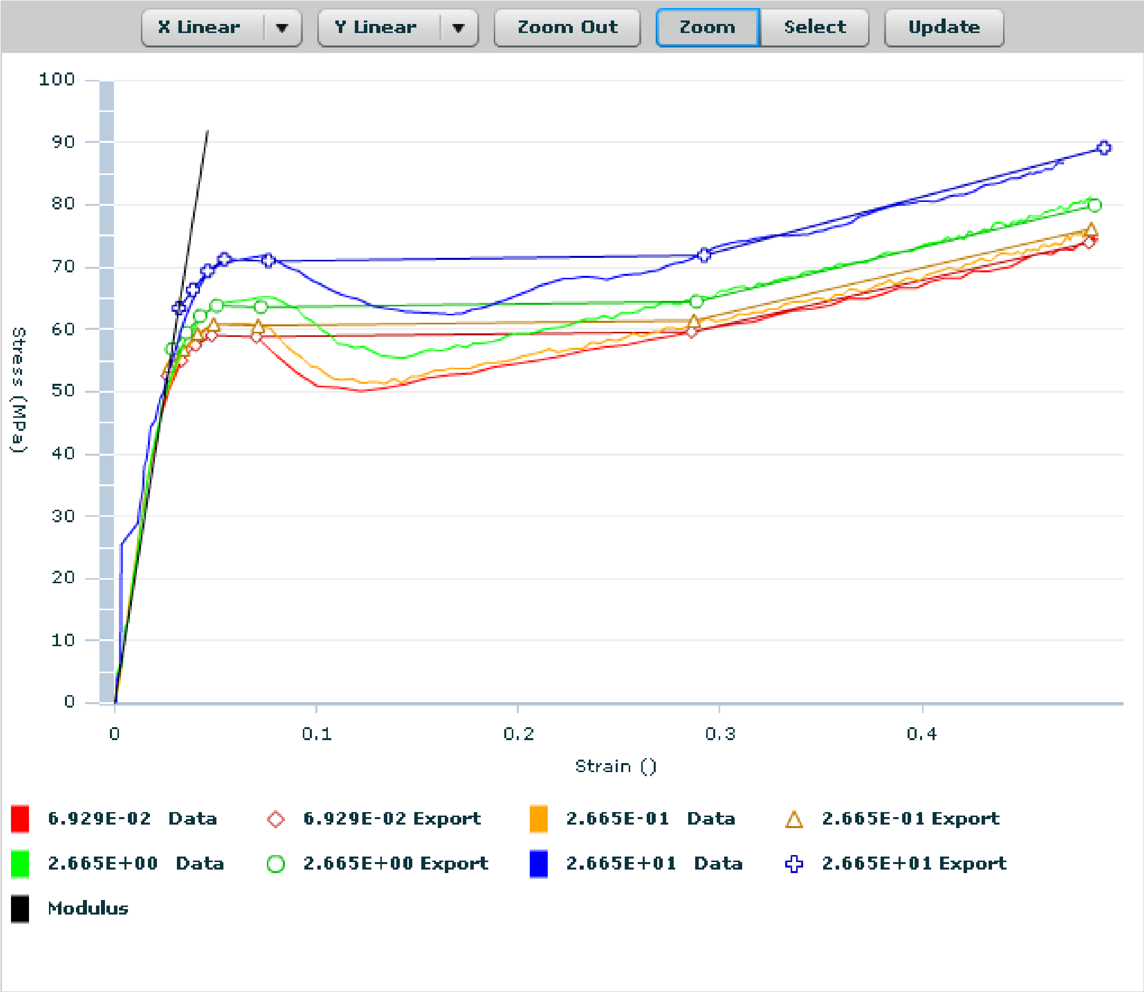
Strain Rate (/s)	Stress Ratio
0.06929	1
0.2665	1.0305054545454546
2.665	1.081002509090909
26.65	1.2063636363636363

lcsr



Modeling Post-Yield & Failure

lcsr



Writing the material file

Ls-Dyna MAT_024 (LCSR)

