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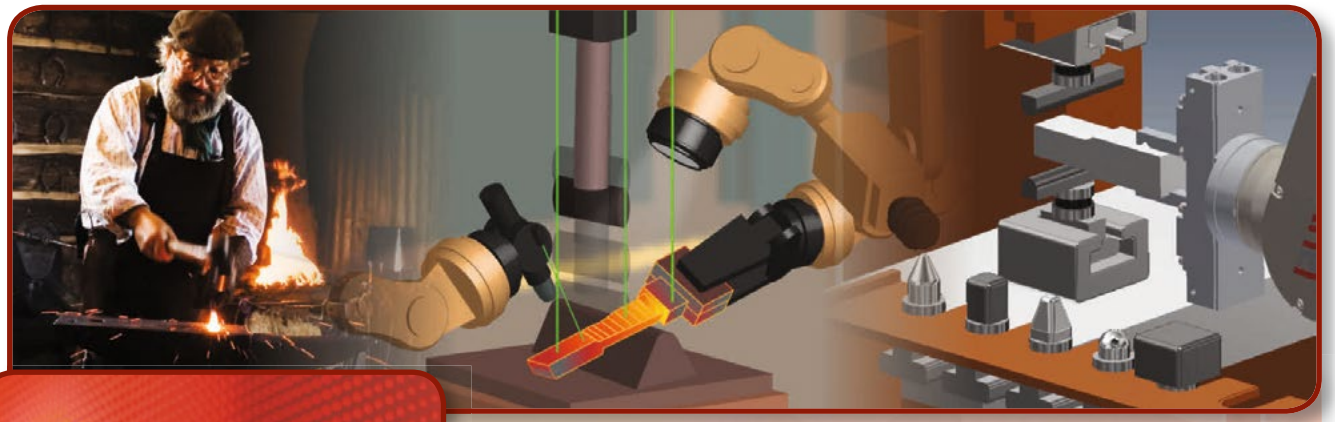

TMS Releases Report on Potentially Disruptive Technology

Owen Daly

TMS officially released its newest technical study, *Metamorphic Manufacturing: Shaping the Future of On-Demand Components,* at the TMS 2019 Annual Meeting & Exhibition (TMS2019), held in San Antonio, Texas, March 10–14. The study, which was supported by the U.S. Office of Naval Research (ONR) and the Lightweight Innovations for Tomorrow (LIFT) Manufacturing Institute, is focused on defining metamorphic manufacturing (MM), identifying foundational elements of MM, outlining specific technical challenges preventing full development and adoption, and offering recommendations and action plans on how to jump-start this new manufacturing technology.

According to the report, metamorphic manufacturing combines the incremental thermomechanical deformation of a blacksmith with the

Glenn Daehn, *Metamorphic Manufacturing* study team lead, reviews the impact that this technology could have on the future of manufacturing during an information session held at TMS2019 with study team members and meeting attendees.

TMS Studies Available for Free Download

Metamorphic Manufacturing: Shaping the Future of On-Demand Components:
www.tms.org/MetamorphicManufacturing

Verification and Validation of Computational Models Associated with the Mechanics of Materials:
www.tms.org/VerificationandValidation

Additional TMS Studies

The entire suite of TMS studies is available at:
www.tms.org/Studies

Figure 1. A visual synopsis of the five fundamental elements of metamorphic manufacturing. (*Metamorphic Manufacturing: Shaping the Future of On-Demand Components*, 2019, p. xxiv.)

precision and control of intelligent machines and robotic systems. Glenn Daehn, study team lead and the Fontana Professor of Metallurgical Engineering at The Ohio State University, describes this novel manufacturing approach as the "third wave of digital manufacturing," following subtractive or computer numeric control (CNC) machining and additive manufacturing (AM). Daehn noted that metamorphic manufacturing's "impact could be every bit as great as the impact of additive manufacturing." He further explained that MM improves upon both CNC machining and AM by reducing the amount of raw material loss and enabling the ability to tailor material properties through locally controlled deformation. With recent advances in the field of integrated computational materials engineering (ICME), "fully realized metamorphic manufacturing would span the materials engineering process, from material discovery and development to commercial component creation," said Daehn.

Jian Cao, study team member and Cardiss Collins Professor at Northwestern University, sees the integration of computational tools and processes such as MM into the metal forming industry as a revolutionizing opportunity. Of this integration, she said that "metal forming was often considered old and dirty, but now we actually have the opportunity to bring digital technology and robotics into the industry." Similarly, Daehn said, "this is extending open die forging, which is a large industry already…we are adding another layer of sophistication onto that, which should take open die forging to the next level." He noted a particularly impactful trait of MM is the ability to adapt the same system to create many different types of parts, eliminating the high material and energy cost of creating a new die for each new component and dramatically reducing time to market.

