Forming of scrap-based aluminium sheet – evaluation of formability and modelling

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THE SWEDISH Manufacturing R&D Clusters

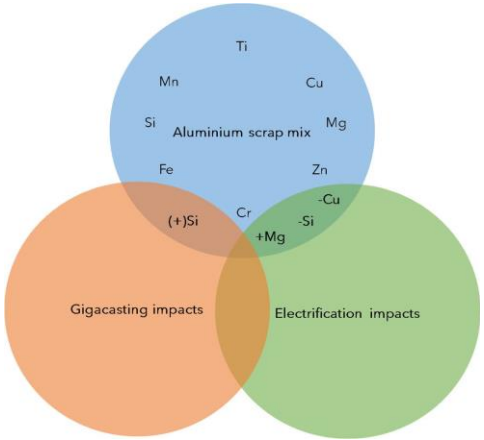
AP&T

AGENDA

- Project Brief
- **Introduction – Warm Forming**
- Material Characterization
- **Forming Tests at AP&T**
- **Validation of Simulation**
- Results and Outlook

Climate smart high-performance aluminium sheets (ClimAl)

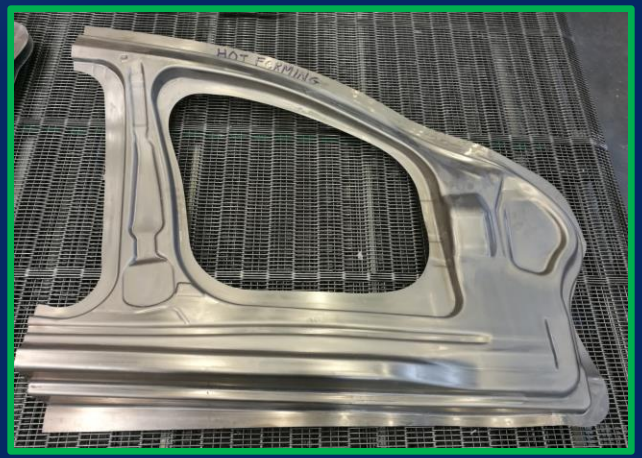
- Scope and objective
  - Identify critical trace elements and synergies on recrystallization and deformation hardening
  - Develop alloying principles that enables high secondary content allowing castability, rollability and formability
  - Validate material and process using demonstrators
- Covering value chain
- Project duration October 2022-October 2025
- Budget; total 10 MSEK whereof 5 MSEK from Vinnova



WORLD-LEADING SOLUTIONS FOR EFFICIENT SHEET METAL AND FIBER FORMING

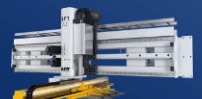
AP&T provides metal and fiber forming industries worldwide with state-of-the-art technology and know-how.

Being the technology leader in selected niches, we focus on sustainable production systems offering the highest customer value and lifetime performance.

