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B-spline Based Topology Optimization for Metal Hybrid Additive-Subtractive Manufacturing

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Hybrid additive-subtractive manufacturing is an emerging technology, which is capable of fabricating complex raw part through additive manufacturing (AM) and then finishing the part to meet surface and dimensional requirements through subtractive machining [1]. Therefore, a large design space could be explored to ensure design creativity, and the derived size, form, and surface quality satisfy engineering requirements.

However, there are key current issues that are impeding the marriage between hybrid manufacturing and topology optimization: 1) Inability to connect the topology optimization result to commercial CAD system for post-editing, 2) Difficulty in post-machining topology optimized AM parts due to their highly complex shapes, and 3) Uncontrollable expense in manufacturing because of cost information absence in the optimization problem formulation.

To fix these issues, this research contributes a B-spline based topology optimization method capable of interfacing commercial CAD systems, accounting for post-machining requirements, and also effectively controlling the overall manufacturing cost. Specifically, both the B-spline control points [2] and feature modeling history will be adopted as the shape and topology variables, because under the B-spline based topology optimization framework, starting from different feature modeling histories will lead to distinctive design results. A 'feature modeling history' topological derivative concept is proposed and highlighted as a novel approach to switch feature modeling history during the optimization process. Consequently, both the B-spline information and feature modeling history are important assets to interface CAD for user-friendly post-editing. Moreover, the topology optimized AM component would be composed of only machining-friendly surfaces, which can be economically and efficiently finished by pocket machining [1] and 3-axis freeform machining. Other than that, a cost estimation function is established based on the B-Spline information and the employed hybrid manufacturing process [3,4]. It will be embedded into the formulation of the optimization problem, through which the overall manufacturing cost can be approximately constrained below the expected limit.

In summary, the technology developed will significantly shorten the design phase during new AM product development, which will potentially lead to wider adoption of AM. Effectiveness of the proposed method will be proved through studies of several real parts.

References

[1] J. Liu, and A.C. To. Topology optimization for hybrid additive-subtractive manufacturing. *Structural and Multidisciplinary Optimization*, in press. doi:10.1007/s00158-016-1565-4.

[2] W. Zhang, L. Zhao, T. Gao, and S. Cai. Topology optimization with closed B-splines and Boolean operations. *Computer Methods in Applied Mechanics and Engineering*, 315:652-670, 2017.

[3] Z. Bouaziz, J.B. Younes, and A. Zghal. Cost estimation system of dies manufacturing based on the complex machining features. *International Journal of Advanced Manufacturing Technology*, 28:262–271, 2006.

[4] M. Baumers, C. Tuck, R. Wildman, I. Ashcroft, E. Rosamond, R. Hague, Combined build-time, energy consumption and cost estimation for direct metal laser sintering, 23nd Annual international solid freeform fabrication symposium, in Austin, TX, 2012.