Modelling of flow-drill screw connections in large-scale crash analyses

Johan Kolstø Sønstabø, PhD, Enodo

David Morin, Associate professor, Simlab (NTNU)
Magnus Langseth, Professor, Simlab (NTNU)

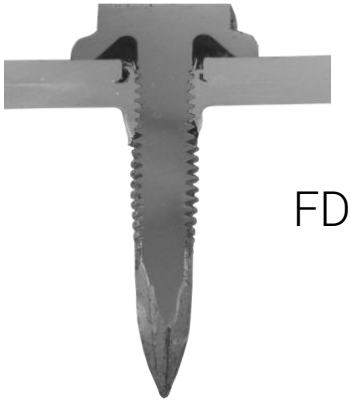
Outline

- Context and motivation
- Macroscopic modelling of FDS
- Calibration and validation procedure
- Component test simulation
- Remarks

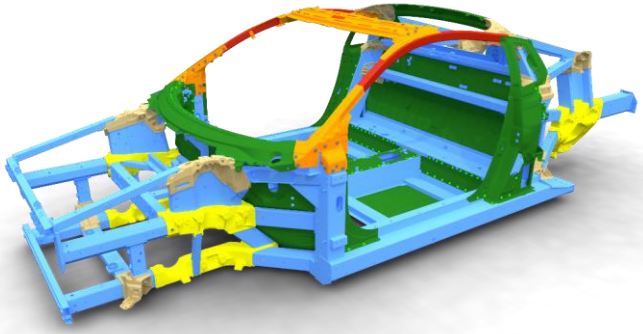
Enodo

Context

- Lightweight vehicle design.
- Many dissimilar materials.
- Different joining techniques utilized.
- Flow-Drill Screw (FDS) connections.



FDS

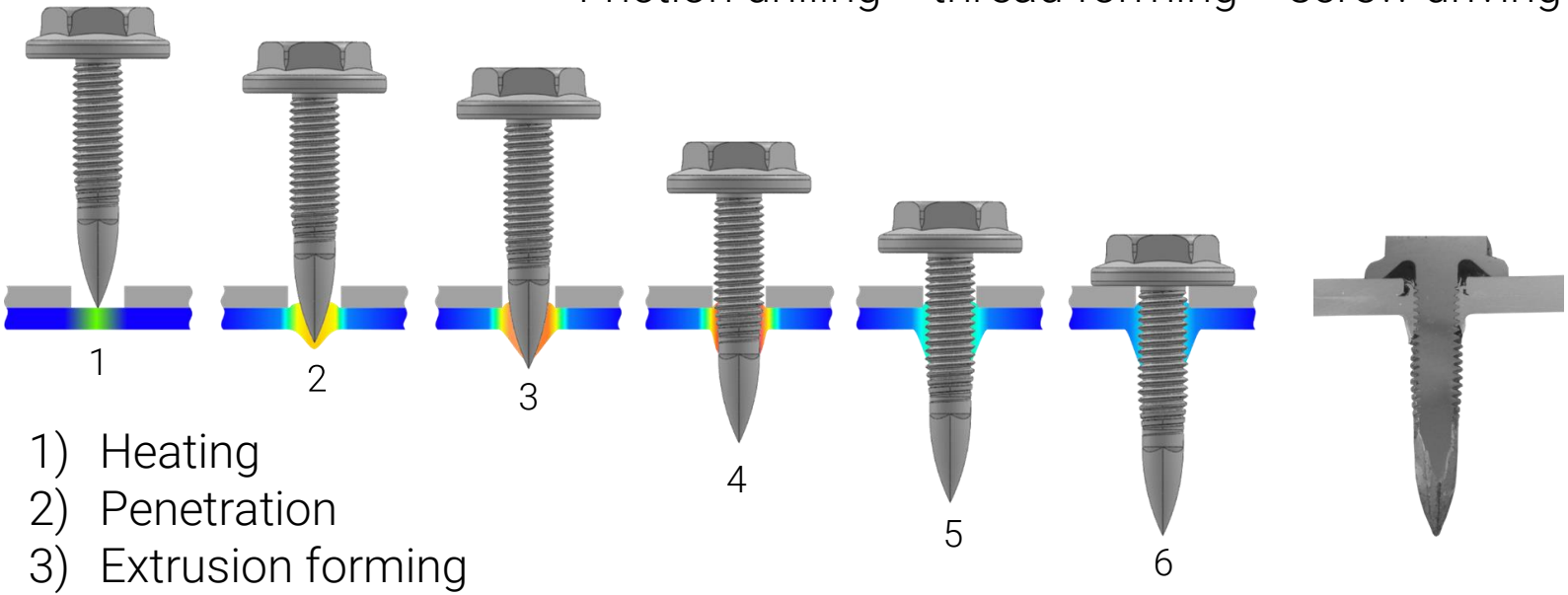


Aluminium ablation castings
Aluminium GDC castings
Aluminium extrusions
Aluminium sheets
UHS steel
Steel sheets

*Image courtesy of Honda R&D Americas, inc.

The FDS process

Flow-drill screw =
Friction drilling + thread forming + screw driving

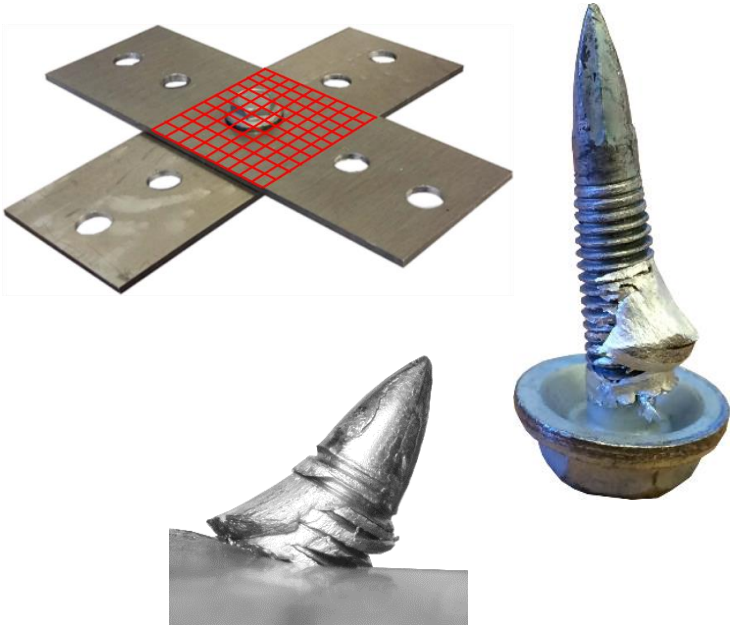


1) Heating
2) Penetration
3) Extrusion forming
4) Thread forming
5) Screw driving
6) Tightening

