Meeting future challenges in forming and joining
Cluster: Forming and Joining

Session leaders:
Johan Berglund RISE
Joakim Hedegård, SWERIM

Agenda

1. Cluster Forming and Joining, very short introduction
   Johan Berglund, RISE
2. Ongoing research in Forming and Joining
   Johan Berglund, RISE and Joakim Hedegård, SWERIM
3. Which way up? Effects of forming on composite properties
   Yvonne Aitomäki, RISE
4. Innovative methods for joining of mixed light-weight material combinations
   Klara Trydell, SWERIM

Cluster Forming and Joining

Leader: Stephanie Robertson, Volvo Cars

Coordinator: Johan Berglund, RISE

Members from:

- AP&T
- Gestamp
- University West
- Luleå University of Technology
- MD Material Design
- RISE
- Scania
- Stansefabrikken
- SWERIM
- Volvo Cars
- Volvo Construction Equipment
- Volvo Trucks

Cluster Forming and Joining

Objective

- Develop efficient, flexible and robust manufacturing techniques for manufacturing components, materials, tools and machines

Activities

- Discussing research projects and funding possibilities
- Presentation and discussion of research results and challenges
- Cluster conference session

- Pulse meetings via Teams every month (30/60 min)
- Physical meetings 2 times/year, industry visits, discussions
- Other meetings for specific topics

Ongoing research in Forming and Joining

Johan Berglund, RISE

Joakim Hedegård, SWERIM

Ongoing research in Forming

<u>Circularity</u>

- ClimAl
- ThermLight2

<u>E-Mobility</u>

- FO-BI
- SafeBat

<u>Digitalisation</u>

- I-Stamp
- PREDICT

Presenter: Johan Berglund, johan.berglund@ri.se

ClimAl - Climate-smart high-performance aluminium

- Project scope and objective:
  - Enabling a broad use of sheet metals based on secondary aluminium for increased competitiveness and a significantly reduced carbon footprint.
- Partners:

JÖNKÖPING UNIVERSITY School of Engineering

RI. SE Research Institutes of Sweden

AP&T AUTOMATION · PRESSES · TOOLING

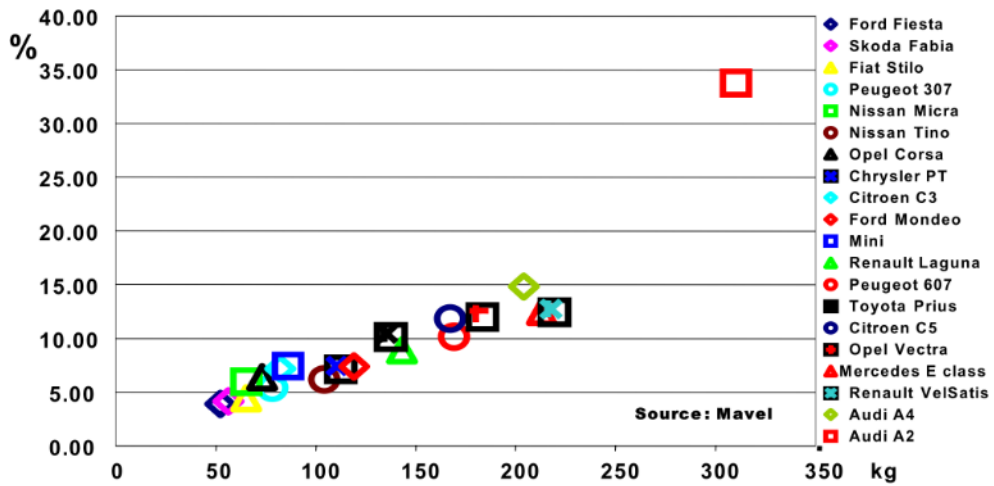
GRÄNGES

Polestar

STENA RECYCLING

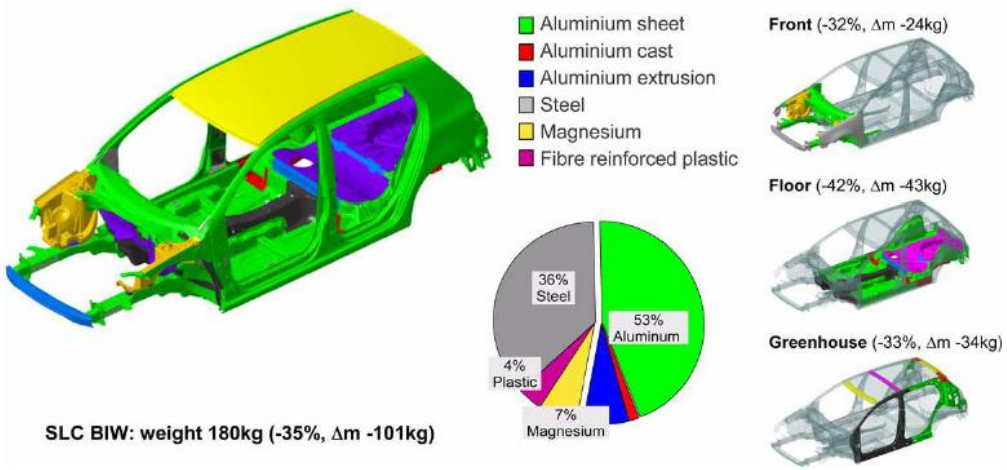
- Financing: VINNOVA Metallic Materials (Diarienr. 2022-02602)
- Project duration: 2022-10-28 to 2025-10-27
- Contact: Lluís Perez Caro, lluis.perez.caro@ri.se

- Current challenges
  - Aluminium sheet content in a car is around 30 kg/car (primary aluminium)
  - 66 million cars produced annually give this 31 878 ktons of CO_2
  - Using 100% recycled sheet metal can reduced this to 990 ktons globally
  - With green electricity, it could be zero
  - Lighter cars are critical for reducing the climate footprint of transport



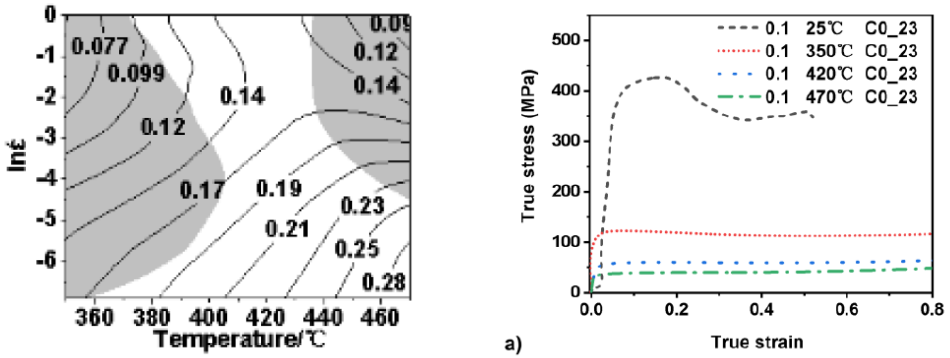
Hirsch Materials Forum Volume 28 (2004)

