



Open Innovation Platform for Optimising Production Systems by Combining Product Development, Virtual Engineering Workflows and Production Data.

Revolutionising Additive Manufacturing: Open-Source High-Fidelity Modelling Solutions for WAAM

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ADVANCING WAAM PROCESS MODELLING WITH EBBAMS: OPEN-SOURCE HIGH-FIDELITY SOLUTIONS

At the forefront of making innovation in additive manufacturing simulation accessible, EBBAMS is developing open-source-based modelling solutions for Wire Arc Additive Manufacturing (WAAM). Building upon the framework of PIONEER, the mission is to deliver high-fidelity multiscale, multi-physics models capable of predicting process-induced defects, optimising material properties, and accelerating the adoption of WAAM in advanced engineering. We have adopted an Efficient Modelling Workflow that optimises both accuracy and speed, from geometry import to thermal analysis:

- **Input Preparation:** Part geometry is prepared in STL or CAD format and imported into OpenFoam for meshing.
- **Simulation Execution:** Steady-state or transient simulations analyse heat conduction and fluid flow.
- **Parameter Calibration:** Minimal model fitting (e.g., heat source efficiency) ensures rapid alignment with experimental data.
- **Validation:** Initial results align closely with experimental literature, with further refinement using data from AIMEN and MX3D.

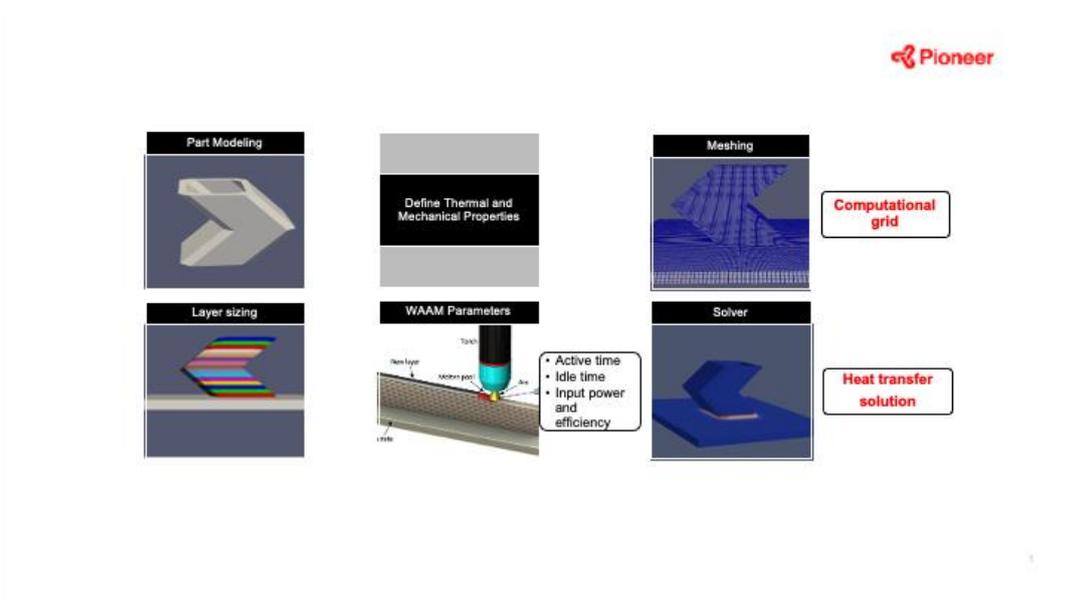


Figure 1: WAAM Process Modelling

A COMPREHENSIVE MULTISCALE FRAMEWORK

The EBBAMS modelling framework is divided into three interconnected elements: Thermodynamics Modelling Tool, Thermal Modelling and Residual Stress Model.

- Thermodynamic Modelling Tool:** Utilising OpenCalphad, a powerful open-source tool based on the CALPHAD approach, we compute thermodynamic properties and phase equilibria for various materials. Our initial trials on several alloys provided insights into the utility of the platform in providing equilibrium calculations and Scheil-Gulliver solidification data, enabling robust sensitivity analysis of chemical composition variations on the quality of the predictions. A key challenge in WAAM process modelling is the availability of precise material characteristics, particularly thermophysical and thermo-mechanical properties. While there are commercial tools offer solutions, their high costs present a barrier. OpenCalphad addresses this challenge by leveraging open-source databases from literature, enabling cost-effective predictions for alloys, ceramics, and other material systems.
- Thermal Modelling:** Developed on the open-source OpenFoam platform, EBBAMS thermal model integrates temperature-dependent thermophysical properties such as density, conductivity, and specific heat. The model employs a layer-activation approach, advancing beyond traditional element activation methods to dramatically reduce simulation times from hours to minutes.

Key features include:

- Steady and transient thermal-fluid modelling.
- Conjugate heat transfer with buoyancy, turbulence, and radiation effects.
- Geometry import (e.g., STL, CAD formats), adaptive meshing, and streamlined heat transfer solving.
- Initial validations against literature data demonstrated prediction accuracy with minimal fitting parameters.

CURRENT AND FUTURE WORK

- EBBAMS is currently developing a **Residual Stress Model** that integrates thermal predictions from OpenFoam to predict residual stress distributions. The effort focuses on achieving high fidelity while maintaining computational efficiency, paving the way for comprehensive process-structure-property understanding.

This initiative empowers manufacturers to predict defects, tailor material properties, and streamline production, ultimately enhancing the scalability and sustainability of WAAM technology.

Follow us in revolutionising additive manufacturing within PIONEER—where innovation meets accessibility through open-source excellence.

ABOUT THE PROJECT

This Horizon Europe project took off in January 2023. PIONEER develops and implements an interoperable Materials-Modelling-Manufacturing Ecosystem, enabling multidirectional dataflow throughout the material value chain by connecting the production's various stages. Combining a design-by-simulation approach with manufacturing and quality data, PIONEER optimises product development strategies in high-mix/low-volume production schemes.

Project Title: Open Innovation Platform for Optimising Production Systems by Combining Product Development, Virtual Engineering Workflows and Production Data.

Project ID: 101091449 | **Start Date:** 01/01/2023 | **Project Duration:** 36 Months

Project Partners:



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