CAE from a material suppliers point of view

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Dow.com

Overview

Setup of a material supplier

- The Dow Chemical Company - Dow Automotive Systems

Materials for the automotive industry

- Sustainable lightweight materials
- Adhesives to join lightweight solutions

CAE aspects

- Material characterization and modeling + application development
- Simulation of Stiffness – sounds simple but is complex

The Dow Chemical Company

History

- Founded in 1897 by Herbert H. Dow in Midland, Michigan.
  (extraction of chemicals from brine)
- Supplies a broad range of products and services to customers in approximately 180 countries.
- Integrated value chain aligned to high-growth sectors such as packaging, agriculture, coatings, electronics, construction, infrastructure, water and automotive
- $57 billion annual sales in 2013
- Employs 53000 employees worldwide
- 6000 products manufactored at 201 sides in 36 countries around the globe

The Chemical Industry - Dow

Turning Feedstocks into Essential Products

Salt

Gas

Oil

Coal

Biomass

Recycle

Building & Construction
3.1%

Electronics
3.7%

Agriculture
12.5%

Wire & Cable
1.8%

Coatings
4.8%

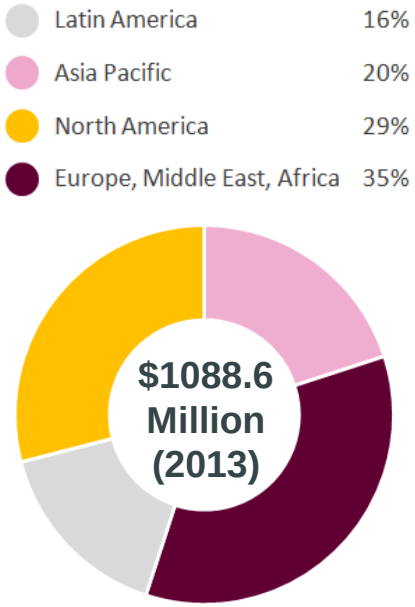
Automotive
1.9%

Packaging and speciality plastics	21.3%
Hydrocarbons	12.1%
...	

Dow Automotive Systems

Proven Track Record

- Serving the transportation industry since 1988 (business facing unit)
- Located close to OEMs and tier suppliers worldwide; more than 700 people with expertise in operations, supply chain, R&D, advanced engineering, sales, technical/customer service and other business support services.
- Our customer account teams interact with product/application development teams and serve as your focal points for sales and service questions.
- Our Portfolio includes
  - Polyurethanes
  - Elastomers
  - Films
  - Brake fluids and lubricants
  - Glass, structural and specialty adhesives
  - Acoustic management materials

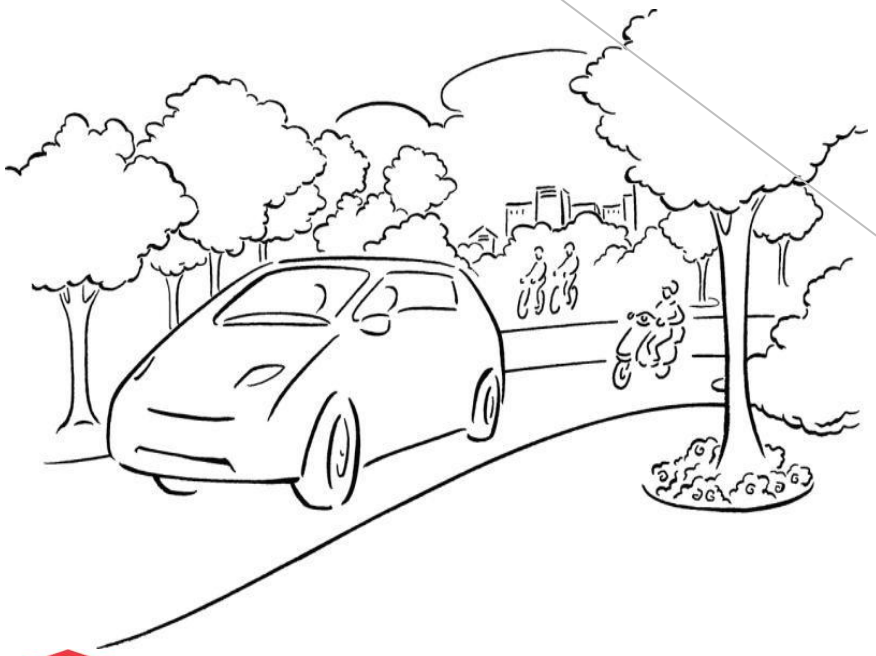


Dow Automotive Systems

Sustainability

Smart Solutions

- Seating solutions
- Interior surface solutions
- Acoustic solutions
- Lightweight solutions
- Renewable raw materials
- Cabin/Interior air quality



Lightweight solutions – delivering CO_2 reduction and fuel efficiency

- BETAFOAM™ polyurethane foams
- BETAFORCE™ polyurethane adhesives
- BETAMATE™ structural adhesives
- VORAFORCE™ epoxy systems
- VORAFUSE™ M cast and molding compound
- VORAFUSE™ P pre-preg technology

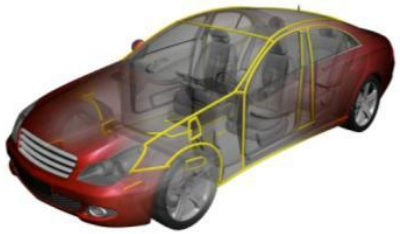
DA Adhesives Portfolio

Broad spectrum of the adhesives mechanical performance – lap shear

Body Shop → 180 ºC, 30′ → Paint → 80-160 ºC, 30′ → Trim Shop → 25 ºC → Repair

BETAMATE™ Epoxy Technology

BETAFORCE™ PU Technology



Selection Considerations

- Assembly requirements
- Substrates bonded
- Substrate coatings
- Cure profile
- Functional performance
- Body or Trim shop
- Manufacturing process