  - Many applications require aluminium sheet solutions
    - Functionality
    - Aesthetics
    - Less energy consumption when recycling



DMG World Media, ISSN: 1475-455X News Article ID: 15697, www.aluminiumtoday.com , Volume 21 No.5 – Sept.-Oct. 2009, p.46-49

- Current challenges
  - Secondary material based alloys have poorer formability
  - Oxides most common
  - Trace elements and with complex chemistry can stop recrystallization and limit formability
  - Hot/warm forming can be a solution
    - Better formability
    - Controlled hardening

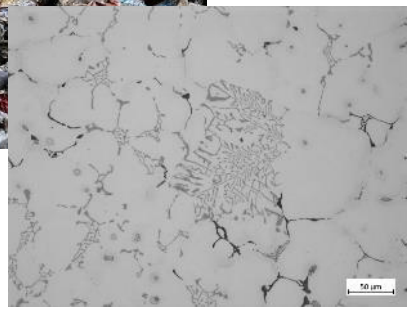


Du, A.; Lattanzi, L.; Jarfors, A.E.W.; Zhou, J.; Zheng, J.;Wang, K.; Yu, G. The Influence of Ce, La, and SiC Particles Addition on the Formability of an Al-Si-Cu-Mg-Fe SiCp-MMC. Materials 2022, 15, 3789. https://doi.org/10.3390/ma15113789

- Method / Result / Description
  - Influence of trace elements on recrystallization of deformation
    - Thermodynamic analysis
    - Experimental work for validation
  - Development and testing of alloying principles for secondary-based sheet metal products
    - Secure castability and rollability
    - Test hot/warm and cold forming
    - Validate through demonstrator forming with a sustainability analysis
  - Broaden the number of alloys that can handle secondary sources
    - Identify critical elements to deal with in recycling
    - Identify steps to reach zero carbon footprint for recycled aluminium sheet

https://www.polestar.com/se/

Stena Recycling AB



ThermLight2 - Paradigm shift in thermal technology for forming of lightweight components 2

Project scope and objective

- The objective of the research project is to develop a novel induction heating technology for heating of lightweight sheet metal in hot stamping.
- In a feasibility study (ThermLight), a new revolutionary induction technology was tested with promising results. The technology will be further developed in the proposed project to be a complete functional system.

Partners

- RISE
- AP&T Sweden AB
- Frauenthal Gnotec AB
- PR Development AB
- TC TECH Sweden AB

Financing

- Grant 4.7 MSEK, total project budget 10.4 MSEK
- The project is carried out within the strategic innovation programme LIGHTer, a joint effort between Vinnova, Formas och Energimyndigheten.

Project duration: 2022-11-07 till 2025-11-07

Contact: Johan Berglund, johan.berglund@ri.se

ThermLight2 - Paradigm shift in thermal technology for forming of lightweight components 2

- Challenges/Plans
  - Heating control system
  - Prediction and control of heat distribution
  - Cost efficiency
  - Demonstrator system

FO-BI - Modelling for high-speed forming of bipolar plates

Project scope and objective

- The project focuses on using **numerical modelling** using detailed **tribological investigations** to connect the final geometry of metallic bipolar plates (BP) for fuel cells with high tolerance requirements, manufactured with a high-speed forming process where the complex shape and dynamic behaviour of the production tools must be **included in a combined product and production development**.
- The project's objective is to combine product and production development for fuel cell plates to manage **rapid adaptation of new designs** to give Swedish **competitiveness and reduced environmental impact**.

Partners:

- RISE AB (Coordinator, project management)
- Cell Impact AB
- Harriet Lidhs Tooling AB
- Lunds universitet
- Oerlikon Balzers Coating Sweden AB
- Alleima AB
- Laser Machining Inc., LMI AB

Financing

- FO-BI is funded with public grants of 2.95 MSEK and an equal amount of in-kind giving a total budget of 5.9 MSEK
- The project is carried out within the strategic innovation programme Produktion2030, a joint effort between Vinnova, Formas and Energimyndigheten

Project duration:

- Three years between 2021-11-15 to 2024-11-15

FO-BI - Modelling for high-speed forming of bipolar plates

Current challenges

- Efficient numerical modelling aspects for challenging application at high-speed forming
- Correspondence between realistic testing of surface conditions in forming and modelling of test set-up
- Material characterisation for improved numerical simulations

Plans

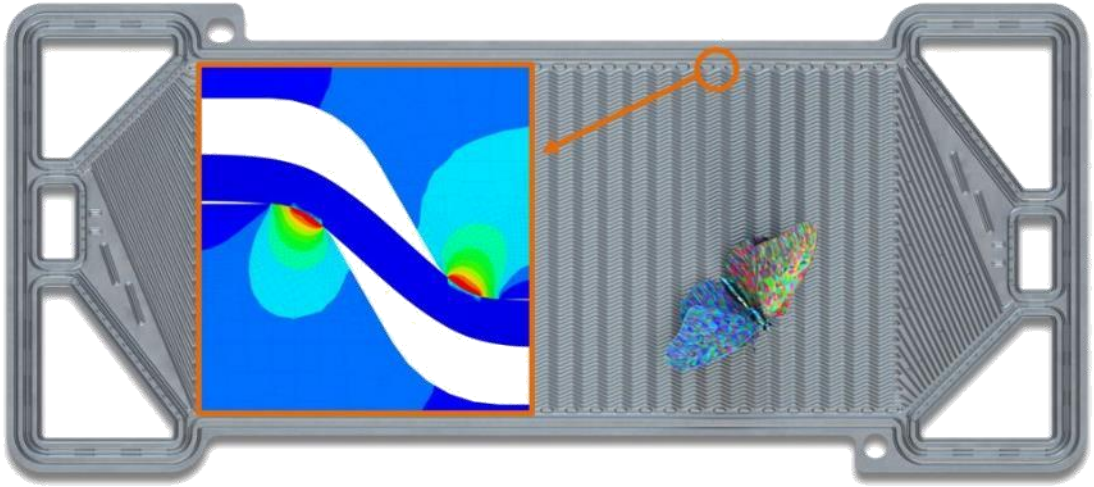
- Study wear mechanisms experimentally using various methods to enable selection and analysis of solutions to mitigate wear
- Simulation support for geometry assurance
- Generate physical results for validation of numerical methods, tool and parts

