Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 67 (2018) 185 – 190
www.elsevier.com/locate/procedia

11th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '17

Self-learning calculation for selective laser melting

Jan-Peer Rudolph[a,*], Claus Emmelmann[a,b]

[a]LZN Laser Zentrum Nord GmbH, Am Schleusengraben 14, 21029 Hamburg, Germany
[b]Institute of Laser and System Technologies, Hamburg University of Technology, Denickestraße 17, 21073 Hamburg, Germany

* Corresponding author. Tel.: +49-40-484010-735; fax: +49-40-484010-999. *E-mail address*: jan-peer.rudolph@lzn-hamburg.de

Abstract

Selective laser melting (SLM) is increasingly used in the industrial production of metallic parts. This creates the need for an efficient and accurate quotation costing. The manufacturing costs of a part mainly result from the machine running time for coating and exposure. At the time of the offer calculation the final orientation of the part in the build chamber and the composition of the build job are typically not known. Addressing this need, this paper presents and evaluates different statistical based methods for an automated and self-learning calculation for SLM given a part's CAD data.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Calculation ; Quotation costing ; Self-learning ; Selective laser melting (SLM) ; Additive manufacturing (AM).

1. Introduction

Additive manufacturing (AM) is increasingly used in the industrial part production. Especially Selective Laser Melting (SLM) established for the powder-based generation of metallic components. AM builds up parts layer by layer based on given 3D geometry data [5,7]. Beside of AM, digitization and networking are current trends in manufacturing engineering. In recent times, the first 3D printing service providers offer the option to place orders online [23]. Cloud-based platforms, which enable automated order acceptance and processing, are in the focus of current research [17,18]. An essential part of a cloud-based manufacturing platform is an effective and efficient quotation costing [17]. This paper presents an automated, self-learning calculation for SLM, which is implemented within a web-based platform. The customer can upload the geometry data of a part via an online form (see Fig. 1). Subsequently, the geometry is checked and an offer is calculated.

The paper is structured as follows: Section 2 presents basics of the SLM process. Section 3 gives an overview of the related work. Section 4 introduces the developed calculation method and the underlying cost model. Section 5 evaluates the method, especially regarding its accuracy. Section 6 gives a conclusion and outlook.

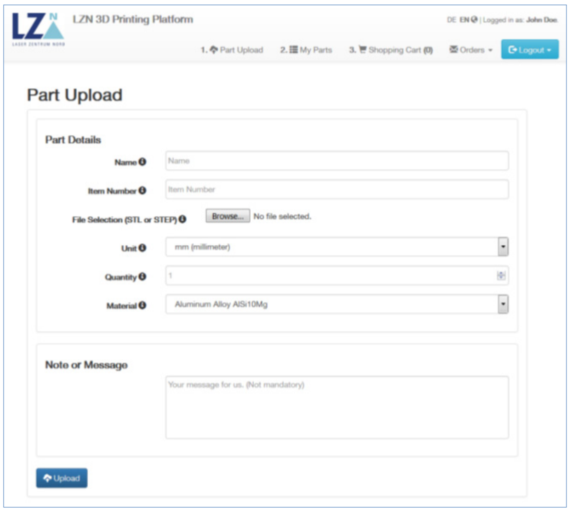

Fig. 1. Part upload via the implemented web platform.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2017.12.197

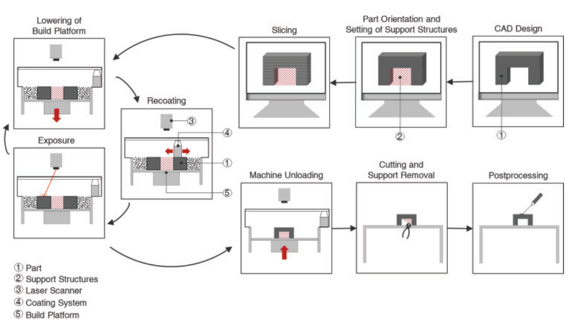

Fig. 2. Basic principle of additive manufacturing using SLM (based on [13]).

