PRESENTATION OF

INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS

Partial Load & Performance Modelling

ASEP Revision 2.0
Actual Status of the DATABASE November 2018

- Database contains now 54 dataset (15 new vehicles since July 2018)
  - 41 vehicles from 13 sources, PMR range 40 kW/t to 330 kW/t
  - Some vehicles with multiple dataset (full load and part load)
  - Mostly M1 vehicles, few N1
  - ICE (mostly Petrol), HEV, PEV

- Model covers
  - ICE, HEVs and PEVs (via simulated engine speed)
  - Part load (not explained in details to IWG ASEP by now)
  - Performance va

- Various Analysis Diagrams and Tools
  - Diagram: Sound vs Engine Speed,
  - Diagram: Sound vs Performance,
  - Diagram: Performance vs Speed,
  - Diagram: Measured Sound vs Simulated Sound
  - Tools: Enable/Disable Parts of the model
  - Tools: Parameter can be changed

*Red highlighted items are new since July 2018*
PARTIAL LOAD SIMULATION

DETAILS
Definition for Partial Load Driving

- Partial load driving means any driving condition which provides positive acceleration greater than 0.3 m/s² between cruising and maximum load driving for a specific engine condition.

- Cruising is defined as low acceleration with a variation of +/- 0.3 m/s² around zero acceleration.
  
  ➢ The acceleration 0.3 m/s² is derived from the allowable tolerance of +/- 1 km/h for the steady speed test according to UN R51.03 Annex 3 paragraph 3.1.2.1.6.

  \[ a_{crs} = \frac{((50^{+1 \text{km/h}}/3.6)^2 - (50^{-1 \text{km/h}}/3.6)^2)}{2(20 + l_{veh}^*)} = 0.30 \text{ m/s}^2 \]

  \( ^*) \; l_{veh} = 5\text{m} \\

- Maximum load driving is the maximum achievable acceleration for a specific engine operation condition.
Definition for Partial Load Driving

mid class passenger car

Source: HM Gerhard; Dialog on Mobility; Brussels 2003
What Parameter to Chose for the Control of the Partial Load Area?

- The position of the throttle?
  - The throttle is a specific design of petrol engines, other technologies do not have a throttle.
  - The percentage of opening of the throttle is directly related to the achievable performance. The throttle diameter is tailored to maximum gas flow at rated engine speed.
  - This means a given percentage of opening of the throttle represents different loads at different engine speeds.

- The percentage of depressing the accelerator pedal?
  - Vehicles have electronic accelerator pedals. The signal response is NOT linear to the engine. The response is mode dependent and integrates driving comfort, fuel economy and performance response.

- The achieved acceleration?
  - The achieved acceleration must be weighted against a reference value. However the reference is dependent on the operation condition of the engine and the gear/gear ratio engaged.
The maximum achievable acceleration is dependent on the torque and power available at a discrete operation condition.

This means the acceleration is dependent on the gear where the acceleration happens and the engine speed which is taken representative for the acceleration phase:

\[ a_{\text{max,test}} = f(i_{\text{test}}, n_{\text{BB}}) \]

This behaviour is taken into consideration under the Sound Transient Function.
Simplified Approach

- The acceleration for a specific gear is assumed constant.
  - This means it is assumed that a vehicle would have always the same maximum acceleration in a given gear over the whole engine speed range.
  - The torque and power curve are considered under the Sound Transient Function via the form factor.

- The partial load is simulated by using the acceleration performance relative to a reference acceleration in one specific gear.
  - For other gears or gear ratios, the reference acceleration is adjusted via the gear ratio.
  - Therefore it is necessary to determine once an reference acceleration, preferably in a low gear, such as 2nd gear.
The Sound Dynamic $\Delta L_{\text{DYN}}$ is the acoustic dynamic between no load and full load.

For the simulation, a hyperbolic function was chosen to adjust for engine speed dependent maximum acceleration and for the typical non-linear transient between no load and maximum load.

