Development of a Lightweight Forged Magnesium Aircraft Seat Component

Eighth Triennial International Aircraft Fire and Cabin Safety Research Conference

27th October 2016

Dominic Henry – Magnesium Elektron
Martin Kemp – Altair Product Design
Agenda

• Introduction
  – Magnesium Elektron
  – Magnesium in the aircraft cabin

• Development of lightweight forged aircraft seat components
  – Intro to Featherlite Aircraft Seat NATEP project
  – Data generation and properties
  – FEA simulation development
  – Forging – Buy to Fly ratio improvement
  – Machining – fast & efficient dry machining
  – Dynamic Testing – 16 G

• Summary
Wrought Products
Casting Alloys
Powders
Recycling
Biomedical

Aerospace, Automotive, Defence, Biomaterials, Graphic Arts, Oil & Gas, Speciality

CUSTOMER FOCUS • PERSONAL GROWTH
EXCELLENCE • ACCOUNTABILITY • INNOVATION

9 manufacturing sites in the UK, Europe & North America
500 employees worldwide
Magnesium – Aircraft Cabin Regulations

SAE International Aerospace Standard – AS8049B

Para 3.3.3 “Magnesium alloys shall not be used.”

….it appears that certain magnesium alloys may have flammability properties acceptable for use in aircraft seat structure ….

Example of no burning after melting (Elektron 43 & Elektron 21)

Example of burning after Melting (AZ31)

AS8049C: “Magnesium alloys may be used in aircraft seat construction provided they are tested to and meet the flammability performance requirements in the FAA Fire Safety Branch document: Aircraft Materials Fire Test Handbook – DOT/FAA/AR-00/12, Chapter 25, Oil Burner Flammability Test for Magnesium Alloy Seat Structure.”
What is Elektron®43?

- Elektron® 43: The latest wrought magnesium aerospace alloy

- Elektron®43: Available as plate, extrusion, forging stock.
  - AMS 4371 - Plate Precipitation Heat Treated
  - AMS 4485 - Extrusions Precipitation Heat Treated
  - MMPDS: Contains –A and –B basis statistical minima
Where are WE43 alloys used?

- **Eurocopter EC120**
- **Bell Agusta 609**
- **MD Helicopter: MD600N**

**Magnesium Elektron**

Customer Focus • Personal Growth

Excellence • Accountability • Innovation
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• Summary
Featherlite Aircraft Seat Project

- UK Government backed scheme - National Aerospace Technology Exploitation Program
- Lightweighting offers economic and environmental benefits
  - Reduced fuel burn and CO₂ emissions.
- Reduce barriers to aircraft interiors OEM’s using UK sourced high performance magnesium alloys
- Develop forging and machining technology to ensure UK based supply chain is economically and technically capable of providing weight saving in the cabin
- Establish a UK based supply chain with a potential global end market not just be limited to seats
Partners and their roles in the Project

• Lead partner with 80 years of magnesium alloy development experience.

• End User (non-funded) with 30 years aircraft interiors experience. European based passenger seat manufacturer for Aircraft OEMs.

• Leading global service provider of precision-forged and machined components in titanium, aluminium and special steels.

• Specialist machinist - Aerospace, Defence, Oil & Gas and Communications - with 5 axis capability.

• A world leader in virtual design solutions with a 20 year track record in developing better products across industries including Auto, Aero, Defence and Consumer.

• Advanced Manufacturing Research Centre (AMRC) with Boeing is a world-class centre for advanced machining and materials research for aerospace and other high-value manufacturing sectors.
Part Selection

Piuma EVO seat put forward for project by Geven
Project Innovation – Work packages

WP1: Component design
- FEA
- HSR Data

WP2: Forging

WP3: Specification
- ASTM / AMS

WP4: Machining

WP5: Recycling

WP6: Product costs

WP7: Validation and Testing

High strength Mg alloy Elektron® 43

Lightweight Aircraft Seat components

CUSTOMER FOCUS • PERSONAL GROWTH
EXCELLENCE • ACCOUNTABILITY • INNOVATION
Project Innovation – Highlights WP1

Elektron®43 High specific strength & energy absorption @ HSR

Genuine Design for Manufacture

External experts used when required

WP1 Component design

CUSTOMER FOCUS ● PERSONAL GROWTH
EXCELLENCE ● ACCOUNTABILITY ● INNOVATION
Altair Product Design Approach
**NATEP FEA Design Development Process**

**Loads Development**
- Develop equivalent static load cases

**Topology Optimisation**
- Use Topology (concept) optimisation to establish load paths.
- Interpret topology results into a new baseline designs.

**Size and Shape Optimisation**
- Develop and parameterise an FE model from the new baseline
- Run size and shape (refinement) optimisation to tune the design under static load conditions

**Design Verification**
- Up to seven dynamic and static test simulations will be performed to verify the optimized design including forward, upward, downward and sideward cases
# Development of FEM – Material Data

## Material Properties for Elektron® 43 vs Aluminium 2024 – T351

<table>
<thead>
<tr>
<th>Property</th>
<th>Magnesium (Elektron® 43)</th>
<th>Aluminium 2024 T351</th>
</tr>
</thead>
<tbody>
<tr>
<td>Youngs Modulus</td>
<td>44 GPa</td>
<td>73.1 GPa</td>
</tr>
<tr>
<td>Poissons Ratio</td>
<td>0.27</td>
<td>0.33</td>
</tr>
<tr>
<td>Density</td>
<td>1840 kg/m³</td>
<td>2780 kg/m³</td>
</tr>
<tr>
<td>Yield Stress</td>
<td>240 MPa</td>
<td>324 MPa</td>
</tr>
<tr>
<td>UTS</td>
<td>350 MPa</td>
<td>469 MPa</td>
</tr>
<tr>
<td>Specific Strength</td>
<td>190 MPa/(g/cm³)</td>
<td>170 MPa/(g/cm³)</td>
</tr>
<tr>
<td>Elongation</td>
<td>12%</td>
<td>6%</td>
</tr>
</tbody>
</table>

