PROVA SCRITTA - TEMA N° 1

FACENDO RIFERIMENTO AL TESTO DELLA CALL ALLEGATA, PREDISPORRE LA STRUTTURA DELLA RELATIVA PROPOSTA.

XIV. Part specific process optimization in SLM

Type of action (RIA or IA)	RIA		
Programme Area	AIRFRAME		
Joint Technical Programme (JTP) Ref.	WP B-3.6		
Indicative Funding Topic Value (in k€)	600		
Topic Leader	Fraunhofer	**Type of Agreement**	Implementation Agreement
Duration of the action (in Months)	18	**Indicative Start Date**[52]	Q1 2018

Topic Identification Code	**Topic Title**
JTI-CS2-2017-CfP06-AIR-02-47	**Part specific process optimization in SLM**
Short description	
Optimization of the Selective Laser Melting-SLM process for topology optimized aeronautical components such as fittings, based on thermal simulation as well as experimental validation. Process parameters shall be adapted for specific geometric features. All results shall be included in a searchable database and a software module shall be developed that is able to transfer identified parameter schemes to a commercial machine setup.	

[52] The start date corresponds to actual start date with all legal documents in place.

1. Background

Additive Layer Manufacturing (ALM) is a key technology in the approach to minimize the environmental impact of air transportation due to the goals defined in the ACARE 2050 agenda. ALM enables the manufacturing of complex and lightweight structures at low cost and directly from digital geometrical data. Selective Laser Melting (SLM) is a powder-bed based ALM technology that shows high potential to produce high quality metal parts and since recently supplements current manufacturing technologies for aircraft design. To mature the application of SLM to large, complex and heavily loaded components, such as fittings for cargo doors the part quality is to be elevated and the whole process chain needs to be investigated.

ALM technologies are strongly linked to topology optimization as a simulation based design approach. This is due to the possibility of manufacturing very complex topology optimized designs and thus reducing the weight of aircraft components by possibly high margins. Currently SLM parts are manufactured based on standardized parameter sets of machine vendors and minor adaptions of operators using predetermined schemes. Those schemes are not able to deal with complex geometries with varying dimensions of topology optimized parts. The process of exposure of metal powder and selective melting depends on the locally inducted energy as well as energy transport and thermal environment. Therefore the thermal process is highly related to the geometry of the part.

Finding parameter sets for topology optimized parts currently means to rely on the operator's experience and also to conduct a certain amount of experiments in order to find suitable parameter sets. Also for very complex geometries, the adaption of machine vendors' predefined schemes might not suffice to come to terms with the geometric complexity of parts. Still, the quality of every SLM produced part is relying on its own part specific suitable parameter set which currently remains to be a cost and time intensive procedure.

2. Scope of work

The topic addresses the development of a methodology in order to adapt SLM-process parameters to geometric characteristics of topology optimized parts in an effective way and independent from machine vendors' parameter schemes. The applicant is expected to conduct studies on the systematic adaption of laser and process parameters for specific geometric features that are relevant to topology optimized designs of metal aircraft parts and particular to fittings of cargo doors that are to be manufactured from AlSi10Mg.

All results of the parametric study are to be included in a searchable database. Based on the created data, a software-tool will be developed which will be able to propose different setups of manufacturing parameters. An automatic transmission to commercial machine setups shall be possible through a Transfer Software package.

The Topic Manager will provide the applicant with complex geometrical data with relevance to topology optimized metal parts. The activity is to be based on thermal simulation (performed with a commercial or non-commercial software) of the build-up process as well as experimental studies and process implementation in a laboratory environment at relevant scale. In a laboratory machine setup, exposure and other process parameters e.g. layer thickness and exposure strategy can be varied and steered in different areas of the part and throughout the build-up process in order to enhance the quality of manufactured samples in terms of criteria such as homogeneity (incl. imperfections), surface quality and thermally induced stresses.

While a complete simulation of the manufacturing process will be limited regarding complex cases, enhanced information about the process should be gained by experimental studies through sample manufacturing. Here it is important to inquire the exposure strategy (e.g. arrangement of laser tracks, line spacing, up and down skin, overlap etc.), the exposure parameters (e.g. exposure speed, laser power), machine parameters (e.g. layer thickness, platform heating etc.) as well as the change of exposure for certain areas (e.g. different exposure for core, contour and adjustments for slender areas). Since the area close to the surface is crucial to the mechanical performance and fatigue behavior, the exposure of the contour shall be a key aspect of the experimental studies. To quantify the part quality, different testing methods shall be applied (e.g. µCT, metallographic analysis, Laser Scanning Microscope, Acoustic Sound Microscope, hardness measurement or other common material test methods etc.). The applicant will conduct sufficient experiments to preserve stochastically significant results and will include results and parameter sets in a searchable database system. Based on this, a software module will be developed that allows transfer of derived process parameters to commercial vendors' machine setups to enable an automatization of the part specific optimization of manufacturing parameters.