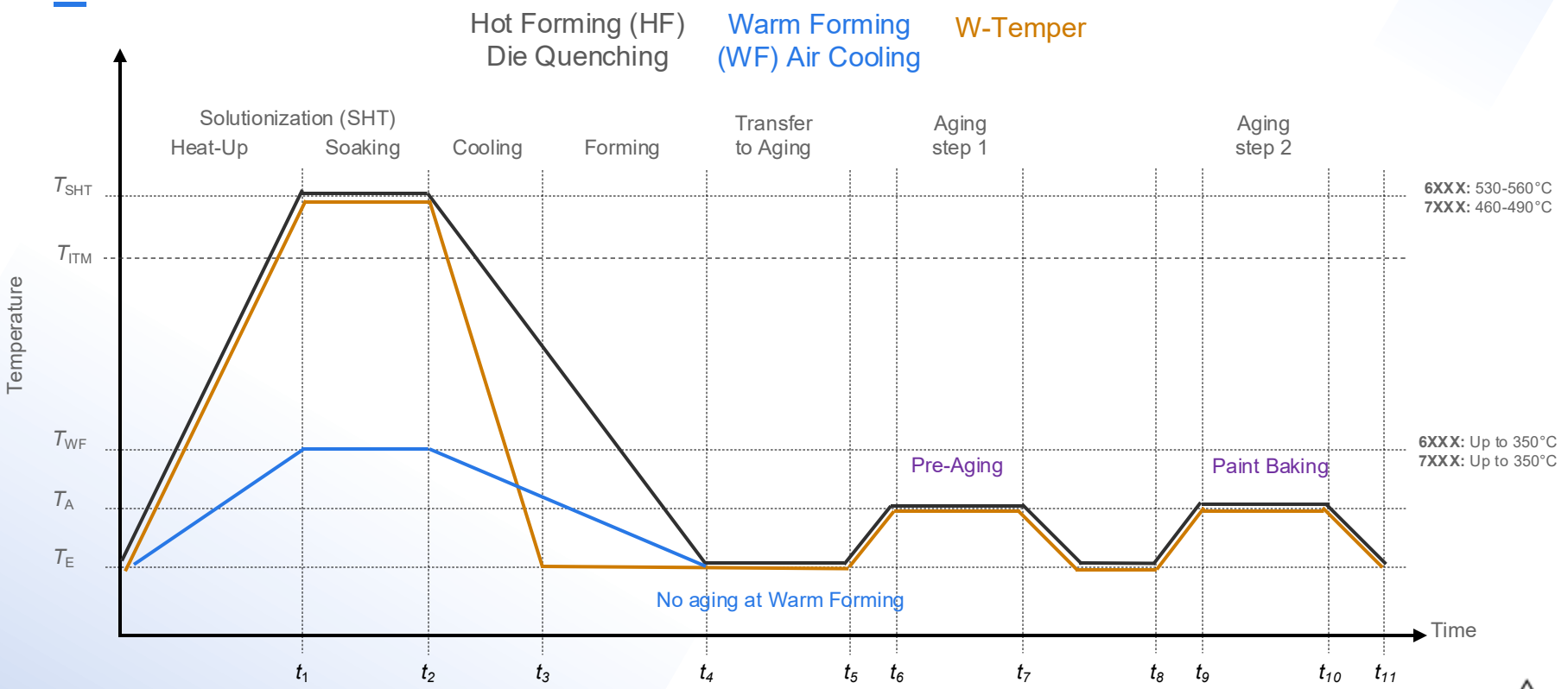


OUR OFFERING:

- Advanced production solutions
- Linear automation
- Servo presses
- Furnace systems
- Services for lifetime performance
- Optimized forming tools



Available processes routes to enhance formability of High Strength Aluminum



Discription of Process Routes: Warm Forming, W-Temper Forming, Hot Forming

Example improved formability depending on part geometry

Cross geometry (AA7075):

Cold Forming | Hot Forming | Warm Forming | W - Temper forming

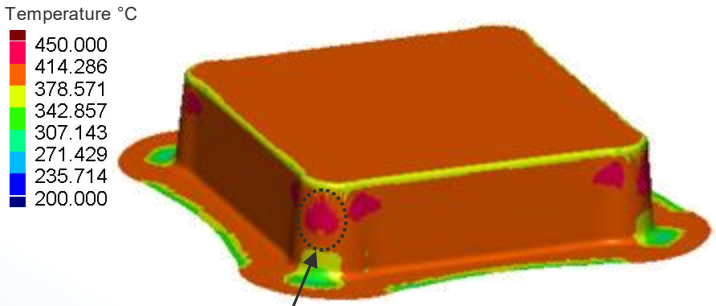
Door ring geometry (AA6010):

Cold Forming

W - Temper forming

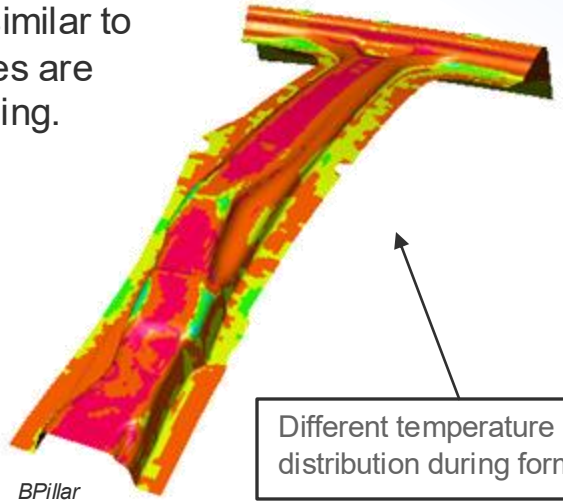
Hot Forming

Why is hot stamping not suitable for every type of geometry?



