November 2017

PRESENTATION OF

INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS

ASEP Development

Development of a Physical Expectation Model Based on UN R51.03 Annex 3 Performance Parameters

5th GRB Informal Working Group Meeting
Tokyo

Data Collection – Feedback from Testing People

- The whole test program is very time consuming: 1 to 2 days per one vehicle
- Partial load testing is challenging, but easier when an electronic lock of the pedal path is used instead of a mechanical lock.
- A lock of the accelerator path will not result in unform acceleration over the operation range of a gear. At low engine speeds the acceleration will we lower, but increase with engine speed.
- Keeping constant acceleration of the test track path is extremely difficult and should not be used, because it requires another engine software.
- Going up to very high speeds made drivers feel very uncomfortable; 120 km/h can only be reached under full acceleration.
- Under partial load a maximum of 80 km/h is possible.
- We need an uncertainty estimation to understand to what precision can be tested.

Sound Model Basic Considerations

1 Tyre

2 Base Mechanics

- The two elements together create the "physical" base model of a behavior of any internal combustion engine vehicle.
- If linked to a type approved reference point, e.g. Lcrs,rep and Lwot,rep, these models will form the minimum sound emission of a vehicle.
- **These two elements are related to the vehicle design and shall not cause a non-compliance.**

3 Dynamics

- This model is the dynamic "add-on" to the minimum model formed by 1 and 2 .
- This is the parameter for adjustment to a maximum acceptable sound dynamic.
- This model 3 can be linked to PMR and/or the acceleration performance of a vehicle.

Reference Values and Available Data

- The Annex 3 test results $L_{crs,rep}$ and $L_{wot,rep}$ can be used as reference for the elaboration of the “expectation model”.
  - $L_{crs,rep}$ is considered to be dominated by the tyre rolling sound with some contribution of the power train base mechanics and very little contribution of the high dynamic sound sources.
  - $L_{wot,rep}$ can be taken as a link for the dynamic model, but needs adjustment for the contribution for tyre rolling sound and power train base mechanics.

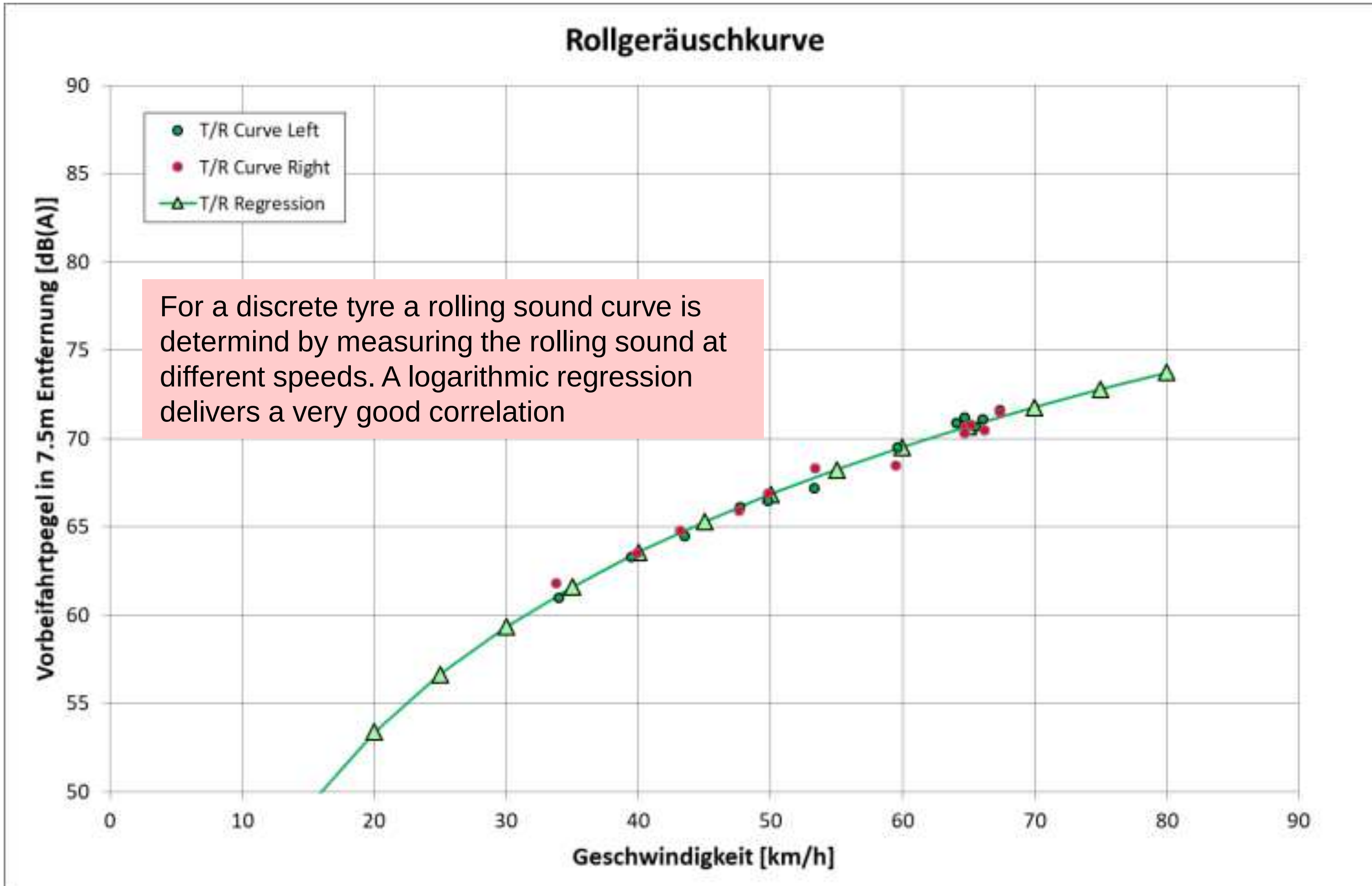
- Further data available from Annex 3 are
  - PMR, $a_{wot,ref}$ a_{urban}, L_{urban}
  - Gear / gear ratio (i, i+1, i+2,…)
    - Vehicle speed $v_{BB'}$
    - Engine speed $n_{BB'}$
    - Acceleration $a_{AA'-BB'}$ or $a_{PP'-BB'}$

- These data can be used as a basis for the three models.

