Optimizing 3D Printing Techniques with Simulation Apps

by **ALEXANDRA FOLEY**

Taking a new technology concept from research in its infancy to a qualified solution ready for industrial use requires rigorous testing and validation. Additive manufacturing (3D printing), for example, first appeared in the early 1980s with a Technology Readiness Level (a method of measuring a technology's maturity for industry use that was proposed by NASA in the 1970s) of TRL 1, and it took decades before it exploded on the industrial markets as a hot new manufacturing technique set to change the world.

➔SIMULATING SHAPED METAL DEPOSITION

Organizations such as the Manufacturing Technology Centre (MTC) in Coventry, UK help to bridge the gap between concept and industry by providing the resources necessary to bring a design from fundamental research (TRL 1–TRL 3) to commercial use (TRL 7–TRL 9). One current endeavor at the MTC is research into the additive manufacturing technique known as shaped metal deposition (SMD).

"SMD has multiple advantages over powder-based additive manufacturing technologies," says Borja Lazaro Toralles, Research Engineer in the MTC's Manufacturing Simulation theme, who has used COMSOL Multiphysics® software to design a model and simulation app of the SMD process (see Figure 1). "Among the benefits of SMD are higher deposition rates, the possibility of building new features upon preexisting components, or even the use of multiple materials on the same part."

Unlike other additive manufacturing techniques that use lasers to melt a thin layer of powder, SMD deposits a sheet of molten metal—which in some cases can be as expensive as titanium—that is built up layer-by-layer on a surface in a process that is similar to welding. "One of the challenges of this is that thermal expansion of the molten metal can deform the cladding as it cools, resulting in a final product that is