Elastic PU Sealants:
BETASEAL™, BETAFILL™, BETATECH™

Elastic PU Adhesives & Sealants:
BETASEAL™, BETAMATE™, BETALINK™

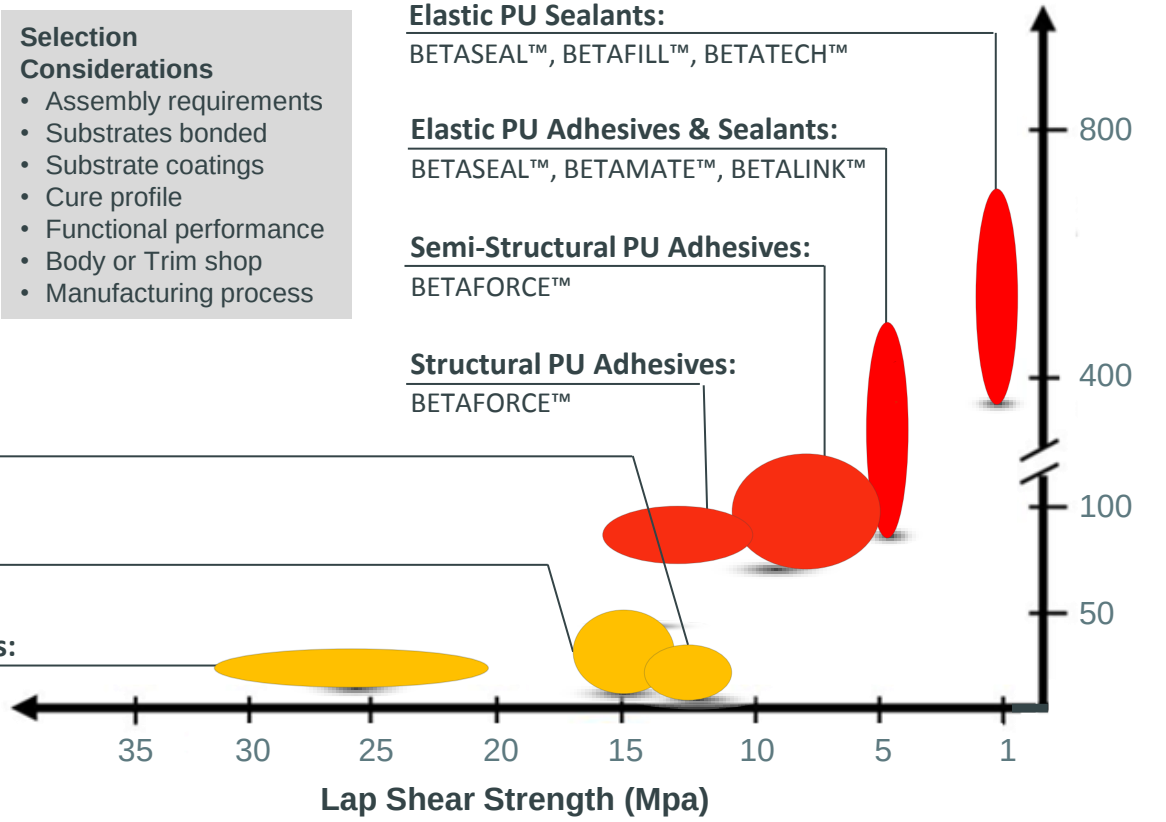
Semi-Structural PU Adhesives:
BETAFORCE™

