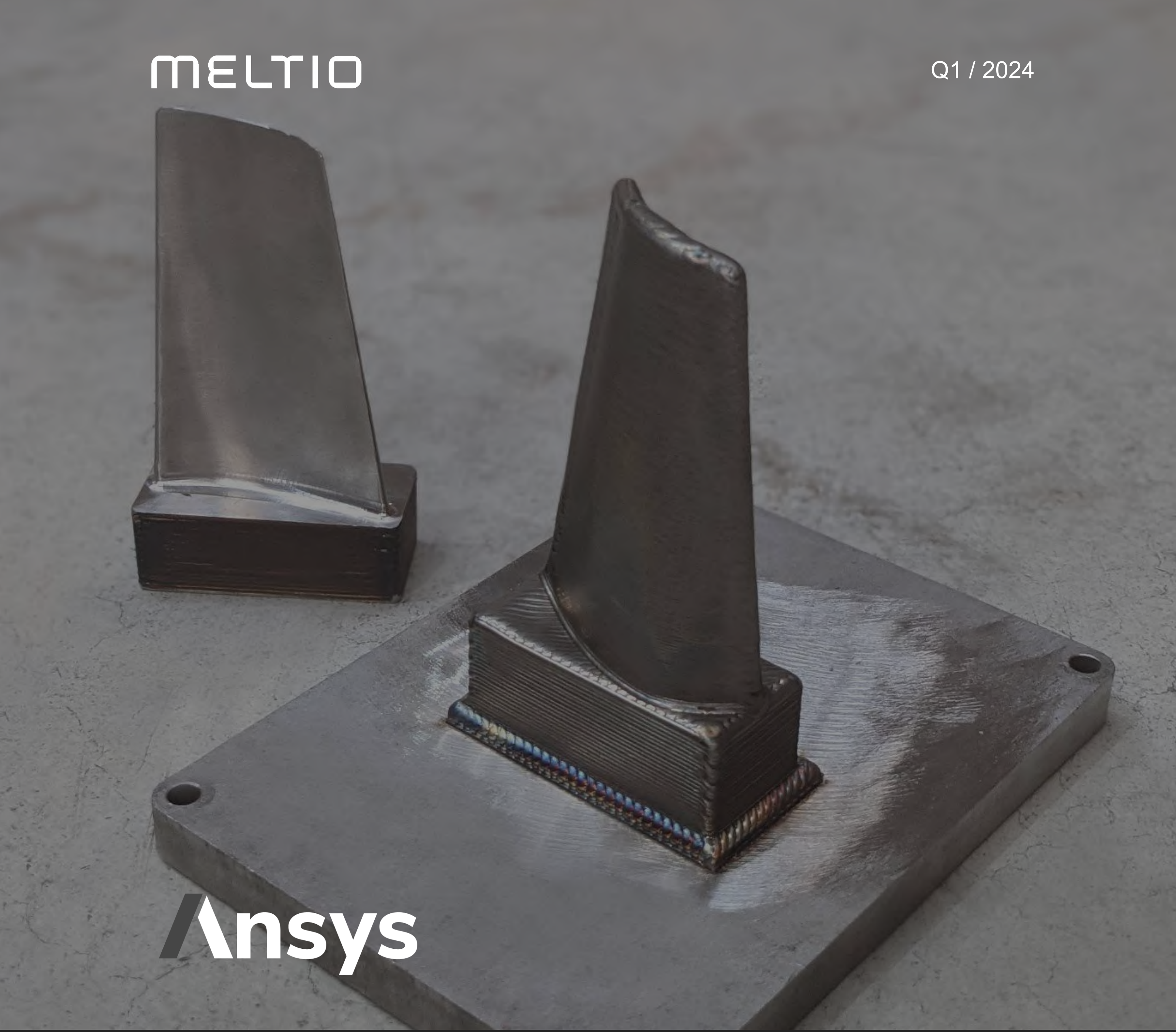
Q1 / 2024



Improving Printability of Large Directed Energy Deposition Components with Simulation

Case Study together with Ansys

Table of Contents

Ansys + Meltio

“This is the first and big step in learning to predict thermo-mechanical behavior in additive manufacturing

