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DAMAGE AND FAILURE PREDICTION OF COMPOSITE ROTORCRAFT BLADES UNDER COMBINED BENDING-TORSION LOADING

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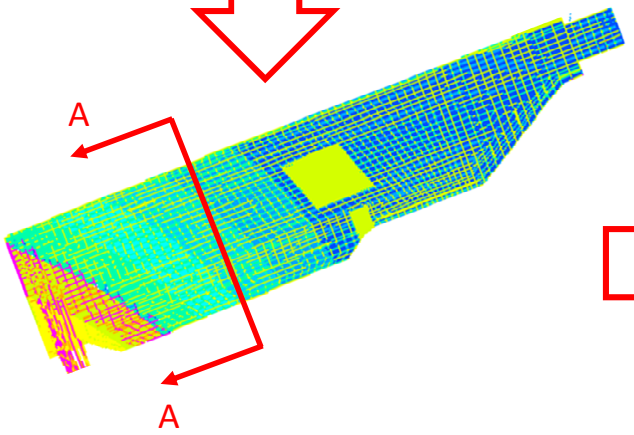
OUTLINE

- Motivation
- Objective
- Specimen Geometry & Instrumentation
- Test Setup
- Test Problems
- FE Model
- Results – Vertical Displacement
- Results – Longitudinal Strain
- Results – Torsion Angle
- Conclusions

MOTIVATION

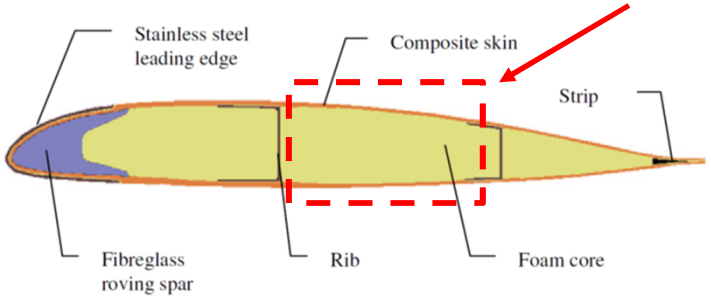
- New generation of dynamic composite parts
- Necessity to assess damage tolerance
- Static and fatigue
- Application for composite helicopter blades
- Technology Readiness Level (TRL ~ 4)

COMPOSITE HELICOPTER BLADES

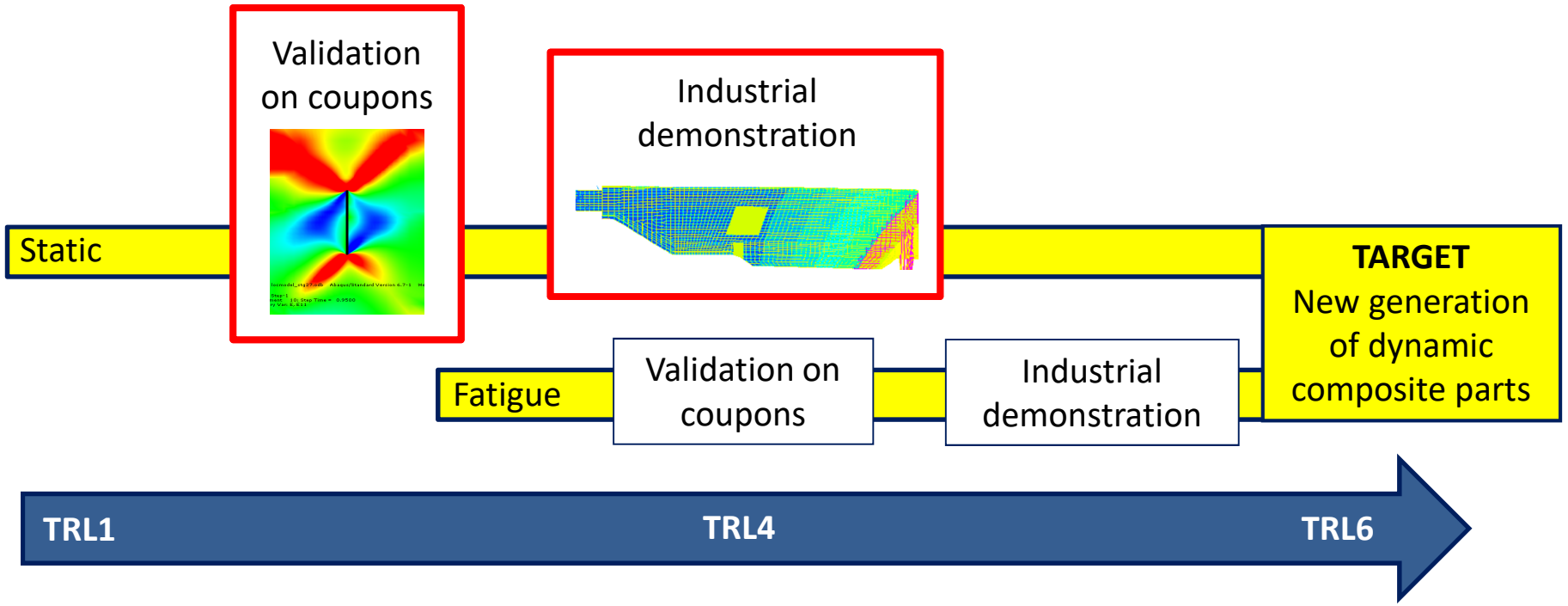


Section AA:

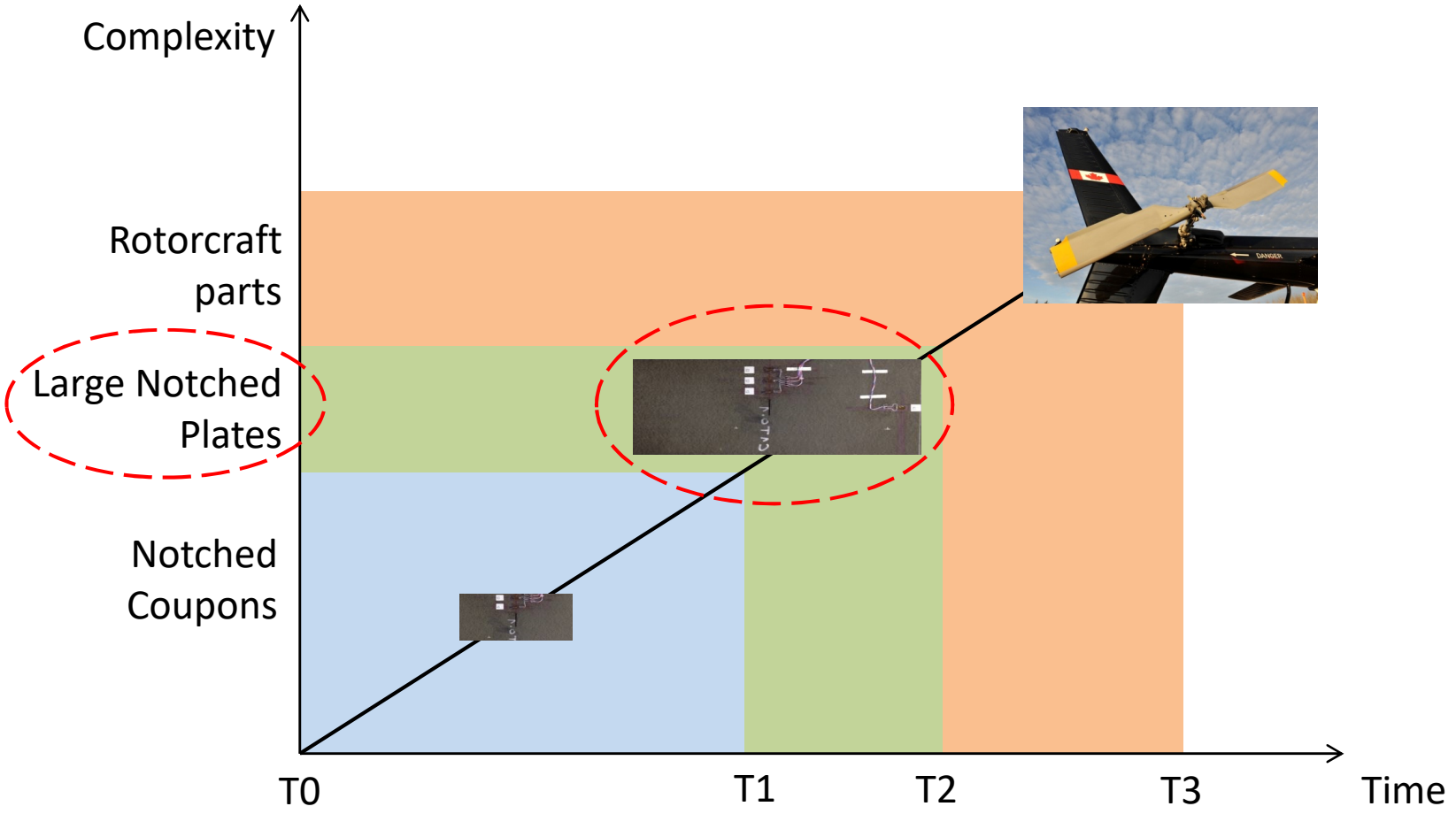
Sandwich-like component



TECHNOLOGY READINESS LEVEL

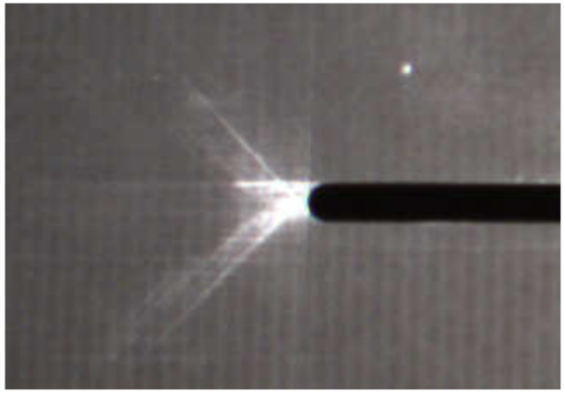


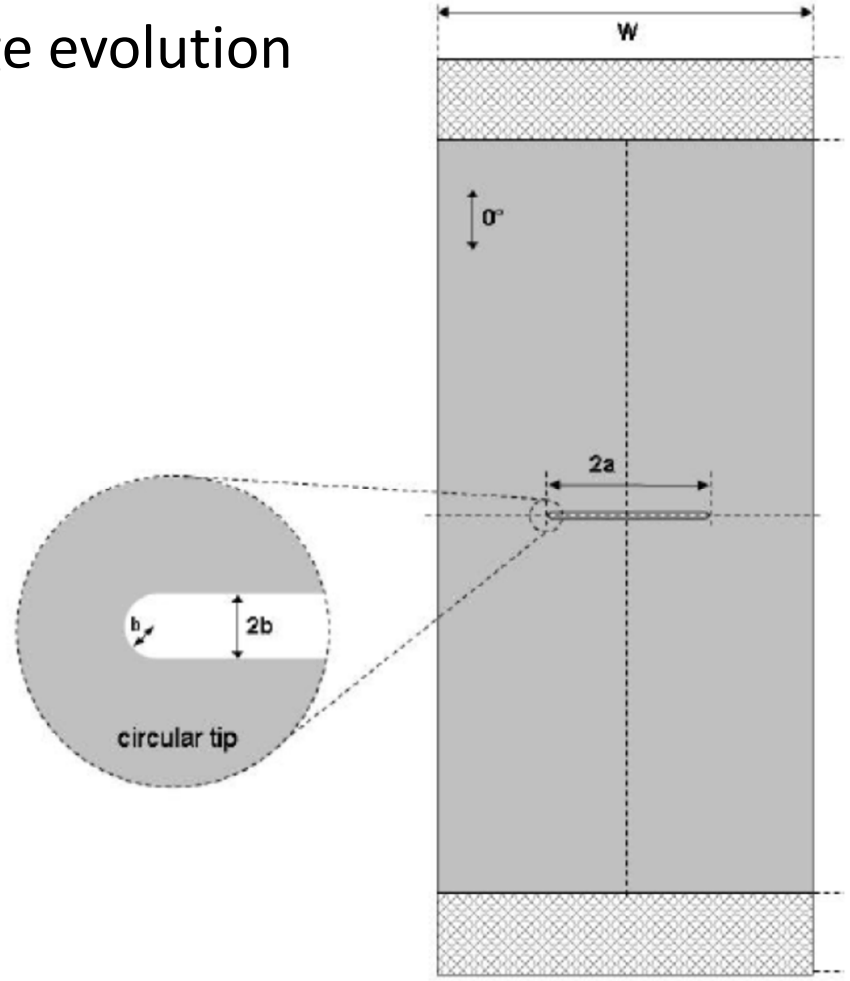
DEVELOPMENT TIME



DAMAGE SIMULATION

- Notch – More severe than usual operational damage
- Stress concentration – Damage evolution
- Static & Fatigue

