ELECTRIC VEHICLES FROM CAR MANUFACTURERS AND COMPARISON OF THEIR TECHNICAL CHARACTERISTICS

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Abstract. Nowadays, the electric vehicles are used more and more often. The spread of such vehicles is clearly facilitated by the rise of fossil fuel prices and environmental pollution resulting from the use of these fuels. In recent years all major automakers are seriously resorted to this issue by including in their model range also electric vehicles. Different solutions are applied in the design of electric vehicles that generally affect the overall characteristics of the vehicles. The aim of the present study is to analyze the technical characteristics of electric vehicles available already in the market and the performance of these vehicles depending on the technical parameters. The published technical information from electric vehicle manufacturer was used as a source information in this study.

Keywords: electric vehicles, performance, technical characteristics.

Introduction

During the development of motor vehicle market there have been several attempts to put into production and sale the personal vehicles, which energy source is an electric battery. Starting from 2009 almost every car producer has presented conceptual models of their own electric vehicles in the world's largest motor shows. In 2010, some carmakers began to offer in the market commercially available electric vehicles.

Now it is possible to buy many newly designed electric vehicles from the car manufacturers, for example, "Mitsubishi i-MiEV", "Nissan LEAF" and "Tesla Roadster" (Figure 1). There are also many companies in the world which rebuild new and second hand internal combustion engine cars to the electric cars.

Several of the newly designed electric vehicles available in the market from the largest car manufacturers are covered in this study. More detailed three of them are studied – *Mitsubishi, Nissan* and *Tesla Motors.* The following data were summarized using different available information sources:

- car body parameters;
- technical data;
- electrical battery structure and arrangement.

Fig. 1. **Electric cars** "***Mitsubishi i-MiEV", "Nissan LEAF" and "Tesla Roadster"***

Materials and methods

The automaker Mitsubishi Motors Corporation presented a conceptual model of the electric car "i-MiEV" in Yokohama exhibition in October, 2006 [1]. The name is an abbreviation of "Mitsubishi Innovative Electric Vehicle". The electric car is designed on the base of the micro car Mitsubishi "I". The Mitsubishi Motors Corporation in collaboration with the French carmaker PSA, which produces and distributes Peugeot and Citroen brand cars, distributes this electric car in the European market also with the titles Peugeot Ion and Citroen C-Zero. The Mitsubishi i-MiEV is produced in Japan and the product distribution has been launched in several countries in America, Asia and Europe as well.

The Nissan Motor Company is one of the first car makers, which started production of electric vehicles on a large scale. In this initial phase one model of electric vehicles is available – Nissan LEAF. The first delivery of the electric vehicle Nissan LEAF to the customer was to the U.S., California, San Francisco in December 11, 2010. Starting from December 13, the car is available in limited numbers, also in Southern California, Arizona, Oregon, and Tennessee States [2]. Since 1992 the automaker Nissan does research and develops the lithium-ion battery technology. From 2007, by establishing a joint venture with NEC – "Automotive Energy Supply Corporation" (AESC), it has developed a new type flat layered lithium-ion battery with a manganese-containing positive electrode [3]. The layered structure provides a better temperature mode and a simple composition. The battery is shown in the Figure 2.

Fig. 2. **Battery and its element**

The "Tesla Motors" is a relatively new American company, but its name is already quite well known in the world with regard to its electric street sports car Tesla Roadster. The company "Tesla Motors" was founded by Silicon Valley engineers in 2003 [4]. With this model the company "Tesla Motors" has shown that electric cars can be economical, ecological, attractive and fast.

The method of analogous comparison is used in this study by which conclusions are made on the design similarity of electric vehicles and technical specifications, which include characteristics of separate components.

Results and discussion

The body is a separate technical unit of the car, which includes all interior and exterior equipment of the vehicle. The body usually is fastened to the vehicle frame. There are also bodies without a frame, monocoque, which fulfill also the function of the frame. The above mentioned electric cars have monocoque bodies, to which all aggregates and assemblies are fixed.

The compared electric vehicles have similar bodies according to the mass, but other technical parameters are different, because the body of each model has its own design solutions, which provide different technical functions. For example, built-in solar panels are integrated in the rear wing of electric cars Nissan LEAF, which provide 12 V car battery charging [5].

The study of electric car bodies and chassis shows that independent suspension and disc brakes are mostly used in electric cars, but their size depends on the number of the carried passengers. But the wheel size and clearance are approximately the same size because these electric vehicles are expected to operate on paved roads. The specifications of the bodies and chassis design are summarized in the Table 1.

For the vehicle to start motion, it is necessary to ensure conditions when the traction force acting to the drive wheels exceeds all resistance forces of the motion. The traction force on the drive wheels is expressed as the engine torque, taking into account the main gear and gearbox ratios, as well as power transmission losses and the wheel radius. In order to analyze all the factors that affect the performance of electric cars, it is necessary to have additional technical information, which is not published by the manufacturers. Therefore, Table 2 summarizes only the main technical parameters that provide an insight into the dynamic and operational characteristics of electric vehicles. One of the most important operating parameters of electric vehicles is the maximum speed and cruising range per charge. According to Table 2, these indicators for the car Tesla Roadster are significantly higher, but for the Mitsubishi i-MiEV and Nissan LEAF at a similar level.