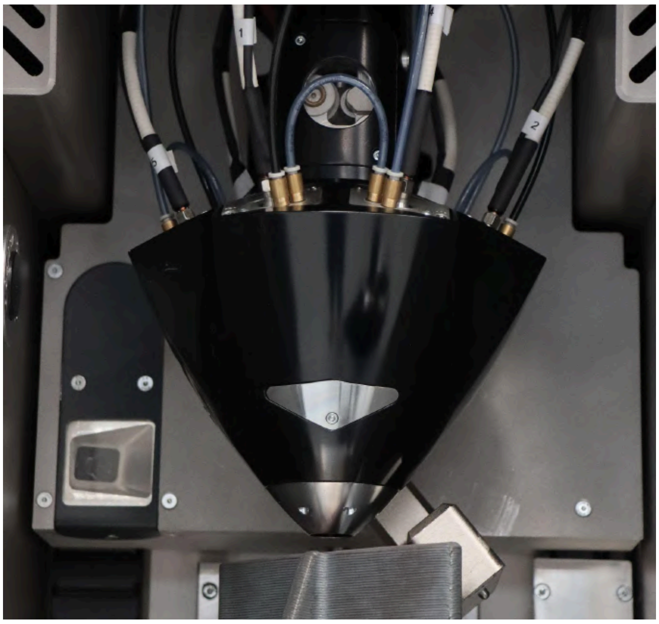
Alejandro Lázaro Martínez
Process and Material Manager / Meltio

Improving Printability of Large Directed Energy Deposition Components with Simulation

In a collaboration between Meltio (Alejandro Martinez and Fran Carretero) and Ansys (Abel Ramos and Dr. Enrique Escobar de Obaldia), the accuracy of Ansys additive manufacturing simulation was evaluated. Using the AM-DED module in Ansys Additive Suite, the printability of a nickel-based turbine blade component was investigated and the results were compared with a physical part.

Challenges

Directed energy deposition (DED), an additive manufacturing (AM) technology, is known for its varied usages that enable manufacturing and the repair of metal components using powder or wire material. While other technologies such as powder bed fusion limit the size of the printing components to the machine build envelopes, AM-DED (wire arc and laser-based wire) processes offer larger build envelopes, high deposition rates, greater cost benefits, and increased manufacturing freedom due to the multiple deposition axes. AM-DED is used today across multiple industries, including mass manufacturing, maintenance, and industrial applications. But despite these advantages, distortions and



residual stresses can potentially be observed in printed components. Especially when manufacturing large metal components that can take days or weeks to complete, it is essential to control the process and avoid manufacturing defects.

Meltio's technology, Wire Laser Metal Deposition is a Directed Energy Deposition (DED) process that functions by precisely stacking weld beads on top of one another, in wire form, when introduced into the laser generated melt pool.

It comes packaged in a compact deposition head, a host of multiple lasers, and capable of processing single and dual wire within the same build.

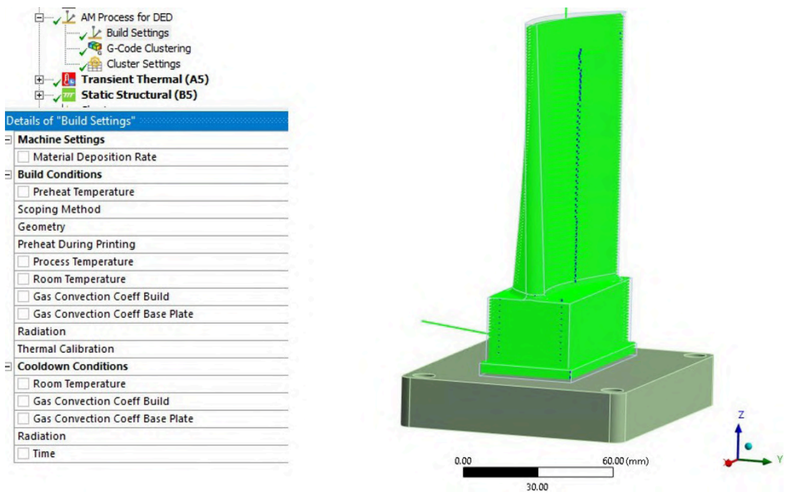


Figure 1. G-code weld path displayed on the turbine blade and process parameters used in Ansys 2023 R2.

