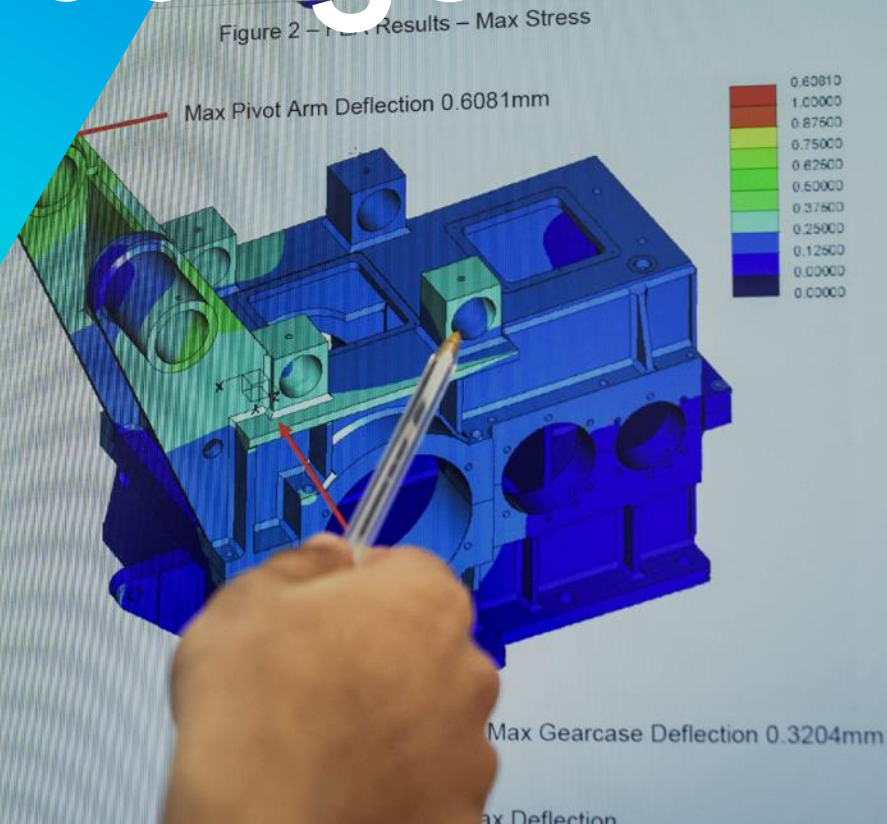


Simulationsgestütztes Design von Klebverbindungen

Alexander Schowtjak



Agenda

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



Dr.-Ing. Alexander Schowtjak

Application Engineer

3M Germany, Industrial Adhesives & Tapes Division

3M at a glance

A woman with blonde hair and safety glasses is looking at a tray of small, white, cylindrical components in a factory setting. The scene is illuminated with a strong red light, and several large industrial robotic arms are visible in the background.

~63,000

people

110

manufacturing sites

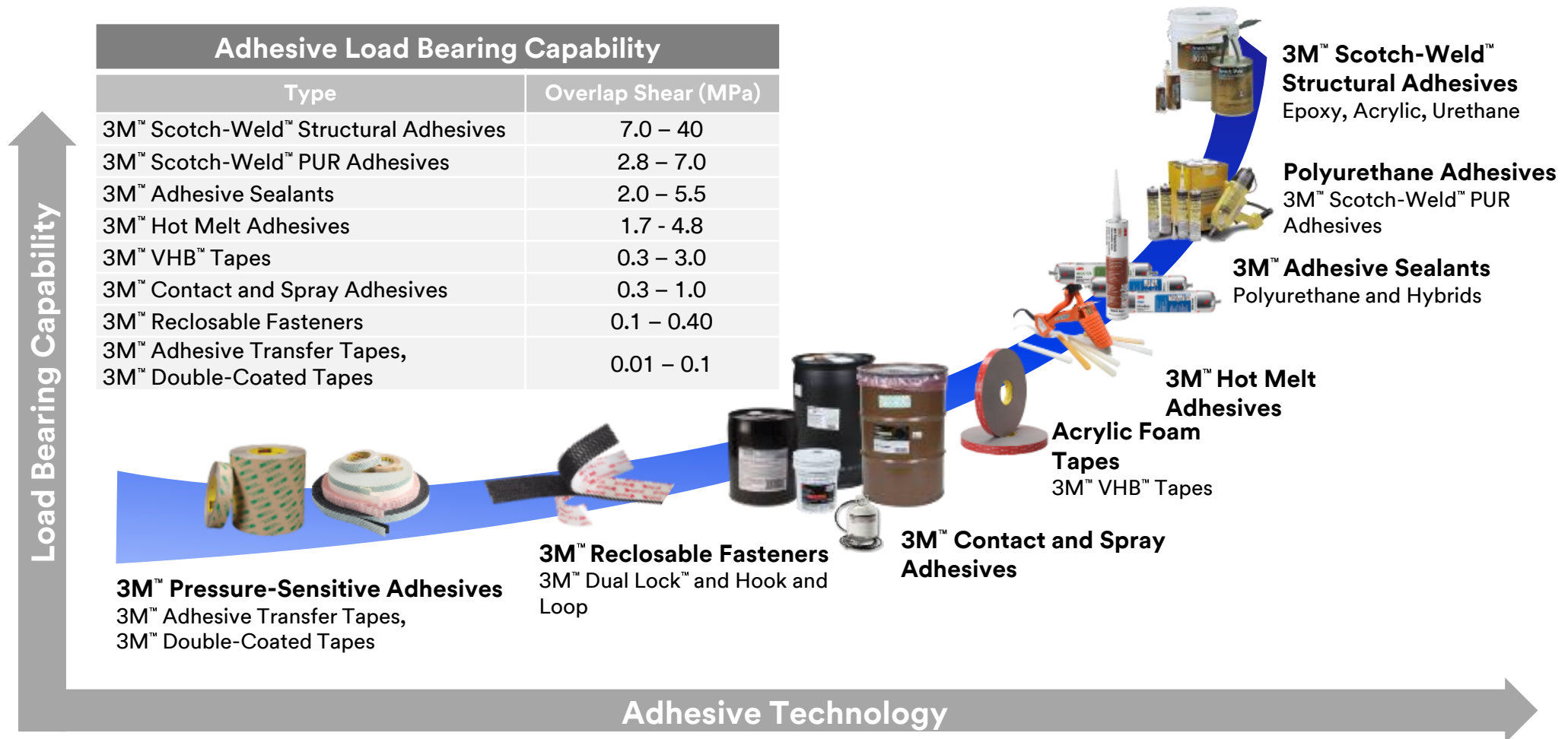
130,000+

patents

~55,000

products

Overview of adhesive technologies



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.



Scotch-Weld™
Structural Adhesive



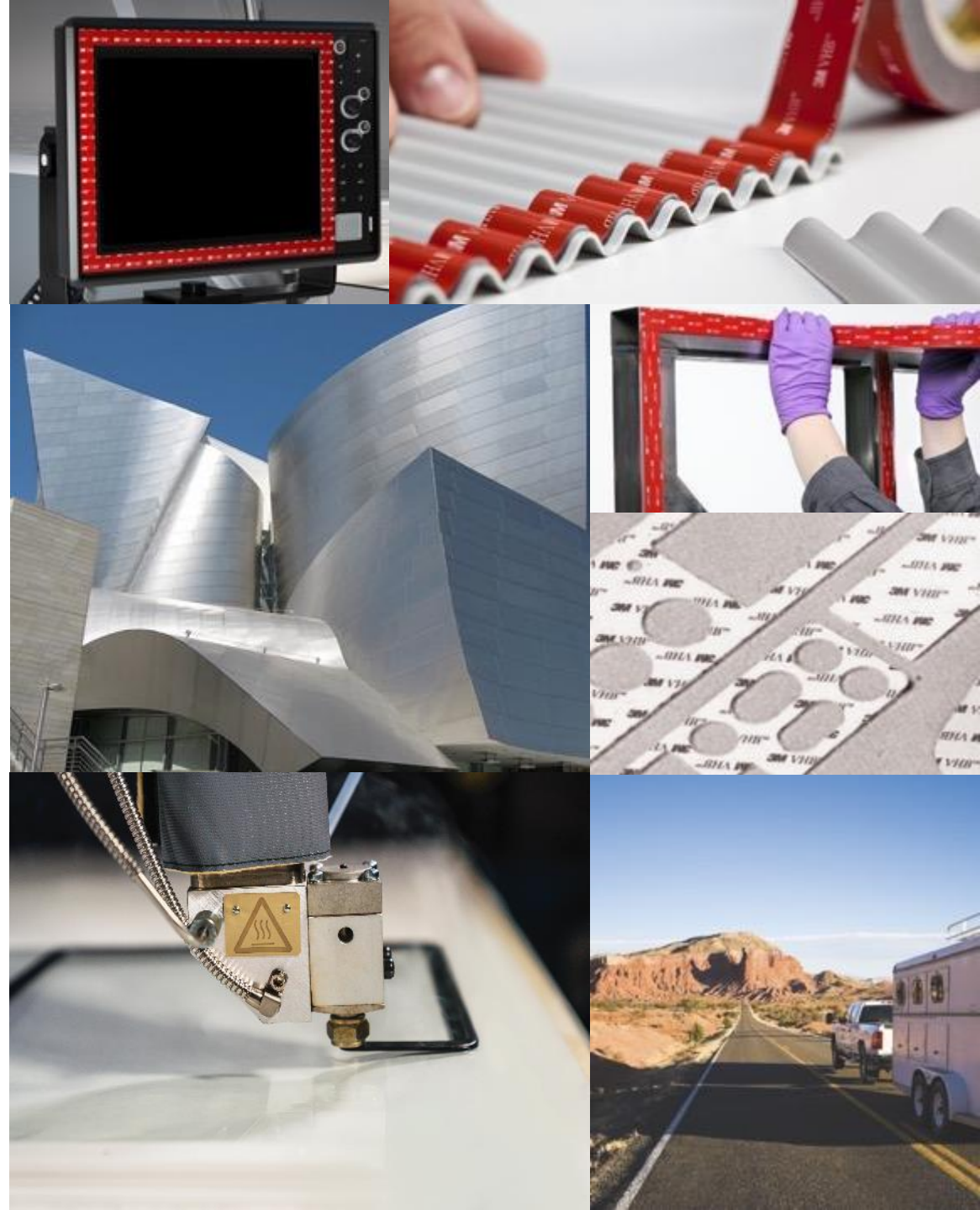
3M™ VHB™ Tape

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

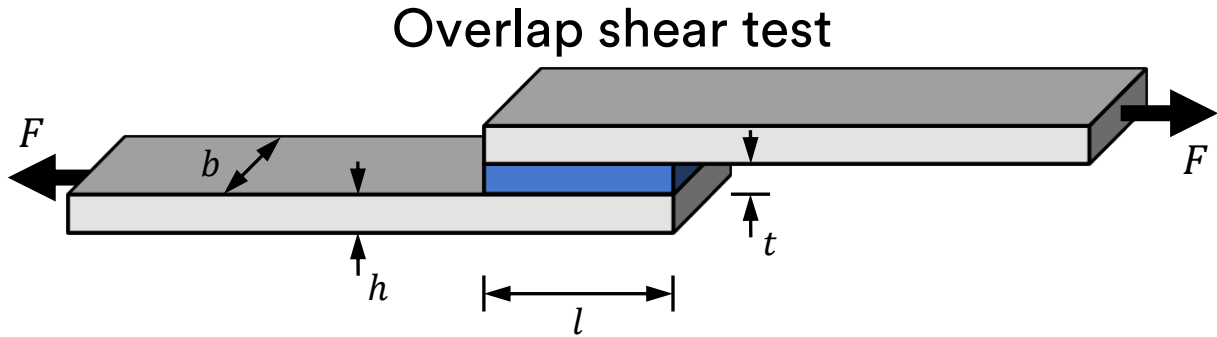
Create new products with almost any substrate – without the need for mechanical fasteners – while enhancing appearances and performance. Join aluminum, steel, glass, plastics, as well as painted and powder-coated substrates – with precision, ease, reliability, and strength.

