Cycle / Gearshifting

Status report about the work of the task force on cycle and gearshift issues; proposals for adoption by the WLTP IWG

Heinz Steven

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After WLTP IWG #19 the gearshift issues task force had an audio-web telco at 30.08.2017. The following items were discussed:

1. Different individual $n_{\text{min\_drive}}$ values > $n_{\text{min\_drive\_set}}$ for acceleration and deceleration phases,

2. Higher $n_{\text{min\_drive}}$ values for the cold start part of the cycle than for the rest,

3. Round robin test for GS calculation tools,

4. More specific text for $P_{wot}(n)$ in paragraph 2(h),

5. Use declared maximum vehicle speed as input for the vehicle classification,

6. Specify that $n_{\text{rated}}$ and $P_{\text{rated}}$ as well as the $P_{wot}(n)$ curve should be values as declared by the manufacturer).
1. Different individual $n_{\text{min\_drive}}$ values

- This item was a leftover from previous meetings and requested by Japan with the following justification:
  
  - It is currently allowed to set a higher $n_{\text{min\_drive}}$ value than defined in paragraph 2 (k), (c) of Annex 2. The aim is to improve drivability by excluding cycle phases with low engine speeds and high load.
  
  - It is obvious that this option is dedicated to acceleration phases, but it would not be needed for deceleration phases.
  
  - Since no drivability problems would be expected during deceleration phases, it is more representative to keep the original $n_{\text{min\_drive}}$ value during deceleration phases.
1. Different individual $n_{\text{min\_drive}}$ values

- The chairman had sent out the document WLTP-GS-TF-32 in which the results of calculations for example vehicles were presented.

- The following side conditions result from other requirements in annex 2:
  - $n_{\text{min\_drive\_up}}$ and/or $n_{\text{min\_drive\_down}}$ must be higher than $n_{\text{min\_drive\_set}}$ as specified in paragraph 2 (k) of annex 2,
  - The max. value is limited by the requirement that the engine speed in the next lower gear must not exceed $n_{\text{max}1}$ as specified in paragraph 2 (g) of annex 2.
1. Different individual $n_{\text{min\_drive}}$ values

- Since the gear use calculation starts with the calculation of possible gears to be used for each sample of the cycle, an acceleration threshold for the separation of up- and downshifts must be specified.
- The chairman proposed -0.1389 m/s$^2$ (-0.5 km/h/s) as threshold.
- The example calculations were performed with this threshold.
- Figure 1 shows the results for the most critical example vehicle for the round robin test (vehicle 8).
Results of example calculations

- $n_{\text{min\_drive\_down}} = 950 \text{ min}^{-1}$
- $n_{\text{min\_drive\_down}} = n_{\text{min\_drive\_up}}$
- $n_{\text{min\_drive\_up}} = 950 \text{ min}^{-1}$

Vehicle 8, RRT, $n_{\text{rated}} = 2000 \text{ min}^{-1}$

Figure 1
1. Different individual $n_{\text{min\_drive}}$ values

The results of the example calculations can be summarised as follows:

• Most critical for the number of modifications is the increase of $n_{\text{min\_drive\_up}}$ with $n_{\text{min\_drive\_down}} = n_{\text{min\_drive\_set}}$.
• The increase of $n_{\text{min\_drive\_up}}$ or $n_{\text{min\_drive\_down}}$ leads to an increase in the number of corrections according to paragraph 4 of annex 2 (Additional requirements for corrections and/or modifications of gear use).
• In extreme cases new additional requirements would be necessary in order to achieve a reasonable gear use time pattern.
• In all cases the average engine speed increased with increasing $n_{\text{min\_drive}}$ values (see figure 2).
Results of example calculations

Figure 2

Vehicle 8, RRT,
\( n_{\text{rated}} = 2000 \text{ min}^{-1} \)
1. Different individual $n_{\text{min\_drive}}$ values