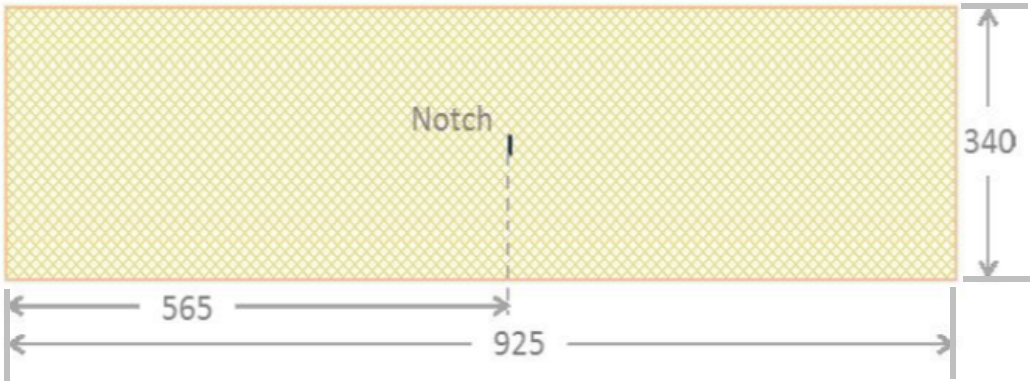




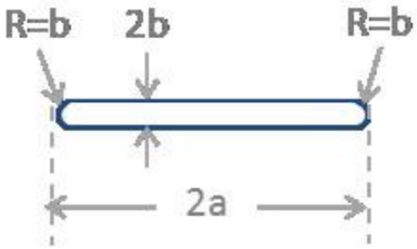
OBJECTIVE

- Use of notched sandwich panels as benchmark for helicopter blade design
- Perform experimental bending-torsion tests in notched sandwich specimens
- Use FE numerical tools to simulate progressive damage
- Limited to static bending-torsion loading
- Compare model predictions to experimental data

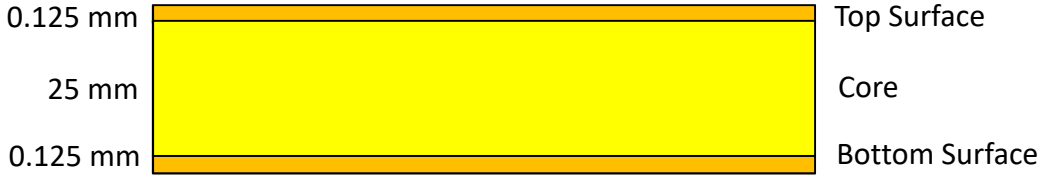
SPECIMEN – GEOMETRY & MATERIAL



Notch



Sandwich construction



Core: PVC Foam – Isotropic

E = 100 MPa

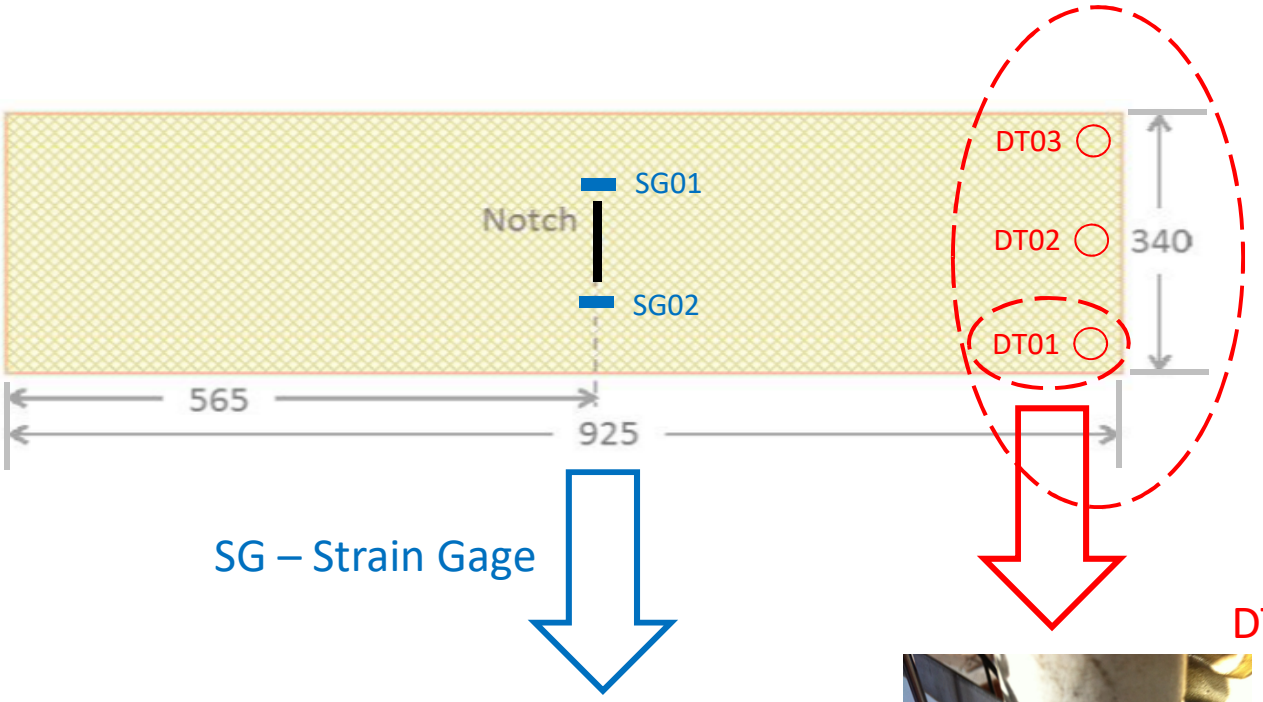
$\nu = 0.3$

Surfaces: Glass Fiber / Epoxy Fabric – Two plies @ 45° each

$E_1 = 23$ GPa; $E_2 = 21$ GPa; $G_{12} = 6.7$ GPa; $\nu_{12} = 0.3$

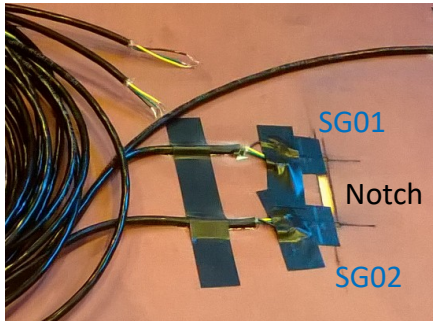
X = 360 MPa; X' = 360 MPa; Y = 540 MPa; Y' = 540 MPa; S = 95 MPa;

