Transmission and Gear Shift calculation in VECTO

(European Tool for HDV CO2 testing)

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Background and Content

Background:
The European Tool for HDV CO2 testing has already a routine to handle different gear boxes in the vehicle simulation. These routines could be basis for the corresponding routines in the HILS model, since the actual HILS model does not provide gear shift models for complex gear box systems.
The approach allows to give any number of gears + transmission ratios as input and provides representative gear shift manoeuvres.

Content:
• Overview European CO₂ test method for HDV and VECTO tool
• Gear shift rules manual transmission (MT)
• Gear shift rules automatized manual transmission
• Skip gears in gear shift manoeuvres
• Automatic transmission, torque converter
Overview test procedure for Heavy Duty vehicles

MODEL

\[ P_e = P_{\text{roll.}} + P_{\text{air}} + P_{\text{acc}} + P_{\text{grad}} + P_{\text{tr.}} + P_{\text{aux}} + P_{\text{cons.}} \]

\[ n = \frac{v \times 60 \times I_{\text{axis}} \times I_{\text{gear}}}{d \times \pi} \]

Fuel consumption map:
steady state + WHTC-correction factors
map + WHTC test measured on engine test bed

Air resistance coefficients:
constant speed with torque measurement

Rolling resistance coefficients: resistance values from tire labeling, EC No 1222/2009

Transmission ratios, transmission losses
OEM specific maps and default values

Power demand at engine from generic \( P_{\text{use}} \) with generic efficiency maps for the auxiliaries
OEM specific maps and intelligent controllers under discussion

Component testing:

Fuel cons., CO₂

Engine

Gear box, axis:
transmission, \( \eta = F(\ldots) \)

Auxiliaries
duty cycle, \( \eta = F(\ldots) \)
Overview VECTO

Actual model:
Backward simulation, adapted for target speed cycles
Programming language: Visual Basic.NET

Simulation of engine power and engine speed:

\[ P_e = P_{\text{roll.}} + P_{\text{air}} + P_{\text{acc}} + P_{\text{grad}} + P_{\text{tr.}} + P_{\text{aux}} + P_{\text{cons.}} \]

\[ n = \frac{(v \times 60 \times l_{\text{axle}} \times l_{\text{gear}})}{(d \times \pi)} \]

Interpolation of fuel consumption from engine map
Correction of FC for transients and "floating map” effects by "WHTC correction factors" (not yet implemented)
Overview VECTO

**User interface for standardised data input**
- Selection of vehicle class
- Input data from component testing
  - Engine fuel map
  - Vehicle curb weight
  - Rolling resistance
  - Air drag
  - Transmission data
  - ...

**Default database**
- Standard parameters (payload, driver model parameters)
- Driving cycles per mission profile

**Core model**
- Driver model
  - Acceleration / braking strategy
  - Gear shift behaviour
- Vehicle longitudinal dynamics
- Drivetrain model
  - Conventional transmissions
  - Transmissions with hydraulic torque converter
- Auxiliary models
- Engine full-load characteristics
- Interpolation from fuel map

**Output metrics**
- g/km, g/t-km, g/m³-km, g/passenger-km, km/h, g/kWh, l/100km
VECTO Gear Shift Model

Gear Shift Model (MT, AT, AMT)

• Up- / Down- Shift based on shift-polygons.
• Polygons are user-defined (during proof of concept phase)
• Final declaration-ready version will calculate polygons based on engine characteristics like full load curve and specific rpm's.
VECTO Gear Shift Model: Additional Rules (1/2)

Allow shift-up inside polygons (AMT)
- Only if torque reserve is provided and rpm is still above Down-shift-rpm

![Diagram showing gear shift rules and conditions.]

Min % from max. positive torque at actual engine speed
VECTO Gear Shift Model: Additional Rules (2/2)

Skip gears (AMT, MT)

- Whenever gear shift is initiated (because rpm crosses up- or down-shift polygon) it is possible to skip gears
- Torque reserve must be provided and rpm must remain below Down-shift rpm
Driver model: traction interruption during gear shifts

- Duration of traction interruption is user-defined in seconds

- Calculation of coast down deceleration:
  - Condition: \( P_{\text{roll.}} + P_{\text{air}} + P_{\text{acc}} + P_{\text{grad}} = 0 \)
  - \( P_{\text{grad}} < 0 \) may result in \( P_{\text{acc}} > 0 \) (downhill \( \rightarrow \) acceleration), check WHVC gradient effects!

- **Engine power in declutched phases** to compute change of engine speed:
  - First time step ("tip out"): \( P_e = 25\% \times (P_e(t-1) - P_{\text{mot}}) + P_{\text{mot}} \) (\( P_{\text{mot}} < 0 \))
  - Time steps >1sec: \( P_e = P_{\text{mot}} \text{ if } n > n_{\text{idle}} \text{ else } P_e = 0 \)

- **Engine speed**
  - results from \( P_e = I_{\text{eng}} \times \dot{\omega} \times \omega \)
  - \( \rightarrow \) influence on acceleration characteristic via transient full load
Automatic Transmission (1/2)
VECTO method adapted to forward calculation

- Same polygon-based gear shift model
- Settings: sequential gear-shifting, shift-up inside polygons
- Torque Converter (TC):
  - Defined as (virtual) separate gear, i.e. only first gear with TC active
  - While TC active: in forward calculation approach: calculation of torque and speed after TC based on TC characteristic