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Development of Russian Driverless Electric Vehicle

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Research Article

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Abstract
The progress of autonomous cars in Russia and throughout the world is summarized in this article. The development of autonomous cars, including electric traction, in other countries is examined. The main phases of the NAMI autonomous electric car experiment are changed. The construction of a sophisticated NAMI autonomous electric car, as well as its key parts and control systems, are discussed together with the main technical solutions. The NAMI autonomous electric car is an example of a project focused on passenger environmental safety. A summary of the NAMI autonomous electric vehicle's bench scale and running test results is provided. Significant benefits of autonomous, ecologically friendly, and energy-efficient transportation are shown.

INTRODUCTION

Recently, autonomous cars with sophisticated automated pilot systems have started to emerge on the roadways of several nations. Google Inc. is the most well-known player in this area. This business is not the only one trying to do away with the need for a human driver. Driverless (autonomous) cars and related technologies are being actively developed by all of the major automakers in the US, China, France, Germany, Italy, and Japan. The outcomes of many unreported initiatives are not accessible in public sources since they are created under directives from the military sector. Software, control system sensors, and complex, knowledge-intensive engineering solutions are all regarded as dual-purpose goods [1-3]. Analytical institutions predict that driverless (autonomous) cars will be widely used until 2025.

RESEARCH METHODS

System analysis, including the breakdown and optimization of engineering solutions, served as the foundation for this investigation. Path planning and vehicle motion in space (environment) were also used. Mathematical logic, set theory, and artificial intelligence were used.MAIN PART

Leading international automakers began actively developing autonomous vehicles in the early 1980s for use in passenger cars, freight cars, military vehicles, agricultural machinery, interfactory vehicles, and transportation traffic at contemporary logistical hubs and storage facilities. Leading automakers including General Motors, Ford, Mercedes-Benz, Volkswagen, Audi, BMW, and Volvo are working on developing autonomous cars, as are major producers of parts like Continental, Bosch, and Delphi.

Activities on development of driverless vehicles are also performed in Russian Federation. Leading R^D institutes, universities and car manufacturers, such as NAMI, Moscow Automobile and Road Construction State Technical University (MADI), Moscow polytechnic university, PAO KamAZ and others.

In the years 2014-2016 State research center NAMI in Russian Federation developed, manufactured and tested experimental electric driverless vehicle (Figure 1).





Figure 1. NAMI driverless electric vehicle (external view) Table 1. Main Specifications of NAMI Driverless Electric Vehicle

Vehicle model	LADA-Kalina 1117	Traction module	
Nominal power (kW)	30		
Maximum power (kW)	70		
Recovery power (kW)	30		
Automotive battery of traction module			
Power intensity (kW*h)	13		
Nominal voltage (V)	316		
Maximum discharge current (A)	250		
Maximum charge current (A)	100		
Steering system			
Type	with electromechanical amplifier	Braking system	
Front brakes	Disc-type		
Rear brakes	Drum-type		
Suspension			
Front suspension type	Samper strut		
Rear suspension type	Trailing arm	Car body	
		Length	4040 mm
		Width	1700 mm
		Height	1500 mm
		Front track, mm	1430 mm
		Rear track, mm	1410 mm
		Clearance	160 mm
		Curb weight	1200
Operating specifications			
Acceleration time to 100 km/h	20 s		
Maximum speed	120 km/h		
Complete charge time (h)	6		
Accelerated charge time (h)	1.5		
Operating temperature (°C)	- 30 … +50		

