Procedia Manufacturing
Volume 5, 2016, Pages 1183–1196
44th Proceedings of the North American Manufacturing Research Institution of SME http://www.sme.org/namrc

Toward Rapid Manufacturability Analysis Tools for Engineering Design Education

Roby Lynn[1], Christopher Saldana[1], Thomas Kurfess[1], Nithin Reddy[2], Timothy Simpson[2], Kathryn Jablokow[2], Tommy Tucker[3], Saish Tedia[4], Christopher Williams[4]
[1]*Georgia Institute of Technology, Atlanta, GA*
[2]*Pennsylvania State University, State College, PA*
[3]*Tucker Innovations, Inc., Charlotte, NC*
[4]*Virginia Polytechnic Institute and State University, Blacksburg, VA*
roby.lynn@gatech.edu, christopher.saldana@me.gatech.edu, kurfess@gatech.edu, nithin.iitkgp@gmail.com, tws8@engr.psu.edu, kwl3@psu.edu, tommy@tuckerinnovations.com, saisht@vt.edu, cbwill@vt.edu

Abstract

Engineering students are often unaware of manufacturing challenges that are introduced during the design process. Students will sometimes design parts that are either very difficult or impossible to manufacture, because they are unaware of the intricacies and limitations of various manufacturing processes. Design for manufacturability (DFM) education must be improved to address these issues, and this work is a vision for implementation of a rapid method for facilitating DFM education in terms of subtractive and additive manufacturing processes. The goal is to teach students about how their designs impact ease and cost of manufacturing, in addition to giving them knowledge and intuition to fluidly move between both additive and subtractive manufacturing mindsets. This work describes use of a commercial high-performance computing (HPC)-accelerated parallelized trajectory planning software package called SculptPrint, which enables students to visualize the subtractive manufacturability of the parts they design. While SculptPrint is currently limited to subtractive manufacturability analysis, this work also describes the future development of a manufacturability analysis tool for Additive Manufacturing (AM). Analysis is performed on a set of sample parts for both subtractive and additive manufacturing. The results demonstrate the effectiveness of advanced manufacturability tools in manufacturing process selection with consideration of manufacturing time, cost, and complexity. A distributed architecture is also examined that will allow students to perform manufacturability analysis without physical access to HPC hardware.

Keywords: GPGPU, High Performance Computing, Design for Manufacturability, Computer-Aided Manufacturing, Additive Manufacturing, Subtractive Manufacturing, Manufacturability Education, Manufacturability Analysis, Distributed Cybermanufacturing

Selection and peer-review under responsibility of the Scientific Programme Committee of NAMRI/SME

doi:10.1016/j.promfg.2016.08.093

1 Introduction

Subtractive manufacturing (SM) is a classical idea that has been evolving for a long time. It is responsible for a large number of parts that are manufactured in the United States and the rest of the world. SM has many advantages over AM, including the ability to shape a variety of materials and the superior surface finish and uniform mechanical properties (strength, elastic modulus, etc.) of the finished part. However, SM can be challenging and requires substantial experience to use effectively. While the rise of CNC (Computer Numerical Control) machine tools has enabled greatly increased part complexity and manufacturing speed, skilled operators are still required in order to use these platforms. The most significant hurdle in the implementation of these machines by novice students, aside from cost, is the difficulty of the required machine programming. This programming is usually accomplished using a computer-aided manufacturing (CAM) package, which creates G-Code to run the machine; CAM is powerful, but it still requires machining experience to fully understand and implement. As a result, the use of CNC machine tools by students for the manufacture of complex parts is very difficult and not commonly taught in typical engineering programs.

Instead, students tend to seek more user-friendly additive manufacturing (AM) processes for producing prototype parts, such as fused deposition modeling (FDM) for plastics and Direct Metal Laser Sintering (DMLS) for metals (Geraedts et al., 2012). AM is the process of building a 3D object in a layer-by-layer fashion. Each successive layer of material is fused with the preceding layer by the application of thermal energy, binders, or curing agents. A variety of AM technologies are currently available for different types of polymers, metals, alloys, composites, ceramics and resins (Frazier, 2014, Wong and Hernandez, 2012), and these AM processes allow easy and convenient creation of complex geometries without extensive manufacturing experience (Anderson, 2012, Gibson et al., 2010, Lipson and Kurman, 2013, Flowers and Moniz, 2002). Unlike SM, AM does not require the use of jigs, fixtures, complex tooling, extensive human interaction, or coolants (Huang et al., 2013). However, this ease of making parts often comes at the expense of additional build time and cost. AM is not always economical, and machining a part can often be less expensive (Pîrjan and Petroşanu, 2013), yet many students have turned to AM as the preferred option for making parts, no matter how simple they are. Since traditional SM is dominant in industry, it is important for students to not undermine conventional manufacturing if they are to become effective manufacturing engineers. Additionally, students need to recognize that AM is not always the best process for realizing their designs in terms of product quality, cost, and manufacturing time; while it is the best option in some cases, subtractive processes are more valuable in other scenarios. Students need to be trained in both AM and SM processes; this will enable them to think about both types of processes and ensure that they have the ability to seamlessly and completely leverage the two across the design spectrum.

This paper describes a framework for use in engineering design education that will provide students with a better and more rigorous understanding of both traditional subtractive manufacturing and additive manufacturing. It promotes the thought processes of students to consider both AM and SM processes, along with combinations thereof. Additionally, this framework gives students added insight into implementation details of these manufacturing processes; it is a first step towards an educational experience that integrates both additive and subtractive manufacturing into the design and build process. DFM principles are well known and can be best taught using a hands-on approach (Bralla, 1999). Students must be comfortable in both the AM and SM realms; thus, Georgia Tech (GT), Virginia Tech (VT), and Penn State University (PSU) have combined their experience in AM and SM processes to provide analysis tools usable in both arenas. The result leverages a software package, SculptPrint, which was developed jointly between GT and Tucker Innovations for rapid manufacturability analysis, visualization, and G-Code creation. SculptPrint removes challenges present in traditional CAM and allows students to rapidly see their designs from concept to production. It also allows for easy design changes and modifications. This work also emphasizes the need for manufacturability analysis for AM.