Table 1

Specifications of bodies and chassis design [6 – 10]

Parameter	Electric vehicle		
	Mitsubishi i-MiEV	***Nissan LEAF***	***Tesla Roadster***
Length, mm	3474	4445	3947
Width, mm	1475	1770	1852
Height, mm	1608	1550	1127
Wheelbase, mm	2550	2700	2352
Front track, mm	1310	1540	1466
Rear track, mm	1270	1535	1499
Ground clearance, mm	150	160	N/A
Minimum turning radius, m	4.5	5.2	N/A
Kerb (dry) weight, kg	1100	1520	1235
Gross vehicle weight, kg	1608	1795	N/A
Seating capacity, persons	4	5	2
Drivetrain layout	RWD	FWD	RWD
Front suspension	Independent	Independent	Independent
Rear suspension	3 link	Torsion spring	Independent
Front brakes	Disc	Disc	Disc
Rear brakes	Drums	Disc	Disc
Tyres	145/65/R15 175/55/R15	205/55/R16	175/55/R16 225/45/R17

The main component defining the dynamic characteristics of electric vehicles is the electric motor. According to the data in Table 2, the electric motor of Tesla Roadster is about 100 kW more powerful, and it has a higher torque and a higher maximum speed, thus ensuring the highest dynamic performance between the selected cars.

The charging options for the selected electric vehicles are different. If for the cars Mitsubishi i-MiEV and Nissan LEAF a full charge can take a similar mode, then Tesla Roadster is intended only for fast charging, which takes up a half shorter period.

Table 2

Dynamic and operational characteristics [6 – 10]

Parameter	Electric vehicle		
	Mitsubishi i-MiEV	***Nissan LEAF***	***Tesla Roadster***
Maximum speed, kmh^{-1}	130	145	201
Power plant max output , kW/rpm	49/2500 – 8000	80/ 2730 – 9800	182/5000– 6000
Power plant max torque, Nm/rpm	180/0 – 2000	280/0 – 2730	374/0 – 5400
Power plant max frequency, rpm	N/A	10390	14000
Electric range, km	150	175	400
Traction battery / V	Lithium / 330	Lithium	Lithium / 375
Full charging time, h	6	7	3.5

The characteristics, which are related to the battery parameters, weight and location, are very important for every electric vehicle. They directly affect the capacity of the vehicle and its dynamic performance. All three electric vehicles have batteries containing lithium-ion cell elements in a metal casing.

Totally 22 battery modules are located in Mitsubishi i-MiEV, each containing four elements. The battery module compartment layout is shown in Figure 3.

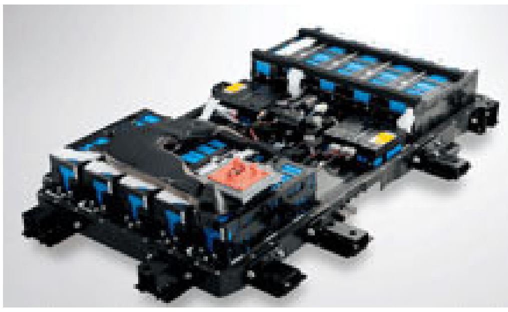

Fig.3. **Mitsubishi *i-MiEV* battery compartment**

The battery compartment is positioned in the lower part of the body. Such a battery arrangement provides a low center of gravity and it does not reduce the car interior and trunk volume. The battery compartment location in the car is shown in Figure 4 [1].

Fig. 4. **Battery compartment location in Mitsubishi i-MiEV:** 1 – motor; 2 – lithium-ion battery compartment; 3 – inverter; 4 – charger

The main parameters of Mitsubishi *i-MiEV* batteries are summarized in Table 4.

Totally 48 battery modules are located in Nissan LEAF, each containing four elements.

The battery compartment is positioned in the lower part of the body. The cross-section of the body is shown in Figure 5. Such a battery arrangement provides a low center of gravity and does not reduce the car interior and trunk volume.

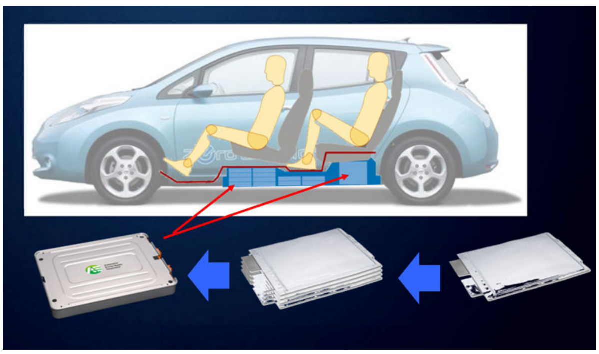

Fig. 5. **Battery compartment layout**

The main parameters of Nissan LEAF batteries are summarized in Table 4.

