# Multiscale Properties IAG Meeting

22 April 2008

## Project SM06

## Knowledge Based Design with Plastics


Louise Crocker

Greg Dean

Neil McCartney

Richard Mera

Simon Roberts


NPL National Physical Laboratory

# Project Outline

- **Objective** - to develop a capability to design with polymers under long-term load

- Model long-term deformation behaviour
  - Non-linear behaviour
  - Multiaxial stress

- Develop non-linear viscoelasticity theory to produce solutions for arbitrary stress and strain histories

- Prepare code, based on this theory, for ABAQUS to obtain solutions using finite element methods

- Evaluate the code

# Non-linear viscoelasticity in SM06

- Stress/strain equations for multiaxial and time-dependent stresses

$$\varepsilon_{ij}(t) = \varepsilon_{ij}{}^{d}(t) + \frac{1}{3}\varepsilon_m(t)\delta_{ij}$$

$$\varepsilon_{ij}{}^{d}(t) = \frac{1}{2}\int_0^t \dot{\sigma}_{ij}{}^{d}(\tau) J(t-\tau)\, d\tau$$

$$J(t-\tau) = J_0 + \Delta J\left[1-\exp\left[-\left(\int_\tau^t \frac{du}{t_0(\overline{\sigma}(u))}\right)^n\right]\right]$$

$$\varepsilon_m(t) = \int_0^t \dot{\sigma}_m(\tau) B(t-\tau)\, d\tau$$

$$B(t-\tau) = B_0 + \Delta B\left[1-\exp\left[-\left(\int_\tau^t \frac{du}{t_0(\overline{\sigma}(u))}\right)^n\right]\right]$$

- Material properties
  - $J(t) = 2(1+\nu)D(t)$
  - $B(t) = 3(1-2\nu)D(t)$ assuming constant Poisson's ratio

National Physical Laboratory

# Summary of current status

- Reduction of the integral equations to differential equations is not possible
- Coding our creep model into a finite element system is now outside the scope of project SM06
- The deliverables in SM06 have been revised
- Discussions have started with ANSYS and experts from Bradford University to develop the FE code within another project

# Revised project deliverables

- Obtaining solutions using a finite element system is now outside the scope of this project

- Consider solutions for the case of uniaxial tension

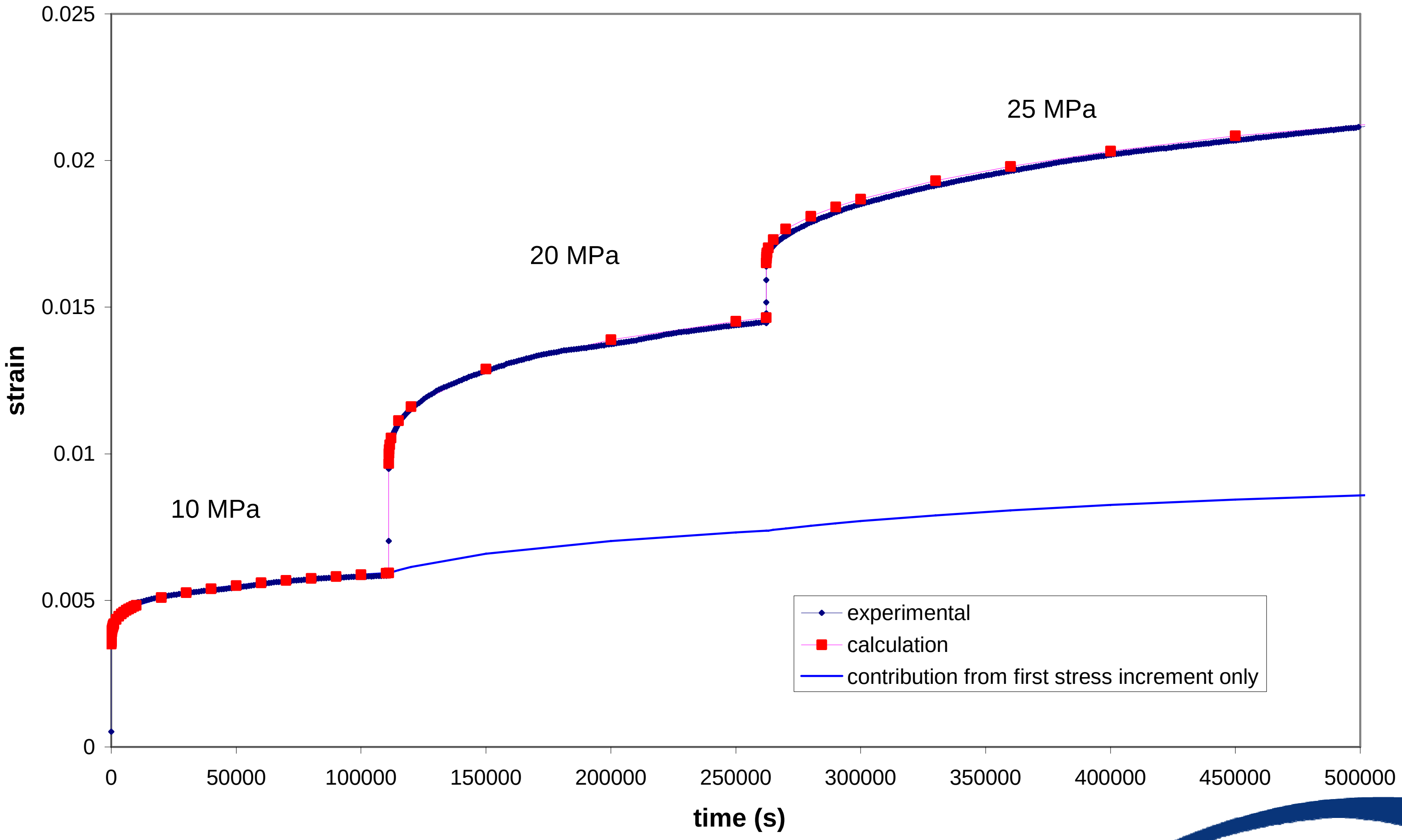
$$\varepsilon(t) = \int_0^t \dot{\sigma}(\tau)\left[ D_0 + \Delta D\left[ 1 - \exp - \left( \int_\tau^t \frac{du}{t_0(\sigma(u))} \right)^n \right]\right] d\tau$$