2. Selective Laser Melting

SLM is an AM powder bed based, micro welding process [5,7]. Fig. 2 shows the basic principle of the SLM process. The starting point is the CAD data of a part. For the data preparation it is converted into an STL file. The STL format (Standard Triangulation Language) has established as de facto industry standard in AM [2,10]. The STL format describes an object by its triangulated surface geometry. In the data preparation phase the build job is composed. This also includes the setting of a part's orientation in the build chamber and the construction of support structures, which fix the part to the build platform. Within SLM multiple different parts can be built simultaneously in one build job. The stacking of parts above each over, as done for Selective Laser Sintering (SLS), is not used in practice, because of the required support structures. The slicing generates the layered data with the exposure vectors for the generation process.

The SLM process itself has three main steps: the lowering of the build platform, the recoating with a new powder layer, and the exposure via a laser scanner system. For the cost calculation the lowering of the build platform and the recoating are considered as one step. Finally, the machine is unloaded. Parts are separated from the build platform and supports are removed. This is followed by a post processing, which may include a final machining of functional surfaces.

Beside of the build job with a part's generation, the complete process chain also includes preliminary and post processing steps [14]. Fig. 3 gives an overview of the full production costs based on the main process steps. The full production costs are divided into material and manufacturing costs. The manufacturing costs are again divided into special direct manufacturing costs, direct manufacturing costs and indirect manufacturing costs. This paper focuses on a cost calculation of the generation process or build process (including coating and exposure).

3. Related Work

This section provides an overview of the relevant, existing cost models, which serve as basis for the development of an automated and self-learning quotation costing for SLM in this paper.

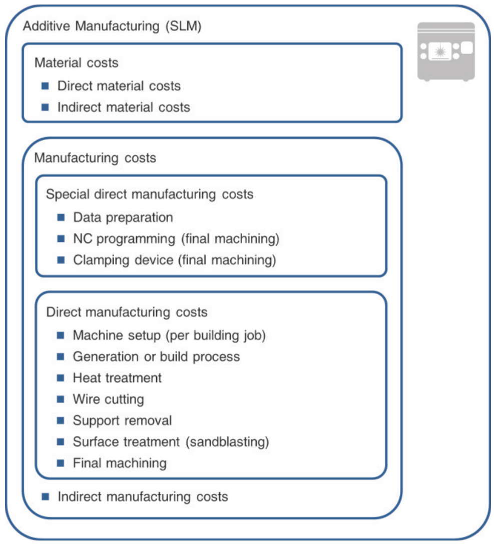

Fig. 3. Structure of full production costs for SLM [19].

Alexander et al. developed a cost model with the aim of finding a part's cost minimal orientation [1]. The model assumes the production of one single part and is evaluated for Stereolithography (SLA) and Fused Deposition Modeling (FDM).

Huang et al. present the concept of a web-based service system for rapid prototyping [9]. The system includes a calculation module for SLA. Basis of the cost model is a slicing of a part's STL data. The orientation of the part is given by the user.

Luo et al. also describe a web-based E-commerce system [12]. Their cost model is not based on a slicing of the data, but on an analytical calculation including the number of required layers and the material volume to be built. The part orientation is given by user input.

Lan et al. present two cost models for a web-based calculation system for SLA [11]. The first model is a rough calculation using a part's weight as single input parameter. The second model considers the process times for coating and exposure, but needs the part orientation as input value.

While the cost models, presented so far, mostly focus on rapid prototyping, Hopkinson and Dickens analyze rapid manufacturing use cases [8]. The authors exemplary compare the costs for injection molding, SLA, FDM, and SLS for a mass production with only equal parts in a build job.

Ruffo and Hague present three cost models with the aim of calculating the costs for a single part in simultaneous production with SLS [21]. The first model presents a splitting of the costs based on the part's volume. The second model is based on a single production of the part. The third model assumes a mass production of parts with the same geometry.

Grund developed an analytical cost model for SLM for the simultaneous production of multiple different parts in one build job [6]. The process time for one single part is determined by the time for exposure and the time for coating. The coating time is split over the parts in one build job via the build height of the parts, the exposure time via the volume of the parts. The usage of the cost model requires detailed knowledge about the composition of the calculated build job.