The battery module compartment layout in Tesla Roadster is shown in Figure 6. The battery compartment is positioned in the back part of the body. Such an arrangement of the battery compartment does not reduce the interior volume and provides extra load on the car drive wheels.

The main parameters of Tesla Roadster batteries are summarized in Table 4.

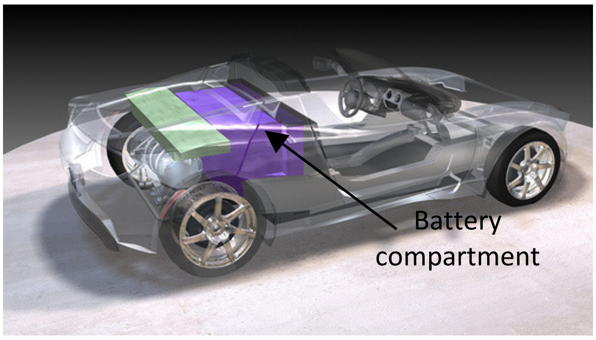

Fig. 6. ***Tesla Roadster* battery compartment layout**

Table 4

Comparison of main parameters of battery compartments [6 – 10]

Parameter	**Electric vehicle**		
	Mitsubishi i-MiEV	***Nissan LEAF***	***Tesla Roadster***
Type of the battery	Lithium-ion	Laminated-type lithium-ion	Lithium-ion
Cell weight, kg	1.8	N/A	N/A
Battery weight, kg	158	N/A	N/A
Battery compartment weight, kg	230	N/A	450
Number of cells	88	N/A	N/A
Number of modules	N/A	48	11
Number of cells in module	N/A	4	69
Cell capacity, kWh	0.187	N/A	N/A
Cell voltage, V	3.75	N/A	N/A
Cell min voltage, V	2.75	N/A	N/A
Cell max voltage, V	4.1	N/A	N/A
Total capacity, kWh	16	24	N/A
Total voltage, V	330	360	360
Max power, kW	N/A	90	90
Slow charging characteristics	6 h, AC 230 V, 15A	7 h pie 230 V / 16A (25 ºC)	N/A
Fast charging characteristics	30 min, DC, 330 V, 150 A (up to 80 %)	30 min, DC, 480 V / 125 A (25 ºC)	3.5 h / 240 V / 70 A

Conclusions

1. The largest carmakers of the world are paying increasing attention to the development and production of electric vehicles by introducing the latest technology and various other improvements in order to improve the operating parameters of electric cars closer to the performance of vehicles working with internal combustion engines.
2. One of the most important factors for successful operation of electric vehicles is the design of the body shape in order to improve aerodynamics, as well as the body use for solar energy conversion into electrical energy.
3. The electric motor has an important role for improvement of the dynamic properties of electric cars. The study shows that using higher power electric motors, both dynamic and operational performance is better.
4. The location of the batteries in the electric car is also important, because it affects the interior and luggage space size as well as the location of the car center of gravity.

5. The battery capacity determines the distance that the car can make between charging. The battery charging time is important. Therefore, continuous studies are carried out on battery weight reduction and capacity increase.

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References

1. Mitsubishi i-MiEV. [online] [16.06.2011.] Available at: http://global.ev-life.com/
2. Nissan To Make History With Delivery Of World's First 100 % Electric Nissan Leaf To California Consumer. [online] [30.01.2011.] Available at: http://www.nissan-global.com/EN/NEWS/2010/_STORY/101210-02-e.html
3. EV technologies in Working Machinery – Global view. Finpro 2010 [online] [16.06.2011.] Available at: http://www.finpro.fi/documents/10304/82c1b231-9f5a-44a0-b2e6-b94fbaf53105
4. Tesla Roadster Sport first drive. [online] [30.01.2011.] Available at: http://www.teslamotors.com/
5. Nissan LEAF. [online] [16.06.2011.] Available at: http://www.nissanusa.com/leaf-electric-car/index#/leaf-electric-car/index
6. Mitsubishi i-MiEV Catalog. [online] [18.06.2011.] Available at: http://www.mitsubishi.hu/miev/pdf/i-MiEV_Catalog.pdf
7. Mitsubishi Motors in UK. [online] [18.06.2011.] Available at: http://www.mitsubishi-cars.co.uk/imiev/specifications.aspx
8. Nissan Zero Emissions. [online] [18.06.2011.] Available at: http://www.nissan-zeroemission.com/EN/LEAF/specs.html
9. 2011 Nissan LEAF.| Owner's Manual. [online] [18.06.2011.] Available at: http://www.nissanextendedwarranty.com/owners-manual/nissan/2011-Nissan-Leaf.pdf
10. Roadster Features and Specifications. Tesla Motors. http://www.teslamotors.com/roadster/specs