**Formula:**

$$\Delta L_{\text{DYN,PL}} = \Delta L_{\text{DYN}} \left( \frac{1- \alpha}{LOAD + \alpha} \right) / \left( 1 - \alpha \right) / \omega$$

**Calibration Part $\omega$:**

$$\omega = 1/(1-\alpha) - \alpha/(1-\alpha^2)$$

The shape of this curve can be adjusted by the **form factor $\alpha$** in a wide range for best fitting.
Adjustable Partial Load Transient via the Form Factor $\alpha$ 

\[ \alpha = 0.005 \quad \alpha = 0.111 \quad \alpha = 1.000 \]
Determination of the Load for a Discrete Test

**Preparation**
- Carry out a reference test in a low gear (e.g. 2\textsuperscript{nd}) to determine the maximum acceleration.

**Perform an ASEP Test**
- Report $a_{\text{test}}$ and the gear ratio $i_{\text{test}}(v_{BB',\text{test}}, n_{BB',\text{test}})$.

**Calculate Load**
- Calculate reference acceleration for the gear ratio $i_{\text{test}}$: $a_{\text{ref, test}} = a_{\text{max}} \times \frac{i_{\text{ref}}}{i_{\text{test}}}$.
- Calculate the load: $\text{load} = \frac{a_{\text{test}}}{a_{\text{ref, test}}}$.

The fraction of load is applied to the complete dynamic $\Delta L_{\text{DYN}}$. 
PERFORMANCE MODELLING
MERGED WITH THE SOUND MODEL
Integration of \( v \times a \) – Concept for the Sound Model

- The actual sound model simulates the general sound sources tyre/road, power train mechanics and dynamics based on type approval test results.
  - This model is based on engine speed and vehicle speed and does not consider performance aspects of a vehicle.
  - However, behind a tested operation condition the acceleration can be very different and thus as well the sound emission of vehicles.

- In 2018 a separate assessment model for performance was developed.
  - This models helps to differentiate between normal and extreme driving conditions.
  - However, this model cannot adequately assess partial load and cruising, as acceleration close to zero will lead to very low although the vehicle speed and thus the tyre/rolling sound could be very high.
Example 1 (normal vehicle)

Example 2 (high performance vehicle)
Performance Model - Based on IWG ASEP Presentation Brussel 2018

Example 1 (normal vehicle)  Example 2 (high performance vehicle)
Real Driving Performance (OICA Presentation February 2017)

- For driving within the typical onroad driving, performance cannot be added, as UN R51.03 Annex 3 is considered to be almost design neutral.
- ASEP Annex 7 and especially the revision 2.0 goes beyond that neutral area.
Integration of \( v \times a \) – Modelling Approach (1)

- For the modelling the performance is calculated by using the vehicle speed \( v_{BB'} \) and the acceleration \( a_{test} \).
- The performance is calculated by:

\[
va_{\text{test}} = \frac{v_{BB'}}{3.6} \times a_{\text{test}}
\]

- For normal onroad driving in urban areas the reference performance is determined by:

\[
va_{\text{ref}} = \frac{v_{BB',Annex\ 3}}{3.6} \times a_{\text{max,Annex\ 3}}
\]

with

\[
\begin{align*}
v_{BB',Annex\ 3} &= 50 \text{ km/h} \\
a_{\text{max,Annex\ 3}} &= 2.0 \text{ m/s}^2
\end{align*}
\]

- The reference performance is \( va_{\text{ref}} = 27.8 \text{ m}^2/\text{s}^3 \)
Integration of v x a – Modelling Approach (2)

- For performances lower than the reference acceleration, there will be no effect to the actual model.

- For performances greater than the reference acceleration, additional sound quotation is applied:

\[ \Delta L_{\text{DYN}(va)} = \beta \times \log \left( \frac{v_{a\text{test}}}{v_{a\text{ref}}} \right)^2 \]

with \( \beta \) as adjustable factor.

- For the actual model, the factor \( \beta \) was set to 8.

- The total dynamic of the vehicle is the set to:

\[ \Delta L_{\text{DYN(tot)}} = \Delta L_{\text{DYN}} + \Delta L_{\text{DYN(va)}} \]

- The total dynamic \( \Delta L_{\text{DYN(tot)}} \) is subject to the partial load model.
The Effect of the $v \times a$ in the Sound Model

The Add On is only applied, when the vehicle truly provides this performance.

For “typical on-road driving” nothing is added for performance.

For a performance of 100 m$^2$/s$^3$ at 80 km/h an acceleration of 4,5 m/s$^2$ is needed.