Enodo

Motivation

Large-scale finite element simulation

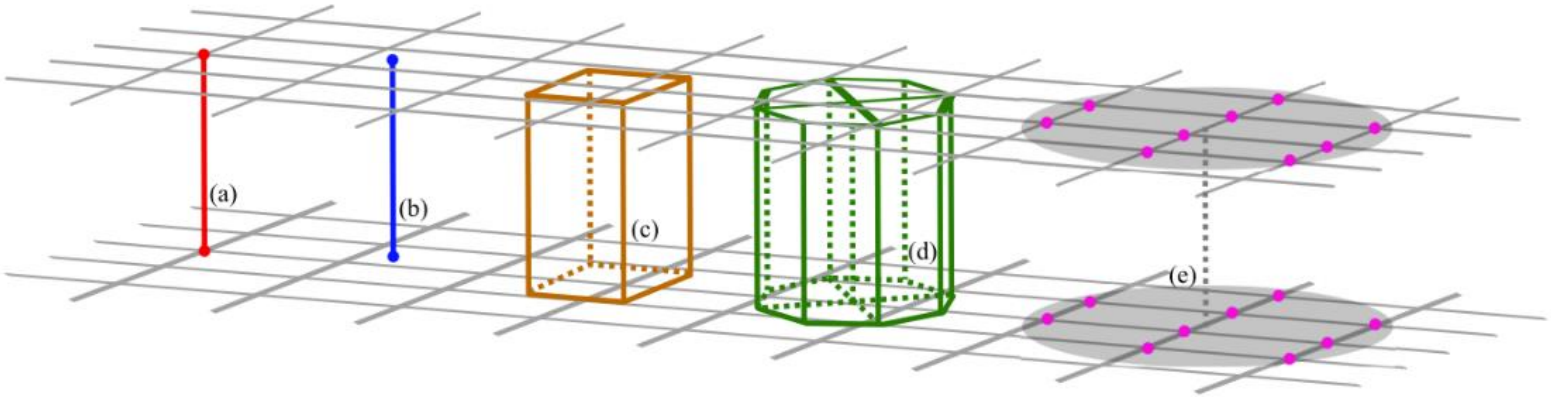


Simplified macroscopic modelling techniques required:

- Low CPU cost.
- Reasonable calibration procedure.

*Image courtesy of Honda R&D Americas, inc.

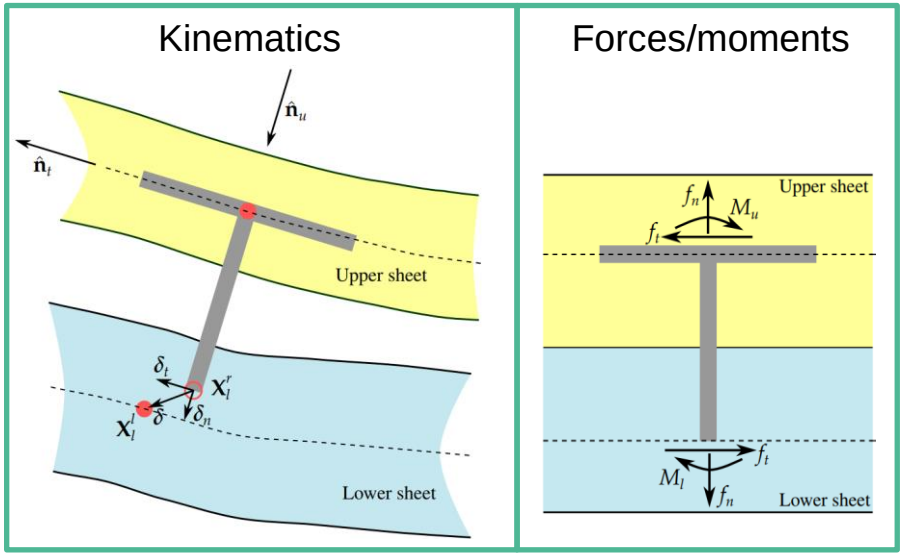
Macroscopic modelling of FDS

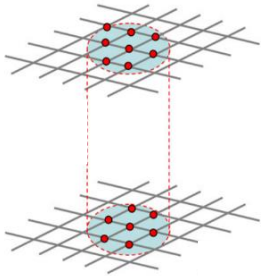


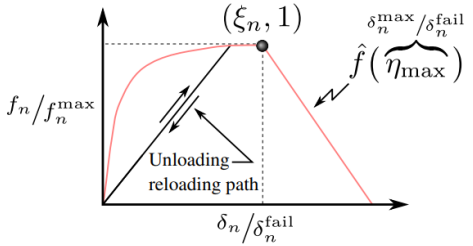
Enodo

Macroscopic modelling of FDS

- Connection modelled with `*CONSTRAINED_SPR2`.
  - Diameter.
  - 3 tension parameters.
  - 3 shear parameters.
  - 3 “mixed” parameters.
  - 2 load shape parameters
  - Optimized to match simulation force-displacement curves to tests results.





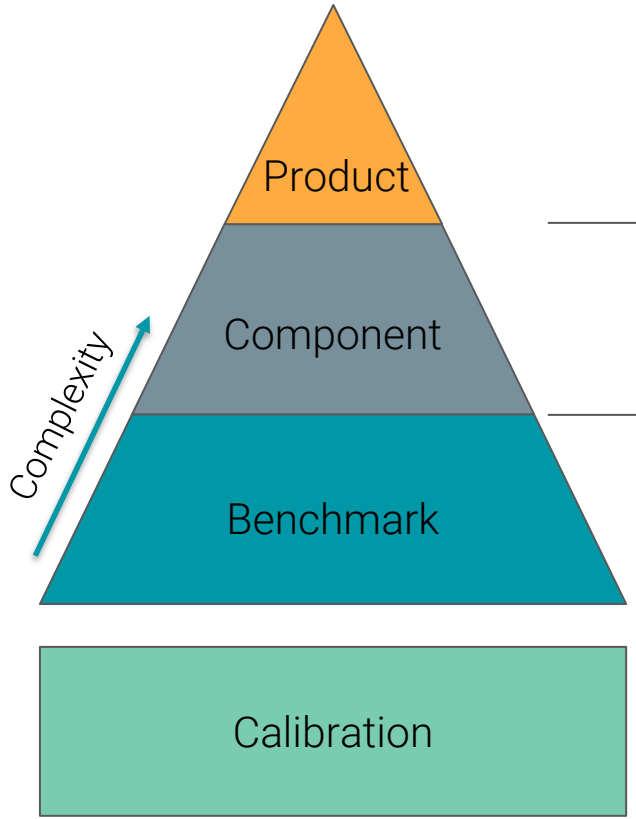


Limitations of macroscopic modelling of FDS

- Deformation and failure not always correctly predicted.
- Stress- and deformation fields are complex (rotation of screw, large plastic deformations and failure of plate material).
- Mimicking the global behaviour.
- Represented by mathematical constraints, the connection is not physically modelled.
- Geometric features (e.g. screw head and tail) not manifested in the model.