Results

- Development of tribo-test rig for suitable test range
- Manufacturing and testing of tools and coatings
- Developed contact parameter settings for simulations
- Analysis of tooling dynamics for improved simulations

Contact person:

- Peter Ottosson (peter.ottosson@ri.se)



SafEBat - Secure Applications for Electric Battery Housing

Project scope and objective

Development and process design of an FRP-aluminium foam sandwich battery housing with integrated sensors and thermal management in true scale

- Weight reduction of 15-20% or mass neutrality when expanding functions
- Thermal function expansion: switchable temperature control and optional passive memory
- Sensor integration for health monitoring of the housing / system
- Increase in underbody protection and proof on experimental stage→at least 20% reduction in penetration depth in the bollard test

Partners

- Swedish: AP&T, RISE
- German: Fraunhofer IWU, Fiber Check GmbH, Havel metal foam GmbH (associated)

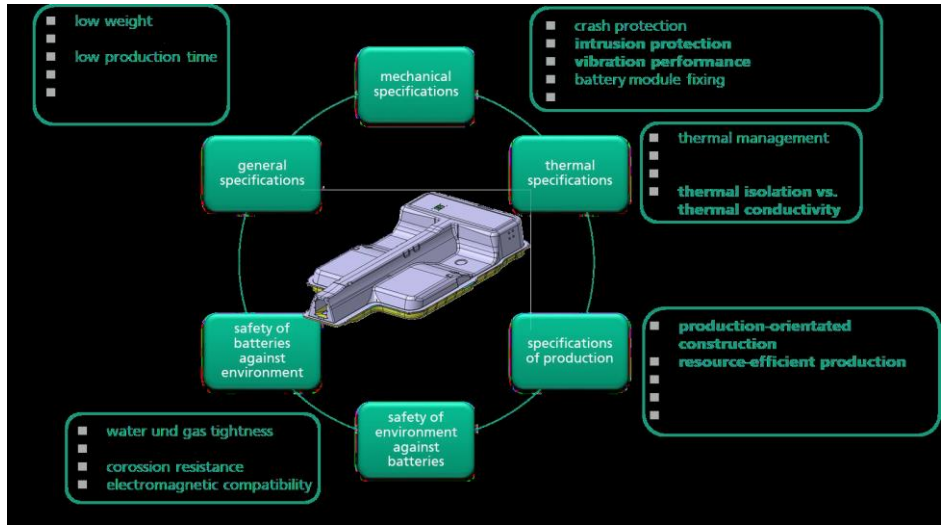
Financing

- Vinnova (Sweden) and AiF (Germany)

Project duration

- 2020-06-15 – 2023-05-31

Contact: Yvonne Aitomäki, yvonne.aitomaki@ri.se



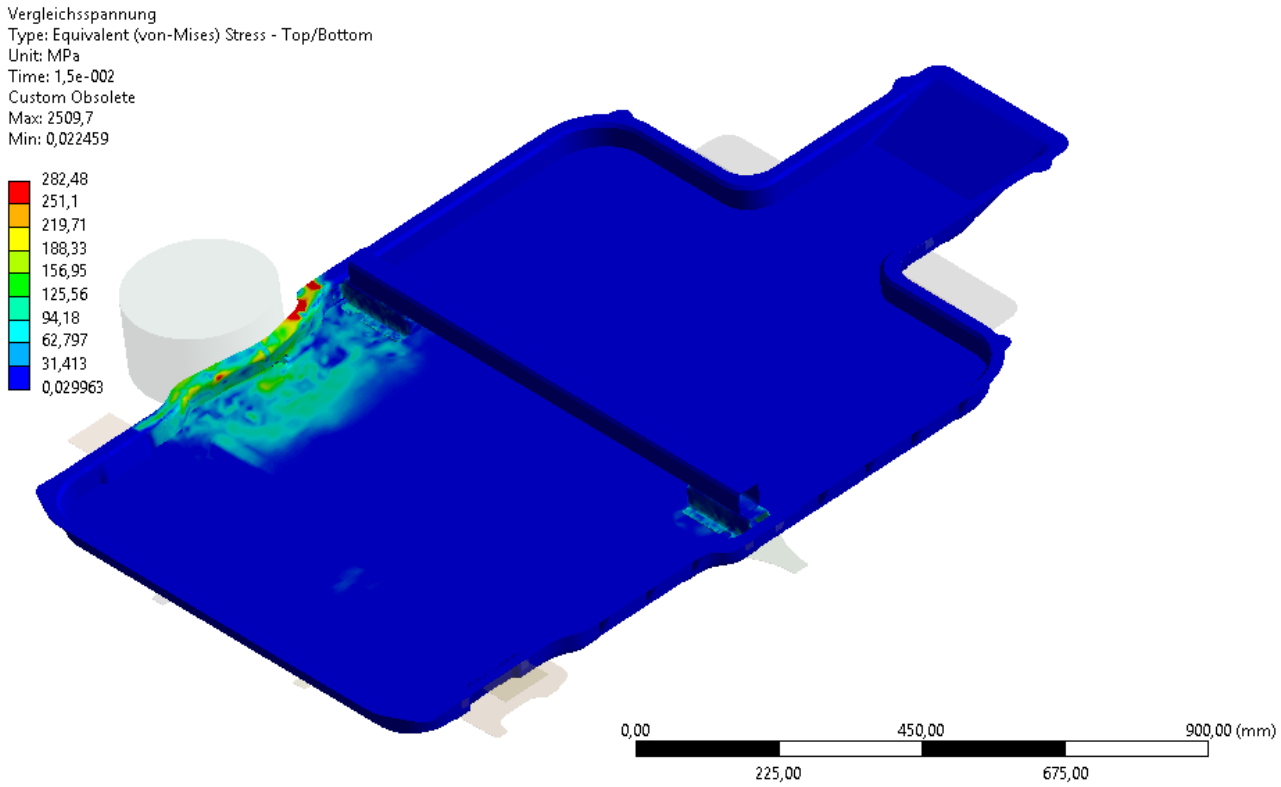
Design of battery box with foam and SMC

<u>Results from pole impact</u>

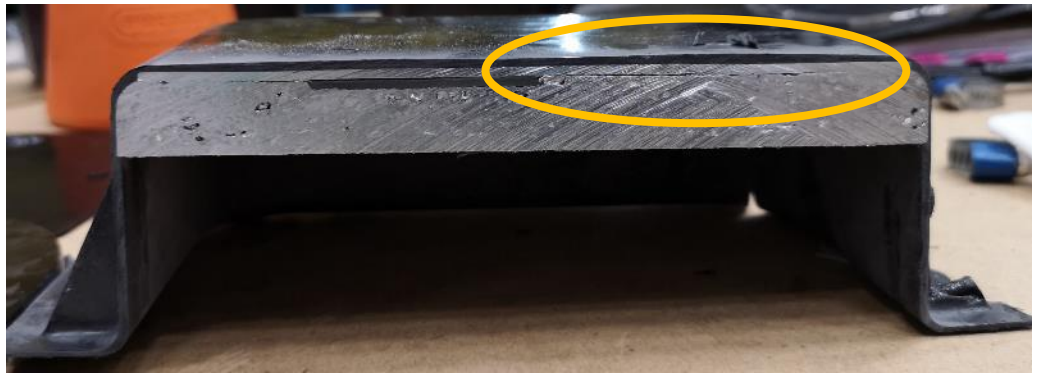
- With new design:

  -75% deformation

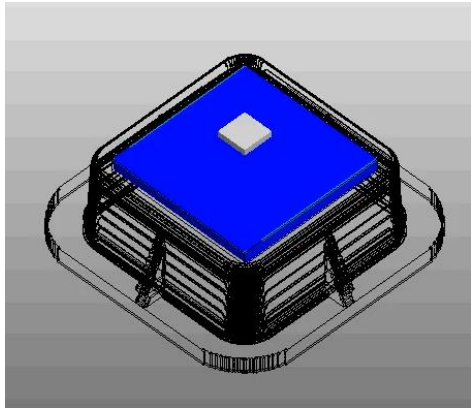
- Brittle damage behaviour most likely reduced through sill load distribution , but an issue : solution - thickening & supporting flange area with ribs



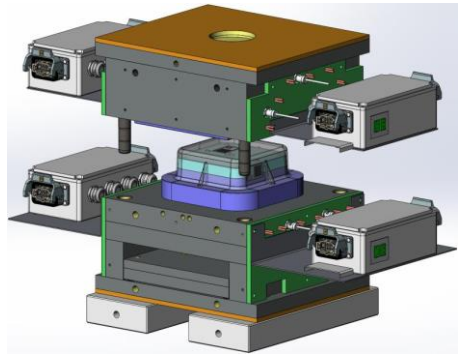
Manufacturing: testing on small demo



- Selection of CF based SMC
  - Density , Mechanical performance, CTE
- To test how Al foam will withstand SMC under the moulding pressure

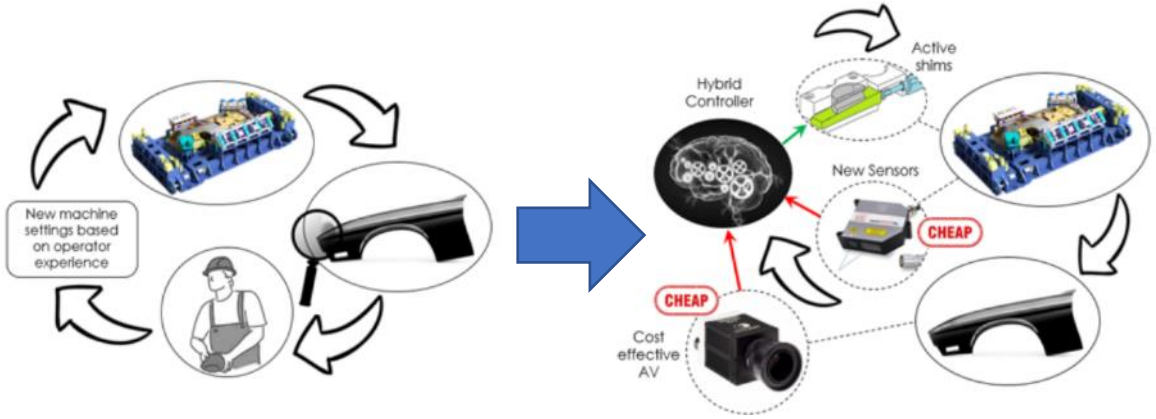


- Simulation showed high local pressure, causing foam deformation.
- Experiments reflected this: showed foam collapse –leading to poor filling
- Current status: New foams being manufactured!



I-Stamp - Intelligent and sustainable stamping processes using hybrid control strategies together with process monitoring

Project scope and objective

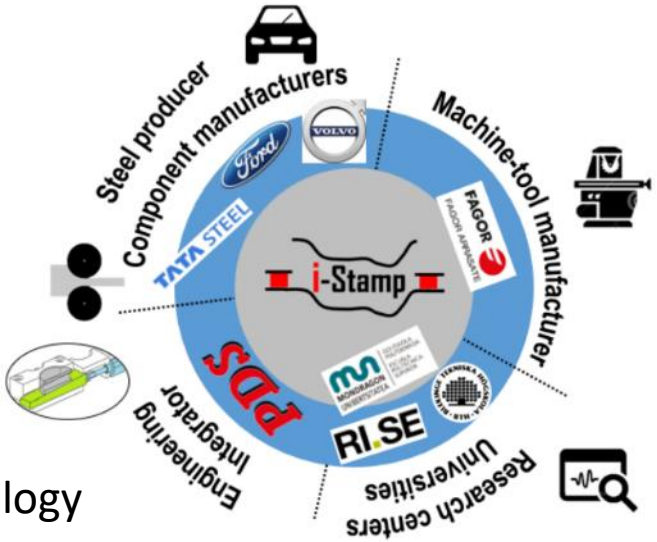


Financing

- Eureka SMART through Vinnova (Swedish part) and CDTI (Spanish part)

Partners

- TATA Steel International
- Ford, Volvo Cars
- Fagor Arrasate
- PDS Engineering
- Mondragon University
- Blekinge Institute of Technology
- RISE



Project duration

- 2022-01-01 – 2024-06-30

I-Stamp - Intelligent and sustainable stamping processes using hybrid control strategies together with process monitoring

Status

- Actuators have been developed
- Sensors for draw in are tested in production with good results
- A first version of the control system is under development

Contact: Daniel Wiklund, daniel.wiklund@ri.se

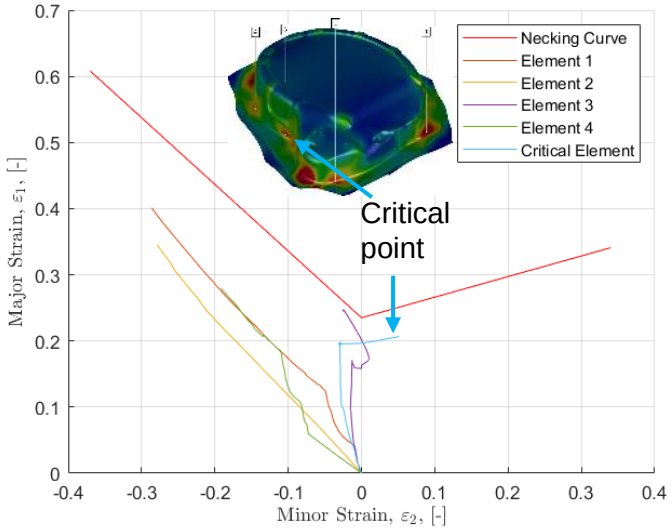
PREDICT - Failure prediction for complex load cases in sheet metal forming

