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MULTHEM
Multi Material Additive Manufacturing for Lightweight and Thermal Management

APMTAC

ECCOMAS 2024

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WEIGHT OPTIMIZATION USING DESIGN TOPOLOGY AND MULTI-MATERIALS FOR AM APPLICATION IN MULTHEM PROJECT

- Presenter: **Brunel University London, UK**

Brunel University London

Conference: ECCOMAS 2024

Organiser: CIMNE

Location: LISBON, PORTUGAL

Date: 4th JUNE 2024

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- Presenter: **Brunel University London, UK**

Dr. Azeem Uddin Azeem Islam	(Research Fellow, CEDPS, Brunel University London, UK)
Dr. Eujin Pei	(Associate Dean, CEDPS, Brunel University London, UK)
Dr. Marta Alvarez-Leal	(CETEMET, Spain)
Dr. Julia Ureña	(CETEMET, Spain)
Dr. Vedant Modi	(Eire Composites, Ireland)
Jose Soler	(AirElectric, Spain)
Jamie Solleiro Rodriguez	(AirElectric, Spain)

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Background…

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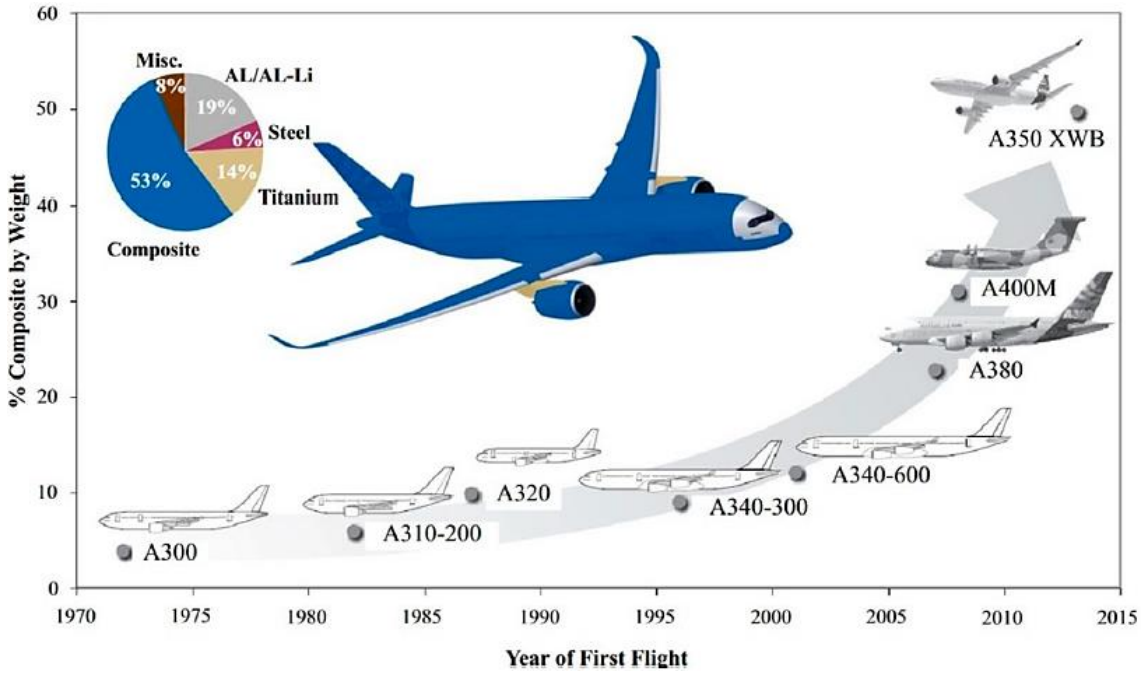
- Current trend of metal replacement for high performance.
- E.g., airplanes…



Source: Xu et al. 2018, Advanced Composites and Hybrid Materials vol 1 p. 460 477

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Multi-Materials and Design Optimization

- **MULTHEM:** Multi Material Additive Manufacturing for Lightweight and Thermal Management

- **Additive Manufacturing:** Design flexibility
- **Multi-Materials:** Light weight high performance **CFC + Al** alloy
- **Design Optimization:** Topology optimization
- **Applications:** Transport sector (aviation + locomotive)

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DOI
10.3030/101091495

Start date
1 December 2022

End date
30 November 2025

Funded under
Digital, Industry and Space

Total cost
€ 4 071 977,50

EU contribution
€ 4 071 977

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Multi-Materials and Design Optimization