1 Tyre Rolling Sound – Application principle

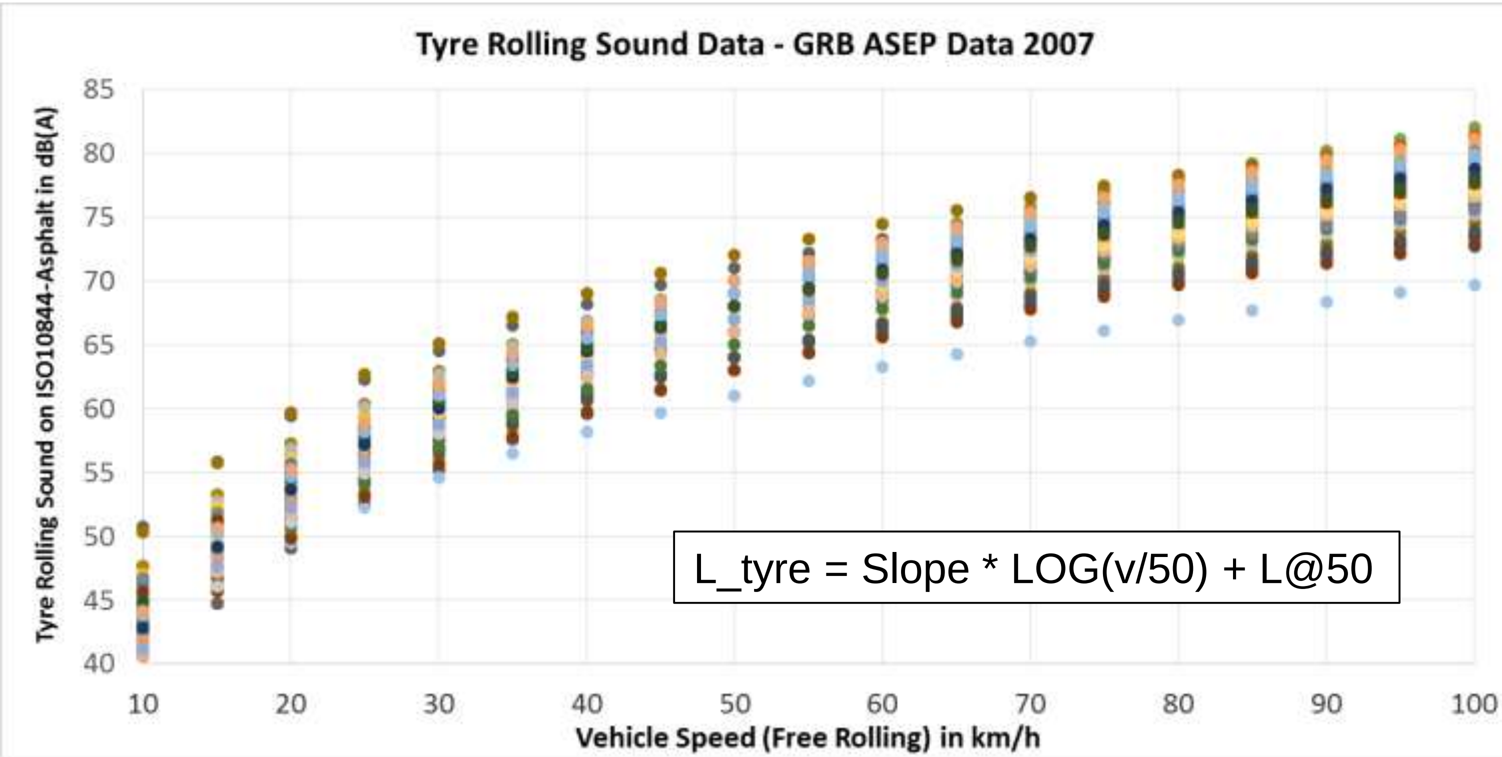
- It is not possible to determine the tyre/rolling sound behaviour of the particular tyre used for type approval.
- But, all tyres that can be mounted to a vehicle have been certified according to UN R117.
- So all tyre have an approval and can be used on the vehicle.
- Hence, any tyre/rolling sound slope shall be accepted.
- For the model the slope variation determined from statistics will be used in the following way:
  - For vehicle speeds below 50 km/h, the lowest slope will be used,
  - For vehicle speeds higher than 50 km/h the highest slope will be used.

1 Tyre Rolling Sound - Modelling



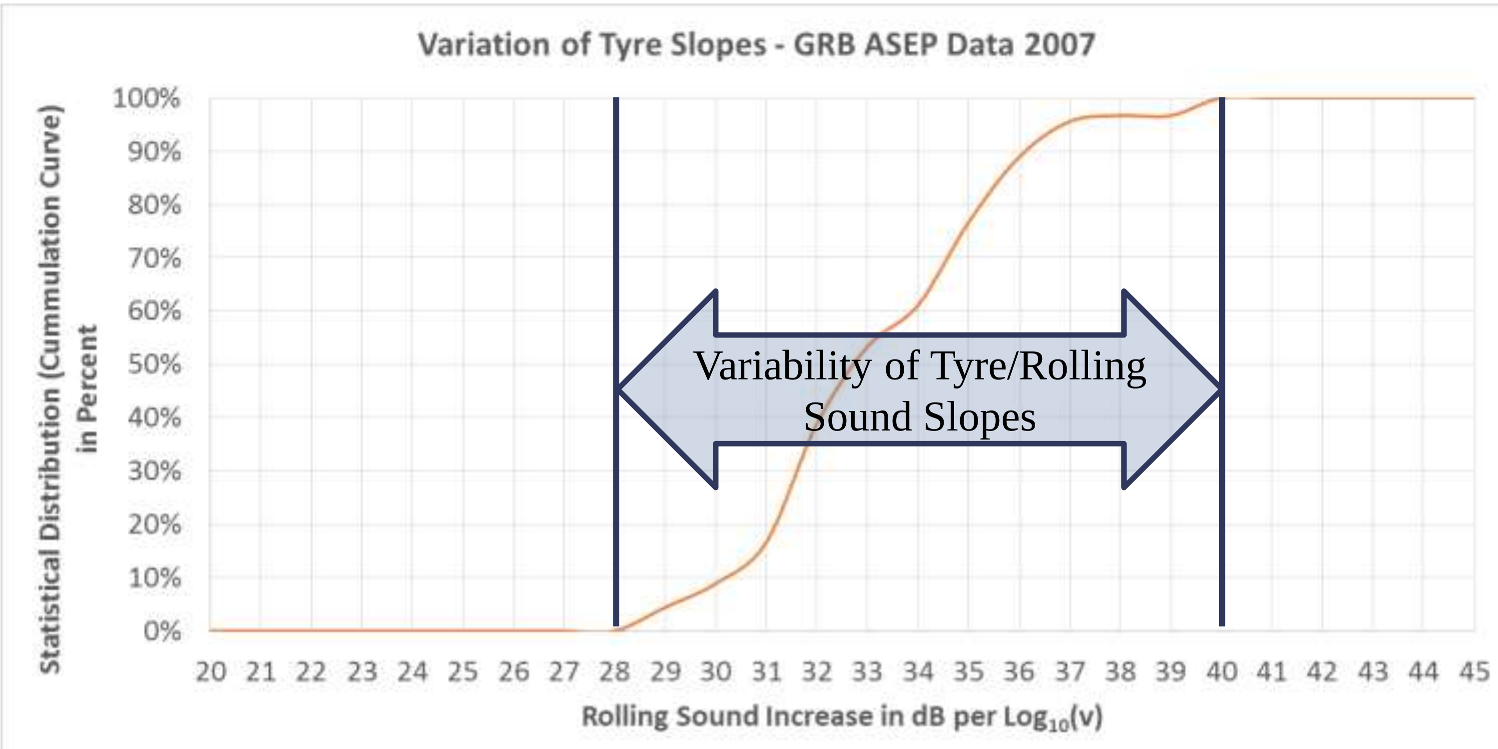
For a discrete tyre a rolling sound curve is determind by measuring the rolling sound at different speeds. A logarithmic regression delivers a very good correlation

