FUTURE REPAIR AND MAINTENANCE FOR AEROSPACE INDUSTRY

Deliverable 5.4 | **Realisation of the software solution for generating a three-dimensional area model and ascertaining the concrete need of repairs and integration of test rig in and final assembly of DMD prototype**

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Executive summary

This Report D5.4 will give an overview of the results, which were achieved by AVAN during the runtime of RepAIR project, related to tasks 5.2.1 and 5.2.2 as described in the DoW. The aim in D5.4 is the realisation of the software solution for generating a three-dimensional area model and ascertaining the concrete need of repairs and integration of test rig in and final assembly of the DMD prototype.

The report consists of 4 chapters that concern the mentioned aim of D5.4. The chapters 2and 3 describe the software solution for generating three-dimensional area model of the broken spare part, that should be repaired and how the concrete need of repair gets ascertained. Chapters 4 and 5 deal with the part of D5.4 that concerns the integration of the test rig in and final assembly ofthe DMD prototype. So the structure of this report follows the structure ofthe description of D 5.4 in the DoW tothe RepAIR project.

At the beginning of chapter 2 you can find a general description of the problems that are solved by the software solution for generating a three-dimensional area model. The goal of the proposed software solution is to reverse engineer worn out parts from an aircraft. For the automated machining ofthe broken spare parts, it is necessary to generate a CAD model ofthe spare part, as such models only exist for the original model, without the damages. So, the damaged part needs to be scanned from multiple positions and that too several times. These multiple scans are then aligned together in a common coordinate reference system to generate a complete and an accurate three-dimensional area model of the damaged or broken part. This generated model serves as an input for the software solution to ascertain the concrete need of repair.

In the following chapters you will find a discussion of the different available approaches for object scanning, such as contact 3D scanners, non contact 3D scanners and Structured light 3D scanners. For each of these approaches their working principles as well as their advantages and disadvantages concerning the requirements of the RepAIR project in general and the DMD prototype are described.

In chapter 2.3 follows an explanation, how the proposed software solution reverse engineers the worn out spare part and generates a three-dimensional area model. Therefore the software follows a process that is divided into several steps which are performed by independently operating components whose output is the input for another, following step. The description follows this process step by step, from scanning the spare pat, over the transformation of point clouds to surface reconstruction.

Chapter 3 of this report is concerned with the part of the software solution that ascertains the concrete need of repair with the final output of machine readable g-code. Due to the mechanical uncertainties and abrasions, the model generated from the scanned part is different from the CAD data of the original part. The main purpose of this proposed software solution is to automate the comparison of generated 3D model data against the standard CAD model. This process helps in determining the missing portions and the locations of the object which need repair. It starts with a general overview of the problem followed by a description of the multiple software modules operating independently in a pipeline. Any of these components is explained in a separate chapter starting with chapter 3.2.1 in which is described, how the generated three dimensional area model is compared to the original CAD model of the

spare part. The geometric topologies of the two models are examined under predefined tolerance to find the missing or damaged portions in the model generated. The final output of this software component is a new three-dimensional area model which represents the missing portions in the worn-out part.

The next chapter explains the software module, which is the next in the pipeline and which is concerned with the construction of a base surface for the additive manufacturing process. The base surface is the surface common to both damaged part and the missing part of the aircraft component.

After having calculated the base surface the next software component determines the different layers which will be laid over each other by the additive manufacturing machine. This process is explained in chapter 3.2.3. The basic concept of this process is to fill the missing portions with the layers and to make an over sized version of original CAD model. Making it over sized is important as the extra size will be removed during the postprocessing after additive manufacturing. This stack of layers keep on growing until it is able to fill the missing portions.

After having calculated all layers that are necessary to repair the worn out part of the spare part, another software module calculates automatically the generic paths for the machine. The software component for this process reads the layers and generates a generic path for the nozzle movement to lay a layer over the damaged part. This path is referred as a generic path because this path is commonly followed by all machines irrespective of the set of instructions that it uses to move the nozzle. This is followed by a last step, in which the generic path is translated into machine specific g-code. A description of the software modules that deal with path generation you can find in chapters 3.2.4 and 3.2.5.

The following chapters 4 and 5 summarize the results of the development of machine technology. This concerns the test rig as well as the DMD prototype. Chapter 4.1 provides a general overview of the prototype machine, including a discussion of the necessity of developing a 5-axis DMD prototype. Therefore a comparison of the two approaches for repairing spare parts using additive manufacturing technologies is included that comes to the conclusion, that the SLM technology is not suitable for repairing bigger parts, for several practical reasons. So there is a need for machine for repairing spare parts using the DMD technology, which was the aim of task 5.2. Therefore in a first step a 5-axis test rig should be developed, which should have been integrated into a pre-existing DMD prototype machine. The purpose of the 5-axis test rig is to enable AVAN to develop and test software components. Although there are first 5-axis DMD machines available meanwhile, there is still a lack of software that is able to automate the build process, not to mention repair processes by the use of these machines. The initial plan, as described in the DoW, was to develop a 5-axis test rig, which can be integrated into an already existing DMD prototype. A feasibility analysis of this approach, came to the result that this strategy is ineligibly. An explanation of the reasons for shifting plans to the development of a test rig that is capable of being used as DMD machine, which means also that all necessary components for the DMD process had to be integrated into this test rig, is give at the end of chapter 4.1.

