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Polymers

Testing and Modeling

Practical high-end solutions

Polymer materials which are very widely used in engineering are known for their nonlinearity and complexity in modeling. Most solid polymers (polyolefins, etc) exhibit nonlinear elasticity, viscoelasticity (possibly nonlinear), rate-dependant plasticity, pressure dependant yield, non-linear modulus changes and/or damage due to hard-soft phases changing morphology, and nonlinear hyper-kinematic hardening at large strains. Successful modeling of these materials therefore needs potentially to incorporate all these effects. Most material model codes, in particular "subroutines" which implement a particular model variant, are most likely to fall short because they lack the infrastructure and large-scale design necessary to implement such features. In Z-mat however there is an extremely flexible framework programmed in a specific way to eliminate technical barriers to realistic feature addition.

Many times there is a significant divide between the testing lab and the CAE department utilizing the material data for simulations. Hopefully that divide is only physical, but more often there is a conceptual gap between a material departments objectives, techniques and experience with those of the CAE modeler. NW Numerics views mechanical testing as a true multi-disciplinary task, requiring significant transfer of knowledge between both mechanical engineers and material scientists.

- *General testing capability with cyclic / relaxation / etc*
- *General finite-strain viscoplasticity & hyper-viscoelasticity*
- *Excellent results in hysteresis*
- *Coupled with failure models in explicit calculations*

Framework Z-mat contains many model implementations which relate to polymers (G'Sell, Arruda-Boyce viscoplasticity, Zener hyper-viscoelasticity, generalized two-layer, etc), and a single generalized multiplicative finite strain framework for hyper-viscoelastic, viscoplastic behavior.

Hyperelasticity More than 10 models including most all implemented in Abaqus or Ansys.

Viscoelasticity Linear and nonlinear viscoelasticity including temperature shift functions.

