Additive Manufacturing Module

Release History and Major Feature Additions

The Additive Manufacturing (AM) Module is an integrated CALPHAD-based FEM tool designed for rapid prediction of melt pool dimensions, thermal fields, printability maps, and solidification rates. The module can simulate any multicomponent alloy without user-provided material property data, using a Thermo-Calc database as input.

Timeline of Major Feature Additions

2023b
June 2023

- AM Module launched as an Add-on Module in Thermo-Calc
- Steady-state and Transient simulations supported
- Different heat sources (surface and volumetric) and fluid flow accounted for
- Couples with kinetic modules: AM to DICTRA (for microsegregation in solidification boundaries during processing) and AM to TC-PRISMA (for precipitation during multi-layer deposition)

2024a
December 2023

- Keyhole model introduced (for Steady-State and Transient with Heat Source from Steady-State type simulations)
- Heat source calibration added (with respect to beam radius and experimental depth / width)
- AM Module added to TC-Python

2024b
June 2024

- Additional calculation types added: batch and grid
- Printability maps added: utilizing grid type simulations and applying geometric constraints to visualize process maps to decide optimum process parameters for printing defect-free samples (Example: lack of fusion $D/t < 1$)
- Keyhole model expanded to include fluid flow

2025a
January 2025

- Absorptivity model included to estimate absorptivity: dependent on wavelength and electric resistivity assuming a flat liquid surface (based on Lorentz-Drude model)
- Thermal Gradient (G) v/s Solidification Rate (R) added as plot quantity. Consequently, AM to CET connection was made possible (to predict columnar to equiaxed grains during solidification for IN718)
- Export results from AM Module to exodus file format introduced (to visualize in external FE tools)

Timeline of Major Feature Additions (continued)

2025b
June 2025

- Beam shaping introduced with core-ring and top-hat type beams: both are surface heat sources similar to Gaussian heat source
- Full ray reflect in keyhole implemented: accounts for full raytracing including upward reflecting rays; results in a slightly deeper keyhole and melt pool

2026a
January 2026

- Electron beam added as heat sourc: effect of lower pressure on evaporation treated (to account for vacuum in chamber) and absorptivity as a function of back scatter constant
- Material properties averaging improved to include separate material properties with keyhole + fluid flow
- Several default settings updated (activate keyhole model, fluid flow, beam radii = 40 µm, etc.) to match machine settings for PBF-LB process

2026b
June 2026

- New feature to predict composition changes caused by evaporation during additive manufacturing. The feature is implemented as a new calculation type, **Evaporation with Steady-state**, as well as a new plotting tab and plot quantities