Enodo

Calibration- and validation strategy



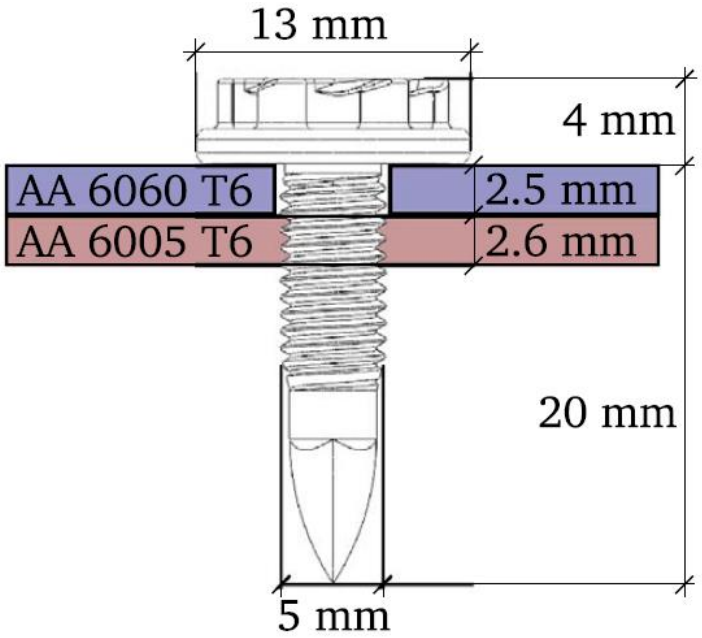
Highly complex (e.g. automotive crash models).

More complex and uncontrolled loadings.

Challenge model with different loadings,
yet simple and “controlled”.

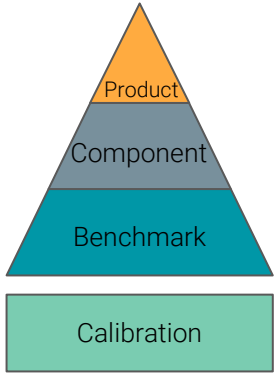
Calibrate to tests under simple and controlled loading.

Connection and materials

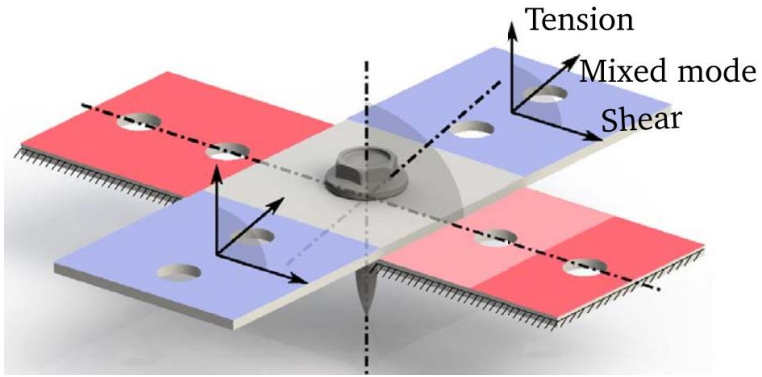


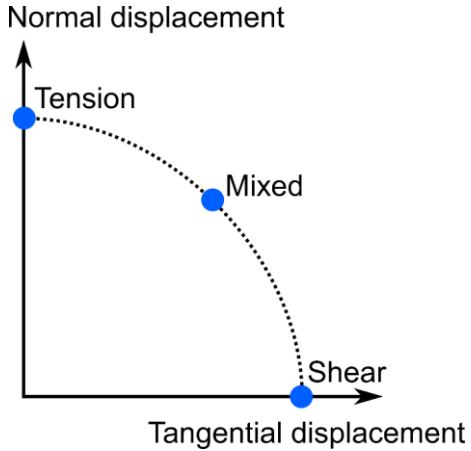
Enodo

Single-connector testing



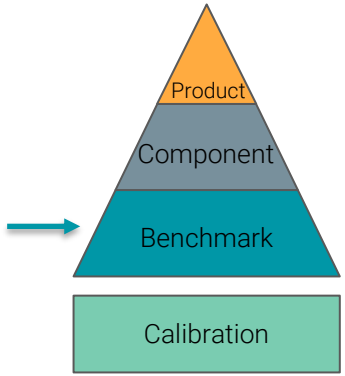
Cross tests



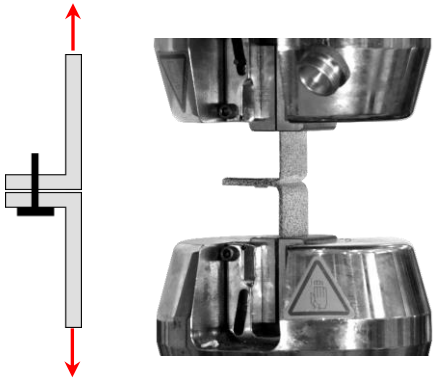


Enodo

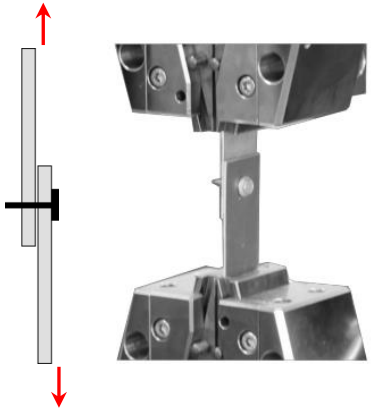
Single-connector testing

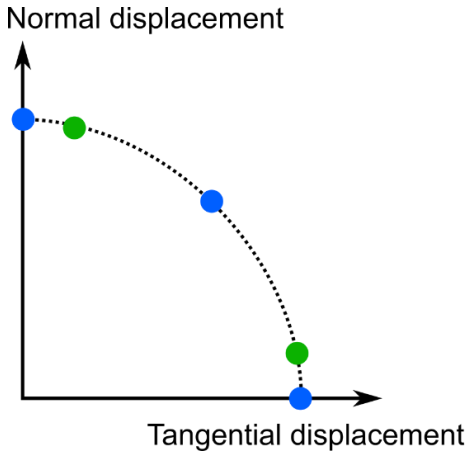


Peel test



Single lap-joint test

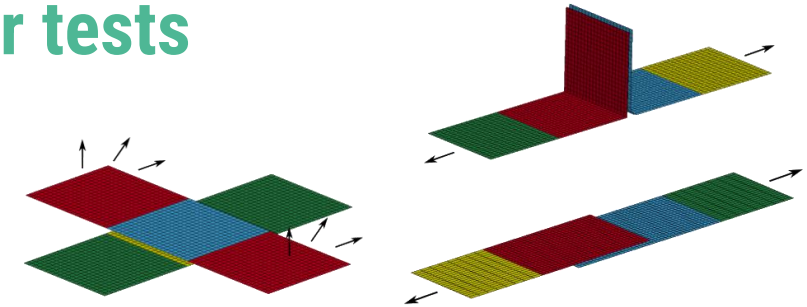


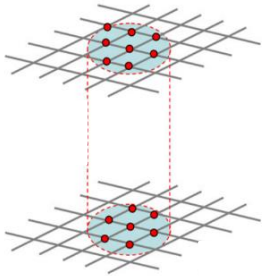


Enodo

Simulations of single-connector tests

- 3 mm x 3 mm shell elements (`ELFORM=16`).
- Clamped parts modelled with `*MAT_RIGID`.
- Surface-to-surface contacts.
- Time scaling applied (explicit analysis).
- Material model:
  - Hershey-Hosford yield surface (a=8).
  - Voce isotropic hardening model.
- Connection modelled with `*CONSTRAINED_SPR2`.



