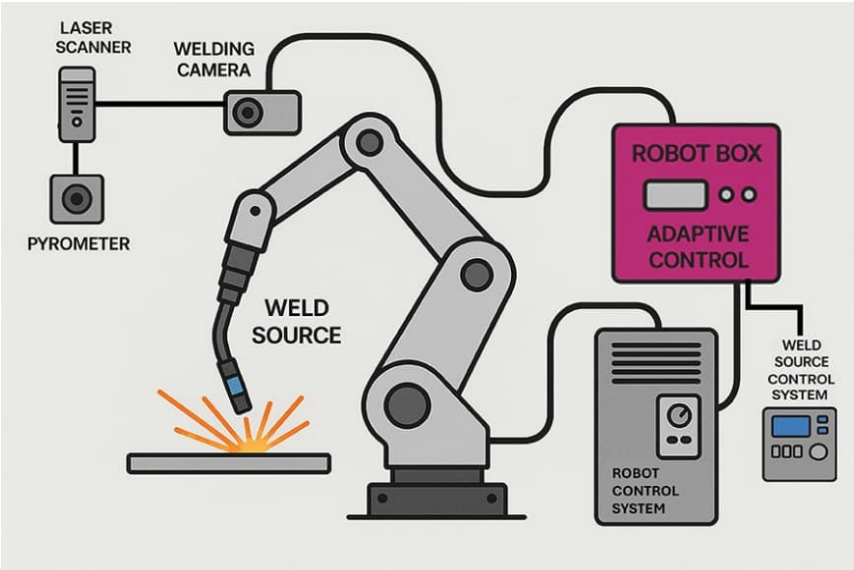
Robot Box: Context and aim

Presenter: Eric Coatanéa (but result of a collective work)

What is ROBOT BOX?

The main objective of the project is to create a Robot Box for easy plug-and-play and control in robotic welding and WAAM, and to test it in associated fields of manufacturing.



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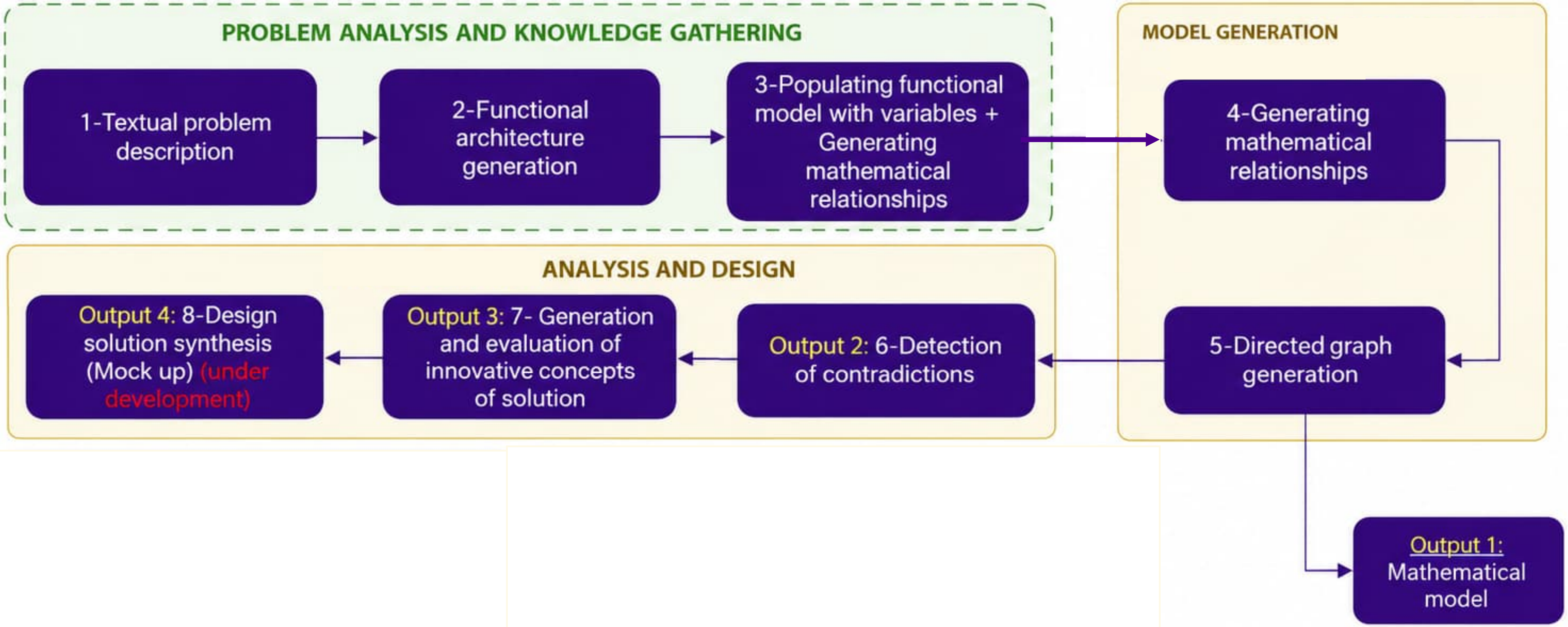
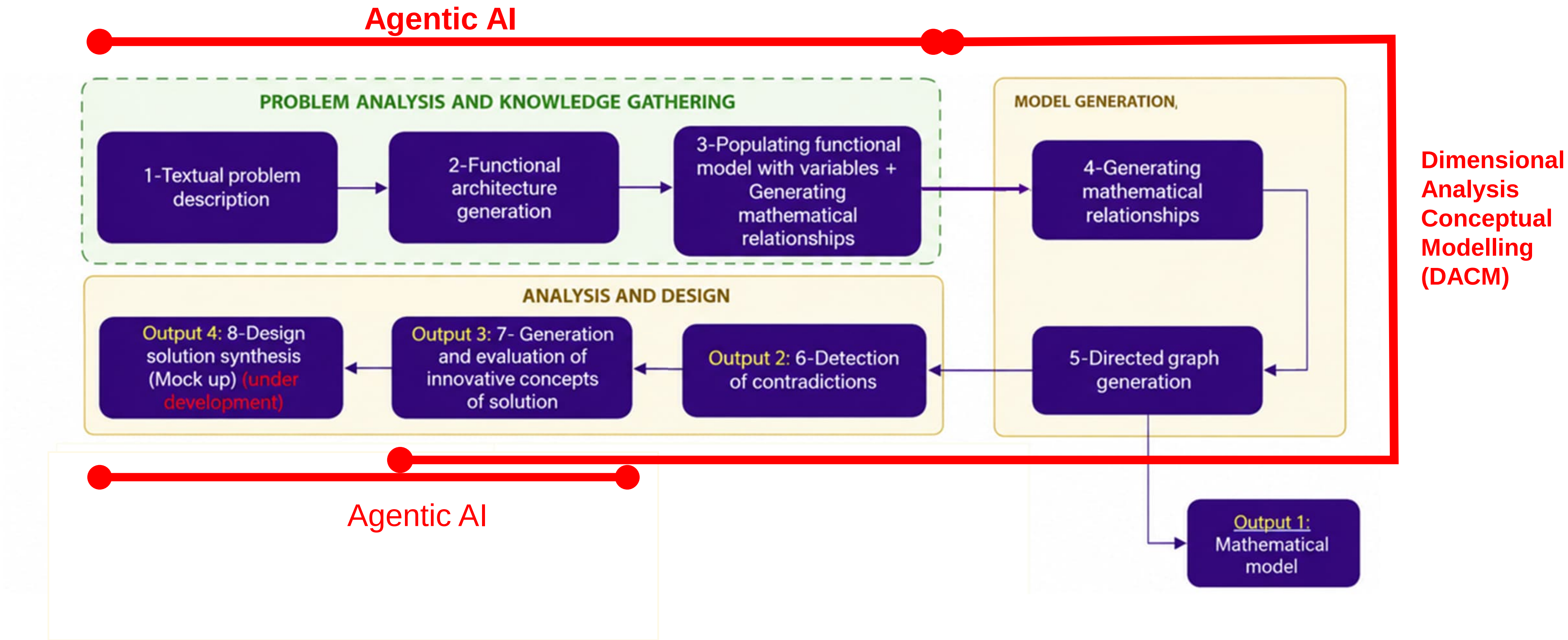
Robot Box: Connection with a new type of AI platform