Tank, Sink

Geometries which are similar to deep drawing geometries are not suitable for hot forming.

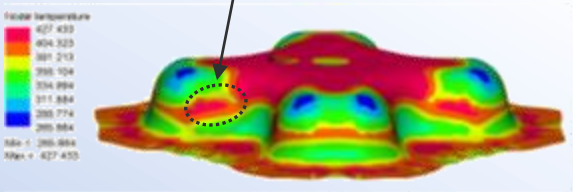


BPillar

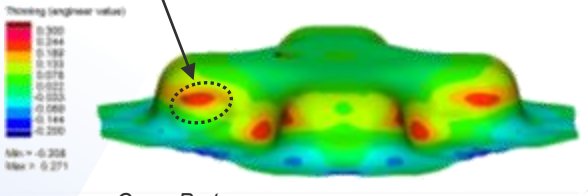
Temperature hot spot in force transmitting zone

The hot spot in the wall region causes high thinning

Different temperature distribution during forming



Cross Part



Cross Part

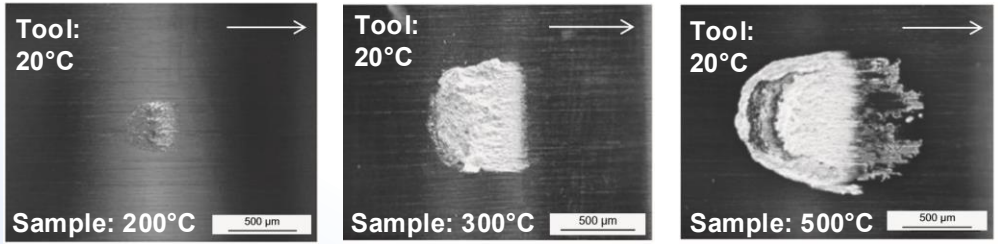
Lubrication system to enable aluminum sheet forming at elevated temperatures

Aluminium and steel are "good friends" – high chemical affinity!

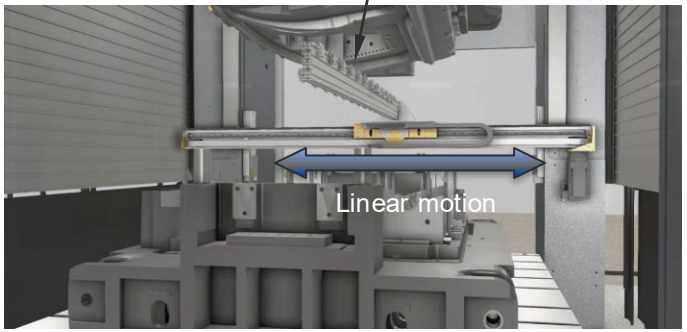
When forming aluminium, strong adhesion and aluminium transfer to the surface of the forming tool occur, as aluminium is especially prone to adhere to the die's bearing surface.

The higher the temperature the more adhering of aluminium occurs between two sliding samples (AA6060 – Tool Steel):

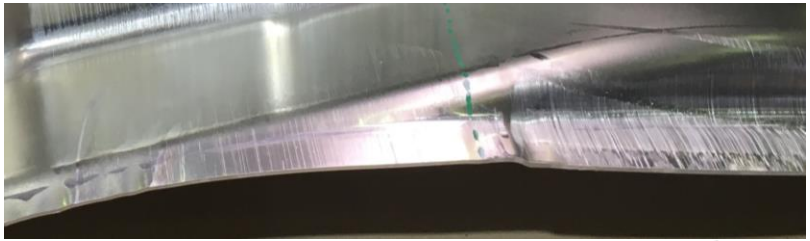
Sliding distances of 4 mm:



Source: J. Jerina, M. Kalin, University of Ljubljana, 2014



AP&T's Lubrication solution to lubricate the tool surfaces – spraying equipment for powder or water-based lubes can be installed
Source: AP&T Sweden AB



- The use of lubricants is crucial when aluminum sheets are formed at elevated temperatures.
- According to state-of-the-art the tool surface must be lubricated to achieve a robust process

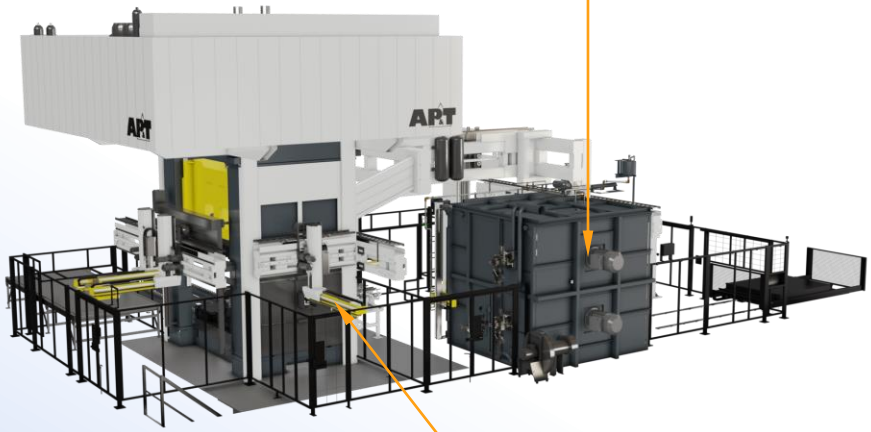
Relevant literature:

Jilin University, Changchun 130025, China
Li, X.; Yan, X.; Zhang, Z.;Ren, M.; Jia, H., (2021)
Determination of Hot Stamping Friction Coefficient of 7075 Aluminum
Metals 2021, 11, 111

Luleå University of Technology , Sweden
Justine Decrozant-Triquenaux
High Temperature Tribology of Aluminium: Effect of Lubrication and Surface Engineering on Friction and Material Transfer
Thesis, 2020

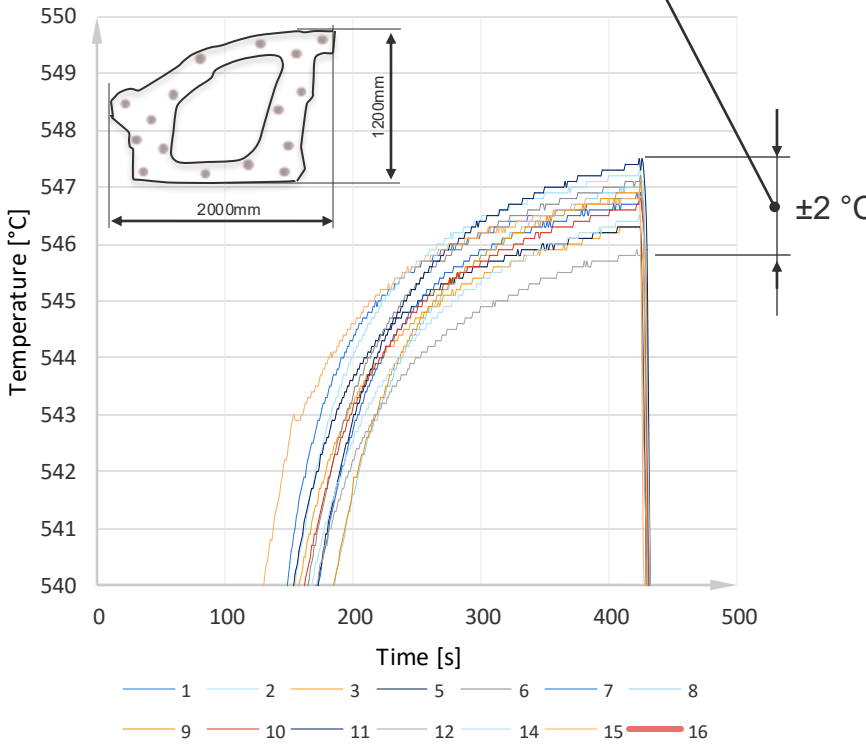
University of Ljubljana, Slovenia
J. Jerina, M. Kalin,
Initiation and evolution of the aluminium-alloy transfer on hot-work tool steel at temperatures from 20°C to 500°C
Wear,Volume 319, Issues 1–2, 2014,