Structural PU Adhesives:
BETAFORCE™

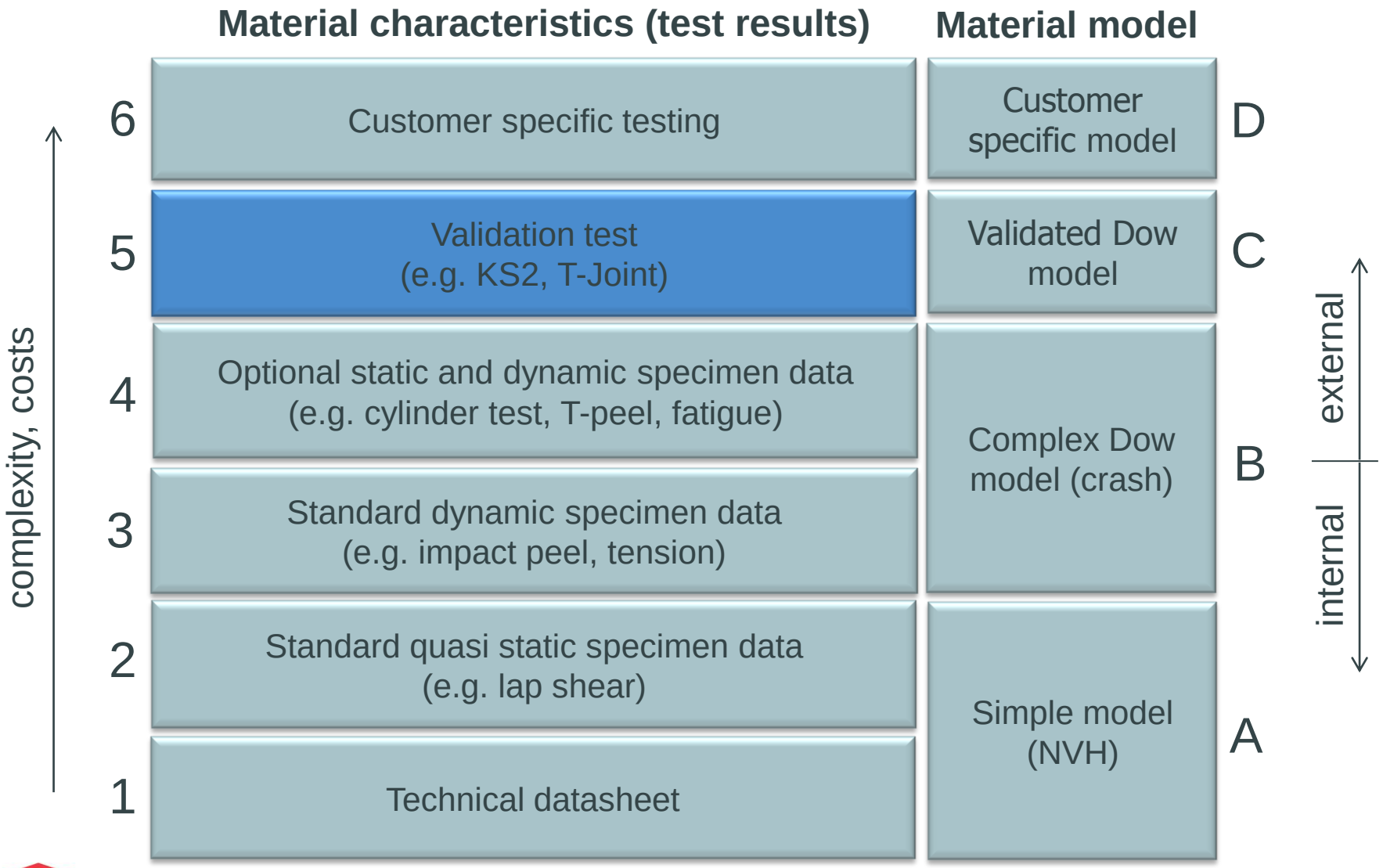
Epoxy Hybrid Adhesives:
BETAMATE™

Epoxy Adhesives:
BETAMATE™ Flex

Structural Epoxy Adhesives:
BETAMATE™



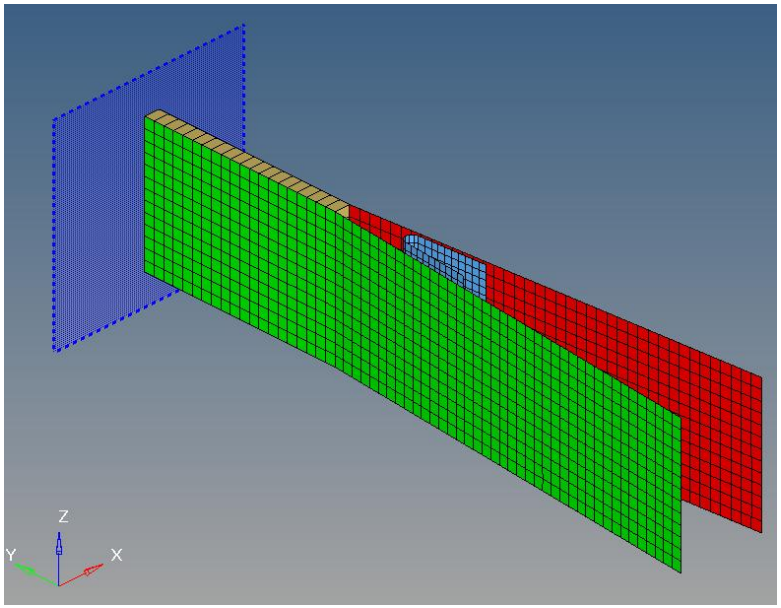
Engineering Data and Modeling



Validation

Impact Peel Test

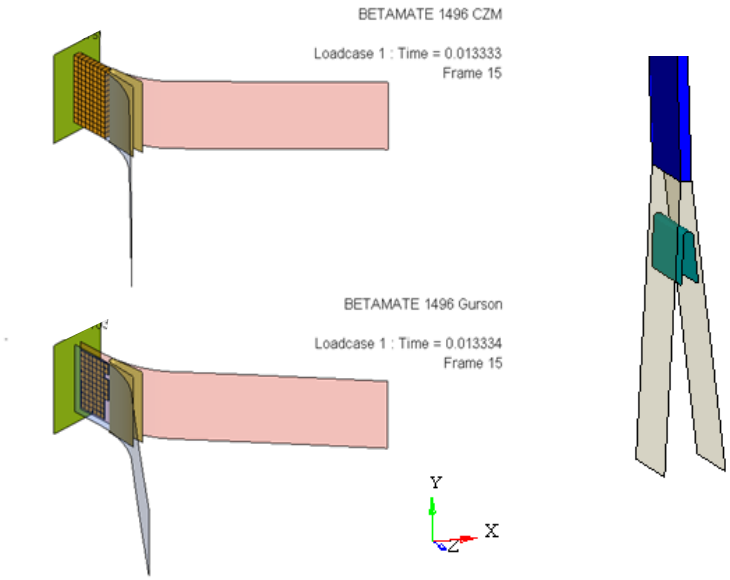
- The impact peel test is according to Ford spec respectively ISO11343
- Hammer Weight: 52.22lb (23.7kg)
- "Drop Height: from Hammer to wedge tip" 10.5in (266.7mm)
- "Approximate Drop Height: Hammer to specimen ≈ 40mm" 226.7mm
- Resulting Impact Velocity: ca. 2.1m/s
- Resulting Input Energy: 52.7J
- Data Measured
  - Transient Force (from load cell)
  - Impact Velocity (from speed trap)

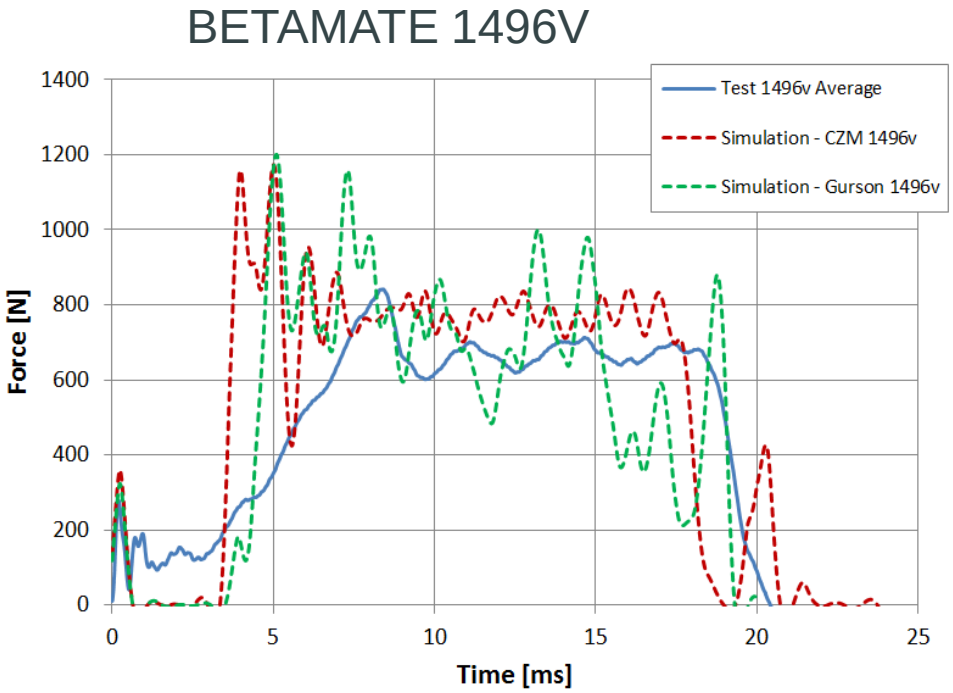


- Substrates: 2mm thick aluminum AA5754
- BLT: set as 0.25mm in CZM material card
- Connection: sharing common nodes
- Geometry and impact setup: according to the test setup
- Element size: ~1.5mm
- Termination time: 0.02ms
- Data output: rigid wall force

Validation

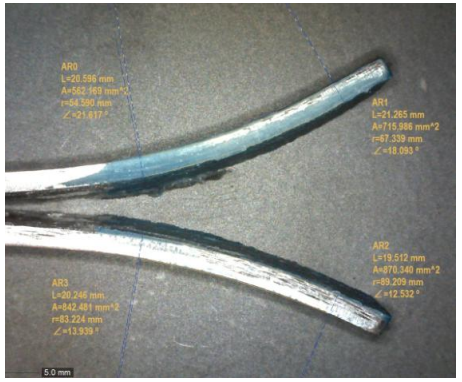
Comparison





BETAMATE 2098

Radius (mm)	Sub#1	Sub#2	Average
Test (Solvent Wipe-2) average	88.11 -10.3%	72.56 +1.0%	80.33 -4.9%
Test (Abrasive Scour) average	72.64 +8.8%	76.33 -3.5%	74.49 +2.5%
Test average	80.38 -1.7%	74.45 -1.1%	77.41 -1.4%
Simulation – CZM	79.05	73.66	76.35

