



**COMSOL
CONFERENCE**
2016 MUNICH

Influence of Notches in Corners of Casement Windows under Thermal Load

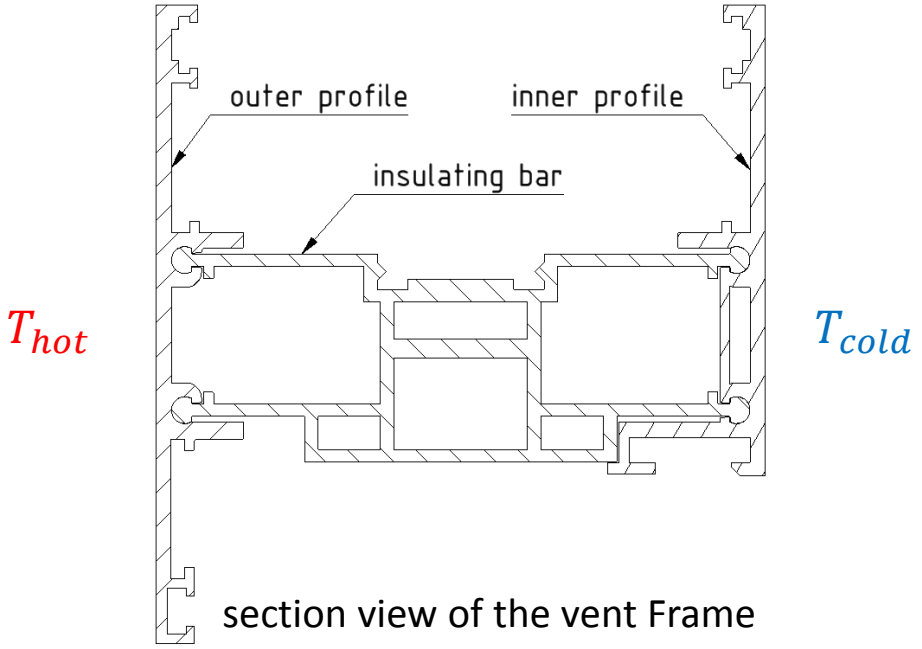
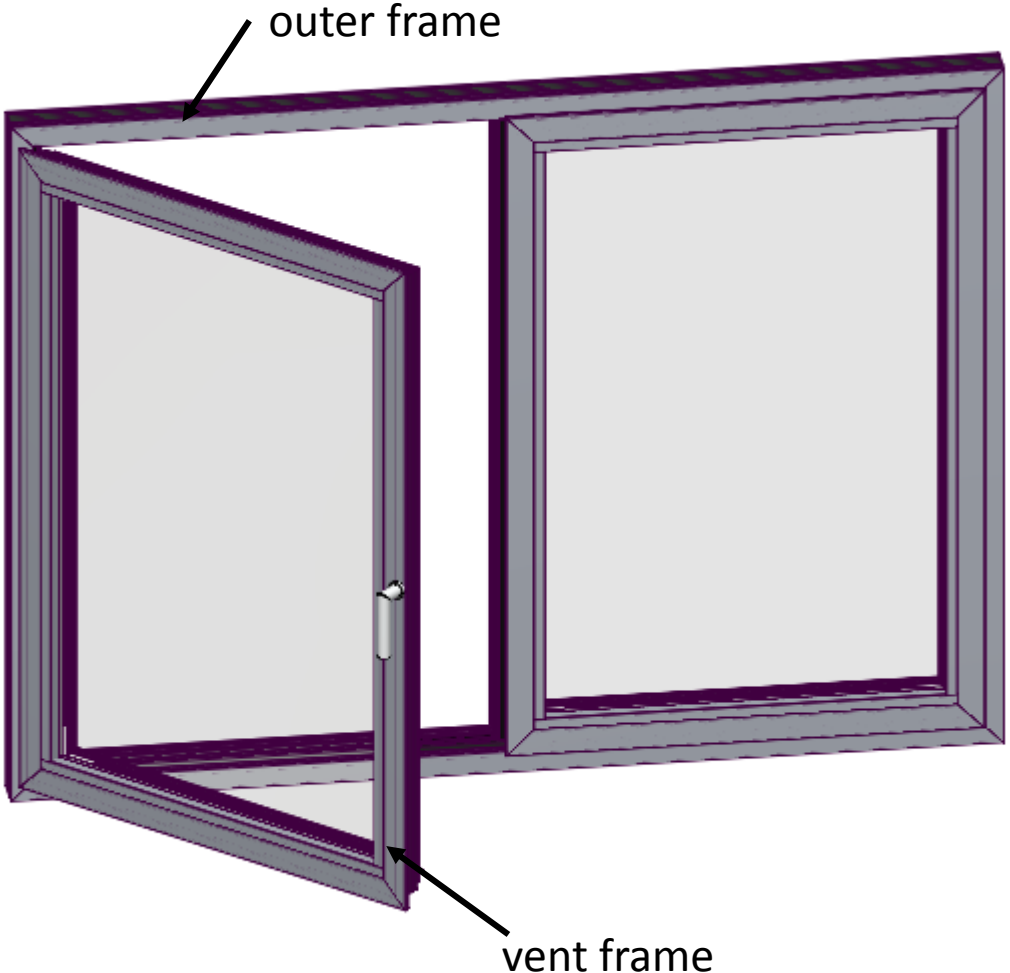
Outline

