Potentials of low-carbon aluminium products in automotive applications

Dinesh Thirunavukkarasu, Kristian Seidel (fka GmbH); Stig Tjøtta (Norsk Hydro ASA)
Agenda

» Introduction

» Motivation

» Approach

» Results

» Summary
fka – Full Vehicle Engineering Service Provider

CEO
Dr.-Ing. Markus Bröckerhoff

Director
Univ.-Prof. Dr.-Ing. Lutz Eckstein

- Strategy and Consulting
  - Founded in 1902 (ika) and 1981 (fka)
  - Total staff of more than 500 employees (ika + fka)
    - ~200 engineers
    - ~80 workers, technicians and apprentices
    - ~220 students
  - References:
    - Automotive customers from Europe, USA and Asia
    - OEM and suppliers
    - Public funded research

- Vehicle Concepts
- Thermal Management
- Acoustics
- Driver Experience and Performance

- Chassis
- Body
- Drivetrain
- Electrics/Electronics
- Driver Assistance
Hydro –
An integrated customer-oriented aluminium company

• Global provider of alumina, aluminium and aluminium products and solutions

• Leading businesses along the value chain; raw materials, energy, primary metal, rolled products, extruded solutions and recycling

• 35,000 employees at 150 locations in 40 countries

• Market cap ~NOK 100 billion/ ~USD 12 billion

• Annual revenues NOK 109 billion (2017)

• Included in Dow Jones Sustainability Indices, Global Compact 100, FTSE4Good
Hydro is pushing the boundaries for low carbon aluminum and use of consumer scrap to create recycled alloys and products helping our customers on the path to zero emissions.

Through the use of renewable power and modern technology we are able to produce cleaner aluminum than ever before.

Hydro REDUXA® is a certified, low carbon aluminum with a maximum carbon footprint of 4.0 kg CO₂ per kg aluminum.

Hydro CIRCAL® is a range of prime quality aluminum made with a minimum of 75% recycled, consumer scrap.

Hydro is working to further develop greener alloys partnering with our forward looking customers.
Hydro REDUXA – Primary billet

REDUXA available in all grades and formats supplied from Hydro’s Norwegian aluminium plants(*)

Max 4.0 kg CO2e per kg aluminium

«All-in» approach
Scope 1, 2 and 3
Certified ISO 14064
EPD
Current legislative regulations mainly focus on emissions generated in the use-phase of vehicles.

Reduction of tailpipe emissions (by i.e. electrification) leads to increased share of emissions generated in the Production and End-of-Life (EoL) phase.

Lightweight design reduces use-phase emissions significantly, but usually generates a higher emission impact in the production phase compared to a conventional steel intensive design.

Holistic approach required to assess lightweight technologies and other CO₂ reduction measures from a life-cycle perspective in order to evaluate the ecological break-even point and economical implications.
Application of aluminium in vehicles offers significant weight reduction potential compared to conventional materials.

Production of aluminium is often related to a higher ecological footprint compared to steel and dependent on the boundary conditions (energy sources, recycling rate, etc.).

Considering the weight saving potential and vehicle use scenarios, the application of aluminium could lead to an ecological benefit.

Open Question: How does aluminium and especially low-carbon aluminium impact the LCA of vehicles?
Motivation
CO$_2$eq footprints by origins

Source: IAI/EAA/Hydro
Motivation
The fka vehicle assessment model as a baseline

→ Methodical assessment of light weighting technologies at an early concept phase of the vehicle development process without an actual layout
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Approach
Definition of generic vehicles & lightweight variants

- Incl. consideration of primary and secondary weight saving effects (downsizing of chassis & engine, scaling of energy storage system, etc.)
Approach
Aluminium Application in Car Bodies

» Outer Panels
  Deep drawing
  EN AW 6016

» Body Structure
  ■ Structural Sheets
    Deep drawing
    EN AW 5182
  ■ Structural Profiles
    Extrusion
    EN AW 6060
    (low performance, i.e. cockpit carrier)
  ■ Structural Profiles
    Extrusion
    EN AW 6082
    (high performance, i.e. rocker)
  ■ Strength relevant components
    Deep drawing
    EN AW 6061
    (i.e. A-Pillar, roof cross member)
  ■ Complex structures
    Casting
    AlSi9Mn

→ Replacement of entire steel materials in Body-In-White through aluminium
Approach
Life Cycle Assessment (LCA)

» LCA according to DIN EN ISO 14044:2006
   „Consideration of all in and outflows (material and energy), as well as potential environmental impact of a product system throughout all life-cycle stages”

GWP Values (Primary):

» AL European Average: 6,70 kgCO₂-equivalent/kg
» Steel: 2,08 kgCO₂-equivalent/kg
» REDUXA®: 4,00 kgCO₂-equivalent/kg

» Consideration of different representative grid-mix scenarios for the use phase of BEV
» Definition of use phase mileage scenario: 150.000 km
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### Results