Actuating mechanisms of the NAMI driverless electric vehicle are as follows: linear actuators; servo drive unit; steering electric amplifier.
Instruments of the driverless electric vehicle are as follows: sensor of linear motions of actuators; linear potentiometer.
The following components are used in the machine vision system of motion control of driverless electric vehicle: AXIS PI346 video camera; SLR 1 lidar; ultrasound sensors.
Driverless electric vehicle operates in three control modes:
"Driver" mode
In this mode the driverless electric vehicle is used as common electric vehicle without any restrictions.
"Remote control" mode
In this mode driverless electric vehicle can be controlled by PC with specialized software or by dedicated joystick.
"Autonomous motion" mode
This mode is driverless control of electric vehicle by means of machine vision system and actuators. Driverless vehicle can either move along corridor passing by obstacles; or reproduce preset trajectory; or perform parallel parking.
Propulsion unit in the NAMI driverless electric vehicle is a Solectria Azure Dynamics 70 kW three-phase asynchronous engine with air cooling equipped with a DMOC 445 invertor. The torque from traction electric motor to vehicle drive wheels is transferred by means of reducer with differential. In order to avoid overloads capable to break the reducer the reducer input shaft is connected with the shaft of traction electric motor by overload coupling. The reducer shell is rigidly connected with the shell of traction electric motor. The traction electric motor with the reducer in vehicle motor compartment is mounted using three-point mounting system of power unit.
Electricity accumulation system is comprised of eight modules, each contains twelve AMP20M1HD-A batteries - 96 battery cells in total. Nominal voltage: 316.8 V, internal impedance: 57.6 μΩ. Control system of battery cell is located in the top part. It is comprised of four boards, each board controls 12 cells. The control system is intended for management and balancing of battery cells, for checking of integrity of battery circuits, voltage and temperature of cells, and for data transfer to battery management system (BMS). Special software provides connection, adjustment, and diagnostics of battery management system from PC via COM port (USART1) or CAN.
Environmental safety of passengers in the NAMI driverless electric vehicle is provided by two air cleaning systems in passenger compartment. They are located in luggage compartment (Figure 2). Clean air from the systems is supplied via ducts located inside the passenger compartment near front seats. In addition, gas analyzer for monitoring of impurity content in the air is placed in the compartment. Controller of air cleaning system is connected to the gas analyzer and the system itself. The latter operates in recirculation mode, that is, it intakes air from the passenger compartment, cleans the air and supplies the cleaned air to the passenger compartment. The gas analyzer transfers the data on air composition to the controller which constantly analyzes content of harmful substance in the passenger compartment and controls operation modes of air cleaning system [4-6].
External view of the NAMI driverless electric vehicle with installed battery cells of traction modules installed in luggage compartment and air cleaning and distribution systems is illustrated in Figure 2.



Figure 2. NAMI driverless electric vehicle with automotive batteries of traction module installed in luggage compartment (1) and air cleaning and distribution system in passenger compartment (2)
Autonomous motion of driverless electric vehicle is provided by motion control system including machine vision system, navigation and orientation system, information management system, and actuators.

The machine vision system generates the image of surroundings, provides recognition of other vehicles, road obstructions, road signs, traffic lights, road marking [7-10]. The information management system is the core of motion management system of NAMI driverless electric vehicle, which is responsible for route arrangement, urgent decisions depending on surrounding traffic, and generation of control signals to actuators. In accordance with the control signals the actuators directly act upon units and systems of NAMI driverless electric vehicle, substituting driver actions. The navigation and orientation system determines the current position of NAMI driverless electric vehicle. The actuator system is comprised of control actuators of electric transmission, clutching, gear shifting, steering, brakes, starter, light and sound equipment, and others. The motion management system of NAMI driverless electric vehicle is comprised of sensors, drives, electronic control unit with components and control board. The machine vision system is comprised of AXIS PI346 video cameras, SLR 100 lidar, ARS 300 radar, eight ultrasound sensors (parktronics), SS series, LTP linear potentiometer and two SANV-10 electromechanic actuators. Two AXIS PI346 cameras are installed behind the front windscreen in upper corners, and one camera behind rear windshield in its center (Fig. 4), which provides maximum visibility in front of and behind the vehicle. Application of AXIS PI346 video cameras in the machine vision system of NAMI driverless electric vehicle provides accurate recognition of
road signs and marks [11-13].
Figure 3 illustrates the video cameras and lidars installed in front part of the compartment of NAMI driverless electric vehicle. Figure 4 illustrates the video camera installed in rear part of the compartment of NAMI driverless electric vehicle. Figure 5 illustrates the radar installed in the front part of NAMI driverless electric vehicle.





