The Criteria for the Determination of the Road Load Tolerance in KOREA

05 ~ 07 Oct. 2015

KOTSA, The Republic of KOREA
(Korea Transportation Safety Authority)
1. Global Fuel Economy and CO2 Emissions
2. Review of Flexibilities
3. The Gap between Type Approval and Realistic Road Load
4. Korea Regulation related to RL Tolerance
5. Derivation of Constant of RL Coefficient considering the FE Test Mode
6. Approving process of RL tolerance
7. Conclusions
1. Global Fuel Economy and CO2 Emissions

Introduction of Global Fuel Economy and CO2 Regulations

Phase in regulation:
- ‘12(60%)’13(75%)’14(80%)’15(100%)
- Test cycle: NEDC → WLTP (‘17)

Proposed:
- 68-78 g/km for 2025

~’16 : 35.5 mpg (15.1 km/l)
~’25 : 54.5 mpg (23.2 km/l)
Test cycle: Combined mode (FTP-75 + HWFET)

Phase in regulation:
- ‘12(30%)’13(60%)’14(80%)’15(100%)
- Test cycle: Combined mode (CVS-75 + HWFET)

Regulation at 2020 will be tightened by 54%
- Test cycle: JC08 → WLTP (‘18)

WLTC in Japan: Low+Medium+High-Speed
2. Review of Flexibilities

Flexibilities Between Type Approval vs. RDE

Source: TNO Report, 2012
3. The Gap between Type Approval and Realistic Road Load

- Ratio of realistic and Type Approval road load test results of all tested vehicles

<table>
<thead>
<tr>
<th></th>
<th>Type Approval</th>
<th>Realistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>S1</td>
<td>146</td>
<td>0.39</td>
</tr>
<tr>
<td>S2</td>
<td>110</td>
<td>0.35</td>
</tr>
<tr>
<td>S3</td>
<td>95</td>
<td>0.49</td>
</tr>
<tr>
<td>S4</td>
<td>80</td>
<td>0.38</td>
</tr>
<tr>
<td>S5</td>
<td>86</td>
<td>0.17</td>
</tr>
<tr>
<td>S6</td>
<td>157</td>
<td>0.62</td>
</tr>
<tr>
<td>S7</td>
<td>74</td>
<td>0.53</td>
</tr>
<tr>
<td>S8</td>
<td>84</td>
<td>0.55</td>
</tr>
</tbody>
</table>

- Relative CO₂ emissions of Euro 5 and 6 vehicles in a NEDC test with different road load settings

- Round-robin test
  - Type Approval Value
  - TNO test results with Type Approval road load settings

- Type approval vs. Realistic road load
  - TNO test results with Type Approval road load settings
  - TNO test results with realistic road load settings

※ Source: TNO Report “Roadload determination of passenger cars”, 2012
Mitsubishi Scandal

F/E Scandal - CD/setting

FE exaggeration of Mitsubishi Motors

Nation FE Test and Mitsubishi’s illegality

Coastdown test on the track

Tire friction
Aerodynamic drag

Road load value
Road load disguised by Mitsubishi Motors

Self-Report

Vehicle test on the C/D
simulated road load

FE calculation

Formal approval from Japan MOLITT

Catalog publication from FE calculation
Determination of tax reduction range

Source: Japan asahi article, 2016. 5
KOREA regulation related to Fuel economy & Running resistance test

⇒ “Regulation for Test procedures for Energy efficiency, Greenhouse gas emission and Fuel economy for Motor Vehicles”

- Article 12 (Running resistance test)

(1) The running resistance test shall, upon compliance test, be performed in accordance with Article 6, in the providing ground defined by the Minister of MOLIT.

(2) If the tolerance of running resistance value between measured by testing agency pursuant to Clause 1 and specified by the manufacturers is within 15%, the value specified by manufacturers shall be accepted. Herein, the tolerance means the discrepancy of energy considering fuel economy mode. If exceeding the tolerance, the value measured by testing agency shall be applied.
5. Derivation of Constant of RL Coefficient considering the FE Test Mode

Energy Loss Calculation

- The instantaneous dynamometer power is defined by:

\[
Power_{propulsion} = \left( m \times \frac{\partial (V)}{\partial t} + F_{\text{roadload}} \right) \times V
\]

- Inertia force: overcome change in momentum

\[
\sum F = m \times a
\]

\[
F_{\text{propulsion}} - F_{\text{RoadLoad}} = m \frac{\partial (V)}{\partial (t)}
\]

\[
Power = Force \times Speed
\]

- Road load force: caused by wind resistance and other vehicle level losses

\[
F_{\text{roadload}} = A + B \times V + C \times V^2
\]

- Inertia force: overcome change in momentum

Road load force caused by: wind resistance, rolling resistance, friction losses, and other vehicle level losses
Derivation of Constant of Road Load Coefficients on the basis of Korea Regulation

- **Energy loss**_{ FTP-75(kJ) }:
  \[
  \int_0^{2477} (f_0 + f_1 v_F + f_2 v_F^2) \times v \, dt = \int_0^{2477} (f_0 v_F + f_1 v_F^2 + f_2 v_F^3) \, dt \\
  = f_0 \times \int_0^{2477} v_F \, dt + f_1 \times \int_0^{2477} v_F^2 \, dt + f_2 \times \int_0^{2477} v_F^3 \, dt \\
  = f_0 \times A(F)_{f_0} + f_1 \times B(F)_{f_1} + f_2 \times C(F)_{f_2}
  \]

