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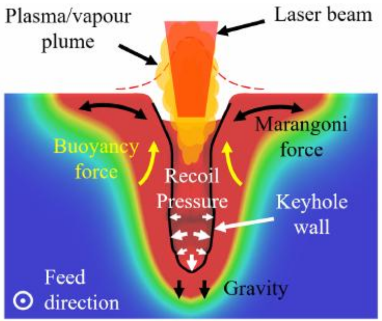
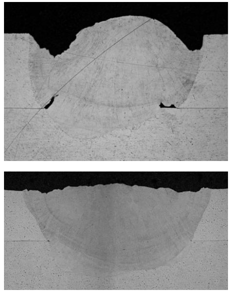
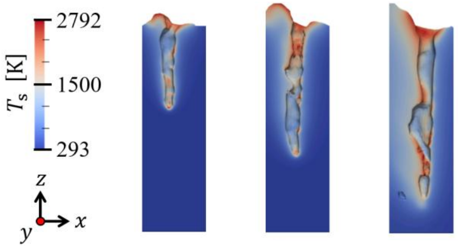
Laser welding research at University of Skövde

Virtual Manufacturing Processes (VMP) – University of Skövde

Andreas Andersson Lassila



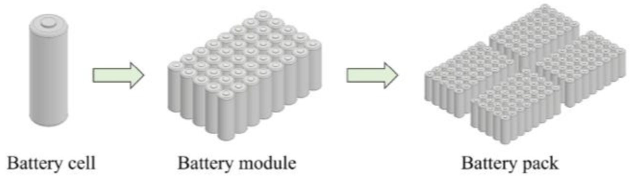


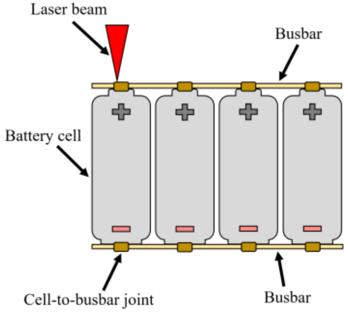


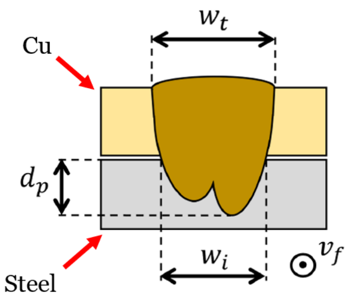
Research projects within laser welding

- **QWELD** (Vinnova/ Produktion 2030)
  - Project partners:
    - Aurobay
    - CEJN
    - Furhoffs
    - Koenigsegg
    - RISE
    - Volvo GTO
  - Finished: Summer 2025
- **LaserBATMAN** (Vinnova/EU)
  - Project partners:
    - Aurobay
    - Volvo GTO
    - DTU
    - Resolvent
  - Finished: Summer 2025

MB-MOO of laser welded cell-to-busbar joints







- Battery systems for electrical vehicles (EV)
  - Many Li-ion cells connected in series/parallel to form a battery modules/pack
  - Cylindrical cells (Ni-plated steel for cell terminal and Ni-plated Cu for busbar)
  - Requirements:
    - Good mechanical strength
    - Low electrical resistance
    - Good fatigue properties

- Challenges with laser welding of cell-to-busbar joints:
  - Joining of dissimilar materials → different thermo-physical properties → cracks, porosities, etc.
  - Obtain a good contact area between cell and busbar and at the same time avoid full penetration into the cell:
    - Maximize w_i
    - Must have control over d_p
  - Reduce the heat impact due to laser power.