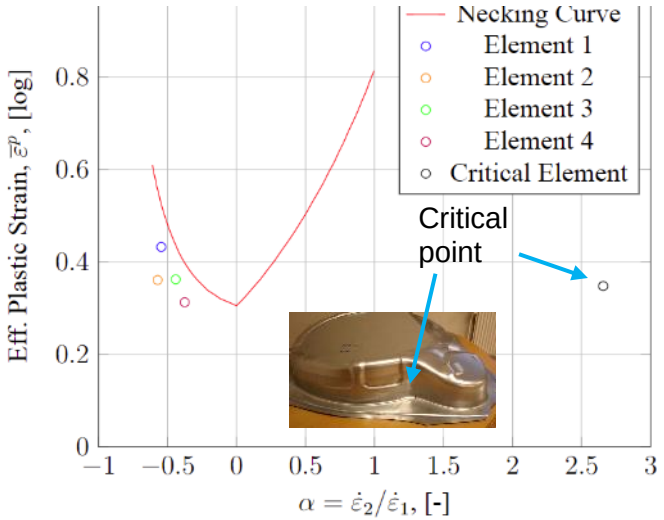
- Project scope and objective
  - Increased accuracy in FE-model failure predictions by developing advanced material models and calibration techniques.
  - Prediction of process adjustment to prevent failure using AI.
- Partners:

- Financing: VINNOVA FFI Sustainable Production (Diarienr. 2020-02986)
- Project duration: 2021-01-01 to 2023-12-31
- Contact: Lluís Perez Caro, lluis.perez.caro@ri.se

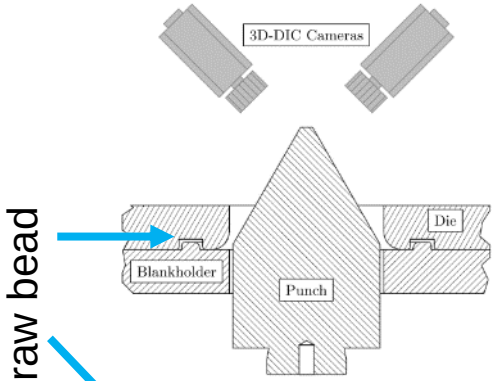
PREDICT

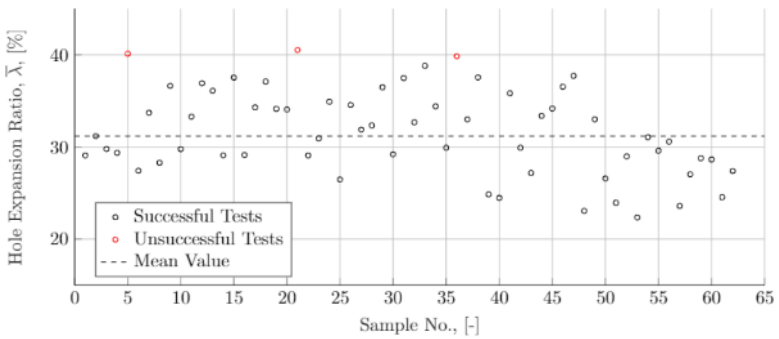
Non-linear strain path
• Transformation of FLC





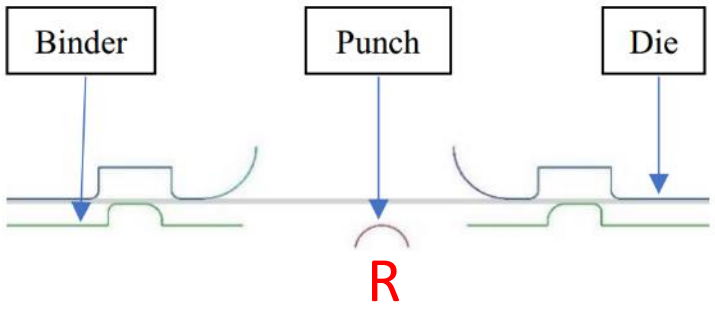
Edge formability
• Hole expansion ratio test • Updated BC • Use DIC

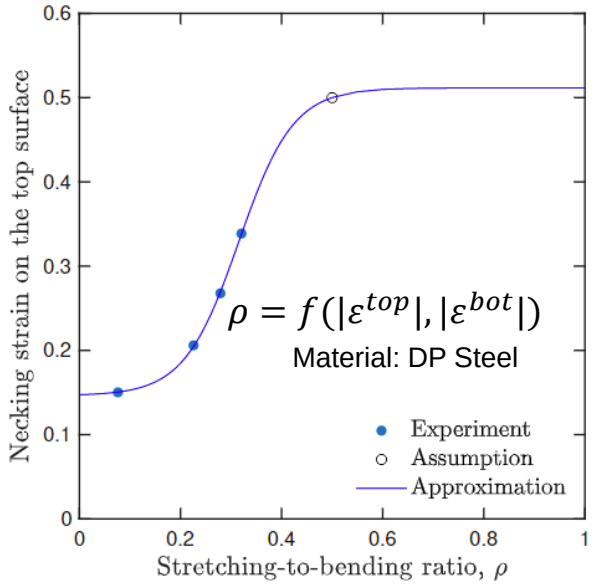




Stretch-bending
•Stretch-bending ratio ρ • Necking strain

Experiment on radius R3, R6, R10





Ongoing research in Joining

Circularity
- IDEAL
- MIDWEST
- AluCAD

E-Mobility
- COMMIT

Digitalisation
- WELDVISI
- MADBOND

Presenter: Joakim Hedegård, joakim.hedegard@swerim.se

IDEAL - Improved Resistance Spot Weldability of Aluminium for Advanced Light-Weight Designs

- Project scope and objective

Increased knowledge regarding how material properties, defects and disturbance factors, process settings and choice of equipment impacts the resistance spot weldability of aluminium in order to enable increased use of aluminium castings, extrusions and sheet material.