#### Weight Impact

<table>
<thead>
<tr>
<th>Segment</th>
<th>Combustion Engine Vehicle (ICE)</th>
<th>Battery Electric Vehicle (BEV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compact Class Segment</strong></td>
<td><img src="#" alt="Graph" /></td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>1255.7</td>
<td>1493.6</td>
</tr>
<tr>
<td>Impact (%)</td>
<td>-13.7</td>
<td>-13</td>
</tr>
<tr>
<td>Secondary reduction</td>
<td>incl. 4.6%</td>
<td>incl. 4.5%</td>
</tr>
<tr>
<td><strong>SUV Segment</strong></td>
<td><img src="#" alt="Graph" /></td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>1553.3</td>
<td>2306.6</td>
</tr>
<tr>
<td>Impact (%)</td>
<td>-13.6</td>
<td>-10.7</td>
</tr>
<tr>
<td>Secondary reduction</td>
<td>incl. 4.6%</td>
<td>incl. 3.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Range</strong></th>
<th><strong>Incl. Secondary Reduction</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>200 km</td>
<td>4.6%</td>
</tr>
<tr>
<td>400 km</td>
<td>4.5%</td>
</tr>
<tr>
<td>600 km</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

**Vehicle Types:**
- **Combustion Engine Vehicle (ICE)**
- **Battery Electric Vehicle (BEV)**
General Results - Internal Combustion Engine Vehicles
Impact of Aluminium European Average

- Increased GHG emissions in the production phase
- Compensation of increased GHG emissions in use phase
- Reduced impact over the full life cycle

- Greenhouse gas emissions [kg CO2-eq.]

- Increased GHG emissions in the production phase
- Compensation of increased GHG emissions in use phase
- Reduced impact over the full life cycle

- Ecological break-even point

- Steel
- Aluminium
General Results - Internal Combustion Engine Vehicles

Impact of REDUXA®

Production Use Phase (150,000 km) End-of-Life

Significant reduction of GHG emissions in the production phase compared to AL European Average

Shift of ecological break even point to lower mileages or even zero

Reduced absolute impact over the full life cycle

Greenhouse gas emissions [kg CO2-eq.]

- Steel
- Aluminium 4.0
General Results – Battery Electric Vehicles
Impact of Aluminium European Average

- Absolute light weighting potential with aluminium decreases with increased size of battery
- The considered scenarios lead to increased GHG emissions in the production phase
General Results – Battery Electric Vehicles
Impact of Aluminium European Average

Use phase emissions generated are highly dependent on electricity grid mix

Low overall use phase emissions cause a shift of the ecological break-even point to higher mileages

→ Detailed scenario based analysis required if reasonable in use phase
Development Target: Favourable reduction of GHG emissions has to be achieved over the full life cycle.

Especially in regions with a high share of sustainable sources, Aluminium European average achieves a marginal benefit over the full life cycle compared to steel – “Are the efforts reasonable? → Yes!”
General Results – Battery Electric Vehicles
Impact of REDUXA®

Greenhouse gas emissions [kg CO2-eq.]

- **Significant reduction of GHG emissions in the production phase compared to AL European Average**
- **Shift of ecological break even point to lower mileages or even zero**
- **Reduced absolute impact over the full life cycle**
- **A marginal benefit of Aluminium European average over the full life cycle turns to a significant benefit for the application of REDUXA®**
- **Aluminium application will gain more relevance from a sustainability perspective**

Production | Use Phase (150,000 km) | End-of-Life
---|---|---
Steel | Aluminium 4.0

GHG emissions:
- Steel: 0, 5000, 10000, 15000, 20000, 25000, 30000 kg CO2-eq.
- Aluminium 4.0: 0, 5000, 10000, 15000, 20000, 25000, 30000 kg CO2-eq.
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Summary
Key Findings

» The electricity mix of the specific regions have a big influence on the CO₂ footprint of a BEV

» REDUXA® 4.0 is a key enabler to reduce full vehicle production emissions and allow a better CO₂ footprint from the first kilometre onwards

» While the application of Aluminium European Average in BEV is not favorable from a GHG perspective in the production and use phases for regions with a high share of sustainable energy sources, REDUXA® 4.0 can cause a lower environmental impact in all life-cycle stages

» The highest absolute environmental benefit from light weighting with aluminium in BEVs can be achieved in regions with a high share of fossil energy sources

» A reduction of the use phase emissions by light weighting results in a higher overall relevance of the production phase, thus materials like REDUXA® 4.0 gain more importance

» Lighter cars lead to smaller battery packs for the same driving range. Further work in a separate study will focus on the economic trade off between light weighting costs and battery/ drivetrain costs under varying conditions
**Summary**

**Key Findings – Schematic Impact Illustration**

- **GWP Use [kg CO₂-eq.]**
  - Reference
  - HSS
  - Best-Case
  - Worst-Case

- **GWP Production [kg CO₂-eq.]**
  - Hydro 4.0
  - Aluminium
  - Best-Case
  - Worst-Case

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- **Favourable Light Weighting from a GHG perspective**
- **Unfavourable light weighting from a GHG perspective**

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**Range for material footprint**
Dinesh Thirunavukkarasu
Thank you for your attention.