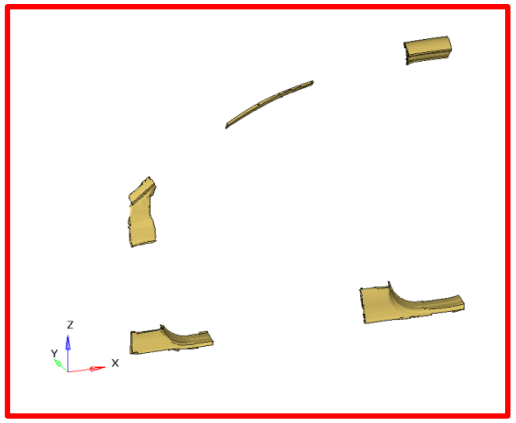


IIHS Small Overlap Frontal Crashworthiness

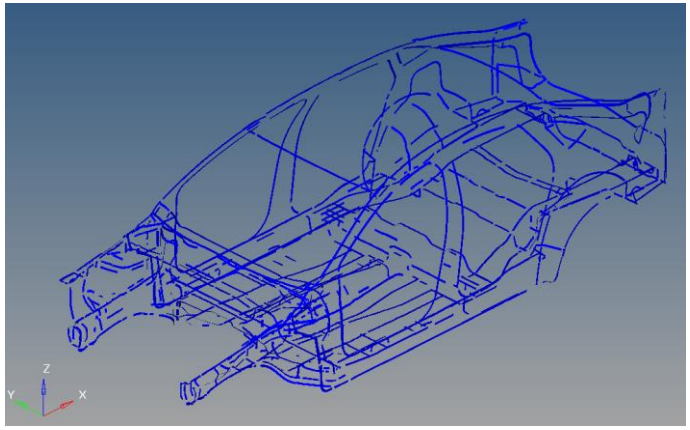
Structural adhesive and LWR

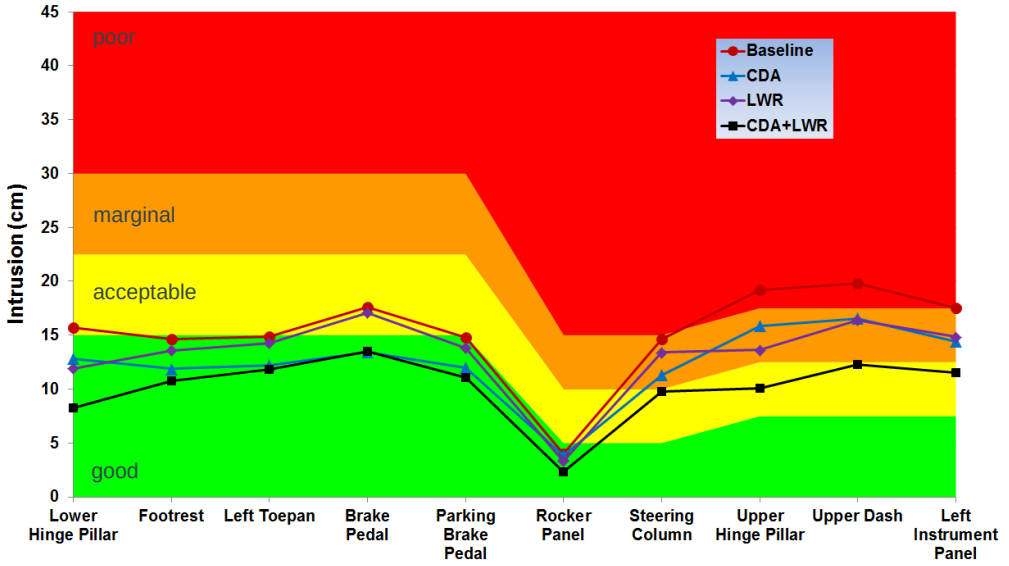
Full LWR in 3~20mm gaps 3.2kg/side

LWR Optimized 0.9kg/side



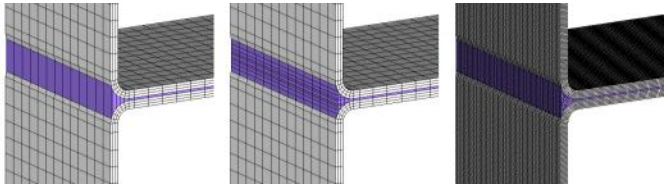
CDA length: more than 100 meters (0.966kg)