Low Volume Production – Aluminium Hot Forming Line



AP&T Aluminum Line at Fischer, Achern
Source: AP&T Sweden AB

High accuracy and fast heating rates enable short soaking times



Temperature evolution during SHT – AA6xxx – 2.5mm, AP&T Jet Heating system
Source: AP&T Sweden AB

Formability study in ClimAL project (AP&T and RISE)

A non-conventional material with a scrap-friendly specification was used and tested in different conditions.

Material from Gränges:

- Variant 1: AA4115-H18 (before annealing).
- Variant 2: AA4115-H24 (partially annealed).
- Variant 3: AA4115-O (fully annealed).

AP&T's goal in the project:

- Investigating formability of warm formed AA4115

RISE:

- Material characterisation.

Material characterisation

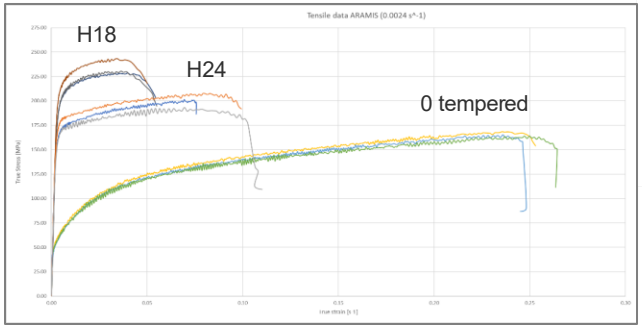
Full material characterization for aluminium sheet materials within the ClimAI-project:

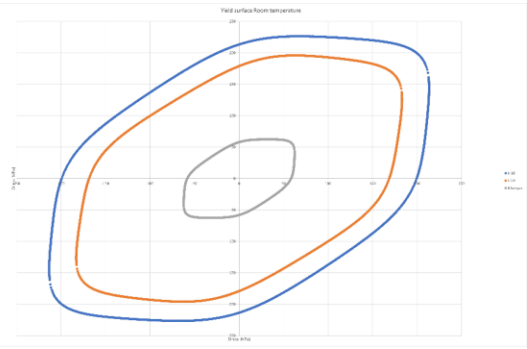
- Tensile
- Plain strain
- Biaxial
- FLD

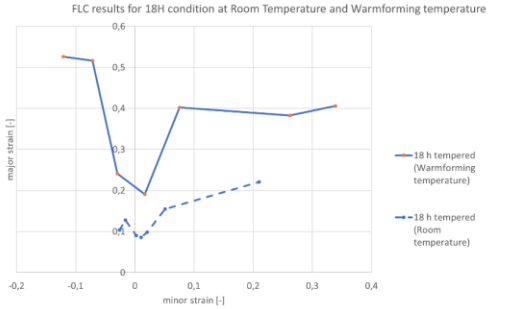
Tests were done for:

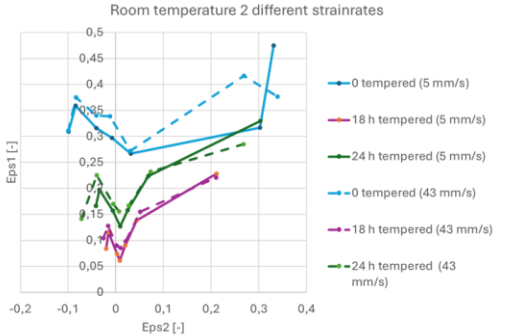
- Different material conditions (e.g. H0, H18, H24)
- Room temperature and Elevated temperature (warm forming conditions)
- Two different strain rates