Architecture of the machine learning platform



Hybrid approach used for developing the platform



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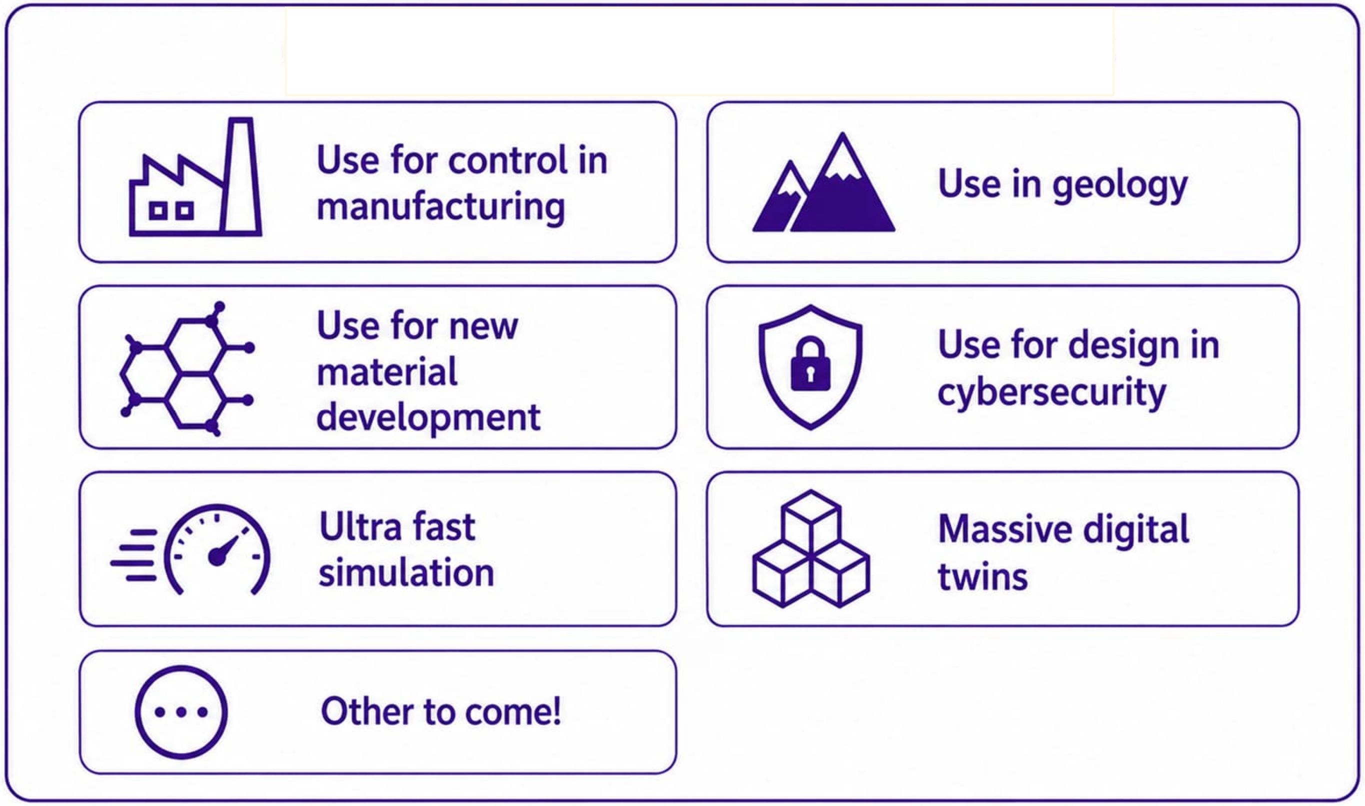
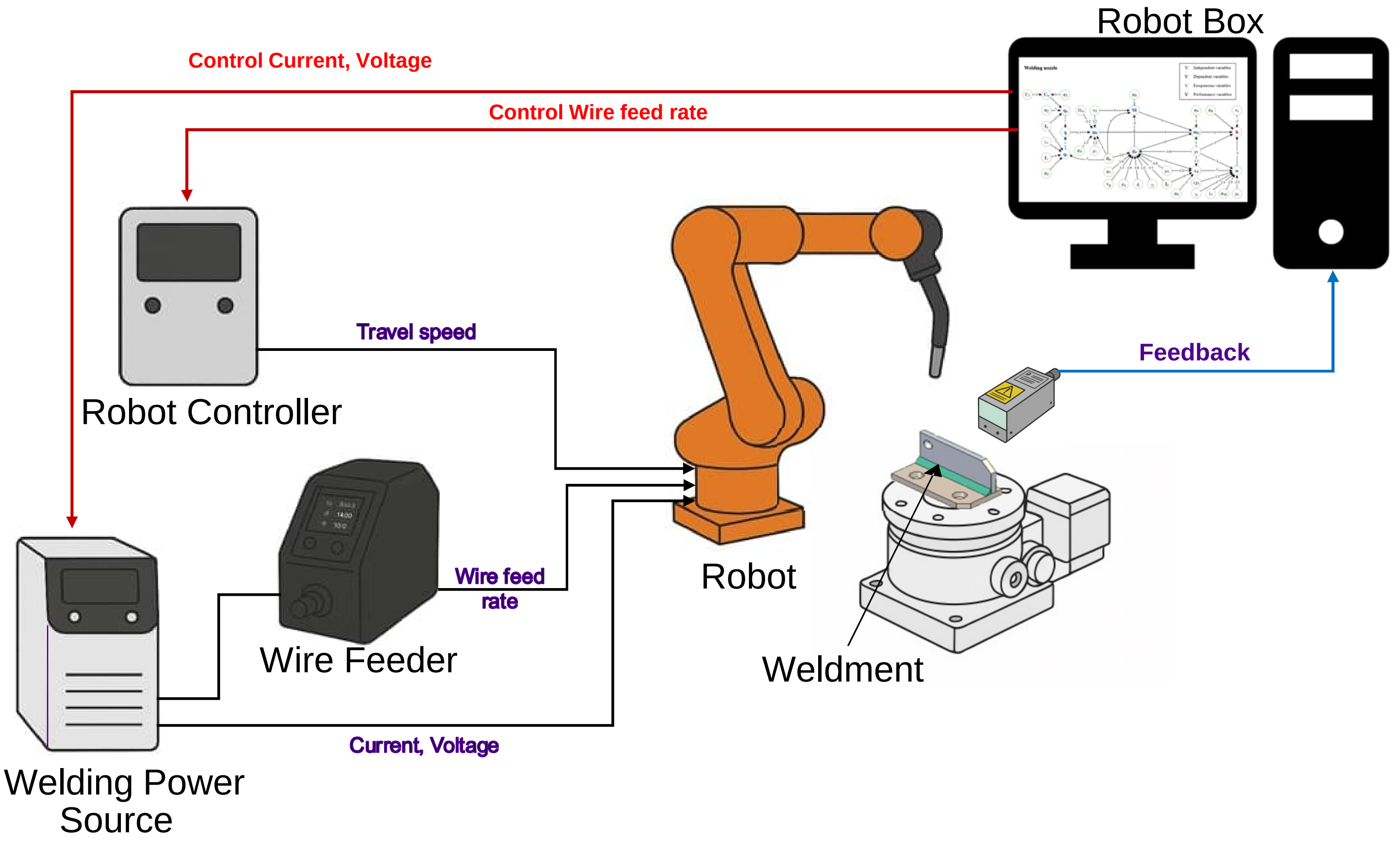
Some possible usage of the platform

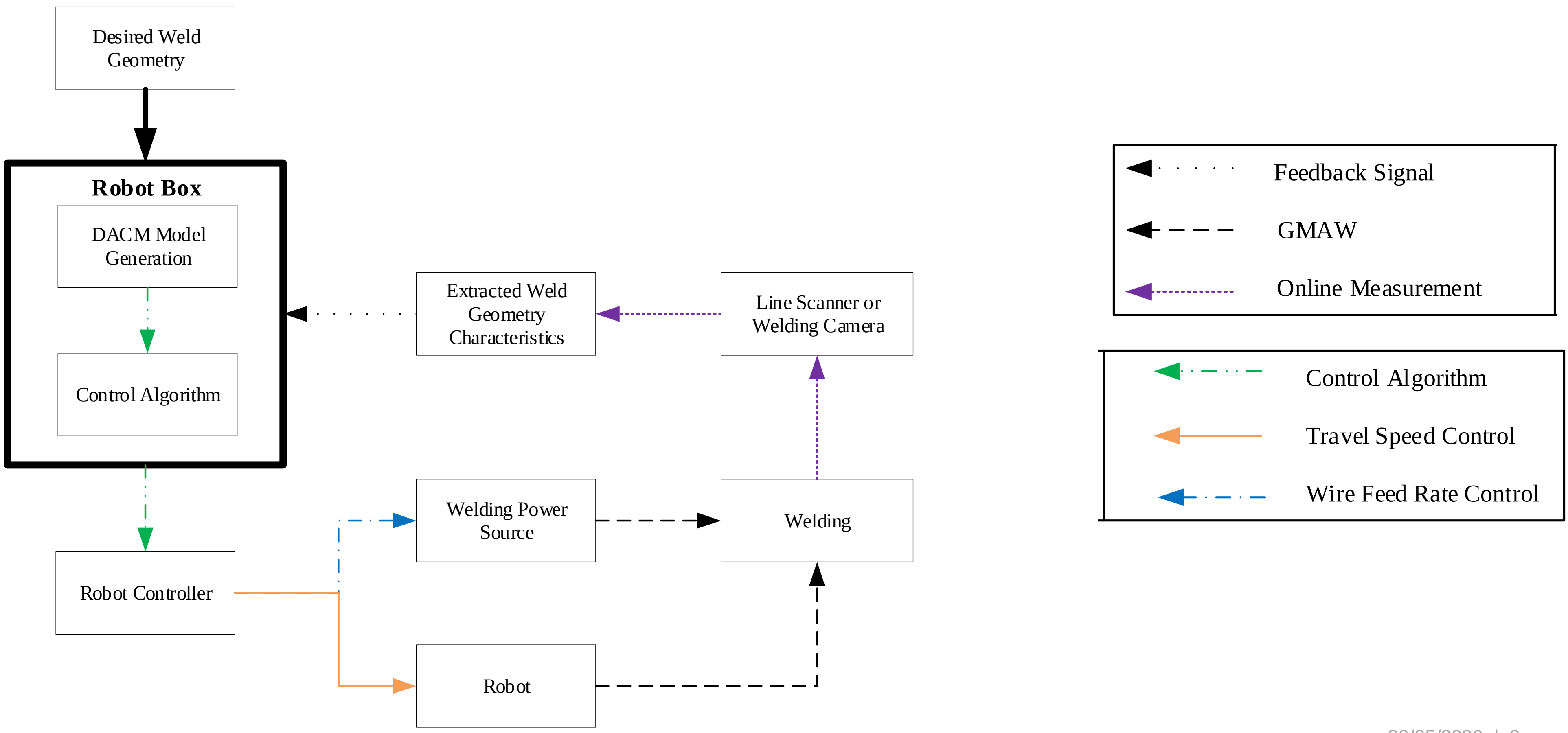


Robot Box: Development of control methods in robotic welding

Use of Directed Graphs (DACM)