1 Tyre Rolling Sound



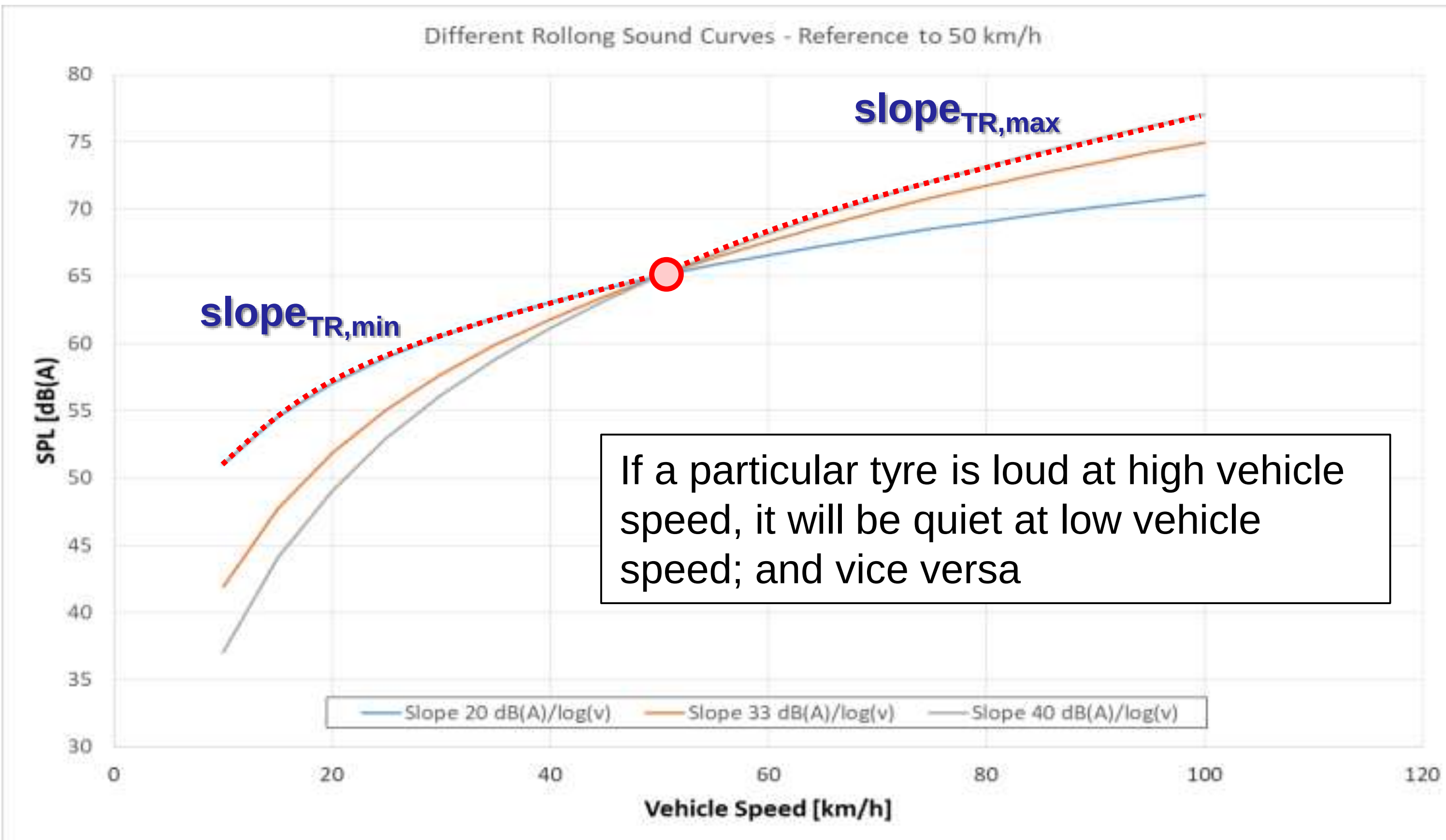
1 Tyre Rolling Sound

Analysis of the GRB ASEP Data 2007 – Tyre/Rolling Sound of 90 set of tyres



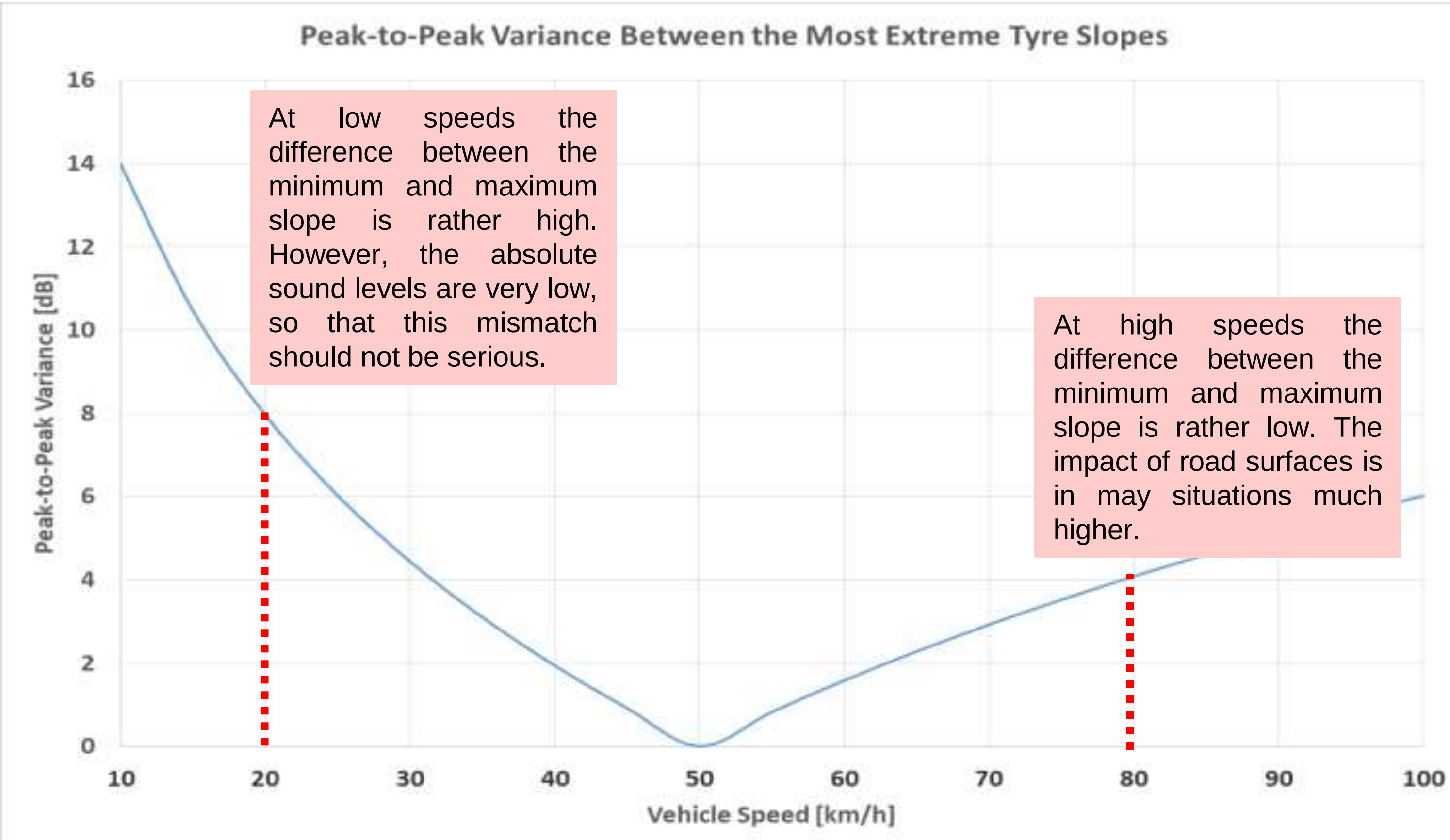
The Database from 2007 shall be supplemented with new data, to verify if changes in tyre design happened and to increase the knowledge.

1 Tyre Rolling Sound



1 Tyre Rolling Sound

Consideration on the maximum error in the model



 July 2017

1 The "Prediction Model" for the Tyre Rolling Sound

- The chosen function is:

$$L_{TR,NL} = slope_{TR} * LOG_{10}(v_{test} / 50) + L_{REF,TR}$$

There will be a **$slope_{TR,min}$** for test speeds below 50 km/h and a **$slope_{TR,max}$** for speeds above 50 km/h.

