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EDITORIAL

Introduction to the Special Issue on Design and Simulation in Additive Manufacturing

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As a key technology in the advanced manufacturing field, additive manufacturing (AM) technology introduces a new design concept that is guided by function rather than by manufacturing, promoting the rapid development of the high-tech industry. However, as-fabricated parts have an unstable performance in quality due to rapid heating and rapid cooling induced by energy source. Therefore, quality control of the manufacturing process, which is mainly studied by numerical simulation, is one of the most active research topics in the AM field. In the view of increasing attention in AM technology, this special issue contributes to highlighting recent challenges and developments of AM-based design and simulation, with focuses on microstructure stability and evolution, multi-physics problems and process enhancements.

This special issue is organized by six guest editors who have made important contributions in the field of AM and AM-based design and simulation. There are nine papers accepted after a critical peer review process. Topics include three-dimensional physical models and finite element analysis models of the AM process, AM-based structure design and simulation, heterogeneous object modeling methods, and others.

The summary of accepted papers in this special issue is shown as follows:

As is known to all, the processing parameters play an important role in the final performance of as-fabricated parts. Dai et al. [1] proposed a three-dimensional physical model of the randomly packed powder material irradiated by the laser beam, where the transformation of the material phase, the melt spreading, the interaction of the free surface of the molten pool and the recoiling pressure caused by the material evaporation were taken into account. The model performed the simulation of the thermodynamics behavior within the molten pool and the surface morphology evolution during selective laser melting (SLM), revealing the effect of the processing parameters on the melting behavior of the powder material, the melt convection, the surface morphology evolution and the densification behavior.

Though AM technology has the ability to fabricate parts with complicated structures, it cannot precisely fabricate large overhangs, especially those hangs close to horizontal or over the void region. As-fabricated parts might be derailed from the original design model due to these overhangs, and this manufacturing error would make the performance of the parts unable to meet the design requirements. Xia et al. [2] put forward a new finite element (FE) analysis model which simulated the layer-by-layer AM process with consideration of manufacturing error and staircase effect. The proposed model can predict the performance of the AM objects in the design stage, assisting designers to optimize their design model by simulation.

During the SLM process, spatter always easily generate due to the acute interaction between laser and powder. Spatter particles will contaminate the fresh powder and cause defects in the internal structure, seriously affecting the manufacturing quality of as-fabricated parts. In order to control spatter behavior, Wang et al. [3] adopted the finite element method to simulate the transient temperature field during the SLM process and study the formation mechanism of spatter. The dynamic behavior of spatter during the SLM processing was observed by a high-speed camera to verify the simulation result. The correlations between the light intensity of the molten pool, the spatter, and the internal defects of the part were established. These correlations will contribute to achieving real-time monitoring and online control in the SLM process.

Three-dimensional printing (3DP) has become one of the most popular manufacturing technologies nowadays. However, the collision and penetration of the binder and the sand bedding, which are the key to the accuracy of the 3DP process, is difficult to observe and measure. In order to simulate the porous structure of the sand bed in the 3DP process, Gao et al. [4] proposed an equivalent cylindrical penetration model that avoided errors caused by only changing the porosity without changing the spatial structure. Furthermore, the simulation model of the binder penetration process for multi-nozzle and multi-layer was established to reflect the complete penetration process and predict the sand agglomeration.

A large number of complex structure designs, which are of great significance in various fields, eventually come true with the help of AM technology. For example, Wang et al. [5] designed a novel micromixer with complex 3D-shape inner units which is of great value in the chemical industry and manufactured it through SLM. The performance and the mechanism of the novel micromixer were investigated by the Villermaux–Dushman reaction system and Compute Fluid Design (CFD) simulation. The results of the research showed that the novel micromixer mainly contained two types of mixing behavior (collisions and swirls), achieving higher mixing efficiency and lower pressure drop compared to a conventional micromixer.

The implant needs to be customized to accurately match the patient's body, so AM technology has broad application prospects in the biomedical field. However, there are still some problems that need to be solved before AM technology is put into clinical application. Chen et al. [6] conducted exploratory research on computer-aided design and SLM fabrication of a bionic porous titanium spine implant. In the research, the mechanical properties of as-fabricated implants were measured, and the measurement results showed that as-fabricated implants had better performance in some aspects compared with traditional implants. In addition, some suggestions were proposed to optimize the structure design and SLM fabrication of the implant.