1. Introduction
2. Task 1: Pre-Investigation
3. Task 2: Main-Investigation
4. Conclusion

- Leading suppliers of high-quality window, door and facade systems made from aluminium, PVC-U and steel
- Head office is in Bielefeld (Germany)
- International presence in more than 80 countries
- 4,630 employees worldwide



The Casement Window

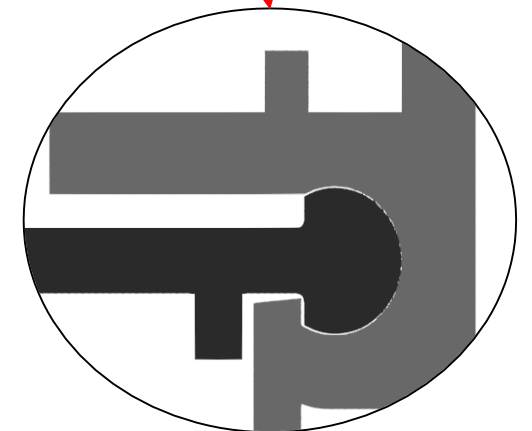
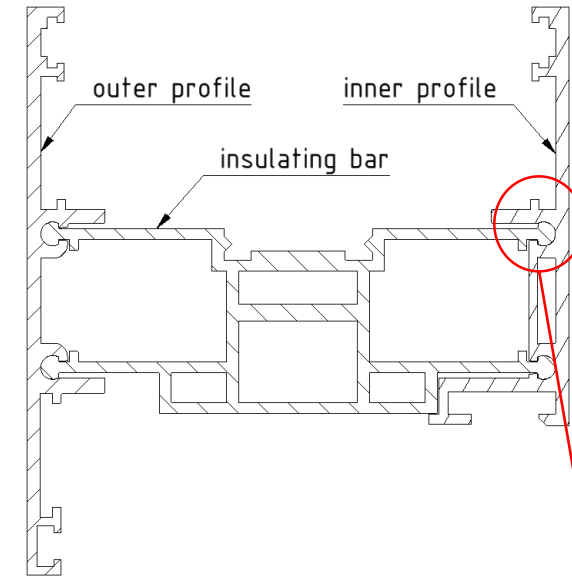
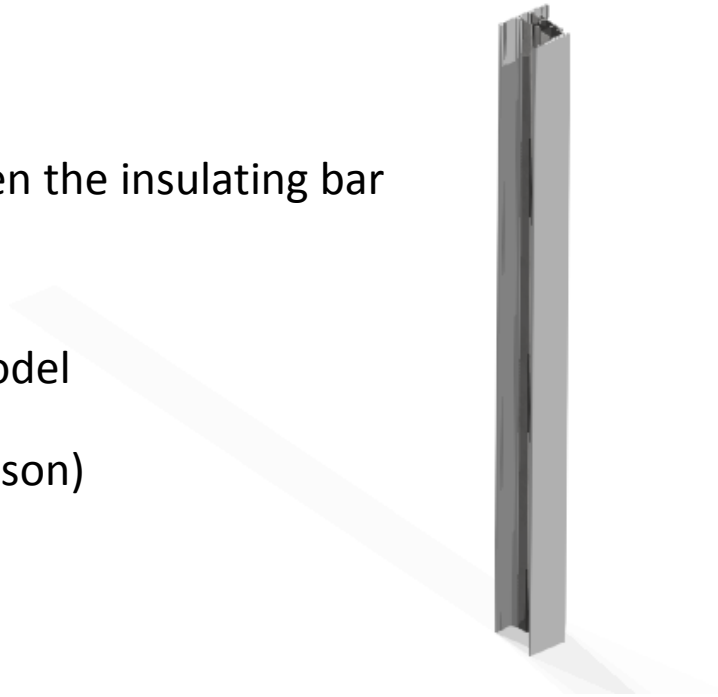


Problem: The difference in temperature causes a deflection in the corner of the profile

Task 1: Pre-Investigation

Deflection of an extruded one-meter profile

- $\Delta T = 60 K$
- Glued connection between the insulating bar and the profiles
- Linear-elastic material model
- Analytical result (comparison)



Task 2: Main-Investigation

Deflection of a profile in a corner

- $\Delta T = 60 K$
- Notches on the insulating bar for the following lengths (x)
 - 60 mm
 - 100 mm
 - 150 mm
 - 200 mm
- Aluminum profiles deform elastic-plastic
- Comparison: Glued and contact case

