Ministry of Education and Science of Ukraine

ODESSA NATIONAL ACADEMY OF FOOD TECHNOLOGIES

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2018

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ELECTRIC PASSENGER TRANSPORT VEHICLES: TECHNICAL CHARACTERISTICS AND ENERGY EFFICIENCY

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Electrical passenger transport vehicles: technical characteristics and energy efficiency. Classifications and characteristics of electrical passenger transport vehicles are presented. Some technical advantages and disadvantages of the electrical vehicles are considered. The energy efficiency of the recent electrical vehicles is presented and analyzed.

Key words: electrical passenger transport vehicles, technical characteristics, energy efficiency.

Introduction

Transport vehicles, put into motion with electric energy, are of great relevance, due to their basic characteristics – ecological safety and low level of noise emissions. [15].

First attempts for building of electrical vehicles are done in the first three decades of XIX century. Then have been elaborated the first rotating electrical machines. [8].

Electric transport vehicles are put in motion from electric energy, which is turned into mechanical from traction engines or from stationary electromagnetic systems. The contemporary development of technology allows different transport vehicles to be put in motion with electric energy – railway (trains, trams, and metro), automobile (passenger and transport, lifting, construction and agricultural machinery), some tracking machines (military, agricultural), water and air transport vehicles. [7]

All these are characterized with different construction peculiarities, technical parameters and efficiency of usage of the consumed energy.

The purpose of the paper is to compare the different technical parameters of the different types of electric passenger transport vehicles and to analyze their energy efficiency.

Analytical review

Classification of the electric transport vehicles

Transport vehicles, driven with electric energy are two types, depending on the position of the power source – autonomous and non-autonomous. The first type transports the energy source, i. e. it is part of it, and the second type – receives energy from an external source. The main representatives of the autonomous electric passenger transport vehicles are the automobiles (private and public transport – taxi transportation) and buses. Non-autonomous electric transport vehicles drive in cities and outside the cities. Representatives of the first group are metro (underground urban rail vehicle), trolleybuses, trams, and inter urban – rail trains (IEC – inter urban express), including and driven with electromagnetic fields (MAGLEV, (magnetic levitation over a non-track path), Transrapid – magnetic levitation over a single rail).

Electric transport vehicles most commonly are driven through rotating electric machines or trough interaction of magnetic fields. The construction and principles of action of these drive systems are shown on [2].

Electric energy, Електрическата енергия, supplying the transport vehicles can be with constant or varying parameters (electricity, voltage). Very often in the transport vehicles (autonomous and non-autonomous) devices are used, which turn the electric energy in the appropriate type of driving system. Autonomous and non-autonomous transport vehicles use different technologies and technical systems for transmitting and producing of electric energy, including and renewable energy sources.

Road infrastructure, used by the electric transport vehicles is an indicator by which they can be classified on rail and non-rail. Trams, metro, interurban trains are representatives of the first group. Second group includes vehicles, which use the road network of the classic automobile transport (automobiles, busses, and trolleybuses) and a few special tracks (for driving with electromagnetic fields).

Electric transport vehicles can be driven directly by a driver, or indirectly (without a driver) – trough modern electronic and communication systems. Representatives of the second group are taxi automobiles in Singapore and few high-speed interurban vehicles. (MAGLEV) [11,13,16].

Results of work

Technical characteristics of the electric passenger transport vehicles

The factors, which determine the necessary power for putting into motion of the electric transport vehicles, are: the resistance forces, which have to be overcome during the start-up and movement, the mechanical and electrical losses and the speed of movement. [1, 10]. Electric energy is used for not only driving into motion, but also for light, signaling, air-conditioning, navigation systems, directing and so on. Therefore, the total power of the electric transport vehicles needs to be greater than that for putting into motion.

•Autonomous electric transport vehicles – automobiles (electro mobiles) and busses (electro busses).

Distinctive feature of these transport vehicles is that they do not require special road infrastructure and are supplied from private resource of electric energy, which is part of their equipment. Main disadvantages are their limited power and the necessity of building of technical systems (electro stations) for charging them with electric energy.

The power of the autonomous electric transport vehicles depends on the characteristics of the used sources of electric energy (accumulators, superconductors, fuel cells, etc.). Some more-important characteristics are: energy density, kW / kg, electrical capacity, Ah, current magnitude and charge and discharge duration, charge-discharge cycles, discharge depth, resistance to extreme conditions (high and low temperatures, etc.).