- **Energy loss**_{ HWFET(kJ) }:
  \[
  \int_0^{765} (f_0 + f_1 v_H + f_2 v_H^2) \times v \, dt = \int_0^{765} (f_0 v_H + f_1 v_H^2 + f_2 v_H^3) \, dt \\
  = f_0 \times \int_0^{765} v_H \, dt + f_1 \times \int_0^{765} v_H^2 \, dt + f_2 \times \int_0^{765} v_H^3 \, dt \\
  = f_0 \times A(H)_{f_0} + f_1 \times B(H)_{f_1} + f_2 \times C(H)_{f_2}
  \]

### Table

<table>
<thead>
<tr>
<th>Unit : N</th>
<th>Unit : lbf</th>
<th>Regulation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_{f_0}</td>
<td>B_{f_1}</td>
<td>C_{f_2}</td>
<td></td>
</tr>
<tr>
<td>FTP-75 (3bag)</td>
<td>17.4</td>
<td>945.0</td>
<td>58880.2</td>
</tr>
<tr>
<td>FTP-75 (4bag)</td>
<td>23.4</td>
<td>1174.5</td>
<td>68057.1</td>
</tr>
<tr>
<td>HWFET</td>
<td>16.5</td>
<td>1338.0</td>
<td>110662.3</td>
</tr>
</tbody>
</table>

1. Speed profile: FE Regulation of KOREA
2. “Target speed < 15 km/h” → regarded as zero (0)
3. Decimal display of Energy loss → round off the numbers to the nearest hundredths.
4. Denominator is the road load energy provided by manufactures

Internal combustion vehicle

Notification

Hybrid vehicle

All type vehicle
## 5. Derivation of Constant of RL Coefficient considering the FE Test Mode

### Energy Loss Calculation using the Derived Constants

<table>
<thead>
<tr>
<th>Description</th>
<th>C.E based on T. Value (kJ)</th>
<th>C.E based on C.value (kJ)</th>
<th>RL difference (%)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target value</strong></td>
<td><strong>Confirmed value</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coefficients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f0(N)</td>
<td>124.50</td>
<td>160.771</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>f1(N/KPH)</td>
<td>0.53612</td>
<td>0.56216</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>f2(N/KPH^2)</td>
<td>0.0290</td>
<td>0.0290</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>1. Energy loss diff. considering the FE test cycle (individual)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FTP-75 test cycle (3-bag) ((17.4<em>f0+945.0</em>f1+58880.2*f2))</td>
<td>4380.5</td>
<td>5036.2</td>
<td>15.0 (OK)</td>
<td>“Target speed &lt; 15 km/h” → regarded as zero (0)</td>
</tr>
<tr>
<td>FTP-75 test cycle (4-bag) ((23.4<em>f0+1174.5</em>f1+68057.1*f2))</td>
<td>5516.6</td>
<td>6396.0</td>
<td>15.9 (NG)</td>
<td></td>
</tr>
<tr>
<td>HWFET test cycle ((16.5<em>f0+1338.0</em>f1+110662.3*f2))</td>
<td>5980.8</td>
<td>6614.1</td>
<td>10.6 (OK)</td>
<td></td>
</tr>
</tbody>
</table>
6. Approving process through Road Load Compliance Test in Korea

- **Vehicle Selection**
- **Run-in (Authority)**
- **Coast down Test (Authority)**

**Energy Loss Calculation considering Fuel Economy Mode (FTP-75, HWFET)**

- **Evaluation Criterion of Road Load Tolerance**
  1. Energy loss diff. considering the FE test cycle (individual)
  
  → Energy loss calculation using the constant of road load coefficients given in table of previous slide

- **Energy Loss difference is within 15%?**
  - **YES**
    - Specification RL value shall be applied for FE test
  - **NO**
    - Audit RL value shall be applied for FE test
7. Conclusions

- KOREA derived and updated constant \((A_{f0}, B_{f1}, C_{f2})\) of RL coefficients for RL tolerance calculation based on energy loss considering fuel economy test mode (FTP-75 & HWFET).

\[
\text{Energy loss (kJ)} = f_0 \times A_{f0} + f_1 \times B_{f1} + f_2 \times C_{f2}
\]

\[
A_{f0} = \int_0^{t_{\text{cycle}}} v_F \, dt, \quad B_{f1} = \int_0^{t_{\text{cycle}}} v_F^2 \, dt, \quad C_{f2} = \int_0^{t_{\text{cycle}}} v_F^3 \, dt,
\]

- FTP-75(3-bag): \(A_{f0} = 17.4 \text{ km}, B_{f1} = 945.0 \text{ km}^2/\text{h}, C_{f2} = 58,880.2 \text{ km}^3/\text{h}^2\)
- FTP-75(4-bag): \(A_{f0} = 23.4 \text{ km}, B_{f1} = 1,174.5 \text{ km}^2/\text{h}, C_{f2} = 68,057.1 \text{ km}^3/\text{h}^2\)
- HWFET : \(A_{f0} = 16.5 \text{ km}, B_{f1} = 1,338.0 \text{ km}^2/\text{h}, C_{f2} = 110,662.3 \text{ km}^3/\text{h}^2\)

- The method of using constants derived from road load coefficients considering the fuel economy test mode was devised for use by relevant authority during the verification of road load specifications provided by the manufacturer.

- For the road load verification, the derived constants will be used for the amendment of fuel economy regulations in KOREA by the end of this year.

- KOREA hopes that In-Service TF refers to our study for the road load determination.
Thank you very much ! !

E-mail : cha1052@ts2020.kr