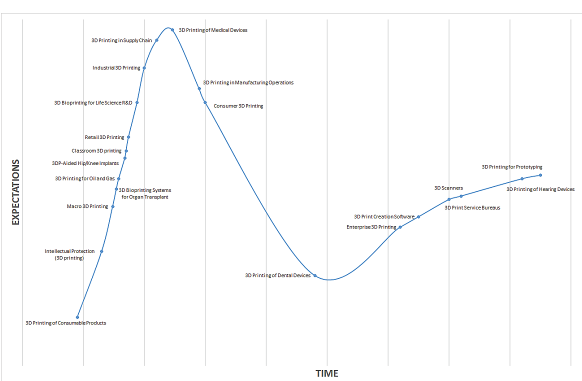
White Paper

The ANSYS Vision for Simulation-driven Product Development in Additive Manufacturing

Additive manufacturing, or 3-D printing, has the potential to radically change the way in which products are conceived and designed. The additive process allows for unprecedented design complexity and design freedoms. Full subassemblies can be produced in one print eliminating costly joining operations. Parts can be customized and produced in small, made-to-order batches. Parts can be produced when and wherever needed — at home, in the work or battle field, at the assembly line. For additive manufacturing to become ubiquitous, and its promise fully realized, the current design and simulation tools must also radically evolve.



Introduction

While additive manufacturing (AM) has actually been around for decades, primarily serving the prototype and tooling market, more recent advances in printers has made the AM market shift into mainstream part production. With the advent of reliable and capable printers for metals, AM is being applied to produce lightweight designs for highly-engineered fields such as automotive and aerospace. The AM space is rapidly evolving, with new printer manufacturers and updates to existing lines coming fast and furious. Considerable research dollars are being spent around the world to further the understanding and control of the print processes, material characterization, and other aspects of the part build. ANSYS has been closely involved with many of these researchers and institutes in order to keep abreast of this evolving field.
While many would argue that we are still early in the "hype cycle," there are not only many companies actively using AM in production, but many more which have purchased printers and are exploring their potential benefit.
For AM to become mainstream, there must be more than just advancements in the printer hardware — advances in the design software and the simulation software must also occur. ANSYS is uniquely positioned to capitalize on its longtime strengths in simulation-driven product development (SDPD) to help facilitate the move to mainstream.

Challenges Faced Today

There are three primary challenges faced with designing and printing parts today. These center around the design tools, the design-build iterations, and the lack of cohesion in the software tool stream.

The first challenge is that design tools are not formulated to design for AM. The current tools (including CAD) are based on historical knowledge and patterns learned from decades of designing for well- established manufacturing techniques: machining, casting, welding, forging, stamping, etc. While AM design knowledge is increasing, the industry cannot rely on simple rules of thumb; a more physics-based approach is required.

The second challenge is that while we have exceptional design freedom, not all designs can be reliably printed. Designs are made, given to the printer operator, and if the build (print) fails, the designer or engineer must redesign. This redesign-build iteration is costly and time consuming.

The third challenge is that to address specific applications, , numerous specialized tools have emerged in this space, including specific design tools (mainly around topology optimization or latticing), specialized print pre-processing tools (orientation, supports and slicing), and print simulation tools. Designs and data cannot be used in a seamless process, but instead must be transferred manually from one tool to the next to complete all the steps from design to build.

Simulation-driven Product Development

ANSYS has long made simulation-driven product development (SDPD) a reality, not only through our physics simulation software, but through our geometry creation and manipulation tools and our superior workflow. Iterating early in the design cycle and using simulation to create and test virtual prototypes leads to better and optimal designs, as well as compressing the total design time.

Designing for traditional manufacturing processes could easily be accomplished through design knowledge and rules (minimum radii, draft angle, sizing, etc.). While specialized software exists for simulating these traditional processes, they are rarely required in the design cycle.

With AM, this is no longer the case; the design and the production process are much more intimately linked, and the engineer must consider the process in the design up front to ensure successful builds.

ANSYS Vision

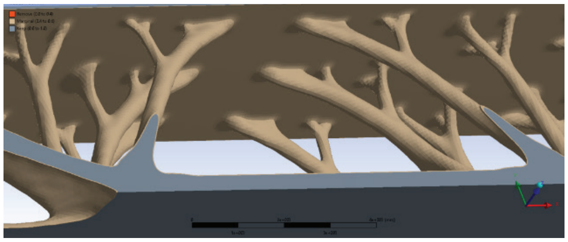
Our long-term vision is to place a “Print” button in ANSYS Mechanical. Given the design space, the engineering requirements and the printer parameters, the software would produce a printer-ready design based on physics. This vision may seem to be a far-off goal, but it serves to focus our development plans and lend clarity to our efforts.