Lassila, A. A., Andersson, T., Ghasemi, R., & Lönn, D. (2024). Enhancement of joint quality for laser welded dissimilar material cell-to-busbar joints using meta model-based multi-objective optimization. Journal of Advanced Joining Processes, 10, 100261. https://doi.org/10.1016/j.jajp.2024.100261

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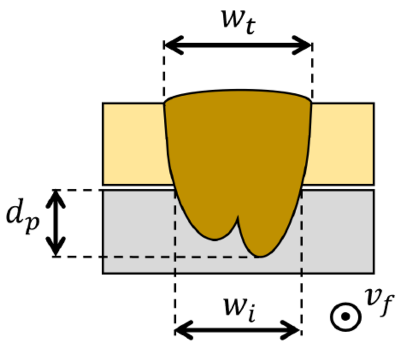
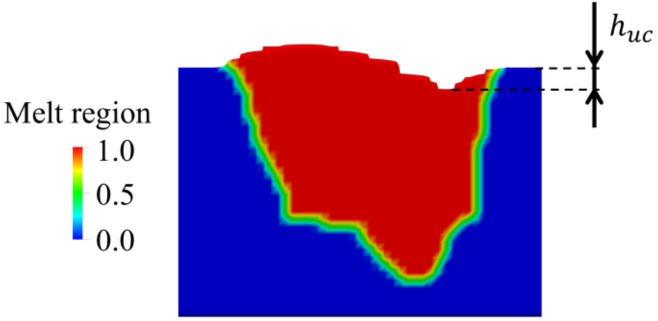
MB-MOO of laser welded cell-to-busbar joints

17/10/2025





- Find a set of optimized process parameters for:
  - Maximized interface width
    - Important for a good connection area, i.e. low resistance
  - Minimized undercut formation in the weld joint
    - Reducing the undercuts in the weld joint reduces the risk for crack initiation
  - Minimized in-process temperatures
    - Too large heat impact due to laser power can damage the battery cells
  - Limited or constrained joint depth
    - Too large joint depth will damage the cells
- Three quality measures of the weld joint → Multi-objective optimization (MOO)

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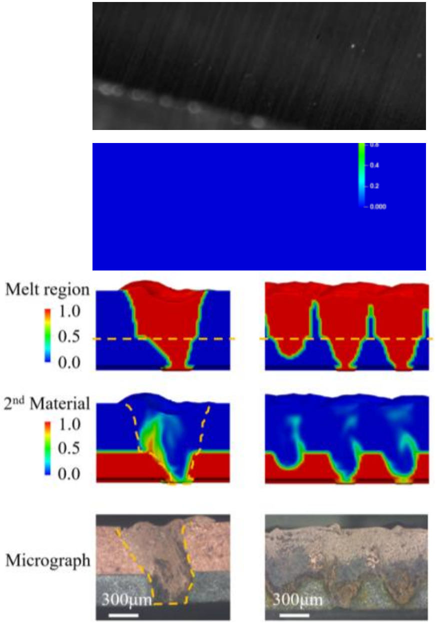
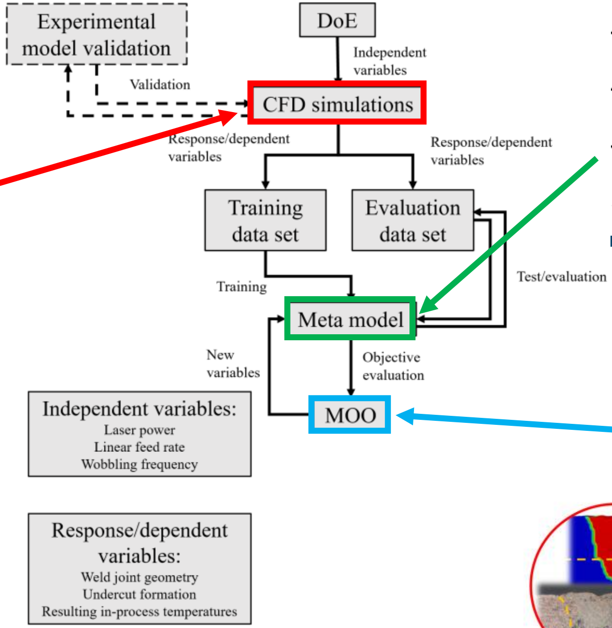
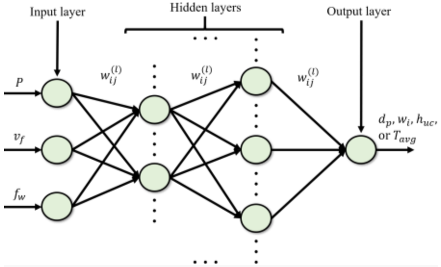
MB-MOO of laser welded cell-to-busbar joints