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MULTHEM: Real Use Cases

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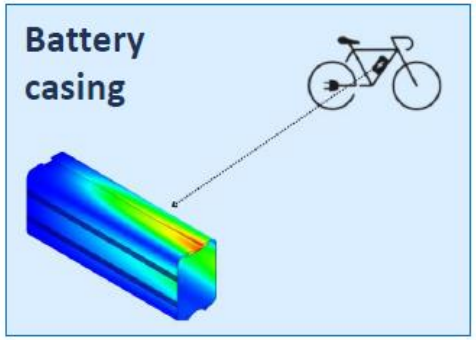
- Components…

KPIs
Mass Reduction 30% - 50% reduction
Product Performance 20%
Lead time reduction by 35%

KPIs
Mass Reduction 30% - 50% reduction
Improve Thermal Performance by 20%
Mechanical Properties by 15%



KPIs
Mass Reduction 30% - 50% reduction
Thermal Performance below 85C
EMI sheilding efficiency reduce from 60dB to 25dB

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Methodology

- **Characterised Materials with Joining Data:**
  - 3D Printed {CFC + Al / metal} various combinations. Initial trials with original metal material
- **Simulation Analysis:**
  - Multiple inputs
  - 3D printing constraints
  - Remodelling & Multi-system Design Analyses
  - Iterative
- **Weight Reduction:**
  - CAD Simplifications
  - Multi-materials
  - Topology optimization

PEKK-CF
E = 9125 MPa
HDT = 285 °C
ρ = 1.33 g/cm^3

PA6-CF
E = 5500 MPa
HDT = 140 °C
ρ = 1.21 g/cm^3

Source: https://multhem.eu/documents/LightMe%20Conference.pdf

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The Use Cases

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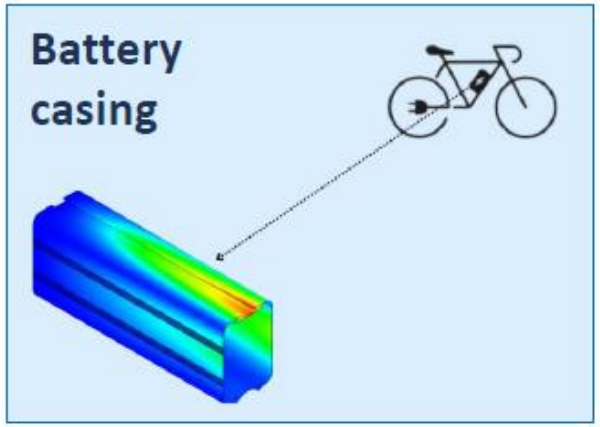

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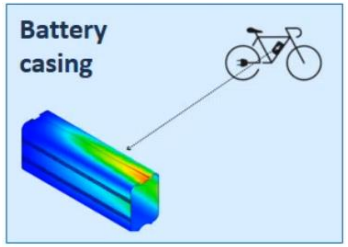
Use Case: EV Battery



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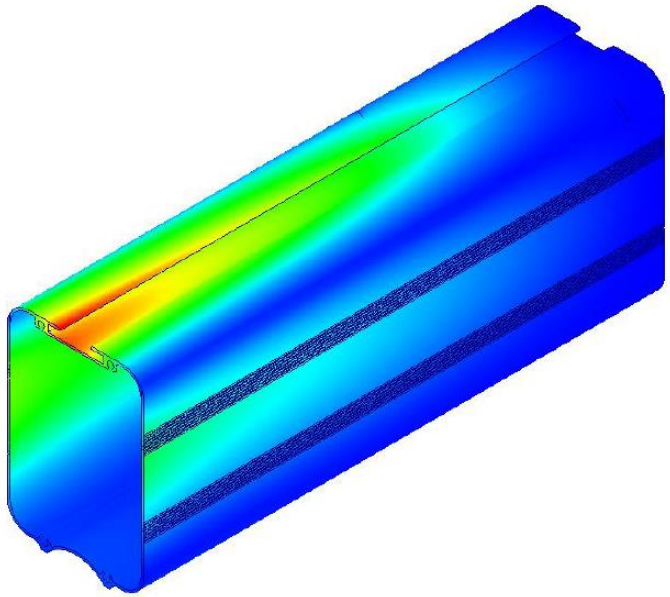
- **Mass Target Set:** e.g., 30% - 50% reduction



