ASEP IWG #12

2019.07.09-11
ASEP IWG #12 meeting
@Berlin

JASIC
1. ASEP Sound Model - Apply to Series-HEV
2. Summary of test results
3. Ideas to solve the issue
Mechanism of Series HEV

Driven by motor
ICE is only as generator.
No relationship between vehicle speed and ICE engine speed.

Series-HEV

![Graph showing engine speed vs. vehicle speed for Series HEV]

- ASEP Sound Model - Apply to Series-HEV

- Engine Speed $n$, rpm
- Vehicle Speed $v$, km/h
- A3_wot (D)
- A3_crs (D)
- $n_{\text{wot}}$
- $n_{\text{partial}}$
- $n_{\text{crs}}$
### Test vehicle information

<table>
<thead>
<tr>
<th>Spec.</th>
<th>Test vehicle</th>
<th>Vehicle-08 (Series-HEV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>Power unit</td>
<td>Motor</td>
</tr>
<tr>
<td></td>
<td>Max. power</td>
<td>80 kW</td>
</tr>
<tr>
<td></td>
<td>mro</td>
<td>1285 kg</td>
</tr>
<tr>
<td></td>
<td>PMR</td>
<td>62.3</td>
</tr>
<tr>
<td>Engine for power generation</td>
<td>1198 cc</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max. power @ 5400 rpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tyre size</td>
<td>185/70R14</td>
</tr>
<tr>
<td>R51-03 Annex 3</td>
<td>D-range</td>
<td>D-range</td>
</tr>
<tr>
<td>Conditions</td>
<td>Gear</td>
<td>V, km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n, rpm</td>
</tr>
<tr>
<td>Vehicle running</td>
<td>D</td>
<td>14-103</td>
</tr>
<tr>
<td>(Wot, Partial, Crs)</td>
<td></td>
<td>2400-5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3-4.0</td>
</tr>
</tbody>
</table>
Overview of Sound Model

A  Tyre Rolling Sound Model, $L_{TR}$

$$L_{TR} = \text{Slope}_{TR} \times \log\left( \frac{n_{test}}{50} \right) + L_{REF,TR}$$

$$L_{REF,TR} = X\% \text{ of } L_{CRS,REP}$$

X % (Tyre noise contribution at cruise test in Annex 3 is actually set to by 90%)

B  Power Train Base Mechanic Sound Model (No Load), $L_{PT,NL}$

$$L_{PT,NL} = \text{Slope}_{PT,NL} \times \log\left( (n_{test} + n_{shift}) / (n_{CRS,REP} + n_{shift}) \right) + L_{REF,PT,NL}$$

$$L_{REF,PT,NL} = (100 - X\%) \text{ of } L_{CRS,REP}$$

C  Dynamic Model, $L_{DYN}$

$$L_{DYN} = \text{Slope}_{DYN,NL} \times \log\left( (n_{test} + n_{shift}) / (n_{WOT,REP} + n_{shift}) \right) + L_{REF,DYN,NL}$$

$$+ \Delta L_{DYN} \times \Delta L_{Partial}$$

$$L_{REF,DYN,NL} = L_{REF,PT,NL} - 15$$

$$\Delta L_{DYN} = [ L_{WOT,REP} \circ \text{L}_{TR}(V_{WOT,REP}) \circ L_{PT,NL}(n_{WOT,REP}) ] - L_{REF,DYN,NL}$$

$\Delta L_{Partial}$ (See right figure)

D  Expectation level, $L_{exp}$

$$L_{test} \leq L_{exp} = (L_{TR} \oplus L_{PT,NL} \oplus L_{DYN}) + \Delta L_{MARGIN}$$
ASEP sound model can work well at most of conditions. Only $L_{test}$ on cruise test at lower vehicle speed exceeds $L_{exp}$ by sound model if using $X=90\%$.
If using the fixed value $X = 90\%$, $L_{\text{test}} > L_{\text{exp}}$ at low vehicle speed.

If using actual measured value $X=78\%$, sound model can fit.

Influence of $X(\%)$; tyre noise contribution of $L_{\text{crs}}$
The Reason of Underestimation with fixed X=90%

If 78% of X change to 90%,

A Tyre sound level $L_{TR} \rightarrow +0.6$ dB
B Power train sound level $L_{PT,NL} \rightarrow -3.4$ dB

In case of X=90%, $L_{PT,NL}$ (mechanical sound) is underestimated.
Due to higher contribution of $L_{PT,NL}$ at low vehicle speed, $L_{exp}$ is lower than $L_{test}$.
At higher vehicle speed or acceleration conditions, $L_{TR}$ (tyre sound) and $L_{DYN}$ (dynamic sound) are combined, then less influence of X values.

At CRS condition, $L_{TR} + L_{PT,NL} = L_{exp}$
The sound model can be applied to series HEV at most of operation conditions except for the condition at low speed and low load.

In this condition, since mechanical sound model is dominant, estimated uncertainty is not better than the other conditions which sound model is combined three models.

Then, X% which links to mechanical sound level is sensitive.

→ Need consideration only at low speed and low load condition.
Using proper value of $X$ for each test car instead of fixed value can improve sound model.

**Measure coast-by test (tyre sound level) to use measured $X\%$.**

Con; Need additional measurement

**Use formula for relationship between engine speed $n_{CRS}$ and $X\%$.**

Function of $n_{CRS}$ (engine speed in Annex3 cruise test at 50km/h)

$$X(\%) = 10 \left( \frac{L_{TR}^{10}}{L_{CRS}^{10}} - 1 \right) \times 100$$

$$X = -0.0182 \times n_{CRS} + 109.8$$

$$r = -0.82$$
Thank you for your attention.