RepAIR

FUTURE REPAIR AND MAINTENANCE FOR AEROSPACE INDUSTRY

Deliverable 6.1 **Definition of part classes and generalization of requirements**

Gereon Deppe[1], Jonas Ørbæk Hansen[2]
[1] University of Paderborn, [2] Danish Technological Institute

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Project Coordinator
Prof. Dr.-Ing. Rainer Koch (University of Paderborn)

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Further contributors	*Katia Laiger, University of Paderborn* *Christian Lindemann, University of Paderborn* *Marco Plaß, University of Paderborn* *Thomas Reiher, University of Paderborn*
Authors	*Gereon Deppe, University of Paderborn* *Jonas Ørbæk Hansen, Danish Technological Institute*
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Short description	*In this document part classes are developed that are based on part's requirements. They support the decision making regarding Additive Manufacturing workflows which are required for a specific part. Currently, repair processes are complex and consist of several different steps. The analysis of those processes in combination with the integration of Additive Manufacturing leads to common rules for similar process flows and thus enables efficient manufacturing and repair chains for parts that have similar characteristics.*

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Executive summary

In order to support the aim of RepAIR (i. e., the integration of Additive Manufacturing (AM) into existing aerospace repair processes), the objective of this document is to set-up part classes. To be able to use the repair and manufacturing chains efficiently, aerospace parts are analysed for similar characteristics to group them for matching workflow processes as they are currently complex with several different steps. AM carries the potential to improve the repair process as it is more flexible than conventional manufacturing technologies. The part classes will help to make the decision process for an AM repair solution faster and more efficient. They are based on the typical AM workflow comprising pre-processing, manufacturing and post-processing. The separation into part classes serves as the foundation for a detailed work plan that has to be developed for the AM manufacturing and repair.

The project focuses on the three AM technologies SLM, EBM and Laser Cladding that produce metal parts. SLM and EBM have a similar production process as both use a powder bed where an energy input melts and solidifies the powder where necessary layer-by-layer. The SLM process uses a laser to do so and the EBM system deploys an electron beam in a vacuum for the melting process. The Laser Cladding machine operates differently. It melts the powder with a nozzle directly at the point of application and thus does not require necessarily support structures like SLM and EBM. It furthermore has the benefit that a milling tool is already integrated and can be used during the manufacturing process. It enables the finishing of every surface of the part as it the milling can be conducted before it is shielded by the rest of the geometry. Currently the SLM and EBM build chambers are limited in their sizes. Further developments will focus on the increase of the dimensions. The Laser Cladding system is already able to manufacture much bigger parts.

Besides the manufacturing technologies, the different materials are important for the specification of part classes. Within the metal AM industry the materials are not as far developed as for the conventional technologies. Nevertheless the most common and important materials for aerospace can be applied. Titanium alloy has a high strength in combination with a relatively low weight. It is corrosion resistant too and has a good machinability. Inconel alloys offer high strength and elasticity as well as corrosion resistance which is important for turbine parts. Stainless steel shows a huge toughness and hardness and is still good machinable. Aluminium alloys are very lightweight and have a good dense structure. Cobalt chromium alloys show very high strength and toughness; they are corrosion resistant and extremely hard.

The post-processing has a major influence on the material properties and is a core element for most of the applications as AM usually does not produce end-product characteristics. There are several different treatments that can be deployed. They can be grouped to heat treatment (stress relieving, hot isostatic pressing etc.), machining (grinding, milling, erosion etc.), physical/chemical treatments (coating, plasma polishing etc.) and others. Different parts (or parts classes) will require different amount and types of post-processing depending on the specific part requirements such as mechanical properties, surface roughness, corrosion resistance, tolerances, etc. Typically, the post processing procedures also depends on the material and AM technology applied.

The AM workflow consists of pre-processing, manufacturing and post-processing. The first one contains always the data preparation for the manufacturing process. Especially for the repair of parts it is often necessary to prepare the part for the AM. This can be done, for example, by milling it to a defined geometry or to treat the surface so new material can be applied. The manufacturing process is characterized by the previously described SLM, EBM and Laser Cladding process. After that the post-processing has to be conducted. For every process the part has to be cut off the build platform; for SLM and EBM, the support structure has to be removed. Then one of the above mentioned post-treatments are deployed to achieve the required properties.

Those properties arise from the requirements of the parts. The document lists several ones that are typical for the aerospace industry. They can be grouped to three different classes:

1) First, the material specific requirements where the material is of major importance.
2) In contrast to that there is the group where the requirements depend on the technology.
3) And the third group is a combination of both where material properties and technology specific characteristics are influence factors for the parts properties.

All of the above mentioned elements are then consolidated to a table which takes the parts' requirements as a basis and combines them with a suggested material, a production technology as well as a suggested post-treatment which provides as an example for the type of post-processing that support the properties of the final part. For every requirement there is also a typical example given in terms of representative aerospace parts. The abstract level of the classification system enables a fast first categorization to a specific workflow. This supports the decision process in its first step. Specific parameters have to be defined in a subsequent detailed analysis.

The last chapter describes briefly the sample parts of the project and assigns them to the previously developed part classes in accordance to their characteristics. This shall help to verify the definition of part classes and can be used in the further project duration for the definition of the repair processes.