AMC TRR277

A07

Wire Arc Additive Manufacturing (WAAM) of High Strength and Individualized Steel Components

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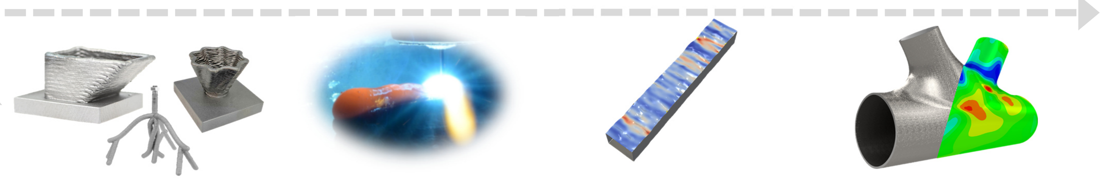
Project summary

This project investigates the use of WAAM for steel components. The four project objectives include: investigating fabrication-related design strategies for WAAM to consider manufacturing constraints; establishing a stable WAAM process for complex components; evolving test methods to capture typical WAAM features; and adopting a digital twin approach for certifying individual WAAM components for safe use in buildings or infrastructure.

Workflow



Initial design → WAAM process → Material behaviour → Component response

Main outcome of 1st funding period

- Mechanical properties became reliable and predictable
- Manufacturing strategies for geometrical features were developed and process constraints were identified
- Effects of print features / manufacturing conditions on the surface quality and material parameters were investigated
- A material model for the simulation of WAAM-components was developed
- Variations of force-flow design method were applied to different case studies

Key collaboration in 1st funding period

- **A04**: A07 and A04 investigated the bond behaviour of concrete and WAAM-rebars with different surface topographies
- **A06**: LPBF-WAAM tensile tests (DIC/ESPI) and characterisation of interface microstructure in collaboration with A06
- **C01**: Simulations of as-built tensile specimens with the method of C01

Project status

WAAM process

- Effects of process parameters (interpass temperature, energy input, active cooling) on material properties were investigated

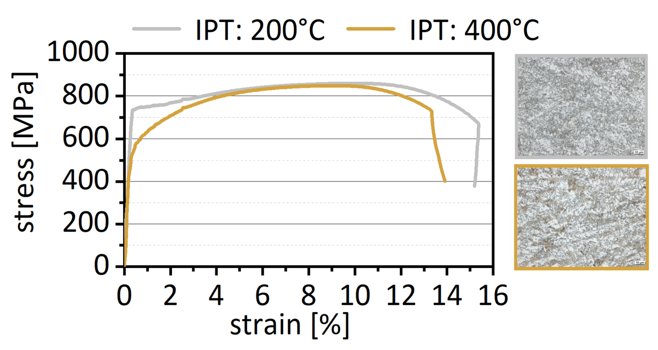


Fig 1: Stress-strain curves and microstructures for different interpass temperatures

- For process monitoring via thermography, a function ε(T) was determined to correct the dynamically changing emission coefficient
- A tolerance range for weld bead distances was identified, in which no lack of fusion occurred

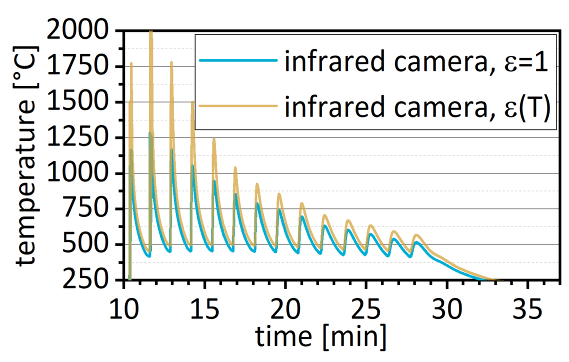


Fig 2: t-T profile with constant ε (blue) and temperature dependant ε (yellow)

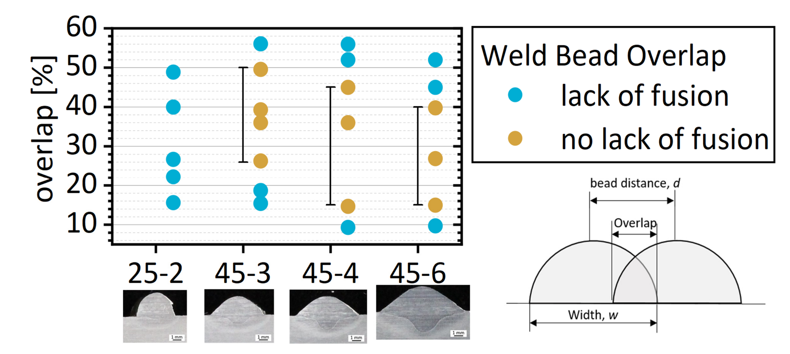


Fig 3: Tolerance ranges for weld bead distances for different process parameters

Material behaviour

- Effects of occurring print features on the material parameters of machined specimens were investigated