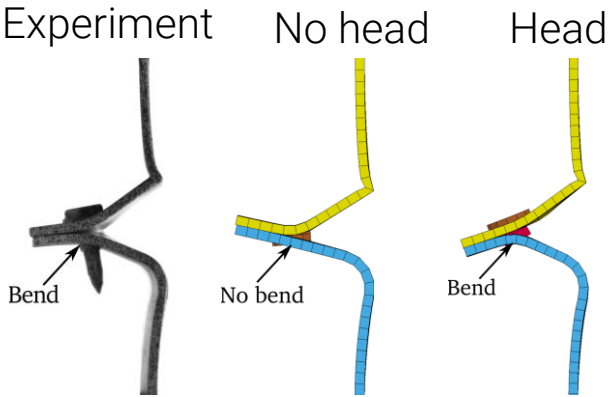


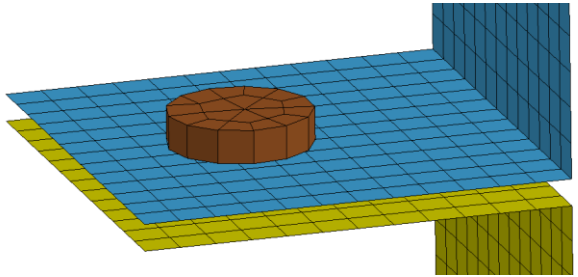
Enodo

Trick

- Not correct deformation in peel test.
- A “head” of solid elements was modelled with `*MAT_ELASTIC` and `*CONTACT_TIED_NODES_TO_SURFACE`.

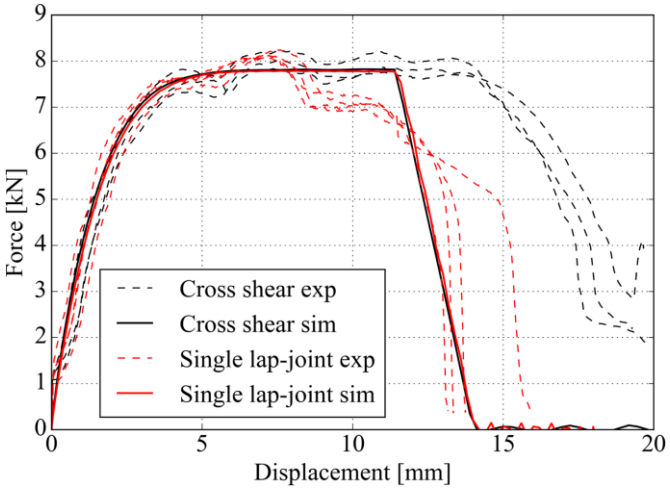
-> Better results.

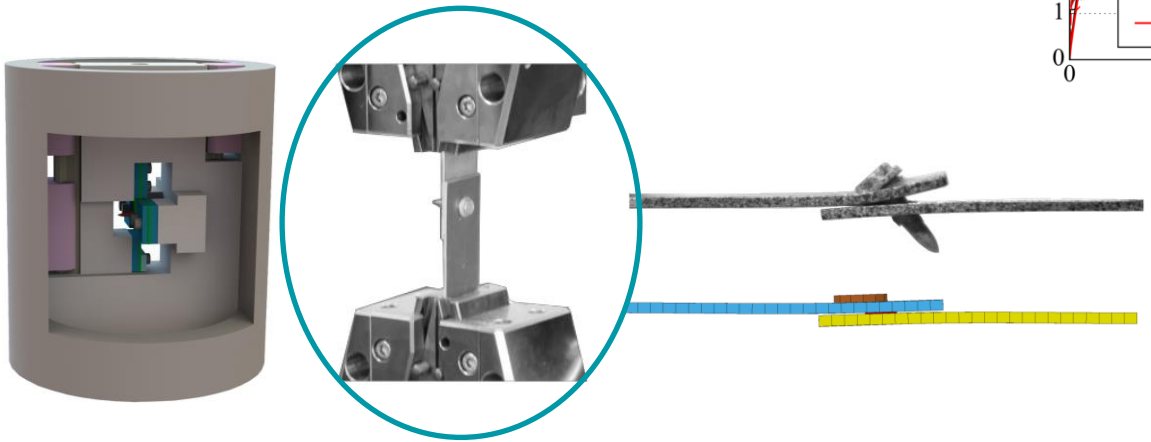


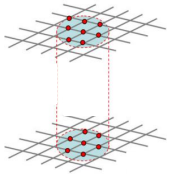


Calibration of macroscopic FDS model

- Significantly different behaviour in cross shear and single lap-joint tests.
- Not captured by the connection model.
- Must make a choice.







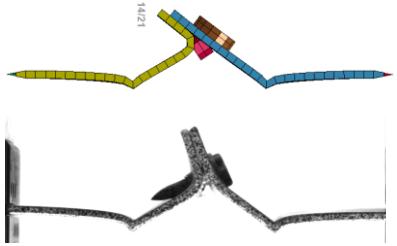
Enodo

Calibration of macroscopic FDS model

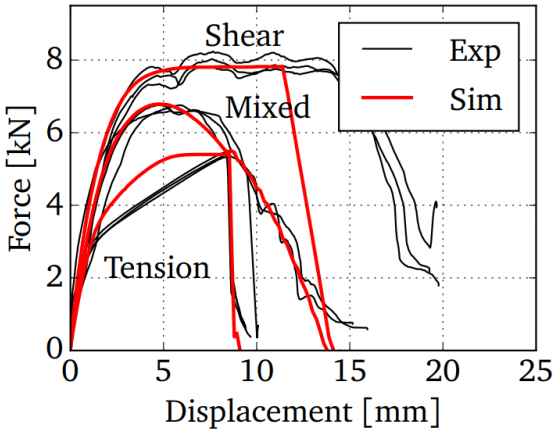
“Tail effect”