- Partners

Swerim, RISE, Gestamp, Volvo Cars, AGES Kulltorp, Gaming Engineering, Hydro Extruded Solutions, Reliefed

- Financing

VINNOVA - LIGHTer

Budget – 5.53 MSEK whereof 2.65MSEK VINNOVA

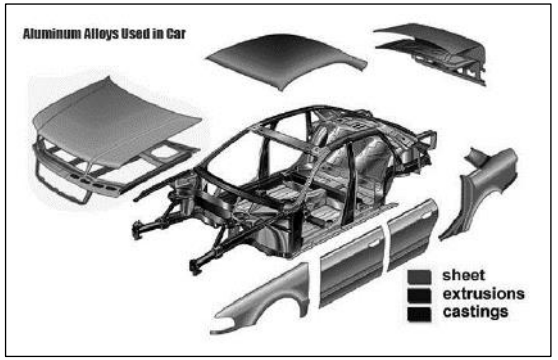
- Project duration & contact

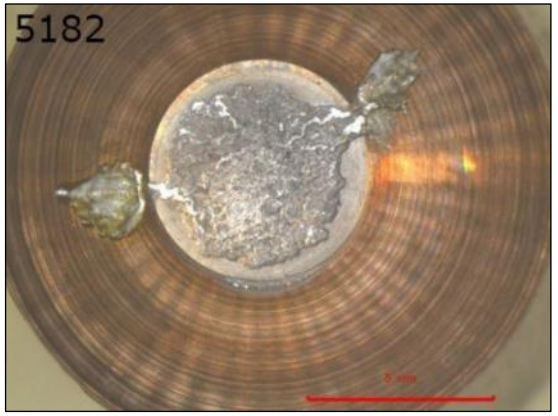
2022-11-02 – 2025-06-30

Contact person: Pia Borg, pia.borg@swerim.se

IDEAL Background, method and aim

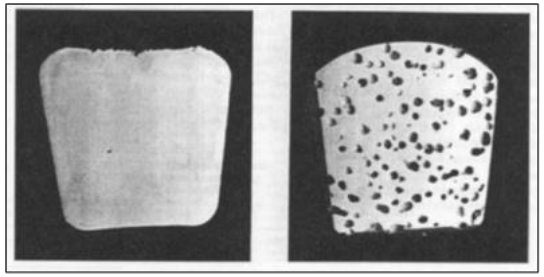
- The increased use of aluminium, castings, extrusions and sheets in the automotive industry requires flexible, robust, and efficient joining methods
- Resistance spot welding is the most commonly used joining method in automotive. However, when it comes to spot welding of aluminium there are issues regarding the need for too frequent dressing intervals, inhomogeneous surface properties and high electrical- and thermal conductivity coupled to the welding process which leads to reduced weldability
- This project aims to achieve strategies for resistance spot welding of aluminium and increase knowledge regarding how material properties, defects, equipment, and process settings impact the resistance spot weldability of aluminium

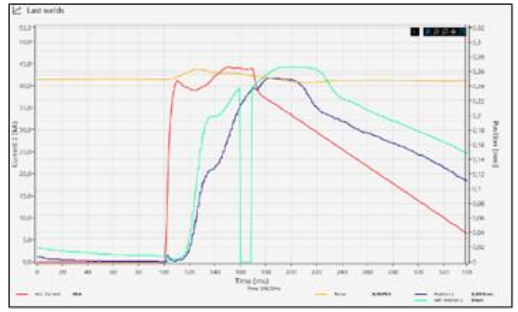




IDEAL Project work

- The project has created a test matrix with materials and material combinations relevant for the automotive industry.
- The project aims to investigate how material properties and the presence of defects, such as surface oxides, porosity, conductivity etc. influence the weldability through combined material evaluations and joining trials.
- The project will also compare and investigate how different welding systems can improve the weldability of aluminium.
- The results from the project will be presented in a guideline for RSW of aluminium, containing information and requirements regarding how material properties and defects impact the weldability and how different issues can be handled by advanced systems and equipment





MIDWEST – an FFI project enabling robotization of important weld improvement methods

- Scope and objective

Mechanised post-weld treatment in welding robot: weld a component, create an adapted path along the weld and treat to reduce stress and increase fatigue life.

- Partners

Swerim, KTH, Chalmers, Volvo CE, HIAB, Gestamp, ToyotaMH, ABB, SSAB, Winteria, Weld-Hit, HiFIT.
And Robotdalen as subcontractor.

- Results so far

Adaptive treatment in robot with HFMI + TIG successful.

Adaptive robotic grinding: proof of concept so far.

Very good fatigue results on specimens & demonstrators

- Financing

VINNOVA FFI-sustainable production
7.8MSEK whereof 3.9MSEK VINNOVA

- Project duration & contact

2020-11-13 – 2023-11-13
Joakim Wahlsten & Joakim Hedegård, Swerim
Joakim.Wahlsten@swerim.se

AluCAD – Aluminium Cast Alloy Development

Vinnova Pre study Diarienr 2022-01670

Project scope and objective

To increase the metallurgical competence enabling development of secondary based strong and ductile cast aluminium alloys without hardening heat treatment – hereby contributing to improved circularity and efficient EV structures. By using secondary non heat treated alloys the **CO_2 reduction potential is in the magnitude of 450 kTon per year and vehicle manufacturer.** The results will target the transportation and other applicable industries for cast aluminium structures.

Partners

Material supplier	Stena Aluminium
Manufacturer	Comptech AB – Rheocasting equipment supplier
Research institutes	RISE; Luleå University of Technology
Vehicle manufacturer	CEVT Vehicle Europe
Research and Project	MD Material Design AB

Financing

Vinnova 500 kSEK, 50% of project budget

Project duration & contact

9 months; November 2022 – July 2023

Contact person: Paul Jonason paul.jonason1@gmail.com

Results

- Preliminary tests show increase in both strength and ductility despite higher Fe levels
- Initial microstudies show additional alloying elements tending to improve properties both by strengthening the aluminium matrix and affecting intermetallic phases
- Results so far indicate a possibility of improving mechanical properties of secondary alloys without heat treatment but by chemical composition only, extending the structural applicability of recycled aluminium - implying significant CO_2 savings:

Årlig CO2 besparing med gjuten sekundäraluminium utan härdning

En OEM a 50 kg primärAl / fordon x 1m fordon = 50 kTon Al /år

Sekundäraluminium		
• CO2 reduktion med sekundäral 10 kg CO2/kgAl x 50 kTon Al/år:	**500 kTon**	Alternativ leg mix AluCAD
Utebliven särskild värmehärdning T6		
• Reducerad energiåtgång: 16 kg CO2 / artikel al x 1 m fordon / år:	**16 kTon**	Alternativ leg mix AluCAD
Rheogjutning		
+ verktygslivslängd, mindre gjutmaskin, låg Si legering		
Tot besparing 1 kg CO2 / kg al x 50 kTon Al:	**50 kTon**	Låg Si för egenskaper AluCAD
Totalt för sekundäral utan värmebehandling Rheogjutning	**566 kTon**	
Möjliggörare för CO2 besparingar enl ovan		
• Rätt sekundärlegering för stabila egenskaper utan värmebehandling		
• Rening av sekundärlegeringar	**- 100 kTon**	
Bedömd ca CO2 nettobesparing inkl möjliggörare ovan	**450 kTon CO2 / år**	