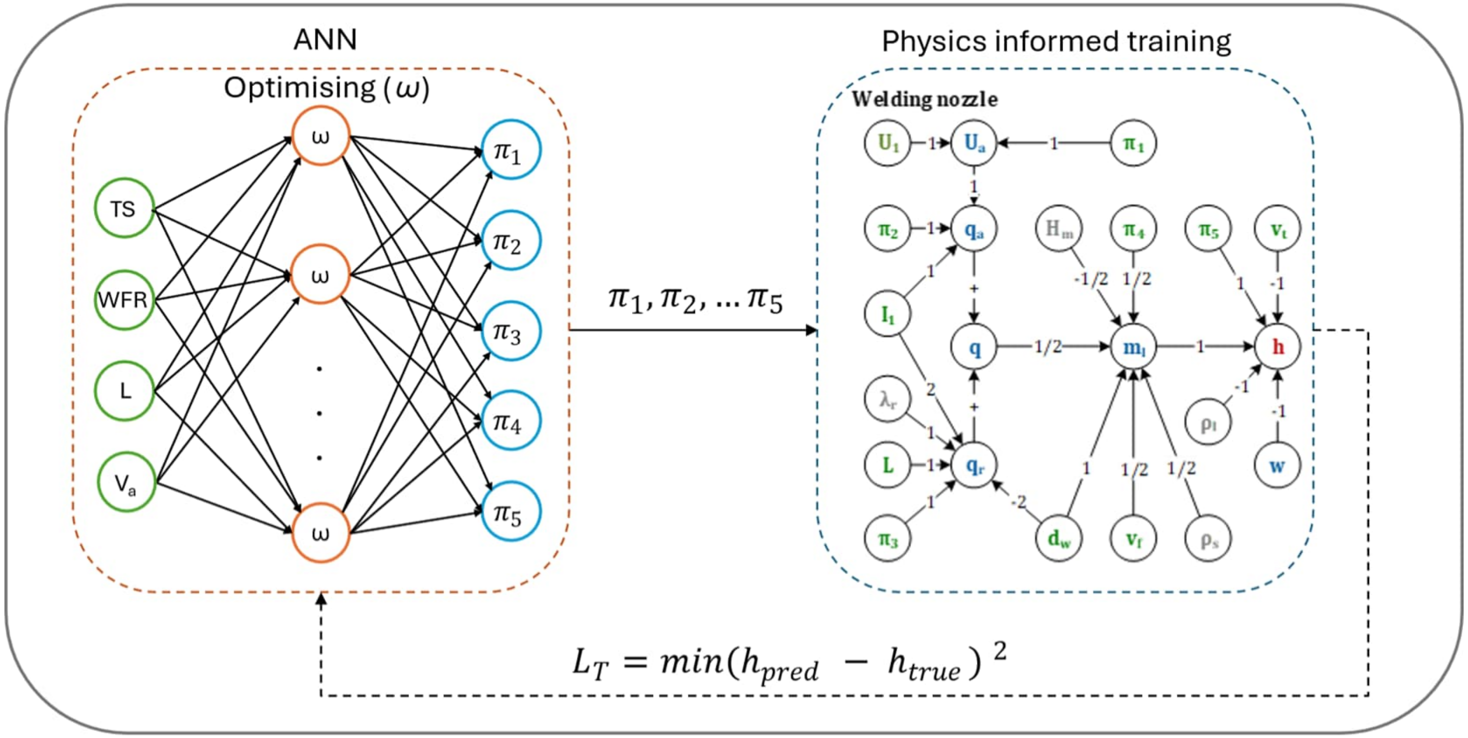


GMAW Control Workflow for Robot Box



Physics-Informed Machine Learning

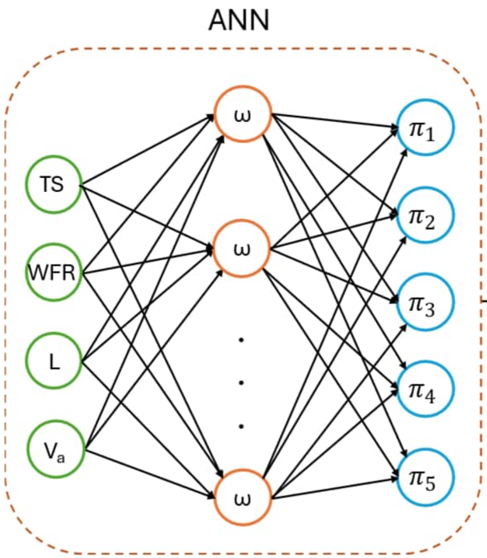
- ***Training***



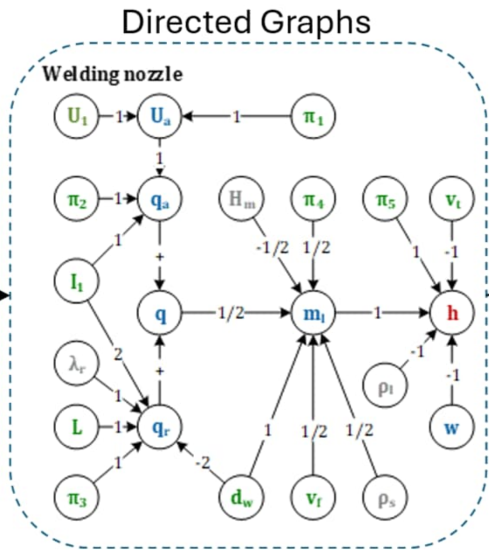
Training data	
Arc Voltage (V_a)	18.3
TS (m/s)	0.002
CTWD (m)	0.01
WFR (m/s)	0.028
Current (I)	80
Bead Width (m)	0.008
Bead Height (m)	0.0026

Physics-Informed Machine Learning

- ***Parameter Selection***

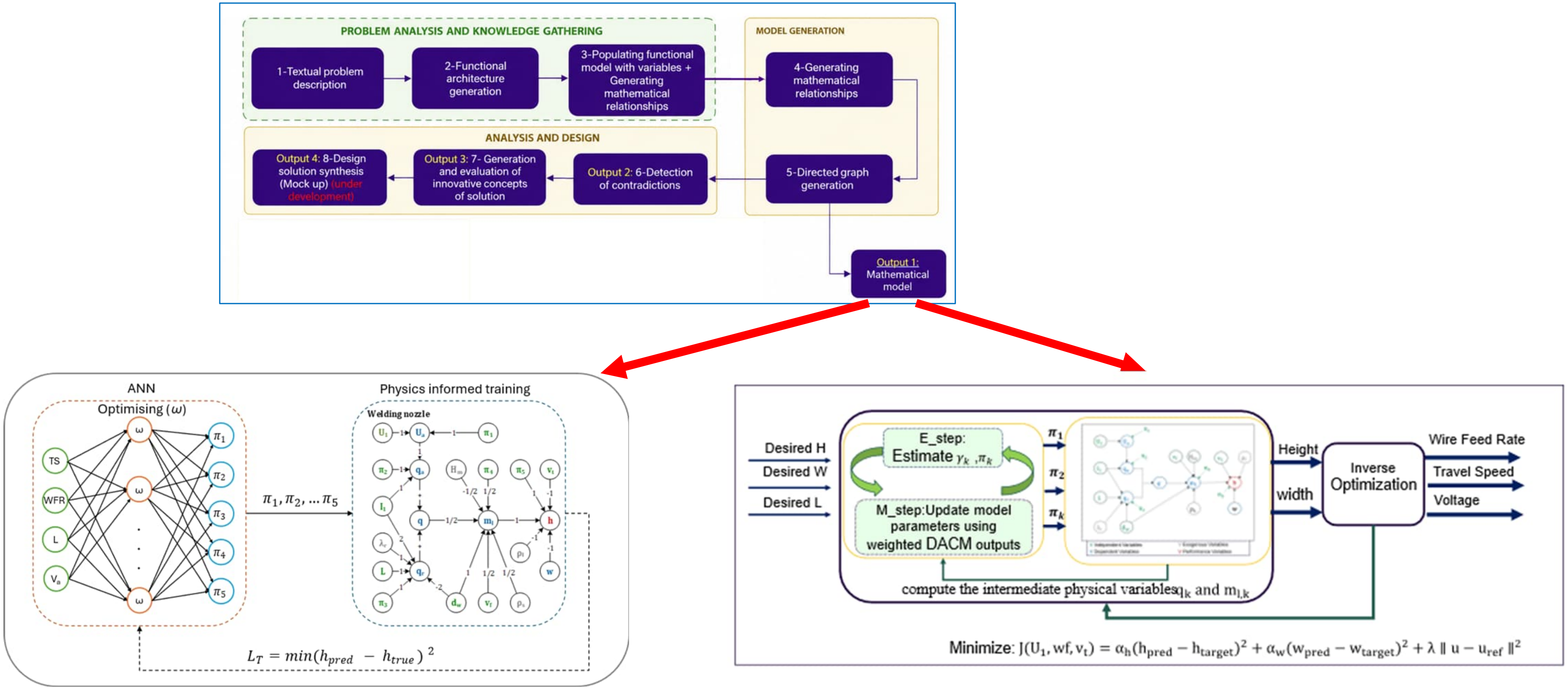


π_1	π_2	π_3	π_4	π_5
1	0.928	0.528	0.788	0.870
2	0.927	0.488	0.784	0.595
..	…	…	…	…
..	…	…	…	…
n	0.xxx	0.xxx	0.xxx	0.xxx



Arc Voltage (V_a)
TS (m/s)
CTWD (m)
WFR (m/s)
Current (I)

