A Framework for Large Scale Fused Pellet Modeling (FPM) by An Industry Robot

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Abstract

Fused pellet modeling (FPM) is an important method in additive manufacturing technology, where granular material is used instead of filaments. In FPM, prototypes are constructed by the sequential deposition of material layers. As the size of the part increases, the problem of long build times and part deformation becomes critical. In this paper, methods for eliminating the void density during deposition and accuracy control principles for large scale FPM processes are studied. By analyzing the ab initio principles of this process, a mini extruder with variable pitch and progressive diameter screw for the large scale fused deposition is proposed. Based on polymer extrusion theory and non-Newtonian fluid properties, each of the design parameters are analyzed, such as the length of different function sections of screw, die shape of extruder nozzle, and the material properties. According to these analysis results, an extrusion process simulation for controlling the filament shape is carried out with multi-physics modeling software and proved the FPM could increase the building efficiency and deposition quality for large size parts.

Introduction

Layered manufacturing with extruded material is one of the most promising rapid prototyping techniques to demonstrated novel design ideas and reduce the product development cycle. This process fabricates prototypes by extruding the material in semi-fluid status through a heated nozzle in a prescribed pattern onto a platform. Various types of material could be applied in this process including polymer, cement, plaster, and wax.

The deposition material should be extruded continuously, stably and under constant temperature during the layered manufacturing process. “Continuously” means there should be no interruption of extrusion when the nozzle is scanning the deposition path; “Stably” involves the stable extrusion amount and accurate geometry of the semi-molten material; “Thermostatic” is to ensure the bonding quality between deposition tracks.

The fused deposition modeling (FDM) developed by Stratasys Inc., has been a leading rapid prototyping technology, which involves layer by layer deposition of extruded material through a nozzle using feedstock filaments from a spool [1]. The material feeding process of FDM realized by two friction wheels rotate reversely to push the filament into a heated nozzle (Figure 1). Because of the advantages of simple structure and easy control, it has been widely used in most of the fused deposition systems. But the weak points of this method are also very obvious, the extrusion force is limited by the surface compressive strength of filament and the contact area between friction wheels and filament. Insufficient friction will cause slip feeding, and too much compressive force applied on the filament might be break it off, both of these will affect the extrusion quality. To shift from rapid prototype to agile fabrication by broadening the

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References

[1] Masood S H. Intelligent rapid prototyping with fused deposition modelling[J]. Rapid Prototyping Journal, 1996, 2(1): 24-33.
[2] Bellini A, Shor L, Guceri S I. New developments in fused deposition modeling of ceramics[J]. Rapid Prototyping Journal, 2005, 11(4): 214-220.
[3] Wang T M, Xi J T, Jin Y. A model research for prototype warp deformation in the FDM process[J]. The International Journal of Advanced Manufacturing Technology, 2007, 33(11-12): 1087-1096.
[4] Jayanthi S, Keefe M, Gargiulo E P. Studies in stereolithography: influence of process parameters on curl distortion in photopolymer models[C]. Solid Freeform Fabrication Symposium 1994. University of Texas, Austin, 1994: 250-258.
[5] Bellehumeur C, Li L, Sun Q, et al. Modeling of bond formation between polymer filaments in the fused deposition modeling process[J]. Journal of Manufacturing Processes, 2004, 6(2): 170-178.
[6] Sun Q, Rizvi G M, Bellehumeur C T, et al. Effect of processing conditions on the bonding quality of FDM polymer filaments[J]. Rapid Prototyping Journal, 2008, 14(2): 72-80.
[7] Li L, Sun Q, Bellehumeur C, et al. Composite modeling and analysis for fabrication of FDM prototypes with locally controlled properties[J]. journal of Manufacturing Processes, 2002, 4(2): 129-141.
[8] Hori Y, Okubo S. On the normal stress effect and the Barus effect of polymer melts[J]. Journal of Rheology (1978-present), 1980, 24(1): 39-53.
[9] Bogale K. Simulation and Design of Extrusion Dies[D]. Arcada University of Applied sciences, Finland, 2011.