National Physical Laboratory

# Evaluation of solutions under uniaxial tension

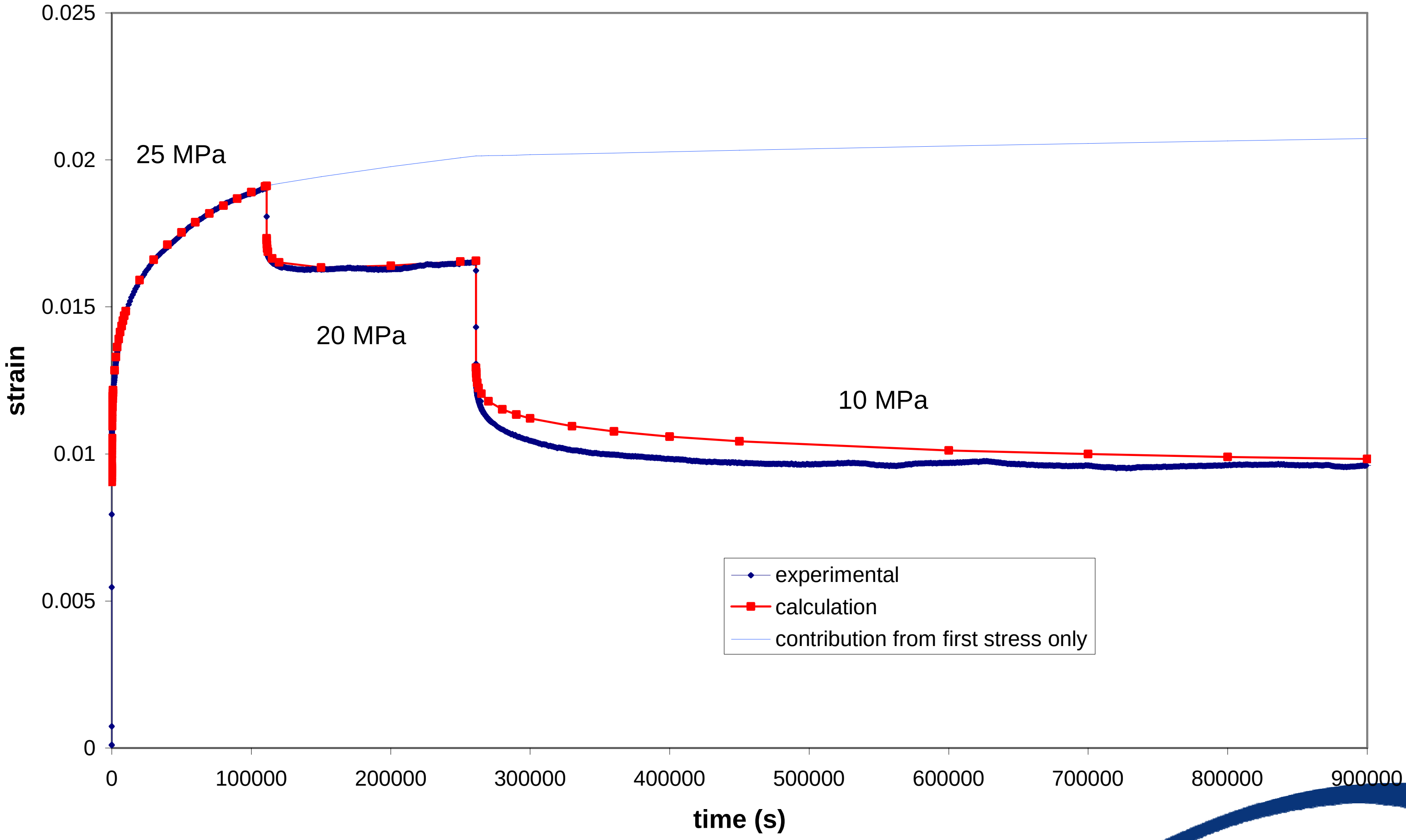
- Compare solutions with experiment for
  - Step-loading creep tests
  - Stress relaxation tests
  - Constant strain rate tests – very low strain rates