LS-DYNA MAT_024

mid	ro	e MPa	pr	sigy	etan	fail	tdel
10025	1e9	1991.83642	0.4	51		73	

c	p	lcss	lcsr	vp

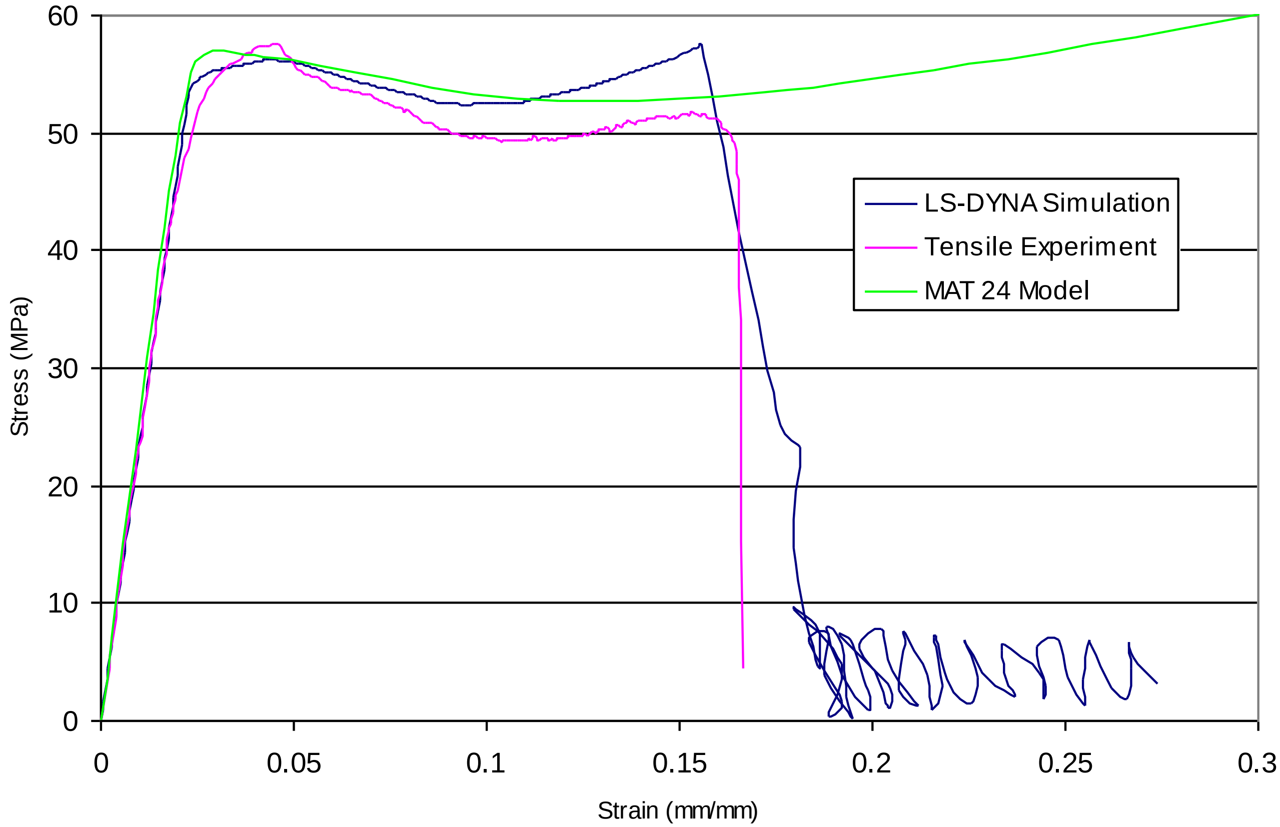
LCSR

Strain Rate (/s)	Stress Ratio
0.06929	1
0.2665	1.0305054545454546
2.665	1.081002509090909
26.65	1.2063636363636363

lcsr

```
*MAT_024
$#      mid        ro         e        pr      sigy      etan      fail      tdel
      10025   1.0E+09 1.992E+03   4.0E-01   5.1E+01   0.0E+00   7.3E+01   0.0E+00
$#        c         p      lcss      lcsr        vp
                                      1002   0.0E+00
$#      eps
 5.608E-03 1.131E-02 1.864E-02 4.065E-02 2.561E-01 4.458E-01
$#       es
 5.497E+01 5.746E+01 5.901E+01 5.882E+01 5.958E+01 7.387E+01
*DEFINE_CURVE_TITLE
lcsr
$#     lcid      sidr       sfa       sfo      offa      offo
       1002         0   1.0E+00   1.0E+00   0.0E+00   0.0E+00
$#                 A1                  O1
           6.929E-02             1.0E+00
           2.665E-01           1.031E+00
           2.665E+00           1.081E+00
           2.665E+01           1.206E+00
```

