

## ELECTRIC AUTOMOBIL - WISHES AND REALITY

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The demands on cars energy resources are given by the following items: power, speed, acceleration, operation range. All these factors are under balance: future wishes and contemporary reality.

The proposal is dedicated to the analysis of demands related to the electric automobiles. As a hopefulness solution of these transport means can be seen for city transport (forwarding, shopping, postal services etc). The technical and economic approaches are discussed, too.

**Key words:** power, energy, operating range, electric drive, application, economics

### 1 Introduction

Electric drive of the transportation means is the most advantageous propulsion technology of all other. Main reasons for its implementing are following:

- high energy efficiency,
- the most favourable mass/output ratio of whole propulsion system i. e. incl. of auxiliary equipment, power regulation and its transmission, (without of energy source),
- zero emission,
- silent operation,
- overload ability.

Massive extension of electric cars hinders absence of the advantageous electric energy source which has comparable characteristic parameters with classical fuel.

How shall be the requirements for the energy source for the supply of electric car? Answer to this question has five parts (following parts 2 – 6).

### 2 Input for the acceleration

Input for a car propulsion system during of acceleration is generally given through the following formula:

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$$k_a(V) = [102 \cdot \xi \cdot a(V) + r_v(V) + g] \cdot V \cdot 2,72 \cdot 10^{-3} \cdot \frac{1}{\eta(V)} \quad (1)$$

[kW/t, 1, m/s<sup>2</sup>, N/kN, ‰, km/h, 1]

Here means:

- $k_a(V)$  ..... specific mass input as the function of speed  $V$ ,
- $\xi$  ..... coefficient of rotation masses,
- $a(V)$  ..... acceleration as the function of speed,
- $r_v(V)$  ..... specific vehicle resistance as the function of speed
- $g$  ..... gradient of the road
- $\eta(V)$  ..... total efficiency of the whole propulsion system as the function of speed - for  $\eta$  holds:

$$\eta = \eta_1 \cdot \eta_2 \cdot \eta_3 \quad [1, 1, 1, 1] \quad (2)$$

- $\eta_1$  ..... efficiency of the traction motor,
- $\eta_2$  ..... efficiency of its regulation system,
- $\eta_3$  ..... efficiency of the power transmission to wheels.

In the next transactions is in consideration a middle passenger car with the specific vehicle resistance according to the tab. 1. The values in this table are valid for a perfect smooth road surface.

Tab. 1

<b>V</b> [km/h]	0	25	50	75	100
<b>r<sub>v</sub></b> [N/kN]	20	22,5	32,0	45,9	62,0

The values of specific mass inputs  $k_a$  for various accelerations  $a$  and gradients  $g$  at the speed on the end of start  $V_E$  presents the table 2.

Tab. 2

<b>k<sub>a</sub> [kW/t]</b>			
<b>a [m/s<sup>2</sup>]</b>	<b>V<sub>E</sub> [km/h]</b>		<b>g [‰]</b>
	50	100	
2,8	52,31	113,70	0
1,4	28,57	66,22	0
2,8	58,36	125,78	40
1,4	34,62	78,31	40

### 3 Input for keeping of the given speed

Specific mass input  $k_v(V)$  for keeping of a constant speed as the function of this speed  $V$  is given through following formula:

$$k_v(V) = [r_v(V) + g] \cdot V \cdot 2,72 \cdot 10^{-3} \cdot \frac{1}{\eta(V)} \quad (3)$$

[kW/t, N/kN, ‰, km/h, 1]

Symbols are the same as in the formula (1) and (2).

In the tab. 3 are to see the values of  $k_v$  for various constant speeds  $V$  on selected gradients of road  $g$ .

Tab. 3

$k_v$ [kW/t]				
V = const [km/h]				g [‰]
25	50	75	100	
1,70	4,84	10,40	18,74	0
3,21	7,86	14,94	24,78	20
4,72	10,88	19,47	30,83	40
6,23	13,90	24,00	36,87	60

### 3 Energy quantity and operational range

Operational range at battery cars is defined by two modes:

1. Theoretical range is the distance which the given car performs with one full battery charge at a given constant speed without stops.
2. Practical range is the distance which the given car performs with one full charged battery with a given speed between starting and stops always regularly after a given distance.