It is proposed to structure the technical activities by using the following Work Breakdown Structure:

WP1 – Laboratory setup - process control and calibration
The laboratory setup is to be calibrated and reviewed. The laser control system shall be able to fulfill the requirements for the transient adaption of process parameters during the build-up process with AlSi10Mg as the material system.
The laboratory machine setup shall be based on a fiber laser with min. 400W but preferably 1000W power output. Adaptable process parameters in laboratory setup will include but not be limited to the control of:

1. Laser tracks by vector input data
2. Laser power and speed with transient adaption along vectors
3. Layer thickness adaption within building-job
4. Platform heating of up to 500°C

Furthermore: inert gas atmosphere and fluid flow control, measurement of laser caustic and temperature distribution throughout the process.
A parameter scheme for a reference sample of simple geometry (e.g. cube, cylinder) with homogeneous microstructure (also in near surface areas), homogeneous surface quality and adequate mechanical properties is to be developed. Additionally, it needs to be confirmed that the parameter scheme has adequate performance in terms of induced thermal stresses.

WP2 – Thermal Simulation and experimental validation
For the calibration of the thermal process simulation with the laboratory setup samples shall be manufactured and characterized. This shall include but is not limited to the measuring of laser penetration width and depth related to laser power, scanning speed, layer thickness etc. Results will serve as input for the process simulation. A relation is to be developed and calibrated between experimental results from the laboratory setup, e.g. energy distribution during build-up, to the thermal simulation process in a way, that the adaption of process parameters in the thermal process simulation can forecast quality criteria.

The simulation shall be able to model as many layers of exposure in one routine that are relevant to the selective melting process and sphere of influence of the laser energy input. In addition, the simulation shall be able to include effects of support structures and platform heating.
The process simulation shall have a significant forecast ability on the adaption of process parameters. The applicant needs to prove this ability on a sample with relevant scale.

WP3 – Sample simulation, manufacturing and testing
A systematic study to find sufficient parameter sets for the manufacturing of geometric structures of topology optimized parts is to be conducted and results are to be included in a searchable database. The build-up process of each geometric sample shall be simulated and simulation results shall be used to adapt parameters for the manufacturing process. Samples are to be manufactured and characterized in terms of quality criteria.
Geometric structures and variations shall include but are not limited to the following:

- Truss structures with varying dimension, cross section and overhang angle.
- Hollow truss structures with varying wall thickness.
- Truss junction of three, four and five connected trusses with angle variations.

The sample matrix, number of variations and characterization is to be agreed on with the project manager, based on reference samples and expected deviations.
The transferability on parameter sets of broader variations shall be demonstrated and well-founded suggestions shall be made how the database could be effectively expanded.

WP4 – Parameter Database and Transfer Software
A searchable database is to be developed and all results from the parametric study shall be included in this database. The database will be able to propose different setups of manufacturing parameters by means of search criteria. An automatic transmission to commercial machine setups shall be possible through a Transfer Software package.
Basic Requirements for the Parameter Database:

- Effective classification and correlation of geometric features (e.g. cross section, overhang angle, wall thickness, number of junction partners, exposure area in xy-plane, ...) to process parameters and quality criteria
- Inclusion of experimental results and expandability
- Effective search methodology

Basic Requirements for the Transfer Software:

- Preparation of the digital input data to the vendor's machine
- Applicable to multiple vendors' machine systems
- Interface to parameter database
- Correlation of database input to part specific parameter set
- Adaption of part specific parameter sets to vendors' parameter schemes

3. Major Deliverables/ Milestones and schedule (estimate)

Major Deliverables and Milestones are summarized in the tables below. Depending on the work description, this list can be extended where necessary.

Deliverables			
Ref. No.	***Title - Description***	***Type***	***Due Date***
Del.1	Concept review	Report	T0+6
Del.2	Sample matrix and test matrix	Report	T0+6
Del.3	Simulation and sample testing report	Report	T0+12
Del.4	Delivery of Parameter Database	Software	T0+18
Del.5	Delivery of Transfer Software	Software	T0+18
Del.6	Final report	Report	T0+18

Milestones		
Ref. No.	***Title - Description***	***Due Date***
M1	Laboratory setup review	T0+6
M2	Thermal simulation review	T0+6
M3	Sample matrix agreement	T0+6
M4	1st Database review	T0+10
M5	Transfer Software specification review	T0+12
M6	2nd Database review	T0+15
M7	Critical Transfer Software design review	T0+15
M8	Final Database review	T0+18
M9	Final Software test and final meeting	T0+18

4. Special skills, Capabilities, Certification expected from the Applicant(s)

- The applicant shall have expertise in the field of:
  - Selective Laser Melting of Metals (or comparable: Lasercusing, Direct Metal Laser Sintering), preferably expertise with AlSi10Mg
  - Control systems of laser optics
  - Process control software and software development
  - Thermal process simulation
- The applicant shall demonstrate capabilities to:
  - Manufacture SLM samples at relevant scale
  - To integrate thermal process control in a laboratory SLM setup with control of laser optics and transient control of process parameters during build-up process
  - Perform tests to quantify quality criteria of SLM samples