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.

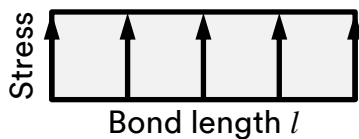


Understanding overlap shear joints

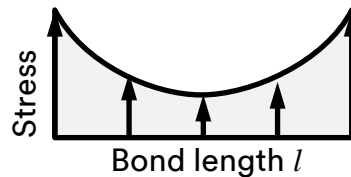


- Eccentric load is inducing bending moment
- Failure, when load > strength

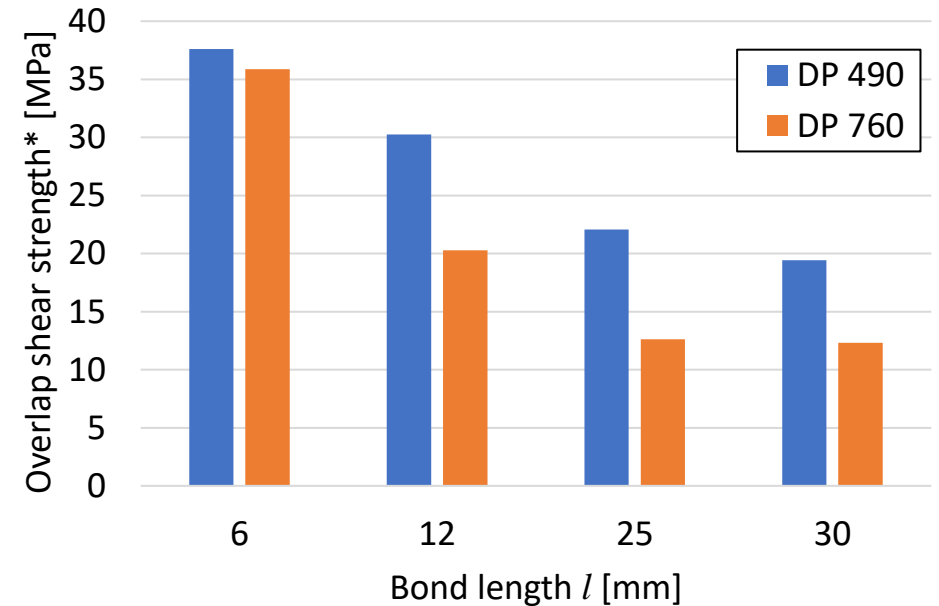
Ideal loading



Real loading



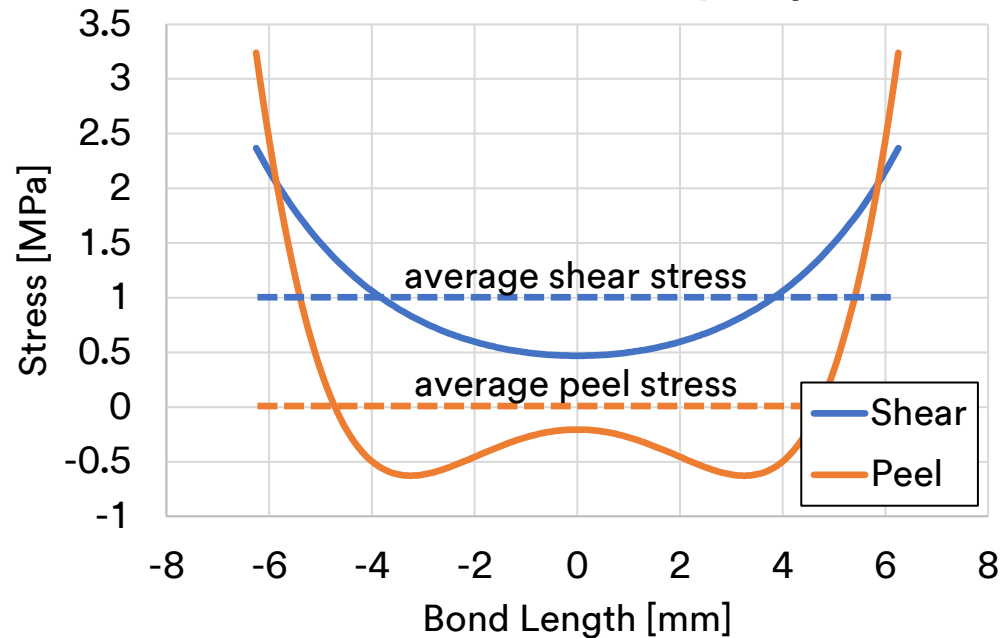
Influence of bond length on strength



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

Effect of adhesive's stiffness

Aluminum bonded with epoxy adhesive



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

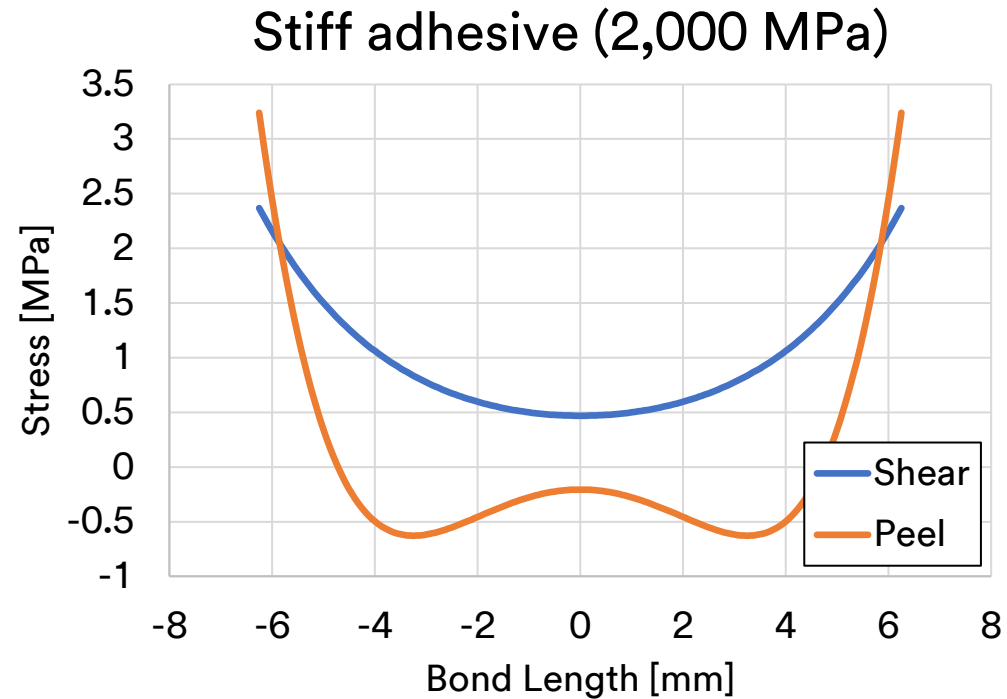
Predictions made with analytical solution according to Goland and Reissner*

Assumptions:

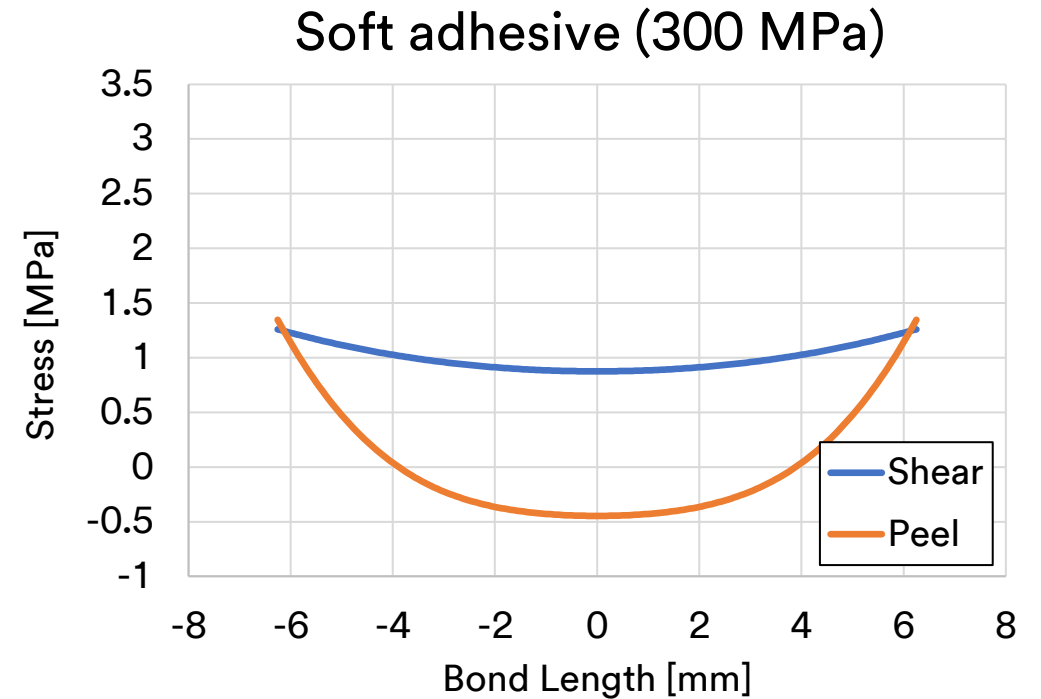
- Small deformations
- Linear elastic adherends and adhesive

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

Effect of adhesive's stiffness



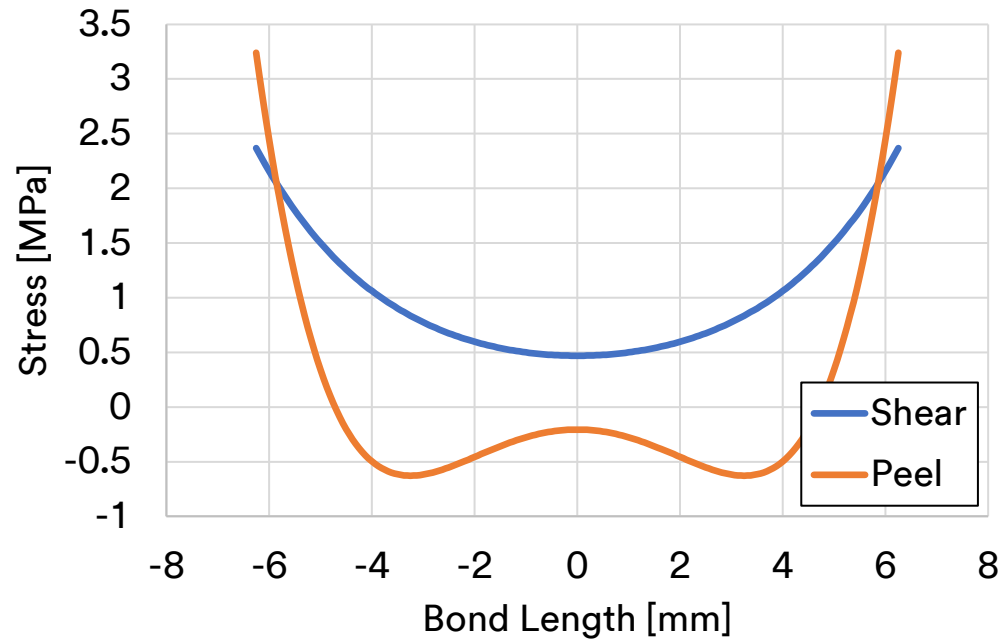
	Young's modulus	Thickness
Adhesive	2,000 MPa	0.25 mm
Substrate	70,000 MPa	2 mm



