3M Science. Applied to Life.™

Simulationsgestütztes Design von Klebverbindungen

Alexander Schowtjak

Agenda

- Introduction
- Overlap shear joint study
- Finite Element Analysis
- Application Examples
- 3M‘s FEA capabilities
- Conclusion

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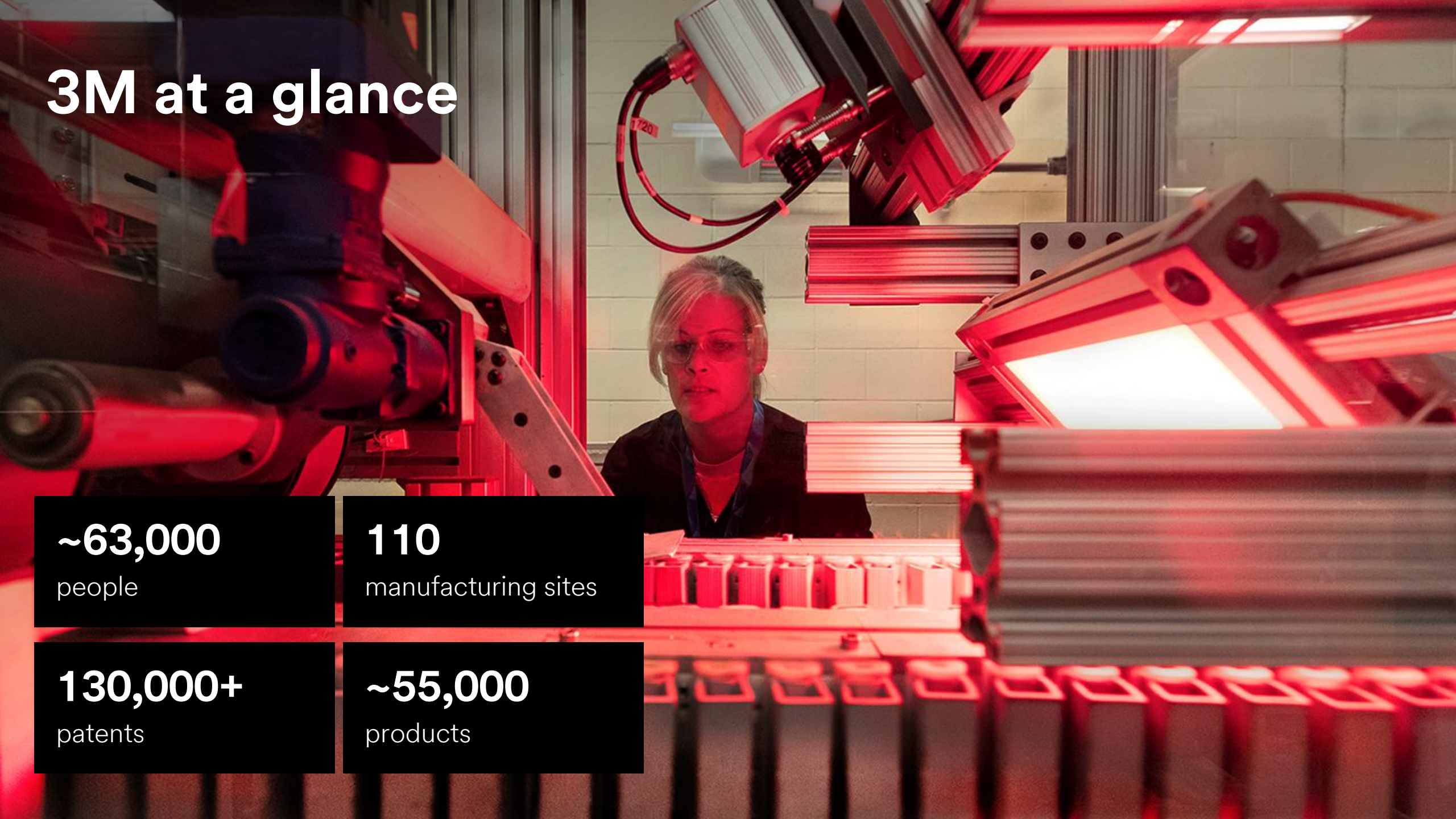
Application Engineer

3M Germany, Industrial Adhesives & Tapes Division

3M at a glance



~63,000
people

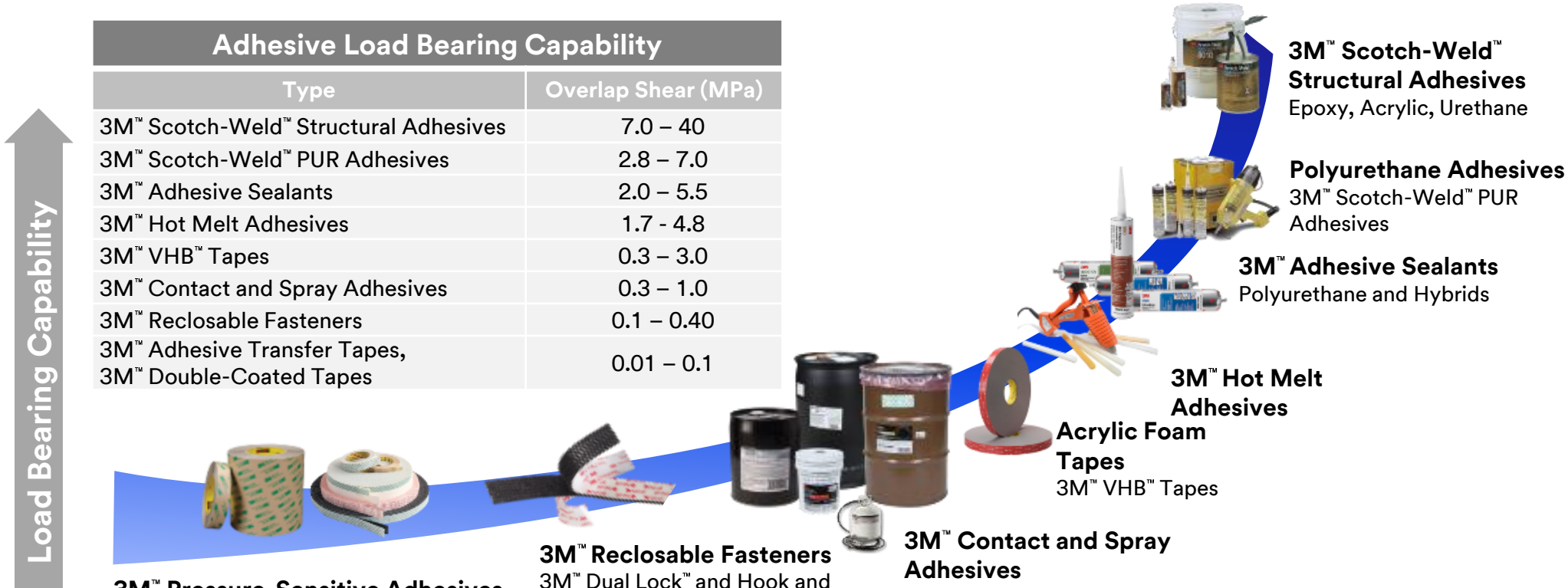
110
manufacturing sites

130,000+
patents

~55,000
products

Overview of adhesive technologies

Adhesive Load Bearing Capability	
Type	**Overlap Shear (MPa)**
3M™ Scotch-Weld™ Structural Adhesives	7.0 – 40
3M™ Scotch-Weld™ PUR Adhesives	2.8 – 7.0
3M™ Adhesive Sealants	2.0 – 5.5
3M™ Hot Melt Adhesives	1.7 - 4.8
3M™ VHB™ Tapes	0.3 – 3.0
3M™ Contact and Spray Adhesives	0.3 – 1.0
3M™ Reclosable Fasteners	0.1 – 0.40
3M™ Adhesive Transfer Tapes, 3M™ Double-Coated Tapes	0.01 – 0.1



3M™ Scotch-Weld™ Structural Adhesives

3M™ Scotch-Weld™ Structural Adhesives improve product aesthetics and create durable bonds that hold strong in extreme conditions. They help industrial engineers and design professionals efficiently manufacture products that are faster, stronger and lighter, with no mechanical fasteners or welds. Leverage 3M's proven selection of low-odor structural adhesives, deep industry expertise and technical support to your advantage.

3M | Scotch-Weld™ Structural Adhesive

3M

3M™ VHB™ Tape

Amazingly strong and virtually invisible, 3M™ VHB™ Tape opens a world of possibilities for both designs and processes.

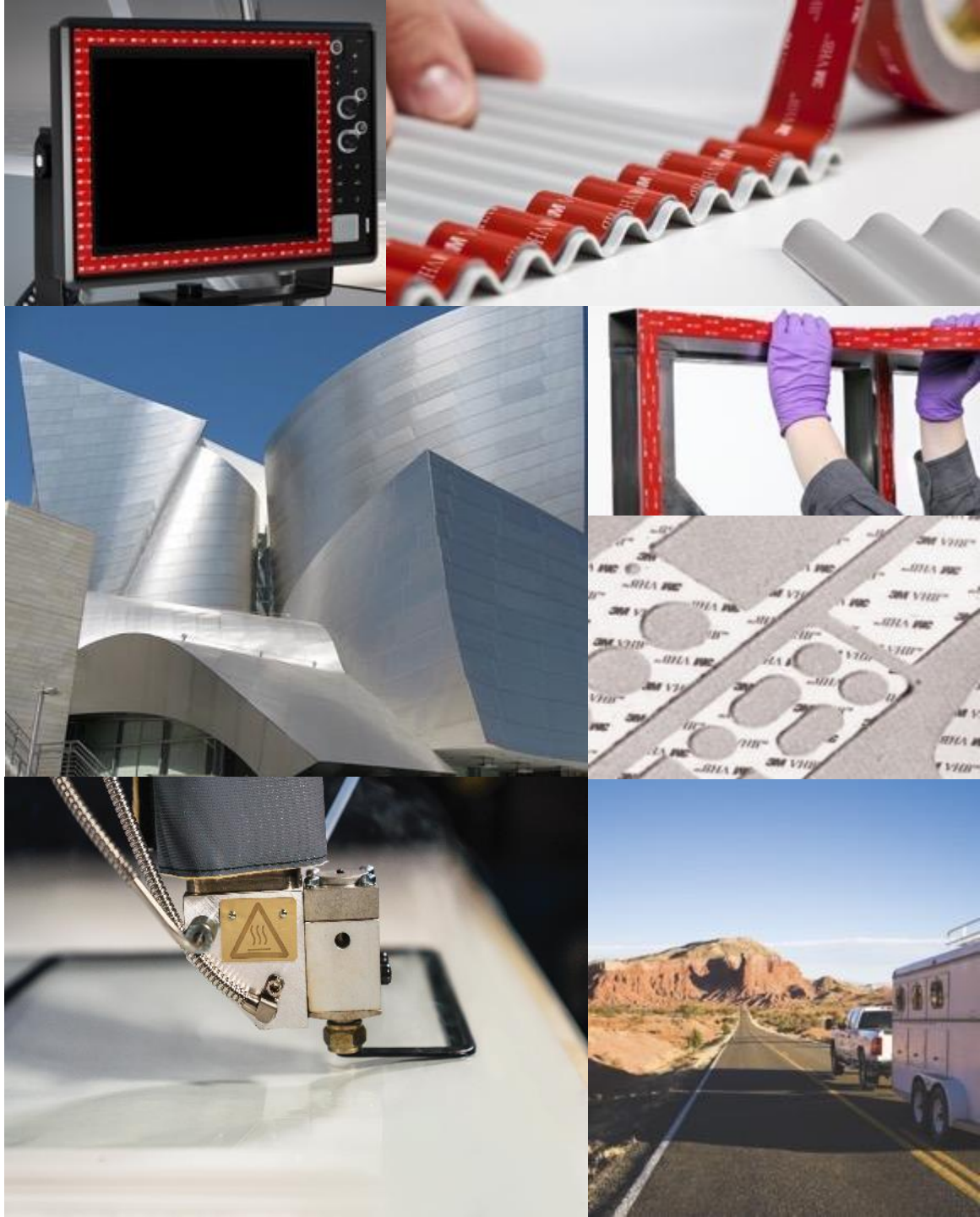
Create new products with almost any substrate – without the need for mechanical fasteners – while enhancing appearances and performance. Join aluminum, steel, glass, plastics, as well as painted and powder-coated substrates – with precision, ease, reliability, and strength.

Bonding with 3M™ VHB™ Tape provides immediate handling strength, increases product performance, and delivers the durability needed for extreme temperatures and applications.