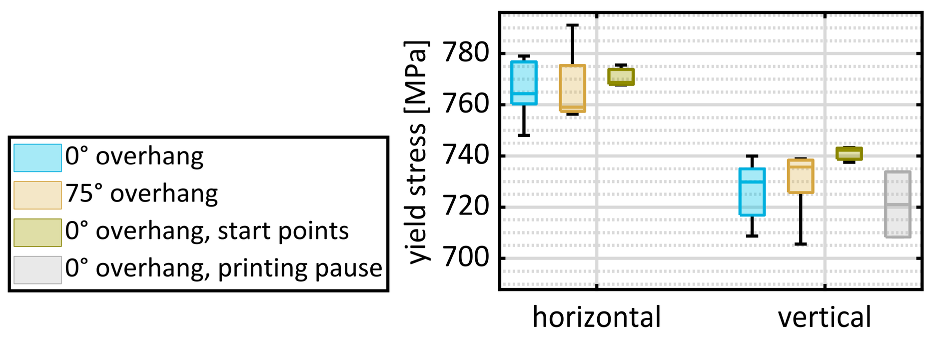


Fig 4: Yield stress for machined tensile specimens cut from different walls

- Influence of the manufacturing positions on the surface quality and their mechanical performance was identified

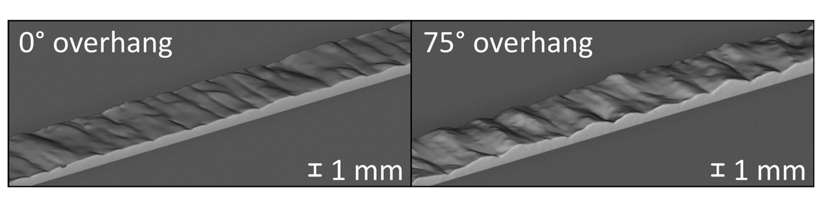


Fig 5: Surface topology of walls with different overhang angles

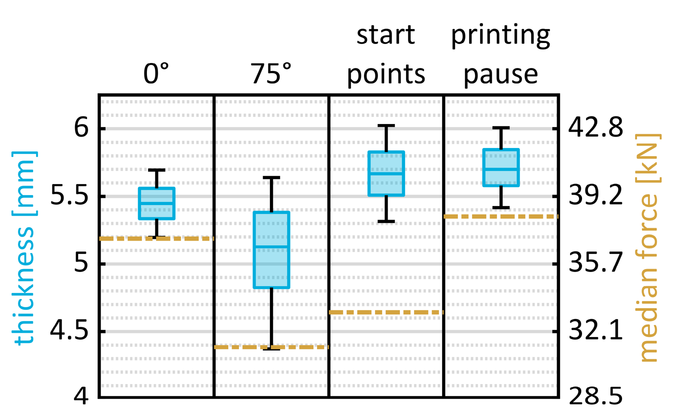


Fig 6: Thickness of walls and median force of as-built specimens from different walls

- Numerical material models for the simulation of as-built WAAM-components were developed

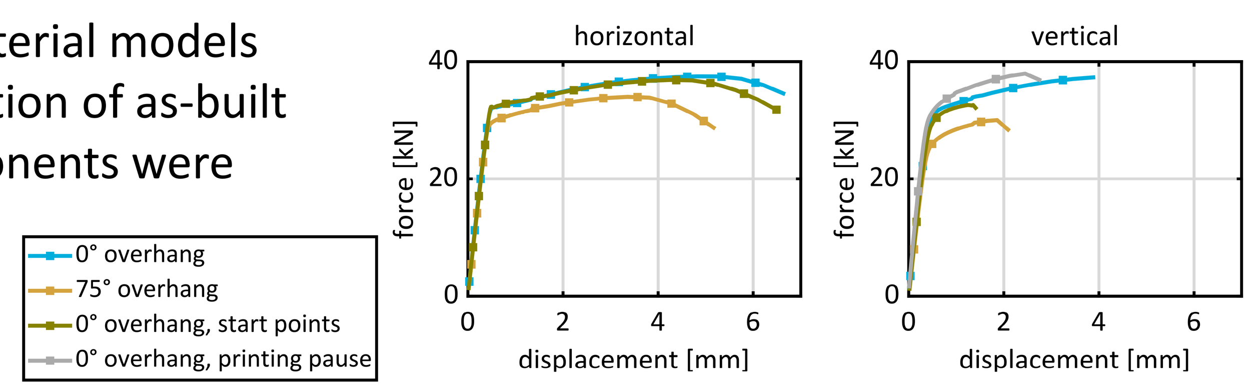


Fig 7: Force-displacement curve for as-built tensile specimens cut from different walls

Project status

Fabrication-related design strategies

- Manufacturing constraints that need to be considered in the early stage of design have been identified and valorised

