«EMR and control of a CVT-based Hybrid Electric Vehicle»

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within CE2I-IDEAL project / OptHyTruck project
I Context and Objective
   a) Context
   b) State-of-the-art about CVT
   c) Objective

II EMR and IBC of the classic gearbox-based HEV
   a) EMR and IBC of the vehicle
   b) Rule-based strategy

III EMR and IBC of the CVT-based HEV
   a) EMR and IBC of the vehicle
   b) Rule-based strategy

IV Comparison between classical gearbox and CVT-based HEV
   a) Rule-based strategy simulation
   b) Optimisation-based strategy simulation
Context and Objective
- Greenhouse gas emission and oil rarefaction conduct to develop more efficient vehicles

- One solution: hybridisation of vehicles

- In classical vehicles, gearbox is used to have a better engine efficiency

- But limited by the little ratios number of the gearbox

- Optimisation of the engine operating point using CVT instead of classical gearbox
« EMR and control of a CVT-based Hybrid Electric Vehicle »

- State-of-the-art about CVT -

Parallel classical gearbox-based HEV

Parallel CVT-based HEV

<table>
<thead>
<tr>
<th>classical gearbox</th>
<th>CVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Discrete ratio : 4 at 7 speed ratio</td>
<td>- Continuous ratio</td>
</tr>
<tr>
<td>- Efficiency : 93-95 %</td>
<td>- Efficiency : 85-87 %</td>
</tr>
<tr>
<td></td>
<td>- More Comfortable in Driving</td>
</tr>
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</table>
Push belt CVT:

- More used in vehicle application
- Pulleys move to change the gear ratio
- Low cost
- Bad efficiency: 87% [Klaassen 2007]
Main Objective: Study of a CVT-based HEV

- Reduction of fuel consumption of the vehicle

- Comparison with a Parallel HEV with classical gearbox

Using Energetic Macroscopic Representation
EMR and IBC of the classical gearbox-based HEV
« EMR and control of a CVT-based Hybrid Electric Vehicle »

- EMR of the Classical Gearbox-based HEV -

Structural Representation of a Classical Gearbox-based Parallel HEV

\[ i_{bat} = \frac{T_{em} \times \Omega_{blt}}{u_{bat}} \times \eta_{EM} \text{ with } n = 1 \text{ if } \frac{T_{em} \times \Omega_{blt}}{u_{bat}} > 0 \]

\[ \int_{M_{veh}} \left( F_{tot} - F_{res} \right) dt \]
- IBC of the Classical Gearbox-based HEV -

\[ \begin{align*}
& T_{em} \quad \Omega_{blt} \quad T_{tot} \quad T_c \quad T_{gb} \quad F_w \quad F_{tot} \quad v_{hev} \\
& u_{bat} \quad i_{bat} \quad \Omega_{c} \quad \Omega_{gb} \quad \Omega_{w} \quad F_{br} \quad F_{tot_ref} \\
& T_{ice_ref} \quad T_{ice_ref} \quad F_{w_ref} \quad F_{br_ref} \quad v_{hev_ref} \\
& S_oC \quad strategy \quad v_{hev} \\
\end{align*} \]
Objective: when the ICE is on, the ICE point are on the optimal operation curve

- ICE is off, The Electric Machine provides the power for propulsion

- ICE is on, The Electric Machine move the ICE point on the optimal operation curve

Strategy of a parallel HEV with gearbox
EMR and IBC of the CVT-based HEV
Structural Representation of a CVT-based Hybrid Electric Vehicle

$k_{cvt} \in [0.425 ; 2.25]$
b) Rule-based Strategy for HEV with CVT

Objective: when the ICE is on, the ICE point are on the optimal point

- ICE is off, The electric machine provides the power for propulsion

- ICE is on, The electric machine and CVT move the ICE point on the optimal point

Strategy of a parallel HEV with gearbox

Strategy of a CVT-based parallel HEV
Comparison between Classical Gearbox and CVT-based HEV
« EMR and control of a CVT-based Hybrid Electric Vehicle »

- Rule-based strategy simulation -

**Simulation with WLTC cycle**

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<th>Type of vehicles</th>
<th>Fuel Consumption (1/100 km)</th>
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<td>CVT-based HEV</td>
<td>4.83 (gain: 8%)</td>
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<td>HEV with gearbox</td>
<td>5.25</td>
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**Comparison between CVT-based HEV and classic gearbox-based HEV**
- Optimisation-based strategy simulation -

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<th>Type of vehicles</th>
<th>Rule-based strategy</th>
<th>Optimisation-based strategy</th>
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<tr>
<td>CVT-based HEV</td>
<td>4.83 (gain: 8%)</td>
<td>4.72 (gain: 1.7%)</td>
</tr>
<tr>
<td>HEV with gearbox</td>
<td>5.25</td>
<td>4.80</td>
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</table>

**SoC (%)**

- **Gearbox**
- **CVT**

**Fuel Cons. (l/100km)**

- **Gearbox**
- **CVT**
Conclusion and Perspectives
Conclusion

- EMR and IBC for CVT-based HEV were realised
- Rule-based and optimisation-based strategy was realised

Perspectives

- Better Torque Converter and CVT modelling
- Online optimal-based strategy of fuel consumption for the two vehicles