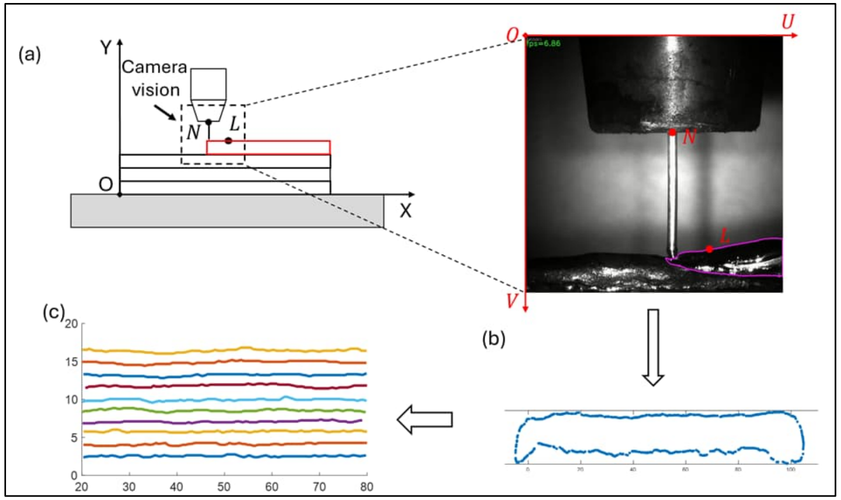
Generation of the control model for Robot Welding



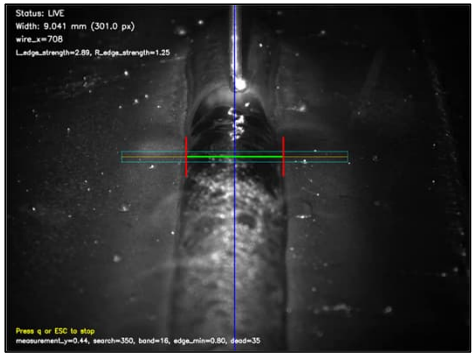
Two Physics-informed models (Left: ANN + DACM, Right: Generalized Expectation–Maximization (GEM) + DACM

Application in Robot welding & WAAM

Integration in Height detection and control



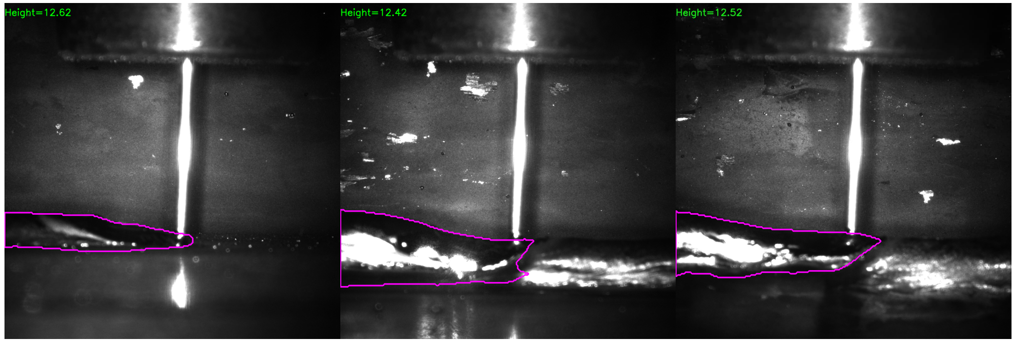
Integration in Width detection and control

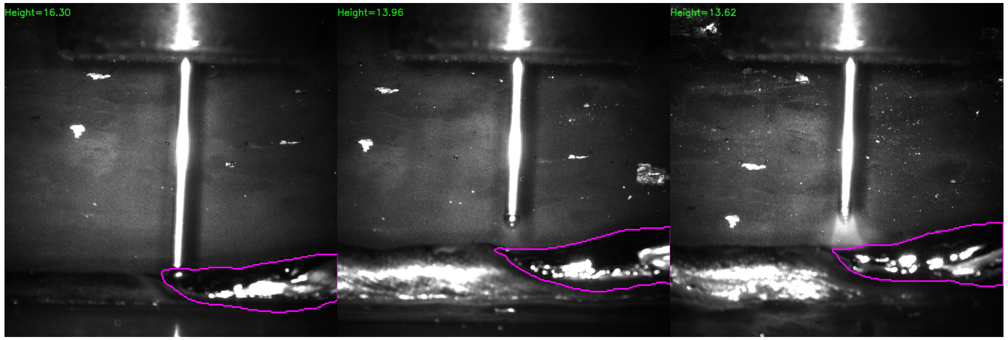


CTWD control

Goal: Maintain the CTWD for each layer in WAAM process to keep the process stable.

Current results:





	1st layer	3rd layer	7th layer
Gap:	12.62mm	12.42mm	12.52mm

	2nd layer	4th layer	8th layer
Gap:	16.30mm	13.96mm	13.62mm

- For the odd layers or the even layers, the gaps are kept in every layer (expect the 2nd layer), however, the CTWD is not maintained the same in both odd and even layers.
- **Reason:** the wire is not located in the middle of the image, for the even layers, the whole melt pool is not captured completely.

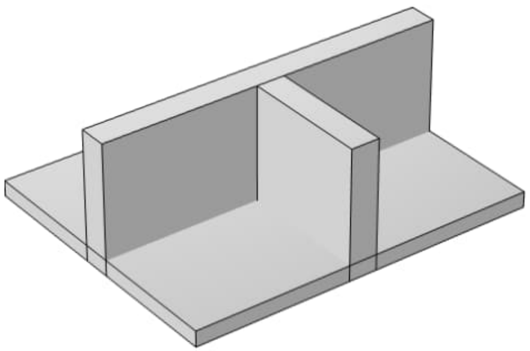
Robot Box: Finite Element modeling

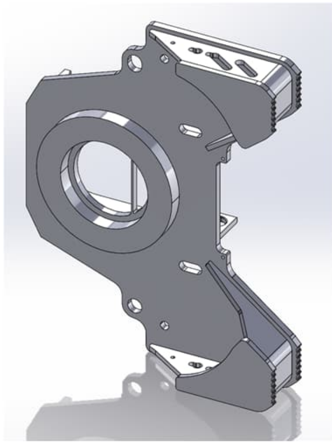
Context

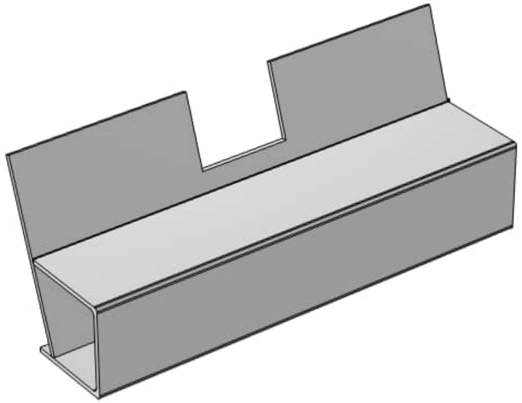
- Three case studies:
  - Case study 1- Multi-line welding plate.
  - Case study 2- Ponsse case study.
  - Case study 3- Weld gap modelling.

Warpage and deformation (Case studies 1 and 2)

→ **Weld gap prediction** (Case study 3)