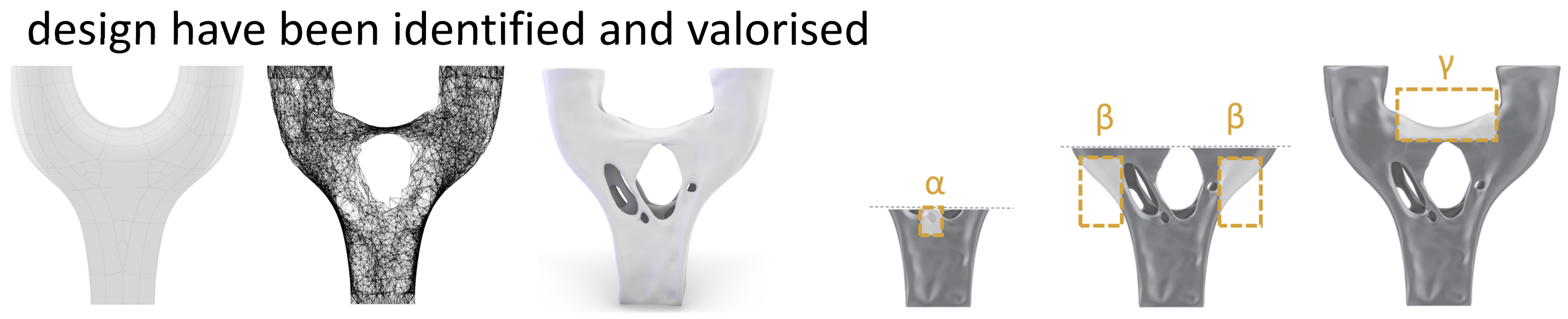


Fig 8: Occurring geometric features after optimising the initial design

	3-DoF	6-DoF	6-DoF + tilt-turn table
α	α < 18°	α < 18°	α < 18°
β	β < 25°	β < 75°	β > 90°
γ	γ < 50° (2*β)	γ < 120° (collision of torch)	γ < 120° (collision of torch)
δ	δ > 34°	δ > 34°	δ > 34°
ε	ε > 19°	ε > 19°	ε > 19°

- Differences in design between WAAM bars, shells and volumes are distinguished and use of lattice for concrete reinforcement is discussed

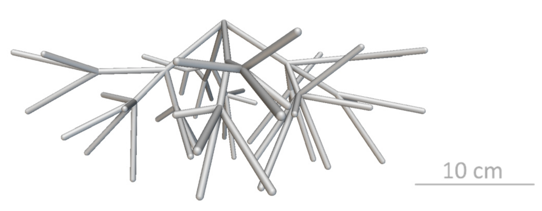


Fig 9: Anchorage structure

Component response and DT

- Buckling tests on imperfect tubes were simulated and performed

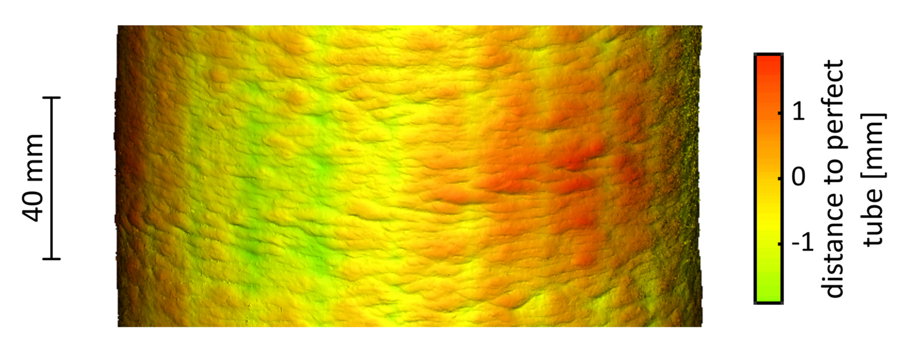


Fig 10: Geometric deviation of the imperfect tube from a perfect tube

- A class structure and methods to connect and store design, process, and testing data was created

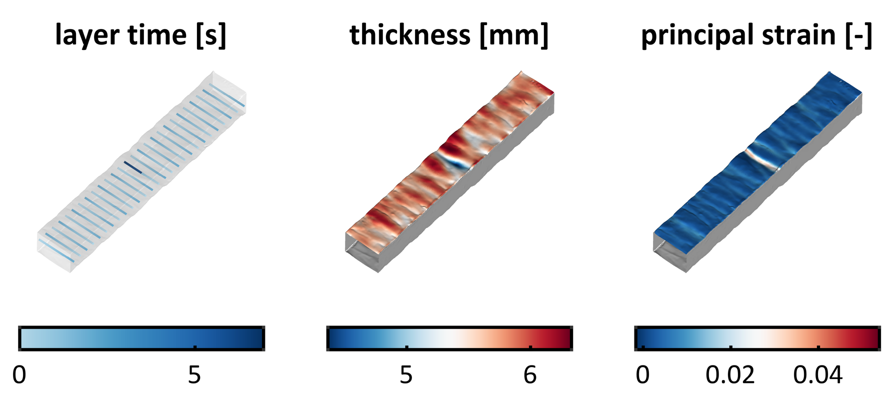


Fig 11: Exemplary data from a digital shadow of a tensile specimen

Large scale demonstrator

- Initial geometry for the topology optimisation was chosen to demonstrate the general manufacturability of a Y-Node

Fig 12: WAAM Y-Node

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