Design without barriers and create your next invention with the hidden power of 3M™ VHB™ Tape.

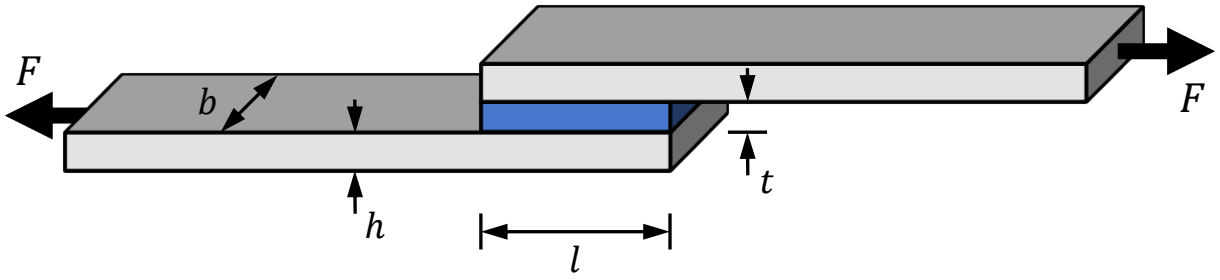
3M | VHB Tape Since 1980

3M



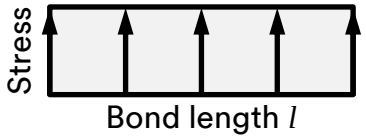
Understanding overlap shear joints

Overlap shear test

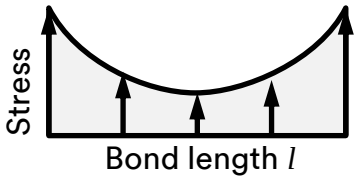


- Eccentric load is inducing bending moment
- Failure, when load > strength

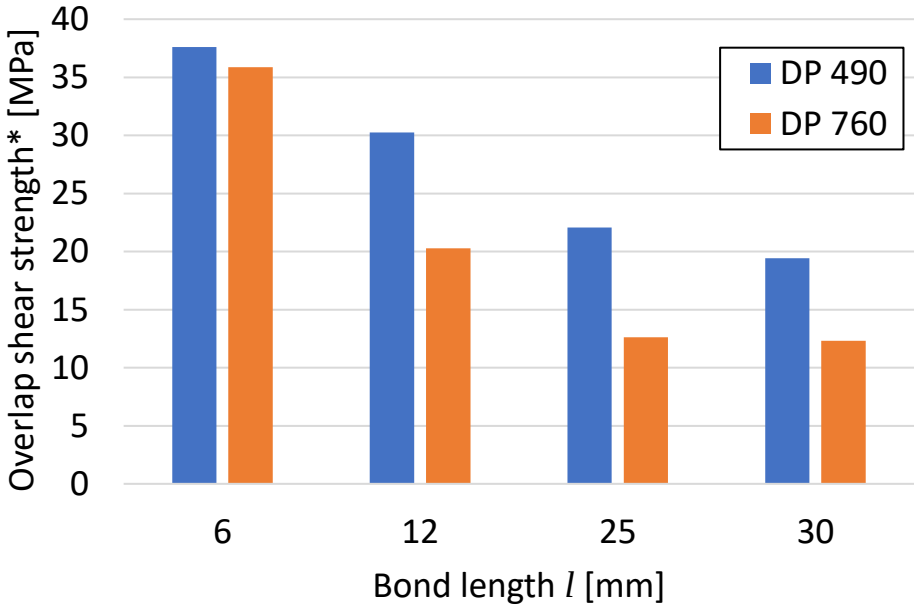
Ideal loading



Real loading

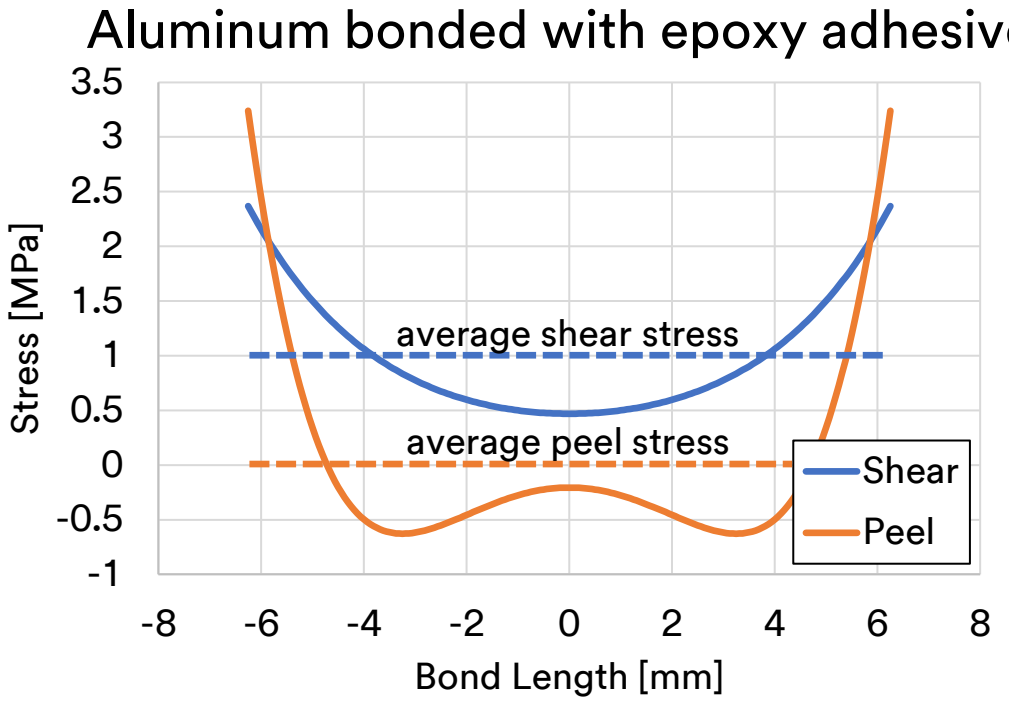


Influence of bond length on strength



*Strength: $\frac{F_{max}}{A_{bond}} = \frac{\text{Force}}{\text{Bonding Area}}$

Effect of adhesive‘s stiffness



	Young‘s modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm

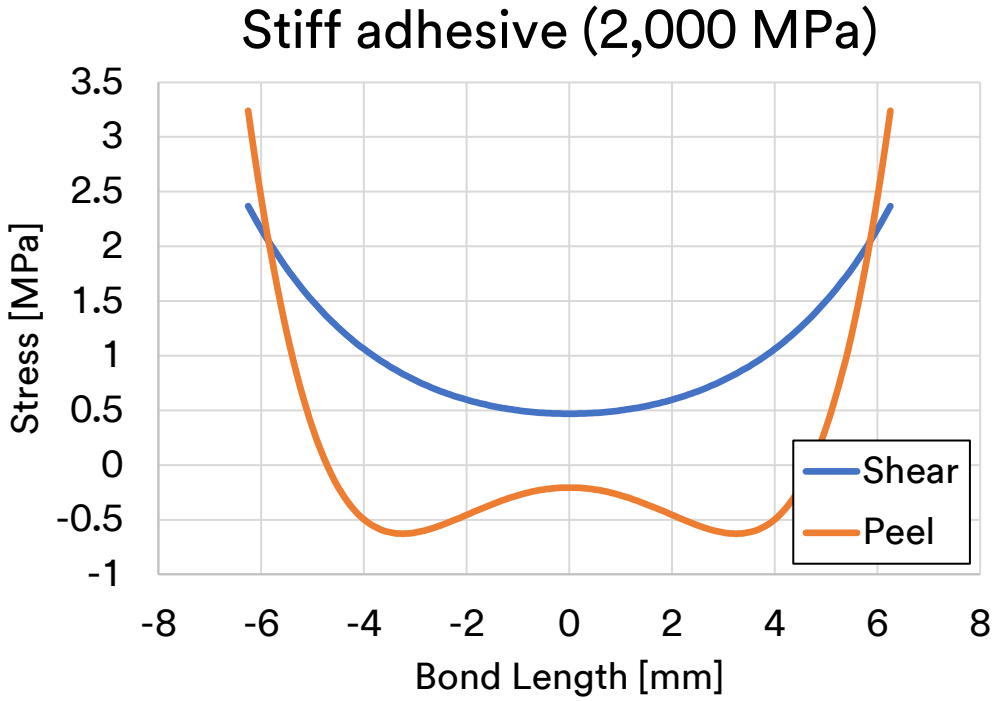
Predictions made with analytical solution according to Goland and Reissner*

Assumptions:

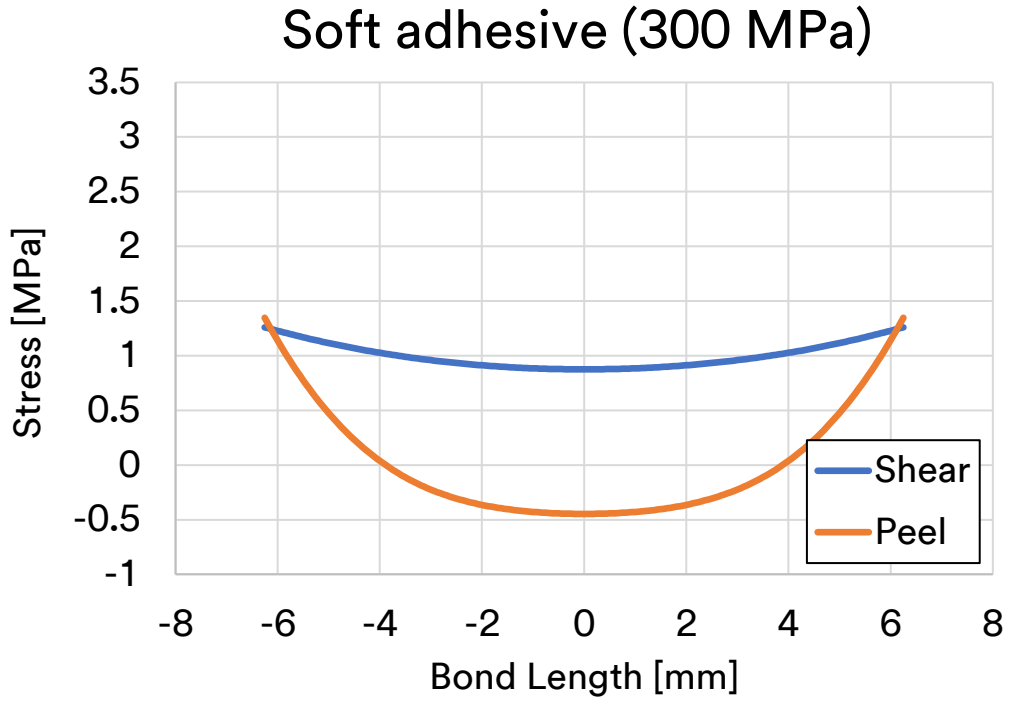
- Small deformations
- Linear elastic adherends and adhesive

*M. Goland, E. Reissner, 1944. The stresses in cemented joints. Journal of Applied Mechanics 11:A17-A27