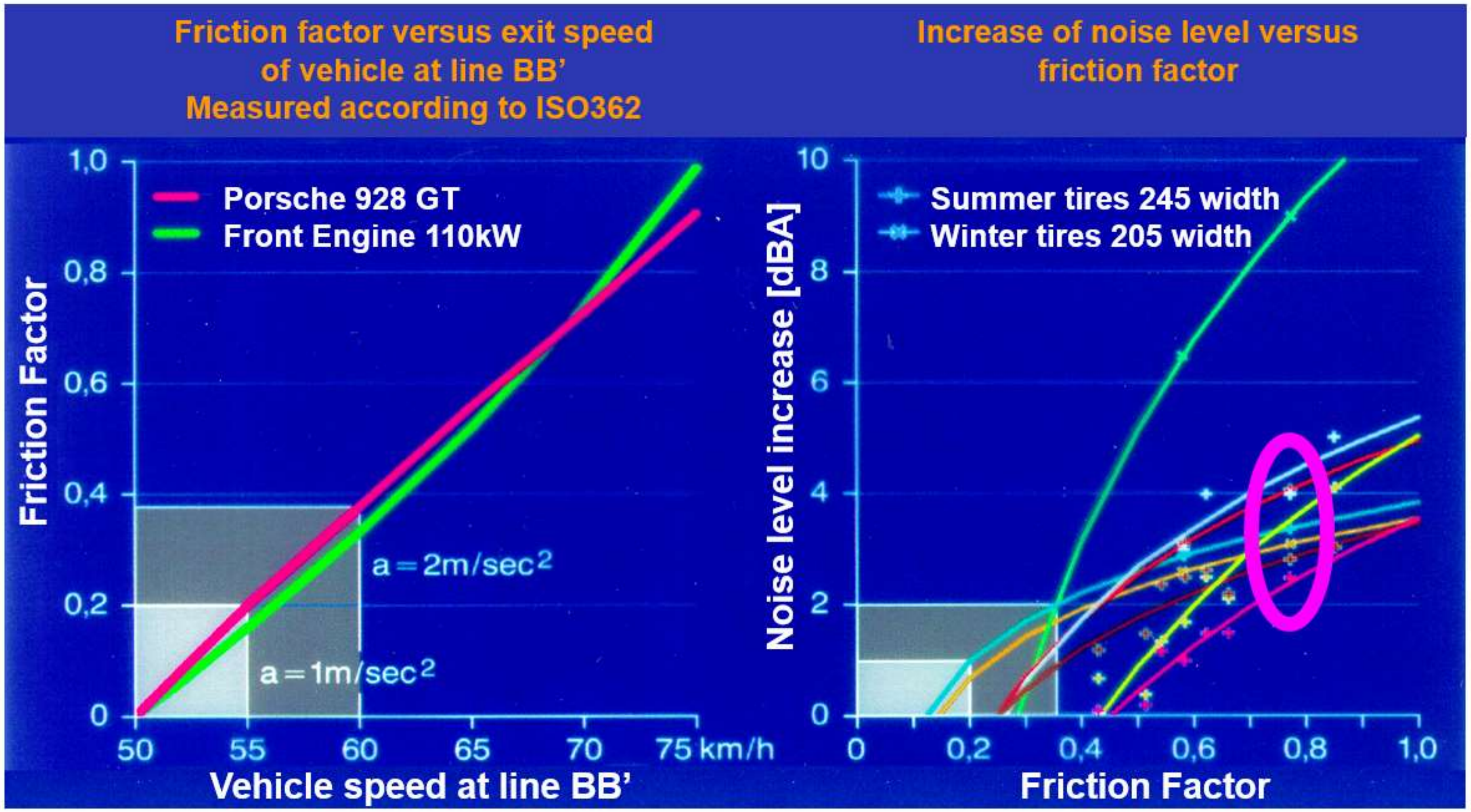
The differentiation accounts for the unknown behaviour of the tyre rolling sound.

The **$L_{REF,TR}$** is a fraction of the steady speed test result of Annex 3 **$L_{CRS,REP}$**.

$$L_{REF,TR} = 10 * LOG_{10}(10^{(x\% * L_{crs,rep}/10)})$$

How much percent (**x%**) of the steady speed result is used in general needs further investigation and might be defined differently for the vehicle categories.

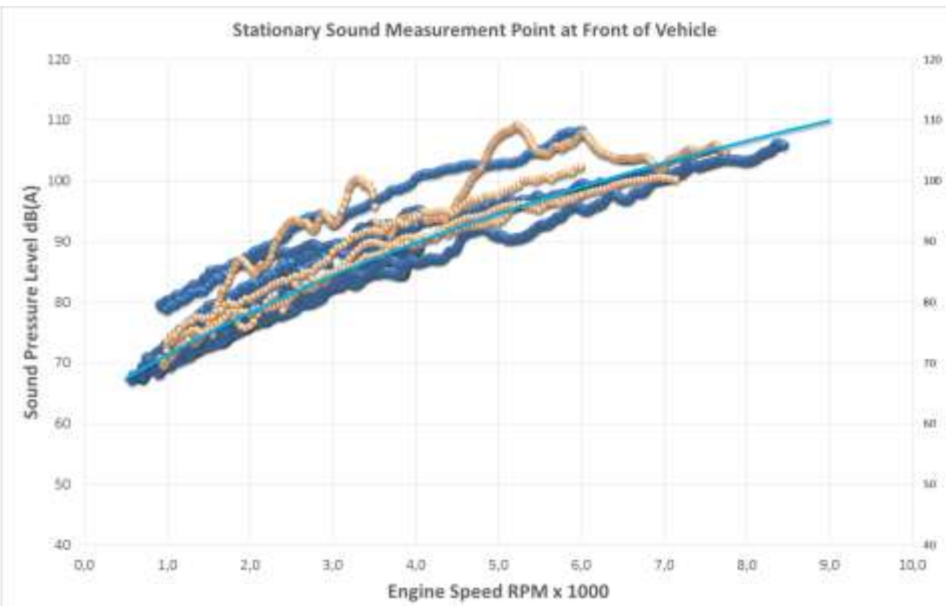
Impact of Acceleration (=Torque =Friction) on Sound



Under extreme acceleration conditions of more than 5 m/s² the „friction factor“ will become greater than 0.8. The tyre rolling sound will increase relative to free rolling sound by **3 dB(A)** or more.

