The Chances and Potentials for Low-Voltage Hybrid Solutions in Ultra-Light Vehicles

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Content

- CULT – Cars Ultra-Light Technology
- Material concept
- Hybrid concept 12 Volt | 48 Volt
- Conclusion
CULT – Cars Ultra-Light Technology

Vehicle curb weight: **600 kg**

**CO₂ emissions:** **49 g/km**

- **Sep. 2010** – *First ideas*
- **Jul. 2012** – *CAD design*
- **Nov. 2013** – *Demonstrator vehicle*
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Material concept

BASE 900 kg

- **Integration of functions** (cancellation of parts) - ca. -80kg
- **New materials** (selective usage of lightweight materials) - ca. -100kg
- **Downsizing** (& use of secondary effects) - ca. -120kg

Weight reduction up to 300 kg

TARGET 600 kg (achieved: 672.5 kg)

- Integrated fuel door
- Multi-material body
- Engine: 660 cm³ instead of 1000 cm³
Material concept

- CRP Duroplast: 8%
- Sandwich Parts: 5%
- Al-Profiles: 27%
- Al-Sheet: 26%
- Al-Castings: 17%
- Steel: 7%
- GRP Thermoplast (Organosheet): 10%

(related to weight)
Material concept

- Multi material body in white
- Fiber composite door and hood
- Composite floor
- Fire wall made of sandwich material
- Composite axle module
- Organic front crash system
Material concept

Weight comparison (without doors & closures):
- CULT: 147 kg (measured incl. Paint)
- Benchmark veh.1 : 240 kg
- Benchmark veh.2 : 222 kg
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- **Hybrid concept**  
  12 Volt | 48 Volt
- Conclusion
Hybrid concept | 12 Volt

Vehicle curb weight: 600 kg

TARGET

Micro Hybrid

Mild Hybrid

12 Volt ……… 48 Volt ……… 100 Volt ………

Conclusion

- Increased recuperation potential by de-clutching the internal combustion engine (ICE) during deceleration states
- Pure e-drive feature for low speeds (<35 km/h), → comfort benefit for stop-and-go traffic or automated parking
- **12 Volt hybrid topology saved 9.5 % CO₂** compared to a conventional stop start configuration
Hybrid concept | 48 Volt

Today

12 Volt

12V

Storage

GEN

12 / 48 Volt

12V

Storage

DC

DC

48V

Storage

GEN

Tomorrow

Power (12 Volt)

Power (48 Volt)

Power (300 Volt)

Current [A]

Power [kW]

0 2 4 6 8 10 12 14 16 18 20

0 50 100 150 200 250 300 350 400

$U = 12 \text{ V}$

$I = 83 \text{ A}$

Power (12 Volt)

Power (48 Volt)

Power (300 Volt)

$P_{\text{demand}} = 1000 \text{ W}$

$U = 12 \text{ V}$

$I = 83 \text{ A}$

Power (12 Volt)

Power (48 Volt)

Power (300 Volt)

$P_{\text{Losses, Wire}} = I^2 \cdot R_{\text{Wire}}$

$R_{\text{Wire}} = \rho \cdot \frac{l}{A}$

$P_{\text{Losses, Wire}} = 31 \text{ W}$

$P_{\text{Losses, Wire}} = 2 \text{ W}$

Relative $3.1\%$

$0.2\%$

Desired wire profile (relative)

Weight for 1 m wire

223 g

22 g

Factor 10!
**Conclusion**

- Curb weight of a vehicle highly influences the dynamic behavior itself.
- An ultra-light structure increases acceleration rates and max. velocity operated by a 48 Volt electrical machine.
- Next to the CO₂ reduction by an intelligent operating strategy, this means a higher Fun-to-Drive value.

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**F = F_{Roll} + F_{Air} + F_{Grade} + F_{Acc} = (m \cdot g \cdot f) + \left( c_w \cdot A \cdot \frac{\rho_{Air}}{2} \cdot v^2 \right) + (m \cdot g \cdot \sin \alpha) + (\lambda \cdot m \cdot a) **

- **F** ... Total vehicle resistance
- **F_{Roll}** ... Rolling resistance tires
- **F_{Air}** ... Air resistance
- **F_{Grade}** ... Road grade resistance
- **F_{Acc}** ... Acceleration resistance

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Vehicle curb weight: 2000 kg vs. 680 kg

**Additional electrical traction potential enabled by ultra-light vehicle structure**
**Conclusion**

- ICE disadvantage concerning the low-end-torque (below 2500 rpm) can be compensated by an electrical boost with the 48 Volt Belt-Starter-Generator
- Full load available at nearly 0 rpm engine speed
## Concept Curb weight | Time 0-100 km/h | Potential