- Based on these results the chairman proposed to limit $n_{\text{min\_drive\_up\_down}}$ to $2 \times n_{\text{min\_drive\_set}}$.
- The current prescriptions allow the manufacturer to use higher $n_{\text{min\_drive}}$ values without any limitation.
- The whole issue was discussed in the GSTF and finally accepted as proposed by the chairman.
- Therefore, this issue is brought to the WLTP IWG with the aim to adopt it.
1. Proposal for adoption by the WLTP IWG

• **Paragraph 2 (k) currently reads:**

(k) Definition of \( n_{\text{min\_drive}} \)

\( n_{\text{min\_drive}} \) is the minimum engine speed when the vehicle is in motion, \( \text{min}^{-1} \);

For \( n_{\text{gear}} = 1 \), \( n_{\text{min\_drive}} = n_{\text{idle}} \),

For \( n_{\text{gear}} = 2 \),

(a) for transitions from first to second gear:

\[ n_{\text{min\_drive}} = 1.15 \times n_{\text{idle}} \]

(b) for decelerations to standstill:

\[ n_{\text{min\_drive}} = n_{\text{idle}} \]

(c) for all other driving conditions:

\[ n_{\text{min\_drive}} = 0.9 \times n_{\text{idle}} \]

For \( n_{\text{gear}} > 2 \), \( n_{\text{min\_drive}} \) shall be determined by:

\[ n_{\text{min\_drive}} = n_{\text{idle}} + 0.125 \times ( n_{\text{rated}} - n_{\text{idle}} ) \]

The final result for \( n_{\text{min\_drive}} \) shall be rounded to the nearest integer.

Example: 1199.5 becomes 1200, 1199.4 becomes 1199.

Higher values may be used if requested by the manufacturer. However, such higher values shall not be used as the lower limit for the full load power curve according to (h) above.
1. Proposal for adoption by the WLTP IWG

- This text shall be modified as follows (modifications supplements are highlighted in yellow):

(k) Definition of \( n_{\text{min\_drive}} \)

\( n_{\text{min\_drive}} \) is the minimum engine speed when the vehicle is in motion, \( \text{min}^{-1} \);

(a) For \( n_{\text{gear}} = 1 \), \( n_{\text{min\_drive}} = n_{\text{idle}} \);

(b) For \( n_{\text{gear}} = 2 \),

(i) for transitions from first to second gear:

\[
 n_{\text{min\_drive}} = 1.15 \times n_{\text{idle}} ;
\]

(ii) for decelerations to standstill:

\[
 n_{\text{min\_drive}} = n_{\text{idle}} ;
\]

(iii) for all other driving conditions:

\[
 n_{\text{min\_drive}} = 0.9 \times n_{\text{idle}} .
\]

(c) For \( n_{\text{gear}} > 2 \), \( n_{\text{min\_drive}} \) shall be determined by:

\[
 n_{\text{min\_drive}} = n_{\text{idle}} + 0.125 \times ( n_{\text{rated}} - n_{\text{idle}} ) .
\]

This value is referred to as \( n_{\text{min\_drive\_set}} \).

The final results for \( n_{\text{min\_drive}} \) shall be rounded to the nearest integer.

Example: 1199.5 becomes 1200, 1199.4 becomes 1199.
• (k) Definition of $n_{\text{min\_drive}}$ (continued):

Higher values than $n_{\text{min\_drive\_set}}$ may be used for $n_{\text{gear}} > 2$, if requested by the manufacturer. In this case the manufacturer may specify one value for acceleration/constant speed phases ($n_{\text{min\_drive\_up}}$) and a different value for deceleration phases ($n_{\text{min\_drive\_down}}$). Samples with acceleration values $\geq -0.1389$ m/s$^2$ belong to acceleration/constant speed phases.

$n_{\text{min\_drive\_up}}$ and $n_{\text{min\_drive\_down}}$ shall be equal to or higher than $n_{\text{min\_drive\_set}}$ but must not exceed $2 \times n_{\text{min\_drive\_set}}$.

However, only $n_{\text{min\_drive\_set}}$ shall be used as the lower limit for the full load power curve according to paragraph 2 (h) above.
2 (h) \( P_{wot}(n) \), the full load power curve over the engine speed range.