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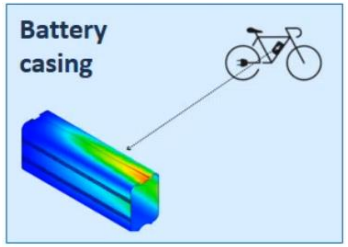
Use Case: EV Battery



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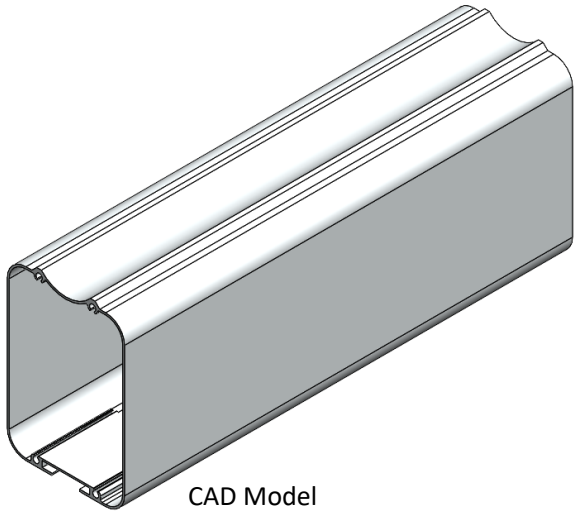
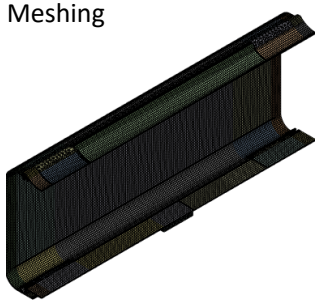
- **Mass Target Set:** e.g., 30% - 50% reduction
- Process…

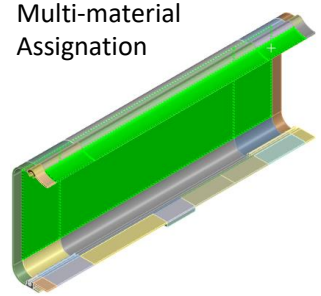

CAD Model

Simplification

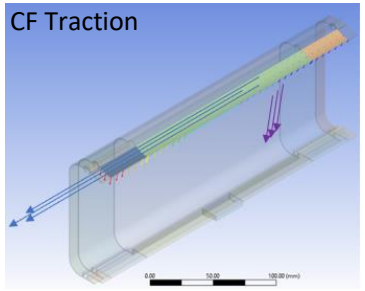
Meshing



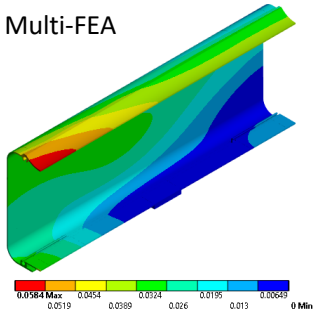
Multi-material Assignation



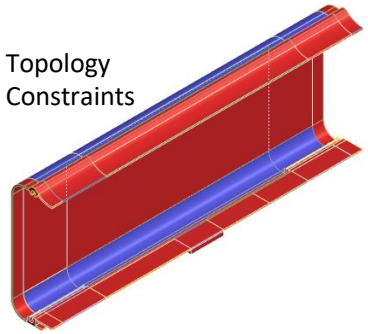
CF Traction



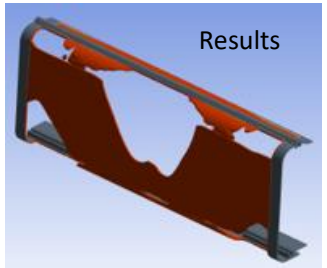
Multi-FEA



Topology Constraints



Results



Multi – Iterative Process

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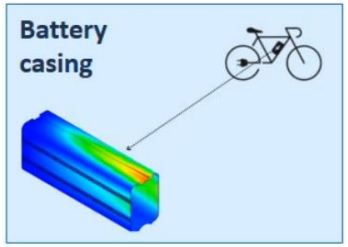
Use Case: EV Battery



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- **Mass Target Set:** e.g., 30% - 50% reduction