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

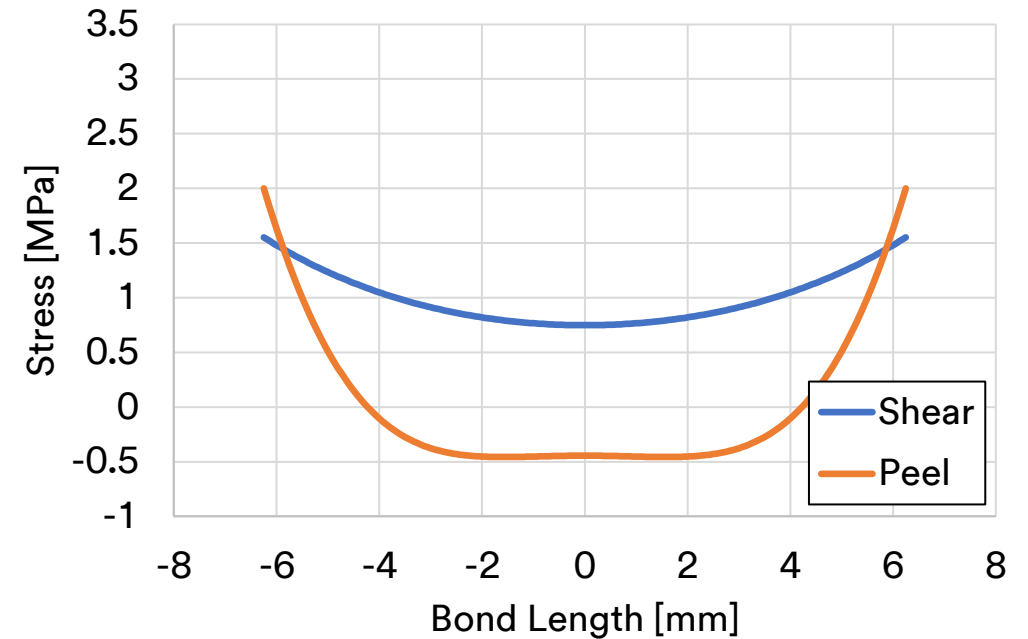
Effect of substrate's stiffness

Aluminum substrate



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

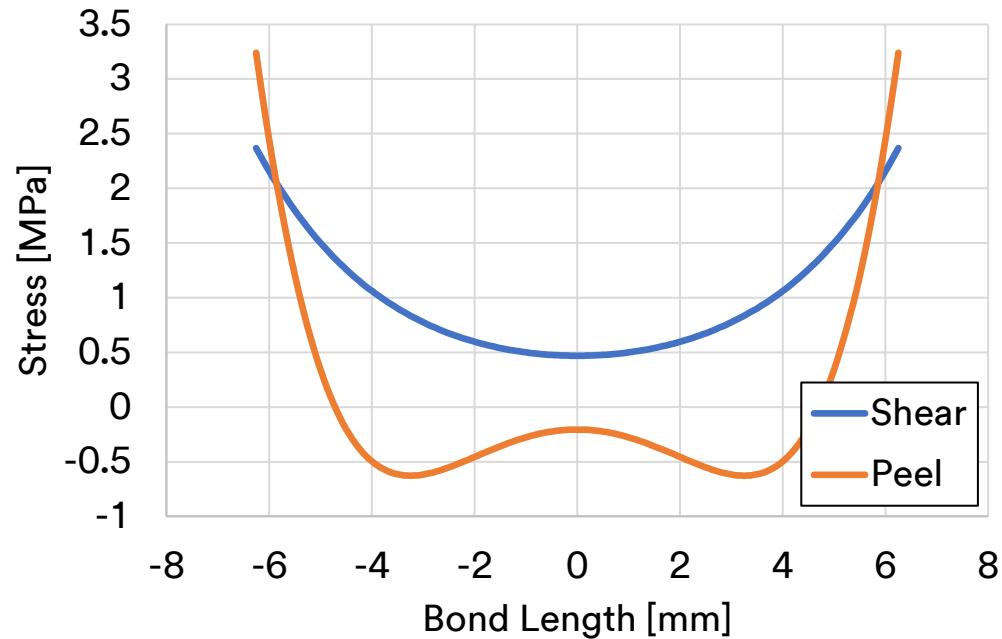
Steel substrate



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

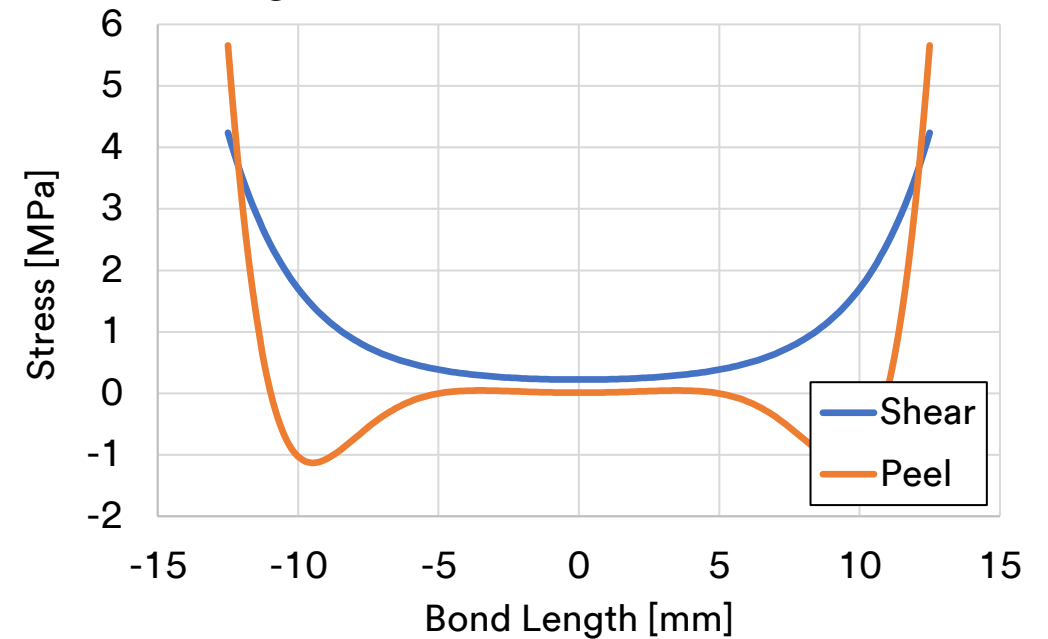
Effect of bond length for same stress

Short bond line (12.5 mm), $\sigma = 1$ MPa



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

Long bond line (25 mm), $\sigma = 1$ MPa



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

Conclusion

Observations

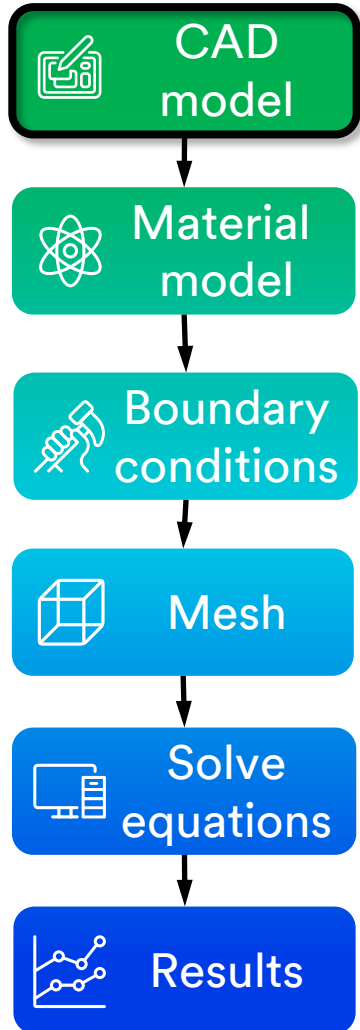
- Stress distribution is not uniform
- Failure always occurs at the stress concentrations → reduce stress peaks

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

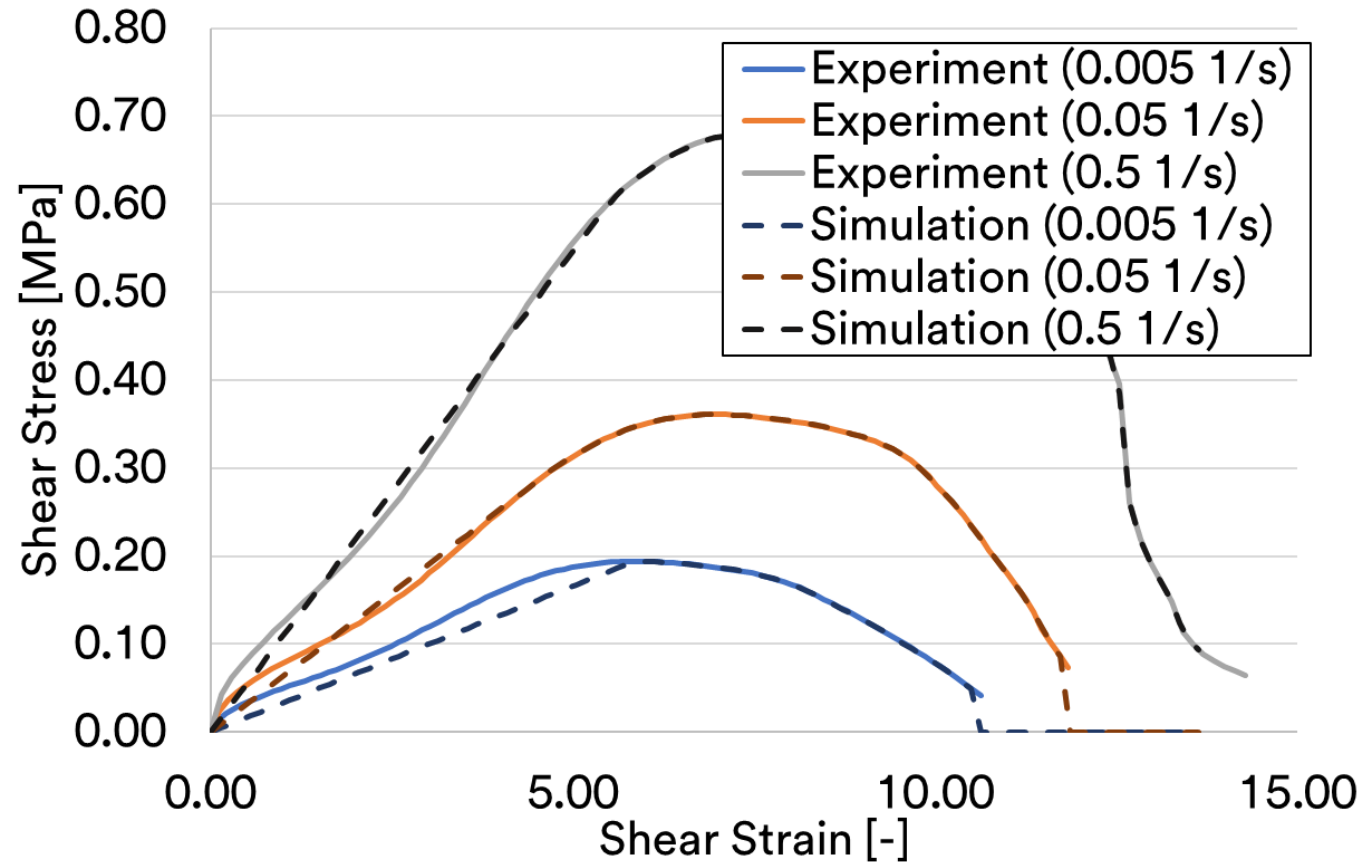
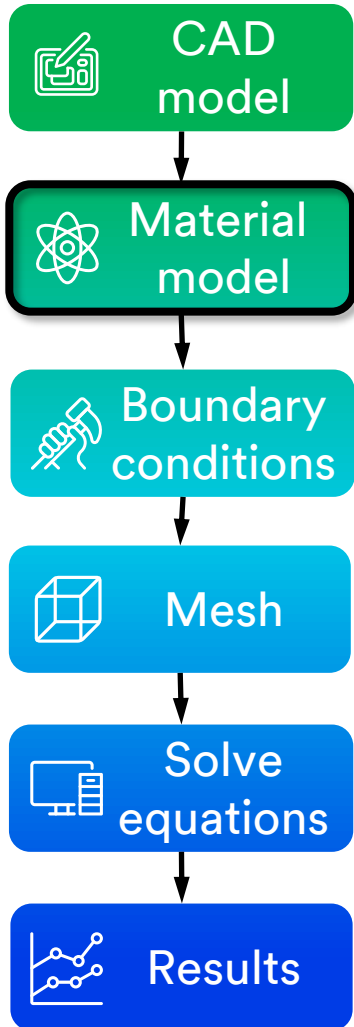
The previous study is based on assumptions such as small strains. For deeper investigations, other techniques like Finite Element Analysis (FEA) are required!