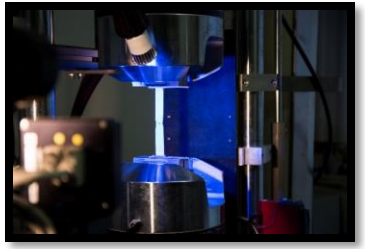
Full-field strain measurements were used to capture the onset of localised necking



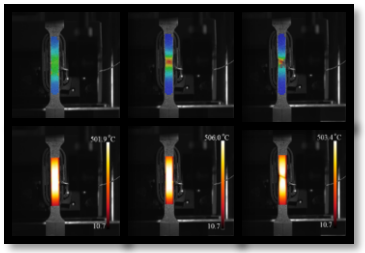








Tensile tests



Visualisation in ARAMIS™ & Infrared camera

Experimental setup for FLC at elevated temperatures

Test setup – Forming Trials

- Initial testing/Warm Forming.
- Determination of material limit.
- Comparision tested parts/simulation model.

AP&T press and the test setup

Radiation Furnace

Cross Die Tool

Test setup – Forming Trials

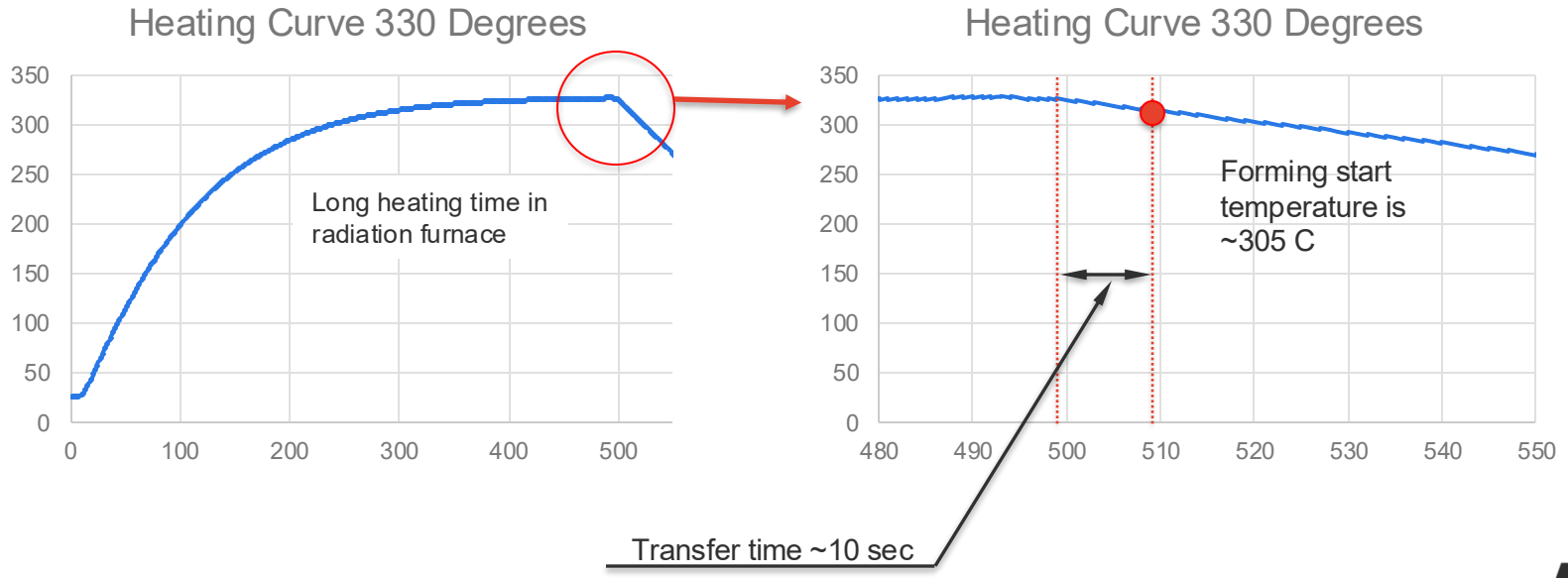
Distance plate/Gap (0.2 mm)