SPECIMEN - INSTRUMENTATION

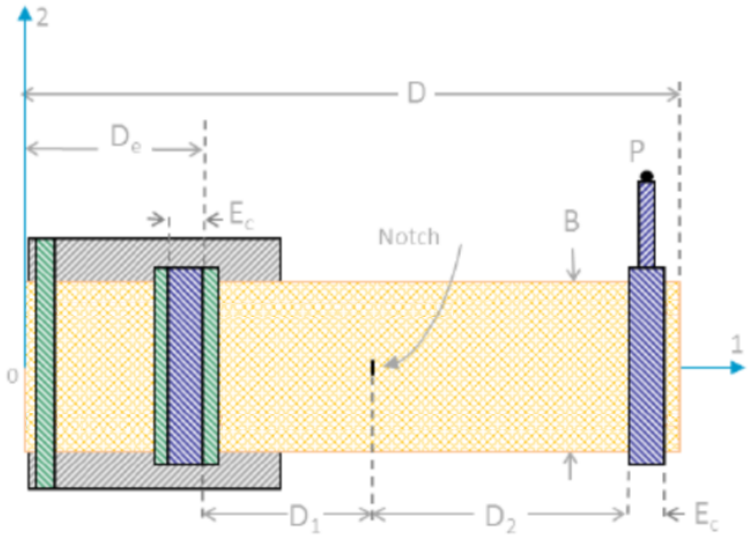


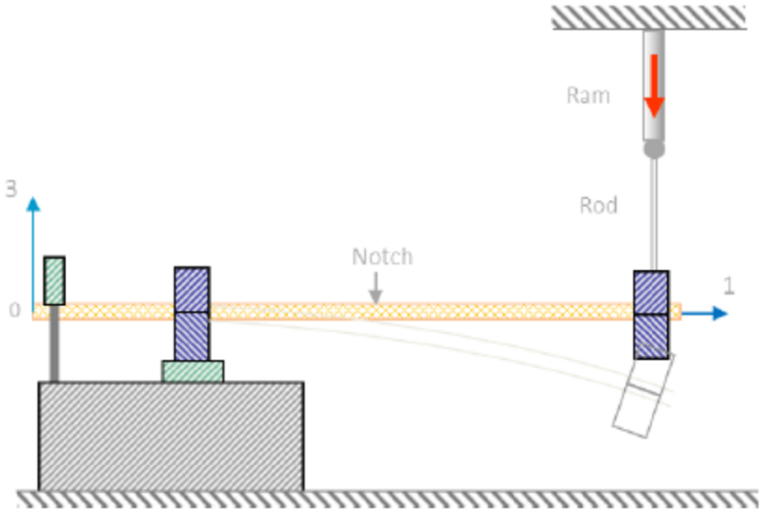
DT – Displacement Transducer

SG – Strain Gage



TEST SETUP

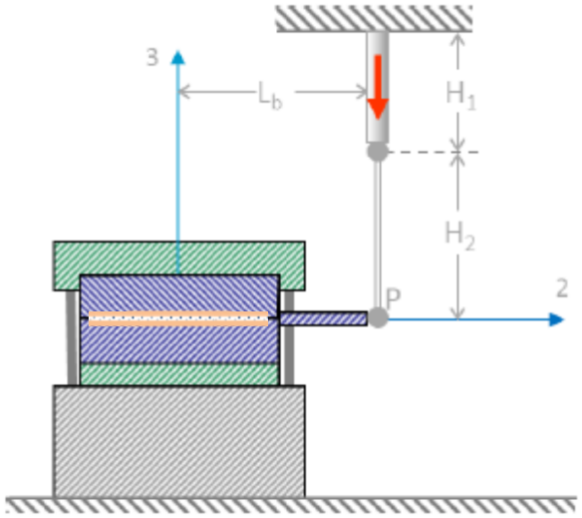




Loading: coupling bending-torsion

B (mm)	D (mm)	D_e (mm)	D_1 (mm)	D_2 (mm)	E_c (mm)
340	925	325	240	300	60

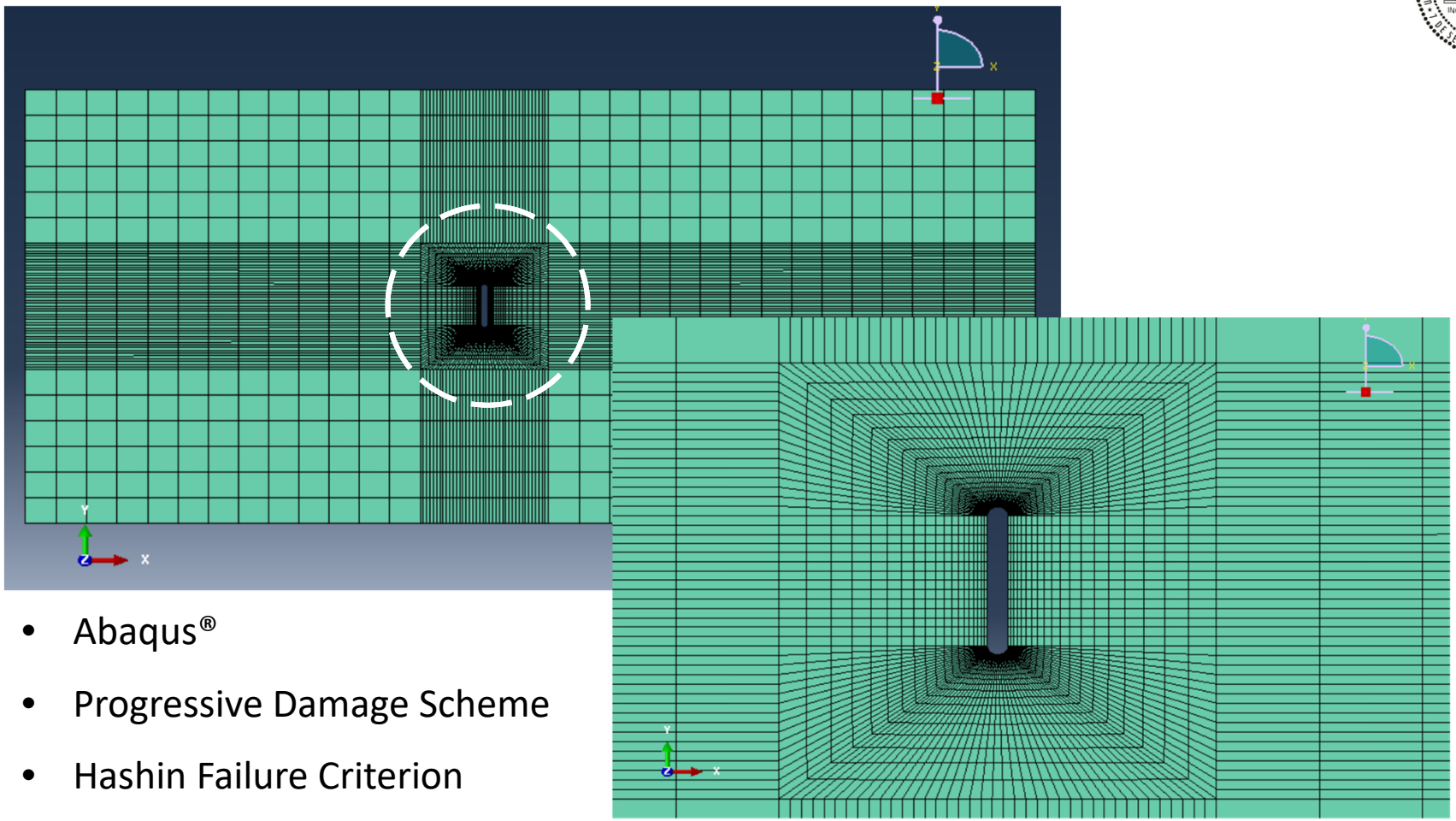
H_1 (mm)	H_2 (mm)	L_b (mm)
500	500	300



TEST PROBLEMS