As outlined in the study, metamorphic manufacturing could provide a more economically and environmentally friendly method for advanced manufacturing as compared, for instance, to some powder metal AM methods. Likewise, the potential to create complex-shaped components without milling away material indicates that MM could offer similar benefits

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>
> ***—Glenn Daehn,* Metamorphic Manufacturing study team lead**

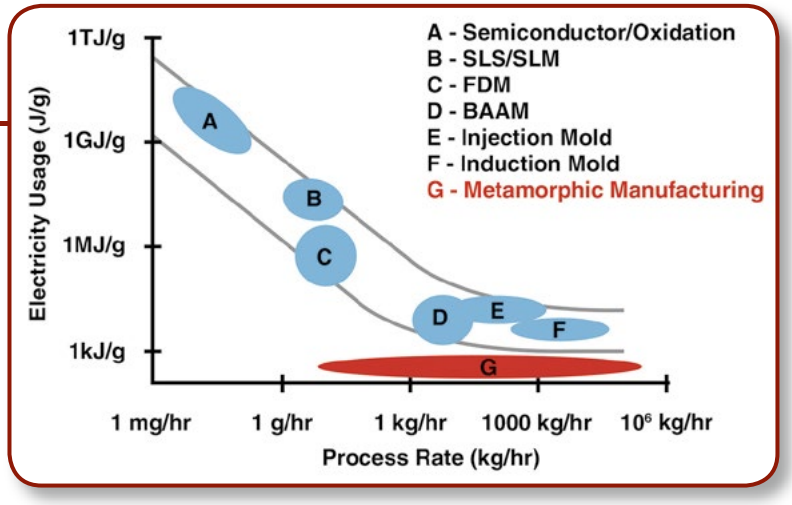

Figure 2. This graph provides rough estimates and comparisons of the Electricity Usage vs. Process Rate for various additive and other manufacturing processes (blue) compared to metamorphic manufacturing (red). Acronym definitions: SLS = Selective Laser Sintering, SLM = Selective Laser Melting, FDM = Fused Deposition Modeling, BAAM = Big Area Additive Manufacturing. (*Metamorphic Manufacturing: Shaping the Future of On-Demand Components*, 2019, p. 9. Graph produced based on inputs from Glenn Daehn and Gutowski et al., "Note on the Rate and Energy Efficiency Limits for Additive Manufacturing," *J. Ind. Ecol.* 21, S69 [2017].)

over methods such as manufacturing through machining.

While the study characterizes MM as disruptive, it also identifies and addresses a number of barriers to the full realization of the technology's benefits. To this point, Daehn believes that the most valuable aspect of the report is the action plans that it offers of "things that we can do as a community to actually start developing" this technology. He also commented that the report "is designed so that readers of various sorts can jump in and start taking actions."

Daehn said he was excited for the report to be released because of "the opportunity to bring a completely new technology to the United States." While the report describes what could be a fully realized MM technology, Daehn noted that this technology could even be advanced beyond that. "I don't see this as something with a clear end point and beginning point, but as part of the technology continuum," he said. "I encourage everyone from students and academic/industry researchers to government agency employees to download the report and start taking action." Those who are interested in helping usher in this technology can download the report for free at www.tms.org/MetamorphicManufacturing.

Fig. 3. A conceptual metamorphic manufacturing suite. (*Metamorphic Manufacturing: Shaping the Future of On-Demand Components*, 2019, p. xxviii.)

Implementing Verification and Validation Practices in the Mechanics of Materials Community

Another new TMS technical report released at TMS2019 was *Verification and Validation of Computational Models Associated with the Mechanics of Materials*, developed with the support of the U.S. National Science Foundation. The report is an examination on the current state of verification and validation (V&V) of computational models in the mechanics of materials (MOM) community. In this context, verification refers to confirming that the mathematical equations that serve as the basis of computational models are accurate, and validation refers to confirming that the results of the predictive models properly represent the physical world, via comparison to experimental results. While V&V has been developed more fully in other disciplines, its widespread development and adoption within the MOM community has been seriously lagging, and is critically important for unlocking the great potential of such models in reducing the time and cost of developing new materials and manufacturing processes.

To address this issue, the report outlines a number of challenges to the development and adoption of V&V in the MOM community that were identified during a workshop of invited researchers and thought leaders on the topic. Once these were determined, the workshop team identified opportunity areas and recommendations for overcoming these challenges, encompassing technical, cultural, and policy-related challenges. Those who are interested in aiding the development and adoption of V&V approaches within the MOM community are encouraged to download the report, at no cost, at www.tms.org/VerificationandValidation.