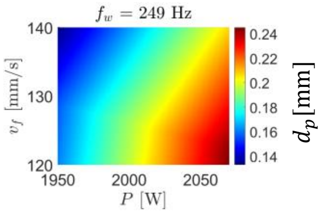
- CFD simulations for generation of training data



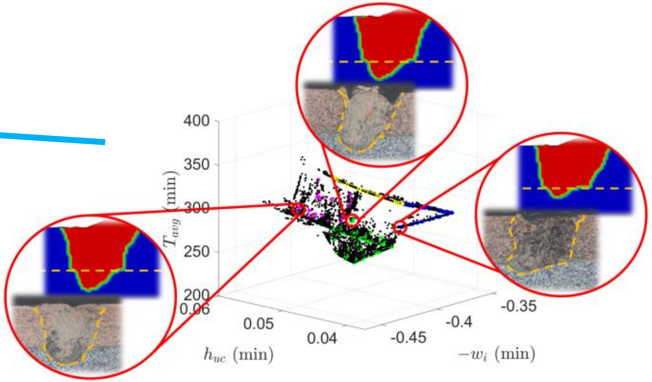


- ANN-based meta models for objective approximation



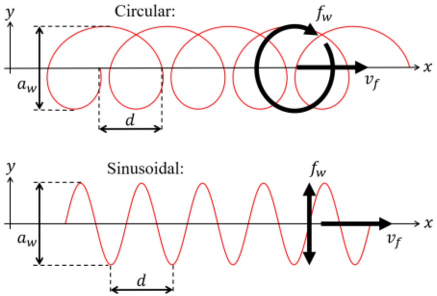


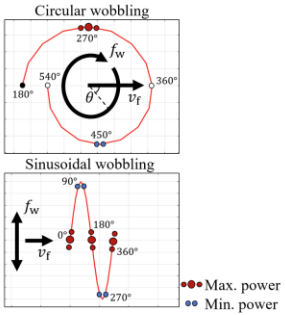
- MB-MOO using NSGA-II

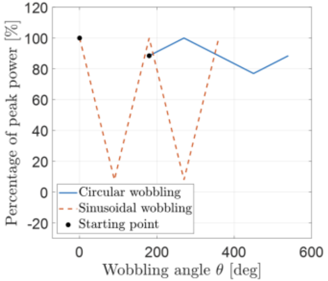


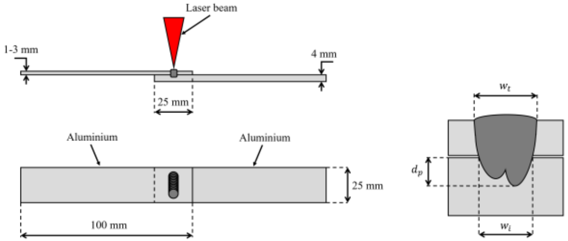
Laser welding of Al cell-to-busbar joints (experimental study)

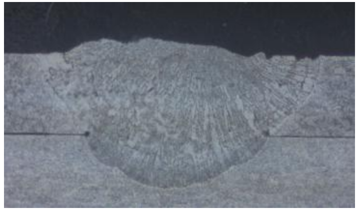
- Simplified geometry (cell-to-busbar joint)
- Material: Aluminium EN AW 1050A (busbar + cell terminal)
- Circular and sinusoidal laser beam wobbling
- Power modulation for a “smoother” energy input
- Investigate the joint characteristics (quality) due to different parameter settings











Laser welding of Al cell-to-busbar joints (experimental study)

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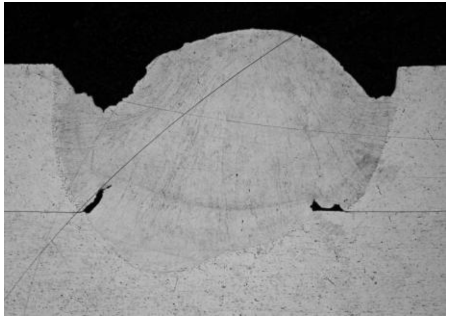
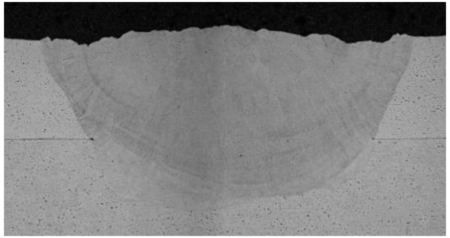
Circular wobbling