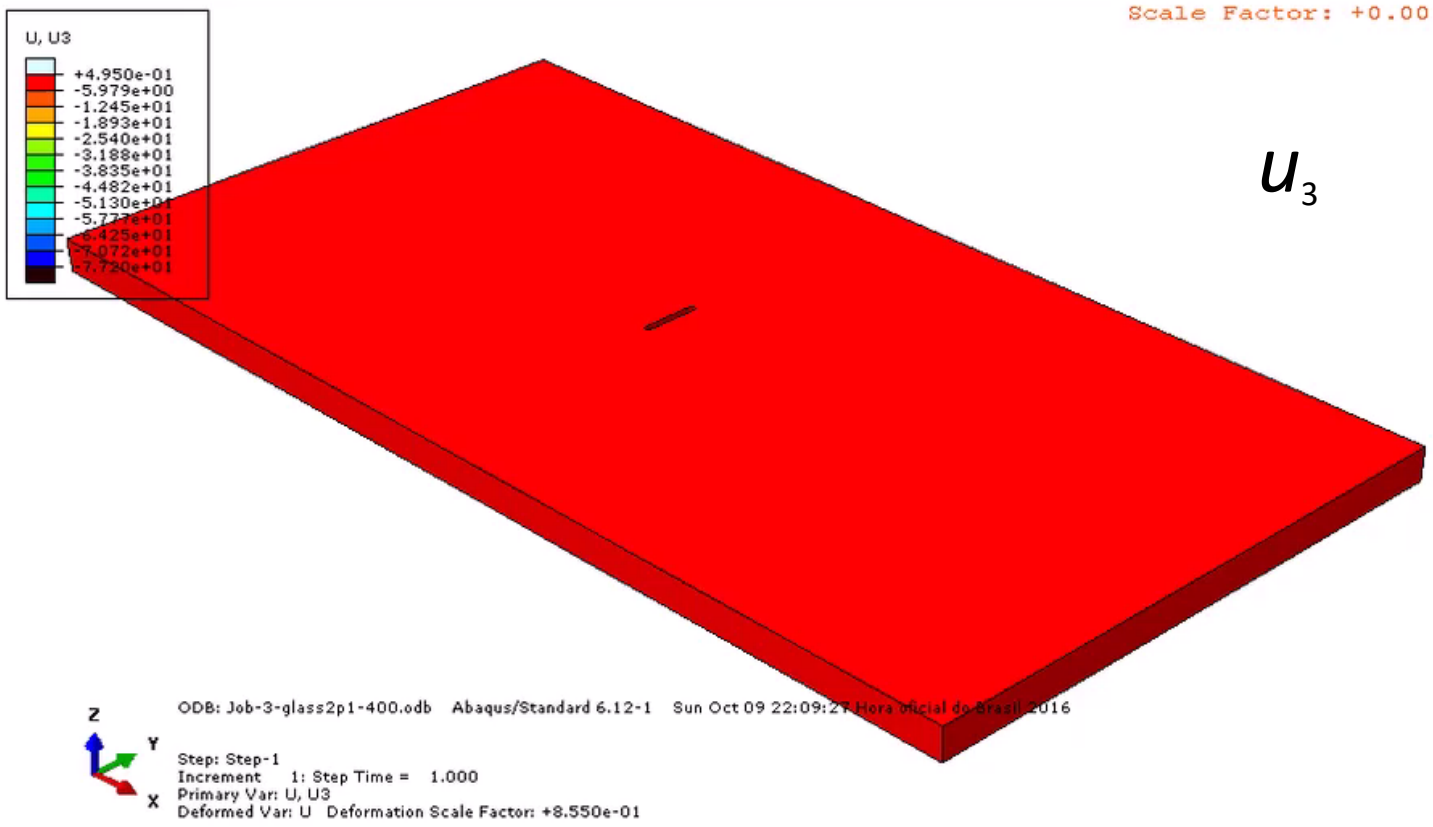
- Hydraulic jack failure
- Weight-step loading
- Specimens ill-designed
- Failure unexpectedly occurred in clamping region
- No progressive failure observed at notch tips
- Discrete loading – failure considered as last step
- Limited comparison model simulation vs. test results

FE Model



- Abaqus®
- Progressive Damage Scheme
- Hashin Failure Criterion
- 16,562 Nodes
- 5,380 3D Shell (Surfaces) + Solid (Core) Elements