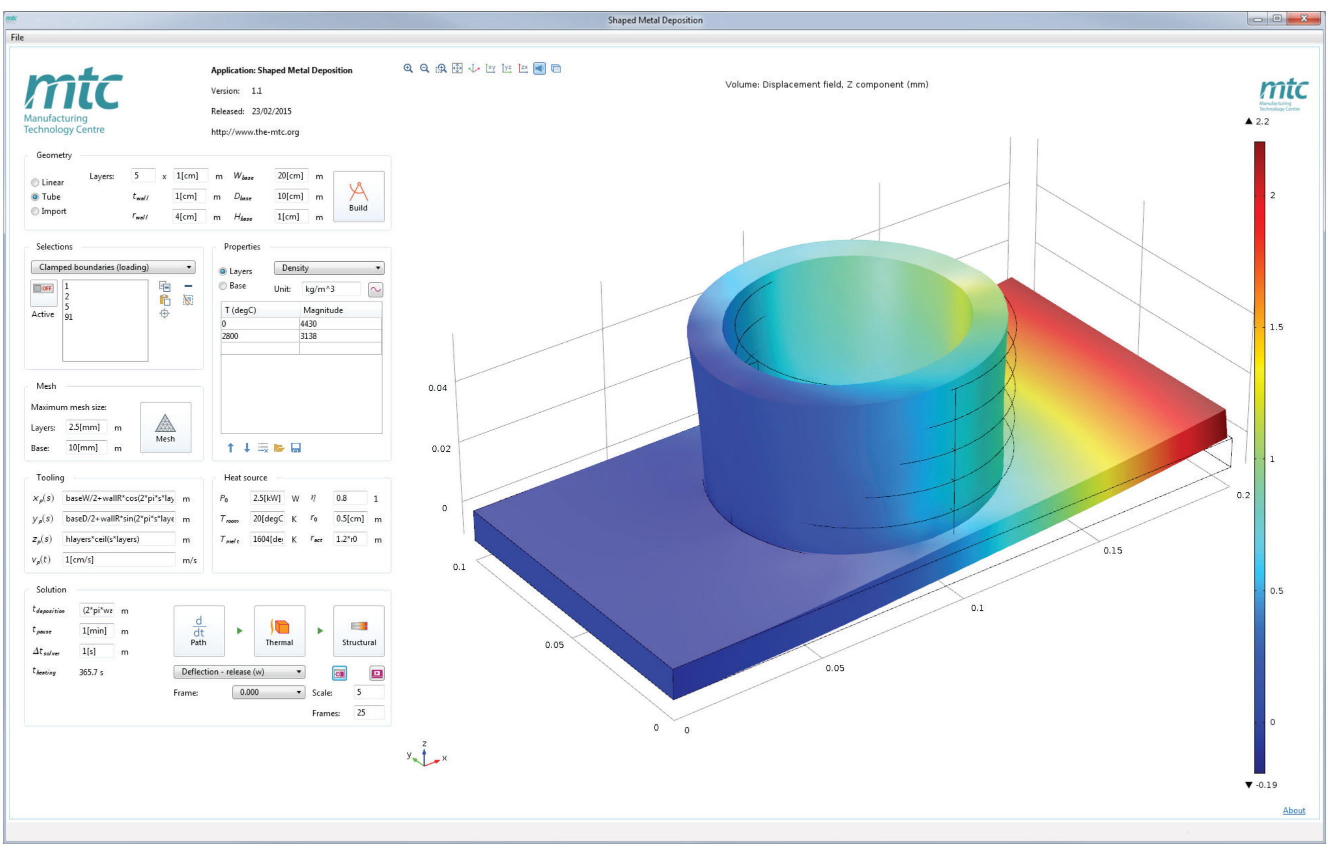

FIGURE 1. Shaped metal deposition (SMD) simulation app created using the Application Builder available in COMSOL Multiphysics. The app computes the residual stresses generated during the manufacturing process and predicts the final deflection of the part.

different than what was anticipated," describes Lazaro Toralles. "In order to predict the outcome of a proposed design, we need either to minimize the deformations or alter the design to account for them." Figure 2 shows an example of a part manufactured using SMD, where deformation occurs after six layers of deposited molten metal have been added. A model of the part, also shown in Figure 2, is used to predict the part's deflection during manufacturing, allowing the designer to update the design accordingly.

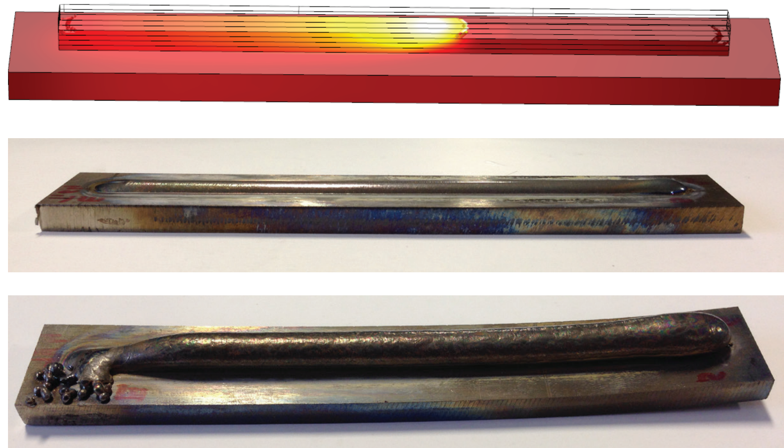

FIGURE 2. During the SMD process, thermal cycling induces residual stresses on the manufactured parts. Top: Simulation of the SMD part. Middle: The part after just one deposited layer, with no noticeable deformation. Bottom: After six deposited layers, deformation is visible to the naked eye.

➔COMMUNICATING COMPLEXITY WITH SIMULATION APPS

The MTC has leveraged the Application Builder in order to more efficiently communicate complex design ideas across multiple simulation and process departments, and to allow app users to easily explore the outcome of proposed designs (see Figure 1). Were it not for the simulation app, the testing and validation of a design would be significantly more time consuming and costly using physical testing alone, due to the materials used in SMD.

Simulating SMD involves solving a time-dependent coupled thermomechanical analysis that predicts residual thermal stresses and deformation, which arise from SMD thermal cycles.

"We built an app using the Application Builder that allows the user to predict whether the deposition process will produce parts that fall within their established tolerances," says Lazaro Toralles. "If not, then the app provides a user-friendly and cost-efficient way to simulate multiple variations to the input until the results achieve an acceptable final deformation."

With this app, users can easily experiment with various geometries, heat sources, deposition paths, and materials without concern for the underlying model complexities. Two predefined parametric geometries are included in the app, and a custom geometry can also be imported.

The MTC team comprising Adam Holloway (left), Borja Lazaro Toralles (center), and Willem Denmark (right) have implemented the COMSOL model, carried out experimental validation, and finally created the SMD COMSOL application.

Currently, the app is being used by members of the team at the MTC who do not have the simulation experience to independently explore different parts and projects for their customers. "Were it not for the app, our simulation experts would have to test out each project we wanted to explore, something that would have decreased the availability of skilled resources," says Lazaro Toralles. "Using the Application Builder, we can now provide user-friendly app interfaces to other MTC teams." The MTC will also offer an app program for their customers.

"The use of simulation apps will help us to deploy technologies at higher TRLs for their practical use in an industrial environment," Lazaro Toralles concludes. "The Application Builder provides us with a powerful development platform through which we can package complex multiphysics models and make them accessible to the wider public." ❖

ABOUT THE MANUFACTURING TECHNOLOGY CENTRE

The MTC provides a unique environment for developing cutting-edge technologies into manufacturing processes by bringing the UK's leading academics, engineers, and industry professionals together to develop and demonstrate new technologies on an industrial scale. This allows clients to develop new manufacturing processes in a safe, neutral industrial setting without the constraints of a commercial production environment. Their members include over 80 organizations, including BAE Systems, GKN, HP, GM, Airbus, and Rolls Royce.