Technology Used

- **Ansys Additive Suite**
- **Ansys Mechanical**
- **Ansys Discovery**

Engineering Solution

In the AM-DED module within Ansys Additive Suite, a custom system is available to simulate thermomechanical behavior during the DED process. A turbine blade component (geometry size) was selected because it showed manufacturing complexity and the potential for high deformations, if no cooling pauses were added to the process. An easy-to-use wizard was used to set up the analysis, discretize the geometry, and select part and base plate materials. In the workflow, the thermal history can be calculated based on process parameters (i.e., material deposition rate, preheat temperatures, dwell times, etc.) and results are subsequently transferred to calculate deformation and stresses in a structural analysis (Figure 2).

Since the order of activation during the printing process influences the thermal history of the component, Meltio provided a G-code file containing the commands used in the 3D printing process. After reading the G-code file, the AM-DED module interpreted the tool path, read the cluster settings, and assigned a cluster activation order that was used in the simulation. To speed up the simulation, a cluster volume that defines the region of activation was defined.

AM-DED printing simulations can help predict warp and defects, and they can also aid in understanding the influence of process parameters. Thermal measurements and process monitoring (i.e.,cooling and printing times) in combination with simulation tools not only helped calibrate the analysis, but also gave insight into understanding the impact of process parameters. For this collaboration, the part was printed first, then real-time measurements were used to calibrate thermal coefficients. The printing and cooldown time of the component was in the order of 4h 53min, with a total of 114 layers and wire length used of 183 m.

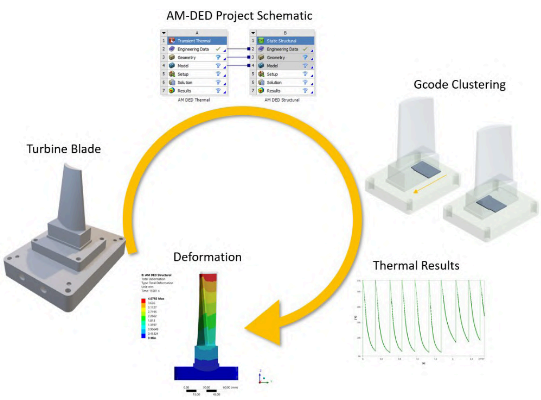


Figure 2. Description of the additive workflow

Benefits

The temperature results were used to evaluate overheating regions and make correlations with thermal sensors. During the manufacturing of the blade, overheating was observed towards the tip of the geometry. This thermal effect is expected and could be improved by allowing longer wait times between layers, enabling different cooling systems, or using different process parameters in the upper layers (Figure 4). Overheating is also not desirable as it can cause nonhomogeneous microstructures, porosity, and other defects.

Once the transient thermal analysis was completed, the thermal history results were automatically transferred to a structural analysis. In AM-DED, the high temperature gradients of AM processes can cause high deformations and residual stresses. Fractures are generally observed if large amounts of overheating are generated during the process, especially close to the anchor bolts. The simulation results can be used to understand and avoid those defects.Fractures are generally observed if large amounts of overheating are generated during the process, especially close to the anchor bolts. The simulation results can be used to understand and avoid those defects.

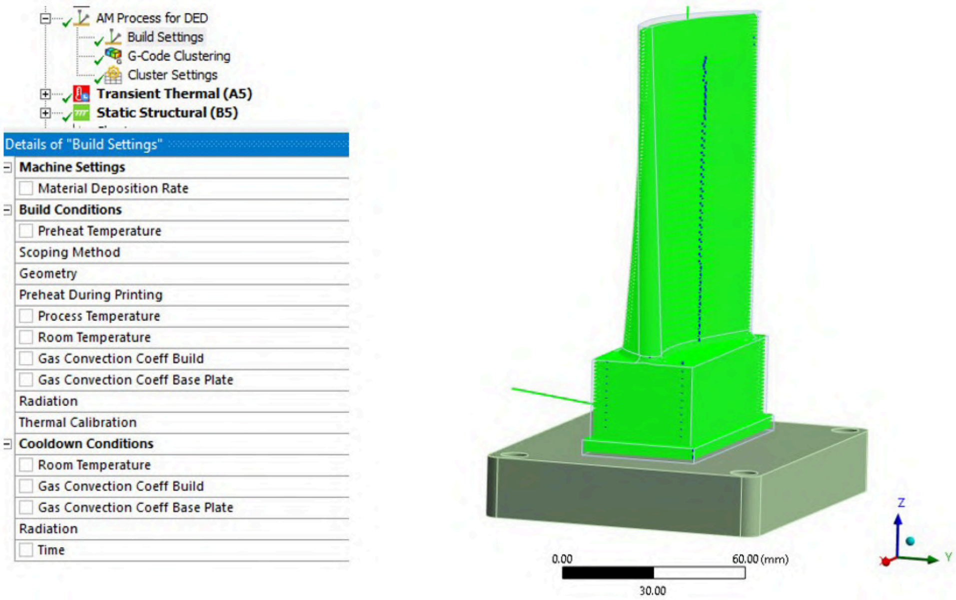


Figure 3. G-code weld path displayed on the turbine blade and process parameters used in Ansys 2023 R2