RESULTS - VERTICAL DISPLACEMENT



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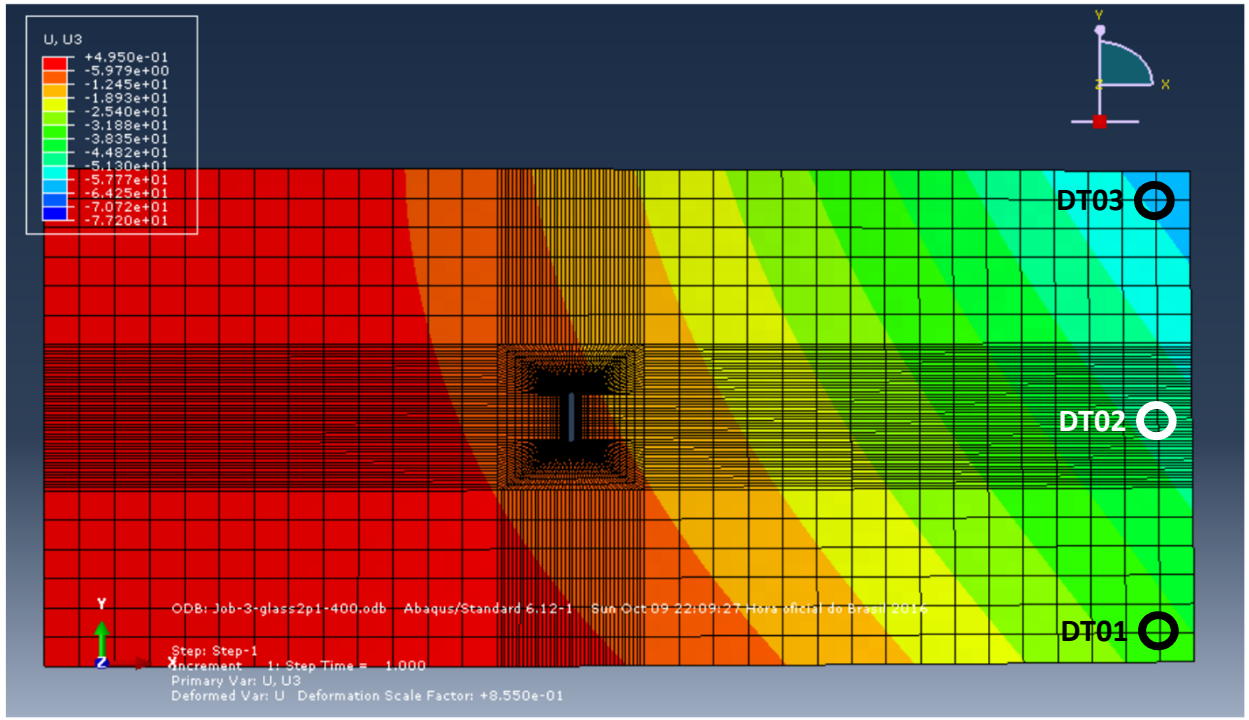

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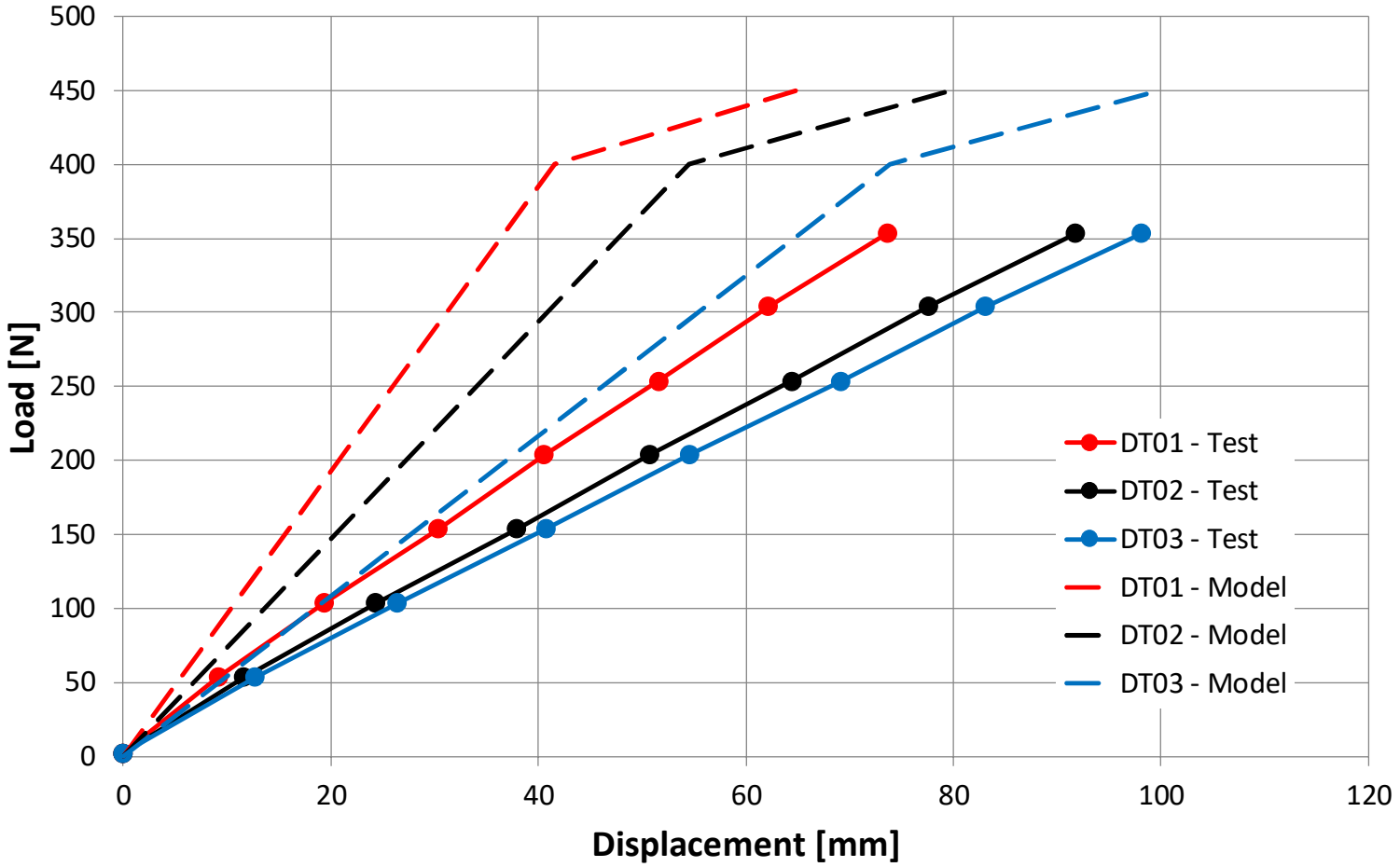
DT – Displacement Transducer