Key Pillars

To enact this vision for AM, three pillars must be addressed:
• Design
• Process simulation
• Material behavior and microstructure

Design

Harnessing the design freedoms for AM and enabling reliable design for AM requires a number of advancements. The freedoms can be unleashed through topology optimization or smart use of lattice and cellular arrangements. Incorporating AM design rules inherently in the design process is also required for success.



Topology Optimization

Topology optimization is well-suited to fully exploit the design freedom provided by additive manufacturing by starting from blank space and iterating to an optimized design while changing both the basic shape and dimensions of the part.

Topology optimization is not a new technology, but companies interested in taking advantage of it have up to now faced several obstacles. Topology optimizers have largely been stand-alone solutions that use relatively basic solvers, limiting the accuracy of the optimized design. Today's topology optimizers require users to learn a new simulation environment and convert the optimized design back into another simulation environment for validation and simulation with respect to other physics such as flow, vibration, nonlinear effects, heat and electromagnetic radiation.

With topology optimization embedded in ANSYS Mechanical and part of the ANSYS Workbench workflow, these obstacles are eliminated.

Lattices and Cellular Designs

Topology optimization reduces weight, while retaining required strength, by removing material from the design space. However, many designs require surfaces to be present for assembly mating, aero surfaces, flow channels, etc. One way to reduce weight under these constraints is to use a cellular design within the volume in order to retain the surfaces, but still reduce weight while maintaining stiffness.

Coupling the density distribution from a topological optimization to the requisite lattice spacing and/or member thickness is an ideal way to use a physics-based design process.

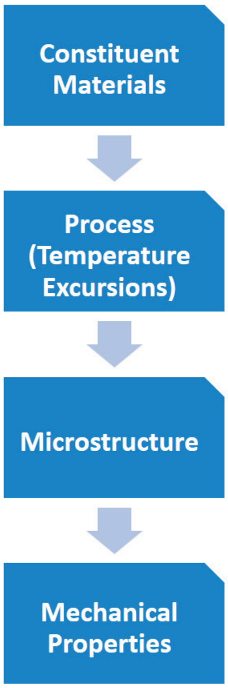
Design Rules

The nature of the print process — adding material layer by layer through a deposition process — leads naturally to some basic design rules for additive manufacturing (DFAM). Minimum feature size, orientation and hole sizing are typical rules. These have been incorporated into ANSYS SpaceClaim as a post-design tool and are also being incorporated into the topological optimization algorithms.

Most rules are specific to the actual print process and to the actual print manufacturer. Additionally, companies learn and adjust the process parameters that affect the upper and lower bounds on the rules as they develop experience. These companies require a tiered rule engine: basic, machine specific, company, and site.

Process Simulation

The print process, especially for metals, entails application of concentrated heat to melt and fuse the material to the preceding layer of solidified material. This continual heating and cooling cycles lead to warpage of the part. This warpage can lead to rejected parts and also to a printer failure — imagine discovering a broken part sixty hours into the build! Additionally, the process can even induce sufficient thermal stresses to break the part from the supports or build plate.



Simulating the build process is key to obtaining a successful design, both for the part and for its supports which both conduct heat from the part and anchor it to the build plate to help the part resist warping and thermal stresses.

Material Behavior

The print process leads to material behavior which tends to be non-isotropic and varying over the print domain. For metals, the heating and cooling cycles lead to the formation of specific microstructures. Predicting the material properties is desirable a priori, so the design and/or process settings can be adjusted to obtain the desired material characteristics.

To capitalize on the promise of AM, designers need to be able to specify the required material characteristics and their distribution (specify hardness in one area and elongation in another, for example) and to be able to back out of the design and process settings to obtain those settings.

Achieving the Vision

ANSYS has a long history of simulation-driven product development. Extending this experience to additive manufacturing leverages many existing strengths:

- Breadth and depth of physics
- Design techniques like topology optimization and latticing
- Workflow and automation
- Compelling geometry manipulation and creation tools, including working with facets
- Strong ties with consortiums and academia

ANSYS will continue to refine and develop the most comprehensive simulation software in the industry, as we enable leading-edge designers to take advantage of new technologies, such as additive manufacturing, and develop the lighter, smaller and more durable products of the future.

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