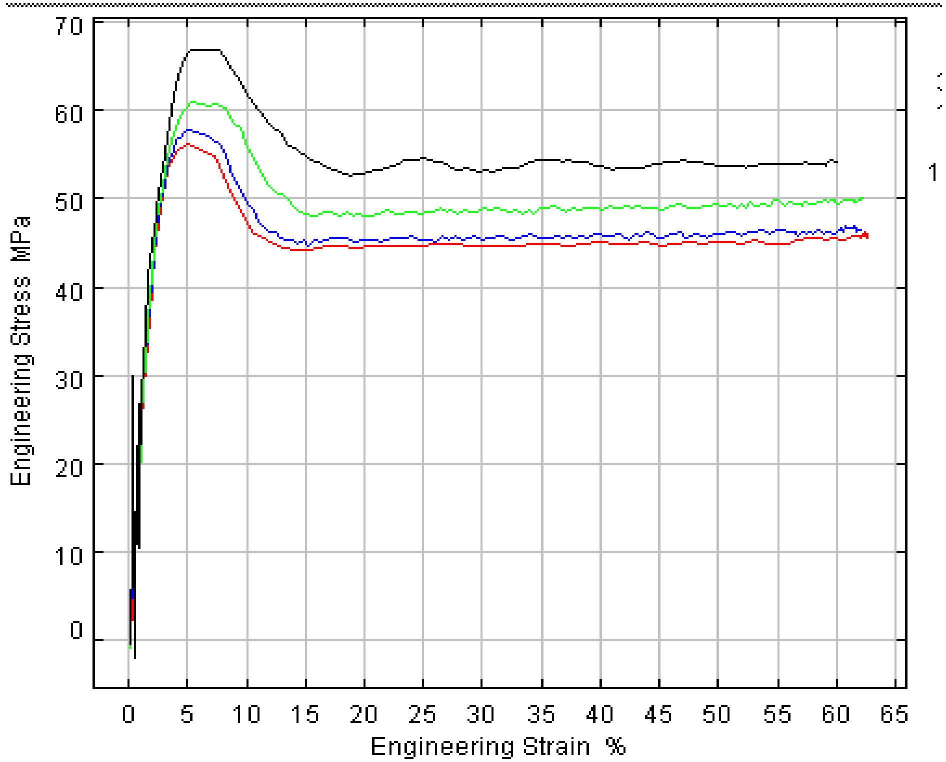
MAT24 validation



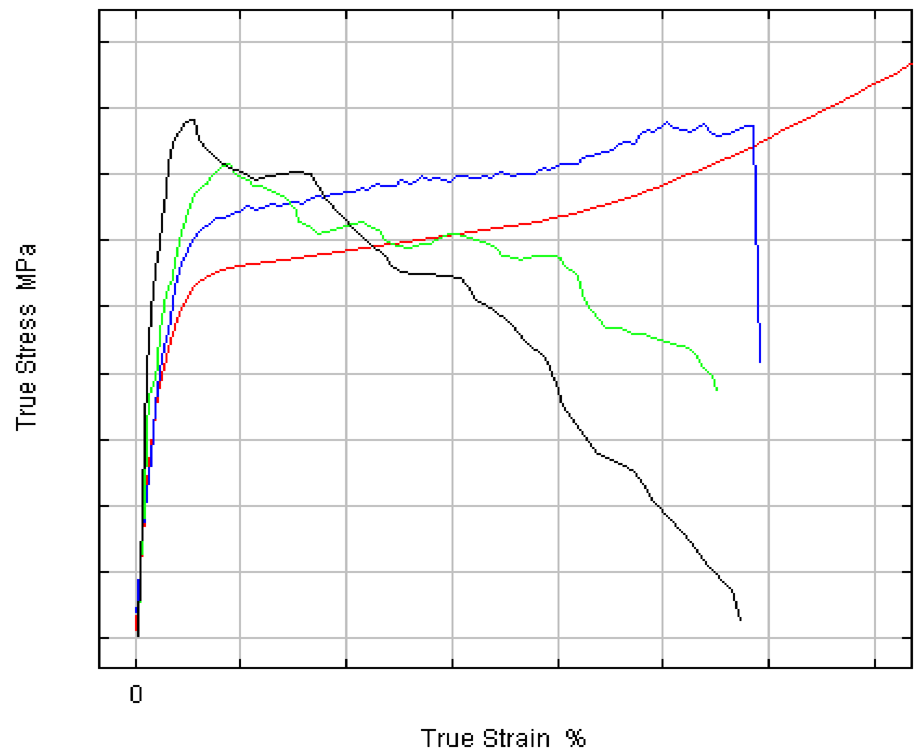
MAT 24 – Fail Limitations

When FAIL f(strain rate)