The power curve shall consist of a sufficient number of data sets \((n, P_{wot})\) so that the calculation of interim points between consecutive data sets can be performed by linear interpolation. Deviation of the linear interpolation from the full load power curve according to Regulation No. 85 shall not exceed 2 per cent. The first data set shall be at \( n_{min\_drive\_set} \) or lower. The last data set shall be at \( n_{max} \) or higher engine speed. Data sets need not be spaced equally. The full load power at engine speeds not covered by Regulation No. 85 shall be determined according to the method described in Regulation No. 85;
2. Higher $n_{\text{min\_drive}}$ values for the cold start part of the cycle

- After WLTP IWG # 19 the chairman of the GSTF got a request from a task force member to allow higher $n_{\text{min\_drive}}$ values only for the cold start part of the cycle. The justification for this request was as follows:
  
  - The option to amend $n_{\text{min\_drive}}$ is always an increase in engine speed and therefore to the disadvantage of the manufacturer in terms of CO$_2$.
  
  - Often the driveability problems which lead a manufacturer to taking up this option are restricted to cold (not fully warm) engine operation.
  
  - A similar concept is already employed in the calibration of automatic transmissions and in gear shift indicators on manual transmissions.
2. Higher $n_{\text{min\_drive}}$ values for the cold start part of the cycle

- This request was also discussed in the web-telco especially with respect to the duration of such a phase.
- Since the duration of the cold start phase is engine and vehicle design dependent, it was agreed that the manufacturer should have the possibility to specify the time span and the $n_{\text{min\_drive}}$ value individually within the low phase of the cycle.
- But the time span should be specified such, that it ends in a stop phase, so that there is no change of $n_{\text{min\_drive}}$ within a short trip.
- This issue is also brought to the WLTP IWG with the aim to adopt it.
2. Proposal for adoption by the WLTP IWG

• (k) Definition of $n_{\text{min\_drive}}$ (further modified as highlighted in green/purple):

Higher values than $n_{\text{min\_drive\_set}}$ may be used for $n_{\text{gear}} > 2$, if requested by the manufacturer. In this case the manufacturer may specify one value for acceleration/constant speed phases ($n_{\text{min\_drive\_up}}$) and a different value for deceleration phases ($n_{\text{min\_drive\_down}}$). Samples with acceleration values ≥ -0.1389 m/s² belong to acceleration/constant speed phases.

In addition, for the values $n_{\text{min\_drive\_up}}$ and/or $n_{\text{min\_drive\_up\_start}}$ for $n_{\text{gear}} > 2$ the manufacturer may specify higher values than specified above ($n_{\text{min\_drive\_start}}$ and/or $n_{\text{min\_drive\_up\_start}}$) and an initial time period of the cycle ($t_{\text{start\_phase}}$) for which these higher values shall be used.

The initial time period must not exceed the low speed phase of the cycle and shall end in a stop phase, so that there is no change of $n_{\text{min\_drive}}$ within a short trip.

All individually chosen $n_{\text{min\_drive}}$ values shall be equal to or higher than $n_{\text{min\_drive\_set}}$ but must not exceed $2 \times n_{\text{min\_drive\_set}}$.

All individually chosen $n_{\text{min\_drive}}$ values and $t_{\text{start\_phase}}$ shall be recorded. However, only $n_{\text{min\_drive\_set}}$ shall be used as the lower limit for the full load power curve according to paragraph 2 (h) above.
3. Round robin test for GS calculation tools

- The round robin test for GS calculation tools is based on 30 example vehicles whose input data were circulated to participants by the chairman.
- One problem occurred which was not foreseen at the beginning:
- European OEMs are not so much interested in the latest calculation tool but more in the tool version compliant to EU/2017/1151 (EU-WLTP legislation).
- This tool version was identified meanwhile, but not all bugs could be corrected, partly because they are related to requirements in annex 2 at that stage of the GTR, that would allow different interpretations or options.
3. Round robin test for GS calculation tools

• 4 participants provided their results meanwhile.
• 1 participant used sub-annex 2 of EU regulation 2017/1151 as reference, the others used GRPE-75-23 as reference.
• 2 of the latter announced that they would deliver also results according to EU/2017/1151.
• The analysis of the results has been started, but it is too early to provide results yet.
• Furthermore, the results from several other participants are expected.
• So, this work is still ongoing; results will be presented in January 2018 in Geneva.
4. More specific text for $P_{wot}(n)$

- A more specific text for $P_{wot}(n)$ in paragraph 2(h) was requested at the last WLTP IWG meeting in Geneva by India.