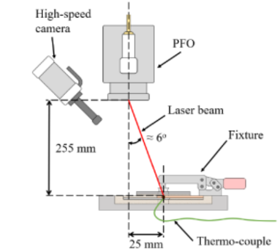


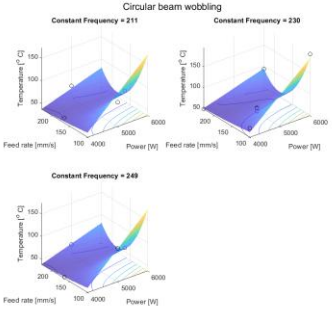
Sinusoidal wobbling

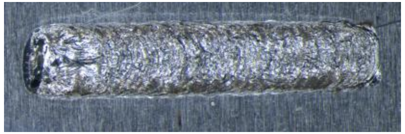


- Independent variables = Power (P), Feed rate (vf), Wobbling frequency (fw), Wobbling strategy, Focus position, etc.
- Dependent variables (quality measures) =
  - Weld seam appearance (undercut, cracks, etc.)
  - In-process temperatures
  - Interface width
  - Welding depth
  - Porosity formation

→ Reduction of undercuts, porosities, and hot cracks







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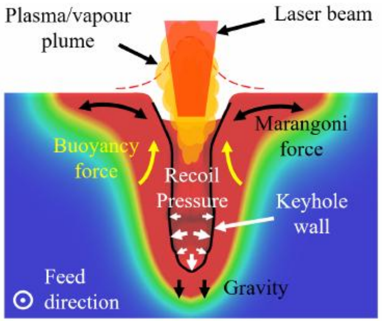
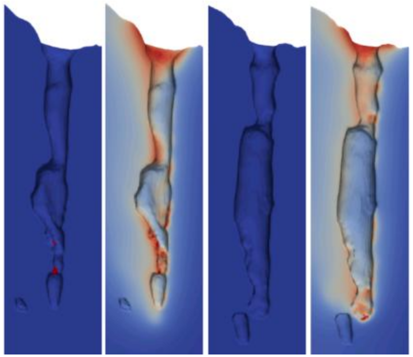
Experimental estimation and numerical investigation of vapourization-induced recoil pressure in laser welding

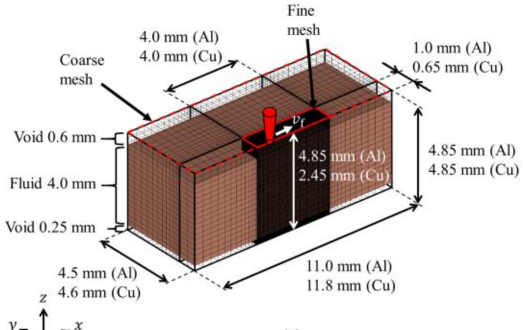




- Vapourization-induced recoil pressure
  - Counter force due to the escaping atoms from the melt pool due to vapourization
  - For keyhole laser welding the recoil force is the most dominant driving force in the melt pool
- Modelling of laser welding processes using multi-physical CFD simulations
  - Important to know the magnitude of the recoil pressure, and how it varies with surface temperature, ambient conditions and process parameters

Andersson Lassila, A., Lundell, E., Andersson, T. J., Lönn, D., Salomonsson, K., & Ghasemi, R. (2025). Experimental and numerical investigation of process-induced recoil force in keyhole laser welding: Insights for validating multi-physics process simulations and modelling assumptions. Journal of Mat. Processing Techn., 341. https://doi.org/10.1016/j.jmatprotec.2025.118895

Experimental estimation and numerical investigation of vapourization-induced recoil pressure in laser welding