Iteration #	Material	Original Battery Mass (kg)	Optimized Battery Mass (kg)	> Reduction (%)	TD - 45deg (mm)
1	sCF-PA6 + Al	0.631		Trial	
2	sCF-PA6 + Al	0.631		Trial	
3	sCF-PA6 + Al	0.631	0.27536	56.36%	0.058406
4	sCF-PA6 + Al	0.631	0.27536	56.36%	0.058463
5	sCF-PA6 + Al	0.631	0.27536	56.36%	0.058402
6	sCF-PA6 + Al	0.631	0.24478	61.21%	0.069147
7	sCF-PEKK + Al	0.631	0.28366	55.05%	0.07391
8	cCF-PA6 + Al	0.631	0.2843	54.94%	0.04562
9	cCF-PEKK + Al	0.631	TBC	TBC	TBC

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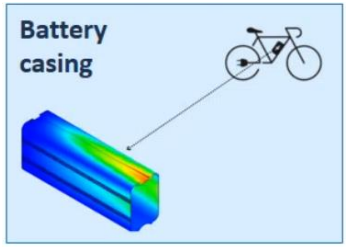
Use Case: EV Battery



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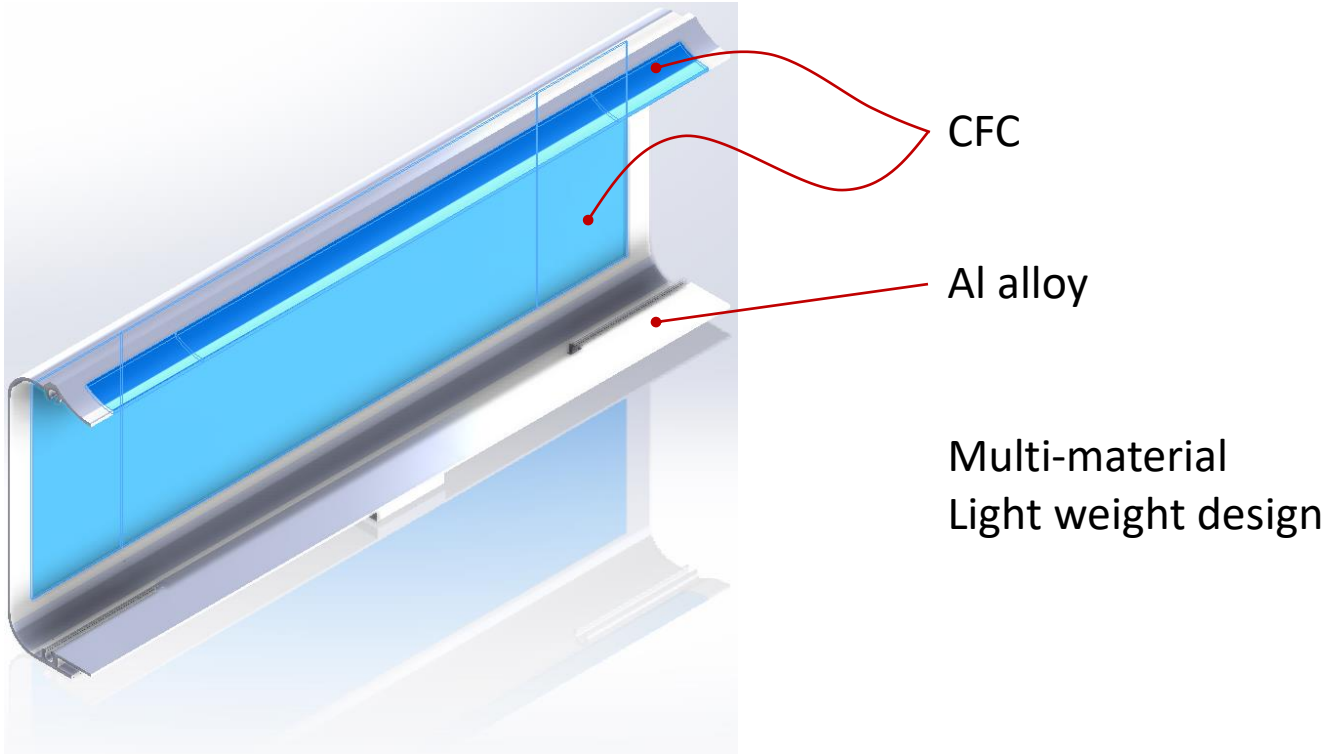
- **Mass Target Set:** e.g., 30% - 50% reduction
- Design Summary…