- High quality data suitable for non-linear dynamic modelling
- Material model requires family of true stress vs true plastic strain curves for rate range
- Strain rate up to 500/s generated at specialist test house
- Elektron®43: High specific strength, high strain hardening behaviour and excellent energy absorption characteristics
Development of Finite Element Model

- Mid Surfaced Seat Assembly FE Model created in HyperMesh suitable for Dynamic and Static Assessment
FE Modelling and Load Case Definition

- Equivalent Static Load Cases Defined for Design Purposes
  - 16g Forward
  - 14g Down
  - 16g Fwd - ATD Restraints
  - Static 12.0G FWD
  - Static 4.0G Sideward
  - Static 7.2G Upward
  - Static 11.5G Down
- Load cases are defined from peak test reaction forces
- Static analysis performed using OptiStruct and Dynamic analysis using RADIOSS

- Dynamic Loading to Represent Physical Test
  - Dynamic Model Developed using Hybrid III dummy models
  - Dynamic Simulations to be defined to represent test cases
Design Space Definition

- Design Space geometry defined to encapsulate existing structure and to add additional space for new stiffening options
- Integrated with current seat structural model using similar modelling strategy to seat structure model
- Sub-Model created to focus on design space and capture boundary conditions
Topology Concept Definitions

- OptiStruct topological optimisation to define architectures
- Simplified static load cases to represent key loading requirements
Example Analysis (based on 16g FWD reactions)
Model verification – preliminary testing

• Testing carried out on machined demo parts
• Material not forged, but used as early indicator of performance and potential success.
Final Design –
19% weight saving vs existing Al 2024 – T351

<table>
<thead>
<tr>
<th>Material / Component</th>
<th>Weight saving (%)</th>
</tr>
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<tbody>
<tr>
<td>Aluminium 2024</td>
<td></td>
</tr>
<tr>
<td>Spreader:</td>
<td></td>
</tr>
<tr>
<td>Front Leg:</td>
<td></td>
</tr>
<tr>
<td>Elektron 43 Mg Rev 3</td>
<td></td>
</tr>
<tr>
<td>Spreader</td>
<td>21</td>
</tr>
<tr>
<td>Front Leg</td>
<td>21</td>
</tr>
<tr>
<td>Elektron 43 Mg Rev 4</td>
<td></td>
</tr>
<tr>
<td>Spreader</td>
<td>19</td>
</tr>
<tr>
<td>Front Leg</td>
<td>19</td>
</tr>
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Project Innovation – Work packages

WP1 Component design
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WP5 Recycling

WP6 Product costs

WP7 Validation and Testing

High strength Mg alloy Elektron® 43

Lightweight Aircraft Seat components
WP2 – Forging Development

- Reducing Buy to Fly ratio through forge process

<table>
<thead>
<tr>
<th></th>
<th>Machining</th>
<th>Pre-NATEP</th>
<th>NATEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy-to-Fly ratio</td>
<td>10 : 1</td>
<td>4.4 : 1</td>
<td>3.3 : 1</td>
</tr>
<tr>
<td>% yield (F2B)</td>
<td>10 %</td>
<td>22 %</td>
<td>31 %</td>
</tr>
</tbody>
</table>

Extruded bar feedstock

Pre-NATEP – excess flash

Improved forge process – reduced flash
Elektron® 43 – Tensile Isotropy forge vs. ext.

Strength (MPa)

<table>
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<tr>
<th>Angle</th>
<th>Extrusion</th>
<th>Forge Spreader</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>45°</td>
<td>275</td>
<td>300</td>
</tr>
<tr>
<td>90°</td>
<td>250</td>
<td>300</td>
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Elongation (%)

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<tr>
<th>Angle</th>
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</tr>
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<tbody>
<tr>
<td>0°</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>45°</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>90°</td>
<td>20%</td>
<td>10%</td>
</tr>
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High strength Mg alloy Elektron® 43

Lightweight Aircraft Seat components
WP4 – Dry machining Elektron®43

- Baseline dry machining characteristics vs aluminium
  - Parts machined on Vertical Milling Centre.
  - Standard (Aluminium grade) tooling used
- Depth of cuts +35% compared to Aluminium.
- Feedrate +40% compared to Aluminium.
- Cycle time saving of approximately 35%.
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High strength Mg alloy Elektron® 43

Lightweight Aircraft Seat components
Successful 16G Dynamic Test

Test: D16026AC Test type 2 (FWD) - Front Facing
Date: 22/02/2016
Seat: C7-0000-000-000

Lab Manager: S. Cicatiello
Test Engineer:
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Summary

» Significant weight saving of Elektron® 43 vs high strength aluminium alloy 2024
  • Successful 16g dynamic testing

» Capabilities developed in the forging of a magnesium alloy suitable for aerospace applications

» Fast, efficient, dry machining of a magnesium alloy safely demonstrated.

» The aerospace industry: improved UK supply chain for downstream processing of magnesium alloys coming out of Magnesium Elektron
Thank you for listening...

A special thank you to all of the following people:
- Martin Kemp and the Altair Product Design team – UK
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- Nacho Blanco, Erdem Ozturk and Omer Ozkirimli - AMRC
- Rohima Begum, Rory Barker, Phil Rogers and many others in the technical department at MEUK
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