designs

Editorial

Design and Applications of Additive Manufacturing and 3D Printing

Mika Salmi

Department of Mechanical Engineering, Aalto University, 02150 Espoo, Finland; mika.salmi@aalto.fi

1. Introduction

Additive manufacturing (AM), or commonly, 3D printing, has been witnessed in various applications and purposes such as industrial applications in consumer products, energy, aerospace, medical, spare parts [1–6] and research and development activities such as prototyping, testing and material development [7–9]. What is common to all of these is that AM is not possible without the 3D model resulting from the design phase. Since AM allows the manufacture of complex geometries, we can improve the performance of the products through that. However, it is challenging to specify the best geometry for each purpose since we can optimize different things such as the mass, strength, price, manufacturing speed or performance. In addition, different AM processes require different approaches. This Special Issue offers a platform for researchers to study and report different design aspects of AM by taking into account differences between AM processes. Five original articles were published in this issue.

For the powder bed fusion of Ti6Al4V, Akram et al. [10] established a linear relationship between percentage elongation and the combined size of α lath and powder layer thickness using the rule of mixtures. They studied the microstructure's effect on the magnitude and anisotropy of the resultant mechanical properties, such as the yield strength and elongation. A Hall–Petch relationship was established between the α lath size and the yield strength magnitude for the as-built, heat-treated, transverse, and longitudinal built samples. Percentage elongation was affected by both α lath size and powder layer thickness, due to its correlation with the prior β columnar grain size.

To increase the spanwise length of the wing of unmanned aerial vehicles (UAV), Bishay et al. [11] studied a new design for the core of span-morphing. The purpose of morphing the wingspan is to increase lift and fuel efficiency. The main components that make up the structure are zero Poisson's ratio honeycomb substructure, telescoping carbon fiber spars and a linear actuator. The design maintains the airfoil shape and cross-sectional area during morphing because of its transverse rigidity and spanwise compliance. The wing model was analyzed computationally, manufactured, assembled and experimentally tested.

Guo et al. [12] compared the shape, porosity and mean curvature between triply periodic minimal surfaces and tetrahedral implicit surfaces. For replacing the conventional Cartesian coordinates, they developed a new coordinates system based on the perpendicular distances between a point and the tetrahedral faces to capture the periodicity of an implicit tetrahedral surface. For the triply periodic minimal surface, various tetrahedral implicit surfaces, including P-, D- and G-surfaces, were defined by combinations of trigonometric functions. For demonstration, they made a femur scaffold construction to demonstrate the process of modeling porous architectures using the implicit tetrahedral surface.

Topology optimization and laser-based powder bed fusion additive manufacturing were utilized by Orne et al. [13] to develop space flight hardware. They redesigned and manufactured two heritage parts for a Surrey Satellite Technology LTD (SSTL) Technology Demonstrator Space Mission and a system of five components for SpaceIL's lunar launch vehicle. During topology optimization, they incorporated AM manufacturing constraints

check for updates

Citation: Salmi, M. Design and Applications of Additive Manufacturing and 3D Printing. *Designs* **2022**, *6*, 6. https://doi.org/10.3390/designs6010006

Received: 14 January 2022
Accepted: 15 January 2022
Published: 19 January 2022

such as the minimization of support structures, removing the unsintered powder and the minimization of heat transfer jumps. The designs were verified by finite element analysis. The components were fabricated, and the AM artifacts and in-process testing coupons have undergone verification and qualification testing.

Chadha et al. [14] explored the AM-enabled combination of function approach for the design of modular products. The approach replaced sub-assemblies within a modular product or system with more complex consolidated parts. This can increase the reliability of systems and products by reducing the number of interfaces and optimizing the more complex parts during the design. The fewer parts and the ability of users to replace or upgrade the system or product parts on-demand should reduce user risk and life cycle costs and prevent obsolescence. A case study for redesigning the AIM-120 AMRAAM Airframe was presented to illustrate the concept.

These studies show many different design and optimization paths for AM. Part consolidation, topology optimization, porous and lattice structures, modularity and optimizing mechanical properties can be performed with AM through design and AM process parameters. This opens a window where possibilities are endless, but finding the best ones is highly challenging. Moreover, the development of new AM processes and materials such as 4D printing will produce totally new challenges for design since dynamic behavior after the 3D printing needs to be considered. These could example include combining topology optimization with 4D printing and functionally graded adaptive metamaterials [15,16].