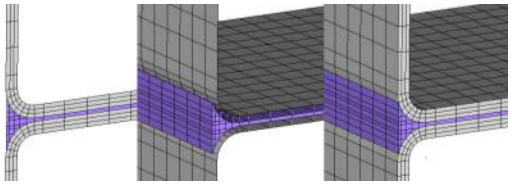


Methodology Development

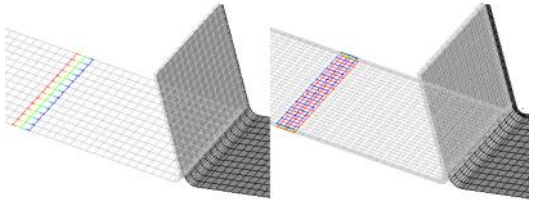
Coach peel CAE findings



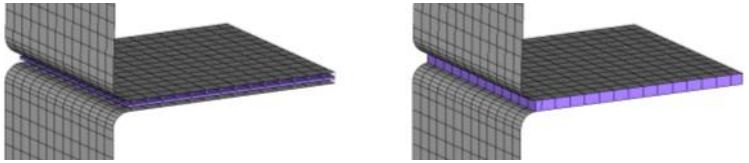
Fillet adhesive element size



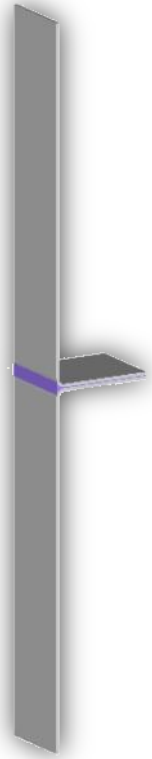
2D, mid-plane, 3D

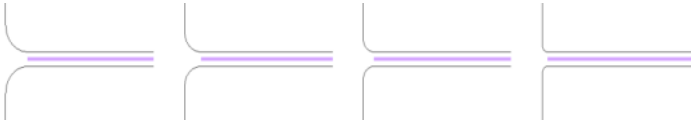


Post-processing: mid-plane point/front surface point

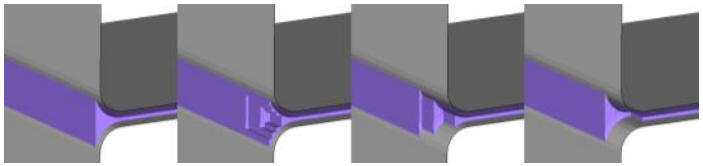


Adhesive modeling: real thickness/gap thickness



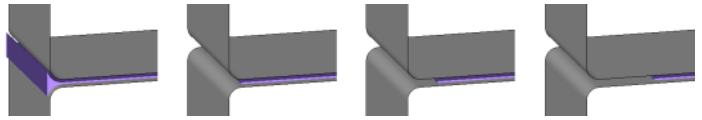


Fillet radii

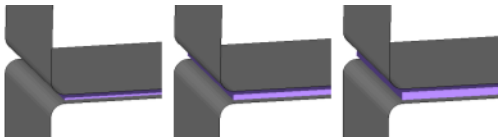


Adhesive absence at fillet corner

Fillet adhesive



Adhesive absence at joint

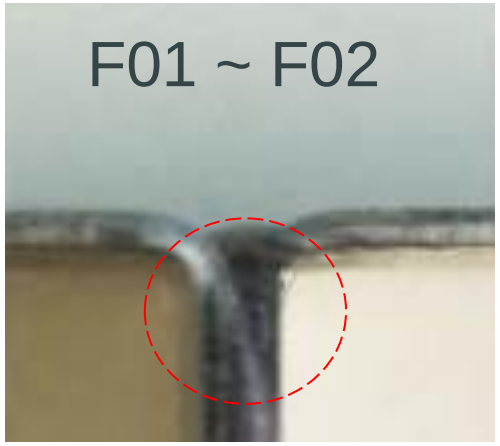


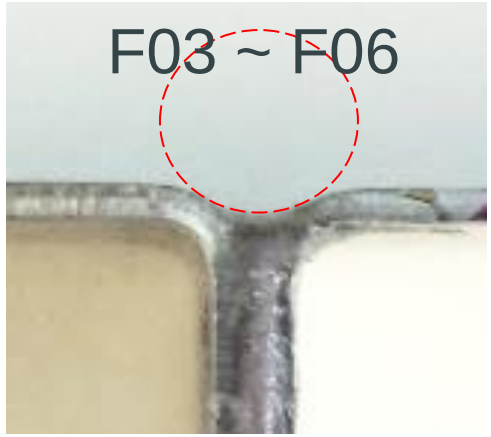
Adhesive thickness

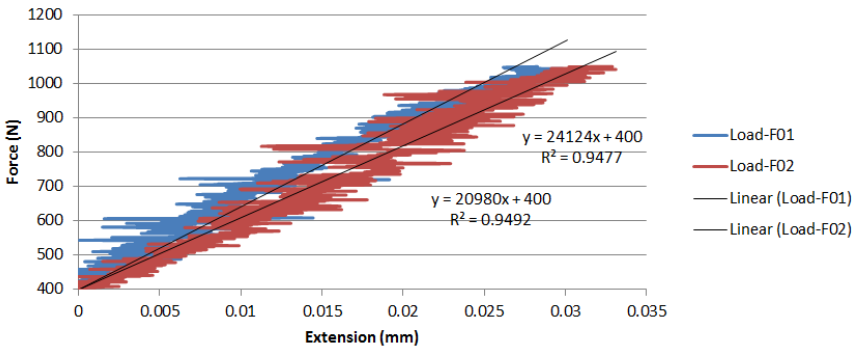
Coach Peel study

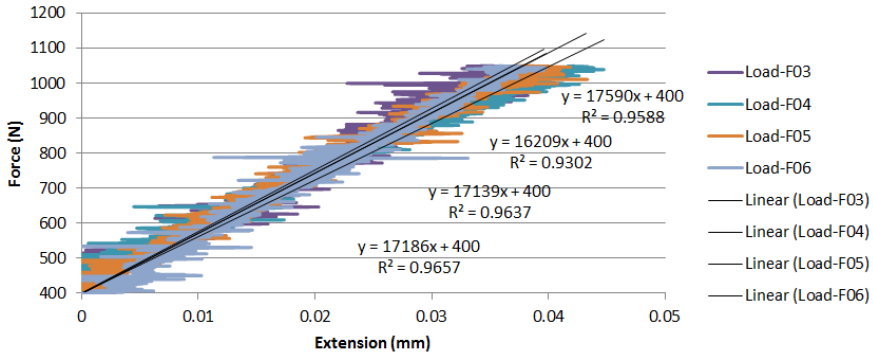
Test result

Sample #	Stiffness	Distance	Radii	BLT	Average Stiffness
Unit	N/mm	mm	mm	mm	N/mm
F01	24124	65.34	1.84	0.26	22552
F02	20980	64.02	1.85	0.23	
F03	17590	65.07	1.80	0.29	17031
F04	16209	64.71	2.03	0.25	
F05	17139	65.90	1.78	0.26	
F06	17186	64.51	1.81	0.25	
Average	18871	64.93	1.85	0.26	18871



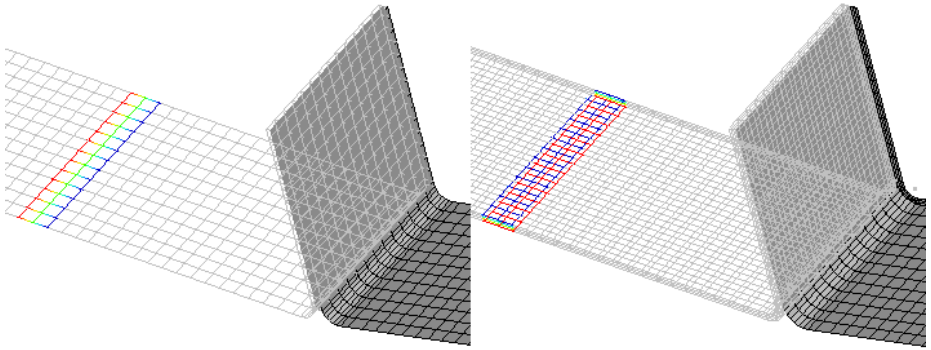


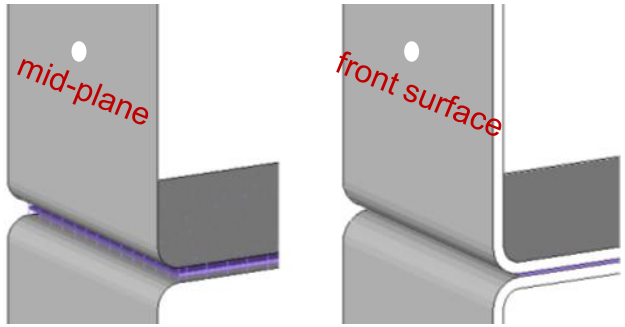




Coach Peel study

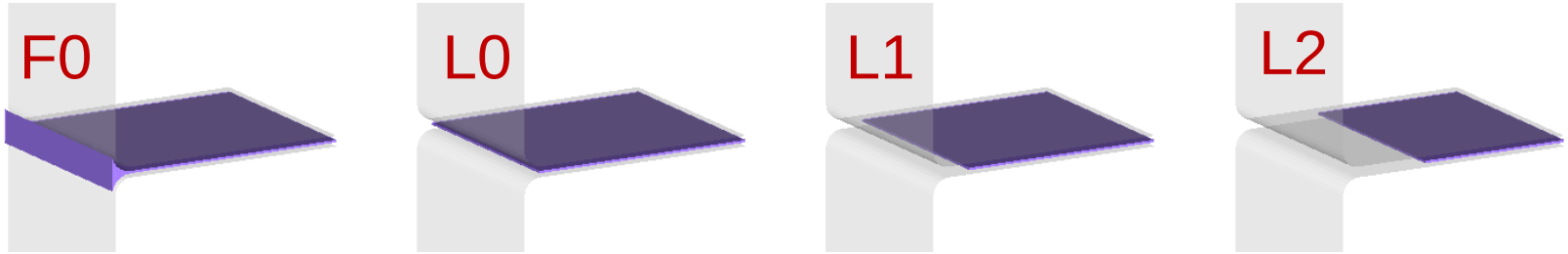
Post-processing





Stiffness (N/mm)	Shell mid-plane	3D front-surface	Test	
F0	37838	32580	22552 *	F01 ~ F02
L0	15310	13290	17031 *	F03 ~ F06
L1	2985	2735	2444	
L2	380	363	345	