Engineering Tensile Stress-Strain Curves



True Tensile Stress-Strain Curves



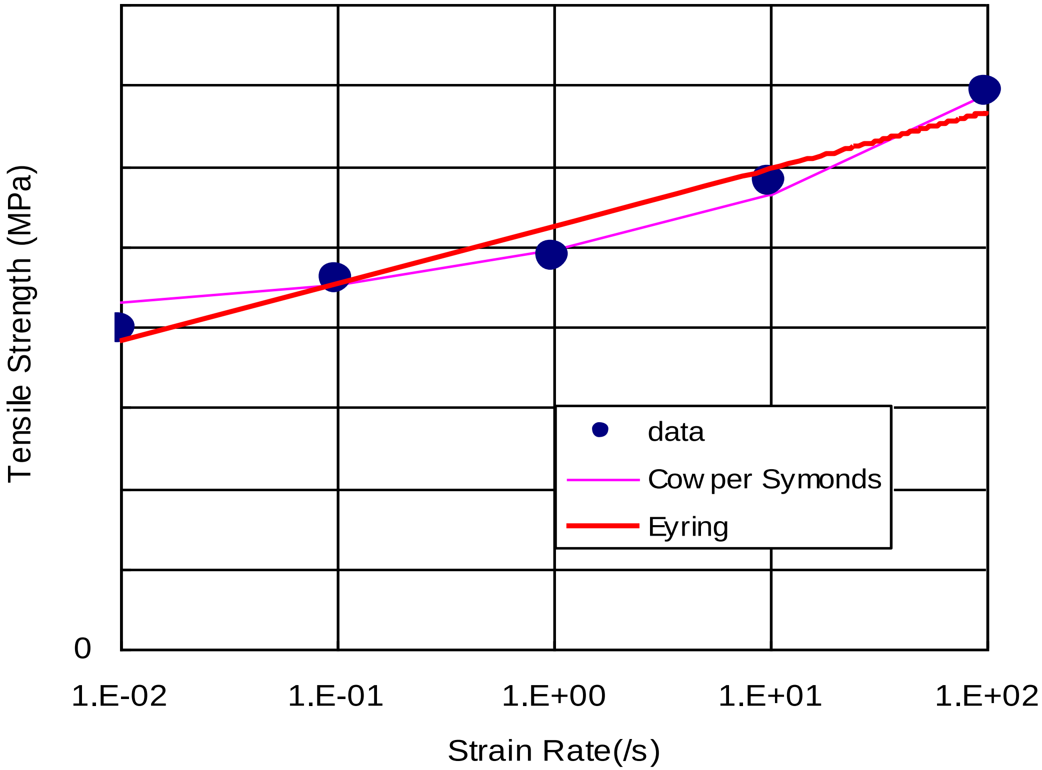
MAT 24 – Rate Dependency

Cowper Symonds

- **Does not correlate well with plastics rate dependency**

LCSR

- **Capture model independent behavior**



MAT 24 – LCSR-Eyring

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

Submit as table using LCSR

MAT 19 – Brittle plastics

Modulus is rate dependent

Small strains to failure

Brittle failure

Failure strain decreases with increasing strain rate

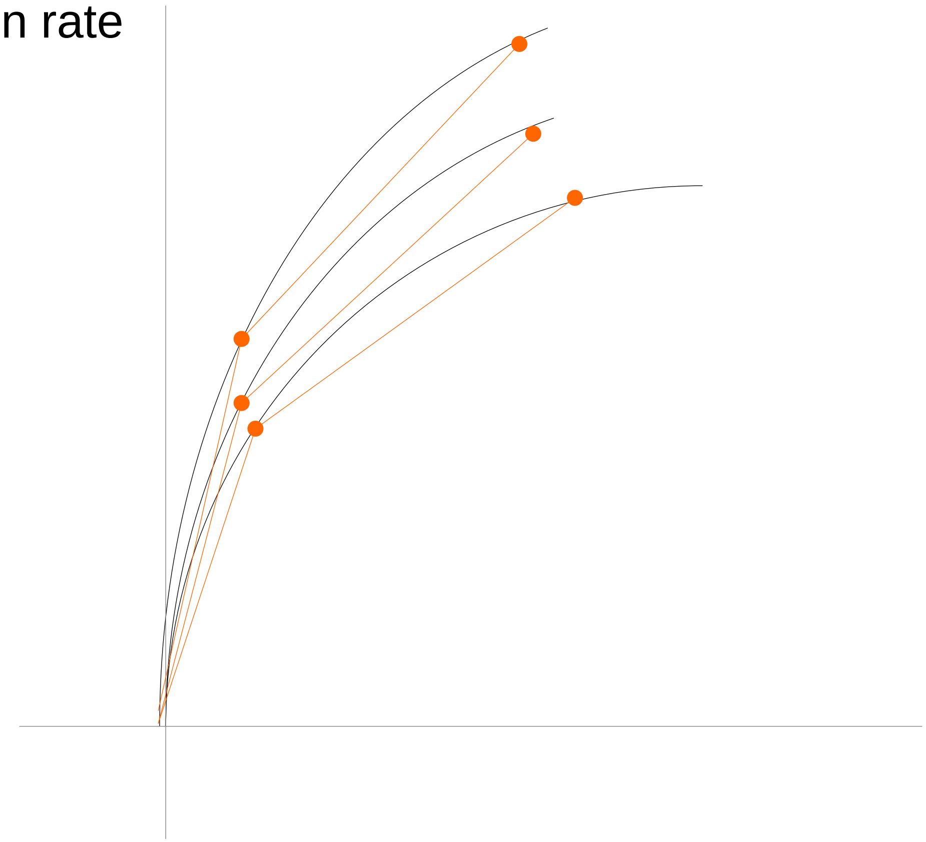
MAT 19 – Methodology