Effect of adhesive‘s stiffness

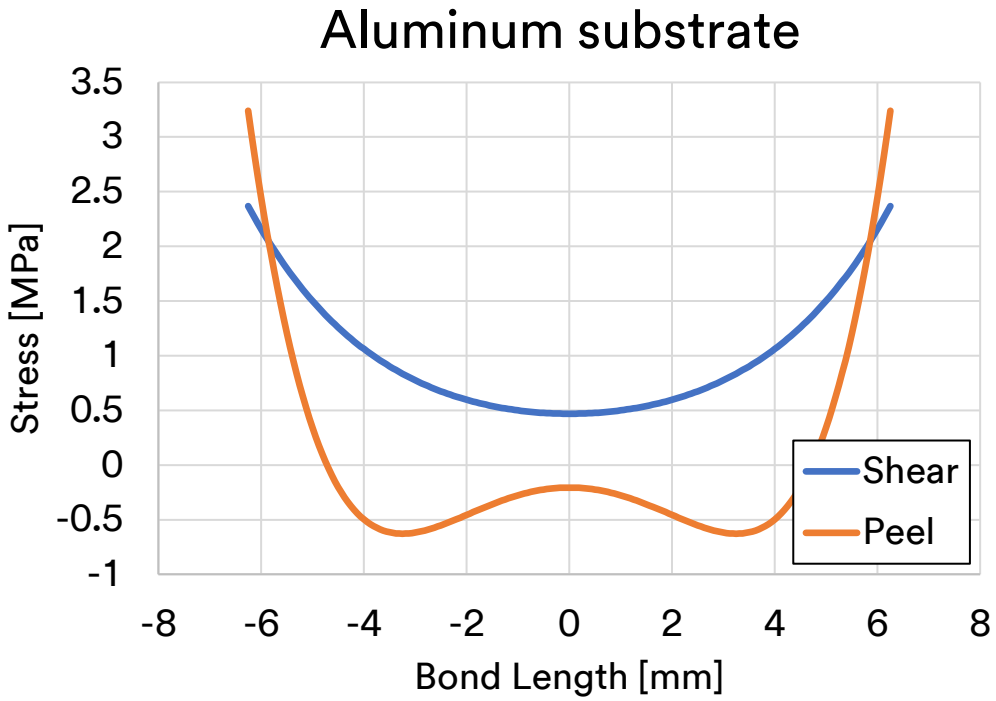


	Young‘s modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm

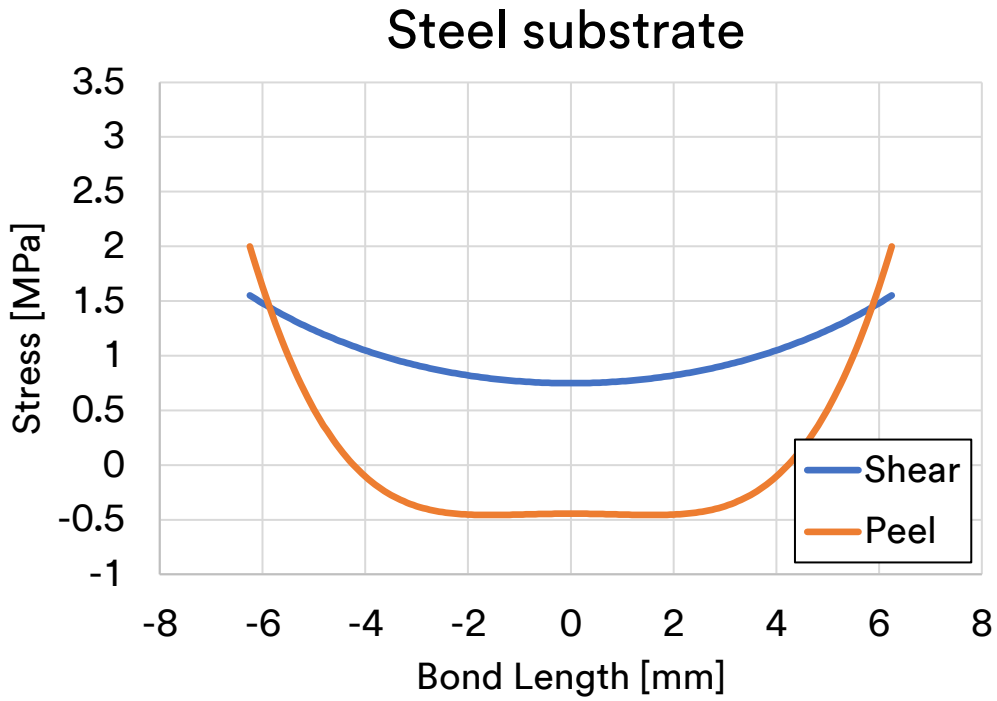


	Young‘s modulus	Thickness
Adhesive	**300 MPa**	0.25 mm
Substrate	70,000 MPa	2 mm

Effect of substrate‘s stiffness



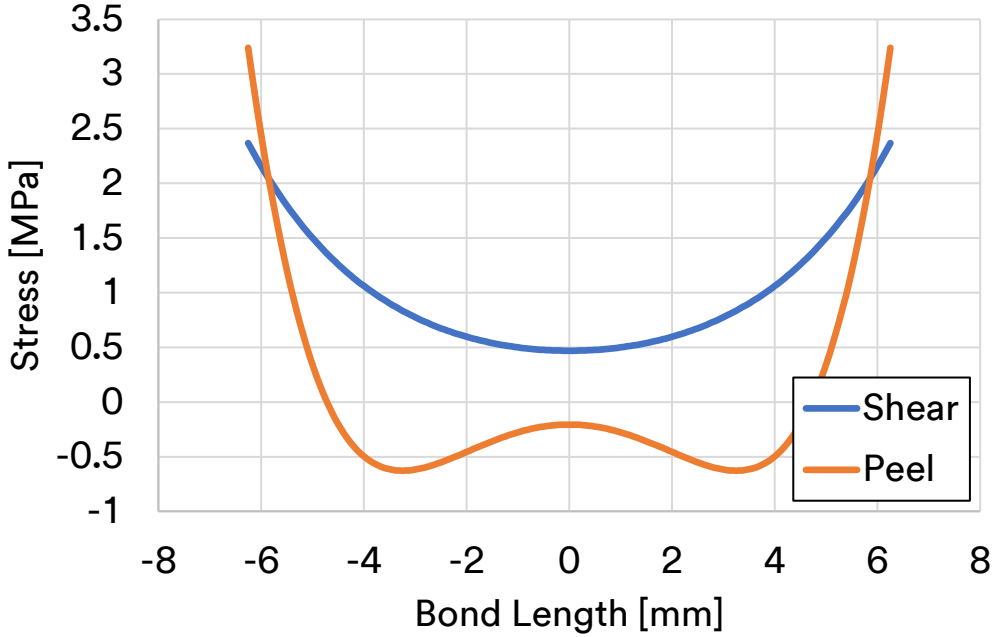
	Young‘s modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm



	Young‘s modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	**210,000 MPa**	2 mm

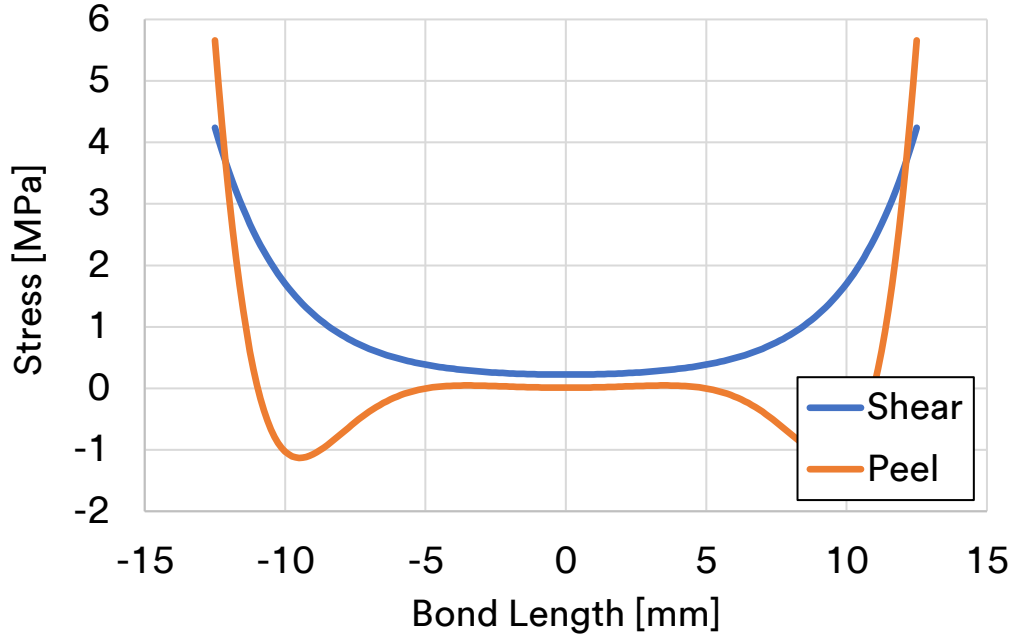
Effect of bond length for same stress

Short bond line (12.5 mm), σ = 1 MPa



	Young's modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm

Long bond line (**25 mm**), σ = 1 MPa



	Young's modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm

Conclusion

Observations

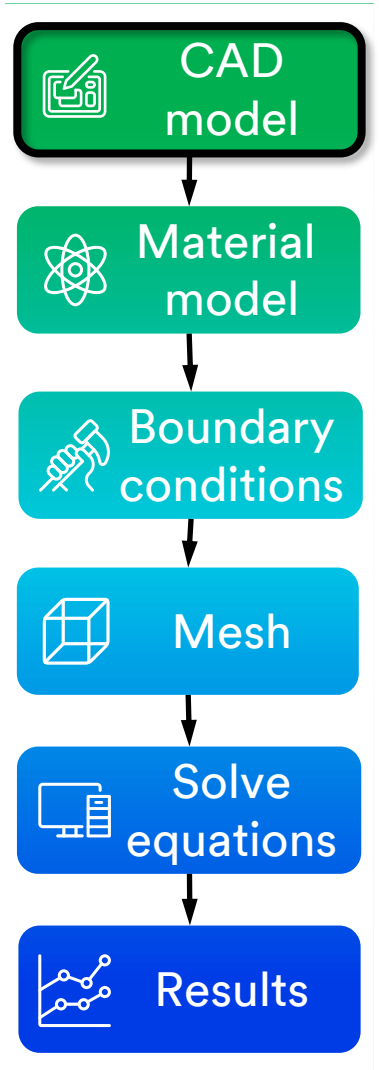
- Stress distribution is not uniform
- Failure always occurs at the stress concentrations → reduce stress peaks

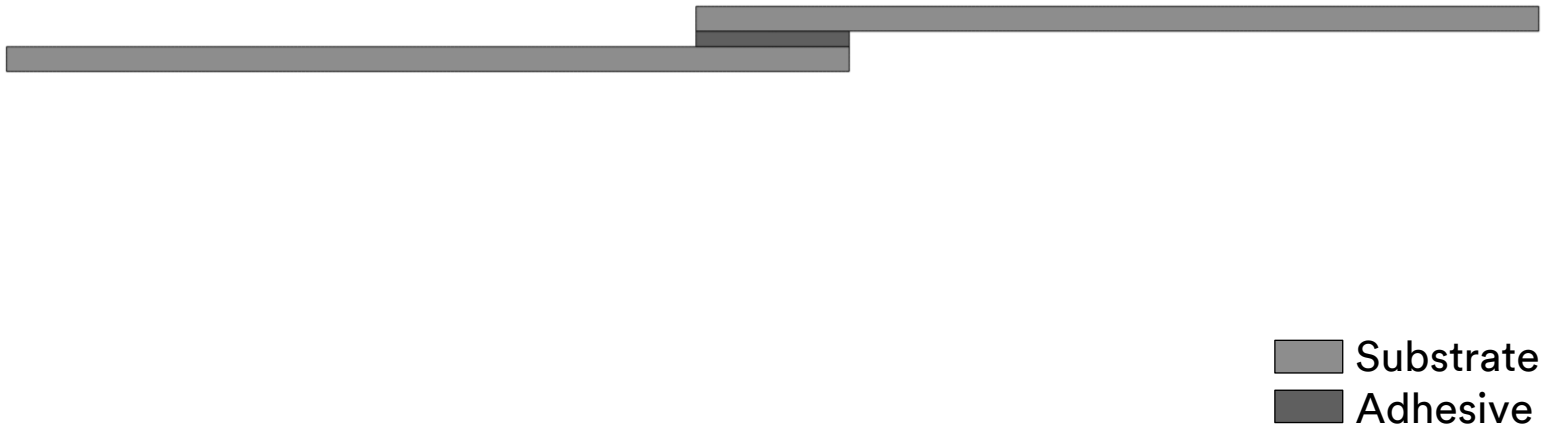
Design guidelines for maximum joint strength

- Compliant (low modulus) and ductile adhesives are great
- Use large bonded area (width over length)
- Use similar adherends
- Use thin bond lines

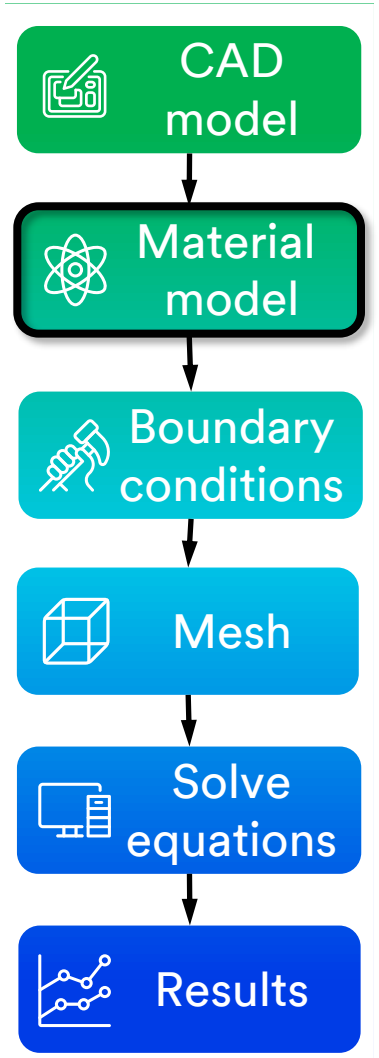
The previous study is based on assumptions such as small strains. For deeper investigations, other techniques like Finite Element Analysis (FEA) are required!