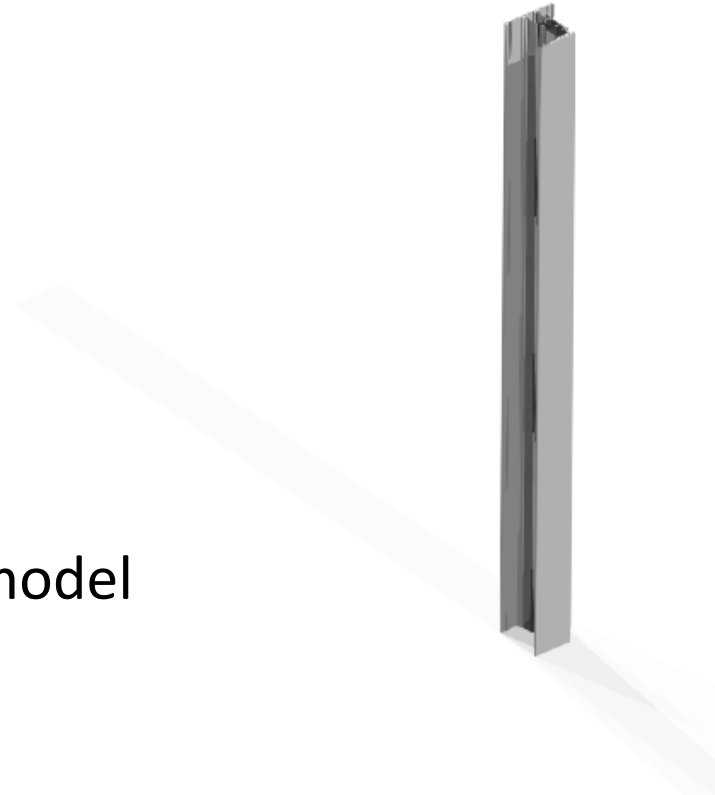


Outline

1. Introduction

2. Task 1: Pre-Investigation

- Constraints } Pre-processing
- Mesh } Pre-processing
- Results → Post-processing
- Analytical result with a simplified model



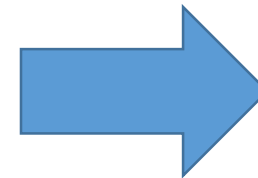
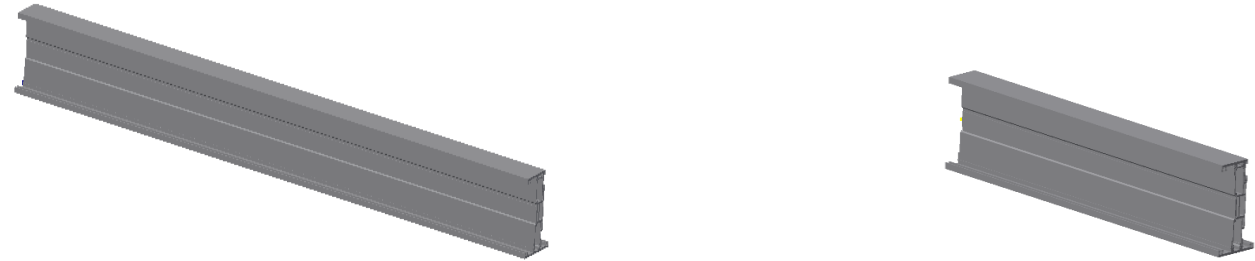
3. Task 2: Main-Investigation

4. Conclusion

Constraints

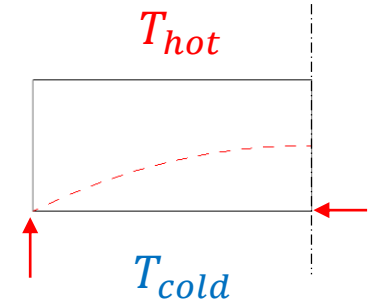
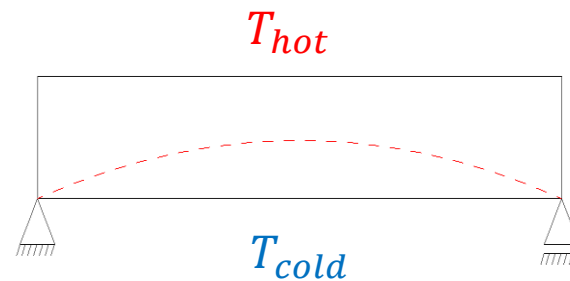
Heat Transfer in Solids