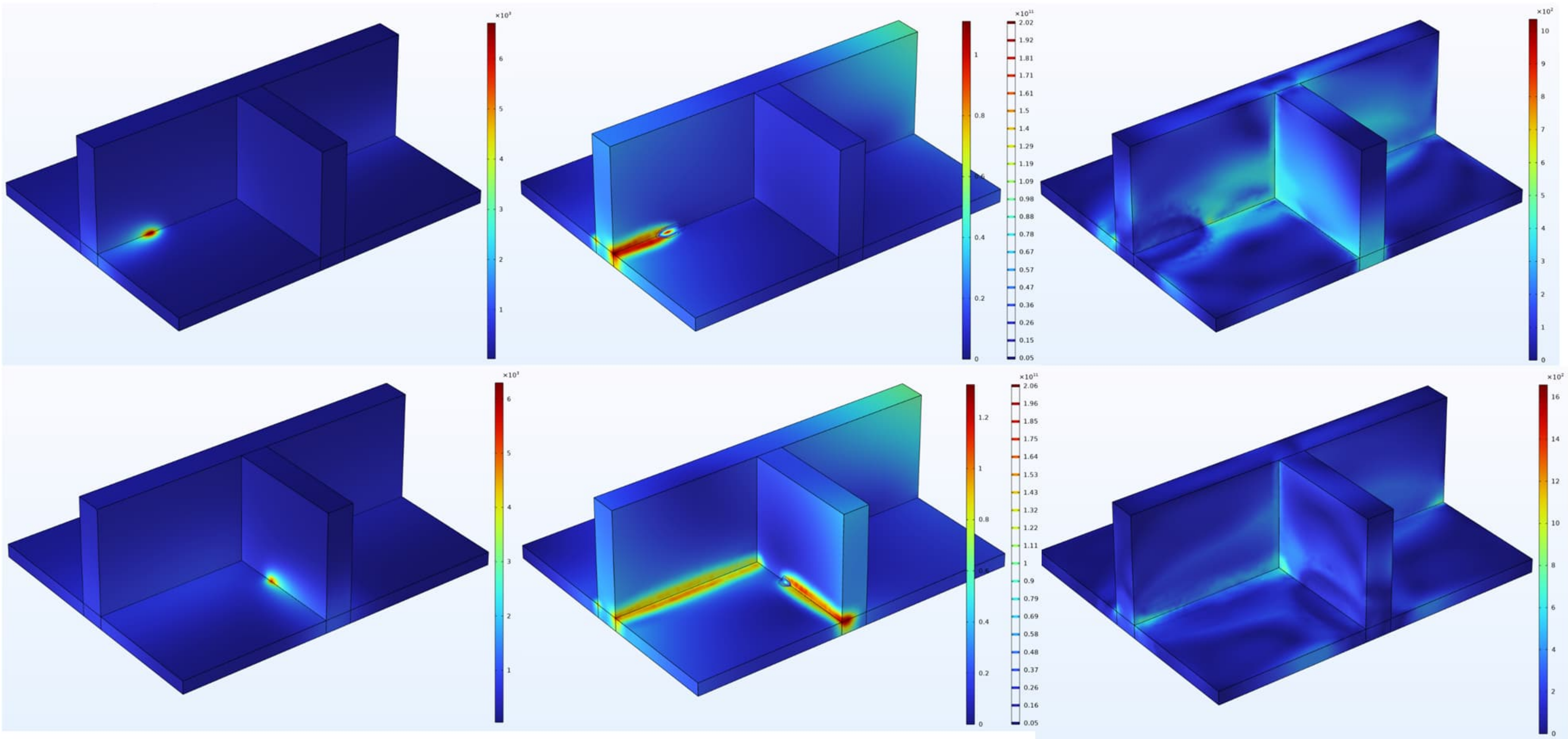


Case study 1 – Multi-line weld plate

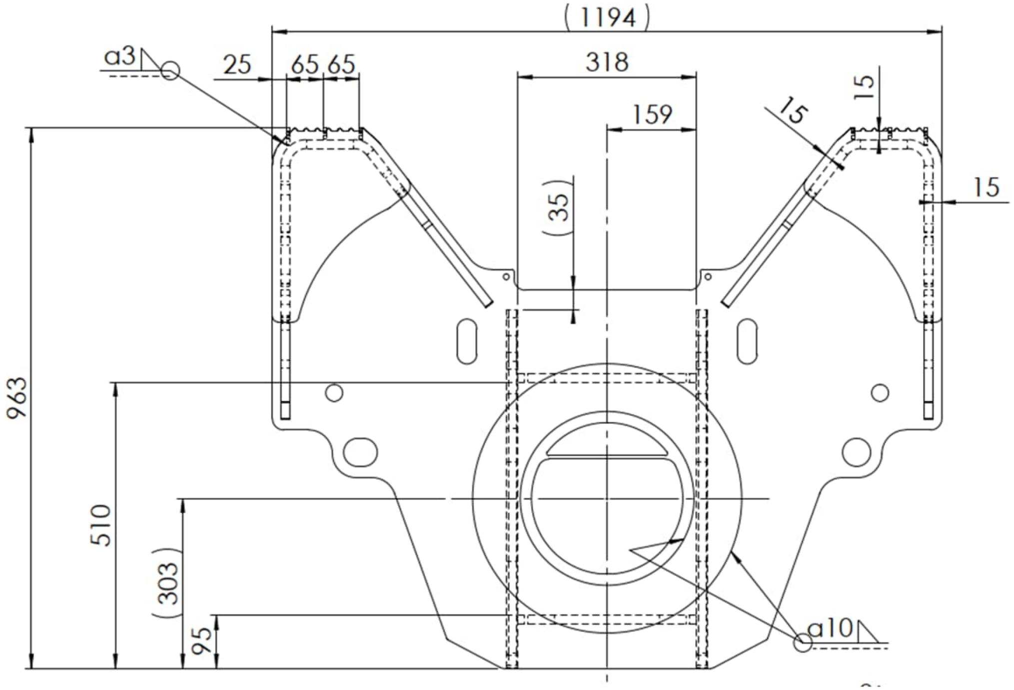
Temperature | **Displacement** | **Stress**