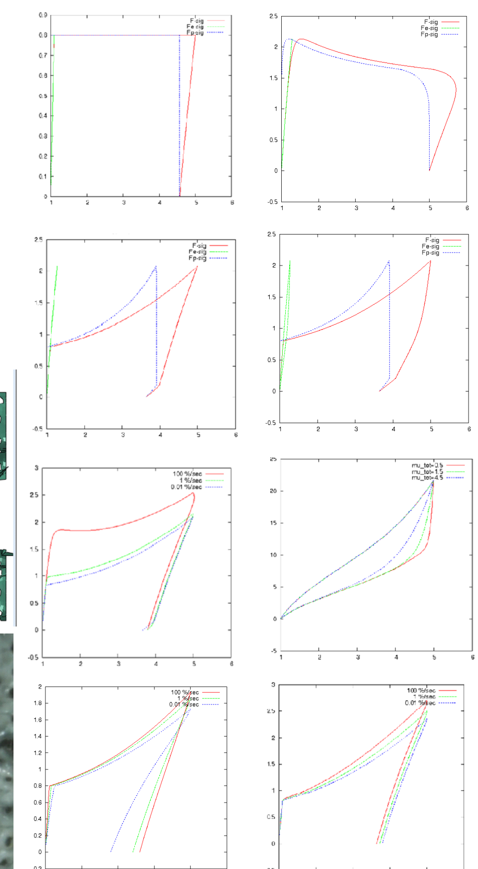
Mullins Two models of mullins effect

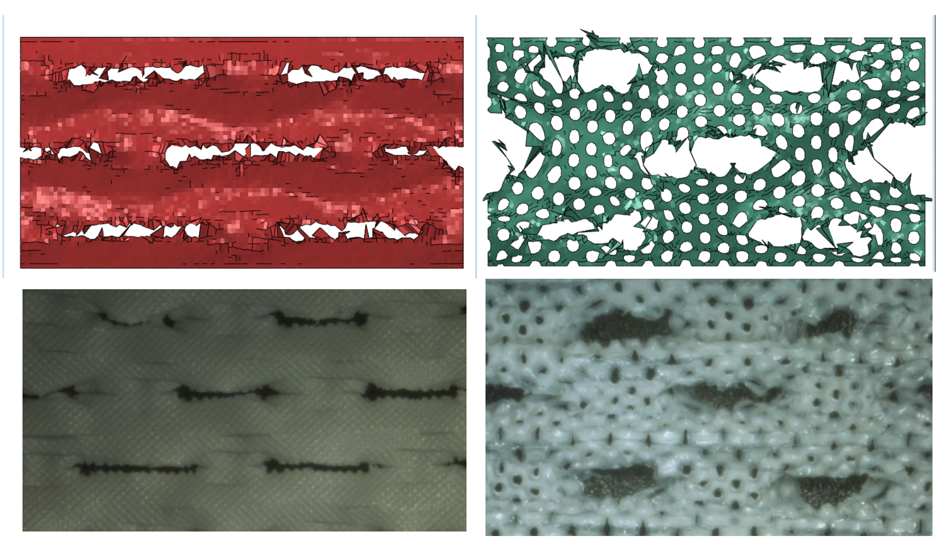
Plasticity / viscoplasticity Yielding effects with various criterion and isotropic hardening/softening laws.

Kinematic hardening Either integrated hypo-kinematic (many models) which simulate hysteresis or hyper-viscoelastic back stresses like Arruda-Boyce 3 or 8 chain back stresses for lock-stretch effects.

Multimat combinations General network models can be easily created with complex VE-VP mechanisms employing all features and having phase percentage evolution.

Example of ways stress strain curves can be controlled with the Z-mat polymer framework



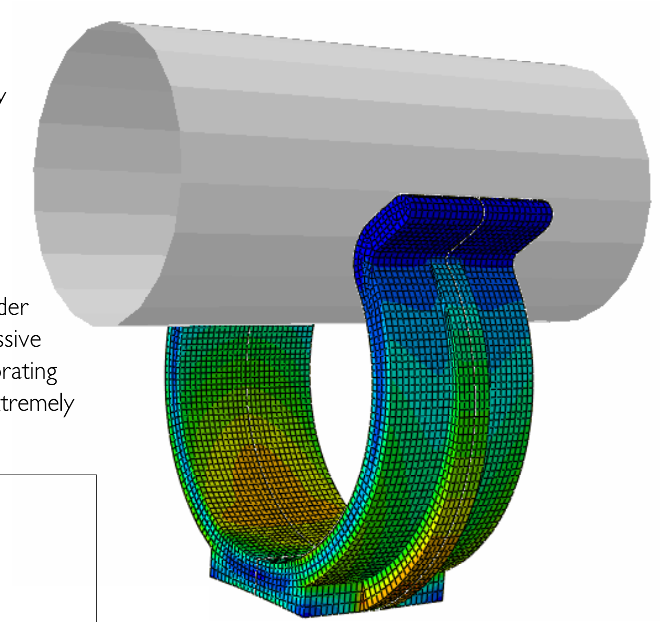


Production analysis of high-speed thin film forming processes

Turn-Key Polymer Calibration Example

Many engineered clips used for example extensively in the automotive industry use a variety of polymer materials, and need to meet performance metrics based on insertion-extraction forces over a number of cycles. It is well known that these clips typically show reduced forces after cycling, which is due to the viscoelastic relaxation, rate-dependant plasticity, and other nonlinear evolutions of the material.

Overall the strains are quite small in this clip, but the material nonlinearities under cyclic loading quite complex. The problem was readily solved with an impressive correlation utilizing a combination of mechanisms "multimat" effectively incorporating nonlinear evolution of the hyper-viscoelastic material. Yielding has also been fit extremely well, and complex loading paths can be tracked reliably start to finish.



```
***behavior voigt_fs
   **material 1. mad1
     *file pa.zmat 2
   **material 0. mad2
     *file pa.zmat 3
   **material 0. mad3
     *file pa.zmat 4
   **phase_evol
        mad1 1.0 - ( 1. - 1./exp( 50. *ETOEQ) ) ;
        mad2 0.0 + ( 1. - 1./exp( 50. *ETOEQ) ) - ( 1. - 1./exp( 11. *ETOEQ) ) ;
       mad3 0.0                                + ( 1. - 1./exp( 11. *ETOEQ) ) ;
   **auxiliary strain_measure ETO
     *measure eng
      **auxiliary strain_eq
        *var_name ETOEQ
       *measure ETO
***return
```