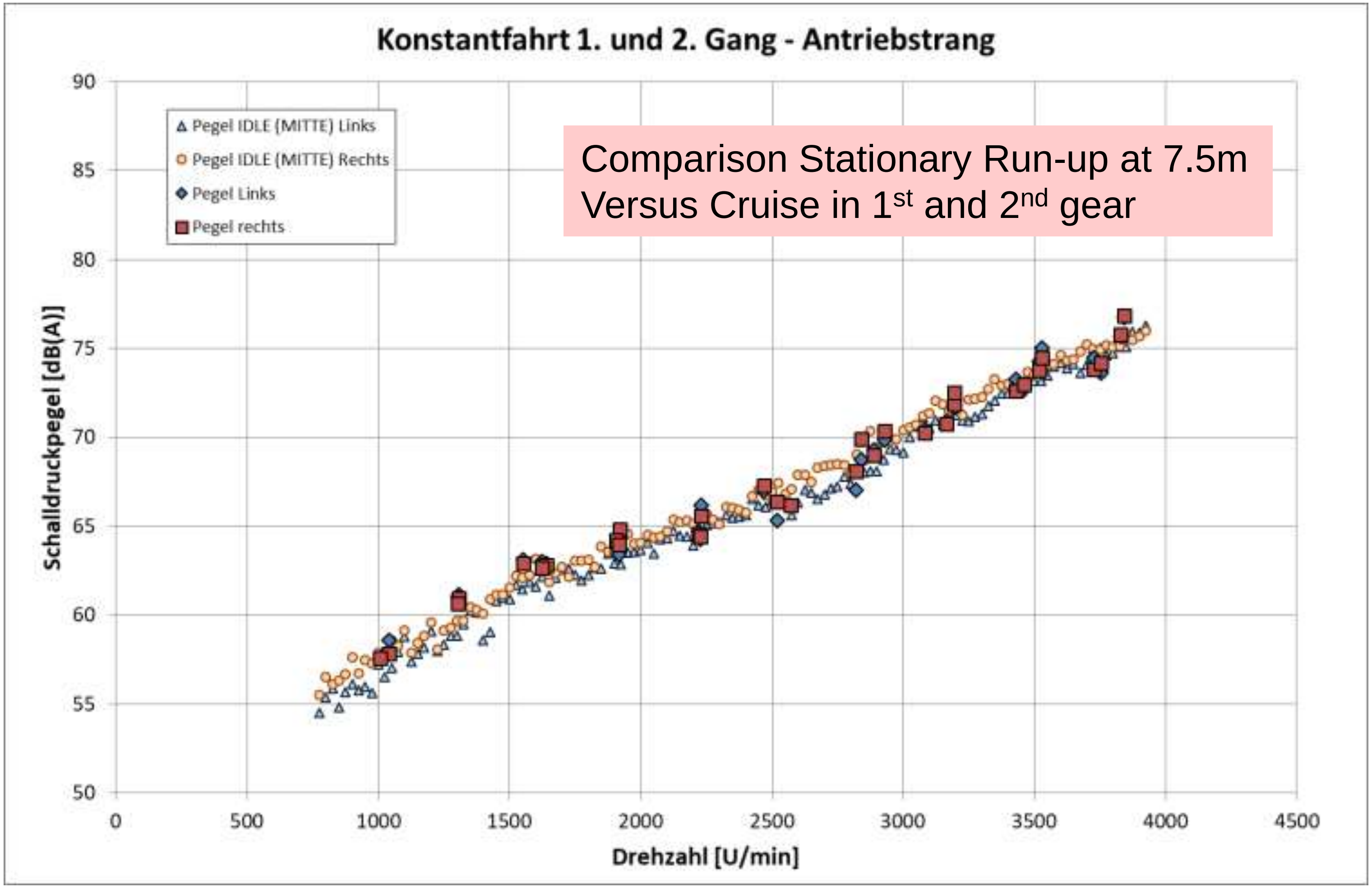
2 The Base Mechanic Model for the Power Train

- For the development of the mechanic model, data are taken when the impact of tyres rolling sound is neglect able.
- This could be an engine run-up in stationary condition or cruise-by tests at very low gears.
- Such data are not available from the GRB ASEP 2007 database.
- The important information is the slope characteristic over engine speed.

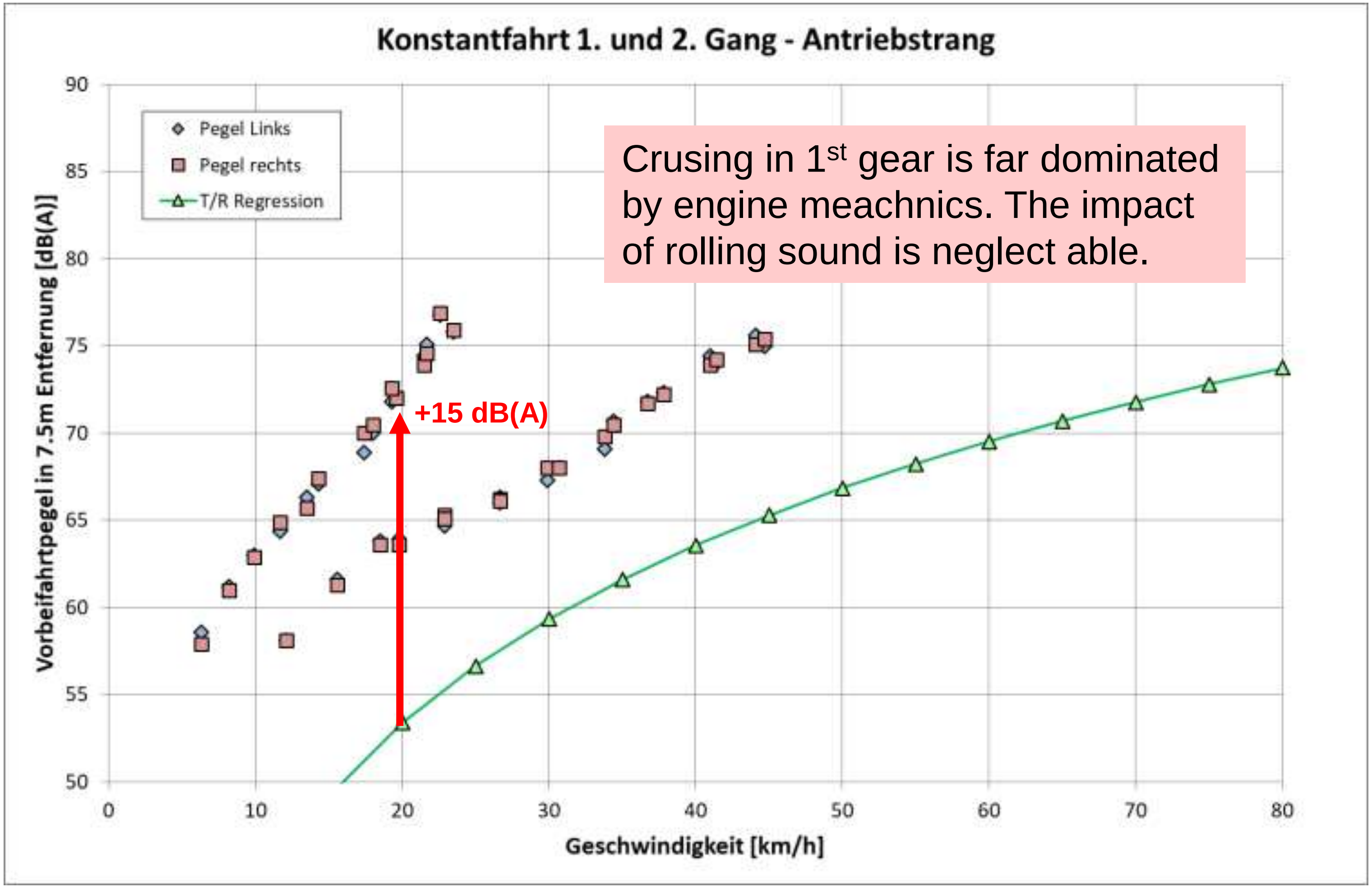


- Excel does provide only a limited capability of fitting curves, that might not be sufficient accurate.
- The recommended model is a shifted logarithm to adapt the slope characteristics better to the real sound behavior of the engine.

2 Base Mechanic - Modelling



2 Base Mechanic - Modelling



2 The "Prediction Model" for the Power Train (No Load)

- The chosen function is:

$$L_{pt,NL} = slope_{PT,NL} * LOG_{10}(n_{test} + n_{shift}) / (n_{wot,ref} + n_{shift})) + L_{REF,NL}$$

A $slope_{TR,min}$ for test engine speeds below $n_{BB',REF}$ and a $slope_{TR,max}$ for speeds above $n_{BB',REF}$ is introduced.

The differentiation accounts for the unknown behaviour of the power train.