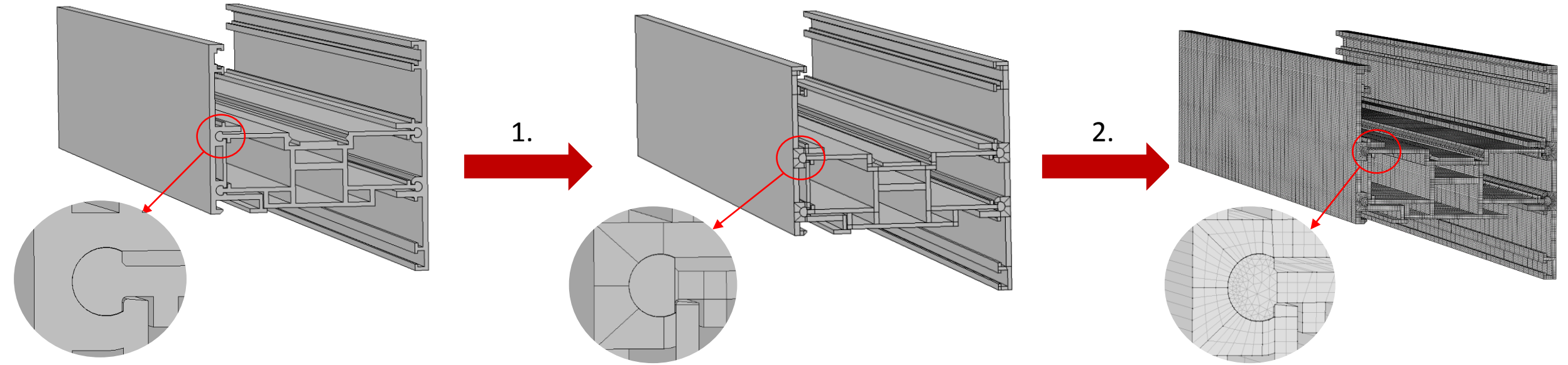
- Temperature
- Continuity



Solid Mechanics

- Prescribed displacement
- Symmetry
- Continuity





1. Step

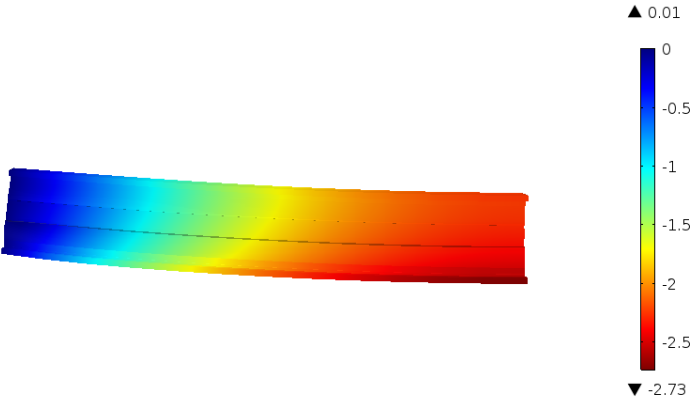
- Cut front face
 - Partition with objects or work planes
- Virtual operations (ignore edges, vertices)

2. Step

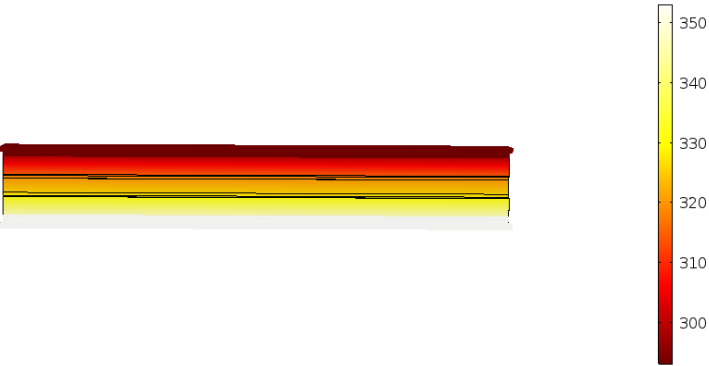
- Mesh the front face
 - Mapped and triangular elements
- Extrude the mesh

Results (Simulation)

