

Investigating the Impact of Mounting Clamps and Frame Adhesive Joints on Glass Breakage of PV-Modules

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Motivation

- Significant increase in glass breakage in photovoltaic (PV) power plants using glass-glass modules with thin (~2 mm) glass [1,2].
- Faults often appear during installation or shortly after. Severe weather or damage during transport can be ruled out.
- An increasingly common type of glass breakage is occurring at clamping positions, often when using clamps with a groove or spikes for grounding
- **Question: Why do modules fail during or shortly after installation?**
- **Approach: Combination of cross section and fracture pattern analysis with finite element modelling (FEM) investigating the clamping stress**

Method

Experimental analysis on modules retrieved from field exhibiting glass breakage

- Fracture pattern analysis to determine the origin of glass breakage
- Analysis of cross-sectional images to determine the laminates position within the frame and the formation of the adhesive joint

FEM Simulations

- Simulation of screw tightening up to 20 Nm during clamping process in PV module assembly on a representative section of the module (Fig. 1, left)
- Comparing clamps containing a grounding groove (Fig. 1, top) to clamps without one (Fig. 1, bottom)
- Comparing different positions of the laminate within the frame (Pos 1: incomplete adhesive joint, Pos 2: fully formed adhesive joint)
- Analyzing first principal stress in the glass, caused by the clamping process

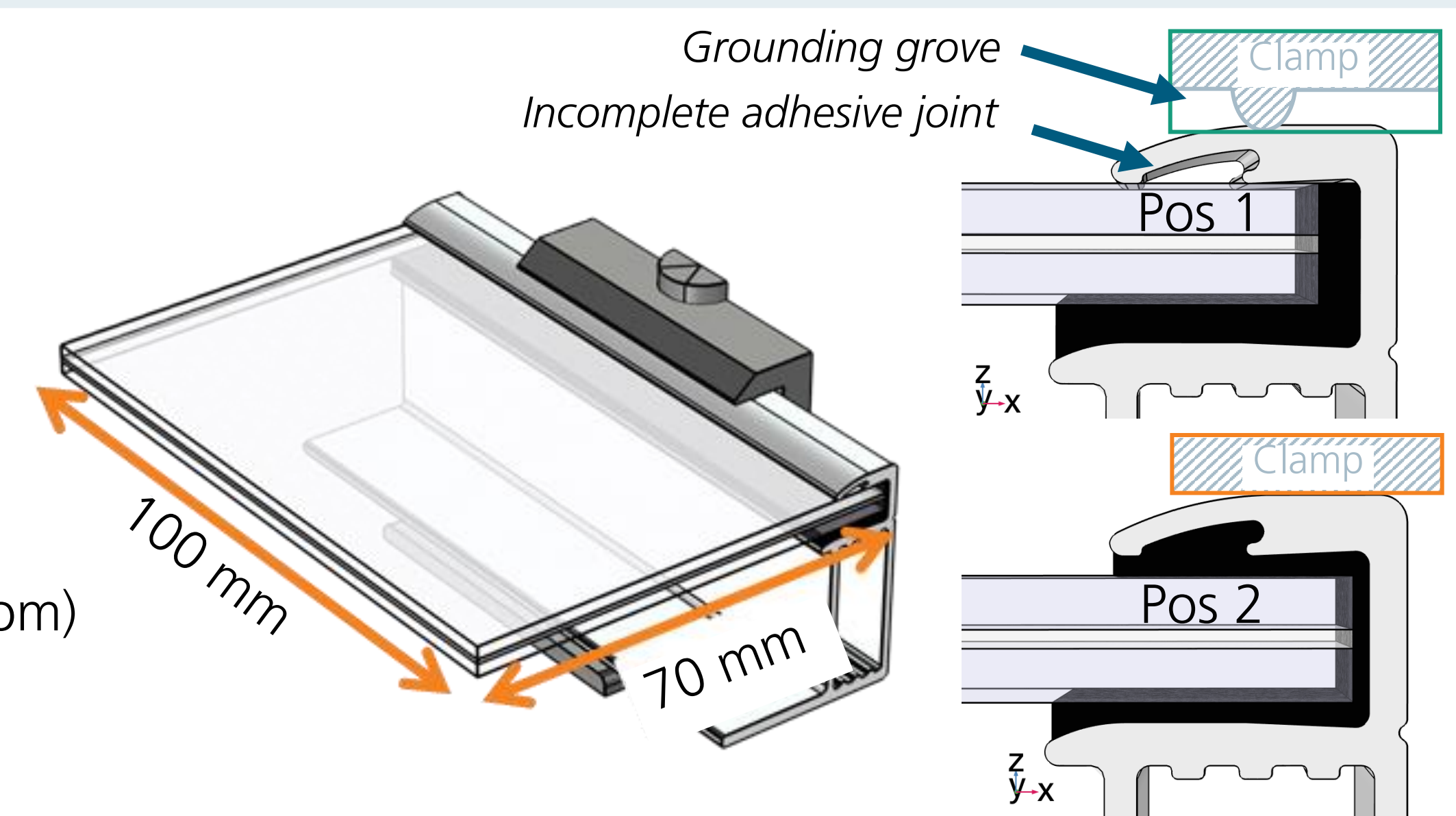


Fig. 1: Simulated representative section, containing the laminate, frame, adhesive, mounting clamp and the screw

