Titanium has desirable properties in terms of strength to weight ratio, corrosion resistance, and biocompatibility [1]. This makes it an ideal candidate for structural applications in aerospace and biomedical components. Lattice structures (made of small individual struts) and thin-walled structures are typically more compliant than predictions from finite element simulations based on elasto-plastic beam theory [2]. Beam theory does not capture the stress concentration at sharp edges, and therefore does not predict the evolution of plastic zones properly. This work focuses on a T-shaped thin-walled structure.

**Goals:**
1. Deriving strains and yield surfaces using both Euler-Bernoulli beam theory and Abaqus simulations and identifying differences.
2. Computing a failure surface using Abaqus.
3. Assessing the evolution of plasticity after the onset of yield and its effect on mechanical behavior using Abaqus.

**Introduction**

- Models are 2D, and infinite width (out of page) is simulated using plane strain elements.
- The loads and boundary conditions are shown in red. Displacements are applied at the top, and the bottom ends are clamped.
- Two models, with and without grips. The model with grips is shown.
- The model without grips only consists of the top and bottom beam.
- The onset of yield and failure are only considered near the joint (where both beams meet).

**Geometry and models**

- Beam theory: $U_a -1 \text{ mm (horizontal elastic loading)}$
- Abaqus:
  - Yield Abaqus, without grips
  - Yield Abaqus, with grips
  - Beam theory, top beam
  - Beam theory, bottom beam

**Elastic Strains**

- Beam theory captures the deflections (not pictured here) in both beams very accurately, with slight deviations when loading horizontally.
- Elastic beam theory accurately predicts the strains in the system, at the exception of the joint itself (where both beams meet).
- The maximum strains occur at the fillets because of strain concentration.
- The strain concentration factors are close to 2, and depend on the direction of loading.

**Yield and failure surfaces**

- Beam theory: $\epsilon_{11} > \epsilon_{\text{yield}}$
- Yield Abaqus: Equivalent plastic strain (PEEQ) > 0
- Failure criterion Abaqus: PEEQ > 0.2

**Evolution of plastic zone**

- Strain concentration of a factor of around two at the fillet is the most important aspect for the onset of yield, and it not captured by beam theory. One could scale the results from beam theory by this factor to obtain satisfactory results.
- The structure is more resistant to horizontal loads than to vertical loads, and there is asymmetry with respect to vertical loads.
- At failure, a significant portion of the zone near the joint has undergone plastic deformation, therefore forming plastic hinges.
- The evolution of the plastic zones can be used as insights to create simplified models using beam elements that replace the joint with nonlinear springs, without the use of computationally expensive 2D finite element analysis.

**Conclusions**

**References**