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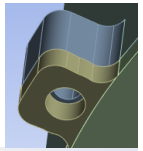
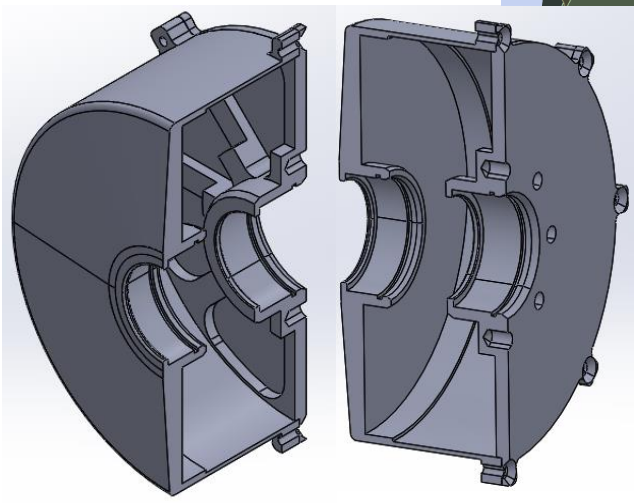
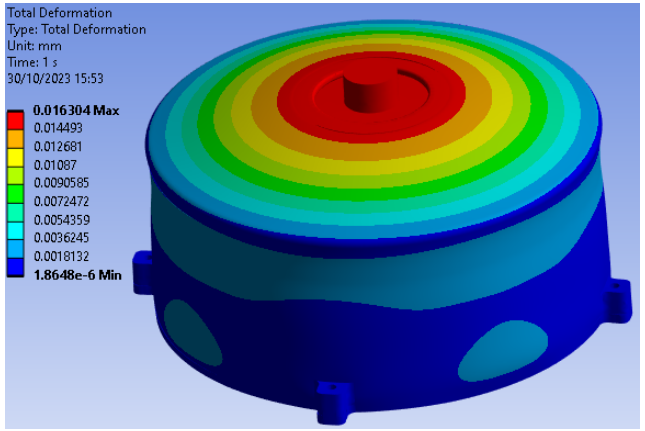
Use Case: Motor Housing

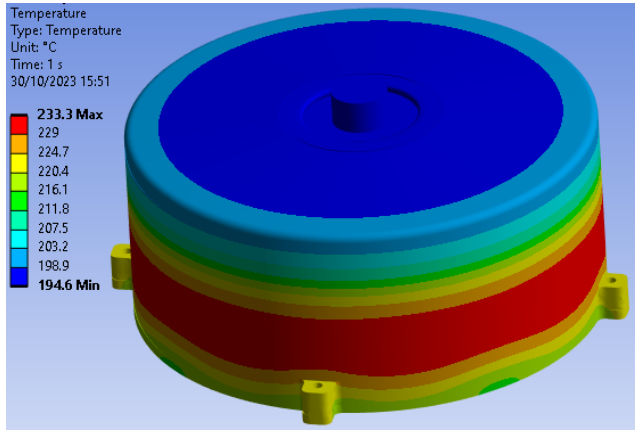
- **Mass Target Set:** e.g., 30% reduction
- Multi-analysis…

Geometrical Simplifications









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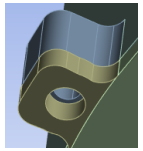
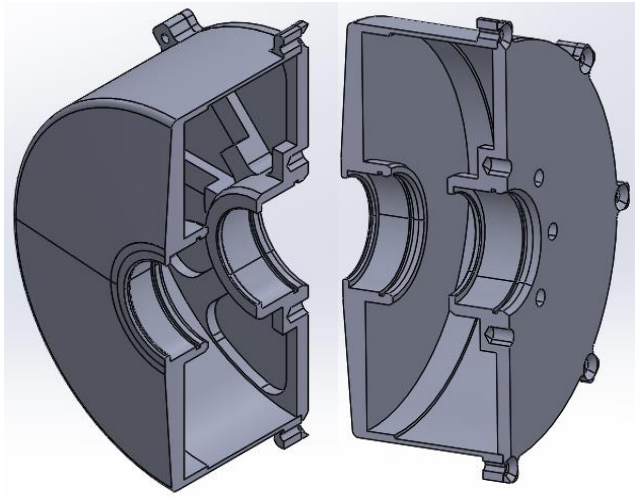
Use Case: Motor Housing

