BRACING AND THE POSSIBILITY OF ITS USING

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Abstract: Electromobility and combined alternative propulsions of city vehicles are currently topic number one. In order to be properly
designed their application has to be obvious. It is calculated with using of the energy recuperated from braking to increase their energy
efficiency. Quantity of this energy is usually determined from the NEDC driving cycle. To what extent can the data from the NEDC cycle rely
and how they different from data from real driving cycles is the subject of this article. The simulations of serial hybrid drive consisting
different components were done.

Keywords: RECUPERATION, NEDC, STOP&GO, REAL URBAN CYCLE, BRAKING, MEASUREMENT

1. Introduction

The importance of electric and hybrid vehicles in the field of transport means is still increasing. In order to properly design
the drives of these vehicles their application and real possibility of its use in the operation has to be obvious. Efficiency
of utilization of these drive systems depends on their right combination and dimensioning. Due to the need to reduce
the vehicle energy consumption and emissions some systems for the accumulation of kinetic energy from braking that would be
otherwise wasted by heat, as well as systems which switch off the combustion engine while vehicle standing as Stop&Go system
are currently designed. Proposals similar devices as well as the hybrids are usually based on driving cycles for determining
of fuel consumption and harmful emissions – NEDC (New European Driving Cycle), FTP (Federal Test Procedure) cycles or
others. These cycles are however simplified and don’t content the grade resistance or real progress of braking deceleration.
In contrast, in normal traffic, there is often a short-term braking, respectively slow down, which can be only a minor source
of recovered energy. The aim of this paper is to show to what extent the use of standard driving cycles for the design of electric drives,
respectively hybrid drives of vehicles, is consistent with real conditions. For the purpose of comparison of standardized and
realistic driving cycles were performed several measurements of real driving cycles in different cities of Poland, Czech Republic
and Slovakia.

![Fig. 1 Real driving cycle of Prague](image1)

Comparison of real drive cycle of Prague and NEDC cycle for measuring vehicle emissions and fuel consumption is shown in fig.
1 and fig. 2. Urban part of NEDC cycle takes first 780 second.

![Fig. 2 NEDC cycle](image2)

2. Measurement description

Cities with higher population, larger size and more complicated transport system, with the expected use of vehicles with alternative
drive systems were deliberately chosen to measure the real driving cycles. A higher proportion of reasons to stop or reduce speed,
which is a potential source of re-use of energy, are specific for these cities. The cities continue in solving of issues of environment
pollution and reducing emissions from transport at the same time.

The fact that each of the three monitored countries has a different geographic structure is reflected even in the elevation profiles of individual cities. Table 1 indicates the basic information of the monitored cities.

<table>
<thead>
<tr>
<th>City</th>
<th>Population [inhabitants]</th>
<th>Population density [persons per km²]</th>
<th>City area [km²]</th>
<th>Elevation [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Katowice</td>
<td>308724</td>
<td>1874,8</td>
<td>164,67</td>
<td>266 - 352</td>
</tr>
<tr>
<td>Wroclaw</td>
<td>632996</td>
<td>2161,7</td>
<td>292,82</td>
<td>105 - 155</td>
</tr>
<tr>
<td>Gliwice</td>
<td>196361</td>
<td>1466,7</td>
<td>133,88</td>
<td>200 - 278</td>
</tr>
<tr>
<td>Prague</td>
<td>1272690</td>
<td>2602,5</td>
<td>496</td>
<td>399</td>
</tr>
<tr>
<td>Žilina</td>
<td>85295</td>
<td>1066</td>
<td>80,03</td>
<td>342</td>
</tr>
</tbody>
</table>

Pictures fig. 3. to fig. 7. show the elevation profiles recorded during the measurement and compare the elevation profiles
differences, which affect the possibility of energy recovery as well as the increase of the demands on the vehicle power unit.

![Fig. 3 Katowice elevation profile](image3)

![Fig. 4 Wroclaw elevation profile](image4)

![Fig. 5 Gliwice elevation profile](image5)
Because it is assumed that electric and hybrid vehicles will be used for transportation to job and shopping by their owners, the measurements were performed in real time of their use, in the time of afternoon rush hours from 14:00 to 16:30 hrs. This time is characterized by growing number of traffic congestions and longer standing at intersections. The most energy-demanding regimes of frequent acceleration and braking were recorded by this way.