Distance Sensor

Temperature Measurement - Heating Curve

- Transfer time of ~10 sec
- Thermocouple type K is used for this temperature measurement

Thermocouple type K



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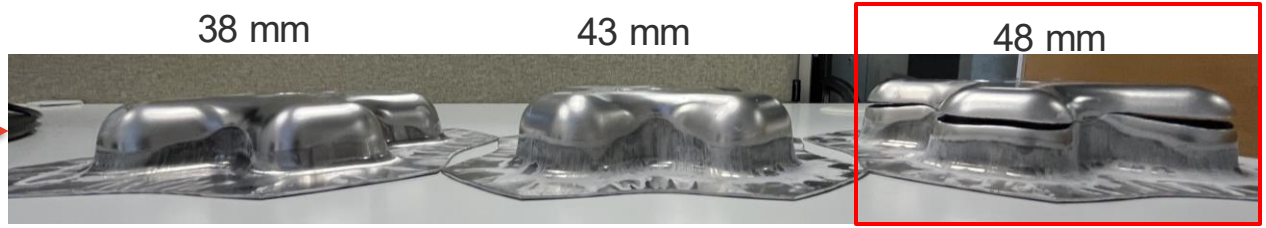
Variant 3: AA4115-O (fully annealed): Cold And Warm Forming results

Cold Formed



Warm Formed

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Variant 1: AA4115-H18 (before annealing): Cold And Warm Forming results

Cold Formed

22 mm (Gap Controlled)

22 mm (Force controlled)

Warm Formed

33 mm

38 mm

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Variant 2: AA4115-H24 (partially annealed): Cold And Warm Forming results

Cold Formed

25 mm

30 mm

Warm Formed

39 mm

47 mm

47 mm (faster forming speed)

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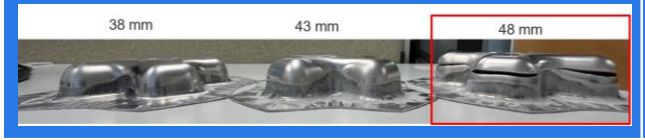
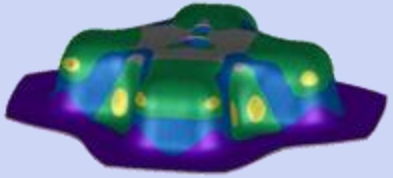
Formability analysis of AA4115 / Cold Forming

Cross Die Test: O-Temper



Simulation:
50 mm
Forming test:
43-48mm



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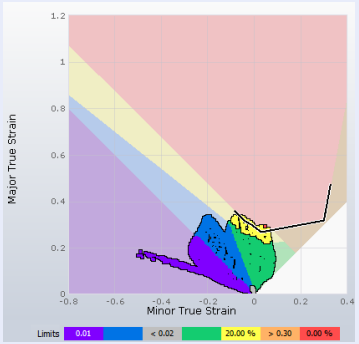
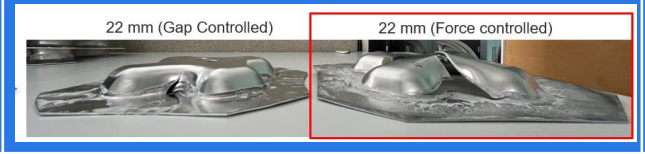
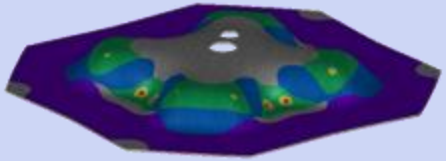


Cross Die Test: H18



Simulation:
25 mm
Forming test:
22mm



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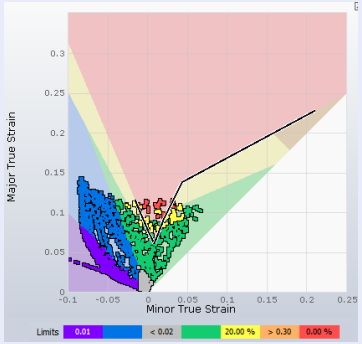
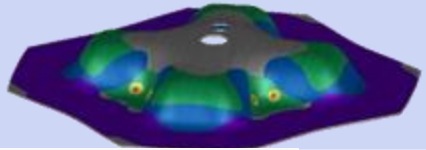