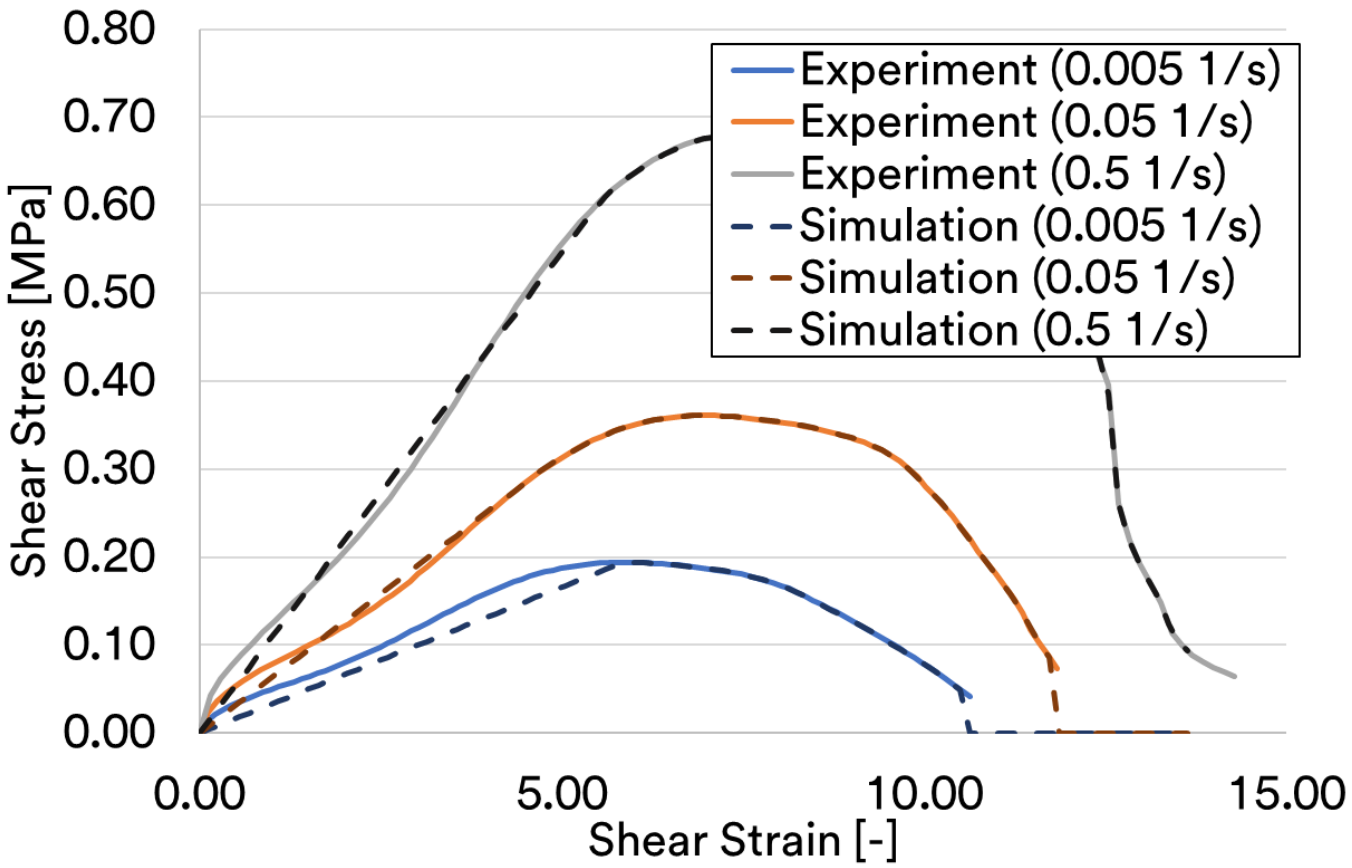
Finite Element Analysis



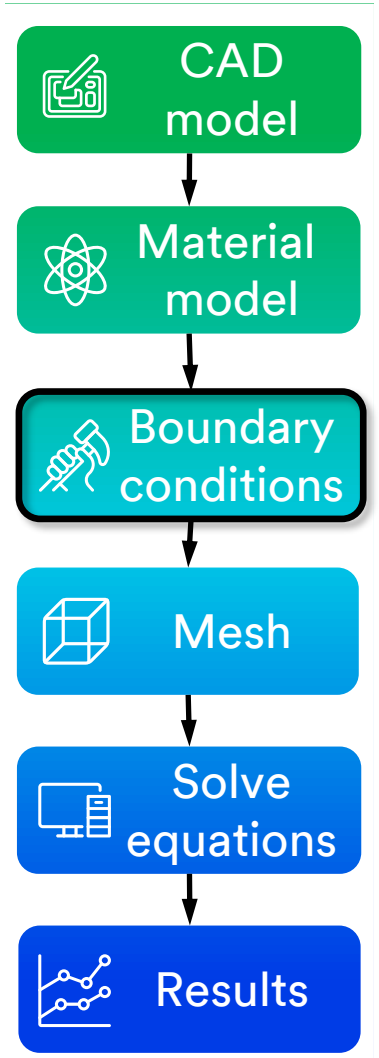


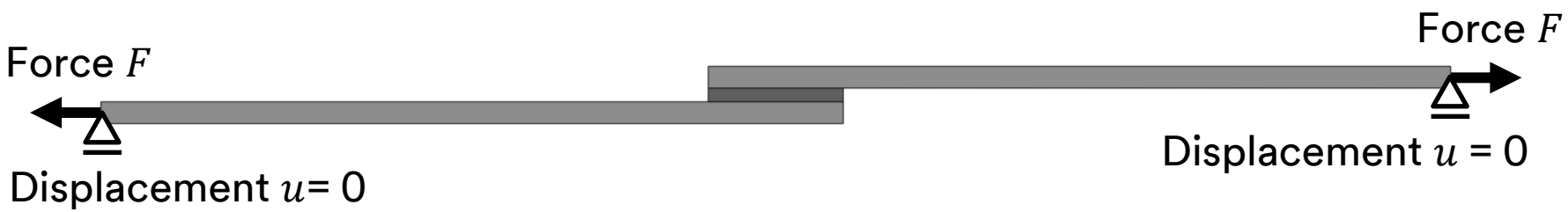
Finite Element Analysis



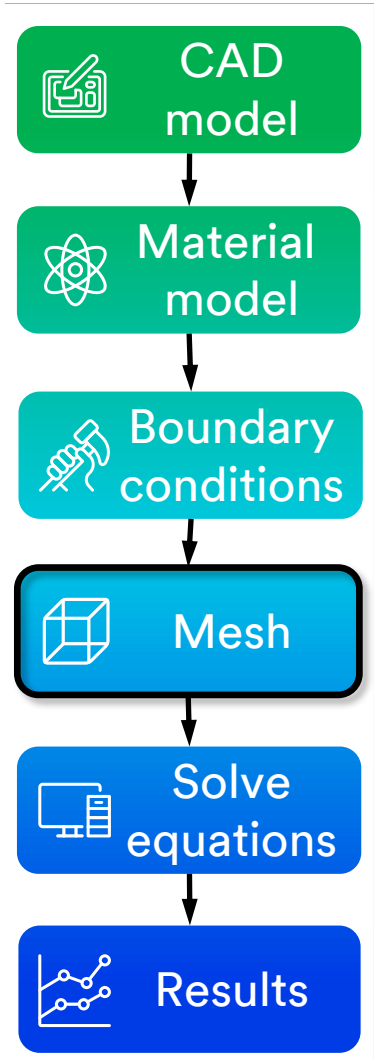


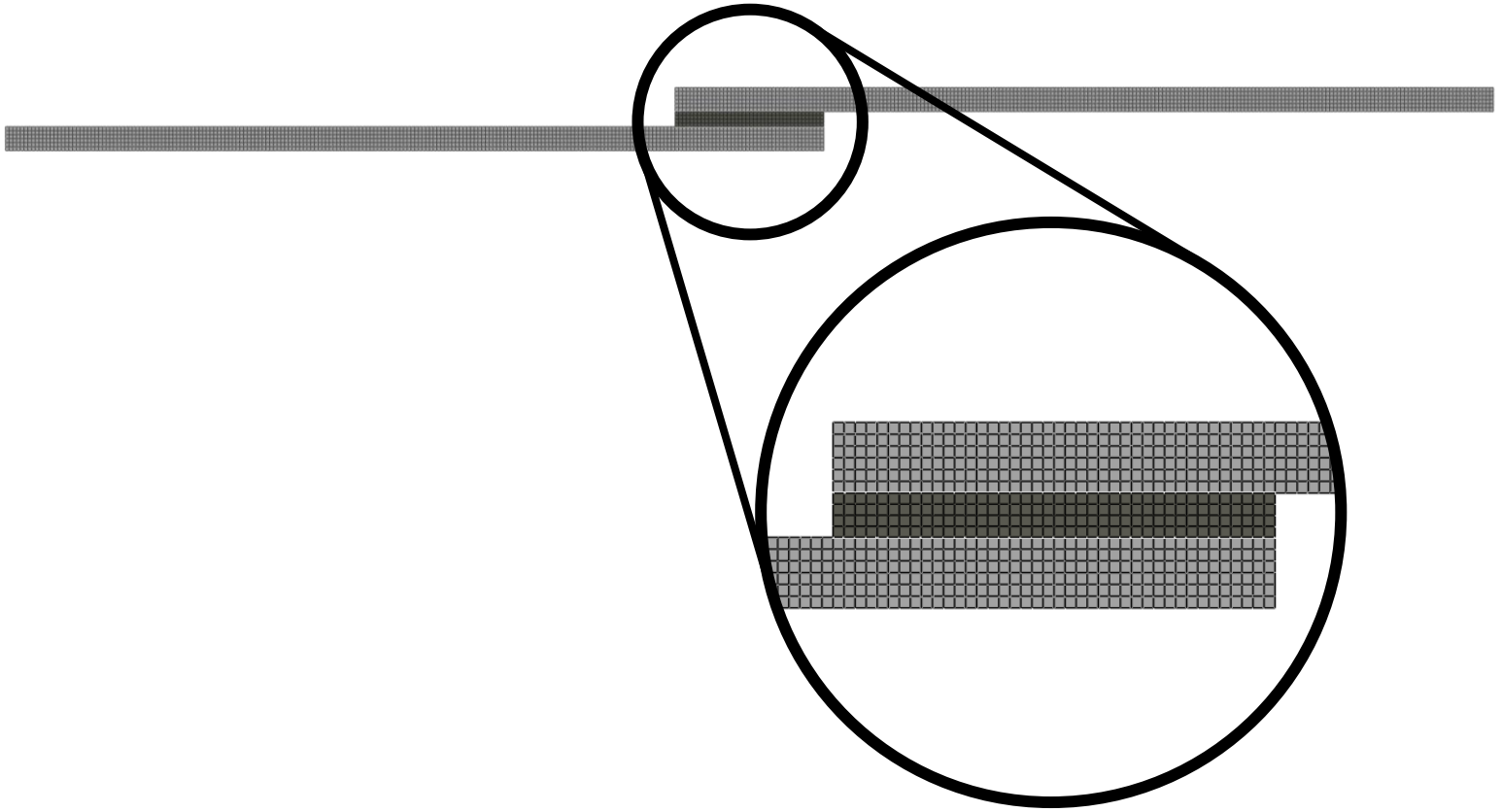
Finite Element Analysis



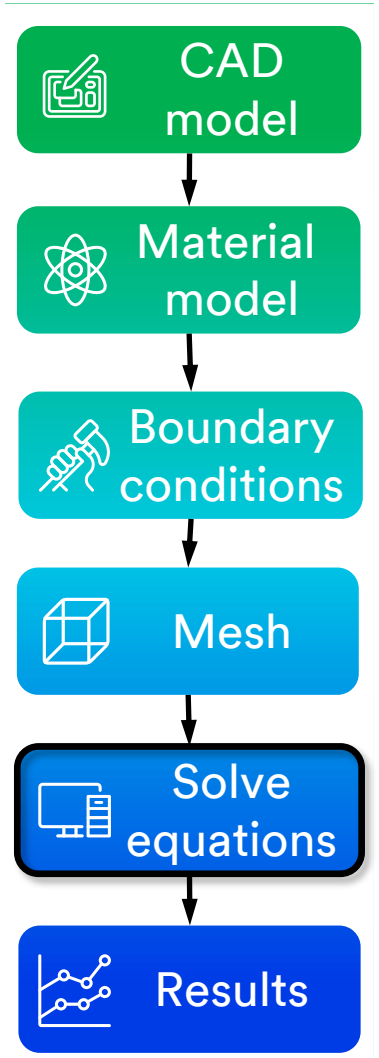


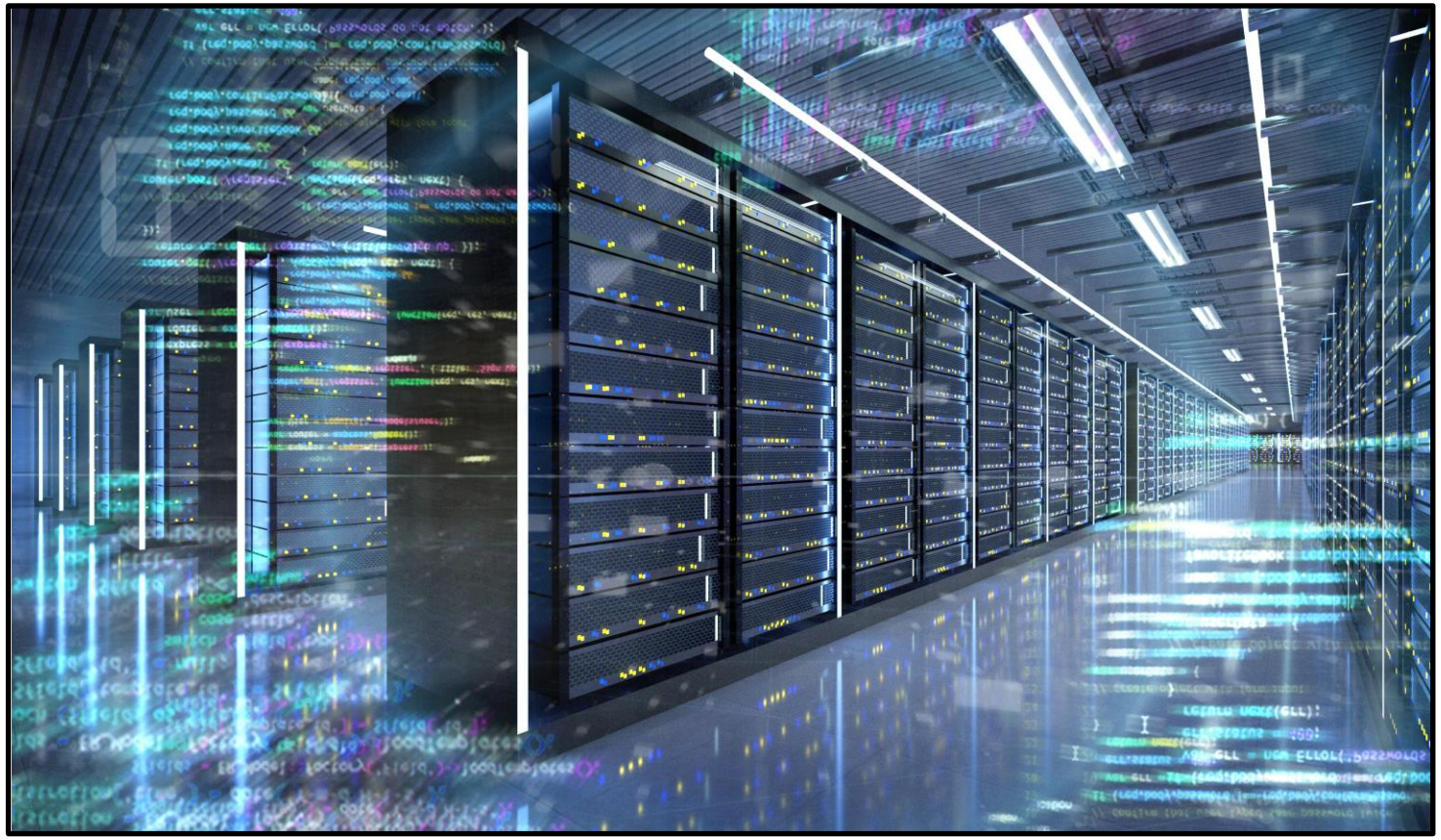
Finite Element Analysis