The porous structure has important applications in the aerospace field, but it is difficult to fabricate through traditional manufacturing methods. Thanks to AM technology, some vital parts with a porous structure in the spacecraft can be fabricated. Wang et al. [7] studied three types of porous unit cells for the regenerative cooling thermal protection system. A combination of experiments and finite element simulations was conducted to measure the mechanical response of these structures under a tensile load. The relationship between the geometry and mechanical properties of a unit cell was established and the deformation mechanism of the porous unit cell was revealed. According to the results, the Gyroid unit cell is more suitable for the regenerative cooling structure than the other unit cells in the study.

Heterogeneous material parts play an increasingly important role in modern industry, but they are difficult to design and manufacture by traditional methods. Computer-aided means are feasible methods to realize the design, analysis, and integrated manufacturing of heterogeneous material parts, but they work efficiently only when the geometry and material information of heterogeneous material parts are expressed in a completely digital way. Zang et al. [8] proposed a new heterogeneous object modeling method based on the Non-Uniform Rational B-Spline (NURBS) method to realize the inverse construction of heterogeneous objects. The new modeling method enables the geometry and material distribution to be better designed according to the actual need, making AM design easier and more practical.

SLM has achieved demonstration applications in some high-tech fields, but the optimization of process parameters is still the main concern of SLM production. Based on the open-source discrete element method (DEM) framework Yade and the open-source finite volume method (FVM) framework OpenFOAM, Cao [9] predicted the multi-layer multi-path process of SLM, and quantitatively analyzed the influence of process parameters (including laser power, scanning speed, hatch space and layer thickness) on the porosity and surface roughness. This new forecasting method is expected to provide a basis for process control in actual SLM production.

In summary, we hope that the studies collected in this special issue can offer a good reference to researchers in related fields and inspire them to conduct further research on design and simulation in AM.

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References

1. Dai, D., Gu, D., Ge, Q., Ma, C., Shi, X. et al. (2020). Thermodynamics of molten pool predicted by computational fluid dynamics in selective laser melting of Ti6Al4V: Surface morphology evolution and densification behavior. *Computer Modeling in Engineering & Sciences, 124(3),* 1085–1098. DOI 10.32604/cmes.2020.010927.
2. Xia, Z., He, Z., Wang, Q., Wang, Y. (2020). A new finite element model with manufactured error for additive manufacturing. *Computer Modeling in Engineering & Sciences, 124(2),* 703–720. DOI 10.32604/cmes.2020.010368.
3. Wang, Z., Wang, X., Zhou, X., Ye, G., Cheng, X. et al. (2020). Investigation into spatter particles and their effect on the formation quality during selective laser melting processes. *Computer Modeling in Engineering & Sciences, 124(1),* 243–263. DOI 10.32604/cmes.2020.09934.
4. Gao, X., Yang, W., Xian, H., Tu, X., Wang, Y. (2020). Numerical simulation of multi-layer penetration process of binder droplet in 3DP technique. *Computer Modeling in Engineering & Sciences, 124(1),* 227–241. DOI 10.32604/cmes.2020.09923.
5. Wang, D., Ye, G., Mai, J., Chen, X., Yang, Y. et al. (2020). Novel micromixer with complex 3D-shape inner units: Design, simulation and additive manufacturing. *Computer Modeling in Engineering & Sciences, 123(3),* 1061–1077. DOI 10.32604/cmes.2020.09842.

6. Chen, X., Wang, D., Dou, W., Wang, Y., Yang, Y. et al. (2020). Design and manufacture of bionic porous titanium alloy spinal implant based on selective laser melting . *Computer Modeling in Engineering & Sciences, 124(3),* 1099–1117. DOI 10.32604/cmes.2020.09619.
7. Wang, X., Wang, C., Zhou, X., Zhang, M., Zhang, P. et al. (2020). Innovative design and additive manufacturing of regenerative cooling thermal protection system based on the Triply periodic minimal surface porous structure. *Computer Modeling in Engineering & Sciences, 123(2),* 495–508. DOI 10.32604/cmes.2020.09778.
8. Zang, T., Zhu, D., Mu, G. (2020). Inverse construction methods of heterogeneous NURBS object based on additive manufacturing. *Computer Modeling in Engineering & Sciences, 125(2),* 597–610. DOI 10.32604/cmes.2020.09965.
9. Cao, L. (2020). Mesoscopic-scale numerical investigation including the influence of process parameters on LPBF multi-layer multi-path formation. *Computer Modeling in Engineering & Sciences, 126(1),* 5–23. DOI 10.32604/cmes.2021.014693.