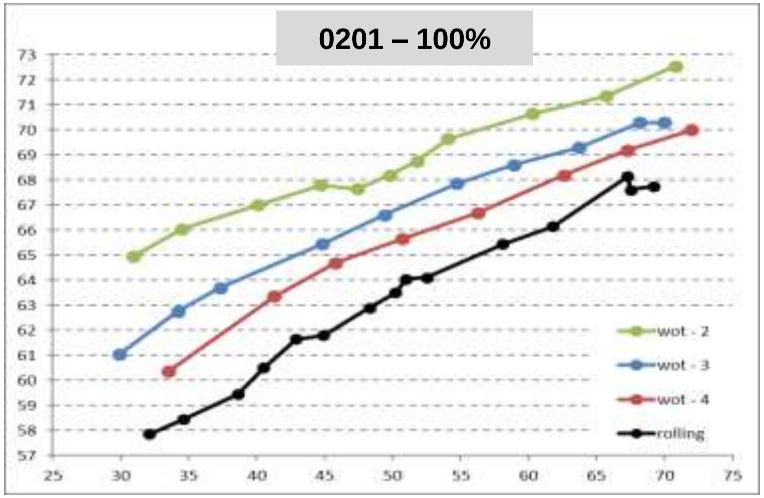
An engine speed shift component n_{shift} is introduced for an optimized curve fitting for the power train model

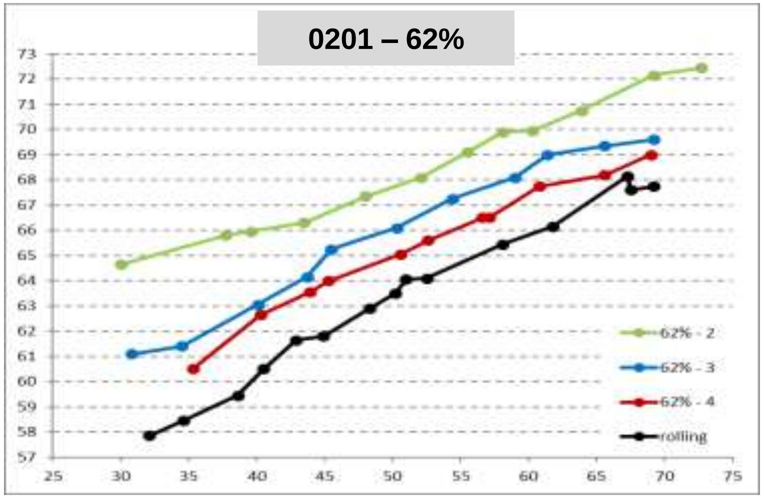
The parameter $L_{REF,NL}$ is the remaining part of the steady speed test of Annex 3 $L_{CRS,REF}$ that was not used in the tyre model before.

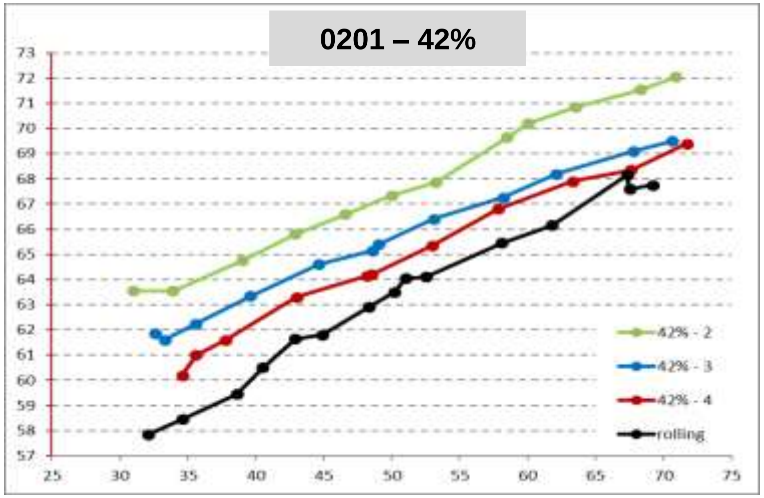
$$L_{REF,NL} = 10 * LOG_{10}(10^{((100\%-x\%)*L_{crs,rep}/10)})$$

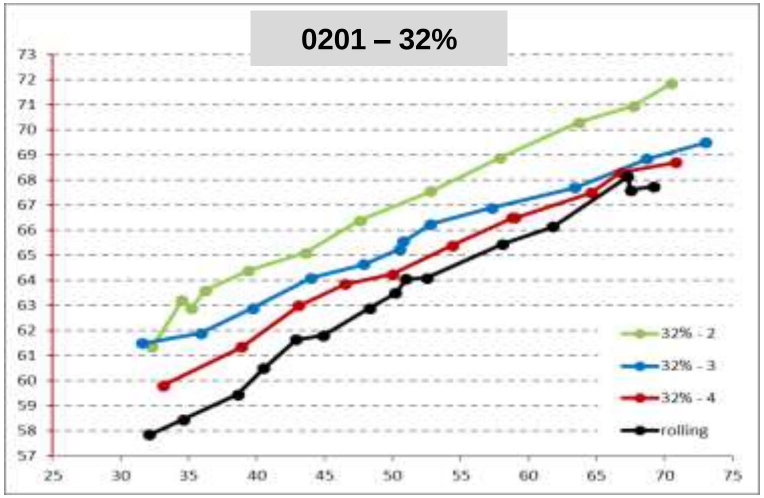
In addition, a small correction for the gas flow is necessary.