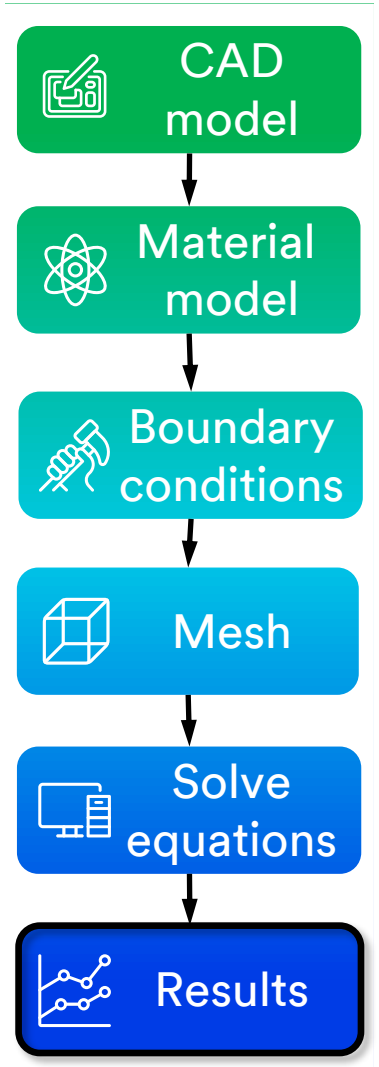


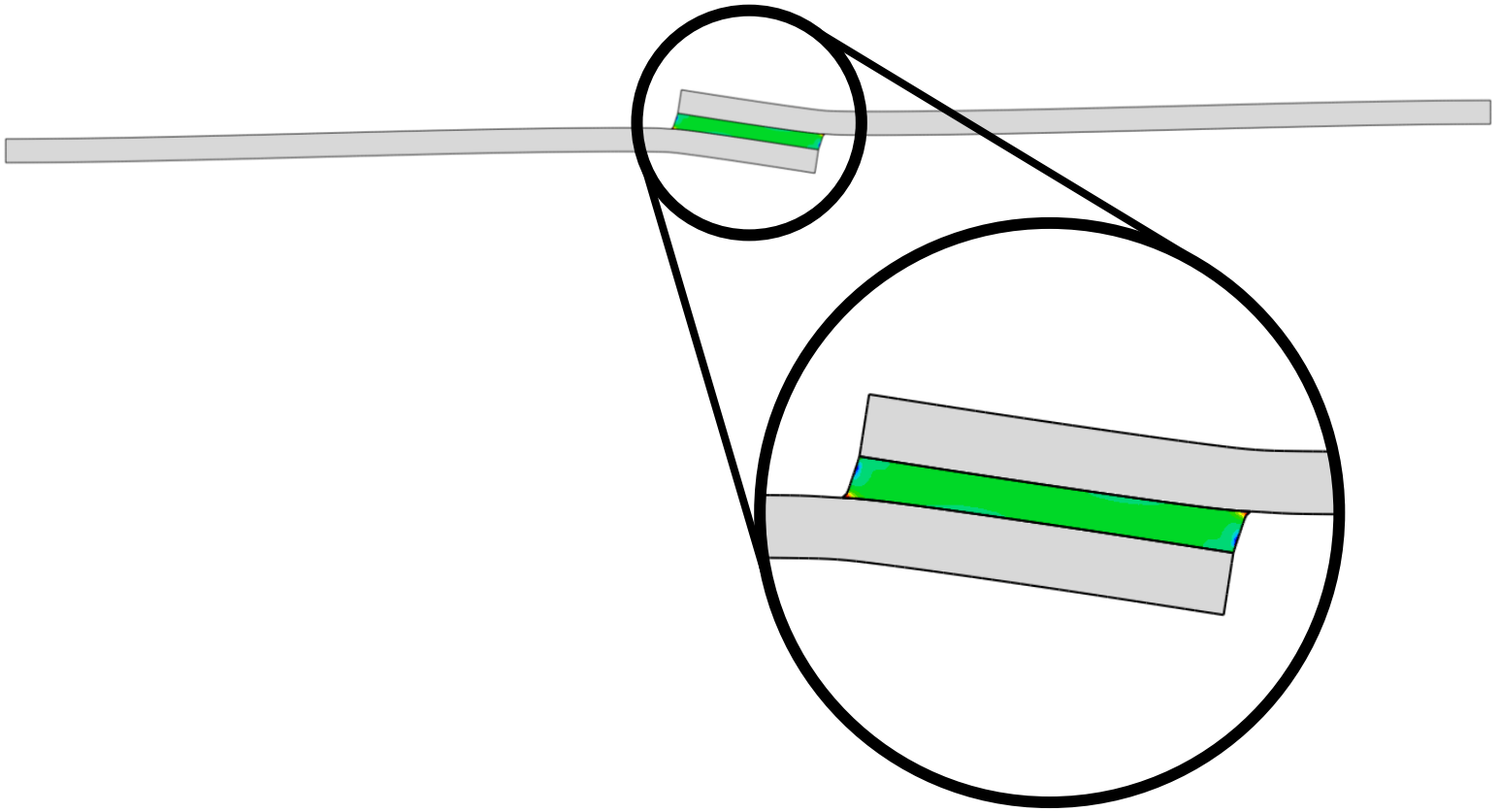
Finite Element Analysis



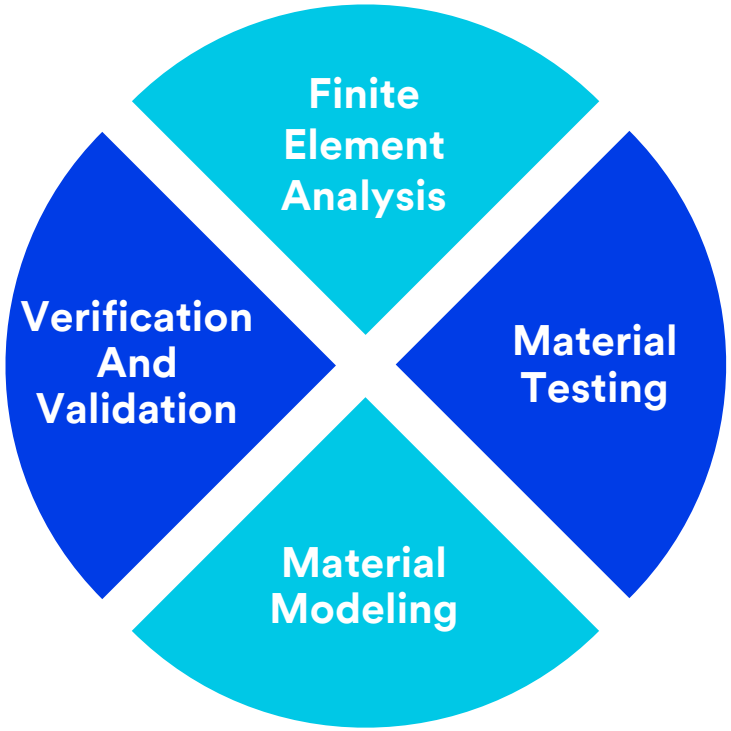


Finite Element Analysis

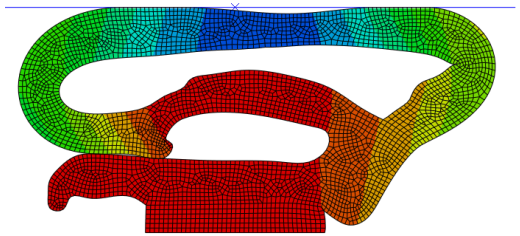




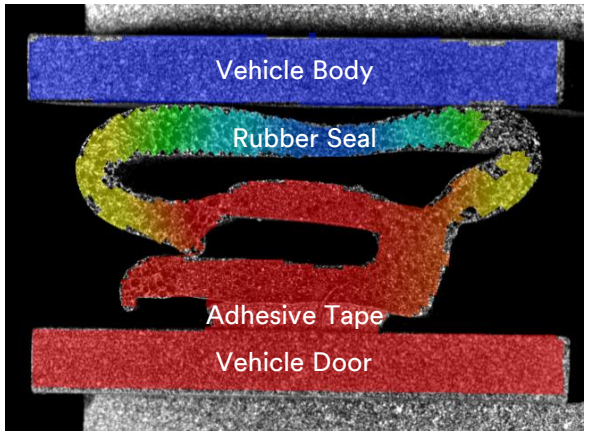
Making predictions using FEA



FE-Simulation

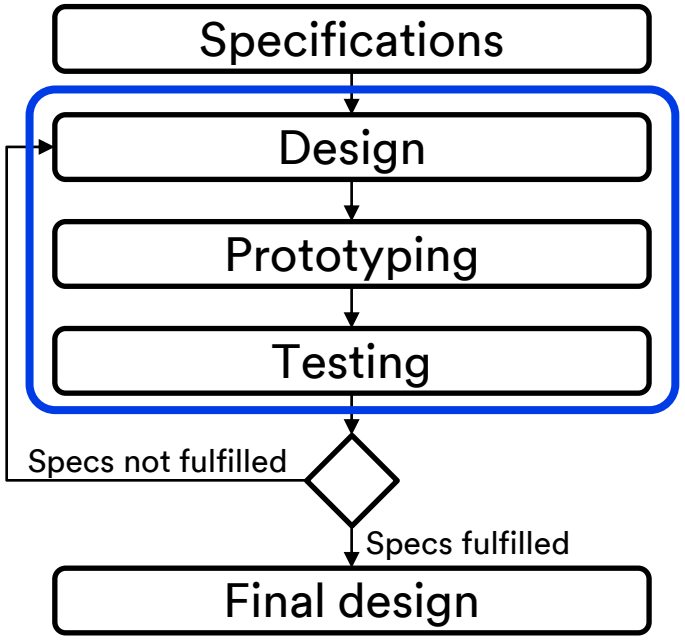


Experiment



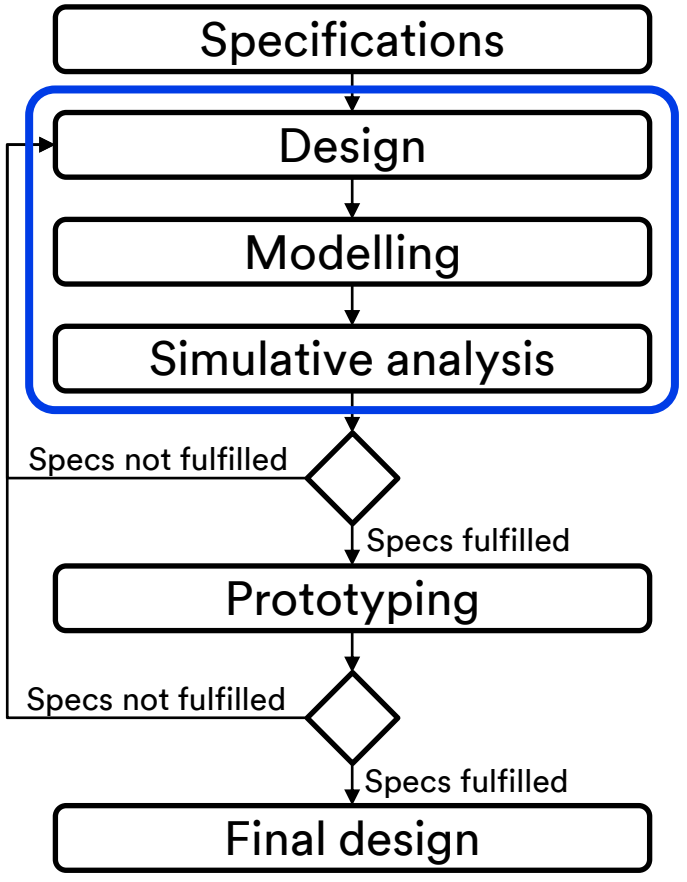