Determine elastic limit at quasi-static strain rate

Use elastic limit for von-Mises yield

Define failure

- **failure stress v. strain rate table**



MAT 89 – Ductile-brittle

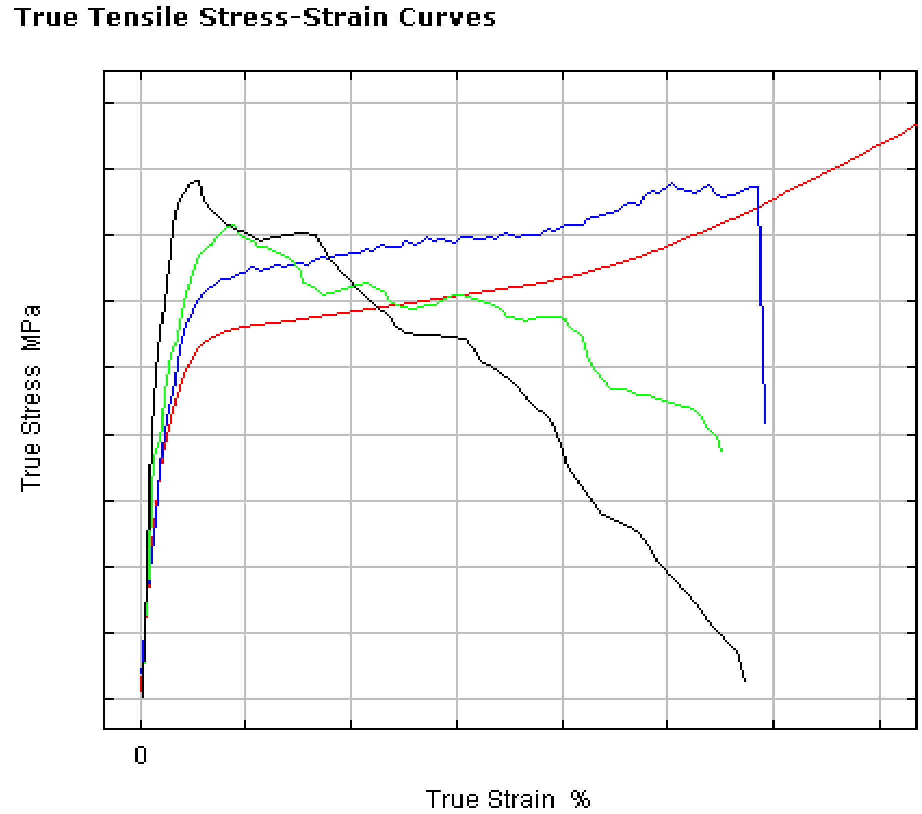
Non-linear behavior

Failure depends on strain rate

Can handle ductile-brittle transitions

Uses stress-strain curve

Limited to shell elements

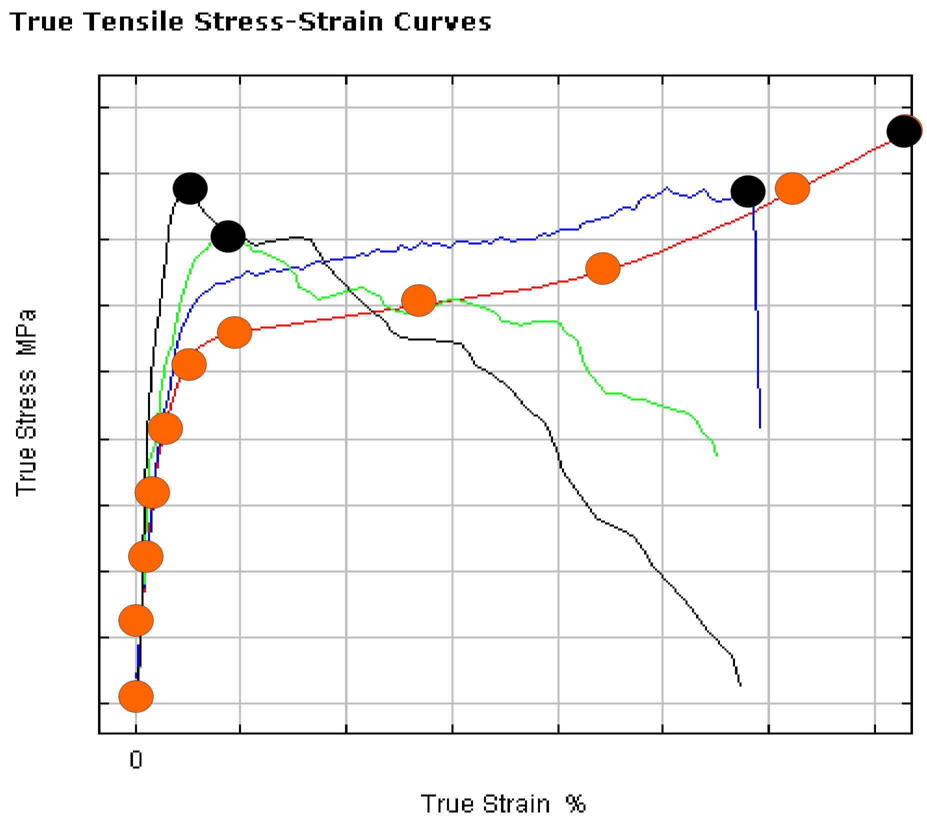


MAT 89 – Methodology

- Submit stress-strain curve

  Submit EMOD

  Submit rate dependency via LCSR-Eyring
- Submit failure strain v. strain rate via LCFAIL



MAT 89 – Workings

Internally decompose quasi stress-strain curve

- **Use EMOD for von Mises limit**
- **Rest of the curve is elastic-plastic**
- **Rate dependency via LCSR**
- **Failure via LCFAIL**

Conclusions

Choice of material model depends on

- **material**
- **test data**

MAT89 is generically applicable

Proper selection = reasonable model

Simple improvements can add power

Validated models represent baseline

Models can be tuned for multi-axial loadings

Matereality data conversion streamlines material parameter creation

Matereality raw dataset and work flow can be applied to other CAE