Cross Die Test: H24

Simulation:
31 mm
Forming test:
25-30mm



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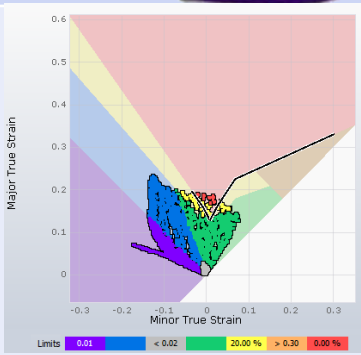
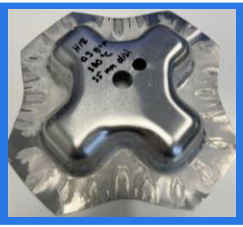
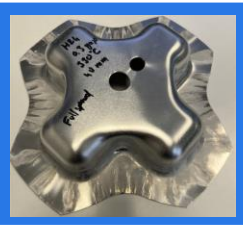
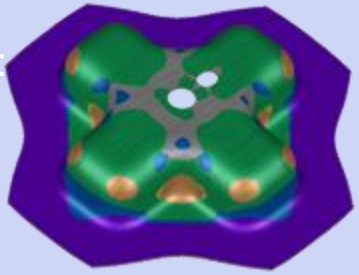
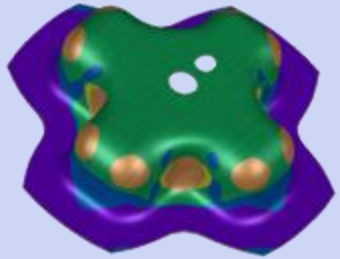
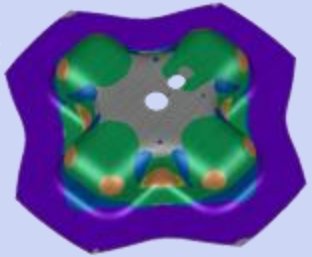


Formability analysis of AA4115 / Warmforming

Cross Die Test: O-temper	Cross Die Test: H18	Cross Die Test: H24
		
Simulation: 44mm Forming test: 43mm	Simulation: 35mm Forming test: 33mm	Simulation: 44mm Forming test: 47mm
		
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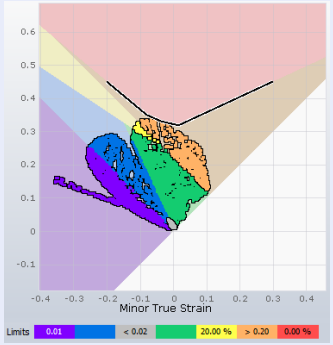	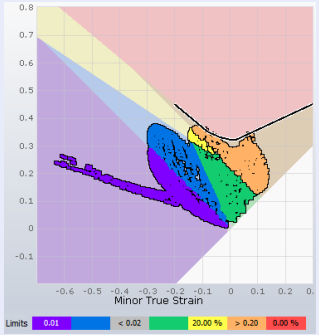	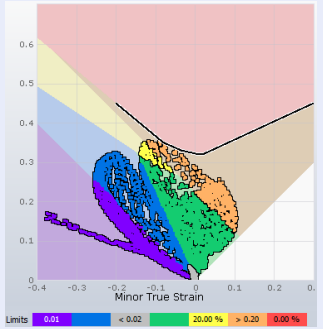

Result and outlook

- Trace elements is not the main issue, but intermetallic particles are crucial
- Formability is significantly improved by warm-forming
- The chosen alloy, AA4115 is “scrap-tolerant”, showing good formability (warm) and is suitable for complex components

- Need for better understanding of hot-tearing
- Inter-metallic particles needs to be studied during rolling operations
- Handling of non-metallic oxides and improved data bases for alloy design

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