Figure 3. Location of video cameras in passenger compartment behind windscreen of driverless electric vehicle

Figure 4. Illustrates the video camera installed in rear part of the compartment of nami driverless electric vehicle





Figure 4. Location of video cameras in passenger compartment behind rear windshield of nami driverless electric vehicle
Figure 5. ARS 300 radar installed on radiator grille of nami driverless electric vehicle

A PS-A-4006 ultrasound sensor facilitates detection of objects and obstructions in short-range zone, automatic parking and provides sensor feedback for accurate vehicle steering in narrow road corridors. The steering system includes LTP linear potentiometer. The LTP linear potentiometer installed on steering rack in engine room facilitates high accurate detection of wheel positions at any instant.The major component of the system is the central processing unit which is a multiprocessor perforimng the following main functions:
Connection with external wireless devices (BLUETOOTH, GPS, and other);
Acquiring image of surrounding near NAMI driverless electric vehicle (radars, lidars, video cameras, parktronics) and its subsequent processing;
Acquiring information about short range surrounding from ultrasound sensors and its subsequent processing;
Data processing from all sensors of the system;
Calculation of motion parameters of NAMI driverless electric vehicle in real time in accordance with the preset algorithms;
Generation of control commands to external actuators in accordance with current state and motion algorithm.
Integration of the control system into vehicle is provided by another device: Mechanism control unit. Its main functions are as follows:
Processing of position sensors of control mechanisms of NAMI driverless electric vehicle;
Control actions for actuators of NAMI driverless electric vehicle;
Data transfer concerning state of control mechanisms of NAMI driverless electric vehicle;
Obtaining of control commands from central processing unit.
Mechanism control unit provides integration with the following mechanisms and units of NAMI driverless electric vehicle:
Actuators of accelerator pedal, primary and parking braking systems, clutch;
Steering drive;
Traction invertor;
Lighting control (position lamps, low and high beams);
Wiper and washer control;
Window raiser control.
Data exchange between the devices is performed by CAN bus, it provides high transfer reliability as well as interference protection in electrical system. The system is powered by battery cells of NAMI driverless electric vehicle.

Electromechanic drive in the braking system controls application of brake pedal and hand parking brake. SANV-10 actuator enables fast application of primary brake and parking brake, hence, fast vehicle stoppage. Two SANV-10 actuators are used in the braking system. One of them is installed in engine room and the other in tunnel assembly.

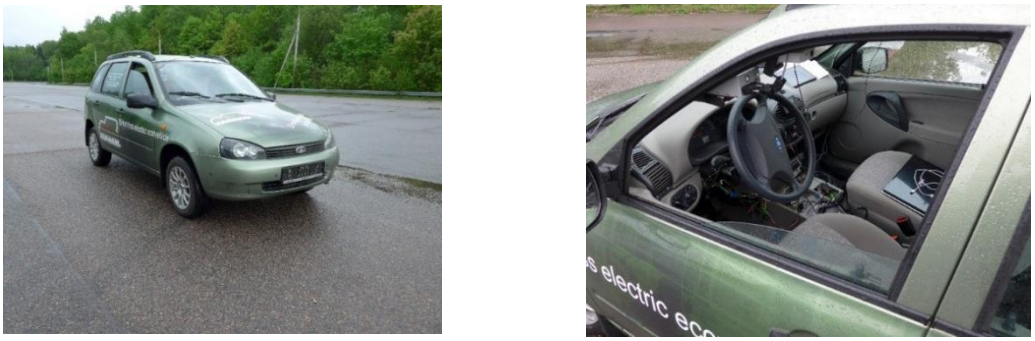
Motion control system performs general computations of vehicle motion: position coordinates, recognition of objects around the vehicle, detection of obstructions. Central processing unit is connected to the system of orientation and navigation in order to process and obtain global coordinates of vehicle position, it communicates with external devices via Bluetooth and is equipped with data storage unit. Image recognition unit is connected to cameras which inspect surrounding objects. High rate of image recognition is supported by parallel computations. Obstructions are detected by means of radar control unit and two lidar units. All units are connected to common CAN bus, which enables controlling actions and data acquisition.