<table>
<thead>
<tr>
<th>Concept</th>
<th>Curb weight [kg]</th>
<th>Time 0-100 km/h [s]</th>
<th>Potential [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis</td>
<td>680</td>
<td>15,6</td>
<td>-</td>
</tr>
<tr>
<td>Boost 48V</td>
<td>680</td>
<td>13,6</td>
<td>-12,8 %</td>
</tr>
<tr>
<td>Boost 48V</td>
<td>1000</td>
<td>16,7</td>
<td>+ 7,1 %</td>
</tr>
<tr>
<td>Boost 48V</td>
<td>1500</td>
<td>21,7</td>
<td>+ 39,1 %</td>
</tr>
<tr>
<td>Boost 48V</td>
<td>2000</td>
<td>27,1</td>
<td>+ 73,7 %</td>
</tr>
</tbody>
</table>
Hybrid concept | 48 Volt

- 680 kg - Basis
- 680 kg - Boost 48V
- 1000 kg - Boost 48V
- 1500 kg - Boost 48V
- 2000 kg - Boost 48V

After 10 Sec.
- 2000 kg 48V Boost: -27 m
- 1500 kg 48V Boost: -10 m
- 1000 kg 48V Boost: +7 m
- 680 kg 48V Boost: +24 m
- 680 kg Basis: +46 m

After 20 Sec.
- 2000 kg 48V Boost: -99 m
- 1500 kg 48V Boost: -58 m
- 1000 kg 48V Boost: -1 m
- 680 kg 48V Boost: +46 m
- 680 kg Basis: +46 m
Hybrid concept | 48 Volt

Theoretical substitution potential by 48 Volt BSG

Velocity [km/h] and Acceleration [m/s²]

- 680 kg - Vehicle power demand
- Max. Power BSG 48V (Motor)
- Min. Power BSG 48V (Generator)
- Driving cycle conditions

New European Driving Cycle | NEDC

- 2000 kg
- 1500 kg
- 1000 kg
- 680 kg

All driving points (100%)

50% 60% 70% 80% 90% 100%
Hybrid concept | 48 Volt

New European Driving Cycle | NEDC

Conventional

|   48 Volt |   63,0 % |
---|---|
Stop start | 12,0 % |
ICE | 23,5 % |
Mechanical brakes | 63,0 % |

Values related to time
Hybrid concept | 48 Volt

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Values related to time

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>48V Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity [km/h]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>100,0 %</td>
<td>- 8,6 %</td>
</tr>
<tr>
<td>95%</td>
<td>- 9,2 %</td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>85%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>82,2 %</td>
<td></td>
</tr>
</tbody>
</table>

**New European Driving Cycle | NEDC**

**Conventional**

- Stop start: 12,0%
- ICE: 63,0%
- Electric driving: 23,5%
- Recuperation: 12,0%
- Mechanical brakes: 3,8%

**48V Hybrid**

- Stop start: 12,2%
- ICE: 30,6%
- Electric driving: 23,5%
- Recuperation: 29,2%
- Mechanical brakes: 12,0%

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TU WIEN

CULT - Cars Ultra-Light Technology
Workshop about Lightweight in Hybrid and Electric Vehicles
Switzerland, 9th - 10th October 2014 | R. Steffan | Slide 18
**Conclusion**

- Up to 17.8% fuel saving potential by exchanging the 12 Volt electrical system by a 48 Volt topology
- By an increasing battery capacity and an external charge support, CO₂ can be reduced to the half
- 48 Volt Plug-In concept defines a unique approach and is enabled by this ultra-light vehicle concept
Hybrid concept | 48 Volt

Other Plug-In configurations

CULT 48V Plug-In

WEIGHT_{\text{delta, Plug-in}} [kg] \ /
RANGE_{\text{electrical}} [km]

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Conclusion

- Successful development of an outstanding and drivable ultra-light vehicle prototype with a curb weight of only 672.5 kg for a 4-seater A-segment car
- Development and integration of an innovative CNG hybrid powertrain
- Due to the ultra-light structure, the 12 volt hybrid system saved additional CO₂ as well as the potential to drive slow vehicle speeds purely electrically

- Due to the promising 48 Volt technology, an additional research project has started outlining the potential of a 48 Volt Belt-Starter-Generator configuration in the context of such an ultra-light vehicle
- The low curb weight allows an extended electrical driving function in terms of acceleration and top speed (up to 90 km/h)
- Regarding the CO₂ legislation, there is a huge CO₂ saving potential using an intelligent operating strategy of internal combustion engine and electrical machine
- Overall, this 48 Volt solution is less complex compared to conventional high-voltage solutions, this finally reduces costs and could convince conservative costumers to buy a hybrid
CULT 12 Volt - hybrid prototype

- KUNSTSTOFF TECHNIK LEOBEN: Production processes for lightweight materials
- ÖGI: Metallic lightweight cast materials
- PCCL: Fiber-reinforced plastics

CULT (Cars’ Ultralight Technologies)

- TU WIEN: Engine/transmission
- AD MANUFACTURING: Sandwich parts (CIMERA material)

CULT 48 Volt - research study

- CPT POWER: Belt-Starter-Generator (12 + 48 Volt)
- SCHAEFFLER ENGINEERING: Software + application support

Styrian Business Promotion Agency

Austrian Climate and Energy Fund

Austrian Society of Automotive Engineers
Thank you for your attention!

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