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A New Approach For A Flexible Powder Production For Additive Manufacturing

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Abstract

The technology of Additive Manufacturing (AM) is an enabler for more eco-friendly lightweight aircraft parts due to the possibility to use the freedom of design. Since the process of laser beam melting is powder bed based, there is a huge influence of the powder quality on the building process. The most common process for the AM powder production is the inert gas atomization based on molten material. There are different process types which are mainly used for a large scale powder production. In order to analyze new or expensive alloys for the AM process, small and flexible atomization plants to produce smaller amounts of powder are needed.

This work summarizes the required powder properties for aluminum alloys as well as the different suitable atomization processes. Current challenges concerning AM powder quality will be described and a new atomization plant concept for high-grade powder in small quantities, based on the process of thermal spraying, will be introduced.

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Keywords: additive manufacturing; powder; atomization; thermal spraying

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Nomenclature

AM	additive manufacturing
SEM	scanning electron microscope

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1. Introduction

The transport volume in aviation is forecast to increase by 45 % between 2014 and 2035 [1]. In order to reduce the greenhouse gas emission, the efficiency of airplanes has to be increased. One option is to reduce the mass by lightweight constructions. This offers the possibility to carry more load with the same CO_2 emission or the same load with a lower CO_2 emission. Another possibility, besides the use of composite materials, is the implementation of topology optimized structural components. These complex geometries are more frequently produced by additive manufacturing (AM). The most common technology is the powder bed based laser beam melting due to the high freedom of design and the application of aviation relevant metallic materials like titanium, aluminum for structural components and high performance nickel-base alloys for engine parts (e. g. Inconel® Alloy 718). Since aluminum alloys are very common in aerospace industries, in particular in combination with alloying elements like silicon, due to their high specific strength [2], hardness [3] and at the same time light weight, the focus of this paper will be on laser beam melting of aluminum alloys. By the usage of AM and the associated topology optimization, part weight, e. g. of a fuel nozzle or a bracket, can be reduced by about 25 % or 54 % compared to the conventionally manufactured part [4,5]. It is estimated, that the aircraft basic weight could be reduced by 4 to 7 % by replacing conventionally parts with AM optimized lightweight components [6]. In particular aluminum alloy components have the highest mass reduction potential [6]. Besides the weight savings, assembly efforts could be decreased by functional integration and part consolidation. An exemplary traditional fuel nozzle consists of 18 individual parts. After design optimization, it can be manufactured in one piece [4].

2. Aluminum powder production for additive manufacturing

The possibilities to produce function integrated parts and one piece solutions instead of assemblies, are due to the layer wise build up of the additive manufacturing process. A laser beam melts up a thin powder layer on a building platform. This powder layer is usually 20 to 60 µm thick, in dependence of the required part quality and the affordable process time [7]. The eligible process parameters must be well adapted to the relevant material. Otherwise, objectionable effects such as a lack of fusion, balling, high porosity [8] and evaporation of alloying elements may occur [9]. Especially for aerospace industries, reliable processes are mandatory. Besides the influence of the process parameters, the initial powder material has an important influence on the resulting part and its surface finish and becomes increasingly important [10,11]. Due to this strong influence, the AM process cannot only be viewed separately, but upstream process steps, e. g. powder production, powder handling and transport, have to be considered.

Aluminum alloys have, compared to stainless steel, a higher reflectivity for laser radiation and a higher thermal conductivity, which makes process improvements more complicated [12]. In order to increase the build rate, a higher scan velocity and thus a higher laser power is necessary [13]. Furthermore, spherically shaped particles are recommended because they are beneficial for flowability and are more likely to result in a uniform powder bed [14].

A variation of the particle size will lead to a different distribution and packing density in the powder bed which influences the heat balance and affects the part density [15,16]. Oxide formations on the particles may result in oxide residues in the part since aluminum oxide has a higher melting temperature than pure aluminum [17]. The upper oxide film of the melt pool evaporates under the laser beam, the oxide films below remain intact or are disrupted by Marangoni forces that stir the melt pool [17]. A different effect is the explosion of the oxide layer due to the thermal gradient and the thermal expansion between the aluminum and the oxide layer [18]. The hydrogen content of the powder can produce hydrogen pores, if the melt pool solidifies faster than the gas evaporates [19].

Table 1 summarizes the influences of the powder particles and possible defects during the AM build up process and in the manufactured part. This information emphasizes the need for high quality powders and reliable processes for powder handling-, storage- and transport-conditions. The impact of the powder quality and the question of how much variation can be tolerated in the powder bed are areas of research [20].