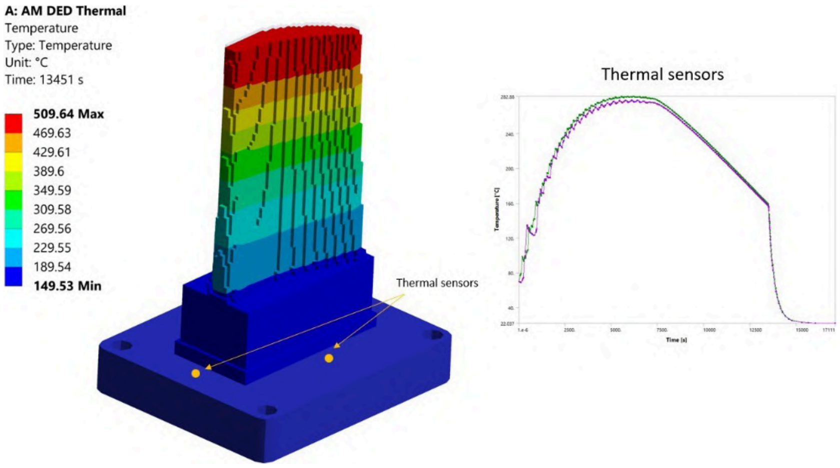


Figure 4 . G-code weld path displayed on the turbine blade and process parameters used in Ansys 2023 R2

Like other AM technologies, DED is also affected by warping effects. As overheating regions accumulate in the upper layers, deformation is also expected in the same locations. In order to test the simulation, a sample blade was purposely printed with an accelerated process that overheated the structure, resulting in a deformation in the tip that reached a maximum value of 4.0 mm compared to the target geometry. If compared with the component height (value in mm), the value could be considered insignificant; however, for the given application, it will require a redesign and or a new print of the component.

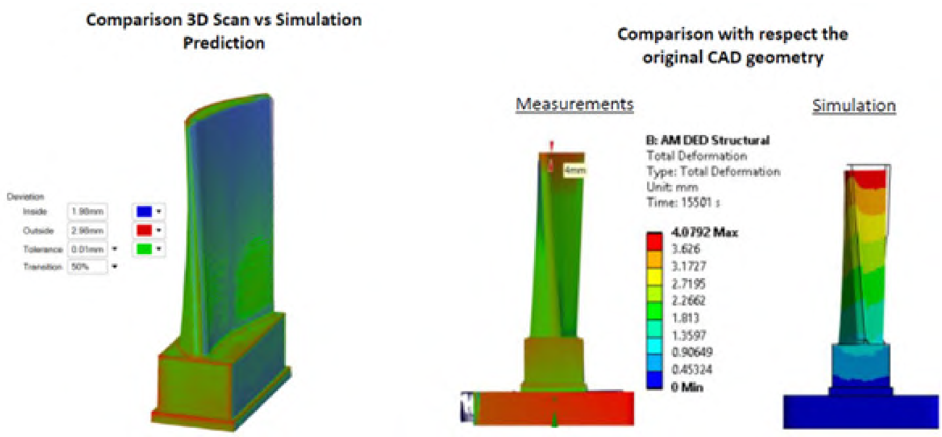


Figure 4. (a) Comparison between the 3D scan versus the simulation prediction; (b) comparison between the measurements, simulation results,and nominal geometry

Meltio was also able to provide a scan of the real printed part, and the results were compared. As can be seen in Figure 5, the measurements indicate a deformation of the order of 4 mm, as predicted in the simulation.

Figure 6. Comparison between turbine blade printed on the base and after removing and machining

Figure 7. Turbine blade printed (DED) removed from the base

Figure 8. Turbine blade printed (DED) on the base

MELTIO
www.meltio3d.com

Ansys
www.ansys.com