2 Partial Load Driving – Influence on Sound - Examples



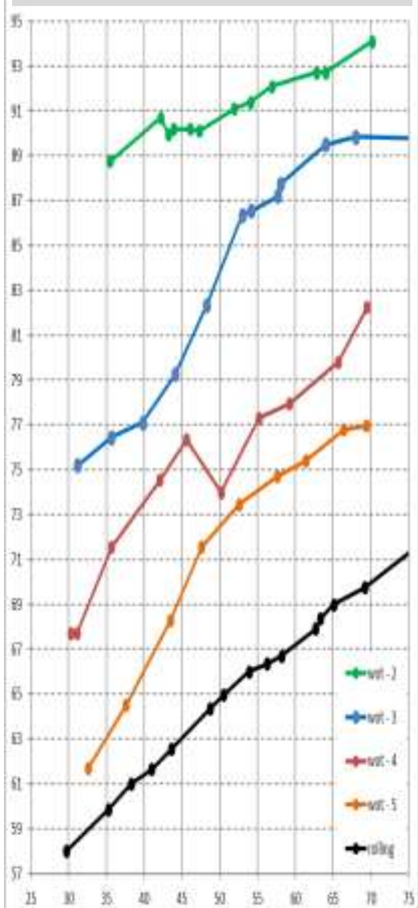




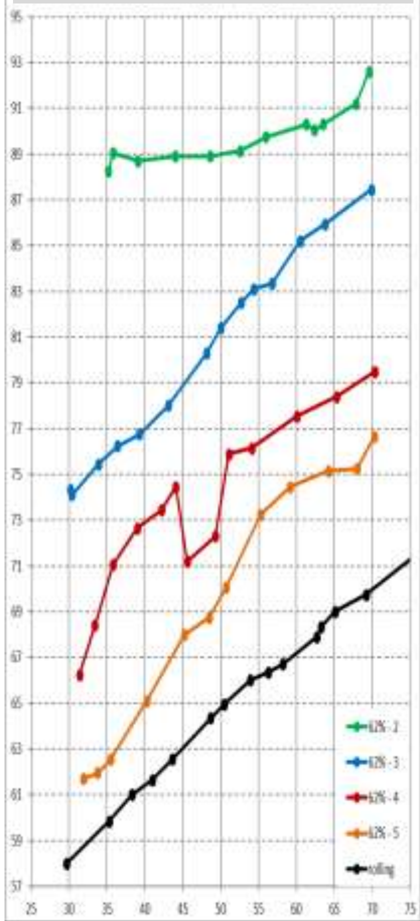


2 Partial Load Driving – Influence on Sound - Examples

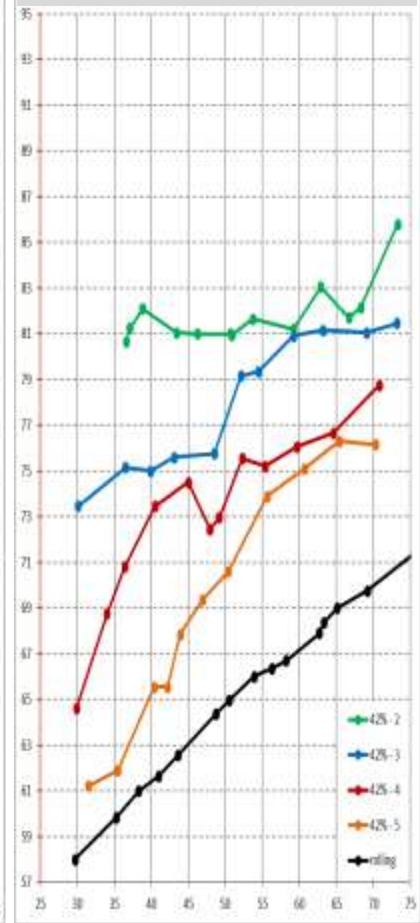
0202 (Sport Mode) – 100%



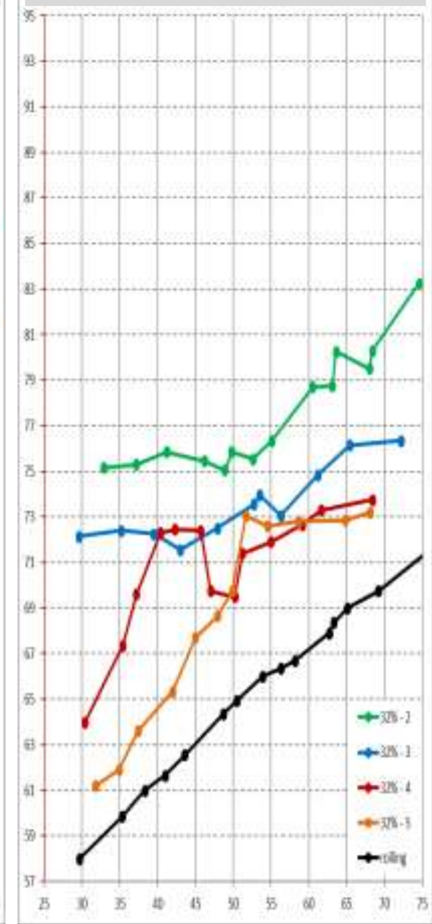
0202 (Sport Mode) – 62%



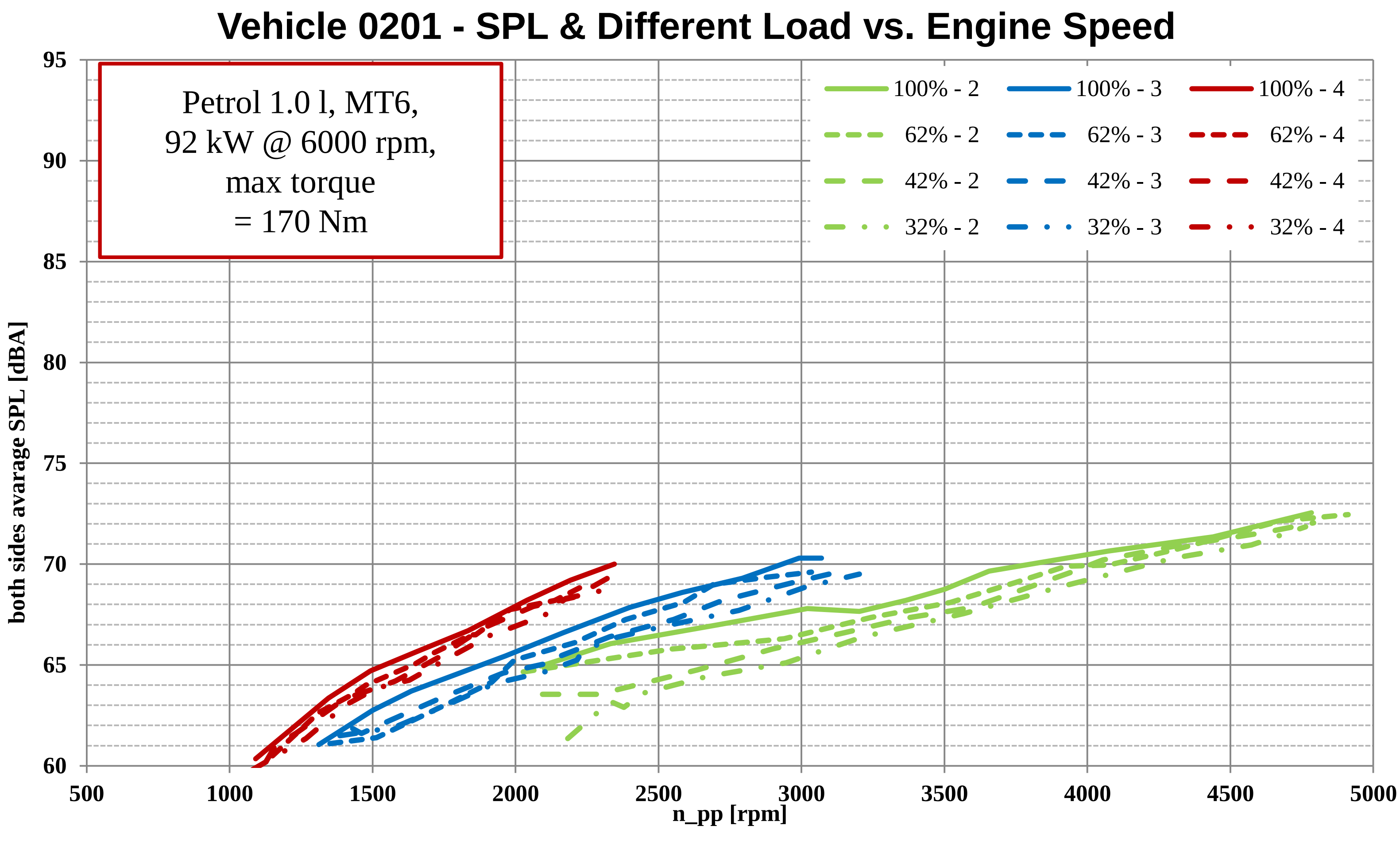
0202 (Sport Mode) – 42%



0202 (Sport Mode) – 32%



2 Partial Load Driving – Influence on Sound - Examples



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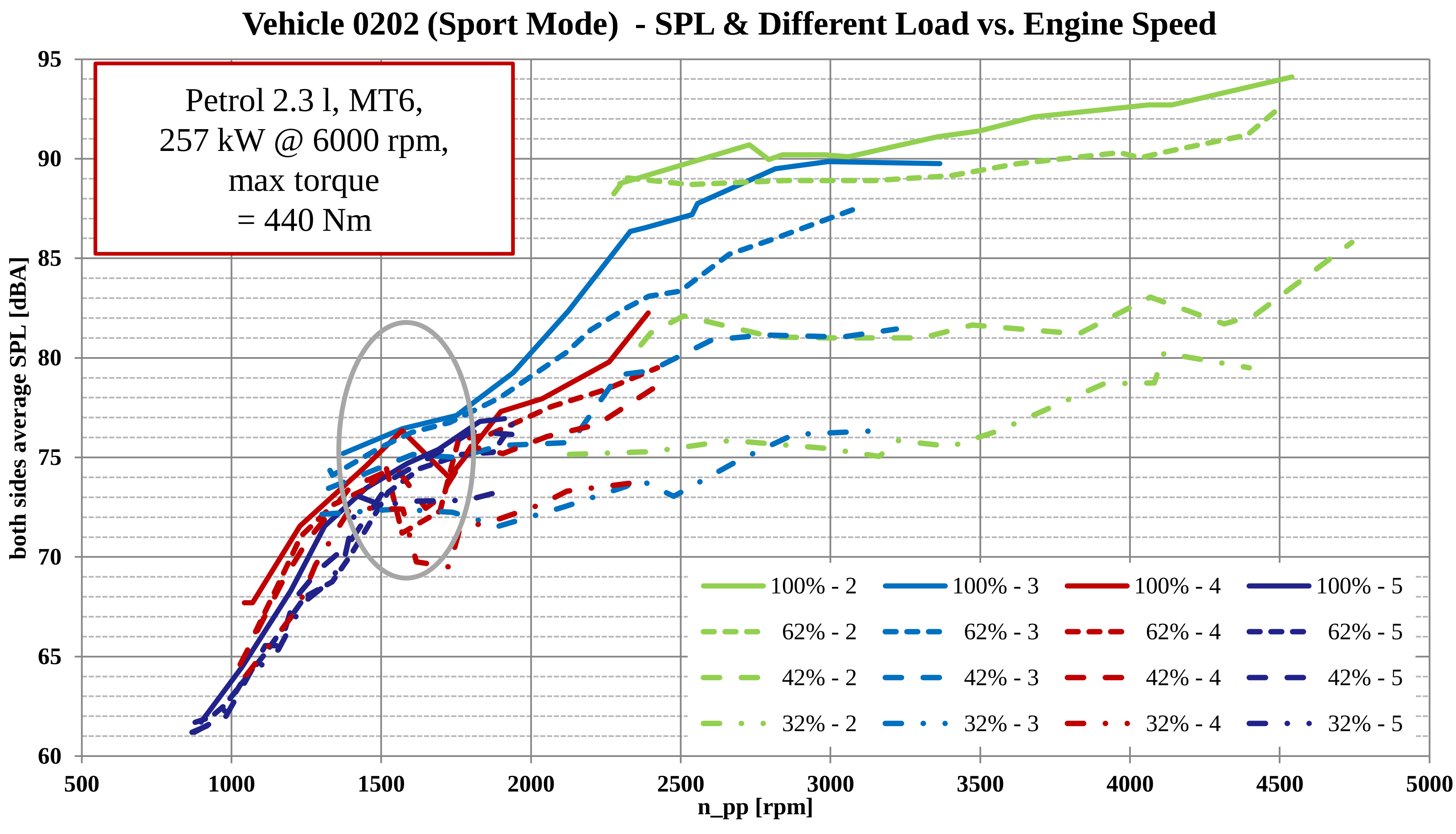
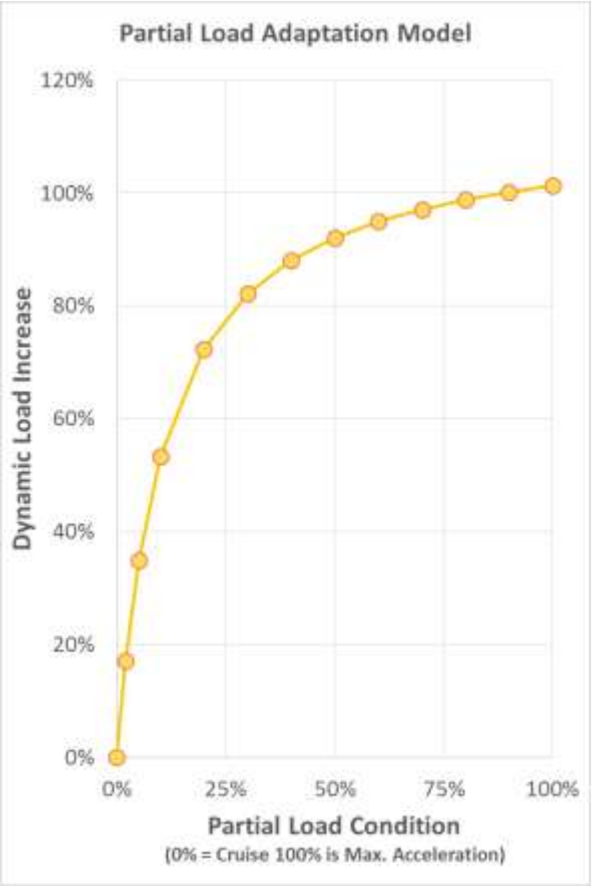


The Partial Throttle Model $\Delta L_{partial}$

- For sound assessment under partial load condition, it is necessary to consider the sound change between no load (cruising) and maximum load (full throttle).
- We need to consider what could be a suitable signal information
  - Position of the accelerator?
  - Opening of the throttle valve?
  - Acceleration versus maximum acceleration?
  - Other…?
- While in Annex 3 the combination of the constant speed test and the acceleration test is linear, we need for ASEP a different model with a high increment from low load positions with an early load saturation at approximately 50% throttle condition.
- More research is needed.
- As a simplification, the full throttle curve might be applied as well to any partial throttle condition.



3 The Dynamic Model

- The dynamic model follow the same construction principles as the power train base model, but with a offset for the high dynamic components.