Funding: JAES Foundation.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: All the articles were refereed through a double-blind peer-review process. The Guest Editor would like to thank all the authors for their excellent contributions. Special thanks to the reviewers for their valuable and critical comments significantly improved the articles. Thanks to the staff of the *Designs* journal, in particular, Ryan Pei, for his efforts and kind assistance.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Bogers, M.; Hadar, R.; Bilberg, A. Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technol. Forecast. Soc. Change* **2016**, *102*, 225–239. [CrossRef]
2. Sun, C.; Wang, Y.; McMurtrey, M.D.; Jerred, N.D.; Liou, F.; Li, J. Additive manufacturing for energy: A review. *Appl. Energy* **2021**, *282*, 116041. [CrossRef]
3. Kestilä, A.; Nordling, K.; Miikkulainen, V.; Kaipio, M.; Tikka, T.; Salmi, M.; Auer, A.; Leskelä, M.; Ritala, M. Towards space-grade 3D-printed, ALD-coated small satellite propulsion components for fluidics. *Addit. Manuf.* **2018**, *22*, 31–37. [CrossRef]
4. Mäkitie, A.; Paloheimo, K.S.; Björkstrand, R.; Salmi, M.; Kontio, R.; Salo, J.; Yan, Y.; Paloheimo, M.; Tuomi, J. Medical applications of rapid prototyping–three-dimensional bodies for planning and implementation of treatment and for tissue replacement. *Duodecim* **2010**, *126*, 143–151. [PubMed]
5. Chekurov, S.; Salmi, M. Additive manufacturing in offsite repair of consumer electronics. *Phys. Procedia* **2017**, *89*, 23–30. [CrossRef]
6. Najmon, J.C.; Raeisi, S.; Tovar, A. Review of additive manufacturing technologies and applications in the aerospace industry. *Addit. Manuf. Aerosp. Ind.* **2019**, *11*, 7–31.
7. Pham, D.T.; Gault, R.S. A comparison of rapid prototyping technologies. *Int. J. Mach. Tools Manuf.* **1998**, *38*, 1257–1287. [CrossRef]
8. Scaravetti, D.; Dubois, P.; Duchamp, R. Qualification of rapid prototyping tools: Proposition of a procedure and a test part. *Int. J. Adv. Manuf. Technol.* **2008**, *38*, 683–690. [CrossRef]
9. Nilsén, F.; Ituarte, I.F.; Salmi, M.; Partanen, J.; Hannula, S.P. Effect of process parameters on non-modulated Ni-Mn-Ga alloy manufactured using powder bed fusion. *Addit. Manuf.* **2019**, *28*, 464–474. [CrossRef]
10. Akram, J.; Pal, D.; Stucker, B. Establishing Flow Stress and Elongation Relationships as a Function of Microstructural Features of Ti6Al4V Alloy Processed using SLM. *Designs* **2019**, *3*, 21. [CrossRef]
11. Bishay, P.L.; Burg, E.; Akinwunmi, A.; Phan, R.; Sepulveda, K. Development of a New Span-Morphing Wing Core Design. *Designs* **2019**, *3*, 12. [CrossRef]
12. Chadha, C.; Crowe, K.A.; Carmen, C.L.; Patterson, A.E. Exploring an AM-Enabled Combination-of-Functions Approach for Modular Product Design. *Designs* **2018**, *2*, 37. [CrossRef]

13. Guo, Y.; Liu, K.; Yu, Z. Tetrahedron-Based Porous Scaffold Design for 3D Printing. *Designs* **2019**, *3*, 16. [CrossRef]
14. Orme, M.; Madera, I.; Gschweitl, M.; Ferrari, M. Topology Optimization for Additive Manufacturing as an Enabler for Light Weight Flight Hardware. *Designs* **2018**, *2*, 51. [CrossRef]
15. Bodaghi, M.; Damanpack, A.; Liao, W.H. Adaptive metamaterials by functionally graded 4D printing. *Mater. Des.* **2017**, *135*, 26–36. [CrossRef]
16. Zolfagharian, A.; Denk, M.; Bodaghi, M.; Kouzani, A.Z.; Kaynak, A. Topology-optimized 4D printing of a soft actuator. *Acta Mech. Solida Sin.* **2019**, *13*, 137. [CrossRef]