RESULTS - VERTICAL DISPLACEMENT



RESULTS - LONGITUDINAL STRAIN

ε_{11}

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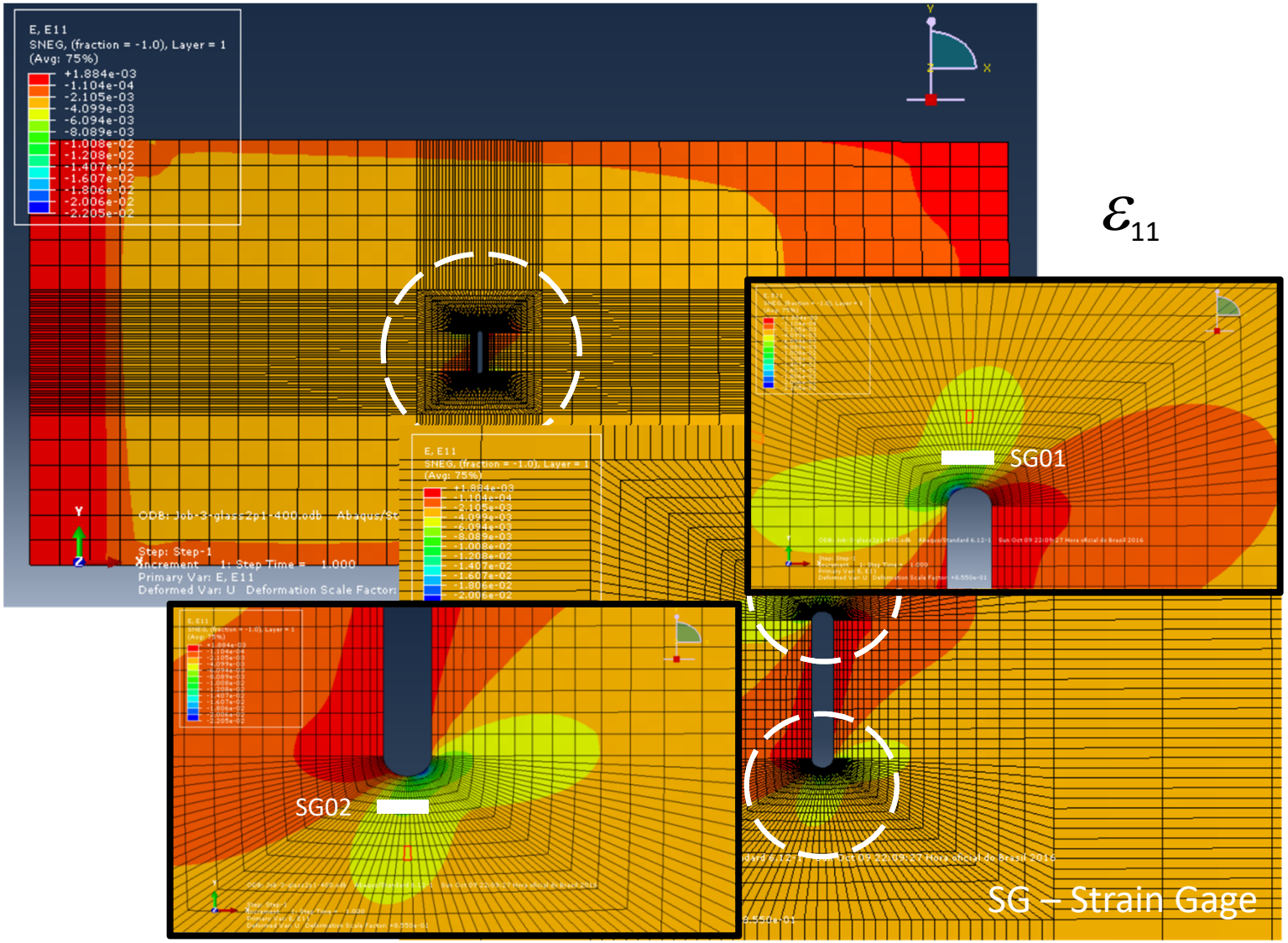