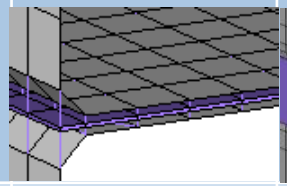
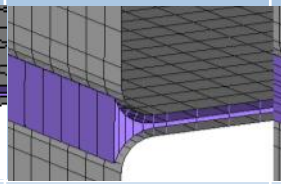
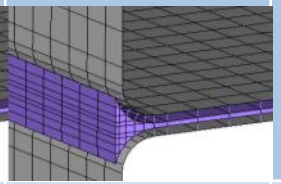
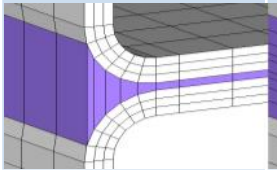
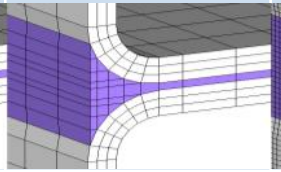
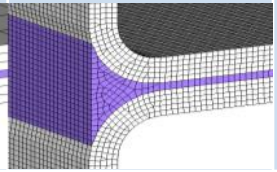
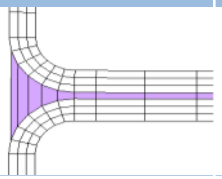
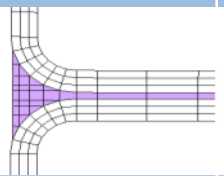
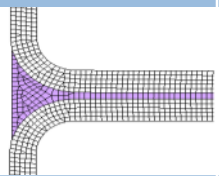
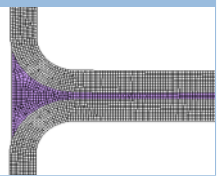
* Test results enties of F0 and L0 are only for reference. The actual sample adhesive at fillet is between the F0 and L0



Coach Peel study

F0 - Fillet adhesive element size & 2D, mid-plane, 3D

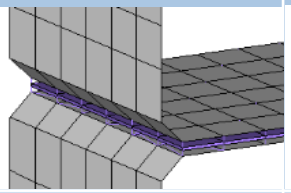
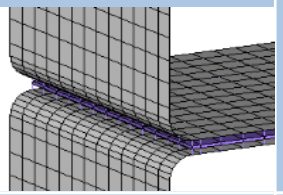
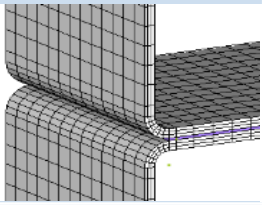
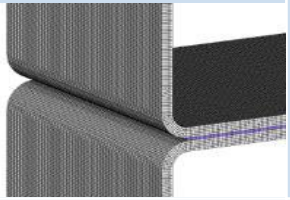
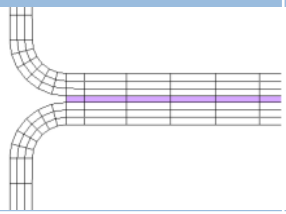
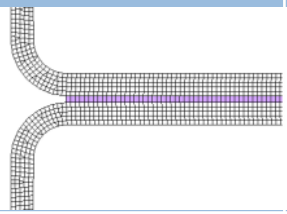
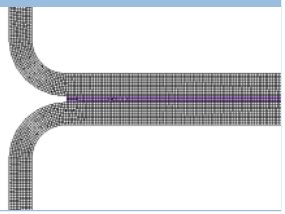
Simulation with coarse meshes are overestimate the stiffness results

Stiffness (N/mm)	Coarse Mesh (4mm)	Coarse Mesh (2mm)	Refined Mesh (2mm)	Fine Mesh (0.2mm)	Finer Mesh (0.1mm)
Conventional F0 (mid-plane)	63513 	42776 	37838 	-	-
3D F0 (front-surface)	-	37606 	32580 	32070 	-
2D F0 (front-surface)	-	33781 	28986 	28367 	28302 

Coach Peel study

L0 - Fillet adhesive element size & 2D, mid-plane, 3D

Simulation with coarse meshes may overestimate the stiffness results

Stiffness (N/mm)	Coarse Mesh (4mm)	Refined Mesh (2mm)	Fine Mesh (0.2mm)	Finer Mesh (0.1mm)
Conventional L0 (mid-plane)	17416 	15310 	-	-
3D L0 (front-surface)	-	13290 	13203 	-
2D F0 (front-surface)	-	11067 	10900 	10186 

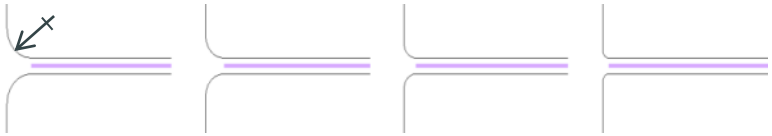
Coach Peel study

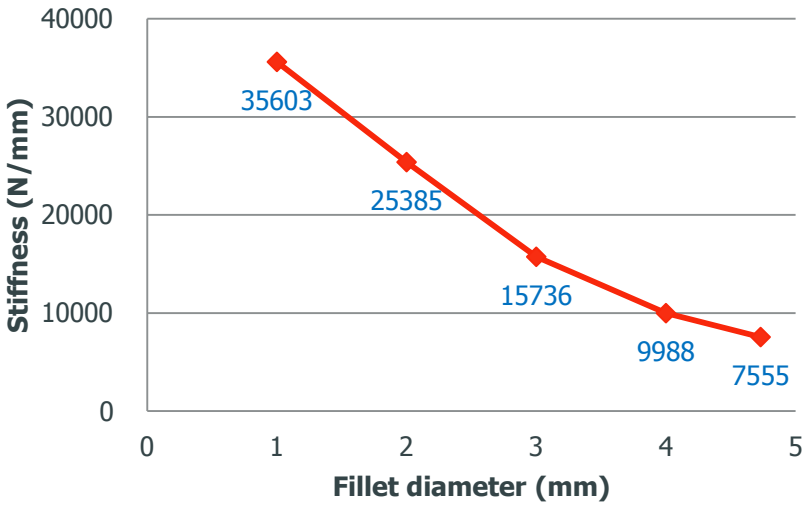
Fillet influence

Bigger fillet results in weaker stiffness

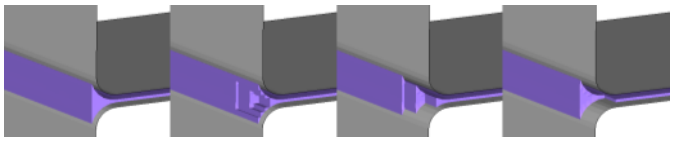
Fillet corner adhesive absence drops the joint stiffness

