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Influence of local dependencies in additive layered manufacturing on serial process design for aerospace applications

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Abstract

The technology of additive layered manufacturing (ALM) achieves more and more industrial applications. The win of freedom in design powered by this technology, makes it to an important technology for aerospace applications due to the high potential on weight savings. And it is also interesting in view of ecological aspects. But therefore a holistic view and understanding on the ALM process and its attended pre- and post processing is important.
Varel plant of Premium AEROTEC is able to provide nearly all required pre- and post processes and in consequence a machine for the additive laser manufacturing was installed in June 2014. Among other things running projects investigate the local dependencies within the cross section of the ALM process regarding the distortion behavior, microstructure and the mechanical properties within the process chain. The knowledge of those influences on the manufactured parts will be used for the design of an efficient process.
The contribution describes the dimensional and shape deviations, the microstructure and the mechanical properties along the process chain for additive manufacture parts. Depending on the process parameters dimensional deviations up to 0.1 mm occurred for the ALM process. Due to the required high performance of parts within the aerospace industry methods for compensation of these deviations will be pointed out to achieve the required accuracy.

Keywords. Additive manufacturing; Ti-alloys; serial production; aerospace

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1. Introduction

Regarding to statistical projections from Airbus air traffic will double within the next fifteen years. To control and reduce the industrial pollution due to carbon dioxide emission from aircraft the aerospace applications have to become more ecological [Airbus Group].

A significant milestone in becoming more ecological is the reduction of weight. The optimization of aircraft components lowers fuel consumption and therefore carbon dioxide emissions.

Pursuing the target of lightening the aircraft new materials like CFK or titanium moved into the focus of attention. Titanium is only half as dense as steel but still has better elongation and nearly the same tensile strength as steel. For that reason titanium is predestinated for aerospace applications. The high price of titanium and the disadvantage of producing 90-95 % waste in form of cuttings during the standard processing of turning and milling stands in direct contrast to the benefits of titanium. For that reason it is uneconomic for a lot of parts in aerospace applications till now.

ALM comes with three main advantages:

1. First of all, there is the reduction of material costs. ALM builds just the structure and uses only the material which is needed. The rate of waste is minimized.
2. Furthermore there is no need for tools anymore and the set-up time is way shorter compared to milling. The tool-less production is the second advantage which leads to maximum flexibility in part production and enables the production of two complete different parts one after the other without changing anything on the machine except the design (CAD) files.
3. Talking about design leads to the third advantage of ALM, the unprecedented freedom in design. The technique has the possibility to change the complexion of existing parts in cause of being unbounded from any rules in design and production. ALM puts that in focus what is essential, either to design parts weight-optimized or to produce them topology optimized. It can even combine best of both without caring about extra costs due to higher complexity of parts and still scores with high mechanical properties similar to standard manufacturing processes.