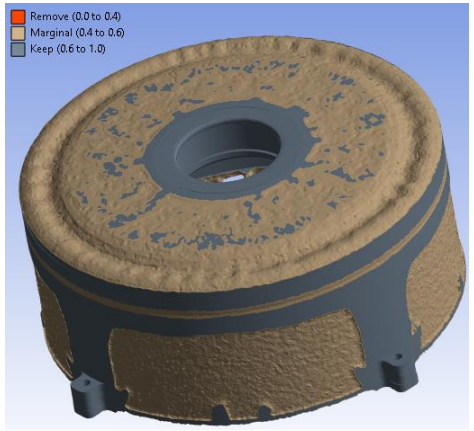
- **Mass Target Set:** e.g., 30% reduction
- Reduced Mass: 27.7%

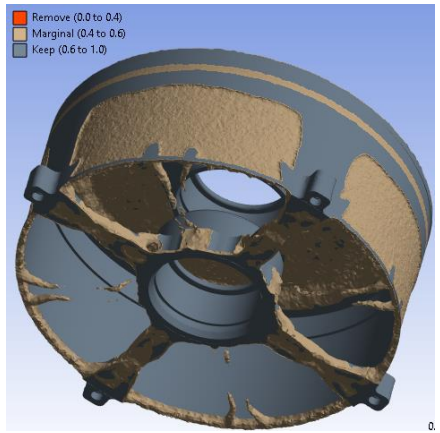
Geometrical Simplifications



Original Mass	1.1663 kg
Final Mass	0.84333 kg
Percent Mass of Original	72.307







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Use Case: Motor Housing

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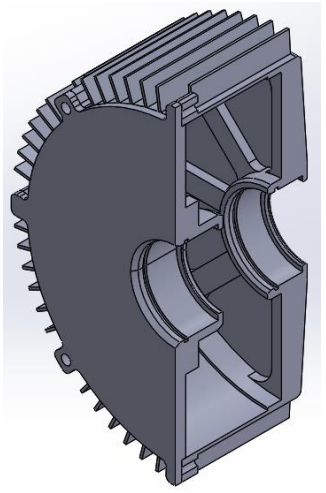
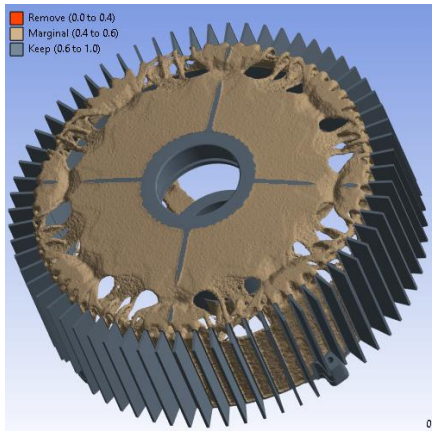
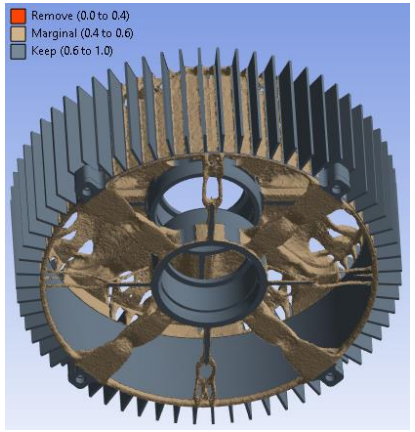
- **Mass Target Set:** 30% - 50% reduction
- Reduced Mass: 37.94%

Fins and Top
Cover spokes





Original Mass	0.37187 kg
Final Mass	0.2308 kg
Percent Mass of Original	62.065



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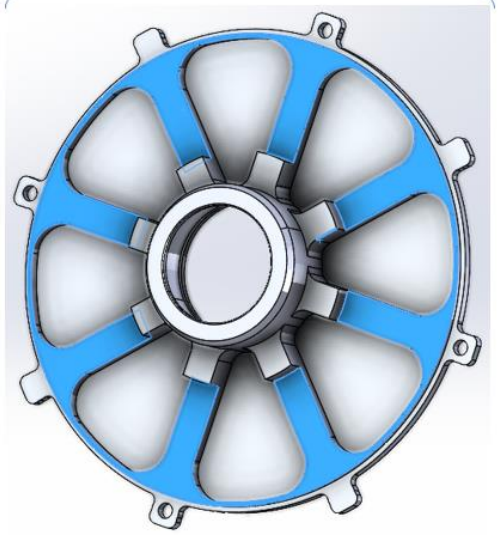
Use Case: Motor Housing

- **Multi-materials:** Next set of iterations…



Multi-material Assignation in Process

Where to place CFC and where to place the metal…

Decisions are based on…

Material properties
- Structural – with CF traction in mind where highest strength is observed
- Thermal – below the max. temperature limit.