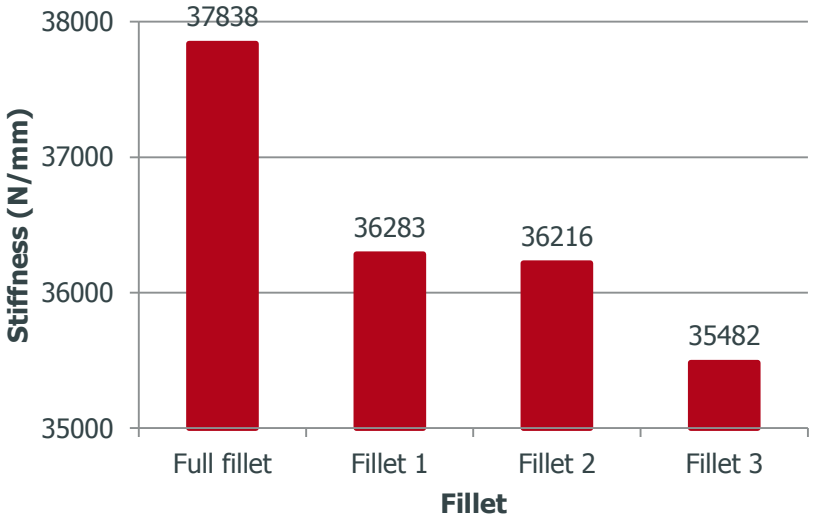
Fillet radii





➢ Adhesive absence at fillet corner

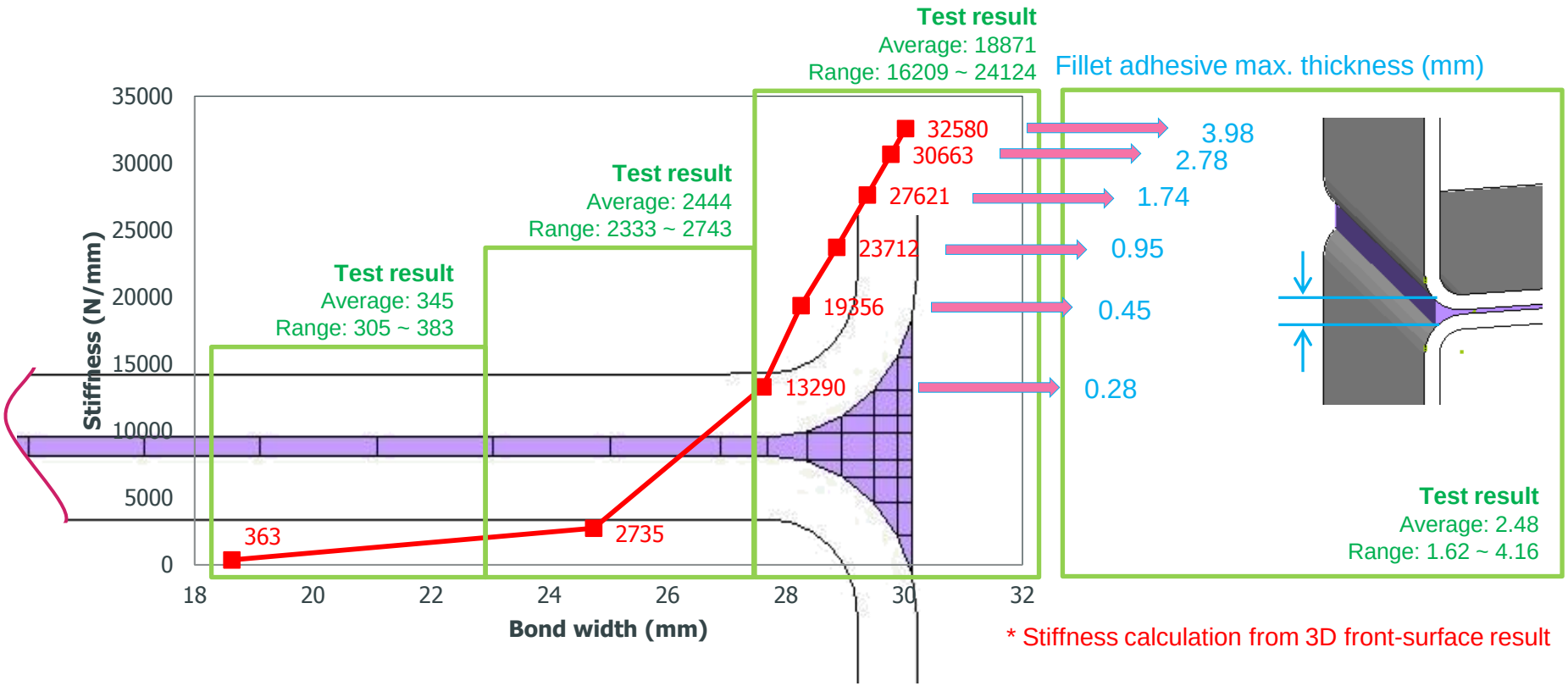




Coach Peel study

Adhesive absence at joint

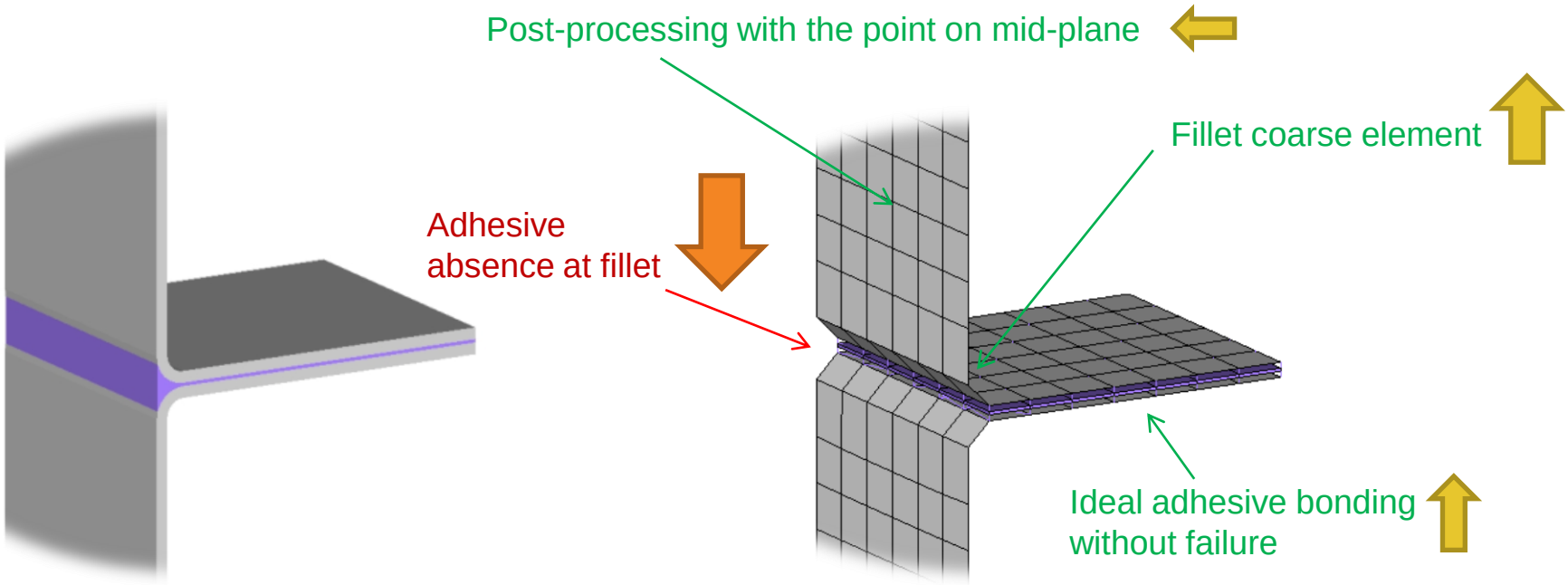
Adhesive absence at fillet end significant decreases the stiffness