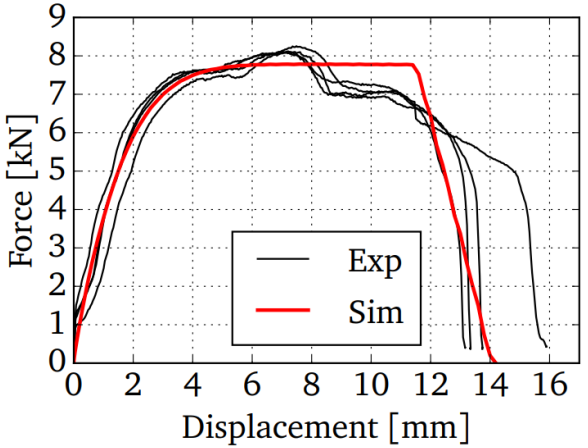
Cross

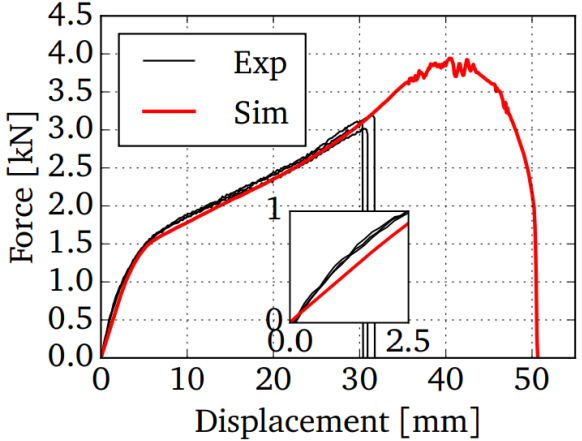
Single lap-joint



Peeling

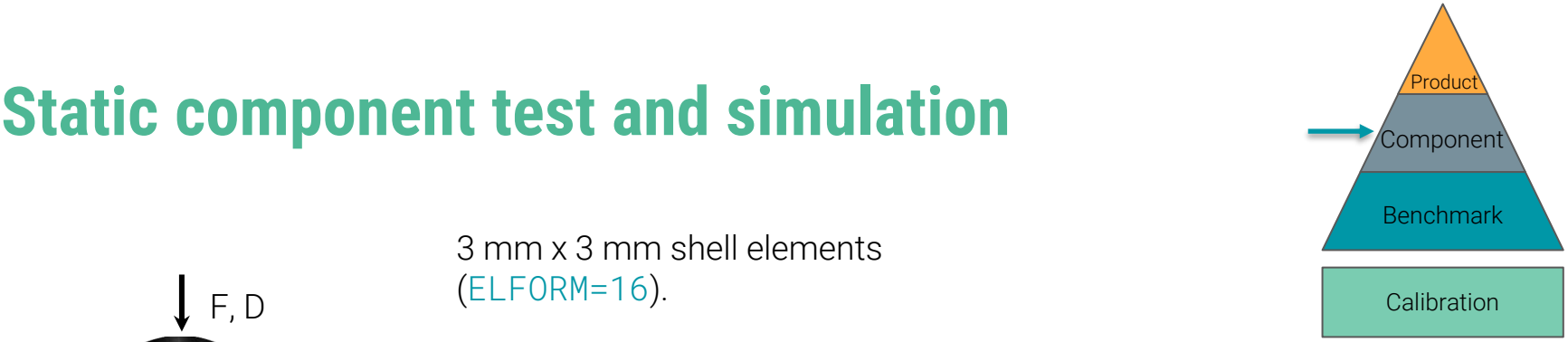


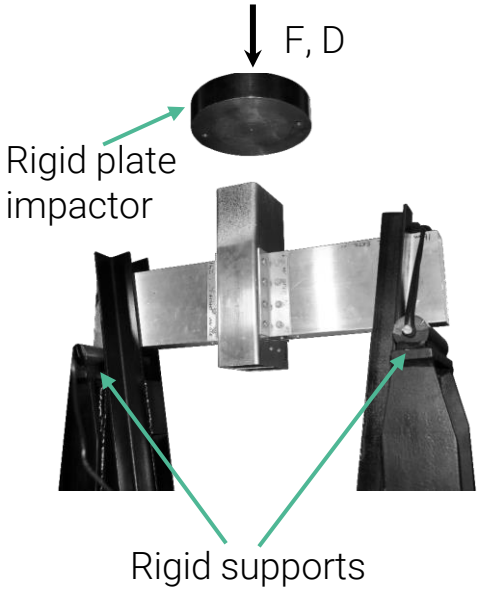




Enodo

Static component test and simulation





3 mm x 3 mm shell elements (`ELFORM=16`).

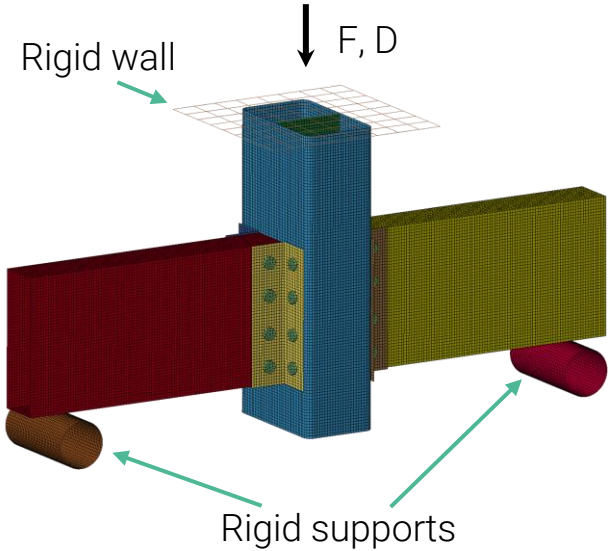
Supports: `*MAT_RIGID`.

Impactor: `*RIGIDWALL_GEOMETRIC_FLAT_MOTION`

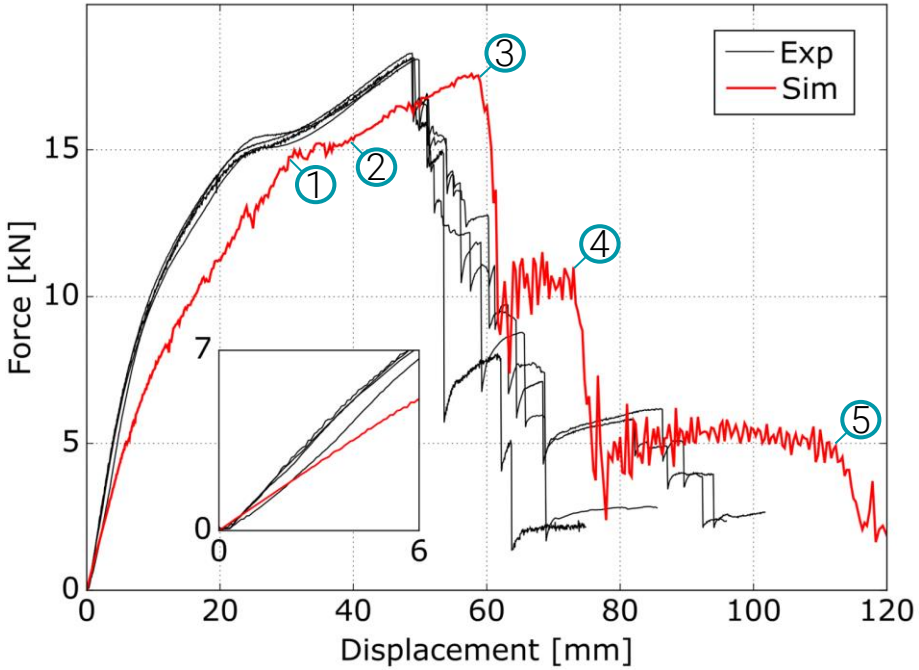
Surface-to-surface contacts.