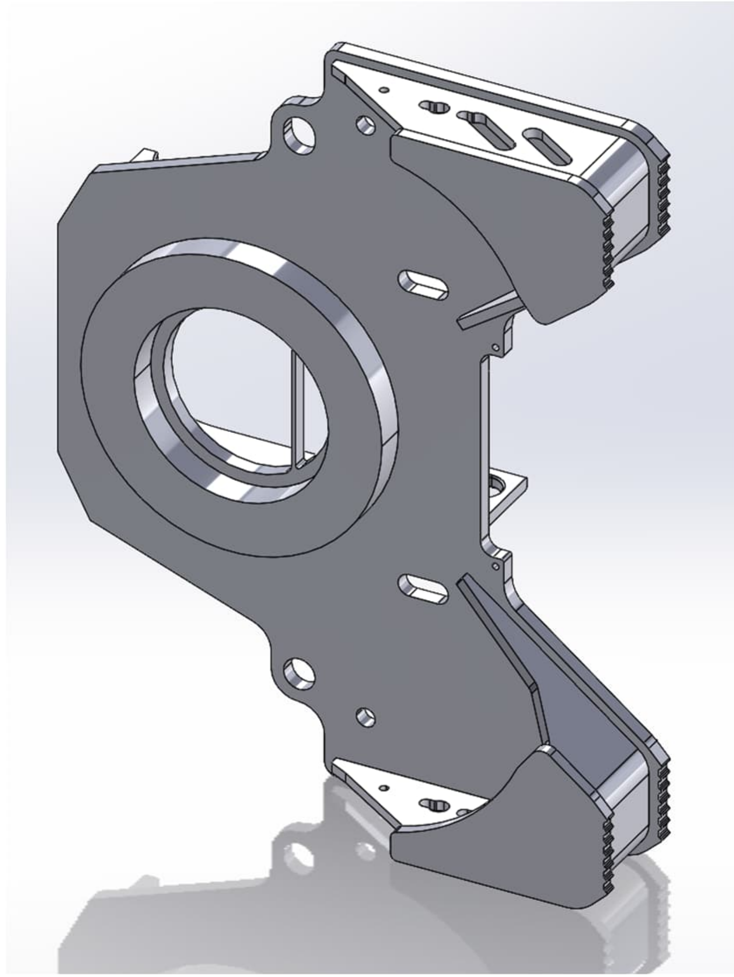
$t = 36.4\ s$

$t = 53.8\ s$



Case study 2 - Ponsse

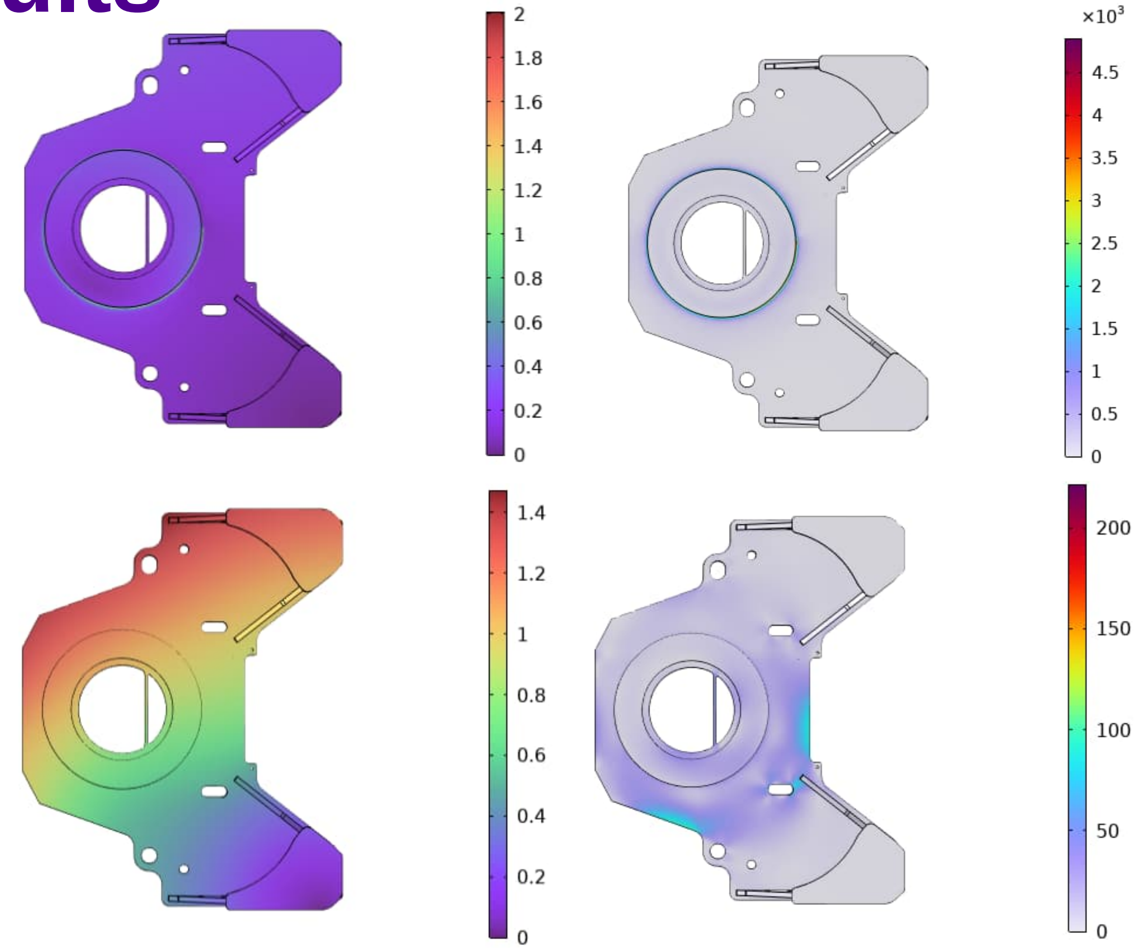




Case study 2 - results

Welding and cooling until room temperature

Stationary step for relaxation



Displacement (mm) **Stress (MPa)**

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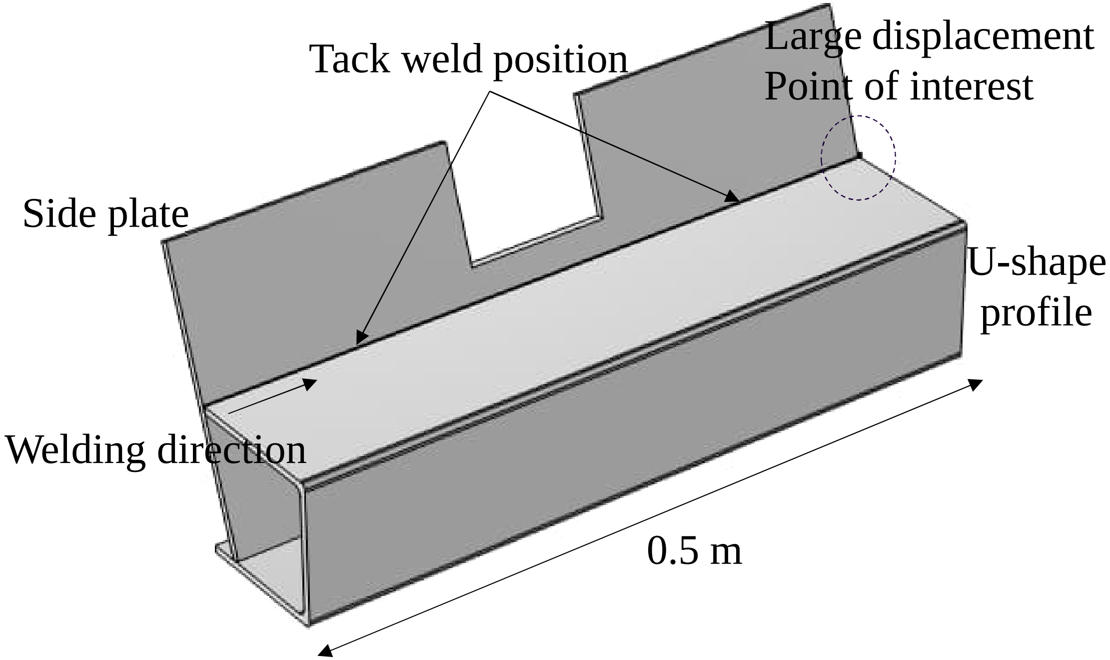
Case study 3 – Weld gap modelling

Problem: Increasing gap between the U-shape profile and side plate.

Objective: Predict and reduce the gap between the U-shape profile and side plate.

Additional complexity: Filling of the gap must be considered.

Modelling approach:
- Normal modelling (without filling)
- Moving mesh
- Mesh activation

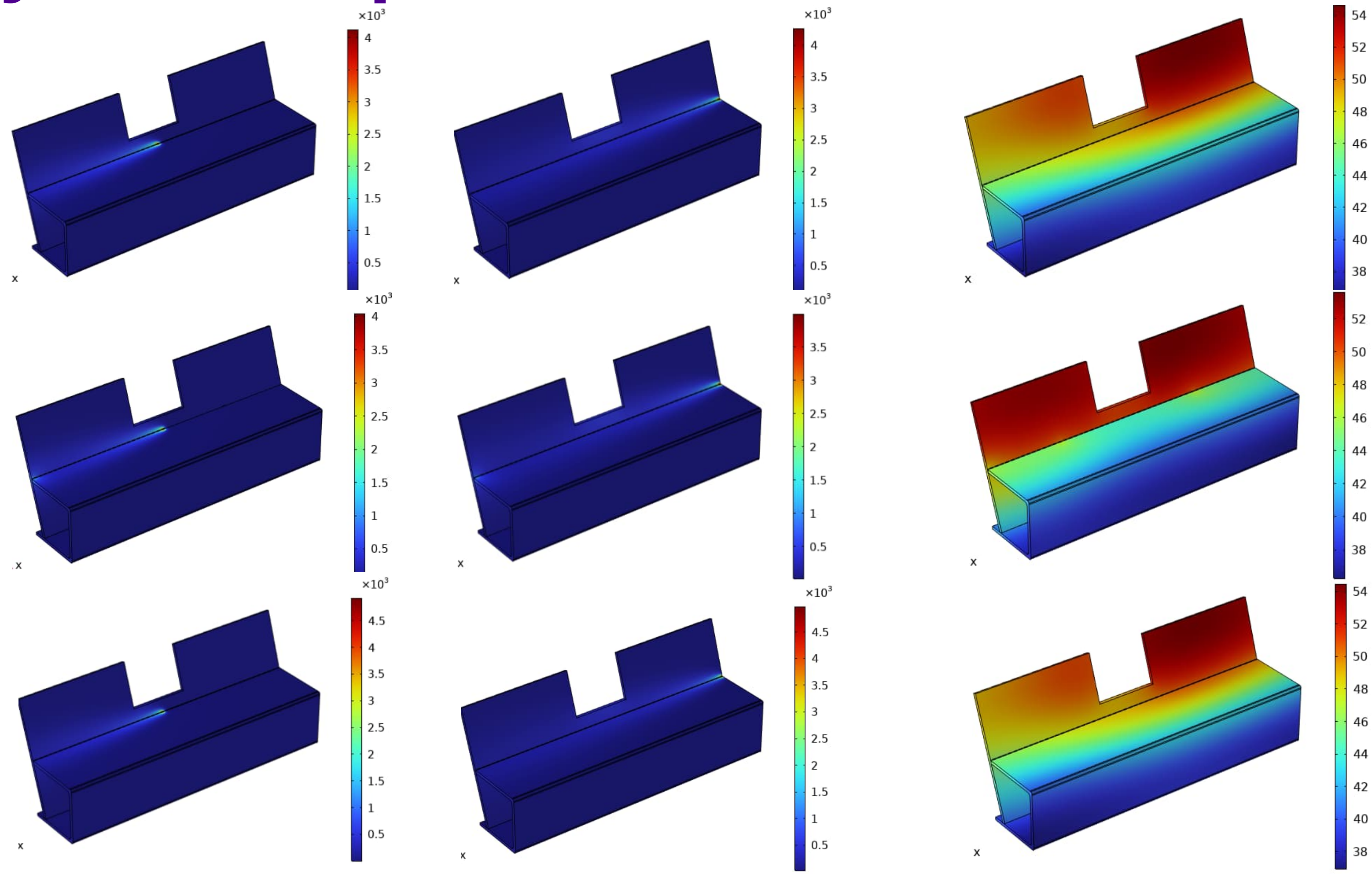


Case study 3 – Temperature results

Normal modelling

Moving mesh

Mesh activation



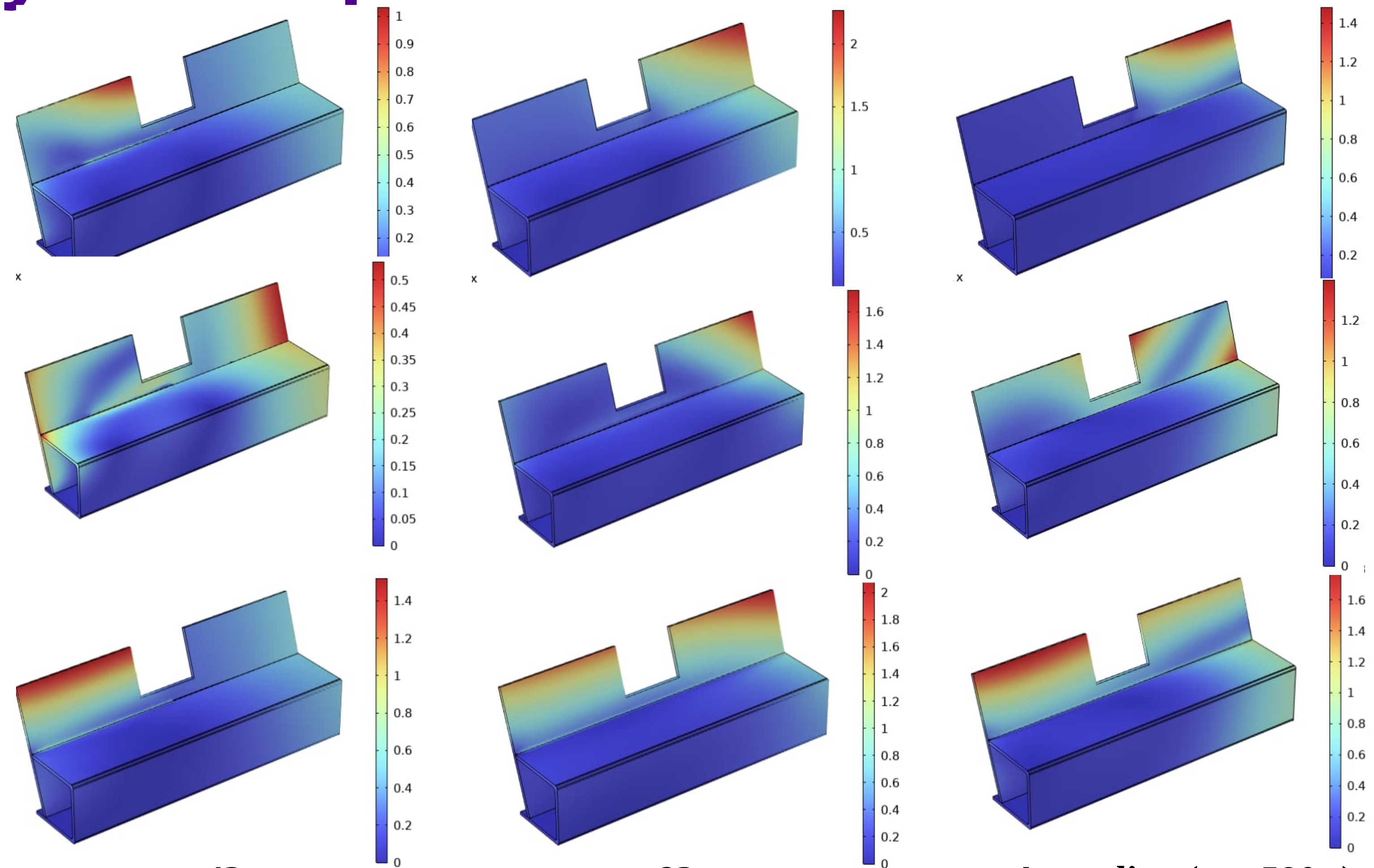
t = 42 s | t = 83 s | At cooling (t = 590 s)