Finite Element Analysis

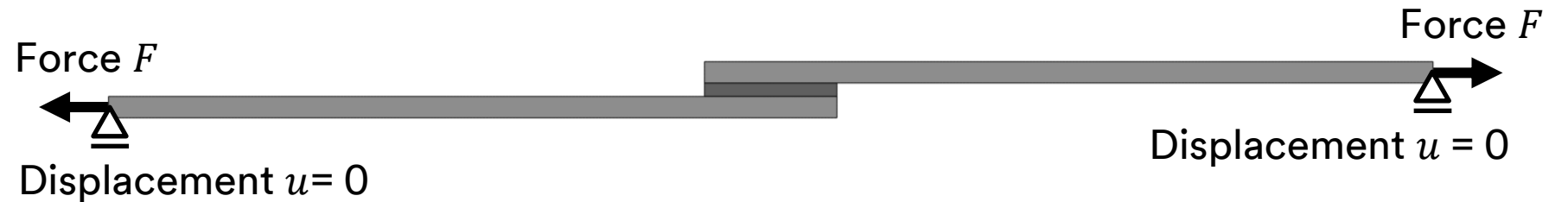
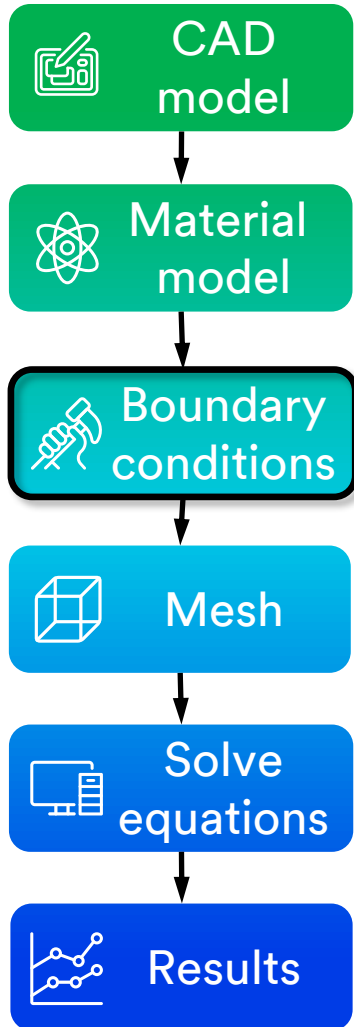


■ Substrate
■ Adhesive

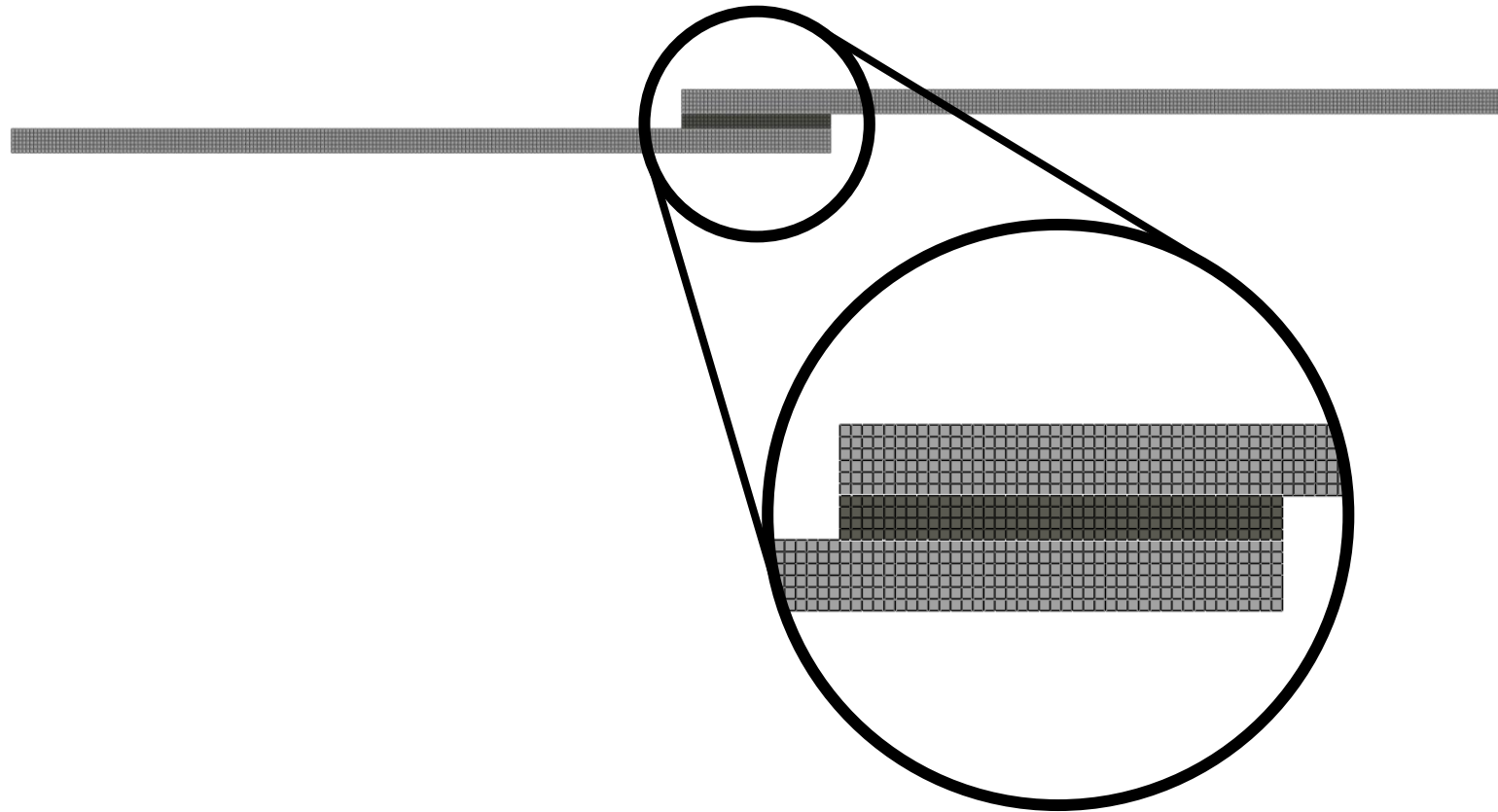
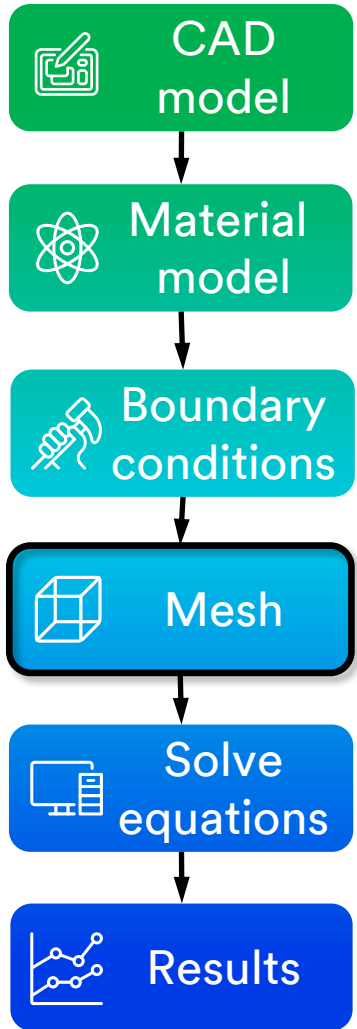
Finite Element Analysis