Energy density and electric capacity of the sources define the maximum self – weight of the transport vehicles, the weight of the payload, speed and duration of motion with one charge. Crucial factors during movement of the autonomous transport vehicles, which determine the power consumption, are the regime of driving (subjective behavior of the driver or electronic systems, during driving without driver, which determine the speed of motion), and the varying road and atmosphere conditions. The last two conditions cannot be controlled. Therefore, to achieve minimum consumption of energy (maximum energy efficiency) from the electric transport vehicles, in concrete driving conditions, is appropriate to purposely affect (driving) on the regime of driving.

Electric transport vehicles, which use road infrastructure (roads), assimilate on average 80% from the consumed electric energy. This amount is 4 times greater, in comparison with the transport vehicles, driven by internal combustion engines (ICE) – fig. 1. With them, the fuel energy (gasoline or diesel) is assimilated only around 20%, because the rest is transformed into non-usable heat. [5].

Main reasons for greater energy efficiency of the electric transport vehicles are:high coefficient of efficiency (CoE) of the driving electric engines – over 80%; the energy is consumed only during movement; the driving electric engines can change from engine into generator regime, during stopping and downhill slopes.The produced electric energy is transmitted back in the power source (recuperation).

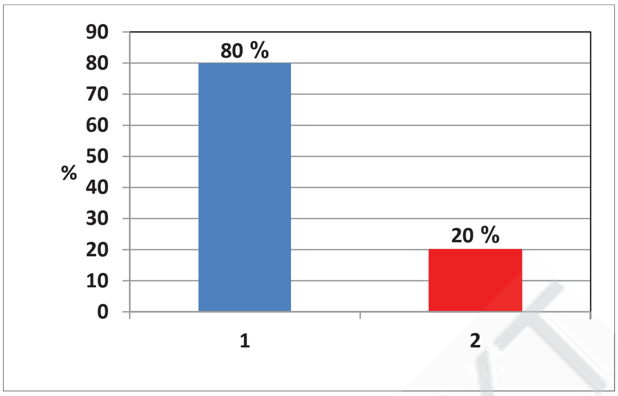

Fig. 1. Total efficiency of transport vehicles using the road network: 1 – electrical; 2 – with internal combustion engines.

Important indicator for energy efficiency of electric transport vehicles is the average value of the consumption of electric energy for driving of 100km, which for the electric automobiles is usually (10…23) kWh. Approximately 20% from this energy is not used effectively (loses) during the charging of batteries [5].

Other characteristic of electric automobiles is the time for charging of accumulators. Producers are searching continuously for a ways to shorten this time. For example lithium-ion accumulators with power (3…6) kW (230 V, 15 A) can be fully charged for about (7…8) h with normal regime of charging, and for (30…45) min – with fast charging. The short time is especially important for taxi electric automobiles. [6].

Electric busses are driven with electric engines, powered by accumulators or supercondensators, placed in the transport vehicle. Similar decisions are used in some models trolleybuses (powered by external contact network), with the purpose of supportive energy source and for emergencies (in malfunctions of the contact network).

Electric buses are almost entirely used in the urban transport, as compared to inter urban transport. The main reason for this is their big weigh, which determines the necessity of powerful electric engines and accumulators. In urban areas, the speed of travel and the length of the routes are limited. These conditions allow, even when there are requirements for great power of the transport vehicle (greater than the self-weight and weight of the payload), the use of electric buses, which undergo a certain route, when the required infrastructure for charging electricity is available.

Electric buses, like electric automobiles, can also use regime of recovery (when braking or moving on slopes), for enhancing the energy efficiency. The average value of the consumption of electric energy for travelling of 1 km by electric buses is around 1, 2 kWh. This value is 10 times more from the consumption of electric automobiles – (0, 10..0,23) kWh/km (fig.2) [5].

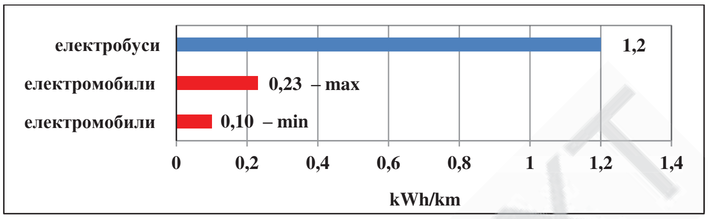

Fig. 2. Specific consumption of electric energy by autonomous electric transport vehicles

Last generation electric buses form the world leader BYD (China), are used in London (fig.3). They are double decker buses with 54 seats and 27 standing places (a total of 81). The supply batteries are iron-phosphate, with power 345 kW, and one charging in urban conditions, ensure travelling a route with length up to 307, 5 km (190 ml). The time for charging is only 4 h and it can use nighttime electricity, which is cheaper [4].The average value of the electric energy consumption is 1,12 kWh/km.