3D printing constraints
- Printing process
- Line width, Layer height etc.

Joining Methods
- Feasibility checks with tests
- Joint strength for the given loads

UNDER INVESTIGATION

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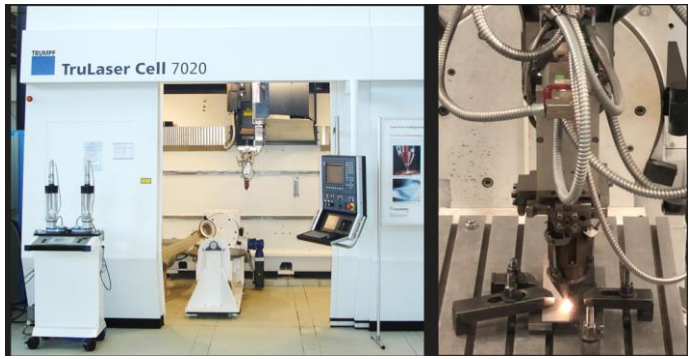
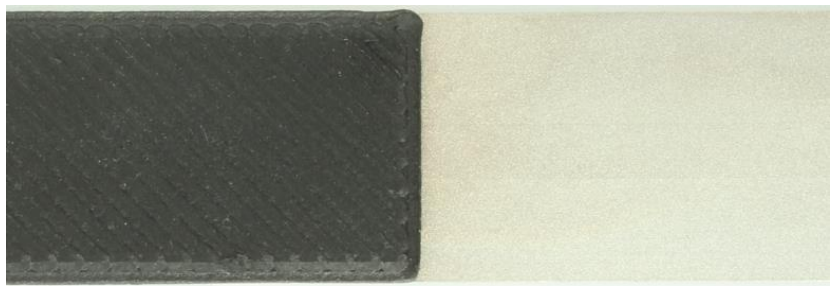
A Glimpse of Joining Methods

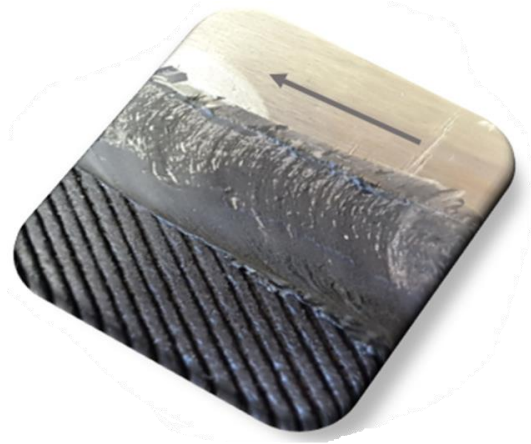
- **EBW** (Electron Beam Welding)
- **LBW** (Laser Beam Welding)
- **FSW** (Friction Stir Welding)



LBW
Credit: Fraunhofer



Joined PA6 CFC + Al Alloy
Credit: Fraunhofer



FSW (CFC + AL)
Credit: CETEMET

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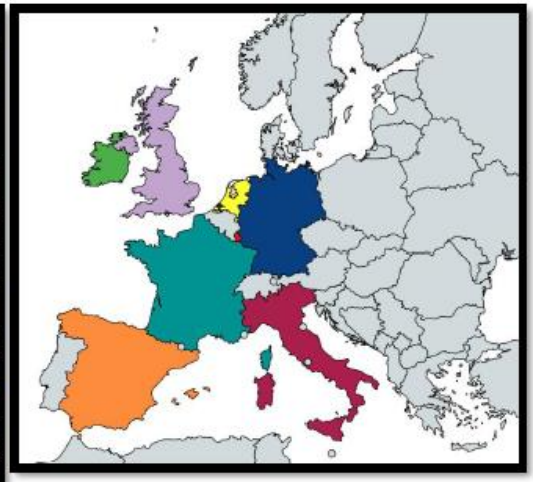

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THANK YOU!

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