Results

1. Experimental results

- Fracture pattern analysis:
Fracture origin in front glass at interface between frame edge and glass in the clamping area (Fig. 2, top)
 - Cross-section analysis:
Incomplete adhesive joint on the top of the laminate is found often (Fig. 2, bottom), resulting in direct metal to glass contact at interface frame edge to glass
- **Origin of glass fracture is at the interface between frame edge and glass, where often an incomplete adhesive joint can be seen**

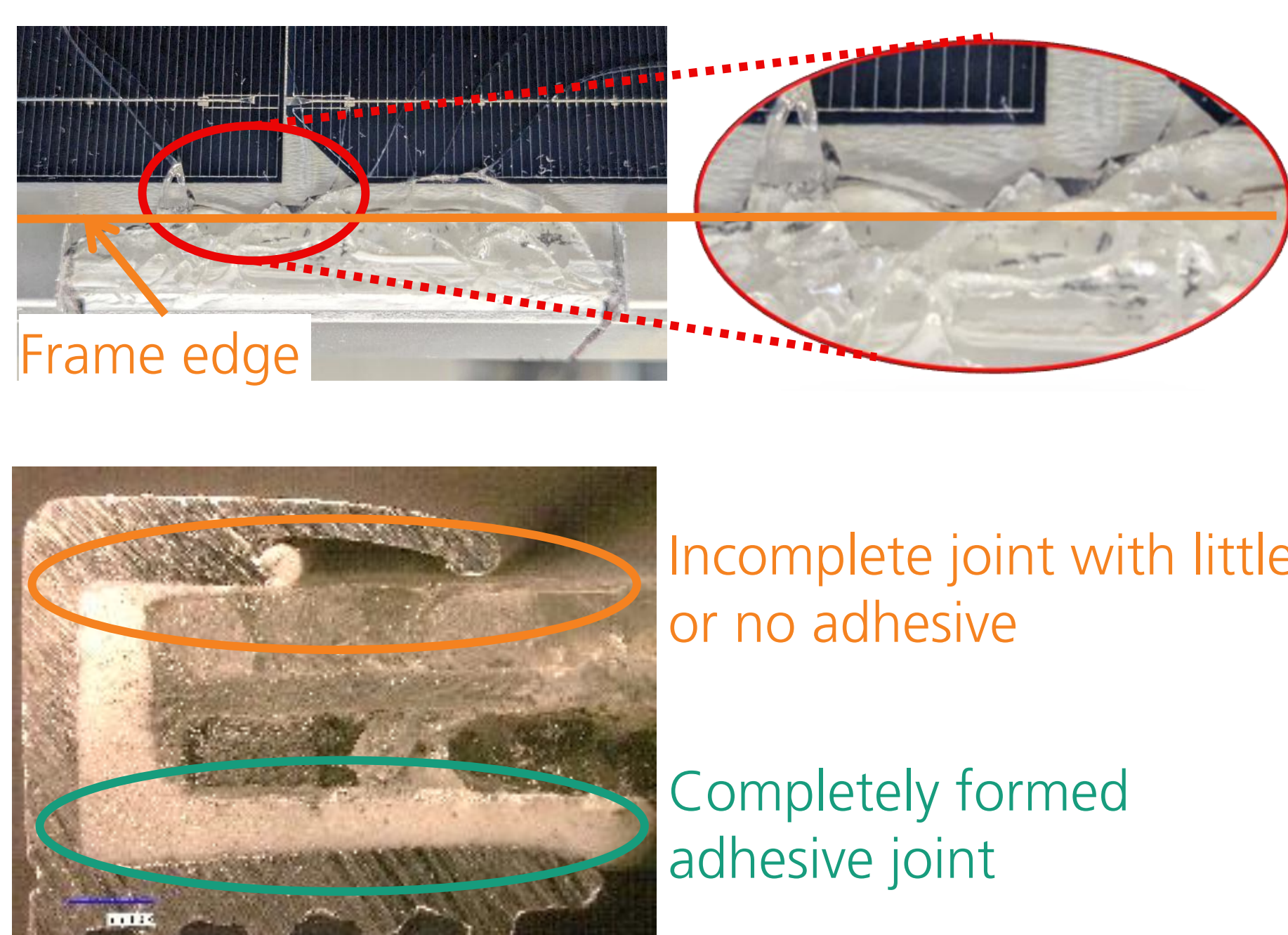


Fig. 2: Fracture pattern analysis (top) and cross-sectional image of incompletely formed adhesive joint