Measurement unit DAS3 (fig. 8) with contactless velocity and acceleration sensor Microstar Non-Contact 1-Axis Microwave Sensor (fig. 8) and Crossys Datron Pedal Force Sensor (fig. 9) for the record of pedal brake pressing were used to record and measure of dynamic quantities. Contactless velocity and acceleration sensor was placed on the side of the vehicle. Values of slope were determined using the GPS receiver, placed on the front hood of the vehicle (fig. 9).

The measuring apparatus was placed on the C-segment class vehicle Hyundai i30 (fig. 10), with a displacement of 1.4 liters, power of 80 kW at 6000 rpm and torque 134 Nm at 5000 rpm and unladen mass 1286 kg. The vehicle was occupied by two passengers and measuring technology with total weight of 180 kg. Driving mode was adapted to the surrounding traffic not to avoid its negative influence.

### Table 2: Comparison of real cycles

<table>
<thead>
<tr>
<th>City</th>
<th>Max. slope [ % ]</th>
<th>Average slope [ % ]</th>
<th>Distance [ km ]</th>
<th>Time [ min ]</th>
<th>Average speed [ km.h⁻¹ ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Katowice</td>
<td>5.2 -5 1.5 -1.4</td>
<td>12.40</td>
<td>41.15</td>
<td>18.07</td>
<td></td>
</tr>
<tr>
<td>Wroclaw</td>
<td>3.6 -4.9 1 -1.2</td>
<td>18.99</td>
<td>54.9</td>
<td>20.75</td>
<td></td>
</tr>
<tr>
<td>Gliwice</td>
<td>12.6 -9.3 1.3 -1.5</td>
<td>12.72</td>
<td>31.6</td>
<td>24.14</td>
<td></td>
</tr>
<tr>
<td>Prague</td>
<td>13.7 -20.1 3.1 -3.5</td>
<td>25.57</td>
<td>62.65</td>
<td>24.48</td>
<td></td>
</tr>
<tr>
<td>Žilina</td>
<td>5.6 -7.1 1.7 -1.7</td>
<td>23.25</td>
<td>44.65</td>
<td>31.23</td>
<td></td>
</tr>
</tbody>
</table>

Picture fig. 11. shows the percentage of decelerating to the driving cycle time. Comparison of these five real driving cycles shown, that the average time of decelerating is 13.1% of the driving cycle time. A very small dispersion of these values for different cities is noteworthy. Picture fig. 11. also shows that in the city part of standardized NEDC driving cycle, which is mostly used in the design of alternative propulsions in Europe, the braking time is up to 20% of the cycle time.

The difference between the average time of decelerating in the real driving cycle and the decelerating time in the NEDC cycle is up to 35%. However, this figure does not reflect the intensity of braking, which presents
the amount of energy that can be saved, but only talk about the braking time in proportion to the time of driving. Because it is difficult recovery energy at low speeds, neither the average time of decelerating during the real driving cycle does not represent the real possibility of using the braking to recover kinetic energy.

Currently the most popular hybrid system is known Stop&Go system. This micro hybrid concept based on the shutting down of the internal combustion engine while standing. Picture fig. 14. shows that the standing time in real driving cycles is about as long as the standing time under consideration in the NEDC cycle. Significant differences may be influenced by the complexity of traffic situations and road network in the city as well as by real-time in rush hours. By using the real driving cycle of the passenger on 75 kg and the baggage on 15 kg. To the baggage was added the weight of selected combustion engine and battery pack.

![Fig. 12. Standing and driving ratio](image)

The time of standing useful for Stop&Go system, possible time of recovery kinetic energy from braking and the time of recovery kinetic energy from driving downhill, which is a part of recovery period, can be determined from the measured data of the moving vehicle and the signal of brake pedal sensor. The times of standing, braking and downhill braking of the vehicle are displayed in fig. 13.

![Fig. 13. Time of use of braking and standing](image)

### 4. Simulation of serial hybrid

The serial hybrid vehicle simulations based on the chosen real driving cycles were made by using the Matlab Simulink. The primary inputs to the simulations were measured values of velocity, acceleration, slope and braking signal from the real driving cycle. Based on these inputs was calculated the required power of the drive.