* Stiffness calculation from 3D front-surface result

Coach Peel study

- Cured adhesive morphology at fillet strong influence the joint stiffness



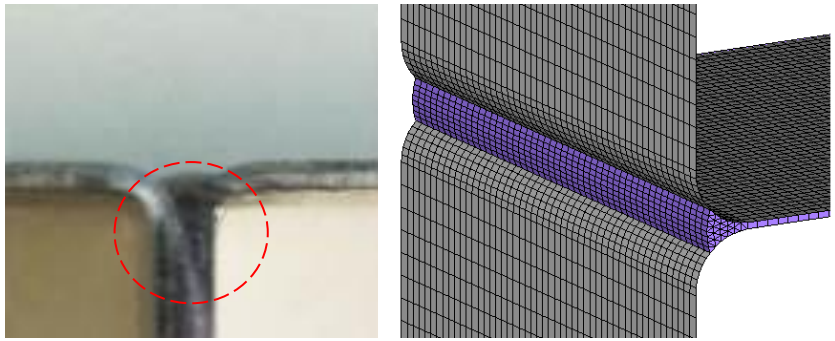
Test result (Average): 18871 N/mm

CAE result: 17416 N/mm

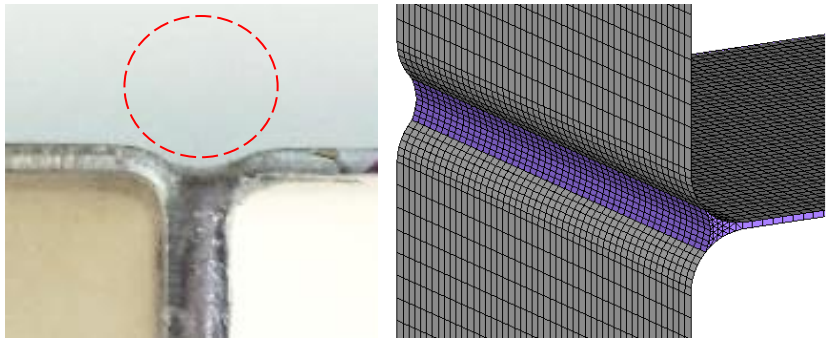
Difficult to compare

Coach Peel study

F01 ~ F02 average: 22552 N/mm



F03 ~ F06 average: 17031 N/mm



Simulation result: 21837 N/mm

Simulation result: 20118 N/mm

- Coach peel modeling
  - Offset shell elements to the bottom surface of strips
  - Solid adhesive elements share nodes with shell elements
  - Fine mesh at the fillet area (0.5mm)
  - Model the detail of the fillet adhesives
  - Post-processing with the point at the surface outer

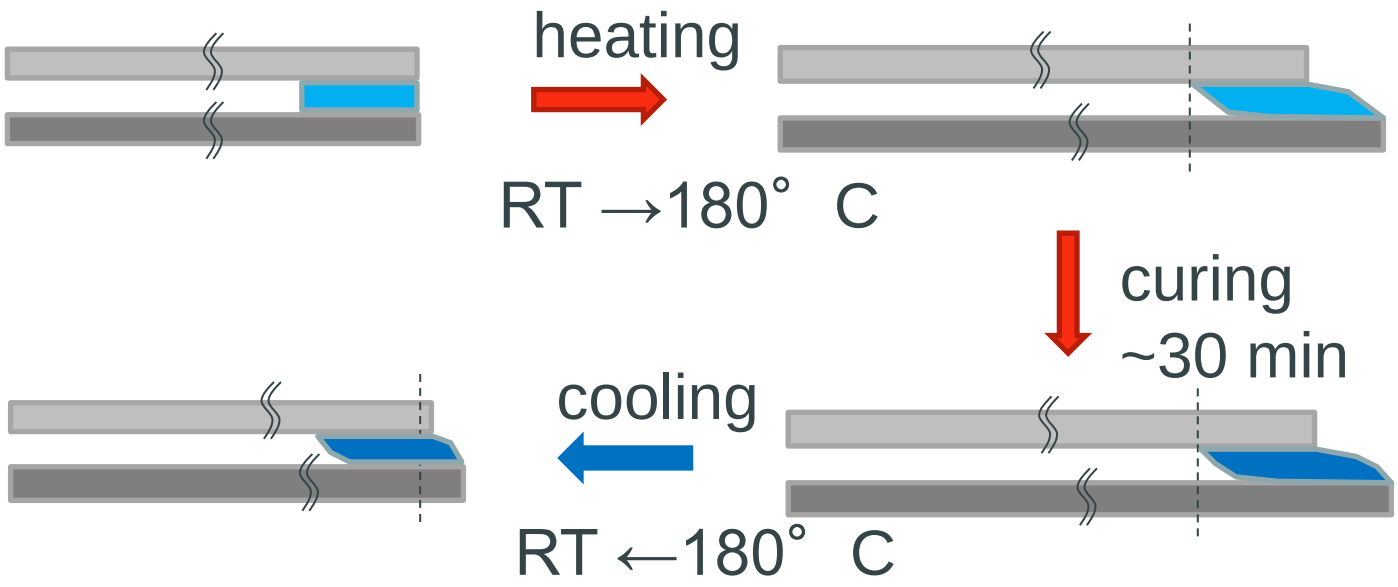
Summary and Conclusion

- From a big-picture point of view the material developing industry and the application developing industry show a differing business setup and focus. If one narrow down to the materials of interest the interest gets strongly connected.
- Engineering departments within a chemical company realize a bridge function (translator) between external engineering focussed customers and the internal material developing chemists.
- A very broad spectrum of products is available. Only for some the more detailed CAE data is available. A characterization and modeling profile has been discussed.
- Predictive accuracy for „complex“ dynamic failure processes as well as for „simple“ stiffness show the need of a good understanding for the CAE problem itself by the engineering executives.

Actual activities/Outlook

e-cure process of adhesives and influence of heat to composites

Structural adhesive cure during the e-coating process (paint shop). With dissimilar materials the different thermal expansion behavior of joint substrates could lead to residual stress build. Furthermore the thermal stability need to be examined for polymeric materials like composites.



If the bonding happen in the trim shop (RT) as usual for 2k adhesives this problem do not occure. Nevertheless, there is also a delta alpha problem to be considered due to thermal cycles: day/night & summer/winter, but without the residual stress consideration and its effects

Thank‘s for your attention