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ScienceDirect

Procedia Manufacturing 21 (2018) 655–662

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

15th Global Conference on Sustainable Manufacturing

Concept of Sustainable Data for a Selective Laser Melting Machine

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Abstract

Due to increased digitalization in the production environment, data, information, and sustainable management approaches should be developed in order to enable production machines for data acquisition, data exchange and data analysis. Especially for additive manufacturing technologies, those approaches are extremely important to detect and avoid failures in the manufacturing process. A critical failure during the manufacturing process could lead to a defective workpiece, wasting resources. Within this context, this work addresses the concept of sustainable data for a selective laser melting machine tool. The selective laser melting process is one of the additive manufacturing technologies that is capable of producing lighter and more complex functional workpieces in comparison to conventional manufacturing technologies. Beyond the use of the machine tool system internal data (e.g. process data, internal sensors), additional information such as energy consumption and data provided using external sensors are required to detect the current condition of production process. In order to observe if the considered data sources are capable of identifying abnormal conditions of the machine tool, failures from five subsystems were inserted during a manufacturing process of a reference workpiece. Four of the five data sources detect failures that influenced the layer quality while they are occurring. Thus, the results could be used to allow the operator to take measures to save energy and resources.

Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).

Keywords: Production, SLM machine, data management, information analysis.

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2351-9789 © 2018 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).
10.1016/j.promfg.2018.02.168

1. Introduction

Intelligent data acquisition, linking and analysis are the basic for making production machines and processes smarter. In this context, enabling of existing systems for data acquisition and exchange becomes more and more important in the production environment. The retrofit of existing machine tools for data acquisition and exchange can be very demanding. This is because different machine manufacturers use various control systems that do not support system internal information exchange, for example. Especially, the implementation of predictive maintenance strategies requires in many cases external sensor information (e.g. vibration) in addition to the use of system internal information. In this context, external sensors should be added to provide information of the condition of critical components in the machine [1, 2].

Through the increasing digitalization in the production environment, large datasets from different sources are generated. Therefore, a suitable data management concept (data acquisition, data processing, data provision and data visualization) is increasingly gaining importance for the purpose of analyzing and improving of production processes. Based on the data management concept reliable analysis of data obtained during the operation can be used to optimize production and maintenance processes of the Selective Laser Melting (SLM) machine tools. Furthermore, information and knowledge can be extracted from acquired data and used to develop data-driven business models and services, such as innovative availability guarantees for production machines [3, 4, 5, 6].

2. Selective Laser Melting

2.1. Process

Additive Manufacturing (AM) is a technique to manufacture workpieces through addition of material, by joining layers with equal thickness [8, 9]. This technique is also known as Rapid Prototyping, Rapid Manufacturing, Layer Manufacturing, and Layer-oriented Manufacturing [7, 10, 11, 12]. The significance of this technique has been increasing over the years due to its capability of manufacturing complex geometries with different materials [13]. According to DIN8580 [14], all these names represent a main group. The work in [8] performs a precise specification with regard to the state of aggregation of the used material (i.e. liquid, solid, or gas), to the physical principles (i.e. melting, polymerization and cutting, among others), and the used method (i.e. stereolithography, laser melting, heat melting, etc.).

Selective Laser Melting manufacturing technology is a special technique of AM. It is a manufacturing process that uses a metal powder bed and a thermal energy supplied by a computer controlled and focused laser beam to build a workpiece [15, 16, 18, 19, 20]. The layer thickness varies from 20 μm to 150 μm and the size of the metal grain has a range from 10 μm to 75 μm [8, 17]. The main steps to complete the workpiece manufacturing start from the design in Computer-Aided Design (CAD) software and finish in a post-processing stage, in which the desired mechanical characteristics are reached. According to [8, 9], the manufacturing of a workpiece begins with the three-dimensional CAD model. After that, the model is digitally optimized in order to reach the dimensional tolerances and properties.

Once these are reached, the CAD model is transformed into a Stereolithography (STL) model, which is a triangulated representation of the CAD model. By manipulating the data of the STL model, it is possible to define the desired position and angles for building the workpiece as well as the melting strategy. With this characteristic determined, the thickness of a layer is specified and the STL model sliced digitally. The generated data containing the manufacturing information is then downloaded to the SLM machine tool in order to be able to manufacture the workpiece. When the generated data is processed by the SLM machine tool, the manufacturing process can be started and a cycle begins. Firstly, a platform is lowered in order to give the desired thickness of the layer. Secondly, a thin layer of metal powder is deposited on the platform using a recoating device. Thirdly, a laser beam is used to melt the selected geometry in the top-most layer of this powder bed. This cycle is repeated until the last layer of the workpiece is melted. The last step is the post-processing of the manufactured workpiece. After the workpiece is produced, it is separated from the platform, cleaned, and depending on the requirements, it may be machined to achieve the specifications.