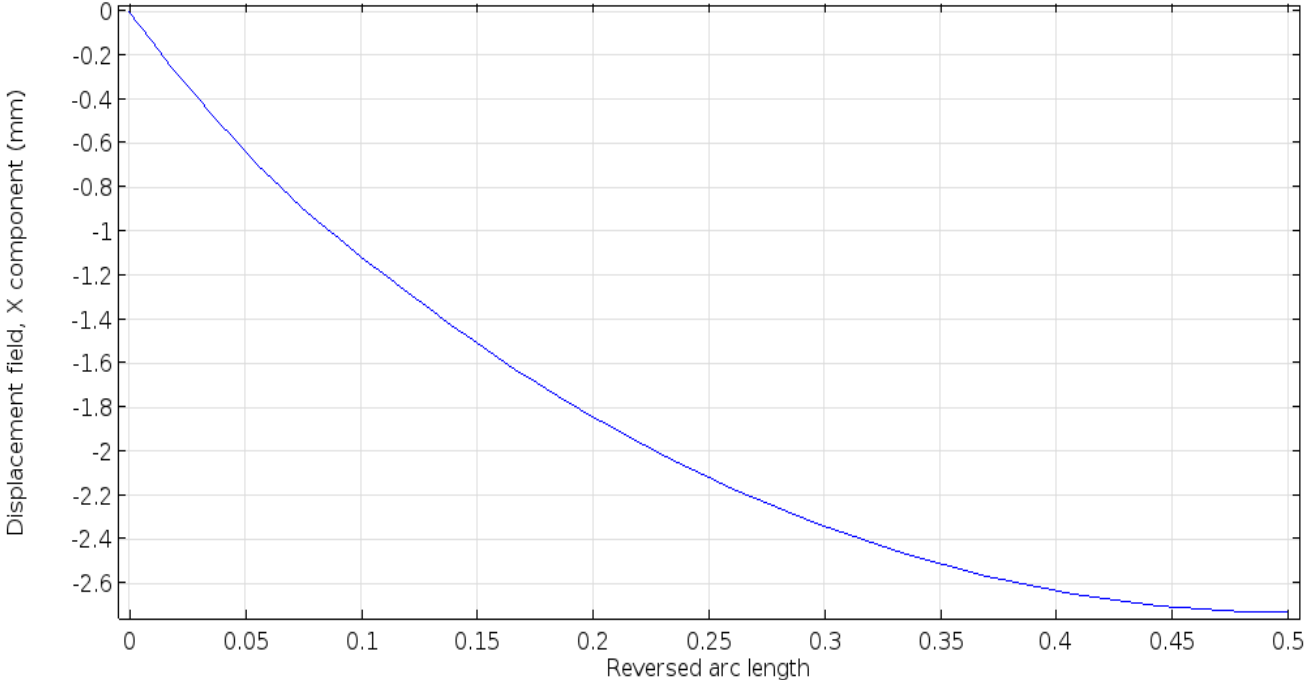
Surface: Displacement field, X component (mm)



I(5)=0.09 Surface: Temperature (K)



Line Graph: Displacement field, X component (mm)



Maximum deflection = 2.73 mm

Analytical Result Of A Simplified Model (Rectangular Profile)

Elongation ε of a fibre

$$\varepsilon = \frac{h}{R}$$

Thermal expansion:

$$\varepsilon_{th} = \alpha_{th} * \Delta T$$

$$R = \frac{h}{\alpha_{th} * \Delta T}$$

Radian measure

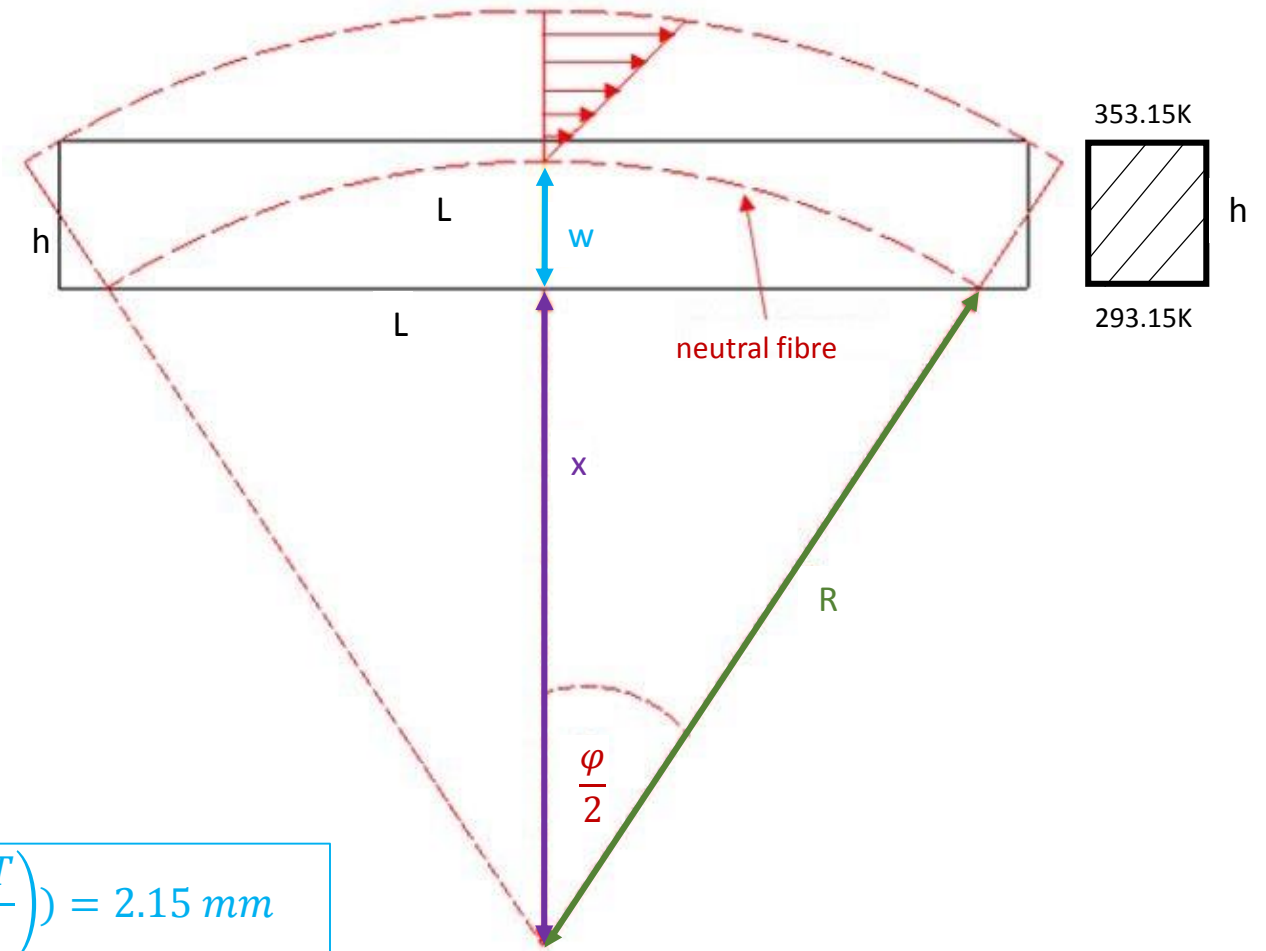
$$\varphi = \frac{L}{R}$$

length x

$$x = R * \cos\left(\frac{\varphi}{2}\right)$$

$$x = \frac{h}{\alpha_{th} * \Delta T} * \cos\left(\frac{L * \alpha_{th} * \Delta T}{h * 2}\right)$$

$$\text{Deflection: } w_{(\Delta T)} = R - x = \frac{h}{\alpha_{th} * \Delta T} * \left(1 - \cos\left(\frac{L * \alpha_{th} * \Delta T}{h * 2}\right)\right) = 2.15 \text{ mm}$$



Outline

1. Introduction
2. Task 1: Pre-Investigation
3. Task 2: Main-Investigation
 - Material Model
 - Constraints
 - Mesh
 - Solver
 - Results
4. Conclusion

} Pre-processing

→ Post-processing



Material Model

Aluminum: elastic-plastic

➤ Bilinear material

▼ Plasticity Model

Plasticity model:
Small plastic strains

Yield function F:
von Mises stress

$F = \sigma_{\text{mises}} - \sigma_{\text{ys}}, Q = F$

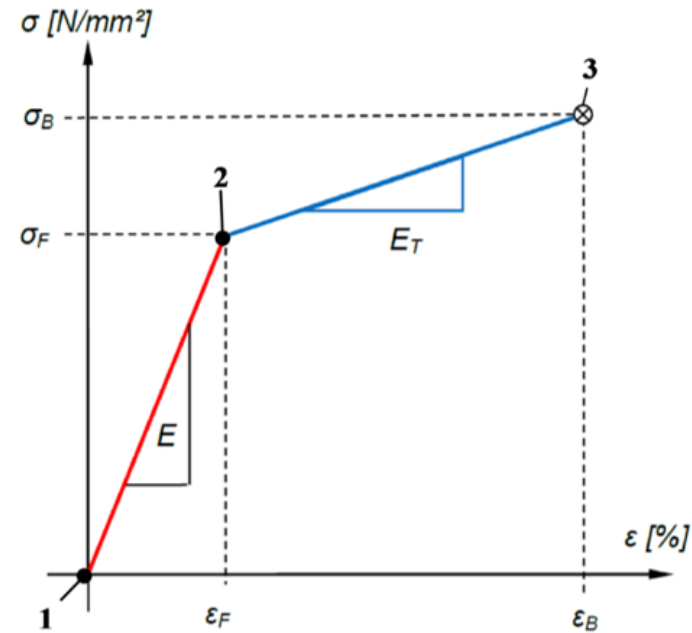
Initial yield stress:
 σ_{ys0} From material

Hardening model:
Isotropic

Isotropic hardening:
Use tangent data

$$\sigma_{\text{ys}} = \sigma_{\text{ys0}} + \frac{E_{\text{Tiso}}}{1 - \frac{E_{\text{Tiso}}}{E}} \epsilon_{\text{pe}}$$