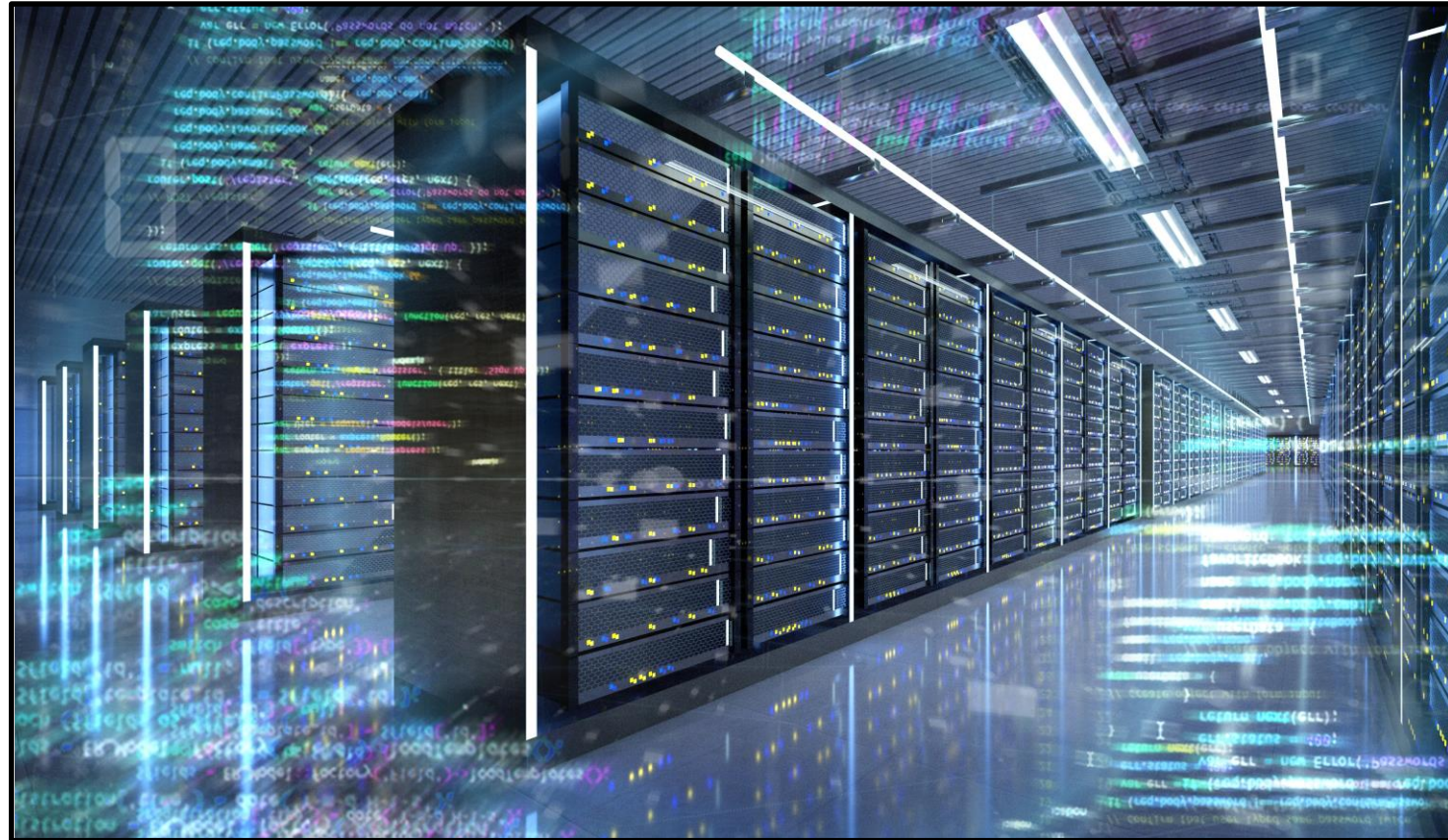
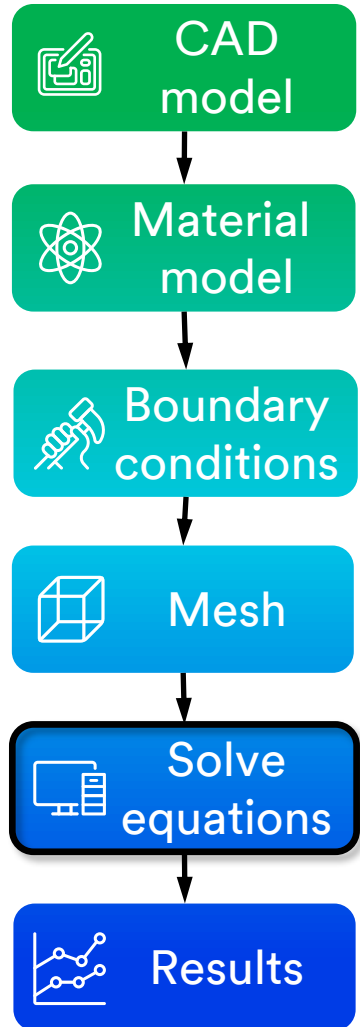
Finite Element Analysis



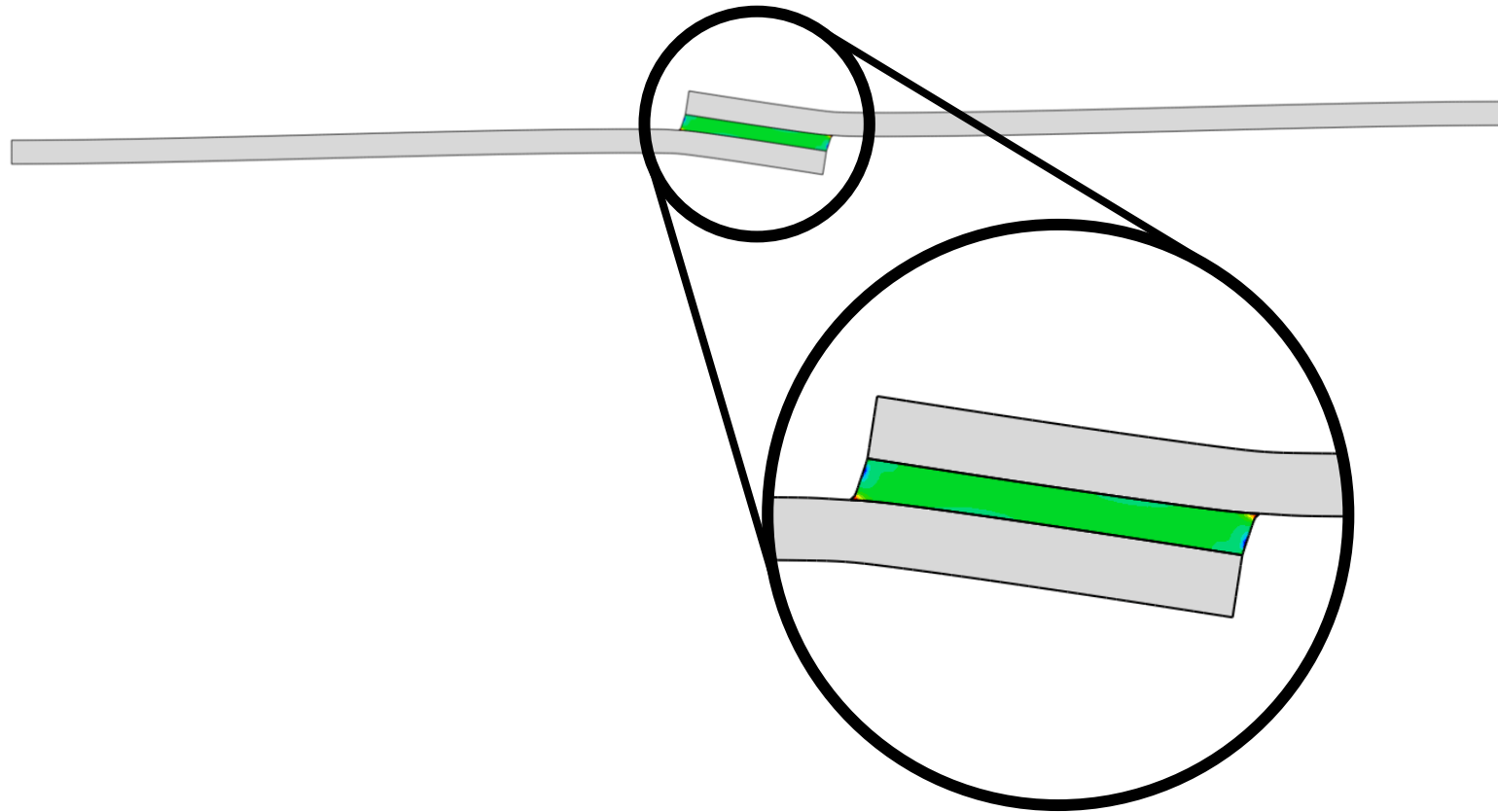
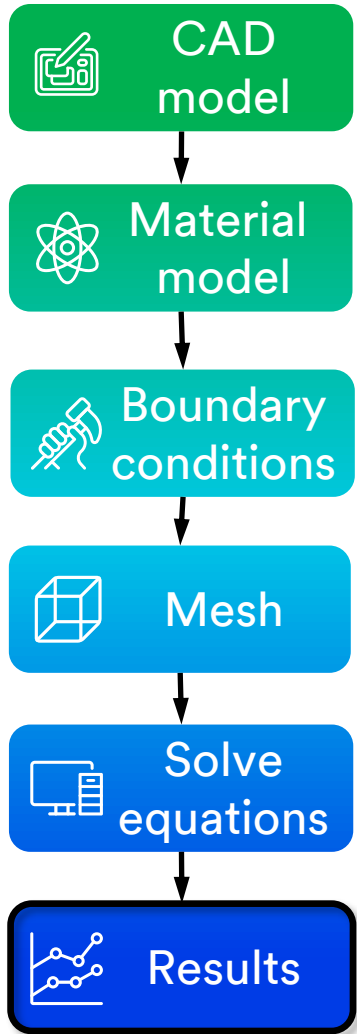
Finite Element Analysis



