Chapter 7

Subtractive Rapid Prototyping: Creating a Completely Automated Process for Rapid Machining

Matthew C. Frank
Department of Industrial and Manufacturing Systems Engineering
Iowa State University, Ames, IA 50011, mfrank@iastate.edu

Abstract:

This chapter presents a description of how CNC milling can be used as a rapid prototyping process. The methodology uses a layer–based approach for machining (like traditional rapid prototyping) for the rapid, automatic machining of common manufactured part geometries in a variety of materials. Parts are machined using a plurality of 2½-D toolpaths from orientations about a rotary axis. Process parameters such as the number of orientations, tool containment boundaries and tool geometry are derived from CAD slice data. In addition, automated fixturing is accomplished through the use of *sacrificial support* structures added to the CAD geometry. The chapter begins by describing the machining methodology, and then presents a number of critical issues that affect making the process automatic and efficient. The CNC-RP process is compared and contrasted to existing RP processes. In particular, we consider the differences in an additive versus subtractive process with respect to accuracy and material choices. The strengths and limitations of rapid machining are illustrated, along with a discussion on the economics of

using rapid machining versus additive RP and/or traditional machining processes to create single or small batches of parts.

Key words:

Rapid Prototyping, CAD, CAM, CNC Machining, STL, Process Planning

7.1. Background

Over the past two decades, numerous *additive* RP processes have been developed. The first commercially available process was Stereolithography, which uses photo-curable resin to create parts layer-by-layer from a vat of liquid. Since then, many processes that utilize layer-based principles have been developed, and today the price of low-end RP systems has decreased considerably. In particular, desktop 3D printing systems that can create concept models have become more commonplace. These systems create *Form* models, which simply represent the CAD geometry in physical form, although they are not useful for much more. Parts are created in weak materials with poor accuracy, however the processes are automated and quite simple to use. On the other end, much work has focused on developing systems that can create truly functional prototypes in strong materials. In particular, new systems were designed to work with metals, such as Direct Metal Laser Sintering (DMLS), Laser Engineering Net Shaping (LENS) and Electron Beam Melting (EBM). The motivation behind these systems is to create truly functional metal parts. In the previous RP systems, the commonly used materials are plastics, paper and powders, which is sufficient for concept models or perhaps plastic injection molded parts, for example. The biggest challenge with metals to date has been in the energy required to create layer based metal parts (e.g.: it is easy to sinter plastic particles, but more difficult to sinter metal). Since sintering cannot produce fully dense parts, systems like LENS use more powerful lasers and a stream of powder while EBM utilizes an electron gun to melt the powder layers. Obviously, the cost of these systems is significantly higher than others and can approach $1 million (US). Unfortunately, LENS and EBM often do not have the accuracy and surface finish capabilities required for the parts they are intended to create. Therefore, post-processing (typically using machining) is common, in order to provide better surface finishes and/or tight tolerances on critical features.