AluCAD – Aluminium Cast Alloy Development

Vinnova Pre study Diarienr 2022-01670

Plans

Pre study

- Complementary Material trials based on preliminary property tests
- Correlation of properties with microstructural analysis to identify how alloying elements affect material properties
- Definition of strong, non heat treated cast alloys for industrialisation based on the pre study

Industrialisation Follow up project

- Complementary material trials based on results from pre study
- Mapping of properties and their scatter in components
- Detailed calculations of CO_2 savings for a defined component
- CAE data generation for defined alloys
- Dissemination of results

Challenges

- Availability of efficient alloying elements for industrial production
- Modifications of existing material logistics for supply of new alloys
- Standardisation and introduction of new alloys to suppliers and end users

COMMIT - Electrical interconnects designed for improved thermal- and mechanical fatigue life

- Project scope and objective

Develop a method for evaluation of thermal and mechanical fatigue properties in order to ensure long service life for electrical joints in batteries

- Partners

Swerim, Volvo Cars, Scania, Northvolt, Polarium, Hydro Extruded Solutions, El-Supply, Lasertech

- Financing

VINNOVA – FFI-Circularity

Budget – 6,05 MSEK whereof 2.85MSEK VINNOVA

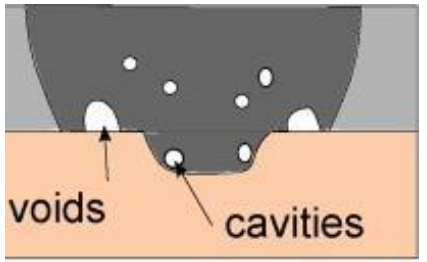
- Project duration & contact

2022-10-31 – 2024-12-31

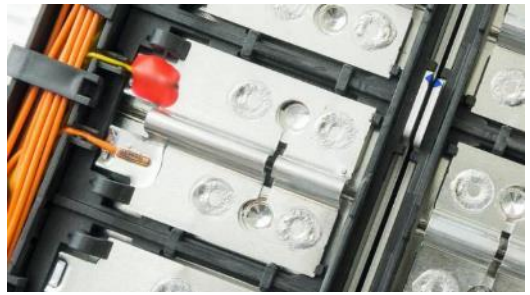
Contact: David Löveborn & Tag Hammam
david.loveborn@swerim.se

COMMIT Background

- Welding of tab to busbar and other electrical joints have challenged manufacturing companies in designing and delivering solutions for high voltage and high current applications.
- The welds are subjected to fatigue loads through vibration and thermal expansion during charging
- The fatigue loads, thermal and mechanical, on welds are not well understood
- As the battery pack stands for a significant part of the total vehicle cost and battery pack repairs are costly, ensuring long service life of electrical joints is very important.



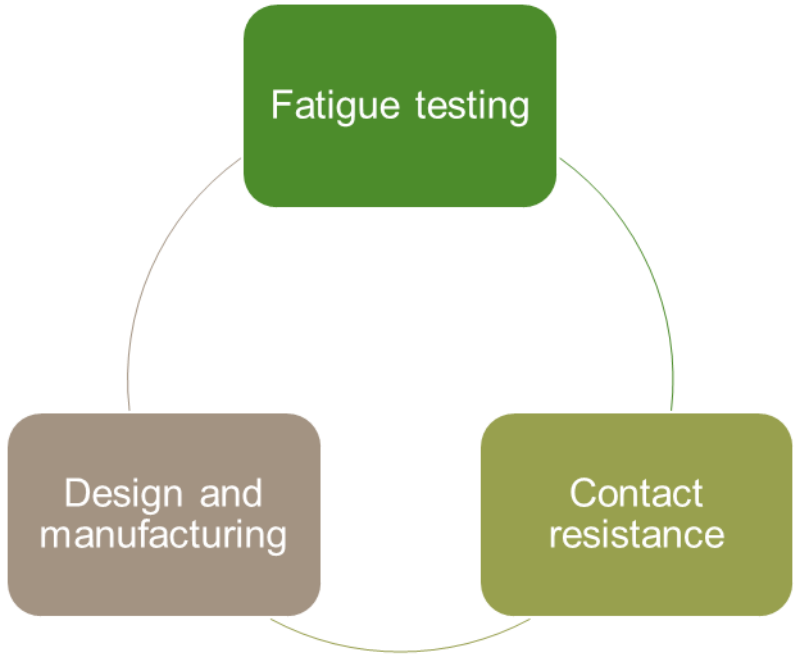
Over-weld

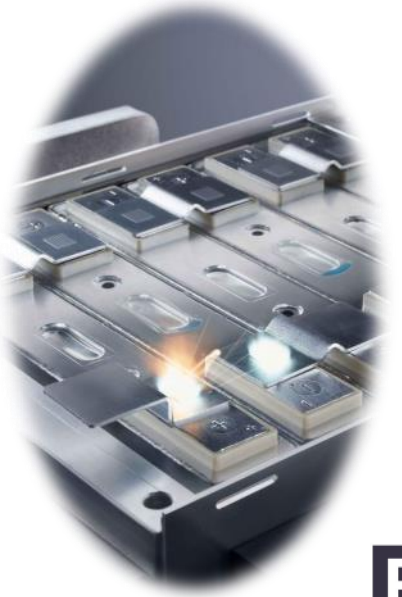


COMMIT Purpose and aim

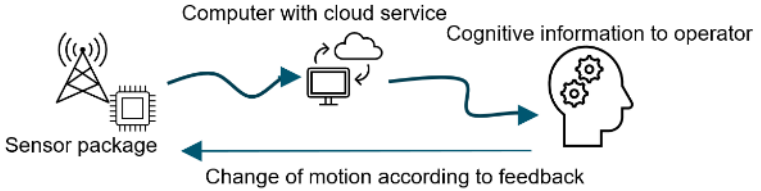
- Goal:
  - Ensuring long service life for electrical joints in batteries.

- How?
  - The project will develop methods for evaluating fatigue performance (both thermal and mechanical). Contact resistance measurement practices will be defined for evaluating electrical joints and guidelines for material choice, design and joining will be presented.





WELDVISI – Cognitive support to the welder by smart sensor handling and visualization of welding process & parameters



- Scope and objective

Create a prototype system with sensors to be attached (clip-on) to the welding gun and an info feedback system in the welding helmet.