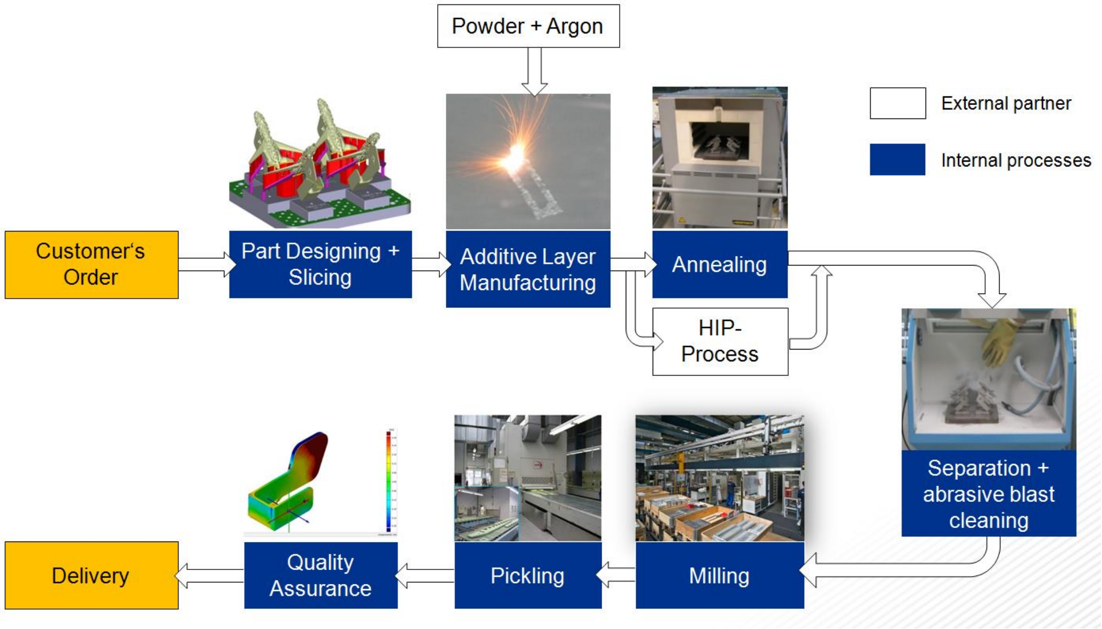

Fig. 1. Process chain of ALM at Premium AEROTEC

The process chain of ALM consists of various pre- and post processes (Fig. 1). Post processes are for example annealing, the separation of the parts and further processing like drilling or milling. Varel plant of Premium AEROTEC owns the most advanced machinery in Europe for turning and milling and is able to provide nearly all pre- and post processes, which comes along with ALM (blue boxes Fig. 1). From part designing via slicing trough to annealing and milling and even the quality assurance can be done in-house. In fact it was just a matter of time that finally in June 2014 the first machine for the laser additive manufacturing of Premium AEROTEC was installed at Varel plant. Premium AEROTEC is on the way to industrialize the first process chain for ALM. In this context the knowledge about the interactions within the process chain is essential. One part of this is the knowledge about the local dependencies of ALM-process and its influence on the process chain.

2. Experimental setup and results

To determine the local dependencies several fracture toughness test specimen were built with two different process parameters. Each building process contains fifteen test specimens in five different areas of the installation space (three specimens in each area). After the ALM process the specimen were measured in three different levels and four different directions. On the vertical z-Axis the levels are 0 mm, 50 mm and 100 mm above the platform. The measurement of the specimen indicates that there are differences in dimensional deviations depending on the positioning in the installation space. The deviation in connection with the different levels on the vertical z-Axis is negligible.

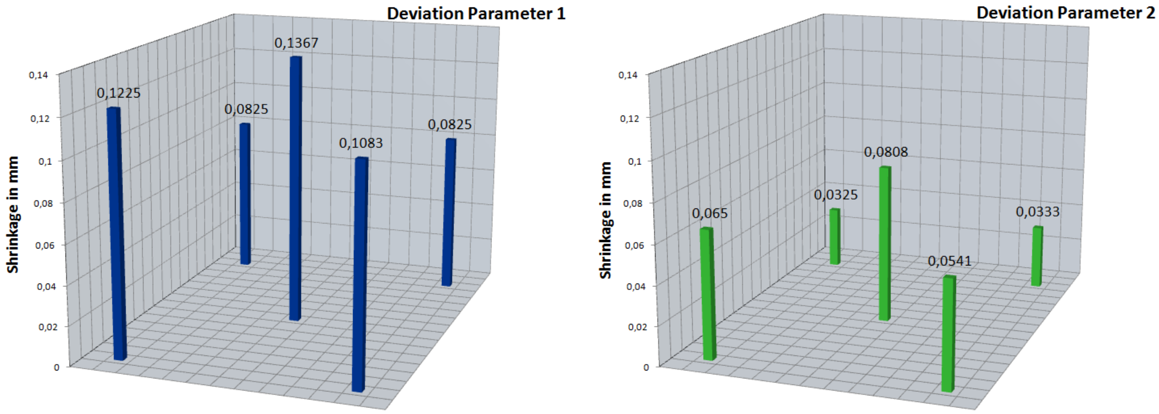

Fig. 2. (a) Deviation parameter 1; (b) Deviation parameter 2

The diagrams in Figure 2 show the shrinkage of the specimen 100 mm above the platform depending on the parameter, while the recoater is working from right to left. It shows that the specimen in the middle of the platform contain the largest deviation, which is 40 % to 60 % higher than in the upper left and right corner. Unattached which parameter is used the deviation in the upper left and right corner is the lowest, followed by the lower right corner.

3. Conclusions and summary

The experiment indicates that the local dependencies have influence on the deviation of parts manufactured with Additive Layer Manufacturing. It is necessary to analyze the local dependencies of the shrinkage in detail and to examine if the local dependencies also determine the mechanical properties. This information is essential to position and to orientate parts to design an efficient process. This subject shall be investigated in BMBF-project INDICAD.

Starting point to compensate the shrinkage is designing the parts with a global offset e. g. of 0.1 mm. This could end in a higher precision of ALM generated parts but comes with a few disadvantages. To oversize the parts goes along with a higher material consumption (Table 1) and leads to a longer build-up time. Furthermore extra weight of the parts comes along with extra time during the post processing. In conclusion it is necessary to inspect in which cases it makes sense to oversize parts or if it is needless and requires a more detailed view. As a further consequence high quality parts should be oriented in a way that areas with low tolerances are placed in sectors with less deviations and vice versa.

Table 1.Impact of oversizing on additional volume

Volume	Volume with 0.1 mm oversize
1 cm³	1.030 cm³
10 cm³	10.211 cm³
100 cm³	101.202 cm³
1000 cm³	1.003.003 cm³

References

Airbus Group. Airbus Global Market Forecast 2014-2033 – Full book. P. 63