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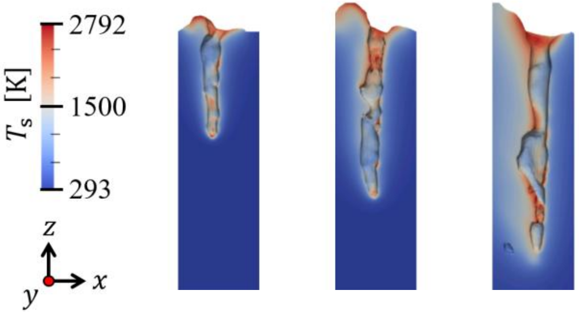

Aim of the study:

- Experimental measurement of vapourization-induced recoil pressure
  - Laser welding experiments for Al and Cu samples
- Numerical prediction and investigation of vaporization-induced recoil pressure
  - Multi-physical CFD simulations
  - Validated models for both Al and Cu laser welding

Andersson Lassila, A., Lundell, E., Andersson, T. J., Lönn, D., Salomonsson, K., & Ghasemi, R. (2025). Experimental and numerical investigation of process-induced recoil force in keyhole laser welding: Insights for validating multi-physics process simulations and modelling assumptions. Journal of Mat. Processing Techn., 341. https://doi.org/10.1016/j.jmatprotec.2025.118895

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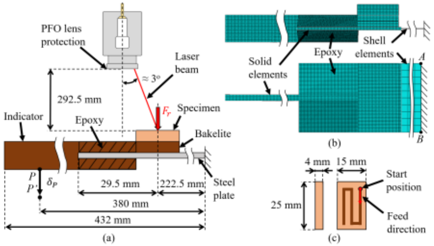
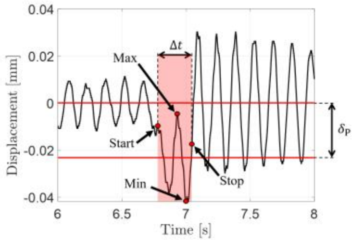
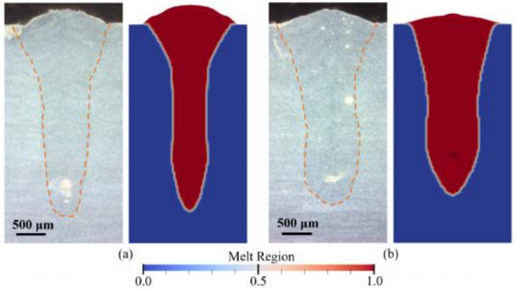
Experimental estimation and numerical investigation of vapourization-induced recoil pressure in laser welding

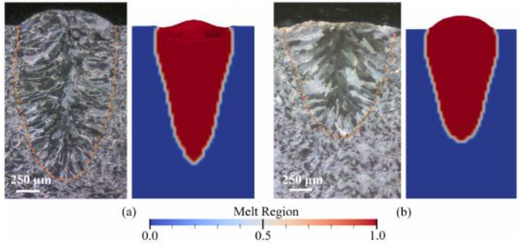
- Experimental measurements of recoil pressure
  - Measurement of specimen displacement
  - Calculation of recoil force from FE-model