- The border slopes were set lower, as typically the no load condition and the full load condition come closer at high engine speeds.
- The reference value $L_{pt,FL}$ is calculated as:

$$L_{PT,FL} = \mathbf{slope} * LOG_{10}(n_{test} + \mathbf{n_{shift}}) / (n_{wot,ref} + \mathbf{n_{shift}})) + \mathbf{L_{REF,FL}} + \mathbf{\Delta L_{partial}}$$

▷ See next slide

The border slopes $Slope_{min}$ and $Slope_{max}$ are typically lower compared to the base model slopes.

The same shifting principle is applied as for the base mechanic system.

Selected parameter:

$$L_{REF,FL} = 10*\log(10^{L_{wot,ref}/10} - 10^{L_{crs,ref}/10}) - \mathbf{DYN}$$

The **DYN** value is the dynamic of whole power train system but typically dominated by the gas flow. In a first approach it is linked to the best acceleration performance of the vehicle.

$$\mathbf{DYN} = 30 * LOG\,(a_{max} / a_{urban}) + (L_{wot,ref} - L_{crs,ref})$$

NOT DISCUSSED DURING IWG ASEP 5 IN TOKYO

Integration of all Modules

- Before the ASEP evaluation, it is necessary to carry out the Annex 3 type approval test
  - The parameter to be reported are: L_{wot} and L_{crs} from the lower or single gear, the acceleration (actually PP-BB), the vehicle speed v_{BB}, the engine speed n_{BB}.
  - For the gear ratio, the maximum acceleration must be known to determine the load condition.

- The expectation level is then calculated

$$L_{exp} = 10 * LOG\left(10^{0,1*L_{tyre}} + 10^{0,1*L_{pt,NL}} + 10^{0,1*L_{pt,FL}}\right) + MARGIN$$

- Compliance is achieved when

$$L_{test}(v_{test}, a_{test}, n_{test}) \leq L_{exp}(v_{test}, a_{test}, n_{test})$$