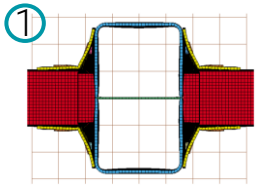
Time scaling applied.

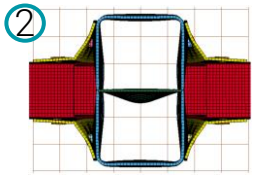
FDS modelled with `*CONSTRAINED_SPR2` and “head”.

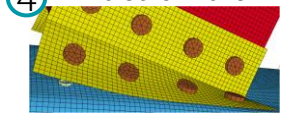


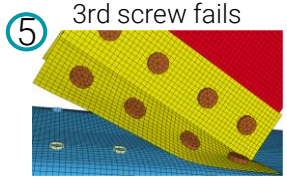
Static component simulation

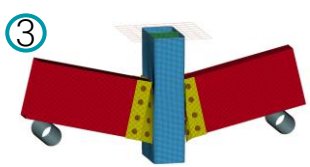


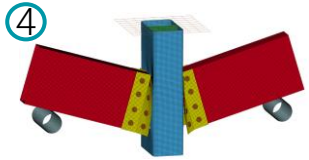


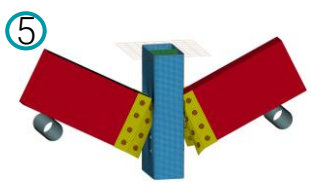






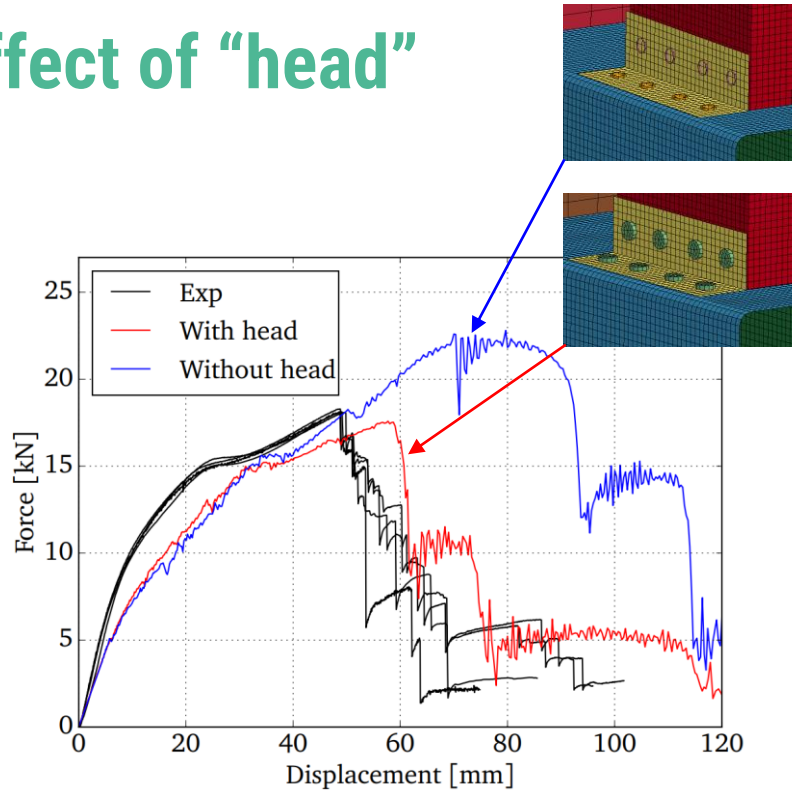


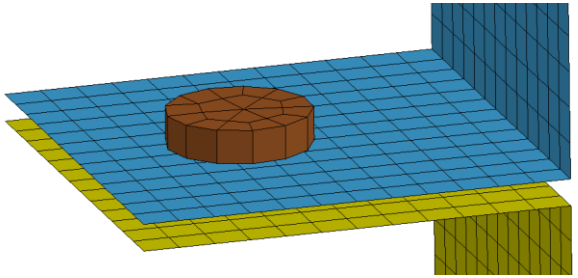




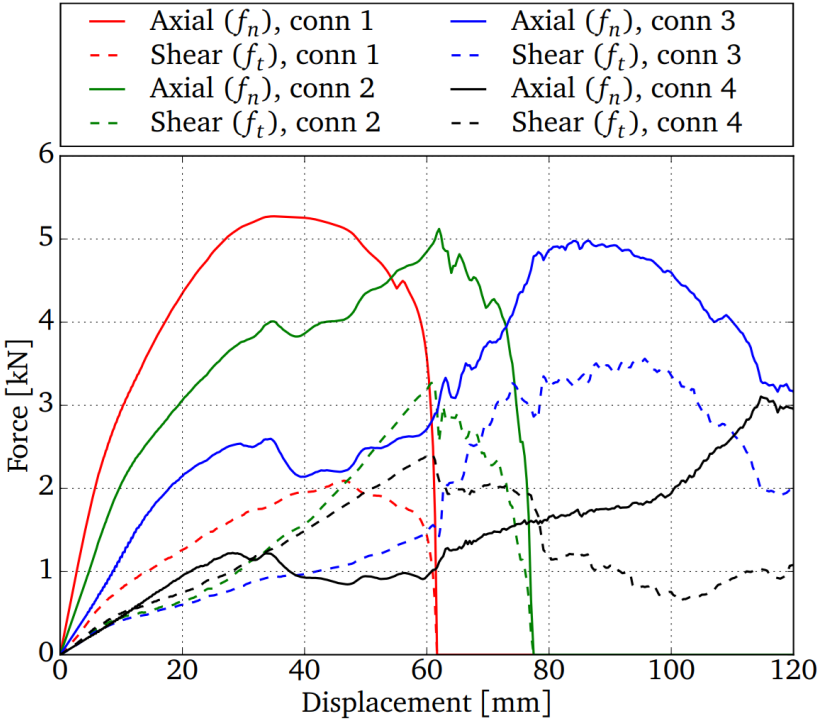
Enodo

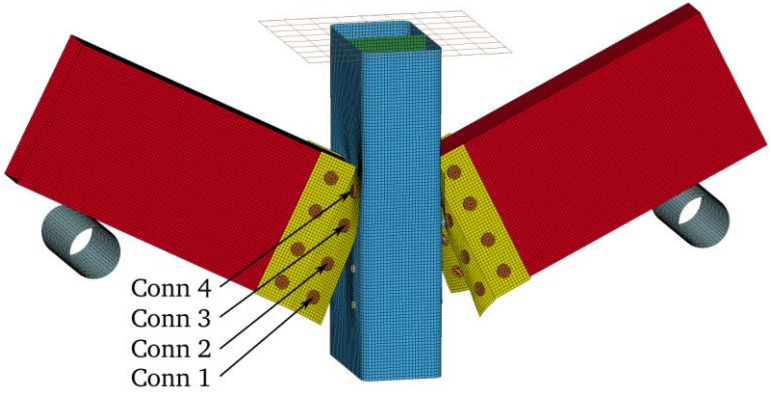
Effect of “head”