2. FEM: Influence of adhesive joint

- Frame adhesive acts as a deformation buffer between frame and glass
- When tightening the clamps an incomplete adhesive joint (Fig. 3, Pos 1) results in a higher local deformation of the glass compared to an ideal joint (Fig. 3, Pos 2)
- A higher local deformation results in a higher first principal stress → Module is more prone to glass breakage
- **Incomplete adhesive joints result in a higher first principal stress in the glass**

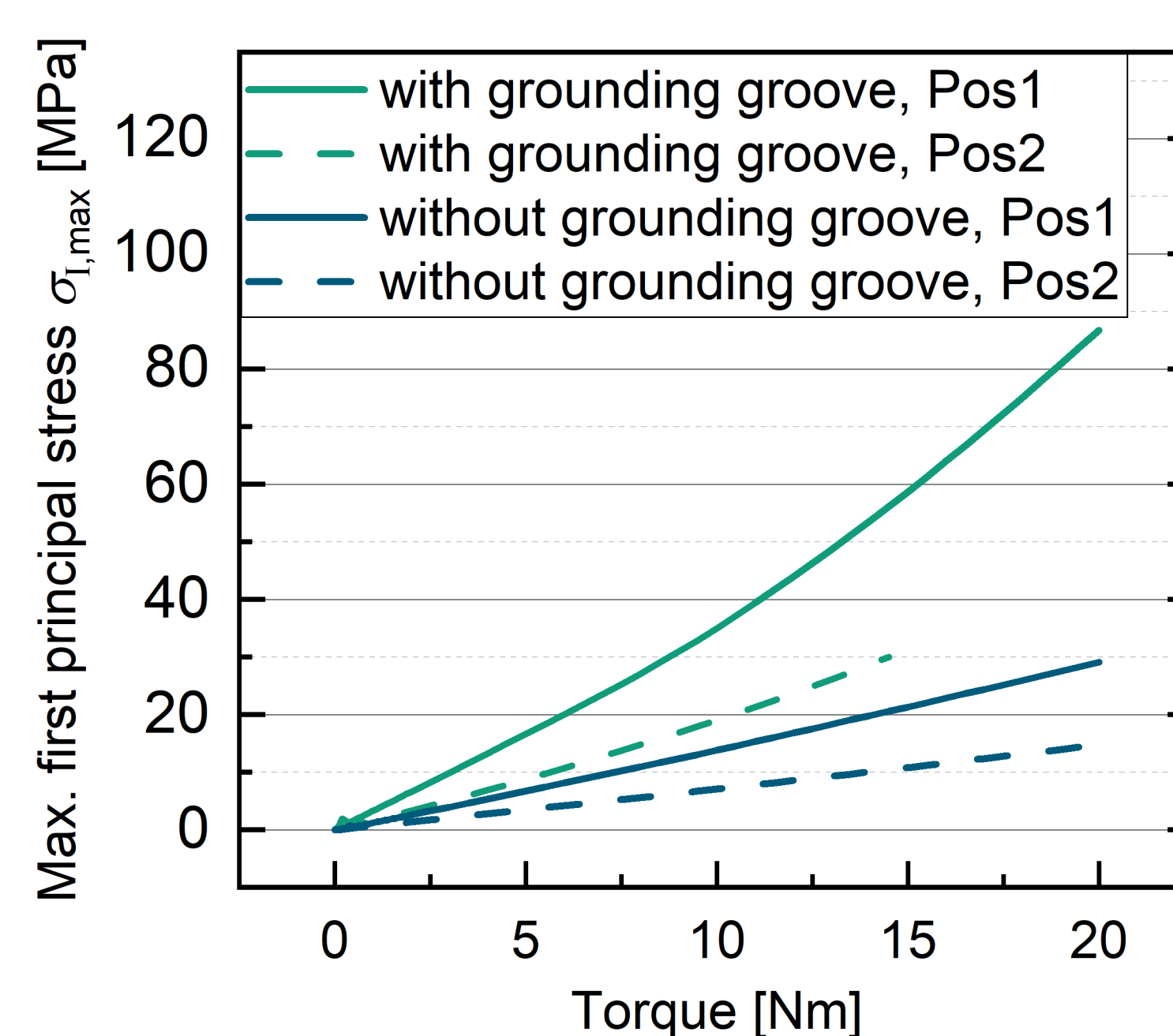


Fig. 3: First principal stress in the front glass for an incomplete adhesive joint (solid) and a complete one (dashed) using a frame clamp with a grounding groove (green) and without one (blue)