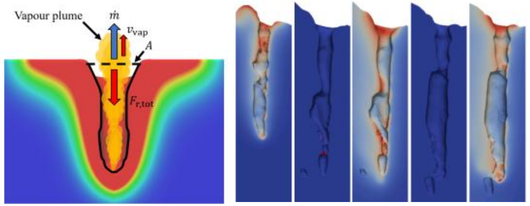


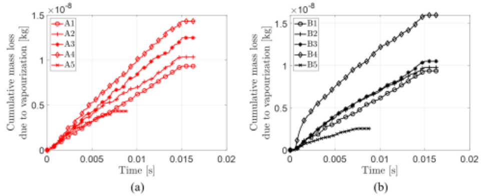
- Calibration/validation of CFD models

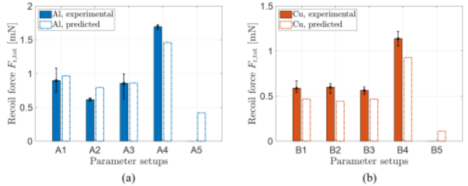




- Prediction/investigation of recoil force







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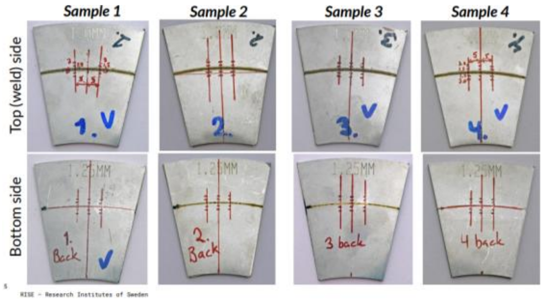
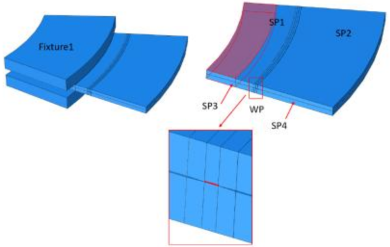
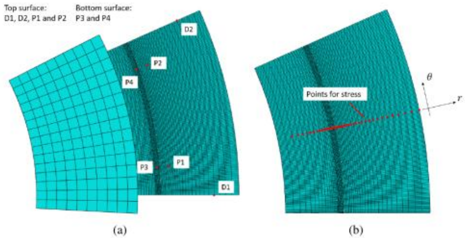
Laser welding of roof drain components of stainless steel

- Today the components are welded using CMT
- Investigate possibilities using laser welding:
  - Experimental measurement of temperature fields, residual stresses, and distortions/deformations with respect to various parameter setups
  - Compare experimental results with FEM simulations:
    - Coupled thermo-mechanical FEM model to predict stress, strain, and temperature fields