Product design

Traditional design



Expensive and time-consuming

Simulation-driven design

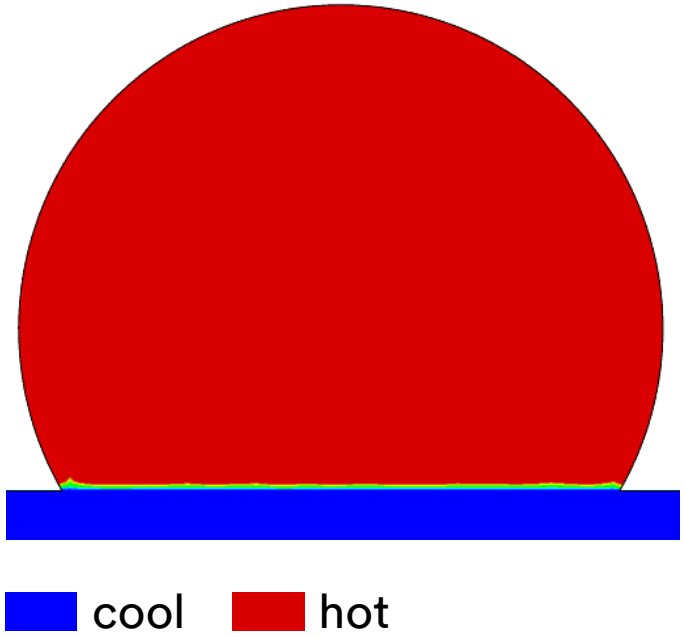


Cheap and fast process

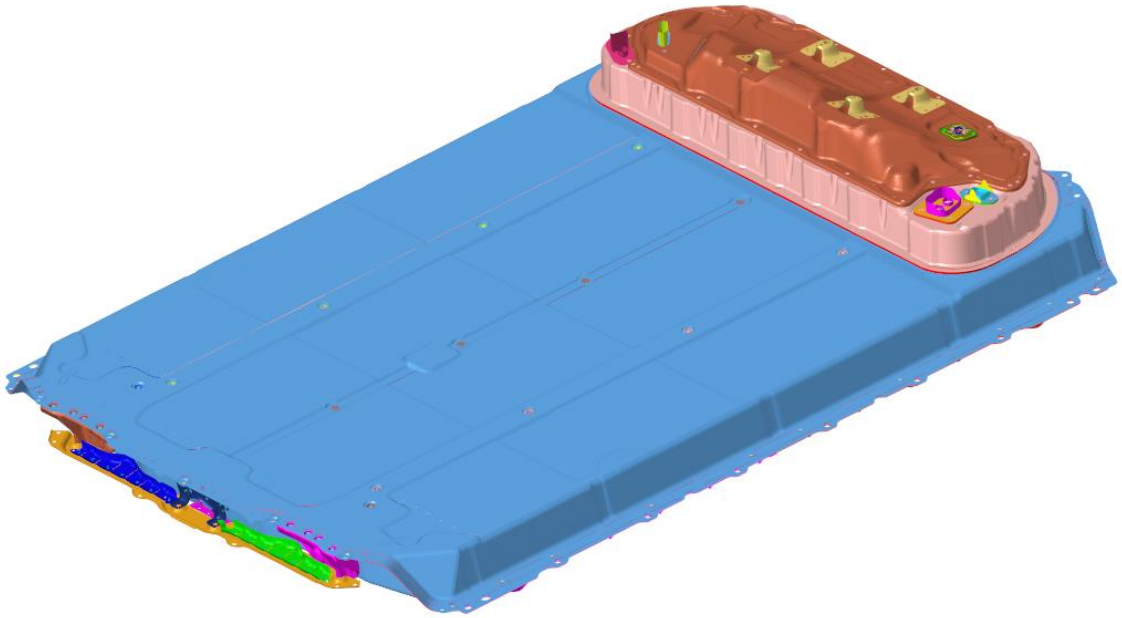
FEA capabilities

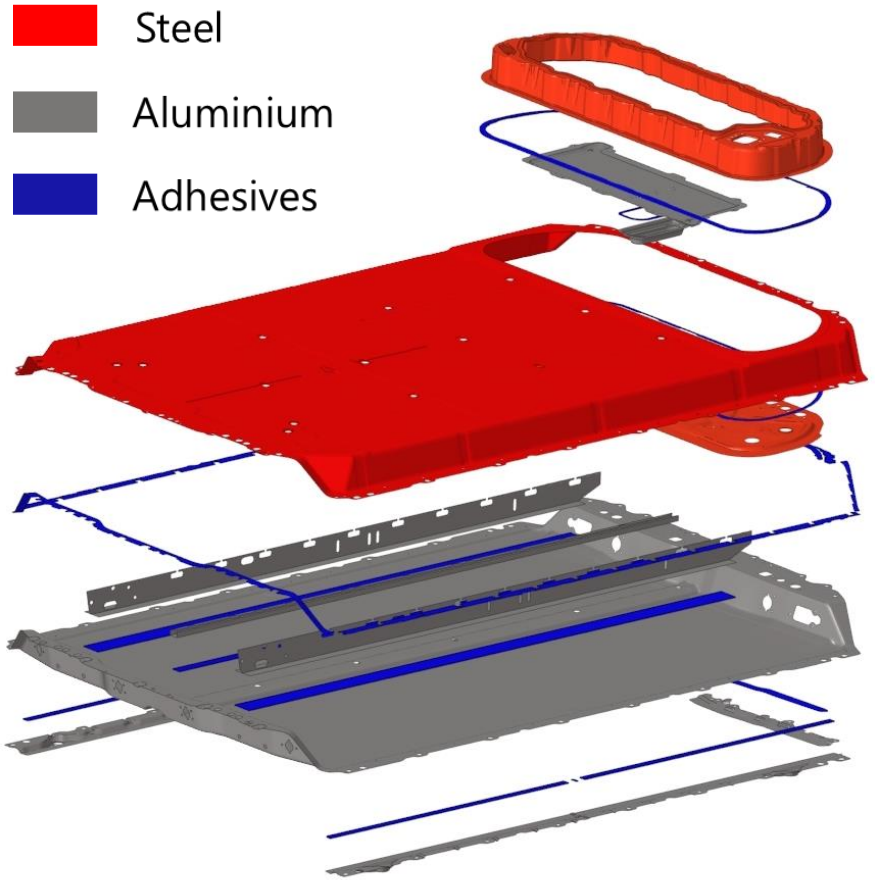
- Deformation analysis
- Failure analysis
- Noise, vibration, harshness analysis
- Wet-out analysis
- Heat transfer / thermal analysis