Case study 3 – Displacement

Normal modelling

Moving mesh

Mesh activation



t = 42 s | t = 83 s | At cooling (t = 590 s)

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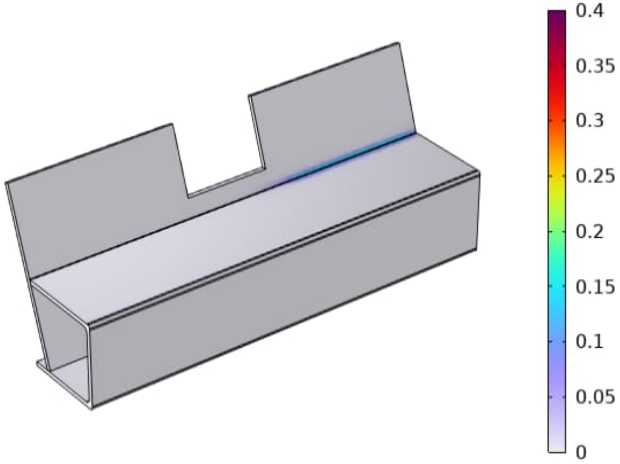
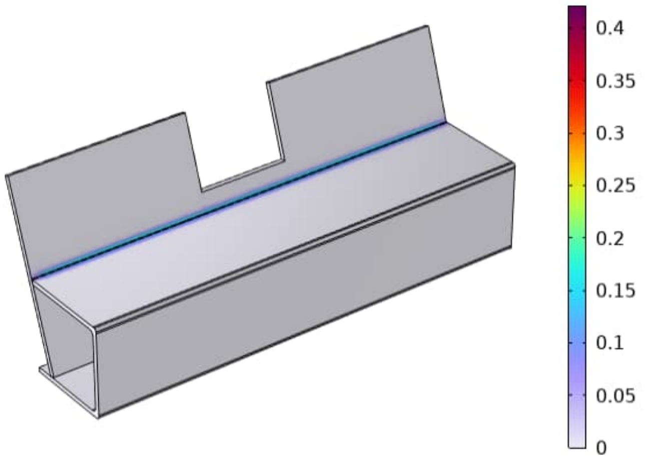
Case study 3 – Plastic displacement

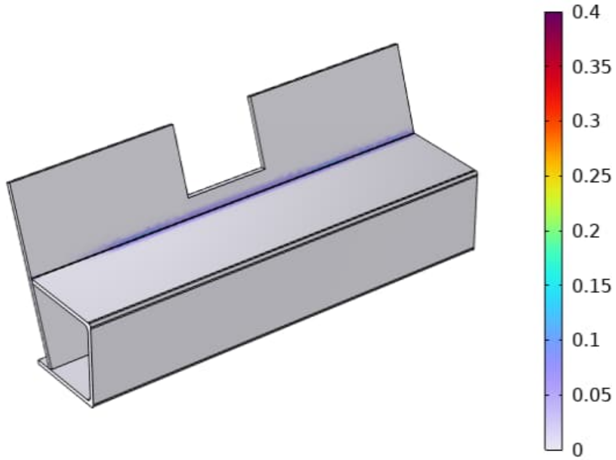
At cooling (t = 590 s)



Normal modelling



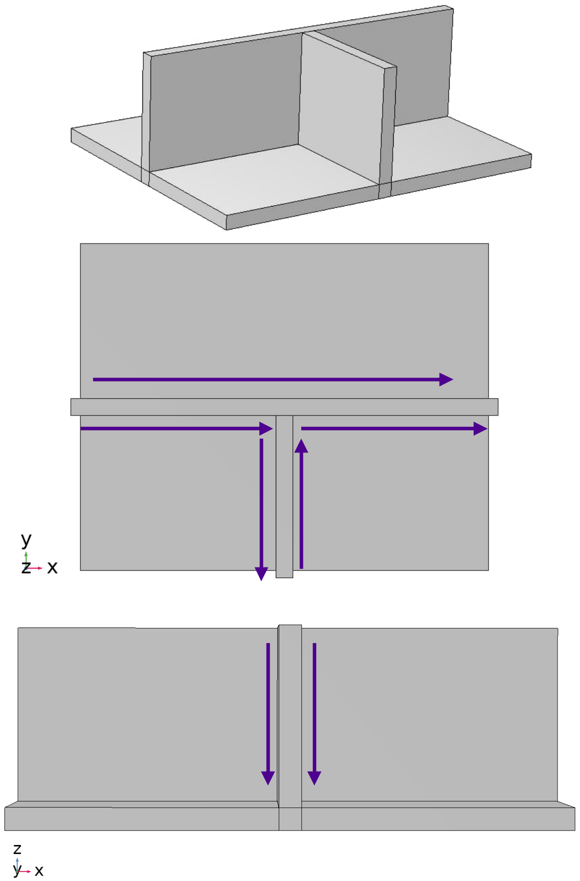
Mesh activation



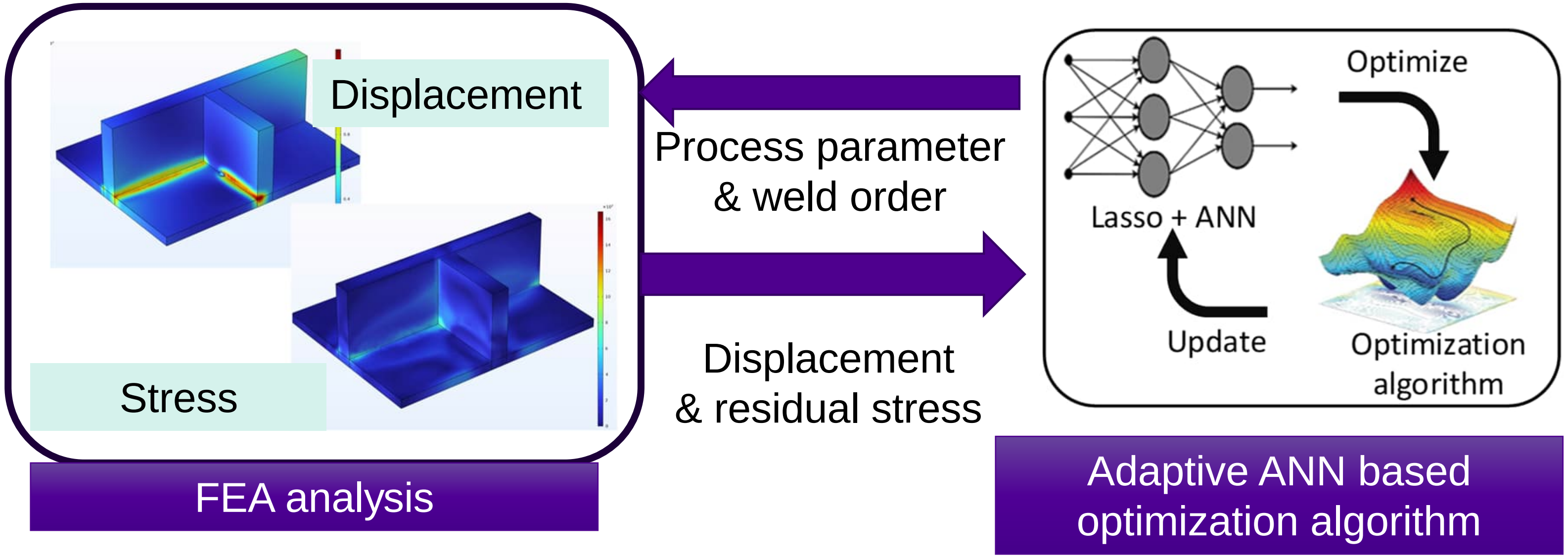
Moving mesh

Robot Box: Adaptable multi-disciplinary optimization

Welding order optimization

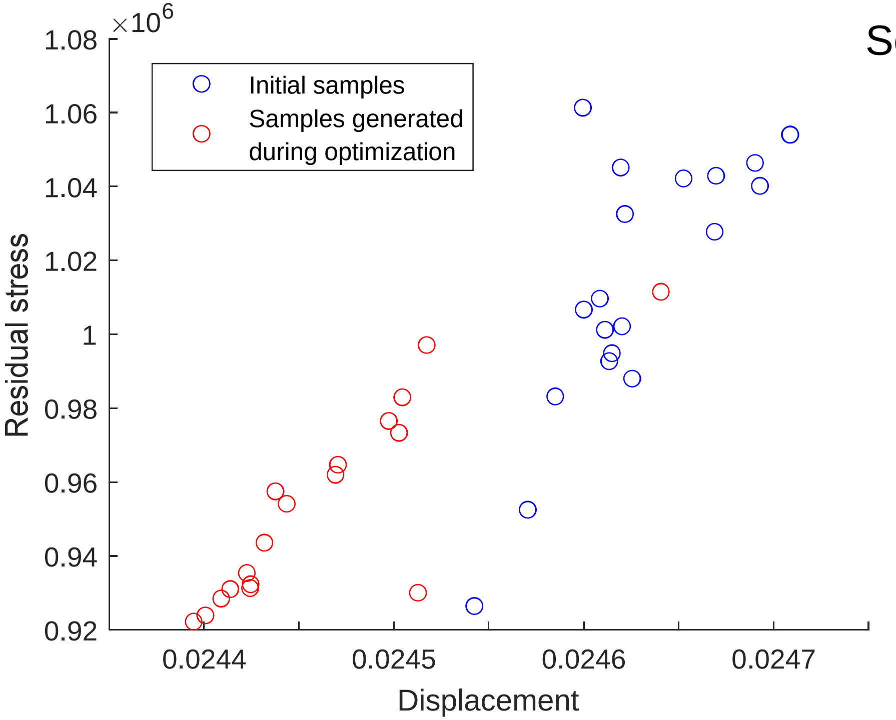


Find a set of **welding order** and the **process parameters** for each path
Minimize **Displacement**
Residual stress