The software of motion control system of experimental NAMI driverless electric vehicle executes main functions of motion control, including maintaining of safe speed, safe distance to vehicle ahead, motion path with regard to preset one, control of turn indicators, audio and light stop alarms, as well as solution of navigation task reserved by satellite system. The software is based on Inka-NAMI proprietary algorithmic and programmed approaches aimed at preventing of vehicle collision with constrictions.

Receiver of the navigation system is installed in passenger compartment. The antenna output connector is in accordance with SMA standard. The antenna is installed in the roof center. Efficient operation of antennas is supported by the important condition: shadowing of GLONASS/GPS satellites by at least 140°. Antenna is fed by high frequency coaxial cable. Powering of the navigation module from 12 V vehicle network is provided by a source of secondary supply (DC-DC converter) on the basis of DA1 TES 2N-2410 diode microcircuit with protection against reverse polarity and conductive noises. The navigation system can be powered from a battery. The interconnection between the receiver and network equipment is provided by ADM 1485 and 74VHC 04 microcircuits. A user of navigation data can directly connect to full-scale NV08C-CSM-BRD navigation receiver. All components of control system of NAMI driverless electric vehicle, except for navigation antenna, are installed in passenger compartment and protected against external impacts and mechanical damages.



Figure 6. Bench Scale NAMI Driverless Electric Vehicle


Fig. 7. Driving Tests of NAMI Driverless Electric Vehicle

The following performances were achieved after tests of NAMI driverless electric vehicle: one- charge driving distance - at least 50 km, maximum driving speed - at least 120 km/h, acceleration time to 100 km/h – at least 20 s, and the motion control system maintains maximum driving speed of 30 km/h; recognition of obstructions - road users; recognition of road signs - at least 30 ones; detection of road marks - main, on straight ways; detection of vehicle position - with the accuracy to 5 m; maintaining of preset distance to vehicles ahead - to 3 m; maintaining of driving speed - with the accuracy to 3 km/h; audio and light alarms - with response rate up to 0.5 s. The air cleaning system eliminates harmful inclusions in the passenger compartment of electric vehicle to the maximum permitted level established by Hygienic regulations GN 2.1.6.1338.

RESULTS AND DISCUSSION

The obtained experimental results are intended for use in the development of the Russian Federation's R&D and engineering complex in the areas of safety, energy efficiency, and energy saving in the transportation industry; in development projects aimed at improving passenger environmental safety and traffic safety; in the educational process of technical higher schools; and in the business operations of automobile companies [14–17].

A whole new level of energy efficiency, environmental protection, and traffic safety for individual cars as well as the entire traffic system would be possible with the application of the experimental findings, including:

1. Increased traffic safety as a result of fewer collisions caused by the use of autonomous vehicle control and passenger compartment air cleansing;
2. The use of electric traction and autonomous control has improved automobiles' environmental performance as compared to current models;
3. A decrease in the negative environmental effects of automobiles as a result of the removal of dangerous pollutants from electric cars;
4. Enhancing passenger environmental safety by effective air purification in the passenger cabin;
5. A higher rate of car recycling and disposal than the current one.

CONCLUSIONS

The NAMI driverless electric vehicle's overall performance and that of its components (traction module, motion control system, and electricity accumulation system) are better than those of Russian analogs and comparable to those of worldwide analogs. In terms of passenger environmental safety, the passenger compartment's air cleaning and distribution system outperforms all known international and Russian equivalents. This configuration is the first worldwide implementation of the designed NAMI autonomous electric car.

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