# Comparison with experiment for step loading
## injection-moulded poly(oxymethylene)



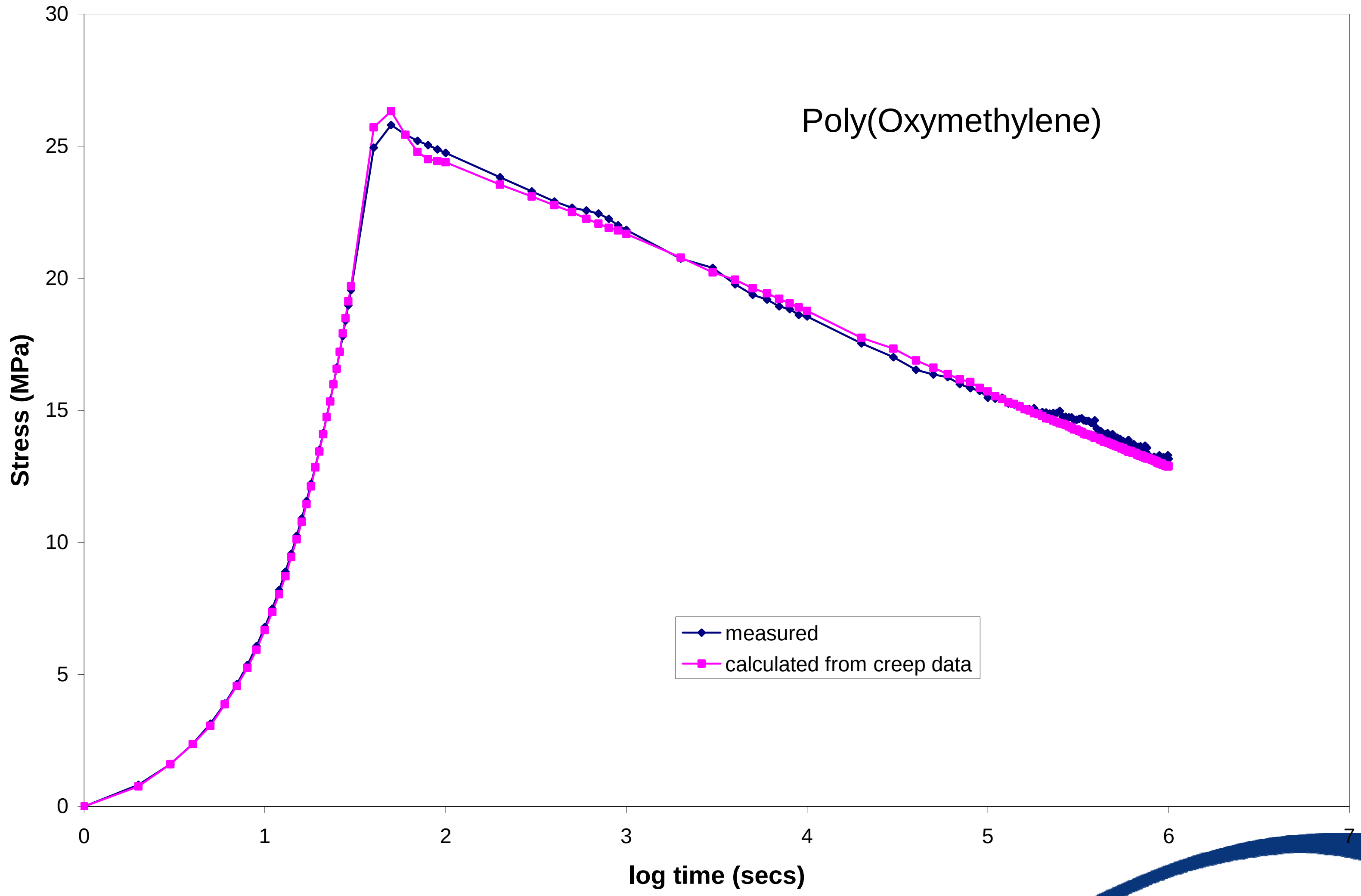
# Comparison with experiment for load removal

## injection-moulded poly(oxymethylene)




National Physical Laboratory

# Comparison with stress relaxation test – strain=0.01



# Next steps

- Further evaluation of the solutions for different stress and strain histories under uniaxial tension
- Prepare publications
- Explore methods for obtaining solutions using a finite element system within a new project
  - ANSYS/Bradford University.