- Mr. Nakhawa promised to prepare a paper in which this request would be described more specifically.

- Up to now, the chairman did not get this paper, so that this issue will also be postponed to the next IWG meeting.
5. Use declared $v_{\text{max}}$ for the vehicle classification

- This issue is only related to the ACCESS calculation tool of the chairman.
- In this tool $v_{\text{max}}$ as calculated according to annex 2 was used for the vehicle classification and thus for the choice of the appropriate cycle.
- In the GTR it is clearly stated in annex 1, that the classification is based on $v_{\text{max}}$ as declared by the manufacturer.
- Therefore one member of the TF required to add the declared $v_{\text{max}}$ value to the input data of the calculation tool.
- This was done and an updated tool was distributed to the TF.
6. Request to clarify which $n_{\text{rated}}$ and $P_{\text{rated}}$ should be used in annex 2

- One member of the TF argued that there could be slight differences between the $n_{\text{rated}}$ and $P_{\text{rated}}$ values declared by the manufacturer and derived from the $P_{\text{wot}}(n)$ curve according to paragraph 2 (h). He requested to specify which values should be used in annex 2.

- Since the $P_{\text{wot}}(n)$ curve is one of the key elements of the gear use calculation, the group agreed that it would be desirable to use the values derived from this curve.

- This issue is also brought to the WLTP IWG with the aim to adopt it.

- In annex 1 for vehicle classification and downscaling the declared values for $P_{\text{rated}}$ and $v_{\text{max}}$ are used.
6. Request to clarify which $n_{\text{rated}}$ and $P_{\text{rated}}$ should be used in annex 2

- The discussions in the IWG # 20 resulted in the request to use in annex 2 the WOT power curve as declared by the manufacturer.

- This curve contains $n_{\text{rated}}$ and $P_{\text{rated}}$ as declared by the manufacturer.

- Therefore the next slide is modified as follows:
6. Proposal for adoption by the WLTP IWG

- **Paragraphs 2 (a) remains unchanged:**

  \( a \) \( P_{\text{rated}} \), the maximum rated engine power as declared by the manufacturer, of the \( P_{\text{wot}}(n) \) curve (see paragraph 2 (h) below) kW;

- **Paragraph 2 (b) should be amended as follows:**

  \( b \) \( n_{\text{rated}} \), the rated engine speed declared by the manufacturer as the engine speed at which the engine develops its maximum power, \( \text{min}^{-1} \). If the maximum power is developed over an engine speed range, \( n_{\text{rated}} \) shall be the minimum of this range. \( n_{\text{rated}} \) shall be derived from the \( P_{\text{wot}}(n) \) curve (see paragraph 2 (h) below), \( \text{min}^{-1} \).
Paragraph 2 (h) should be amended as follows:

(h) $P_{\text{wot}}(n)$, the full load power curve over the engine speed range. The power curve shall consist of a sufficient number of data sets $(n, P_{\text{wot}})$ so that the calculation of interim points between consecutive data sets can be performed by linear interpolation. Deviation of the linear interpolation from the full load power curve according to Regulation No. 85 shall not exceed 2 per cent. The first data set shall be at $n_{\text{min\_drive\_set}}$ of $n_{\text{gear}} > 2$ (see (k), (c) below) or lower. The last data set shall be at $n_{\text{max}}$ or higher engine speed. Data sets need not be spaced equally but all data sets need to be reported.

The data sets, and the values $P_{\text{rated}}$ and $n_{\text{rated}}$ shall be taken from the power curve as declared by the manufacturer.

The full load power at engine speeds not covered by Regulation No. 85 shall be determined according to the method described in Regulation No. 85;
Thank you for your attention!