3. FEM: Influence of clamp geometry

- Using a clamp without a grounding groove distributes force evenly across frame, most of the force is transferred through outer leg of frame
- When using a clamp with a grounding groove, the force to the frame is applied linearly and further inward.
→ Top of the frame bends due to the lever arm
→ Frame exerts linear pressure on front glass
→ High tensile stress at contact region
- **Clamps with a grounding groove results in a higher first principal stress in the glass**

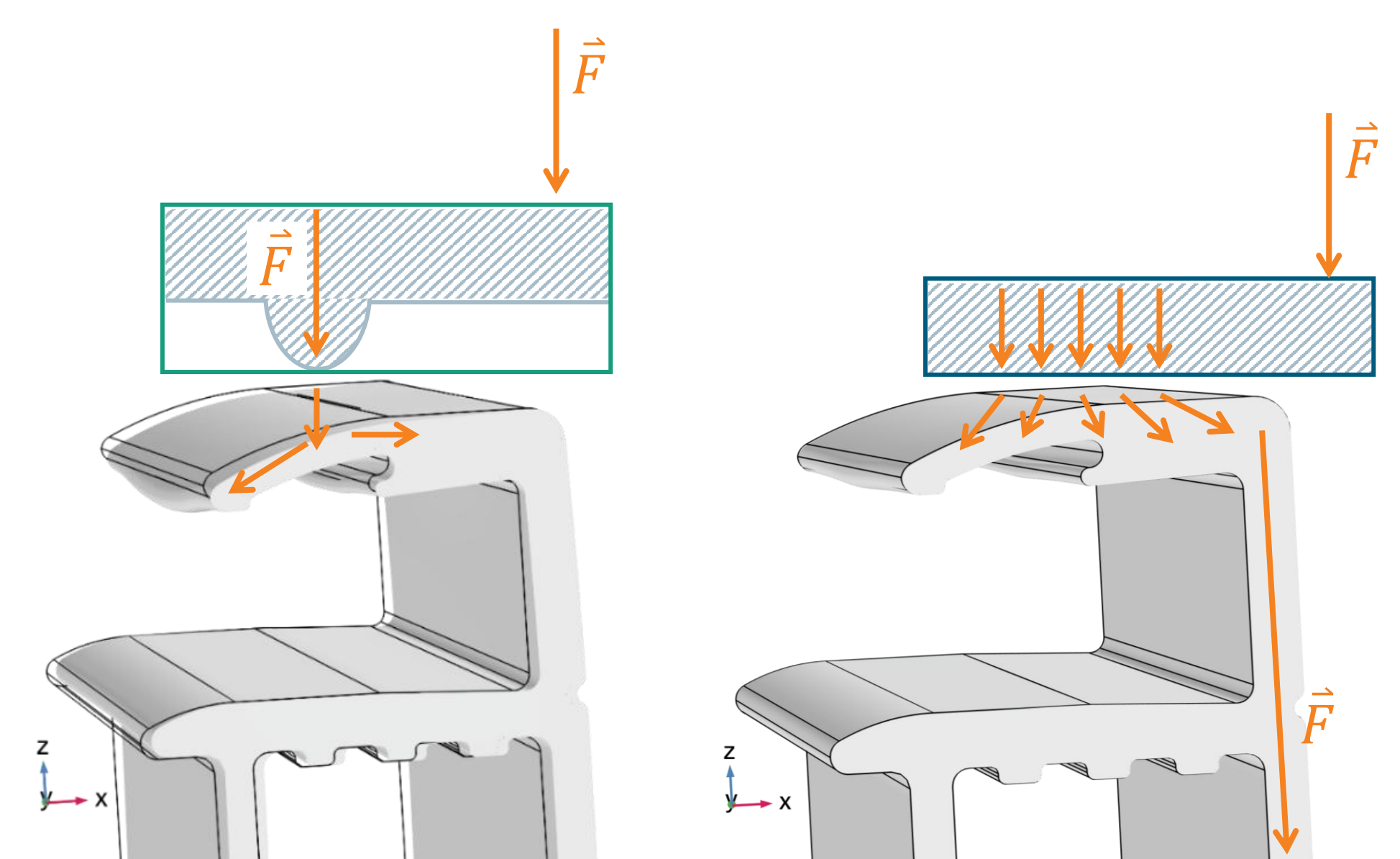


Fig. 4: Deformation of module frame when using a clamp with grounding groove (left) and a clamp without grounding groove (right)

Summary

- Origin of fracture is in the clamping area
- Higher tensile stress in regions with incomplete adhesive joint
- **Process control of adhesive application needs to be carefully monitored**
- Clamps with a grounding groove cause higher frame deformations at the clamping position due to the lever arm resulting in higher tensile stresses in comparison to clamps without a grounding groove



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