Thermal analysis



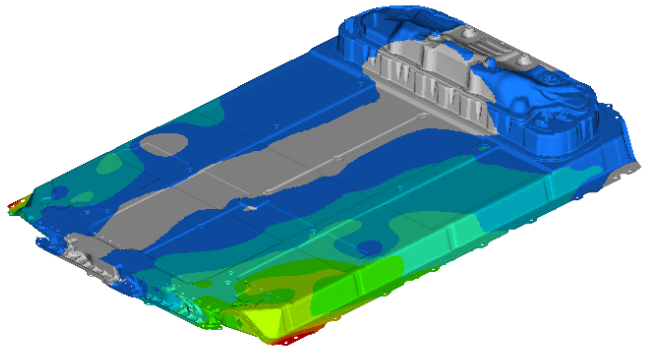
Battery Pack Analysis



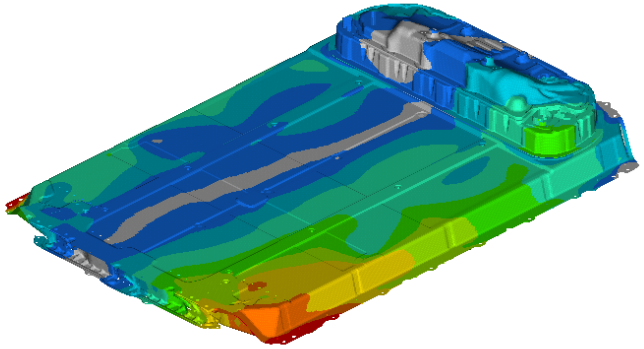


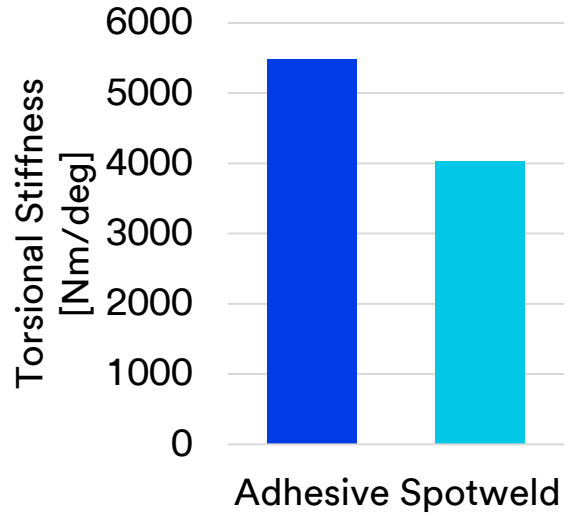
Battery Pack Analysis

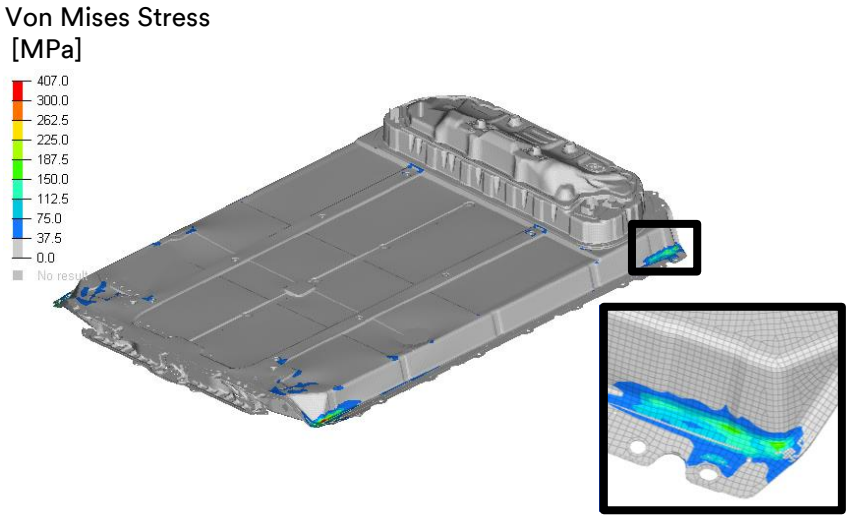
Adhesive

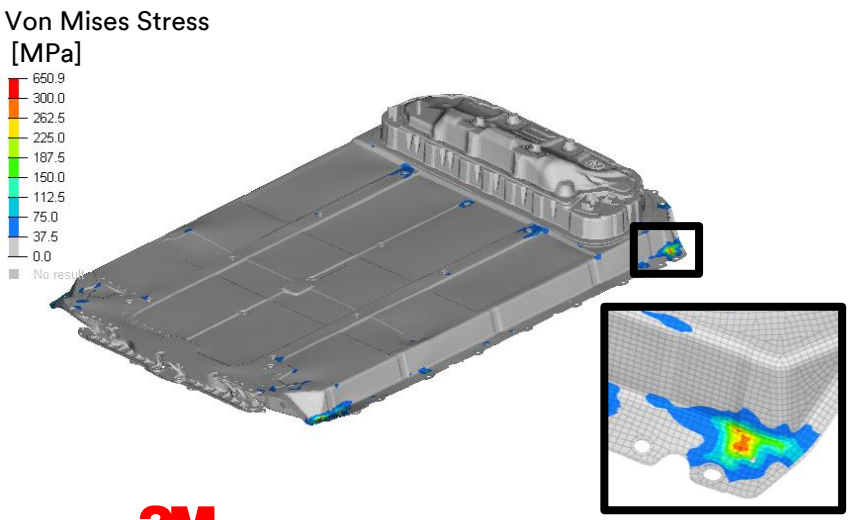


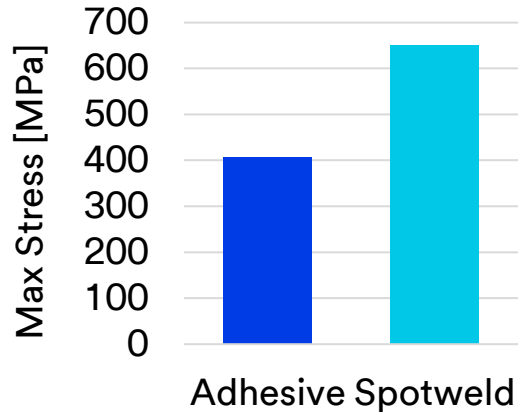
Spot welds





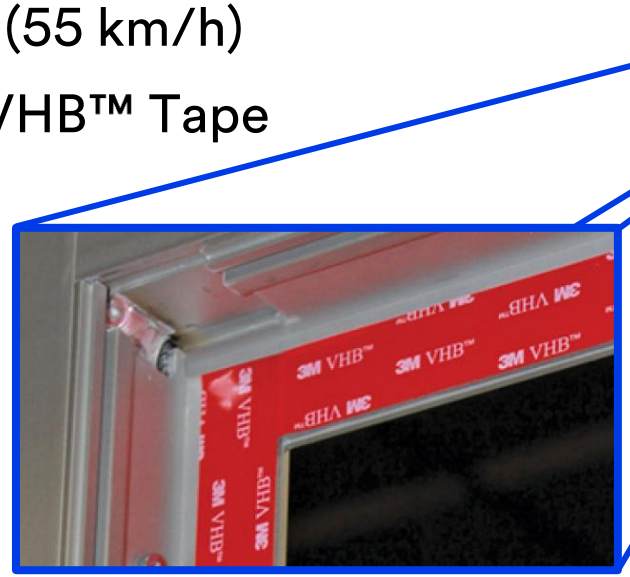






Dura-Storm: Hurricane-proof door

- Withstand extreme weather conditions
- High wind loads (~350 km/h, category 4 hurricane)
- Impact of flying debris (55 km/h)
- Glass is held by 3M™ VHB™ Tape



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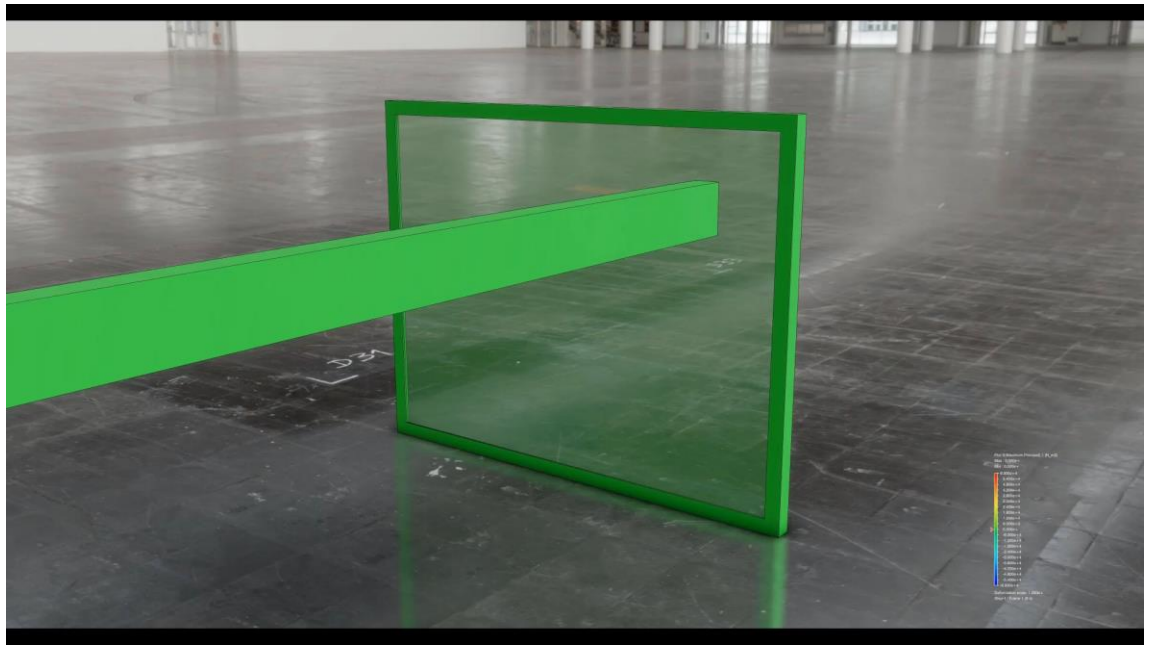
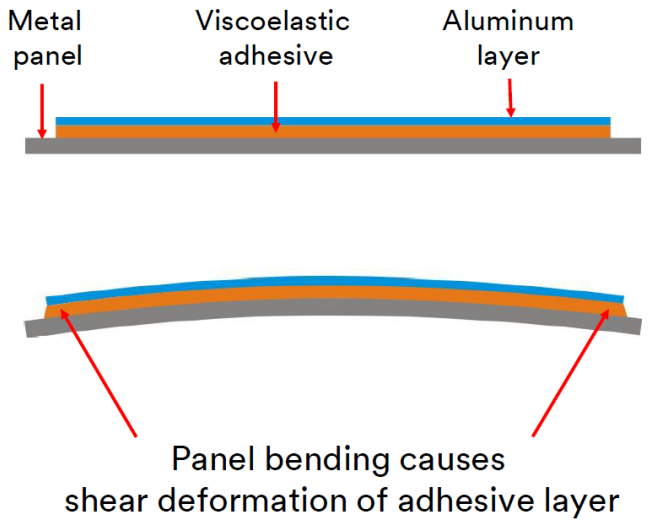


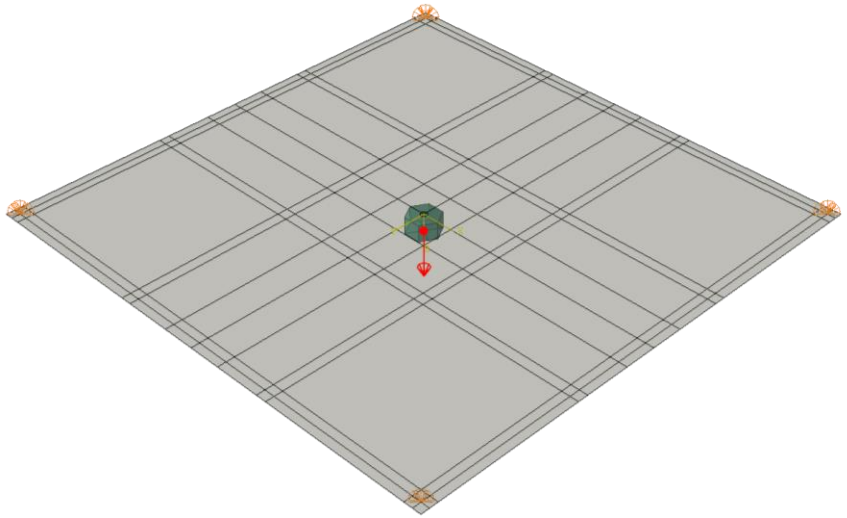
https://youtu.be/Hu6i56lpd-8
(Season 5, Episode 4)