Isotropic tangent modulus:
 E_{Tiso} From material



2. Yield Point
3. Breaking stress

$$E_t = \frac{R_m - R_{p0,2}}{\epsilon_B - \frac{R_{p0,2}}{E}}$$

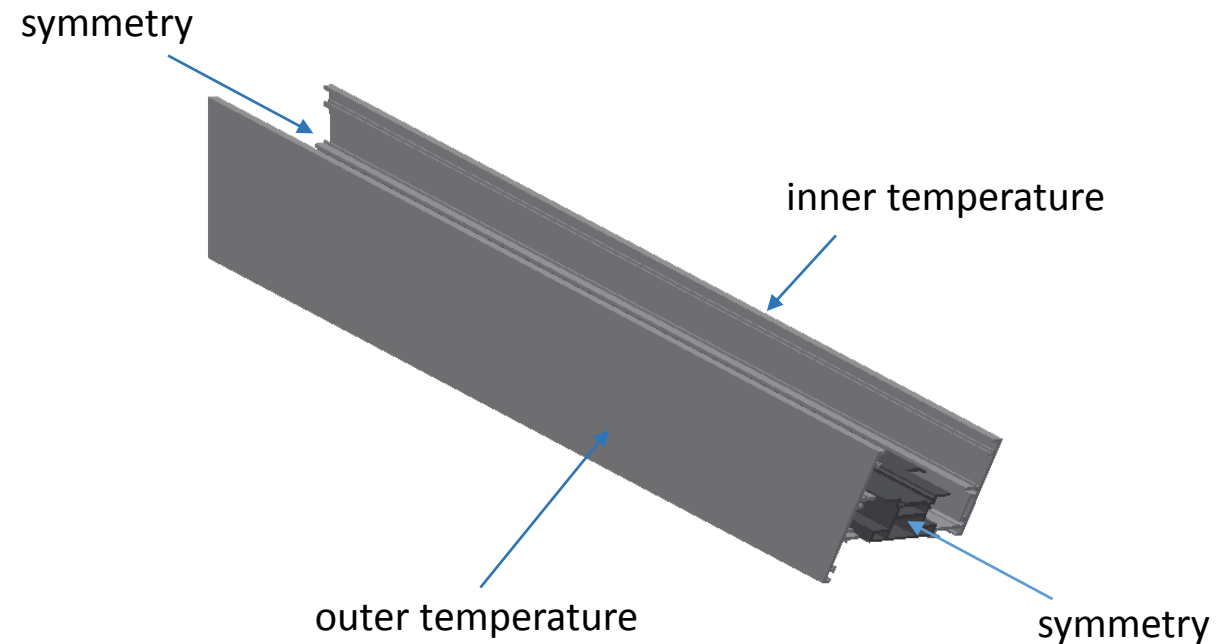
Constraints

Heat Transfer in Solids

- Temperature
- Continuity

Solid Mechanics

- Prescribed displacement
- Symmetry
- Continuity (identity pair) or contact
(contact pair)



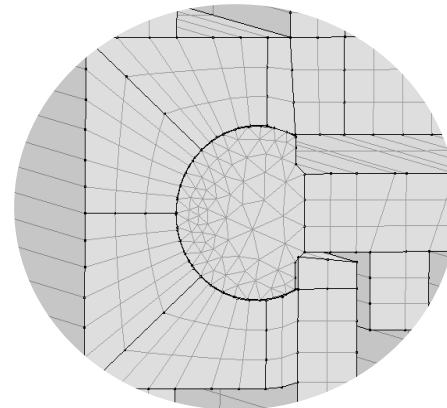
Contact Pair

1. Form assembly:

- Identifies the touching, adjacent, boundaries of all objects

2. Selection

- Source boundary stiffness is higher than the destination boundary stiffness



3. Mesh

- Source boundary has to be finer than destination boundary (twice)

4. Friction (assumed value $\mu=0.2$)

Settings ▼ 📌

Form Union/Assembly

Build Selected Build All

Label:

▼ Form Union/Assembly

Action:

Create imprints

Create pairs

Split disconnected pairs

Pair type:

Relative repair tolerance:

Stationary Solver

- Modify physics tree
- Segregated
 1. Temperature: Constant Newton
 2. Displacement: Constant Newton
- Continuation solver for contact pair

Settings
Stationary
= Compute Update Solution

Label: Stationary

Study Settings

Include geometric nonlinearity

Results While Solving

Physics and Variables Selection

Modify physics tree and variables for study step

Global Definitions

- Component 1 (comp1)
 - Definitions
 - Solid Mechanics (solid)
 - Linear Elastic Material 1
 - Plasticity 1
 - Free 1
 - Initial Values 1
 - Symmetry 1
 - Continuity 1
 - Free 1
 - Prescribed Displacement 1
 - Linear Elastic Material 2
 - Contact 1
 - Free 1
 - Friction 1
 - Heat Transfer in Solids (ht)

Values of Dependent Variables

Settings
Segregated Step
= Compute to Selected = Compute

Label: Segregated Step 2

General

Variables:

Displacement field (Material) (comp1.u)

Components: All

Linear solver: Direct

Method and Termination

Nonlinear method: Constant (Newton)