ε_{11}

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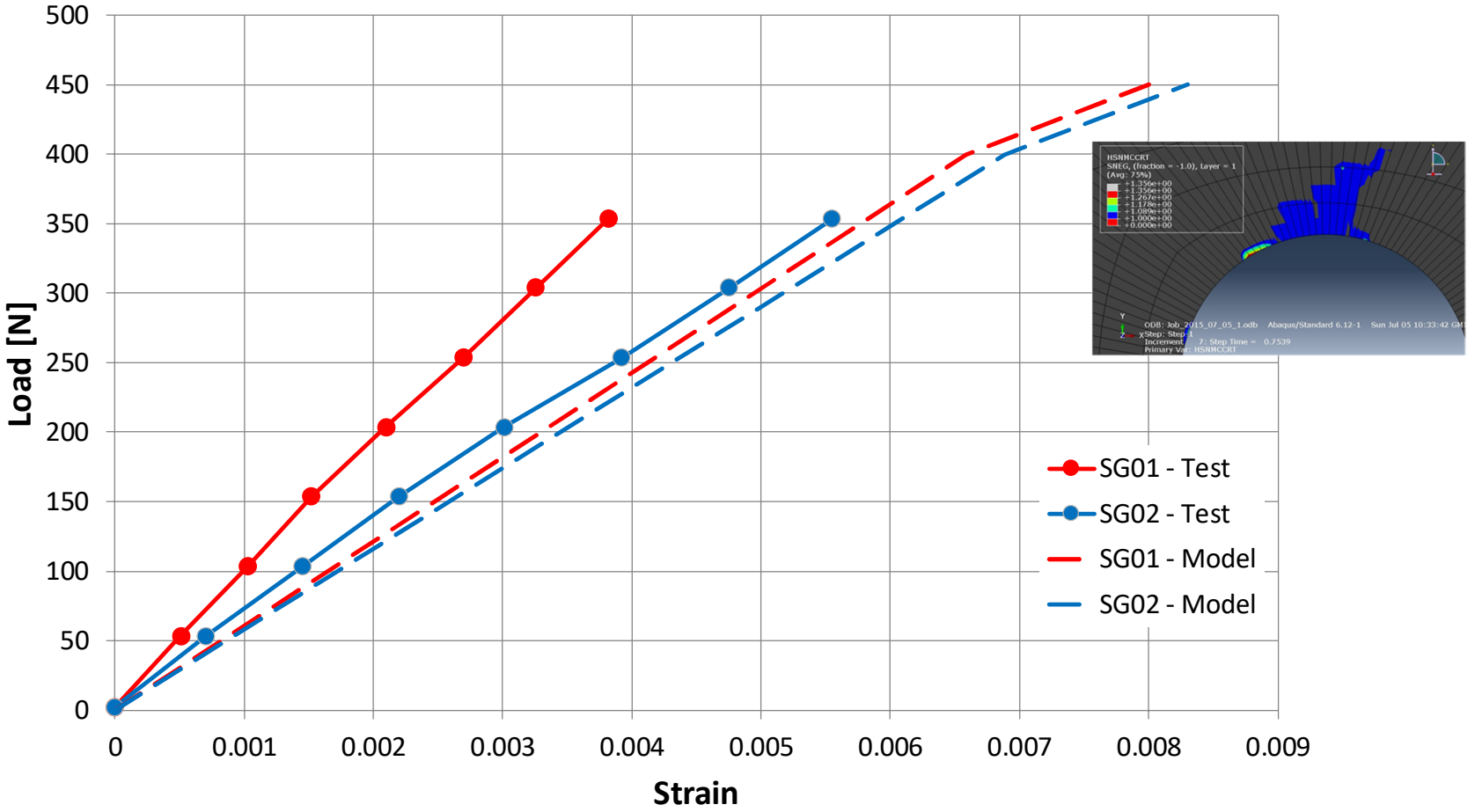
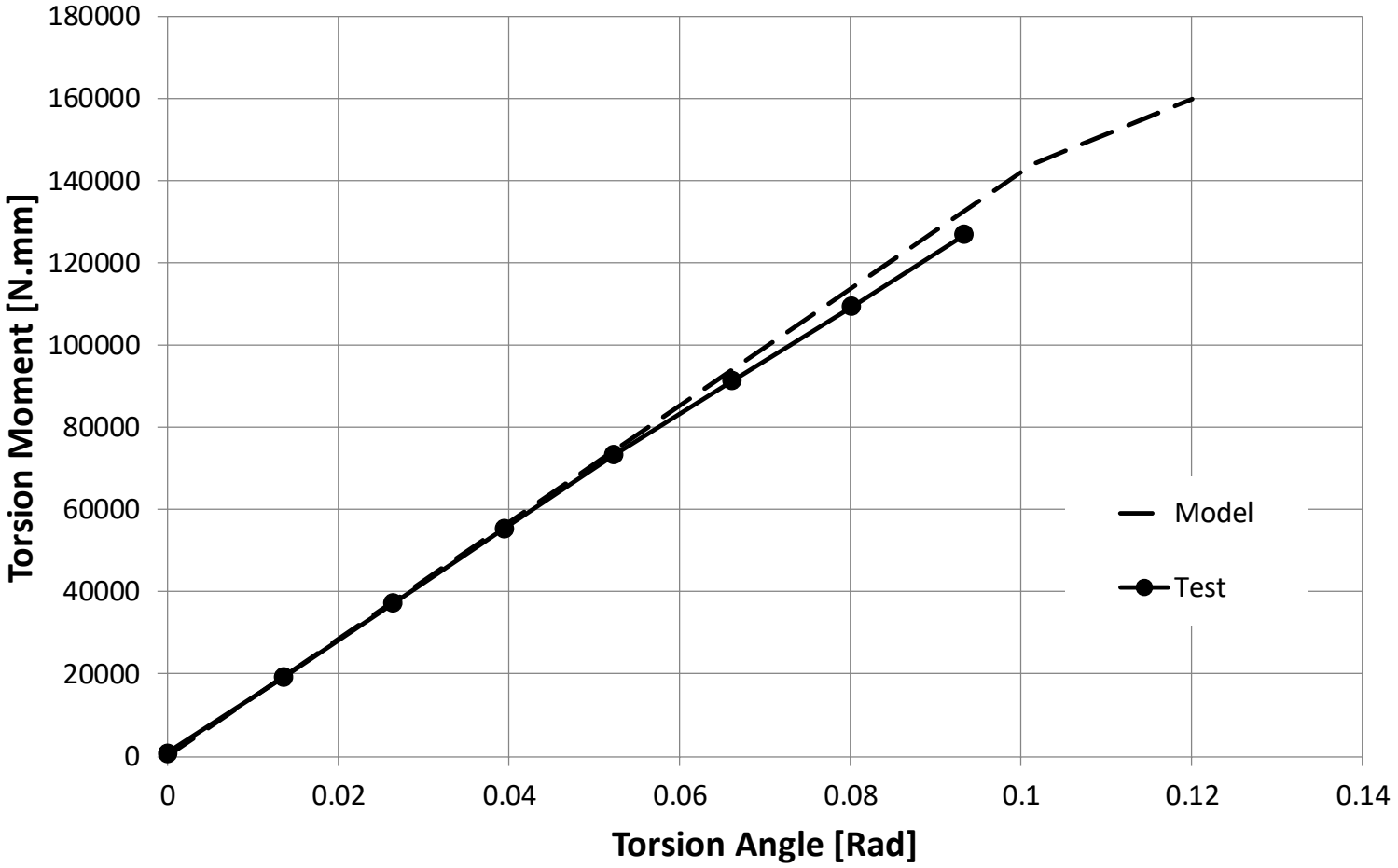


RESULTS - TORSION ANGLE



CONCLUSIONS

- Predictions presented a more rigid model than the test specimen for global vertical displacements
- Longitudinal strains at notch tips were lower than model predictions
- Torsion angle could be captured by model prediction
- Test problems limited results quality
- FE model too simple to predict test data accurately

FOLLOW-UP WORK

- On-going project
- Conclusion of test program
- More instrumentation and DIC for more quality test results
- Test set up more robust
- Limited model needs improvement
- Multiscale analysis with micromechanical failure criterion

THANK YOU!

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