Vibration analysis: Constrained Layer Damping

Constrained Layer Damping



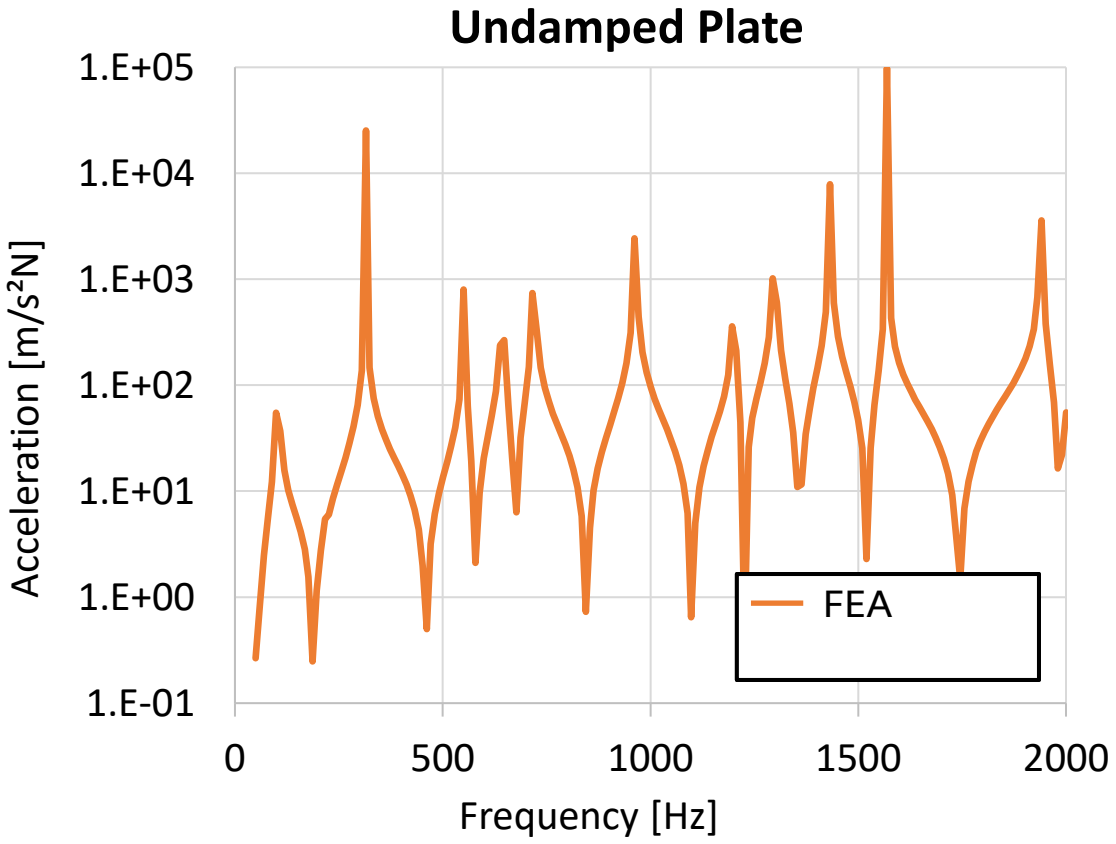
Vibration analysis

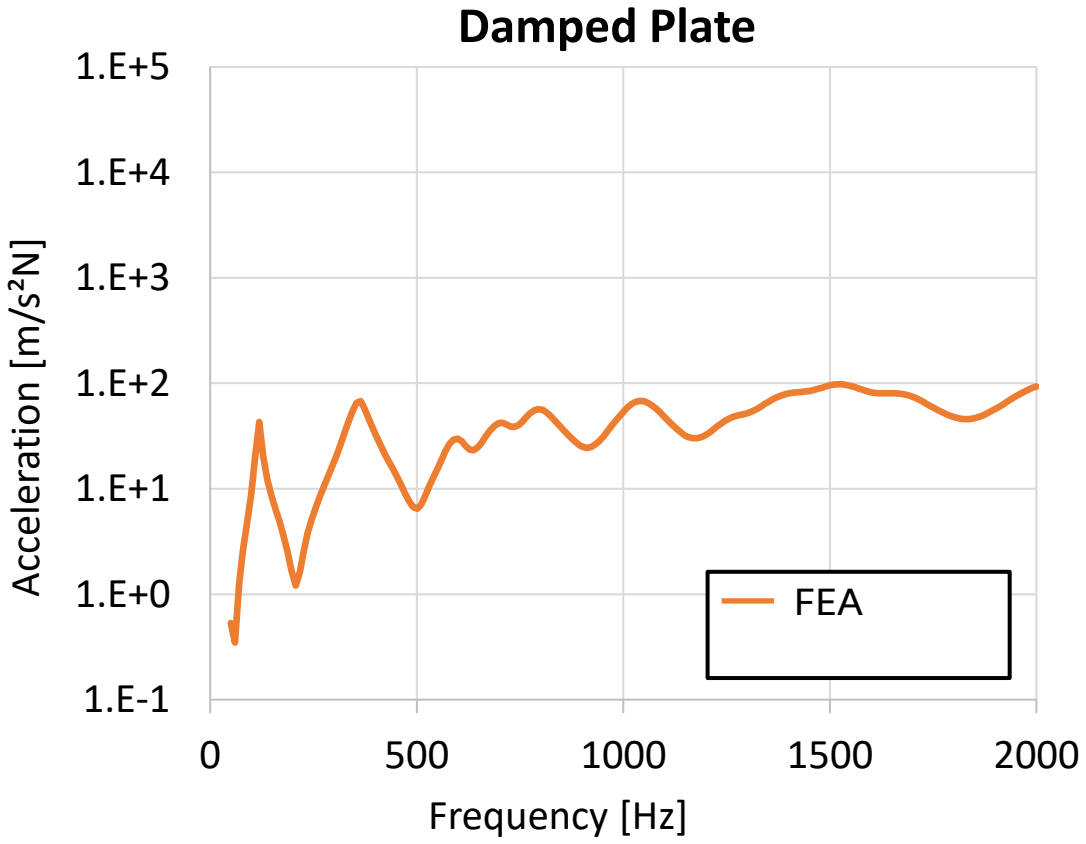


Goals:

- Reduce noise and vibrations effectively
- Ideal application at the right places with the least amount of material

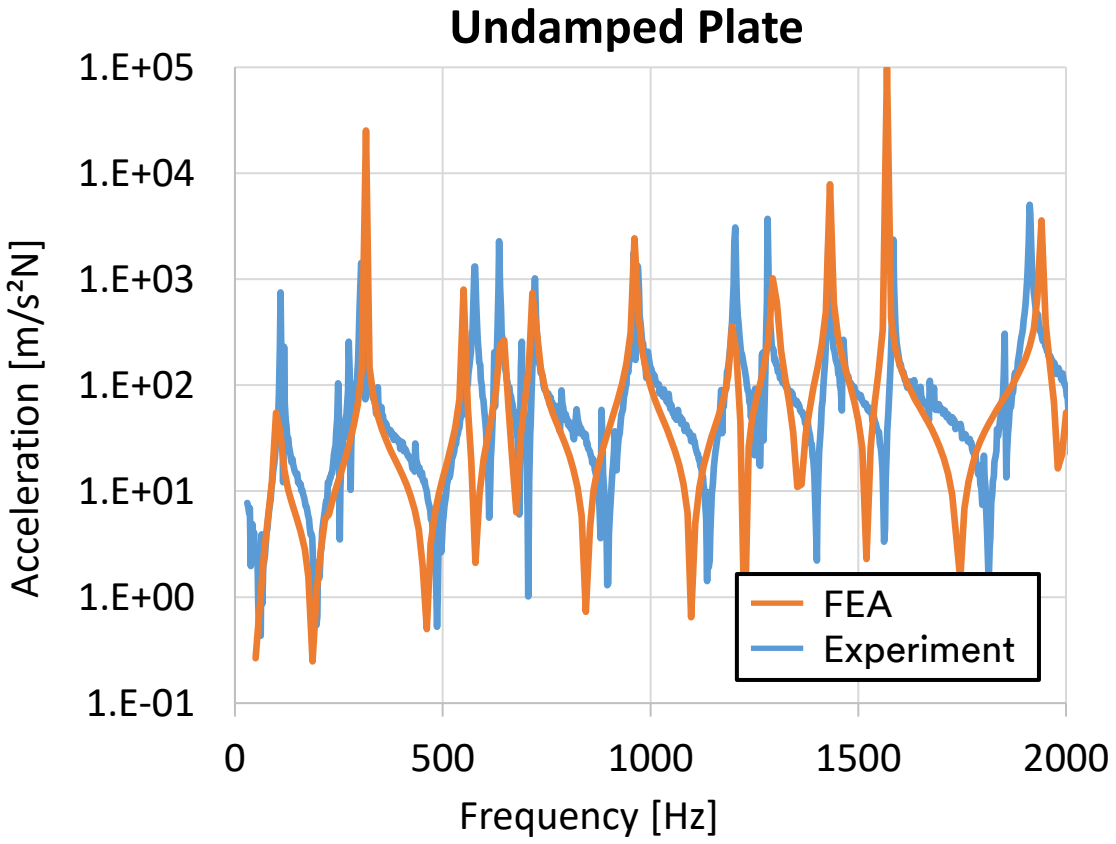
Vibration analysis: Constrained Layer Damping

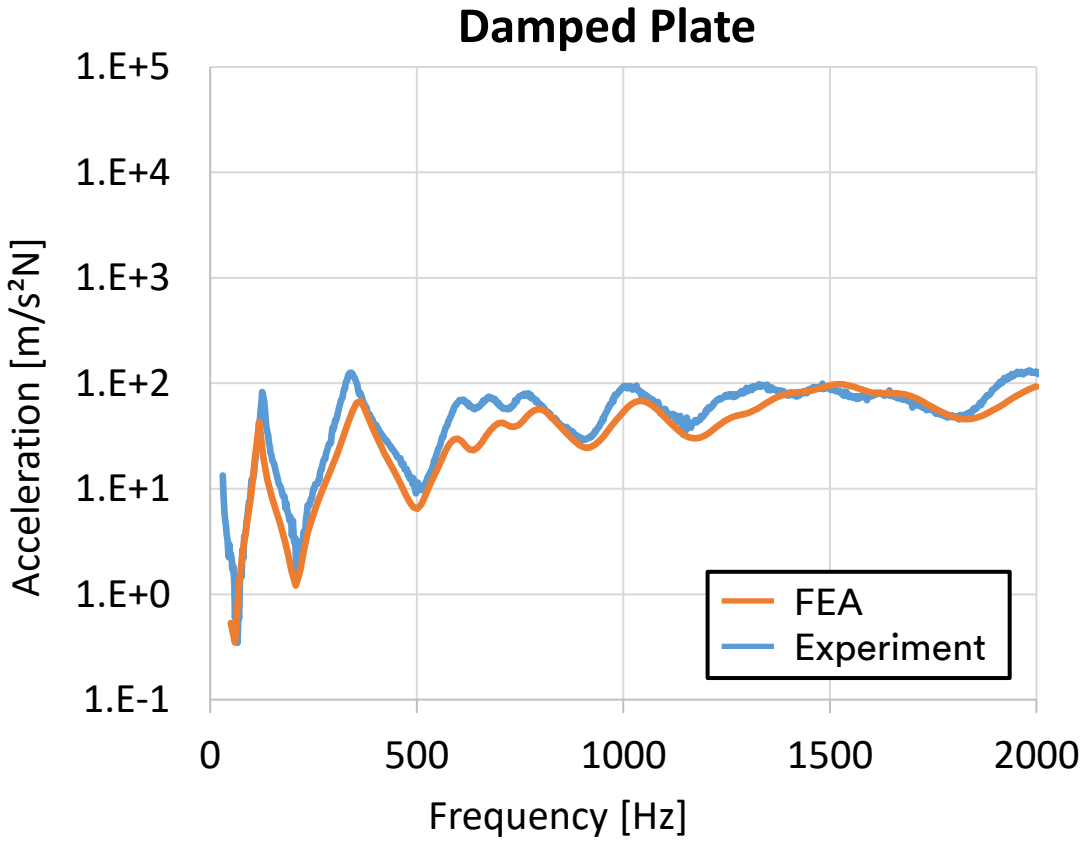




- CLD can reduce vibrations effectively
- Simulation is capabable to predict experimental response

Vibration analysis: Constrained Layer Damping





- CLD can reduce vibrations effectively
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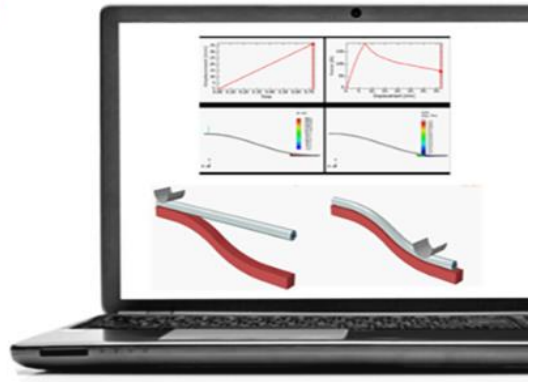
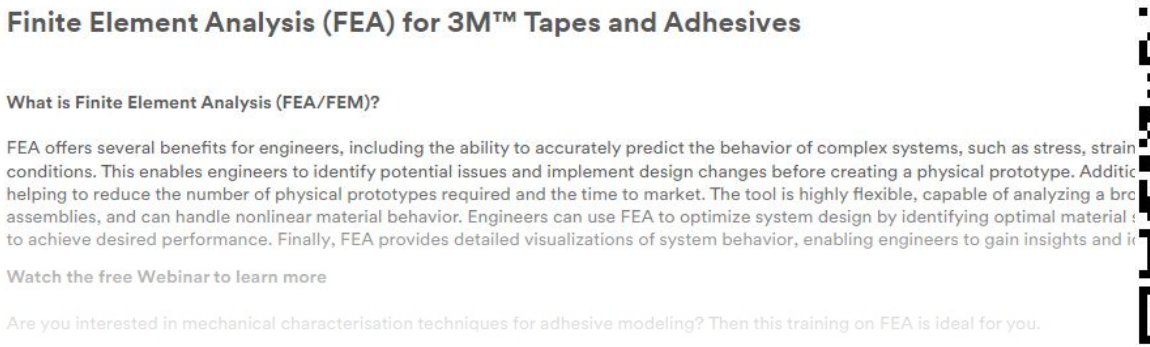
3M‘s FEA capabilities

Material data cards

FEA support

FEA Webpage





Conclusion

1. Simulations offer insights beyond experimental techniques
2. Simulation-driven design can reduce development time, costs and resources
3. 3M offers material data cards and FEA support

Thank You.

Product Selection and Use: Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application. As a result, customer is solely responsible for evaluating the product and determining whether it is appropriate and suitable for customer's application, including conducting a workplace hazard assessment and reviewing all applicable regulations and standards (e.g., OSHA, ANSI, etc.). Failure to properly evaluate, select, and use a 3M product and appropriate safety products, or to meet all applicable safety regulations, may result in injury, sickness, death, and/or harm to property.