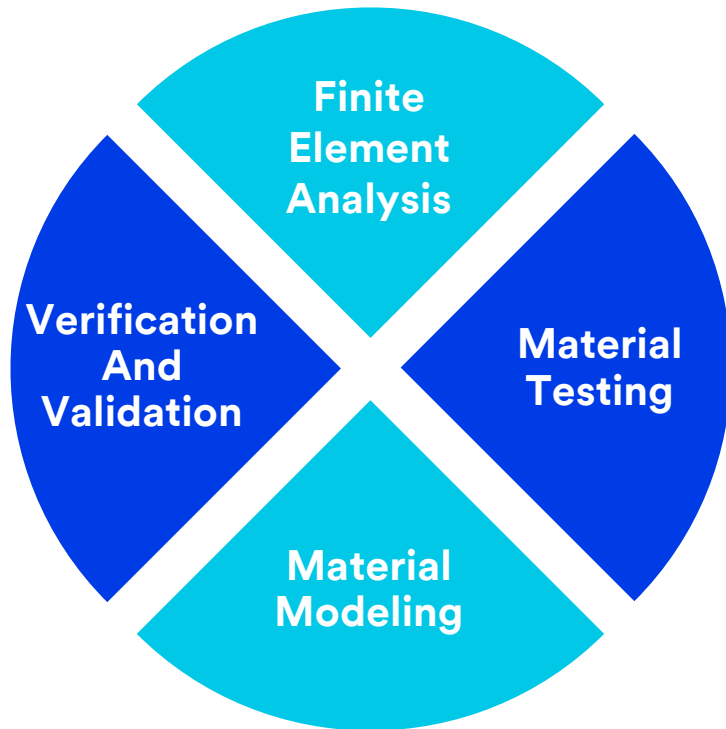
Finite Element Analysis



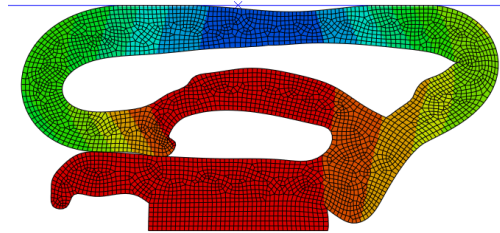
Finite Element Analysis



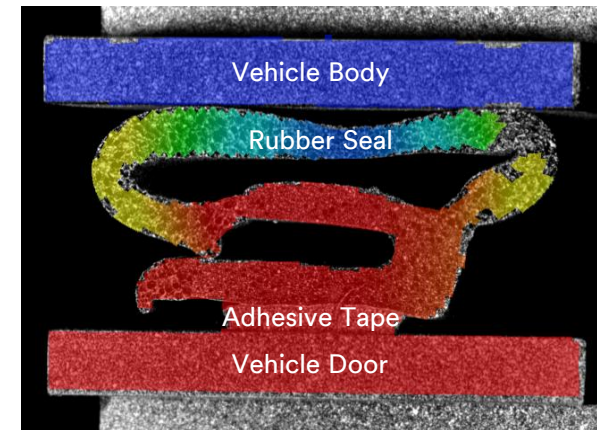
Making predictions using FEA



FE-Simulation

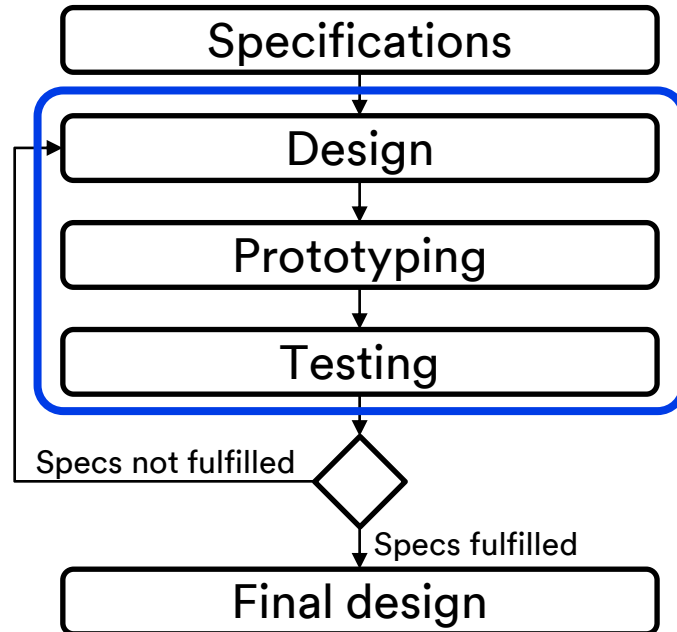


Experiment



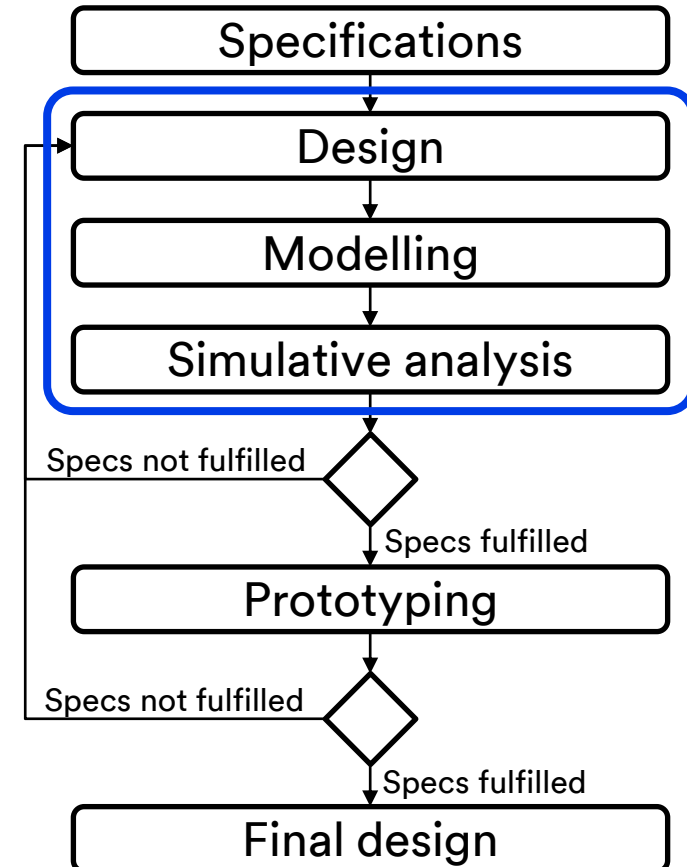
Product design

Traditional design



Expensive and time-consuming

Simulation-driven design

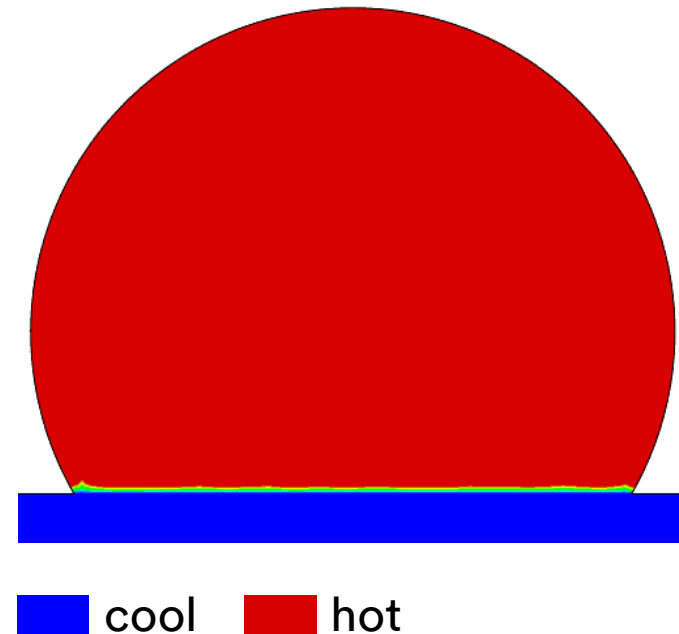


Cheap and fast process

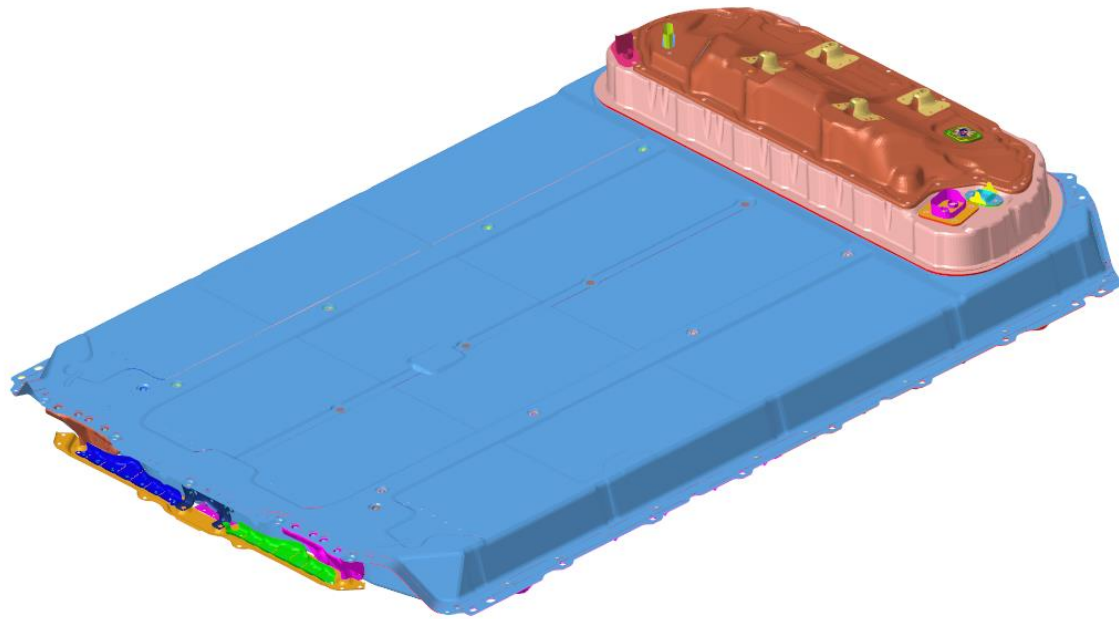
FEA capabilities




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

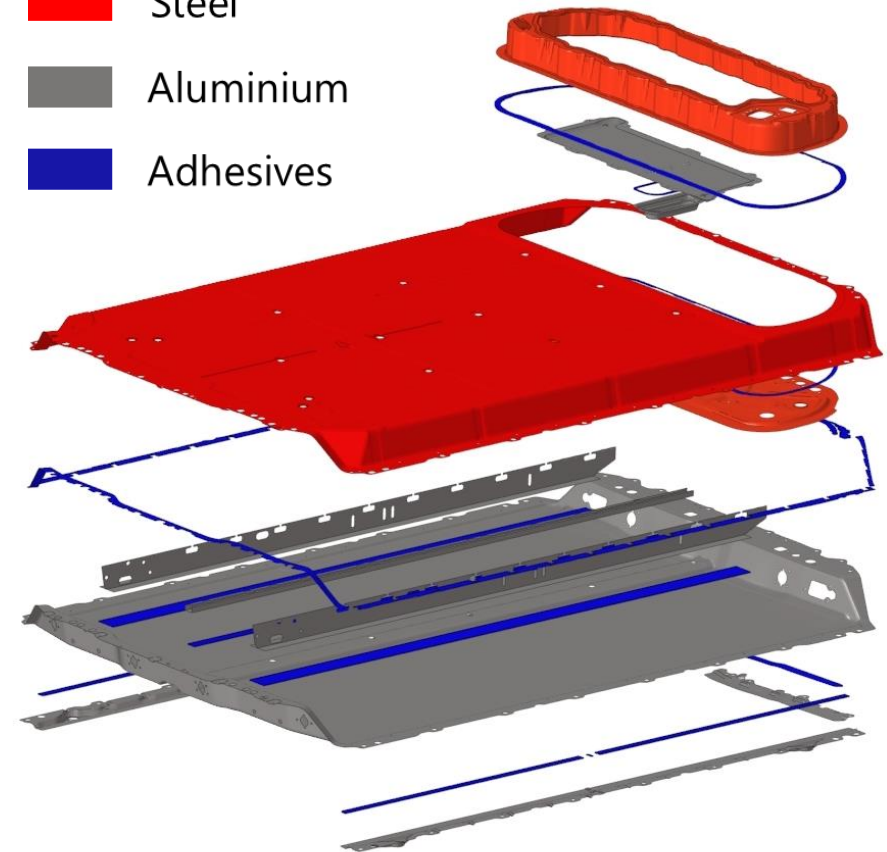
Thermal analysis



Battery Pack Analysis

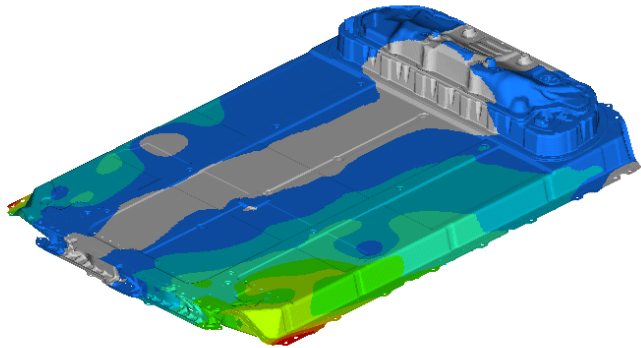


-  Steel
-  Aluminium
-  Adhesives

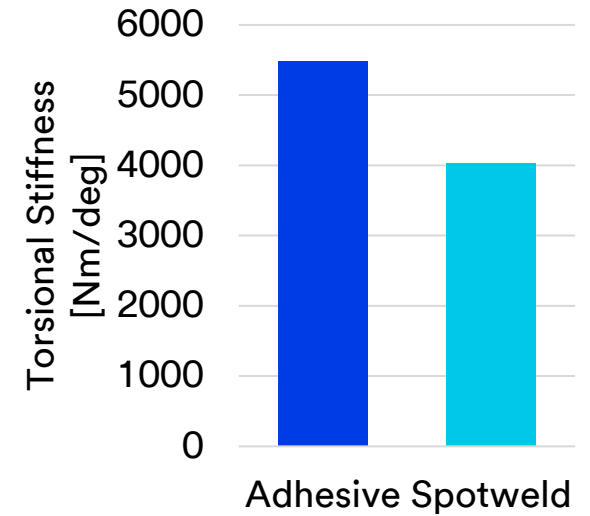
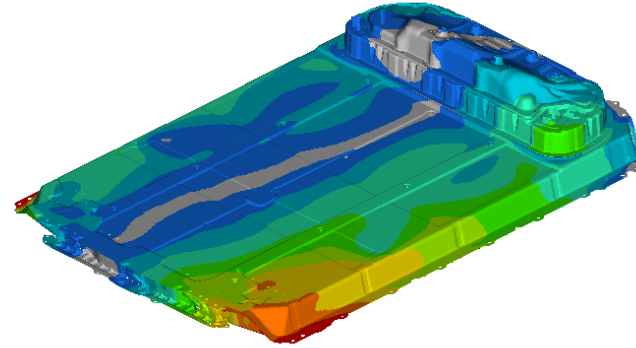


