

Improving Simulation Quality with Reliable Materials Methods

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- Nature of the problem
- Sources of error
- Stepwise approach
- Documentation and Traceability
- Case studies



Why we need accurate simulations

- Early days- simulations were in 'try-out' phase
 - Use any available material data
 - Large commercial material databases with typical data
- CAE today- simulation-informed design
 - Relevant material data
 - Testing of actual material
 - composition
 - processing



Requirements for accurate simulation

- Simulations require accurate material representation
- Linear material models do not present a problem
- Non-linear models get complicated quickly
 - Appropriate finite element
 - Right material model
 - Physical tests
 - Correct material parameter conversion
- Need to check that the simulation is working correctly



Physical tests- Systematic Method

- Look at the property requirement for the model
- Evaluate the physics
- Perform the most scientifically accurate measurement
- Apply measured values to material model



Pros and Cons

- Tests can yield data directly useable in material model
- Tests need to be scientifically accurate- not easy
- Tests attempt to obtain pure modes of deformation not always successful
- Successful test data provides strong basis for material model
- No need for optimization
- Validation of simulation improves confidence



Physical tests- Empirical Method

- Perform a test with good boundary conditions that contains the behaviors of interest
- Simulate the test and use optimization to derive material parameters



Pros and Cons

- Test is easily performed
- Test can contain mixed modes of deformation
- Material parameter generation requires optimization
- Material parameters are 'smeared' across the general model surface
- Risk of localized optima
- Independent validation of simulation is important



Stepwise approach

- Select solver: finite element: material model
- Use Systematic method
- Obtain complete experimental data
 - Real material
 - Actual conditions (temperature, orientation, rate, environment)
- Capture correct physical properties*
- Correctly convert to material model parameters *
- Confirm simulation accuracy by validation *

* steps requiring some expertise



Need for documentation & traceability

- Material properties depend on
 - Composition
 - Processing
 - Test conditions (temperature, rate, environment)
 - Test Lab (instrument, technicians ...)
- Data quality depends on
 - Replication
 - Statistical analysis / choice of representative value
- Material parameter conversion depends on
 - Conversion method & expertise of analyst



Using Digitalization Software

- Capture all the details about
 - the material :
 - composition, processing, availability
 - experimental tests
 - all tests, parameters, variables, source
 - material parameter conversion
 - source material data, conversion process, documentation
 - target solver, material model, unit system
 - validation of simulation
 - Model tuning



Digitalization software- composition

Store detailed compositional information about a composite layup

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Digitalization software- processing

- Processing can affect material properties
- Processing can involve multiple steps
- Store detailed information about processing



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Digitalization software- material data

- Capture data for each replicate from the physical test
- Capture variation in properties with orientation, rate, temperature or other parameters





Digitalization software- traceability

- Capture details of the physical test
- Sample information
- Test parameters
- Test lab and technician

Satisfy the ISO 17025 data reporting requirement





Material Parameter Conversion

- Models often do not use data as measured
 - Conversion calculations are needed
 - Equations must be fit to data
 - Created files and process used are stored



When to use simulation-driven conversion

- Scientifically measure all possible parameters
- Utilize simulation only for the unmeasurable
 - e.g. Stress triaxiality at failure
 - Falling dart is a biaxial experiment
 - Measured biaxial fail strain for ABS is 1.8 (Ericssen Cupping experiment combined with DIC, with advice from Dr. H. Gese.)





Validation of Simulation

- Use target solver, element type, material model
- Use experiment that can be accurately simulated
 - Standardized case, relevant load case
 - Falling dart test for impact
 - Ribbed plate test for elasto-plasticity of polymers
 - Open hole tension for composites
 - Compressive squeeze test for rubber
 - Quantitatively compare simulation to test



Additively manufactured lattice structure





Composites- Open Hole Tension DIC

Confirm that the simulation can predict complex case

- Complex layup- [-45/02/45/90/45/02/-45/0]s
- Complex test Open hole tension ASTM D5766

Experimental strains by digital image correlation (DIC)









Plastic- Impact phenomena









Plastic- DIC strain field validation



Abaqus DIC





Conclusions

- A systematic approach yields a robust basis for simulation
- Material parameter conversion process should be consistently followed
- Digitalization is important to capture diverse data and maintain traceability
- Validate simulation using robust & relevant test case before real life application