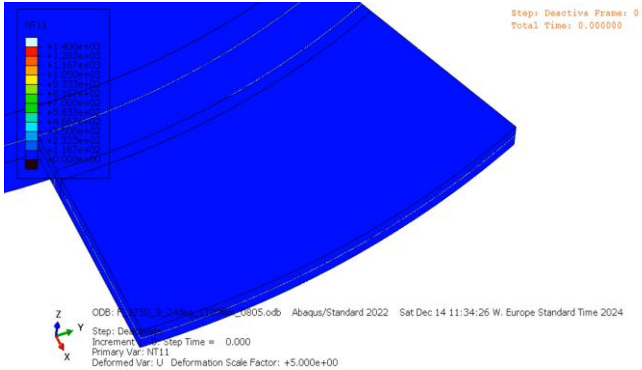




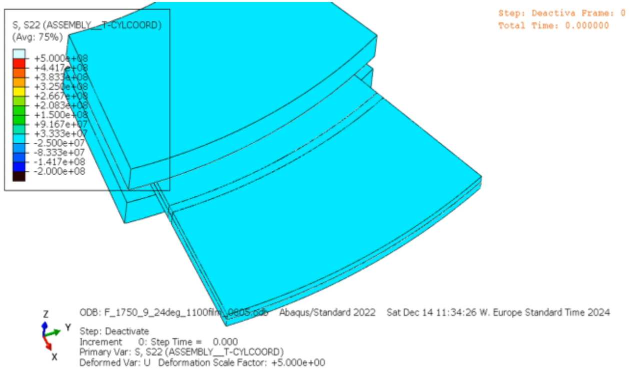


Laser welding of roof drain components of stainless steel

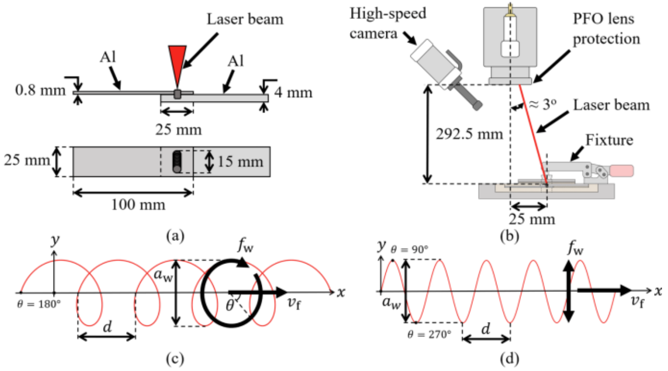
- Predicted temperature fields

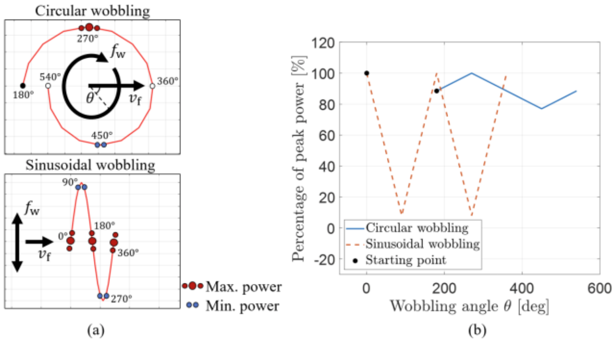


- Predicted stress field/residual stress



Numerical investigation of laser beam wobbling of Al overlap joints





- Ongoing study…
- Numerical prediction and investigation of laser beam wobbling of Al overlap joints for battery applications
  - Multi-physical CFD simulations
  - Validated models for both circular and sinusoidal wobbling strategies
- Aim:
  - Investigate the influence of different wobbling parameters on joint defect formation and process stability
    - Frequency, amplitude, federate, wobbling strategy, power modulation
  - Identify/investigate physical mechanisms behind joint defect formation:
    - Spatter, porosity, undercut,…

Numerical investigation of laser beam wobbling of Al overlap joints

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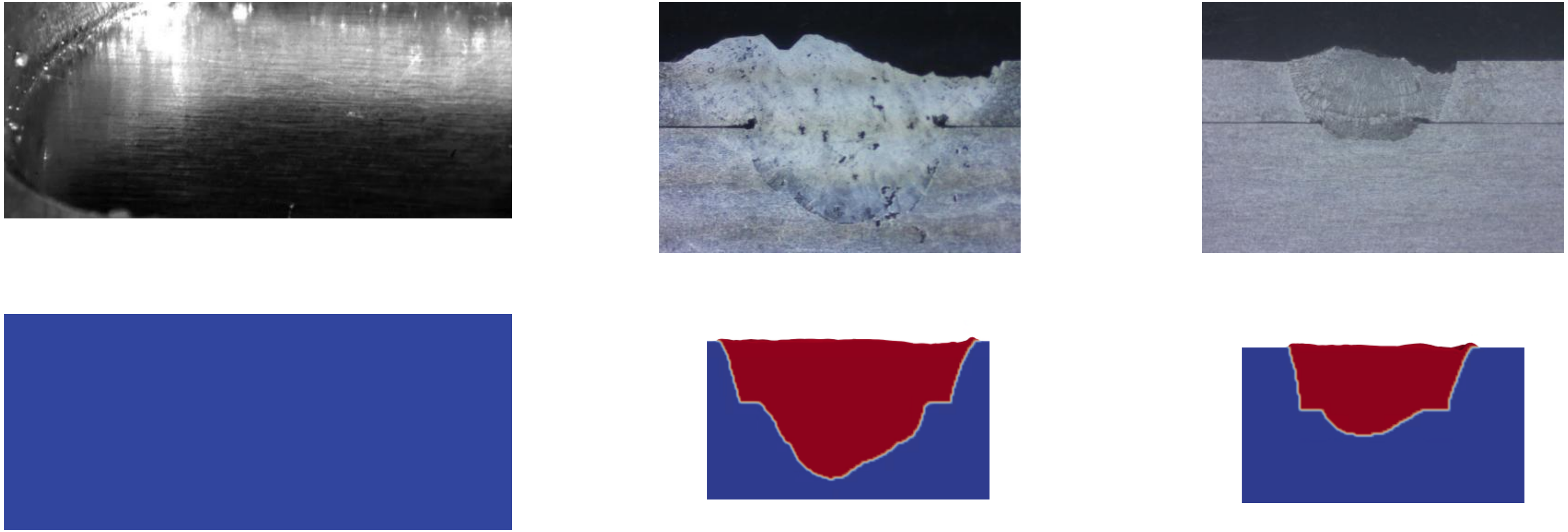
- Comparison between numerical and experimental results



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Thank you!

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References

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