Battery Pack Analysis

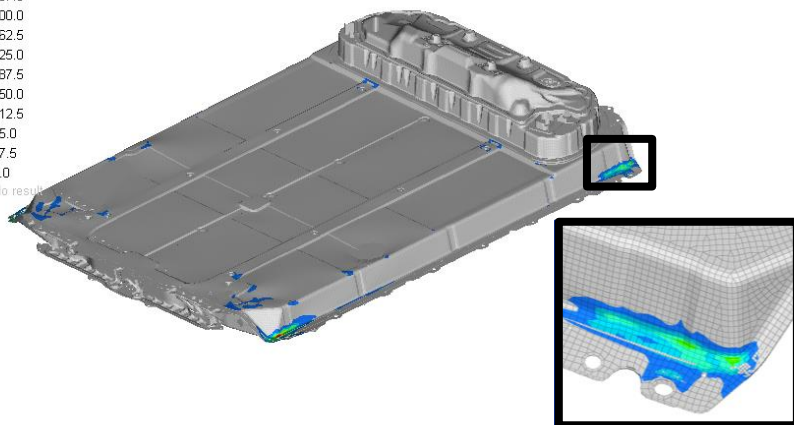
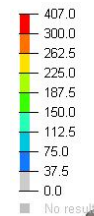
Adhesive



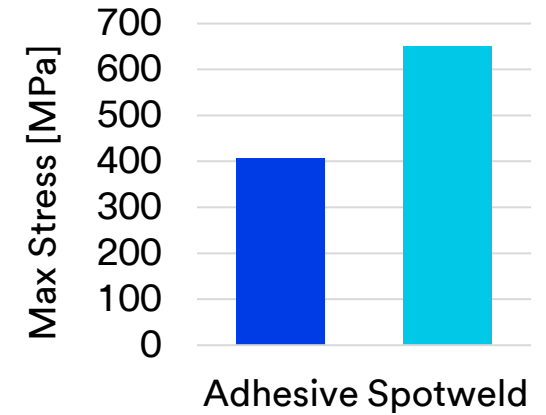
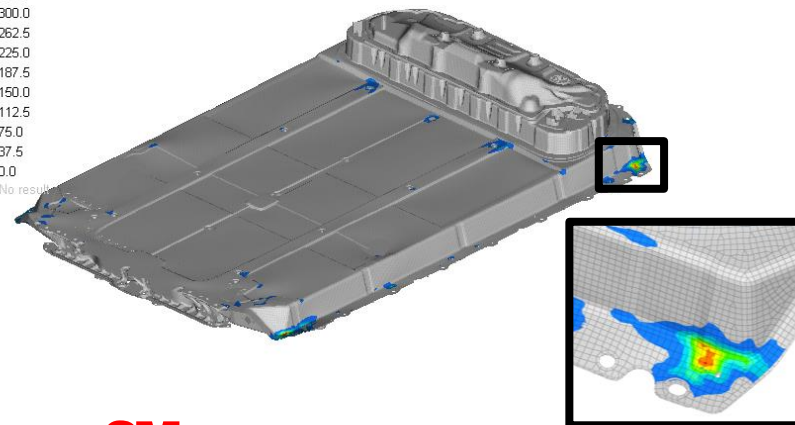
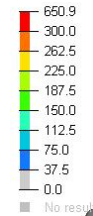
Spot welds



Von Mises Stress [MPa]



Von Mises Stress [MPa]



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

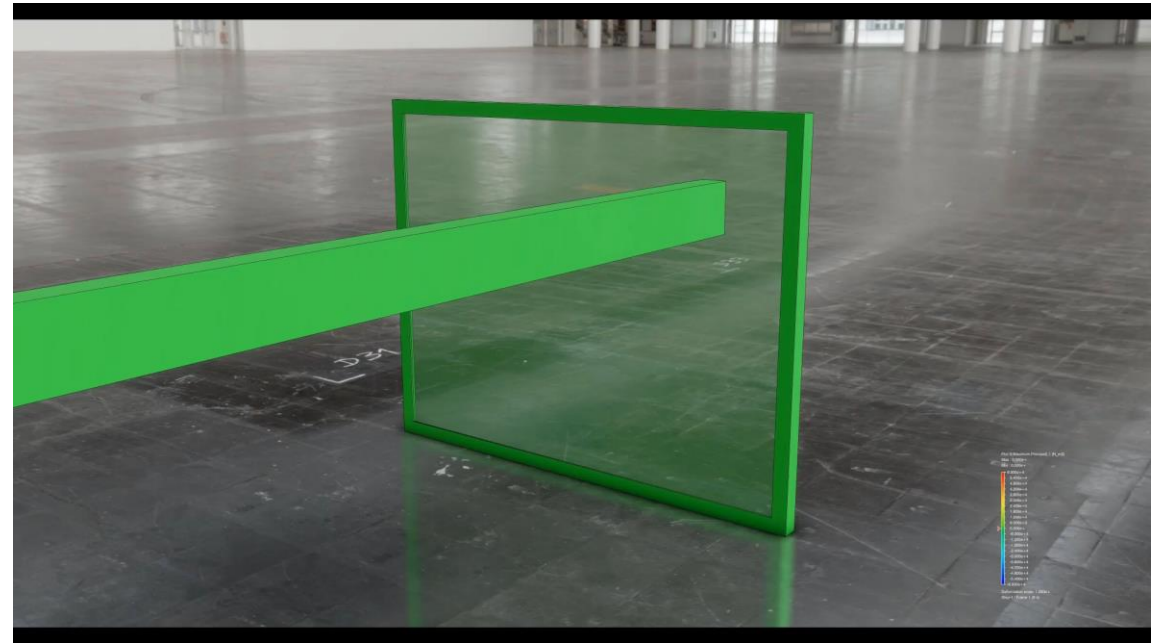


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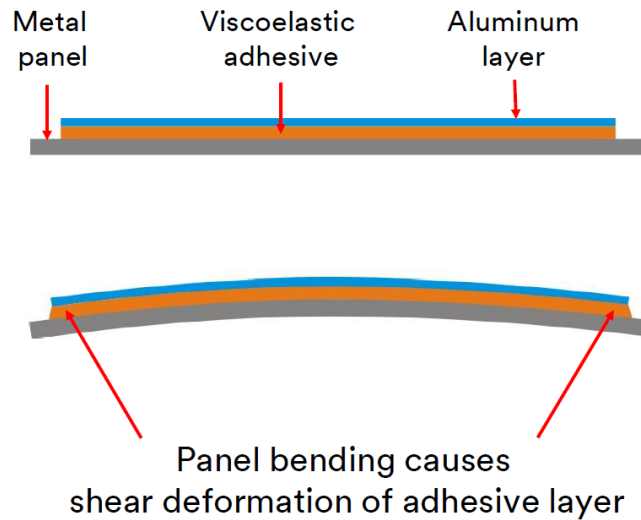


