Chapter 2
Surface Characterization in Fused Deposition Modeling

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ABSTRACT

Fused deposition modeling is a proven technology, widely diffused in industry, born for the fabrication of aesthetic and functional prototypes. Recently used for small and medium series of parts and for tooling, it received particular attention in order to integrate prototyping systems within production. A limiting aspect of this technology is the obtainable roughness and above all its prediction: no machine software and Computer-Aided Manufacturing implements a relationship between process parameters and surface quality of components. The prediction of the surface properties is an essential tool that allows it to comply with design specifications and, in process planning, to determine manufacturing strategies. Recently, great effort has been spent to develop a characterization of such surfaces. In this chapter, prediction models are presented and a new characterization approach is detailed. It is based on the theoretical prediction of the geometrical roughness profile, thus allowing it to obtain, in advance, all roughness parameters.

INTRODUCTION

The competition, in the recent years, increased the identified need of time to market. A successful product development depends on managing resources and circumstances with conflicting objectives. The products must have highest quality, lowest cost and must be produced in a flexible way and in the shortest time (Toriya, 2010; Bramley, Brissaud, Coutellier, & McMahon, 2005). The introduction of new technologies increases the number of options at disposal of industries, but the management of such a manufacturing landscape becomes complex. In such a way, the improvement of the productivity must be accomplished by maintaining, if not improving, product quality. Several factors make this aim very difficult. We can only sign: fast changing in customer desires, significance of aesthetic, environmental

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requirements, decreasing in lifetime, decreasing prices, decreasing budgets, limitation from regulations and standards (Gebhardt, 2003). Thus, the knowledge of the optimum machining parameters is vital, and the industry must acquire as quickly as possible this process parameters for each specific operation. A product requirement, that research has extensively investigated, is the surface quality. It plays an important role on product properties, such as wear resistance, coating and light reflection (Whitehouse, 2011). It is well known that a reliable indicator is surface roughness expressed by several parameters. The intrinsic complexity, arising from surface fabrication, makes its modeling very difficult leading to significant area of interest. In the optics of fabricating a high surface-quality product, the resources necessary to improve the manufacturing chain are numerous and affect several process stages: product design, test, fabrication, market. The efficient use of such resources calls for new technologies. As a result, in the last two decades, a powerful tool for rapid product development has been introduced, namely, rapid prototyping (RP). This term is used in a variety of industries to describe a process for rapidly creating components before final release or commercialization. In a product development context, the term RP was used widely to describe a host of technologies which creates physical part directly from digital data. Respect to traditional technologies, RP builds the parts adding or bonding material, layer by layer: this idea offers advantages in many applications because parts can be fabricated with any geometric complexity without the need for elaborate machine setup or final assembly. Other manufacturing processes require a careful and detailed analysis of the part geometry to determine the sequence of the operations, the needed tools, the process parameters, the machines setup, the fixing systems, and the semi-manufactured products. Conversely, RP needs only part specifications, and process parameters do not depend upon geometric complexity, employing the same semi-manufactured product. These advantages, combined with the recent introduction of new materials and the improvements of part quality and machines accuracy, make these technologies reliable to produce final products and assist the process tooling stage (Hopkinson, Hague, & Dickens, 2005). These aspects determined the wide diffusion in the industry: significant application fields are aerospace, automotive, biomedical, customer product industry, design and tooling (Chua, 1994; Chua, Leong, & Lim, 2010; Ingole, Kuthe, Thakare, & Talankar, 2009; Ivanova, Williams, & Campbell, 2013).

These new evolutions of RP modified the scenarios requiring a new nomenclature. The Technical Committee within ASTM International agreed that the RP acronym was obsolete and it adopted the term Additive Manufacturing (AM) (Wohler, 2008). Now AM is an increasingly important tool for product development which can reduce the fabrication of complex objects to a manageable, straightforward and relatively fast process.

AM involves a number of stages that move from the virtual model to the finished parts (Figure 1). The first step is related to the 3D model generation, typically in CAD environment or by Reverse Engineering techniques. The second step is the conversion to the interchange file: Standard Triangulation Language (STL) file format encloses tessellated surfaces and it has become the standard de facto. In the third step the file is transferred to the prototyping system and process parameters are chosen: part orientation, layer thickness, model and support strategies. The geometry is then sliced into layers and the generated curves are verified. The fifth step regards the support creation. Then, the model, the support and the transition moves toolpaths are generated and saved. The system is ready for an automatic fabrication of physical parts. The last stage is the post processing operations, which consist of the support removal and additional cleaning up, if required.

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