BionicAircraft
Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle

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Bionic Aircraft at a glance

- **Bionic Aircraft Project:** “Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle”
  - Call identifier: H2020-MG-1.2-2015
  - Grant Agreement No.: 690689

- **Consortium**
  - 10 international Partners
    - 1 University
    - 2 Research Centers
    - 5 Industrial Partners
    - 1 SME
    - 1 Standardization Organization

- **Budget and Duration**
  - Overall Budget 7.96 Mio. €
  - Running from 01.09.16 to 31.08.19
Overall BionicAircraft project ambition

**Increasing efficiency** of an aircraft by implementing Additive Manufacturing in all stages of an aircraft life cycle:

- **During manufacturing:**
  due to resource efficient production by Additive Manufacturing Technology

- **During operation:**
  by significant weight saving (>30% of structural components) due to bionic lightweight design

- **In maintenance, overhaul and repair:**
  due to innovative repair methods and new business models for AM components

- **In recycling:**
  by development of new recycling methods for AM material
Structure of BionicAircraft project

Structure of Project

WP1 Ethics Requirements

WP2 Specifications

WP9 Impact and Standardization

WP10 Project Management

Life Cycle of Aircraft

Design

WP3 Automated Bionic Design & Optimization

WP4 High Strength ALM Aluminium Material

Production

WP5 Productive and Efficient ALM Process

WP6 Quality Control Concepts for ALM

Maintenance, Repair, Overhaul

WP7 Efficient After Sales Supply Chain

Recycling and Disposal

WP8 Repair and Recycling Concepts for ALM
### AM sectors and value chains addressed in BionicAircraft

| Bionic Design | · Optimized and standardized design process for biomimetic lightweight products  
|               | · CATIA V5/V6 based toolset for an automated bionic design and related manufacturing processes  
| Materials and Processes | · New high-strength ALM Aluminium alloys  
|                        | · Design guidelines for lightweight Aluminium ALM parts  
|                        | · Highly productive ALM process with innovative beam shaping optics  
| Quality Assurance | · In-process integrity systems for ALM parts  
|                   | · In-line monitoring systems for complex ALM parts  
|                   | · Innovative NDT methods and repair concepts  
| Repair and Recycling | · Resource efficient and cost competitive repair procedures for complex lightweight Al-based parts manufactured by ALM  
|                     | · Innovative ALM-based after-sales supply chain  
|                     | · Recycling for ALM parts and “out of specification” powder  

BionicAircraft demonstrator specifications

Demonstrator 1:
A330NEO Jack Actuator Bracket
Bionic design, Quality Assurance, Repair and recycling concepts

Demonstrator 2:
A340 Hydraulic Block
Quality Assurance, Repair and recycling concepts

Demonstrator 3:
A350XWB T-Mount Fitting
Merging bionic design, material development and QA concepts
Automation in the design process and pre-process

- Bionic Feature Catalogue (CATIA integrated Toolset)
  - Pre-determined, parametrised Bionic features
  - Adaptable to existing CAD models with a mouse click
  - Automation of design and pre-process
  - Including pre-processing tool within CAD environment allows for dynamic changes, no switching between softwares, no data loss

-27% weight!
Gyroid structure
Cuticular structure of butterfly wings
Optimization of solid bodies

Honeycomb structure
Honeycomb of bees
Optimization of surfaces

Technical plant stem
Blade of grass
Optimization of struts

Method of tensile triangles
Load adaptive tree growth
Optimization of transitions

BIONIC AIRCRAFT
Motivation for development of high-strength Aluminium materials for ALM

- Cost of conventional subtractive manufacturing raises with increasing part complexity
- Production cost of AM per part are independent of lot size and complexity
- Lightweight potential is enhanced by opportunities emerging from topology optimization and bionic design

<table>
<thead>
<tr>
<th>Material</th>
<th>ALM Titanium Ti-6Al-4V (TRL 4)</th>
<th>ALM high-strength Aluminium (TRL 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>330 g</td>
<td>191 g</td>
</tr>
<tr>
<td>Weight reduction</td>
<td>-</td>
<td>42%</td>
</tr>
</tbody>
</table>
High-strength Aluminium Powder Development

- Development of Induction Coupled Plasma (ICP) Process for Aluminium powders

- Four material concepts
  - Al-Li-Cu
  - Al-Li-Mg
  - Al-Si-Sc
  - Al-Li-Ca

- Start with screening phase regarding processability

- Selection of Al-Li route based on expected results
Influence of different laser beam shapes

Five different laser beam shapes were simulated, based on 2D modelling of melt depth and width

- Square beam profile offers most advantages in terms of melt pool size and vaporization energy loss
  - Size of melt pool (in powder layer) is increased up to 23% for the same process parameters
  - Scanning speed can be increased up to 25%, while obtaining same size of melt pool
  - Effect of scanning position (powder distribution) on size of melt pool is significant (not shown here)
  - Vaporization can be reduced up to 28% by optimizing the laser beam intensity profile (not shown here)

<table>
<thead>
<tr>
<th>Profile</th>
<th>Size of Melt Pool in Powder Bed (AVG) [µm]</th>
<th>Vaporization Energy Loss (AVG) [J/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaussian</td>
<td>4902</td>
<td>-81</td>
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<tr>
<td>Donut</td>
<td>5189</td>
<td>-76</td>
</tr>
<tr>
<td>Torus</td>
<td>5080</td>
<td>-85</td>
</tr>
<tr>
<td>Square</td>
<td>5497</td>
<td>-73</td>
</tr>
<tr>
<td>TEM01</td>
<td>4960</td>
<td>-95</td>
</tr>
</tbody>
</table>
Test-Rig for evaluation of laser beam shapes

- Newest fiber laser generation
- Racktype design
- 1 kW nominal power

SLM test rig designed for BionicAircraft research activities
- Highly modular designed
- Various system component options
- Integration of beam shaping optics
- Integration of MEGaFiT optical bench

Modular optical bench setup at LZN
- Scanlab 3D scanning unit
- Designed for 1 kW fiber laser
- On-axis integration of components

Individual Laser source
In-line and in-process monitoring

- In-process integrity check
- In-line integrity check
- In-service integrity check
- Life time prediction

HTC and HexMet
AIRBUS
Tecnalia
LZN
Samples for testing of sensing methods

- ALM samples for evaluation of integrity and NDT test systems
Repair of ALM parts by Thermal Spraying

- Modification of Thermal Spray gun to optimize process stability
- Use of coarse powder fraction +45 / -95 µm
- Al-Si-Sc deposits of h = 2 mm successfully applied on AlSi10Mg substrates
Validation of BionicAircraft developments
Thank you for your attention!

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