This test rig, which is named Base machine now, consists of three major parts

- Mechanical System
- Electronic System
- Software System

which are described closer in the following chapters.

Chapter 4.2 deals with the mechanical system of the Base machine. In its first subchapters the machine structure is described. Derived from the overall requirements of the RepAIR projects, the requirements for the Base machine of the DMD prototype have been developed. This requirements are the basis for the mechanical development of the base machine, as explained in chapter 4.2.1.

Chapter 4.2.2 deals with the necessity of having a 5-axis system and its description. Using 5-axis enables the machine to build on uneven surfaces. As the machine will be used for repairing parts, the main use case will be building structures on surfaces that are not even, to reduce the effort for pre processing and as a result to shorten process times.

As the DMD process is not able to provide results, as precise as the SLM process, it is necessary to post process the built structures for example by using a milling head for removing any melted material that is not within the tolerances. Therefore the Base machine is designed for being capable of using multiple tool heads within one system. As a result of this, the machine has to have a tool changing system, which is usable in an automated way and that is able to absorb the forces, which affect the mounting. This multiple tool changer is described in chapter 4.2.3.

The chapters dealing with the mechanical structure of the Base machine are followed by chapter 4.3 that is concerned about the electronic system. At the beginning of this chapter there is an introduction into the electronic system and its requirements, followed by subchapters that are concerned with the different submodules of the electronic system.

Chapter 4.3.1 describes the integrated Safety Circuits, which are integrated into the Base machine to avoid potential hazards due to the fast and powerfull movements of the machine.

In the following chapters you will find a description of the Power Supplies, the Controlling PC, the Fieldbus-Controller and IO-system as well as the Power Output Stages, which have been integrated into the system.

Cahpter4.4 deals with the implemented software system that is necessary for controlling the base functionalities of the Base machine. After giving an introduction into the Software systems and its requirements, you will find an explanation of any of the systems submodules in the following subchapters.

As the test rig is not integrated into the pre-existing DMD prototype machine, all necessary tool heads for the DMD process had to be integrated into the Base machine, to have a ready to work DMD prototype machine. Chapter 5 describes the tool heads, which have been integrated and how they have been integrated into the DMD prototype machine, their functionalities.

Subchapter 5.1 deals with the plastics extruder head that had been integrated into the machine. The main purpose of this tool head was to simulate the Laser tool head during the development process in a safe and cost effective way. Therefore a synthetic material deposition device had to be designed whose features exactly correspond with the requirements, the DMD technology tool head demands from the system.

As the DMD process is not capable of guaranteeing the precision that is required for repairing spare parts within the prescribed tolerances there is need for post processing the structures that are build on the machine. Therefore also a power milling motor, which can have a variety of milling heads, is integrated into the DMD prototype machine. This is described in chapter 5.2

Chapter 5.3 deals with the integration of the scanning head that is needed for the reverse engineering process. Initially it was planned to use a time of flight sensor as scanning device but as discussed in that chapter this was not a suitable solution and the plan had to be switched to the use of a triangulation based laser scanner, which meets all the requirements of the system. As these kinds of devices are very expensive AVAN found an opportunity to get a test device for the time of four weeks to assure that it meets all requirements of the process. So before integrating the scanner into the machine, the necessary software had to be developed completely.

Chapter 5.4 deals with the integration of the Laser Head and all necessary peripheral systems for the DMD process. It is devided into 4 subchapters. Again you will find an introduction at the beginning of the chapter to give an overview of the system setup. The first of the subchapters deals with the tool head itself. It gives a description of the main features of the tool head and how they meet the requirements of the DMD prototype.

Subchapter 5.4.2 describes the peripheral systems that are necessary for the the machining process using the DMD technology as there are:

- Laser
- Inert gas
- Powder feeder
- Cooling devices.

This is followed by a description of the devices for in situ process control in chapter 5.4.3, as there are a pyrometer for monitoring the melt pool temperature in order to control it in real time and multiple HD-cameras to monitor the machining process itself.

Chapter 5.4.4 is concerned with the seafety devices that had to be integrated into the DMD prototype to avoid personal and material damages caused by laser irradiation.

In this report it is explained that the result of the development in tasks 5.2.1 and 5.2.2 mainly address the following Overall Objectives of the RepAIR project:

1. Reduce repair and overhaul costs of complex spare parts by 30% and the turnaround time by 20% through the use of a combination of innovative technologies.
2. Increase the automation level for spare part productions by 20 % through an integrated production.

The DMD prototype provides the complete repairing process on bigger scale inside one platform. With its characteristics of handling bigger parts in an uninterrupted cycle from scanning, preprocessing, repairing and post-processing, makes it optimal platform for increasing the automation level for spare part productions. Besides that the DMD prototype enables to build up structures on uneven surfaces and even overhanging structures without needing support strucutres. As a result, this reduces build times andalso build costs. Another result is the expected reduction of build material compared to powderbed based additive manufacturing technologies, which also reduces the build costs.