Fig. 3. Electric bus BYD on the streets of London

Electric buses, depending on the technical infrastructure, which is built, during stays or in a garage, can recharge their batteries via pantographs from the contact system, situated over the transport vehicle, or in an inductive way. If supercondesators are used, the time for recharging with electric energy is significantly less – **few minutes**. This is important advantage, but the number of cycles discharge and recharge of the condensators is smaller.

Electric buses and electric automobiles can be as total characterized with greater speed during maneuvers and less time for speeding up, except for absence of harmful emissions and noise, in comparison with the transport vehicles with internal combustion engines. Major disadvantage of the electric buses is the smaller length of the route passed, in comparison with the buses with internal combustion engines. [3].

•Non-autonomous electric transport vehicles – railway and non-railway.

The first group are urban (metro, tram) and inter-urban (ICE), and the non-railway – urban (trolleybus) and inter-urban (MAGLEV, Transrapid). All these transport vehicles, as difference from the autonomous, require special infrastructure (with exception of the trolleybuses) and are charged by outer source of electric energy – contact network (for the railway transport vehicles), contact railway (for the metro) and systems for magnetic levitation (MAGLEV, Transrapid). These peculiarities allow the transport vehicles to have enough power and to transport big mases with high velocity. The power of the non-autonomous electric vehicles is determined by the power of the outer power source, and it depends on the characteristics of the transport vehicles and on the conditions of the route and the movement.

Main disadvantage is the necessity for building of complex technical infrastructure for charging with electric energy.

Advantage of the non-autonomous railway transport vehicles, as compared to those, which move on the road transport network (trolleybuses), are: less rolling resistance when moving steel wheels on the rails; better aerodynamic characteristics of the moving composition; less obstacles (especially for metro). For these reasons, the railway transport vehicles are characterized with better energy efficiency (fig.4) and can move with higher speed [12]. The comparison between the railway and non-railway inter urban non-autonomous transport vehicles shows that the second group is characterized with serious advantages. They are: lack of friction between the transport vehicle and the road; small amplitudes of vibration and noise – the noise is up to 30% less; small radii of curvature on the road – the minimum value 75 m is 4 time less, as compared to the railway transport vehicles; overcoming of 10% slopes on the road during escalation, which is 2, 5 times more, than the railway vehicles. [14].

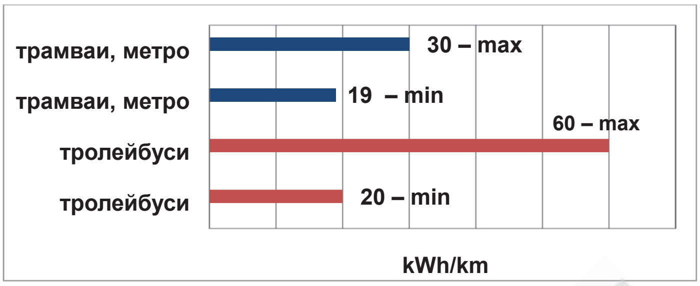

Fig. 4. Specific usage of electric energy of non-autonomous electric transport vehicles

The principle of moving of the non-railway electric transport vehicles (MAGLEV, Transrapid), based on the interaction between electric fields is the reason for the lack of friction between the transport vehicle and the road. This is important condition for moving with high speed (over 400 km/h), with less expenses for technical exploitation.

Inter urban non-railway transport vehicles, except with their undoubted advantages are characterized also and with disadvantages, which are limited to their application.

Main problem is the very high price of the infrastructure – 43, 6 mln usd dollars for 1 km two-way road, including transport vehicles and stations. The road section is in Shanghai (China) and is with length 30 km (fig.5) [9]. Another disadvantage is that only with high speed the energy efficiency is bigger, as compared to railway transport vehicles.

Fig. 5. Non-railway train MAGLEV in China

Serious problem is the big energy consumption for overcoming the resistance of the air environment, which is determining factor during movement with very high speed. The power of the motion system P is directly proportional to the linear velocity of movement v, raised to the 3rd degree, i. $P \sim v^3$. The great power is ensured by strong magnetic fields, whose influence on the passengers and the technical systems must be restricted, or eliminated.

Conclusion

The research of the technical parameters and the energy efficiency of the electric passenger transport vehicles shows that:

- Non-railway transport vehicles (MAGLEV) are most effective during high speed, but the expenses for building of technical systems and road infrastructure are the highest;
- Railway transport vehicles (urban and inter urban) are more effective from those, which move on road transport network, due to lower friction during rolling the wheels, but the expenses for building of infrastructure are considerable;
- With the smallest expenses are characterized electric automobiles and electric buses, with restricted power and length of the road path with one charge of the energy source. Its characteristics are very important factor for the determining of the energy efficiency of these transport vehicles.

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