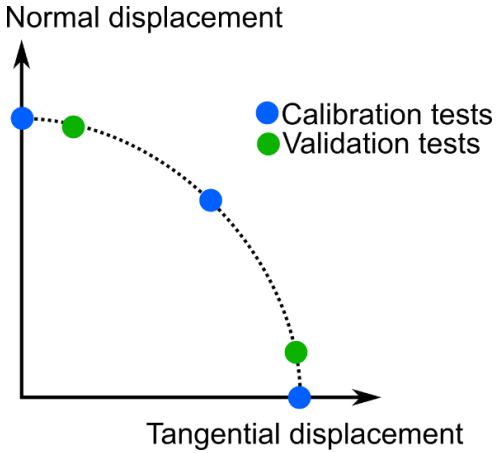


Local forces in connections





Tensile dominated



Enodo

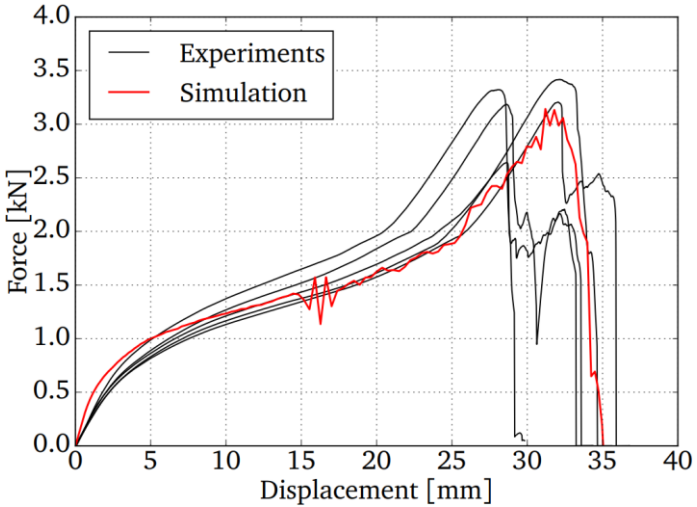
Remarks

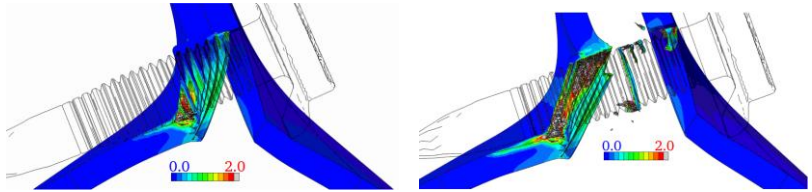
- Proposed modeling strategy for FDS connections gives satisfactory results.
  - Limitation: component test give tensile dominated loads.

- Expensive and time consuming:
  - Macroscopic modelling of connections requires experimental tests for calibration and validation.

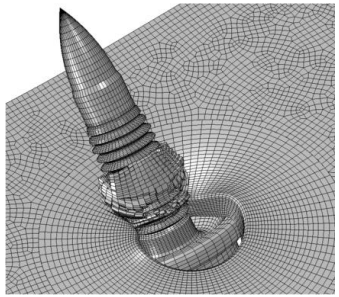
- Virtual testing:
  - Simulations on a smaller scale may be used to calibrate macroscopic models.