In the tab. 4 are presented the results of the calculation according to following formulas:

For theoretical range:

$$R_0(V) = \frac{k_E \cdot \varepsilon_E \cdot \sigma_E \cdot \eta(V)}{r_v(V) + g} \cdot 367 \quad (4)$$

[km, kWh/t, 1, 1, 1, N/kN, ‰]

For practical range:

$$R(V) = \frac{k_E \cdot \varepsilon_E \cdot \mu_E \cdot 10^3}{2,72 [r_v(V) + g] \cdot \frac{1}{\eta} + 1,072 \cdot 10^{-2} \cdot \xi \cdot V^2 \cdot \frac{2 - \eta}{\eta \cdot L_S}} \quad (5)$$

[km, kWh/t, 1, 1, N/kN, ‰, 1, 1, km/h, 1, 1, km]

Here means:

$k_E$  ..... nominal specific mass energy of a given type of battery – see the tab. 5,

$\varepsilon_E$  ..... rate of capacity utilization of nominal energy quantity – from practical reasons is taken always  $\varepsilon_E < 1$ ,

$\mu_E$  ..... relative mass of the given energy source - it is defined as:

$$\mu_E = \frac{M_E}{M} \quad [1, t, t] \quad (6)$$

$M$  ..... mass of the given car,

$M_E$  ..... mass of the battery,

$L_S$  ..... distance between two stops.

Option and selection of values for calculation of ranges in the table 4:

$\mu_E = 0,2$  - but at classical cars with a combustion motor is  $\mu_E \approx 0,03$

$\varepsilon_E = 0,8$

$r_v$  - in according to the tab. 1,

$g = 0$

$\eta = 0,9$

In case we need a larger operational range or a higher speed then we can elect a larger value of parameter  $\mu_E$ .

Tab. 4

Type of battery	Range of battery car [km]		
	Theoretical	Practical	
Lead-acid at V = 50 km/h	57,9	$L_s = 10$ km	55,8
		$L_s = 1$ km	44,0
Lithium ion at V = 50 km/h	297,3	$L_s = 10$ km	287,0
		$L_s = 1$ km	226,3
Lead-acid at V = 100 km/h	29,8	$L_s = 10$ km	27,8
Lithium ion at V = 100 km/h	153,4	$L_s = 10$ km	142,7

#### 4 Disposable electric sources

Fundamental meaning for the characteristics of the electric car has the parameters of disposable energy sources. These parameters are influencing the operational range, acceleration, maximum speed, purchase price and operation costs. In the tab. 5 are compiled these parameters for two types of electrochemical secondary cells.

Very important for the practical utilization of traction battery is the dependence of specific mass output on specific mass energy. Generally decreases the usable accumulated energy with increase of output. This way must be the algorithm of regulation of traction motor adapted to an optimum utilization of disposable energy.

Tab. 5

Parameter	Type of battery	
	Lead-acid	Lithium ion
Specific mass energy $k_E$ [kWh/t]	30 ÷ 40	160
Specific mass output $k_p$ [kW/t]	180	1800
Energy efficiency [%]	50 ÷ 90	> 90
Maximum number of cycles [1]	500 ÷ 800	1200
Relative purchase price [1/Wh]	1	1,4 ÷ 2,6
Relative operation costs [1/Wh, cycle]	1	0,9 ÷ 1,73

## 5 Maximum speed

Maximum speed of electric battery car is given through following formula

$$V_{\max} = \frac{k_p \cdot \varepsilon_p \cdot \mu_E \cdot \eta (V_{\max})}{r_v (V_{\max}) + g + 102 \cdot \xi \cdot a_E (V_{\max})} \cdot 367 \quad (7)$$

[km/h, kW/t, 1, 1, 1, N/kN, ‰, 1, m/s<sup>2</sup>]

Here is:

$k_p$  ..... specific mass output of battery,

$\varepsilon_p$  ..... rate of utilization of nominal battery output - from practical reasons is taken always  $\varepsilon_p < 1$ ,

$a_E$  ..... final acceleration at the maximum speed.

Option and selection of values for calculation according to formula (7):

$$\mu_E = 0,2$$

$$\varepsilon_p = 0,5$$

$r_v$  - in according to the tab. 1,

$$g = 0$$

$$\eta = 0,9$$

Calculation according to formula (7) gives for a horizontal road and a final acceleration  $0,1 \text{ m/s}^2$  at the lead-acid battery the maximum speed 90 km/h. At the utilization of lithium ion battery could have been reached the speed 150 km/h with a large final acceleration approximately  $2,4 \text{ m/s}^2$ .

## 6 Conclusion

It was examined two electrochemical secondary sources of electric energy. Both can find the application for electric car propulsion. The lead-acid battery makes possible to reach an operational range 55 km at speed 50 km/h at stopping after 10 km, but at stopping after 1 km is possible range 44 km only. The lithium ion battery offers more as five time larger operational range under the same conditions. For speed 100 km/h is acceptable only the lithium ion battery which allows operational range 140 km at stopping after 10 km. All mentioned values are valid for the battery weight of 10 % from total car weight and further for the above mentioned conditions. Very high acceleration or the high speeds need a high input for propulsion system. This way decreases the nominal possible energy capacity of the battery. It is not reasonable to require from battery car the same power and performance like from a car with combustion motor, i. e. with fuel technology. We must accept the new and more modest ways to use of electric battery car. It shall be a contribution to higher energy efficiency, to environmental protection and to higher safety of traffic.

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