Damping factor: 1

Jacobian update: On every iteration

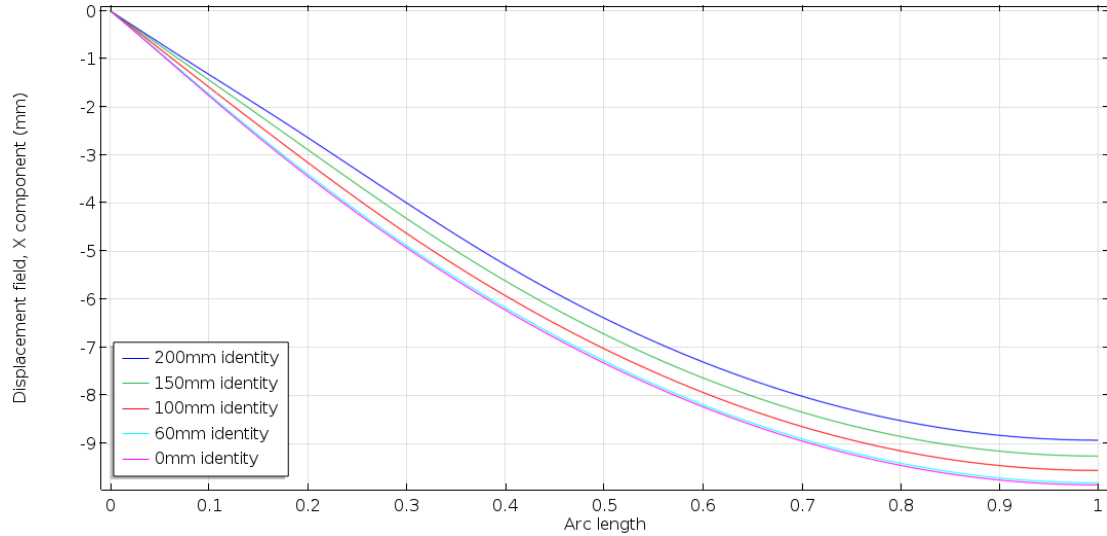
Termination technique: Iterations

Number of iterations: 1

Results (Deflection)

Identity pair case

Line Graph: Displacement field, X component (mm)

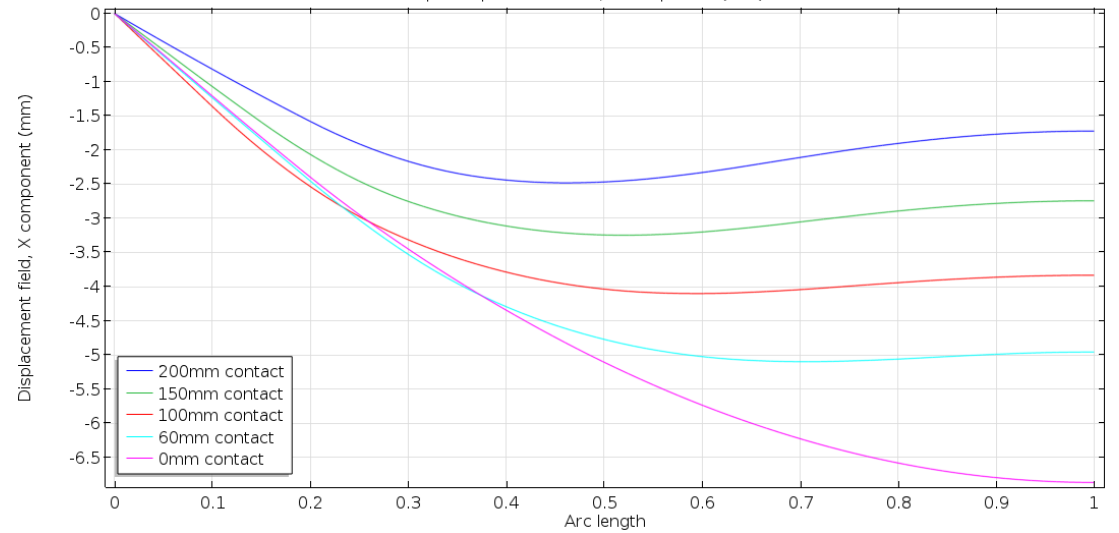


Length of notches (mm)	Deflection (mm)
0	9,86
60	9,82
100	9,56
150	9,26
200	8,94

↑
Reduced
deflection ≈
1 mm

Contact pair case

Line Graph: Displacement field, X component (mm)



Length of notches (mm)	Deflection (mm)
0	6,86
60	4,96
100	3,83
150	2,74
200	1,72

↑
Reduced
deflection ≈
5 mm

Outline

1. Introduction
2. Task 1: Pre-Investigation
3. Task 2: Main-Investigation
- 4. Conclusion**

Conclusion

Pre-Investigation

- In spite of simplifications in the analytics there is a good approach to the simulation
- The influence of air cavities is not significant

Main-Investigation

- Confirmation that notches reduce the deflection
 - Glued pair case: Notches don't reduce the deflection significantly
 - Contact pair case is more suitable
- The length of notches has to be limited
 - By increasing the length of notches, the stiffness reduces

 **Next step: Comparison with a real experiment**

Contact/References

Contact

Jemai.arfaoui@fh-bielefeld.de

Lars.fromme@fh-bielefeld.de

References

1. Schüco homepage: https://www.schueco.com/web2/de-en/company/about_schueco/company_profile
2. COMSOL homepage: <https://www.comsol.com/support/knowledgebase/1102/>