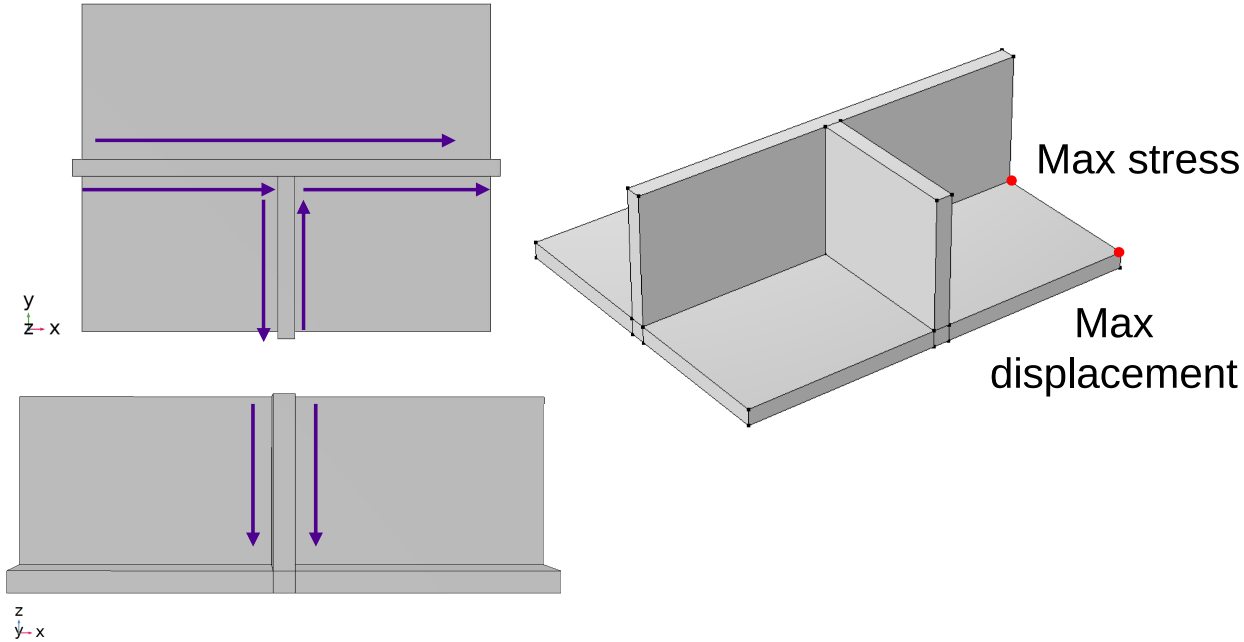


Welding order optimization

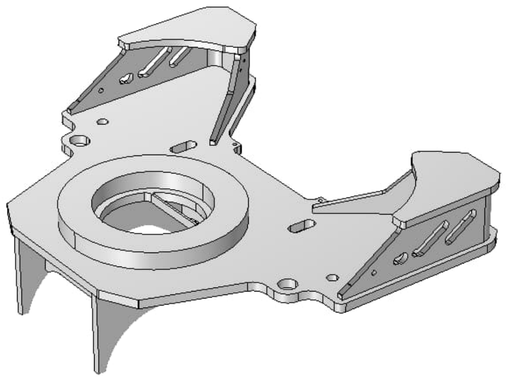
Optimal results for a test run: 20 initial simulations + 18 simulations during optimization



Sequence for the current best solution



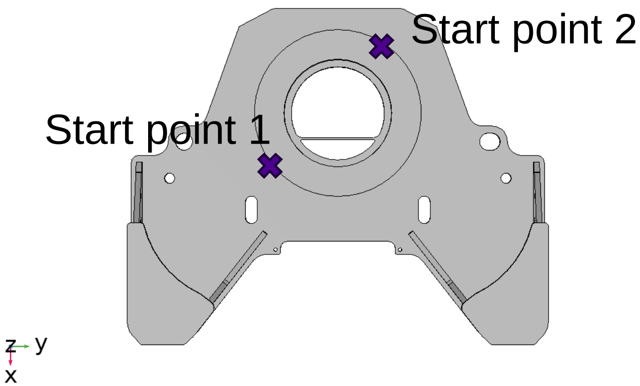
Circle welding optimization



Find **Starting points** for two paths + **process parameters** for each path

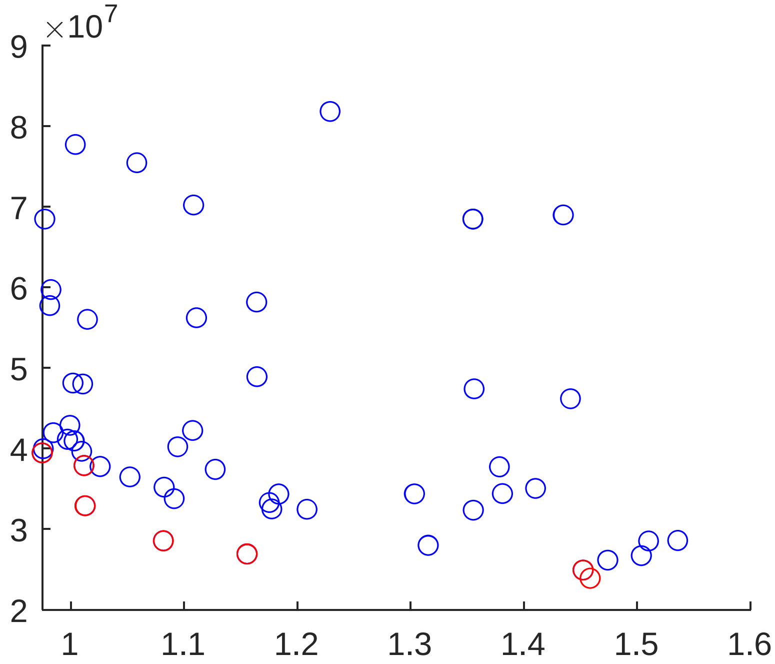
Minimize **Displacement**
Residual stress

s.t. **Heat input**

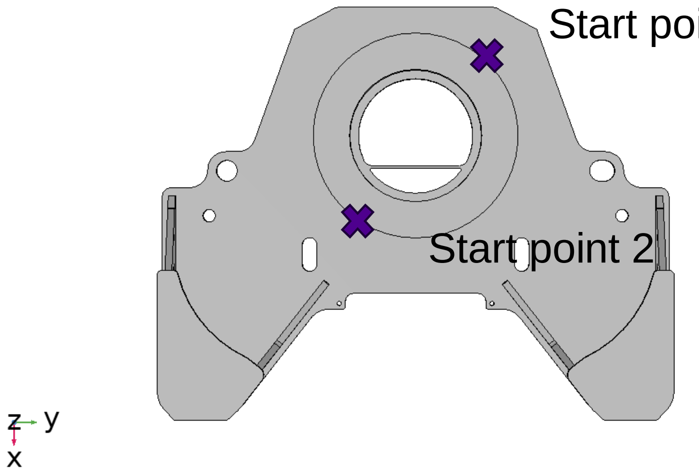


The position of the start point for the two passes are optimized.

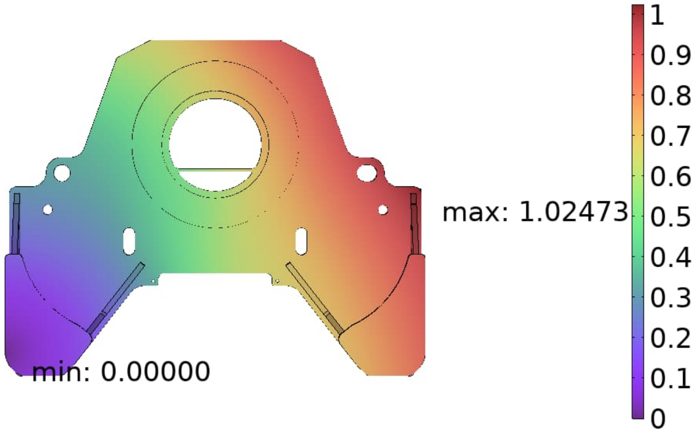
Current runs: 50 simulations



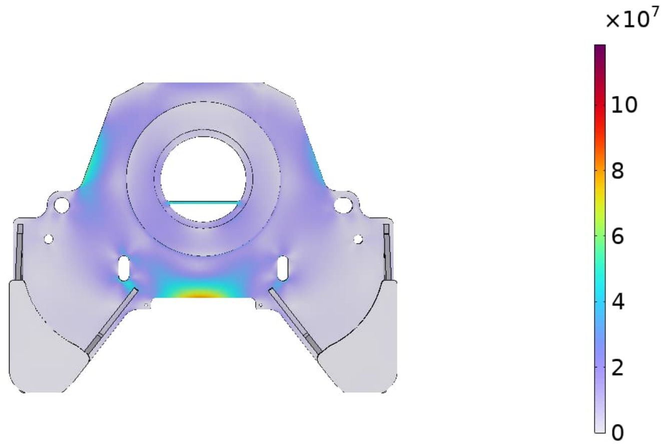
Circle welding optimization



Welding starting points



Displacement



Residual stress