« EMR and Inversion-Based Control of a CVT-based Hybrid Truck »

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FEDER project: Multi-sources hybrid truck with innovative transmission systems

Objective of the project: Comparison of different structures

In the presentation

Innovative transmission + Multi-sources

CVT + Battery + Supercapacitor
1. **EMR and control of the CVT-based hybrid truck**
   - Gearbox and CVT principles
   - EMR and control
   - Energy Management Strategy
   - Results

2. **EMR and control of an Hybrid Energy Storage System**
   - H-ESS principles
   - EMR and control
   - Energy Management Strategy
   - Results

3. **Conclusion & Perspectives**
« EMR and control of the CVT-based hybrid truck »
« EMR and IBC of a CVT-based hybrid truck »

- Gearbox and CVT principles -

 Classical Manual Gearbox

Efficiency: 92%

Continuous Variable Transmission

Efficiency: 85%
« EMR and IBC of a CVT-based hybrid truck »

- EMR and Control -

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Classical manual gearbox

Efficiency: 92%

\[
\begin{aligned}
T_{dvt} &= k_{dvt} \eta_{dvt}^k T_{tc} \\
\Omega_{tc} &= k_{dvt} \Omega_{dvt}
\end{aligned}
\]

with \( k_{dvt} = [k_1, k_2, k_3, k_4, k_5, k_6] \)

and

\[
\begin{aligned}
k &= 1 \quad \text{if} \quad T_{tc} \Omega_{tc} \geq 0 \\
k &= -1 \quad \text{if} \quad T_{tc} \Omega_{tc} < 0
\end{aligned}
\]

Continuous Variable Transmission

Efficiency: 85%

\[
\begin{aligned}
T_{cvt} &= k_{cvt} \eta_{cvt}^k T_{tc} \\
\Omega_{tc} &= k_{cvt} \Omega_{cvt}
\end{aligned}
\]

with \( k_{cvt} \in [k_1, k_6] \)

and

\[
\begin{aligned}
k &= 1 \quad \text{if} \quad T_{tc} \Omega_{tc} \geq 0 \\
k &= -1 \quad \text{if} \quad T_{tc} \Omega_{tc} < 0
\end{aligned}
\]
- Energy Management Strategy -

Rules-based strategy  

Strategy of the hybridization
- Electric at low speeds
- ICE at medium speeds + electric assistance
- ICE at high speed + load the battery

Strategy of the CVT

Recovery of the braking energy

Respect the limitations
« EMR and IBC of a CVT-based hybrid truck »

- Simulation Results -

- Chart descriptions -

1. **Velocity (km/h)**: This chart shows the velocity of the vehicle over time, with the y-axis ranging from 0 to 100 km/h.

2. **Traction power (kW)**: This chart displays the traction power output over time, with the y-axis ranging from 0 to 250 kW.

3. **ICE power (kW)**: This chart illustrates the power output from the Internal Combustion Engine (ICE) over time, with the y-axis ranging from 0 to 250 kW.

4. **Electric power (kW)**: This chart shows the electric power output over time, with the y-axis ranging from -100 to 100 kW.

5. **Transmission ratio**: This chart displays the transmission ratio over time, with the y-axis ranging from 0 to 8.

6. **SoC**: This chart illustrates the State of Charge (SoC) over time, with the y-axis ranging from 0.74 to 0.84.
- Simulation Results -

## Fuel consumption

<table>
<thead>
<tr>
<th></th>
<th>CT-DVT</th>
<th>HET-DVT</th>
<th>HET-CVT</th>
<th>HVT-DVT</th>
<th>HVT-CVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque (Nm) CVT</td>
<td>18,4 L/100km</td>
<td>19,2 L/100km</td>
<td>-13,1 %</td>
<td>-9,7 %</td>
<td></td>
</tr>
</tbody>
</table>

## Energy saving and losses

<table>
<thead>
<tr>
<th></th>
<th>CVT-ICE</th>
<th>CVT-eff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybridization</td>
<td>-4/6 %</td>
<td>-6/8 %</td>
</tr>
</tbody>
</table>

- **Interest of the CVT?**

- **CVT efficiency!**
« Hybrid Energy Storage System »
There is no ideal source

Power density (W/kg)

Energy density (Wh/kg)

Ideal source
+ life time
+ low cost,…

Battery as secondary source

- Autonomy, charging time
- Cost
- Life time

Multi-sources

Supercapacitor (SCs)
Battery
Life time

Vehicle’s viability
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« EMR and IBC of a CVT-based hybrid truck »

- EMR and control -

Battery / SCs + chopper
SCs voltage limitations

\[ \begin{align*}
    i_{\text{hsc-ref/filt}} > 0 & \quad \text{if } u_{\text{sc-m}} > u_{\text{sc-m1}} \geq 0 \\
    i_{\text{hsc-ref/filt}} \leq 0 & \quad \text{if } u_{\text{sc-M1}} \leq u_{\text{sc-m}} < 0
\end{align*} \]

Low-pass filter

\[
i_{\text{b-ref}} = k_{\text{lim}} i_{\text{vsi-mea}} + (1 - k_{\text{lim}}) i_{\text{b-ref-filt}} \quad k_{\text{lim}} \in [0,1]
\]
« Conclusion & Perspectives »
Conclusion

• EMR, control, and EMS of the whole system
• Improvement of the ICE operation BUT increasing of the transmission losses using the CVT
• Current peaks are reduced using the H-ESS
• The battery size can be reduced using the H-ESS

Perspectives

• Optimization-based strategy
• Coupling of the EMS of traction and H-ESS
• Investigate other innovative transmission systems (EVT, DPG,...)
« BIOGRAPHIES AND REFERENCES »
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