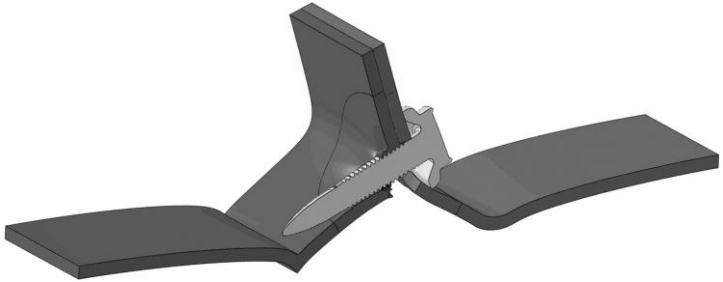
Virtual testing





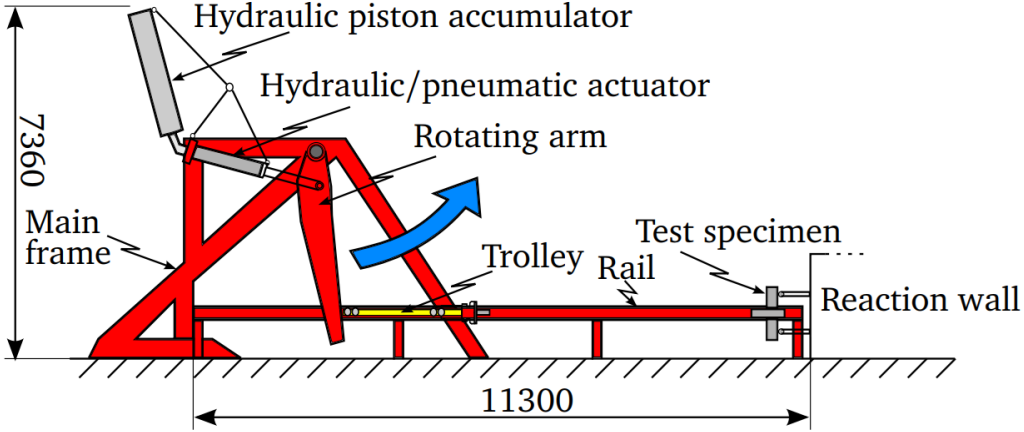
Equivalent plastic strain

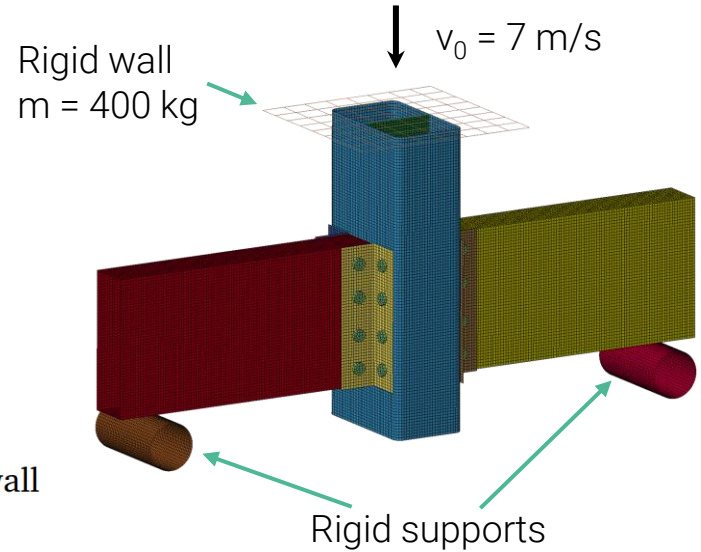




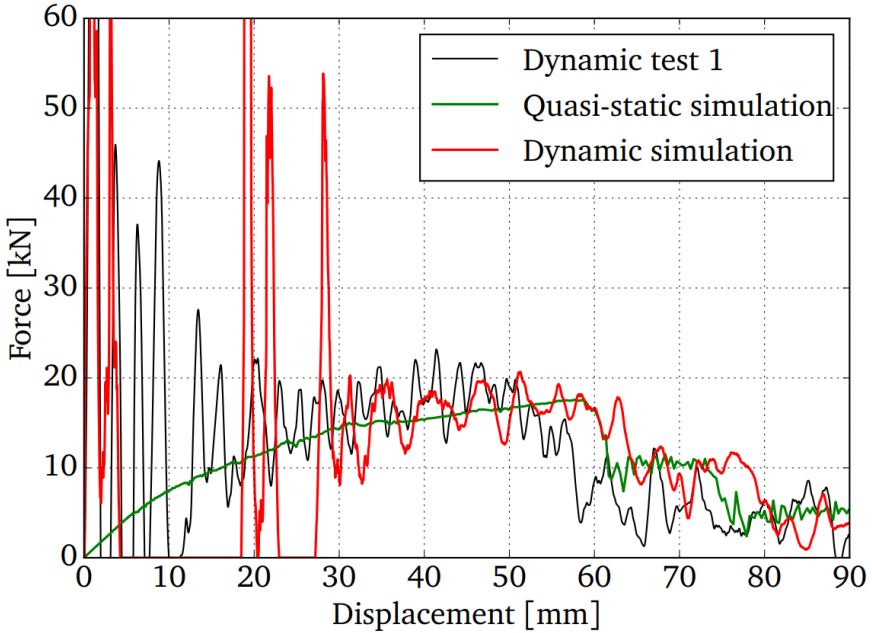
Dynamic component test and simulation

Similar simulation as the static case, but with
`*RIGIDWALL_PLANAR_MOVING_FORCES`





Dynamic component test and simulation

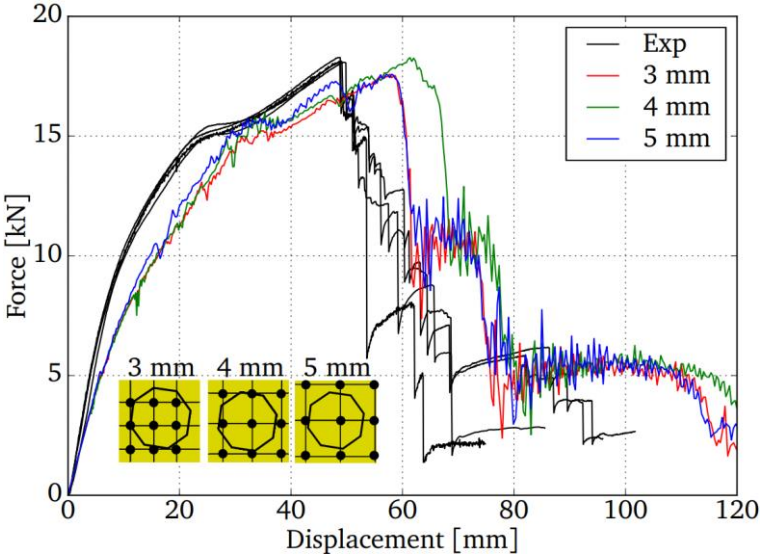


- Period with multiple impact hits longer in simulation, possibly due to lower initial stiffness.
- Similar behaviour after ~30 mm.
- Inertia forces in specimen did not alter the structural response.

Enodo

Effect of…

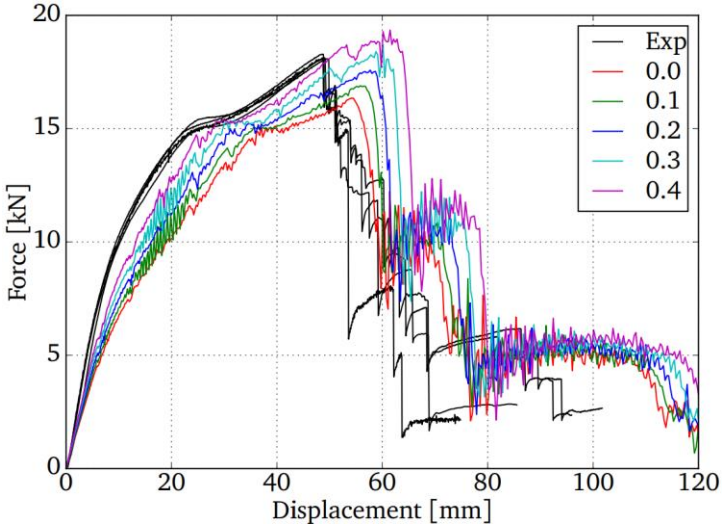
Element size



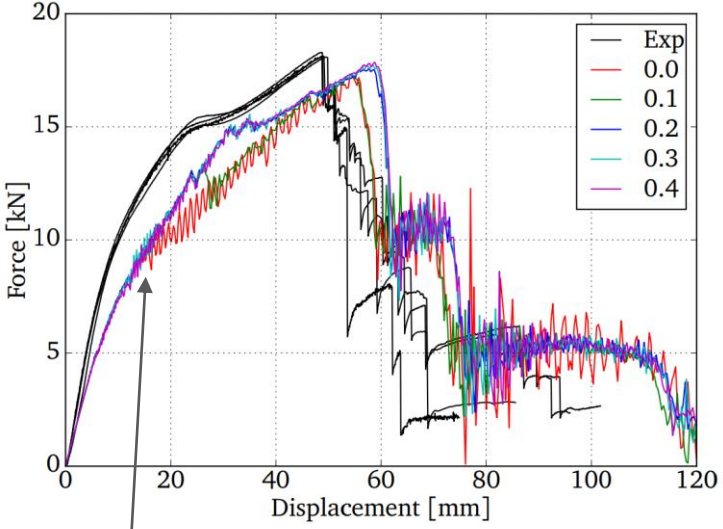
Enodo

Effect of …

Friction coefficient between specimen and supports



Friction coefficient between component parts



Change of deformation mode

Enodo · mail@enodo.no · www.enodo.no