- Partners

Swerim, RISE, MIUN, ESAB, Winteria, ToyotaMH, Väderstad, Ellagro, Maskinarbeten, Uddcomb International, Skyllbergs, Fredrika Bremer (welding school)

- Results so far

Prototype for welding gun in development.

GUI for welding helmet in development.

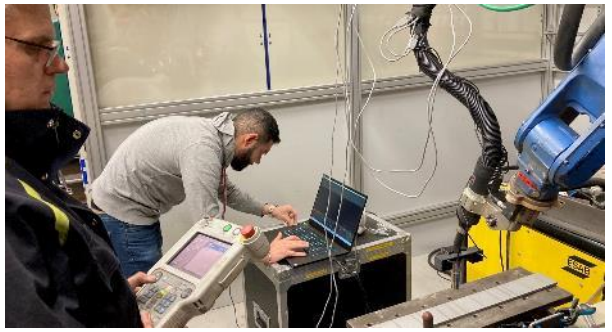
Data collecting & calculation of key parameters on-going.

- Financing

VINNOVA Production2030
4.9MSEK whereof 2.45MSEK VINNOVA

- Project duration & contact

2022-06-09 – 2024-12-31
Joakim Wahlsten & Joakim Hedegård, Swerim
Joakim.Wahlsten@swerim.se



MADBOND – Modelling of adhesive bonding for multi-material design

- Project scope and objective

Development of flexible, digital tools for prediction of deformations, adhesion and fracture in adhesively bonded multi-material components

- Partners

Swerim, RISE, Gestamp, Volvo Cars, ArcelorMittal, EJOT, Composite Service, DYNAMore Nordic

- Financing

VINNOVA FFI-Hållbar Produktion

Budget – 10,3 MSEK whereof 5.15MSEK VINNOVA

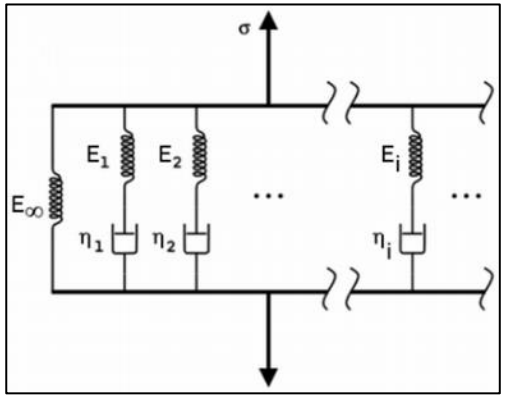
- Project duration & contact

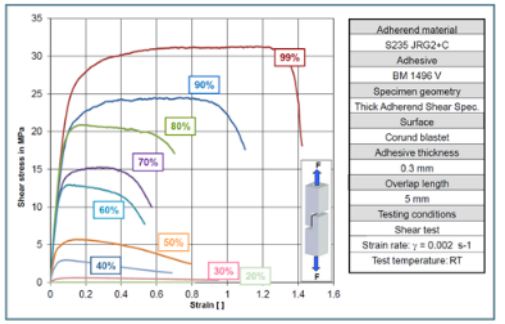
2020-10-20 – 2023-09-30

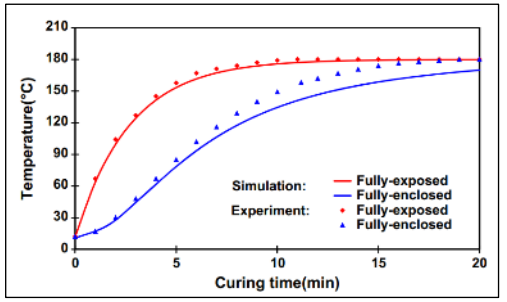
Contact: David Löveborn david.loveborn@swerim.se
and Mohammad Rouhi mohammad.rouhi@ri.se

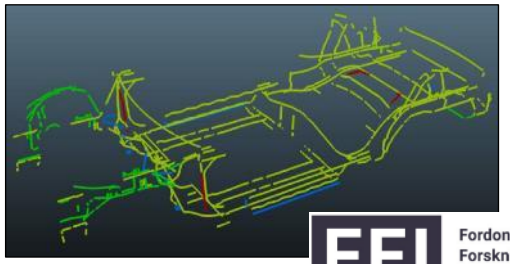
MADBOND Background, method and aim

- Hybrid joining, adhesive bonding in combination with mechanical joining, is commonly used for joining of mixed material components in automotive.
- One large challenge regarding joining of mixed material components is the large differences in thermal expansion coefficient, causing deformations of the component, mainly in the area between two fasteners, during the curing of the adhesive. The phenomenon is known as the Δα-issue.
- The project aims to develop a virtual tool for prediction of deformations and risk for fracture in the joints with respect to properties and geometries in the ingoing materials, adhesives and joints



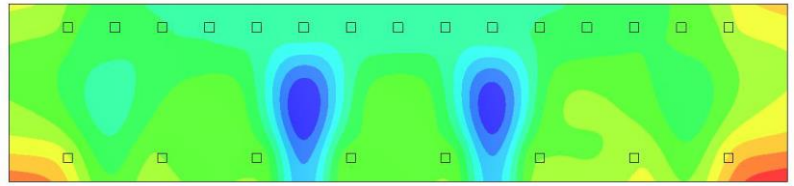




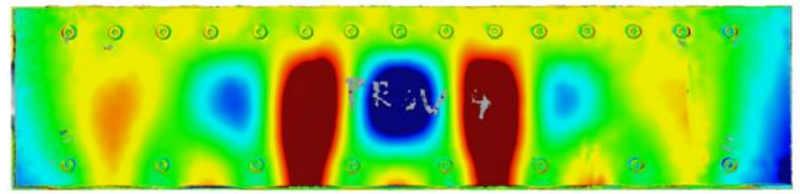


MADBOND Results and further work

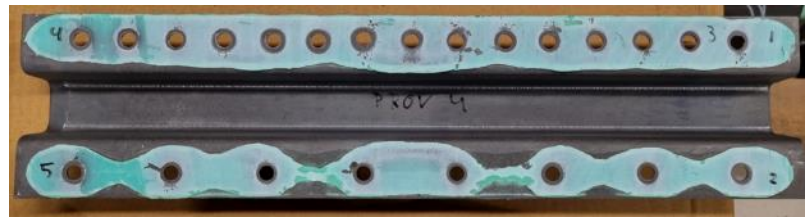
- The experiments and analyses in from the project have resulted in a model which is able to predict deformations in hybrid joined mixed material components.
- The model has been verified on hat-beam profiles, aluminium-lids joined to Usibor-hats, showing that the model is able to predict deformations in lids and the resulting adhesive coverage.
- In order to improve the model, a damage indication criteria will be developed and implemented.
- The project will also create a guideline for mix-material joining.



Simulation



Measurement



Peeled specimen