Dura-Storm: Hurricane-proof door

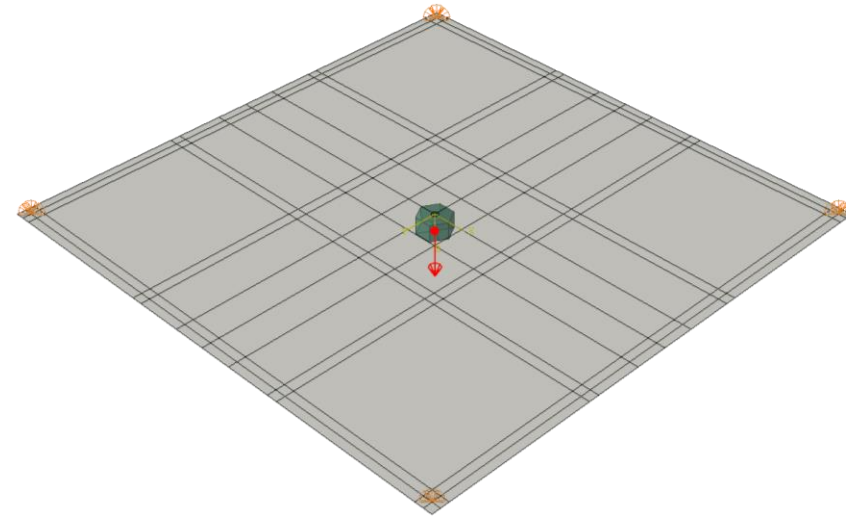


Vibration analysis: Constrained Layer Damping

Constrained Layer Damping



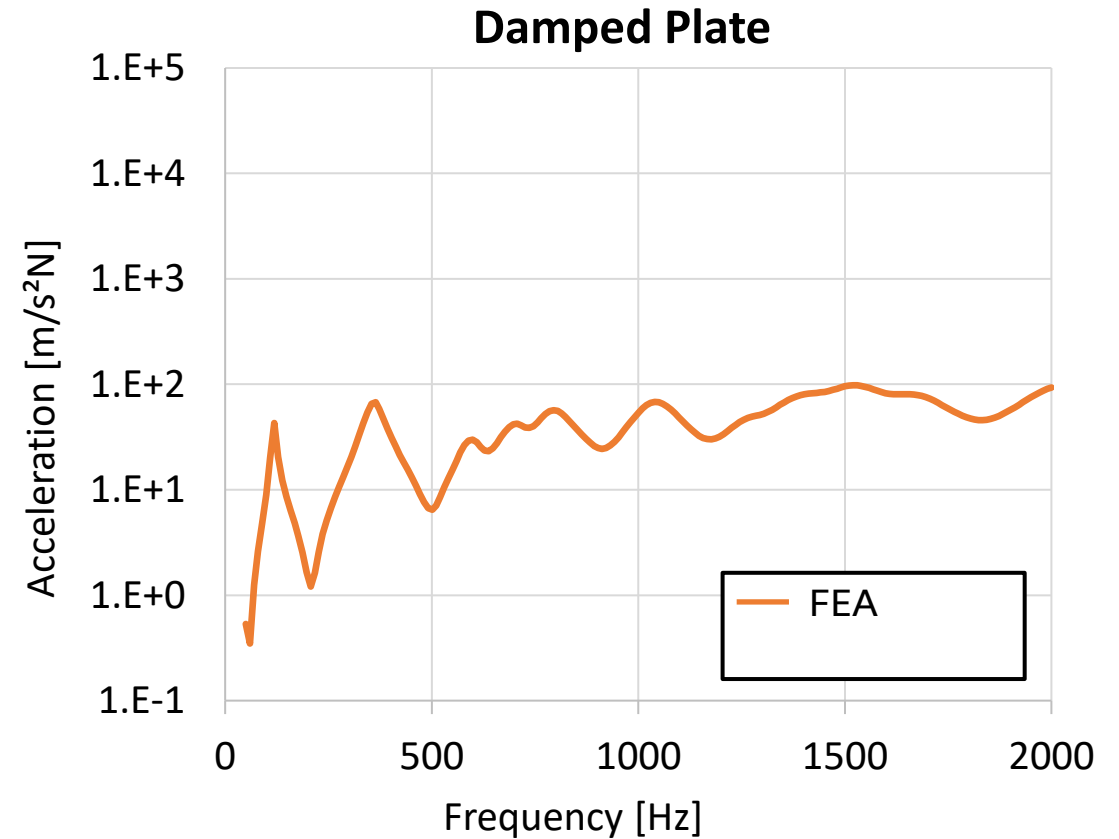
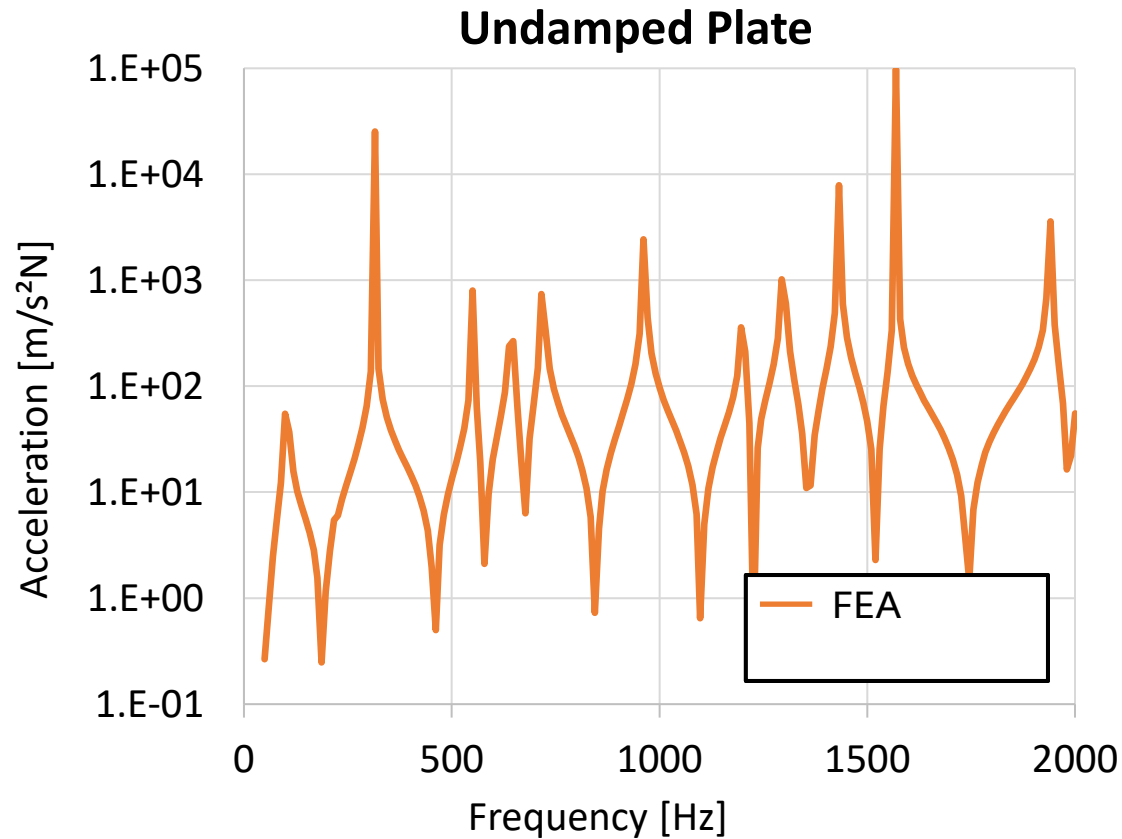
Vibration analysis



Goals:

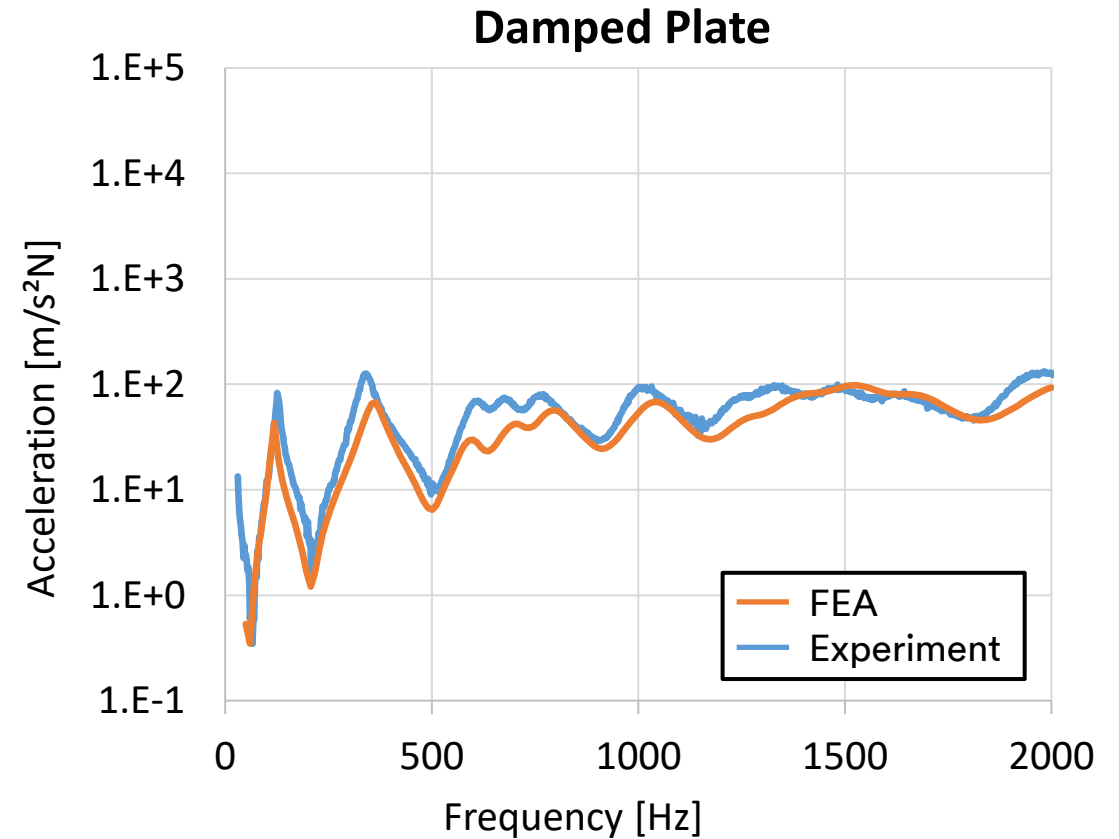
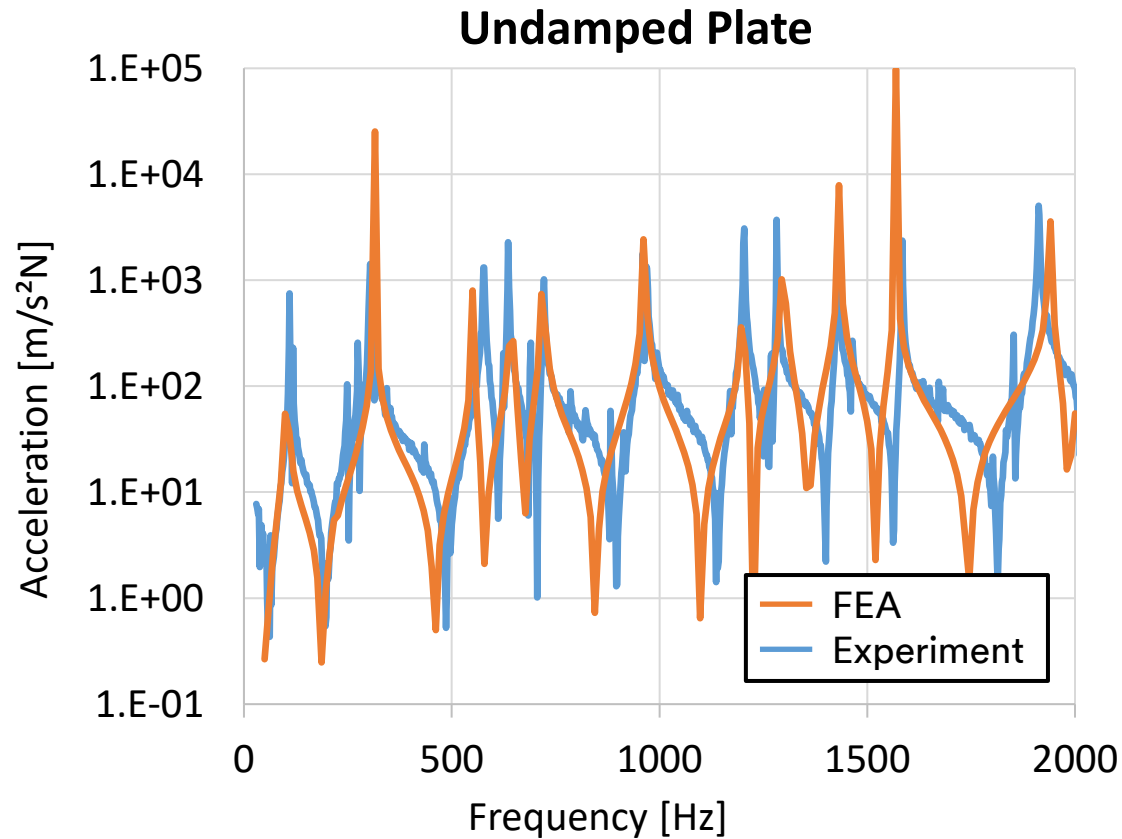
- Reduce noise and vibrations effectively
- Ideal application at the right places with the least amount of material

Vibration analysis: Constrained Layer Damping



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

Vibration analysis: Constrained Layer Damping



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

3M's FEA capabilities

FEA Webpage

Material data cards



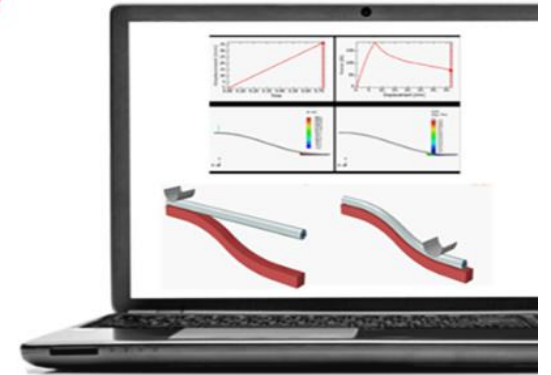
FEA support



Finite Element Analysis (FEA) | Method (FEM) and Modeling

3M's technical support team is ready to support you with answers to your questions around modeling and simulation. Book a 30-min Meeting with our FEA Expert to clarify your questions.

[BOOK A MEETING](#)



Finite Element Analysis (FEA) for 3M™ Tapes and Adhesives

What is Finite Element Analysis (FEA/FEM)?

FEA offers several benefits for engineers, including the ability to accurately predict the behavior of complex systems, such as stress, strain, and deformation under various loading conditions. This enables engineers to identify potential issues and implement design changes before creating a physical prototype. Additionally, FEA helps to reduce the number of physical prototypes required and the time to market. The tool is highly flexible, capable of analyzing a broad range of materials and geometries, including complex assemblies, and can handle nonlinear material behavior. Engineers can use FEA to optimize system design by identifying optimal material properties and configurations to achieve desired performance. Finally, FEA provides detailed visualizations of system behavior, enabling engineers to gain insights and make data-driven decisions.

[Watch the free Webinar to learn more](#)

Are you interested in mechanical characterisation techniques for adhesive modeling? Then this training on FEA is ideal for you.



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.