A key factor in hybrid vehicles is correctly dimensioned size of key components as traction electric motor, internal combustion engine and batteries. The small plug-in hybrid vehicle for two passengers primarily designed for city traffic was chosen for the simulation. To cover all driving modes and needs, the traction electric motor of 15 kW was selected. This motor was used in each simulated configuration. For the simulation were three combustion engines with different displacements selected. Combustion engines operate in one revolution mode where they have the best specific fuel consumption. Subsequently were selected two 240 V NiMH battery packs with the capacity of 34 Ah and 8.5 Ah. Table 3 contains six different vehicle configurations. The basic mass of the vehicle with electric motor was set on 350 kg, the weight of passenger on 75 kg and the baggage on 15 kg. To the baggage was added the weight of selected combustion engine and battery pack.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle 1</td>
<td>505</td>
<td>2000</td>
<td>34</td>
<td>296</td>
<td>49</td>
<td>34</td>
<td>180</td>
</tr>
<tr>
<td>Vehicle 2</td>
<td>280</td>
<td>2800</td>
<td>19</td>
<td>310</td>
<td>30</td>
<td>34</td>
<td>180</td>
</tr>
<tr>
<td>Vehicle 3</td>
<td>120</td>
<td>2500</td>
<td>7</td>
<td>305</td>
<td>13</td>
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<td>180</td>
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<tr>
<td>Vehicle 4</td>
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<td>296</td>
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<td>8.5</td>
<td>45</td>
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<tr>
<td>Vehicle 5</td>
<td>280</td>
<td>2800</td>
<td>19</td>
<td>310</td>
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</tr>
<tr>
<td>Vehicle 6</td>
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<td>2500</td>
<td>7</td>
<td>305</td>
<td>13</td>
<td>8.5</td>
<td>45</td>
</tr>
</tbody>
</table>

The main factor for comparing of the vehicles was range. The range of each simulated vehicle was given by consumption of 1 liter of petrol. Vehicles were compared in three real driving cycles and urban part of the NEDC cycle and in two modes of batteries, start with fully charged batteries and start with fully discharged batteries. In the case of fully charged batteries the vehicle started operate in electric mode. When the state of charge of the battery reached its bottom line, the combustion engine was turned on. In this case, the energy required for electric motor was supplied by generator driven by an internal combustion engine and the rest of energy was stored in batteries. When the state of charge of batteries reached the preset top line, the engine was turned off. In the case of fully discharged batteries the simulation started in hybrid mode (combustion engine was on). In both types of simulation the combustion engines were off when their consumption reached 1liter of petrol. It should be noted that the batteries can not be discharged to the 0 due to their life. The range comparison of fully charged vehicles you can see in fig. 14. The range comparison of discharged vehicles you can see in fig. 15.

![Fig. 14. Comparison of fully charged vehicles](image)

As can be seen in fig. 14. and fig. 15. the greatest range was achieved by fully charged vehicles with 34 Ah battery pack.
Situation is changing with the discharged battery, where the vehicle with heaviest 34 Ah battery pack needs to make more power due to the increased weight of the vehicle. In the comparison of internal combustion engines with charged and discharged batteries, the best result was achieved with 120 cm³ engine due to its lower weight. Engine with displacement of 505 cm³ is bigger than the engine with 280 cm³ displacement, but on the other hand has a better specific fuel consumption which is reflected to a similar range. The engine of 505 cm³ had better results when the batteries were discharged; the engine of 280 cm³ had a slightly better result when the batteries were charged particularly for 34 Ah battery pack. When the 8.5 Ah battery pack was used with the engine of 505 cm³ or 280 cm³ the range was almost same. Engine with 120 cm³ displacement seems to be a best choice, but it should be noted that in the case of fully discharged battery and high power demand such as driving on higher speed, the engine hasn’t enough power to ensure vehicle performance.

5. Conclusion

Although the use of real driving cycle seems based on comparing the real driving cycle with NEDC cycle preferable, the range simulation of small city car with serial hybrid drive shows that this difference is not so significant. The time comparison of driving cycles from the point of the time braking disregards the braking intensity and thus the amount of usable energy for recuperation.

The use of the real driving cycles at the design of some city vehicles (buses, taxi cars) can be appropriate and useful due to their special driving mode with often decelerating.

Nowadays most of new vehicles are equipped with Stop&Go system. From the measurement data can be seen that this system has substantiation and enables decrease the fuel consumption and emissions. It turned out that the standing time in real driving cycles is close to NEDC cycle. In some cities was almost identical.

The simulation showed that the size of combustion engine which achieved the largest range was corresponding to an internal combustion engine with the power close to the mean power measured in real driving cycle at a given mass.

Literature


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