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ELECTRIC VEHICLE MODEL WITH FOUR ELECTRICAL MOTORS BUILT INTO WHEELS

ABSTRACT *This article contains a course of work on construction vehicle model that has four electrical motors built into each wheels. This vehicle is a model of haulage truck applied to ore mining (e.g. copper ore). The main task for such trucks is output or machinery transport in the mines. During the project two models of vehicle are performed (Fig.1, Fig.2). Microprocessor based control system is also designed and built. Vehicle is controlled by Steering Bracket (Fig.5) which contains steering wheel with force feedback system, push buttons, accelerator and brake. Joint between steering bracket and model is realized by interface RS-485. In vehicle model there are composed direct current motors with permanent magnets with three labels commutator. Power supply is consisted of acid battery located in vehicle. The Vehicle Control System becomes divided to two parts. The first part is built in vehicle (Fig.4) and operates as Vehicle Main Control System, and second one is built in Steering Bracket and operates as Main Control Steering System.*

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1. INTRODUCTION

In Polish mines there are approximately 1400 special trucks with combustion engine only. Total installed power of all trucks is equal 150 MW. In average one truck weigh approx. 20,000 kg, its load capacity is similar 20 t.

Traditional haulage truck is consisted of two movable parts joined each other.

These parts are:

- driving module (contains combustion engine),
- dump trailer.

All the wheels cannot be turned horizontally regarding vehicle. Haulage truck can turn only in the hydraulic joint between driving module and its trailer. Both parts can revolve mutually to ensure better wheels contact with the bed rock during driving over obstacles or slopes.

In last years there were some attempts to launch electrical drives into the haulage tracks. Firstly electrical motors were supplied through unrolled wires or contact lines in mine. Practically all the above mentioned solutions appeared not enough efficient.

Replacing combustion engine with electrical motor fed by batteries was also tested and results were promising. In this solution the mechanical and hydraulic systems were the same as combustion counterpart. The best solution, in author opinion, is substituting traditional drive system for system with electrical motors built in all four wheels.

This solution needs necessity of construction of new philosophy and all wheel controllers. The task for new controls should take into consideration following problems: synchronization, protection against wrong operation and driving. Controls also should realize driving program in different conditions as could occur in the working place (narrow footwall drift, different road profiles, sharp turns, steep slopes, changeable hardness and dampness of the drift).

2. BRIEF FOR DESIGN OF CONTROL SYSTEM

Brief of design is following: flexible and module design, which makes as quick as possible modification of elements, repairing or their replacement. Also the development with additional elements should be possible. This solution enables utilization control system with the other model of vehicle. There is obviously possibility to add the third axis or additional modules, which could be use in the future.

3. THE FIRST GENERATION OF ELECTRIC VEHICLE MODEL

The first generation model in scale 1:23, which has been created, is composed of four step motors SH 200 and controls supported by four microcontrollers AT89C2051 for each wheel. Program is written in the Visual Basic. Haulage truck model contains its autonomic battery (12 V, 1.2 Ah). Communication between model and computer is accomplished by using RS232 standard. This model was useful for observation of working control system and driving modules. The control algorithm also used in the second generation of model.

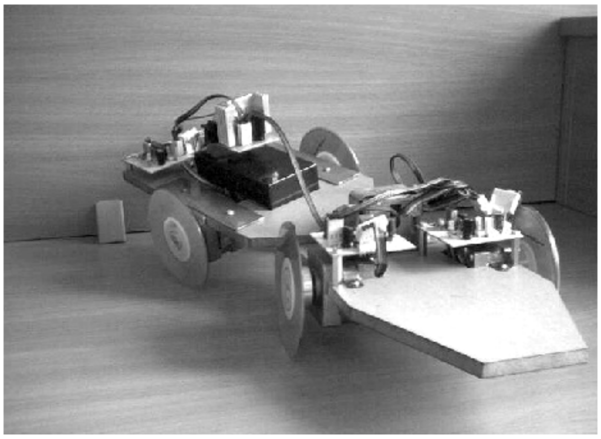

Fig.1. Electric vehicle model the first generation with four motors built into wheels

4. DRIVING MOTORS OF THE SECOND GENERATION OF ELECTRIC VEHICLE MODEL

In vehicle model composed of direct current motors with permanent magnets (UN=3.6 V, TMAX= 2 Nm, nN=230 rpm) with three parts comutator. The double planetary gear provides high driving torque and low rotational speed. Each of used driving motors has own control module. In the motor control modules are composed of mikrocontrollers Atmel AT90S2313 that belong to AVR processors family. The choice of this system was dictated by following feature:

- high speed operation,
- included series transmission UART,

- included PWM,
- supervision of program by WATCHDOG.

Series transmission system UART is indispensable to receive instructions which are sent by Vehicle Main Control System (VMCS) installed in vehicle. Communication between control systems in model is accomplished by using RS232, which is working in TTL levels. It creates internal control area network of vehicle, which allow trensmitting signals for driving motors and data from position measuring systems. In microcontroller AT2313 PWM is included the unit for steering rotational speed of driving motors in each wheel. The PWM unit is configured on 10-bit resolution (steering voltage could receive 1024 different values). PWM outputs control the bridge circuit L298. In this topology there are two transistor bridges and logic control unit. Maximum value of transistors current is equale to 2 A, is permited value of current during pulsed operation 2,5 A. Parallel connexion of two bridge circuits are applied in vehicle model. For proper and reliable operation the WATCHDOG unit is used. In case when Vehicle Main Control System (VMCS) does not receive data microcontroller RESET occurs and software restarts again and turn off the drive motor. Protection is used for case of losing connect between VMCS and Main Controller of Steering System MCSS or motor failure.

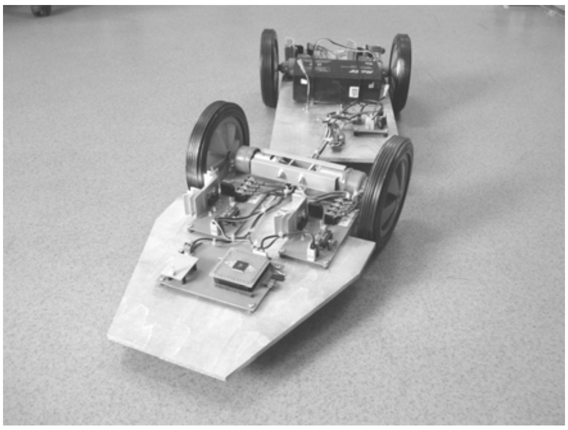

Fig.2. Electric vehicle model the second generation with four motors built into wheels

5. POWER SUPPLY

Power supply is consisted of acid battery located in vehicle (with rated voltage 6 V, capacity 12 Ah) and voltage regulator LM2940CT-5 with low level of voltage-drop approximately equal to 0,4 V. This voltage regulator has temperature and overcurrent protection.

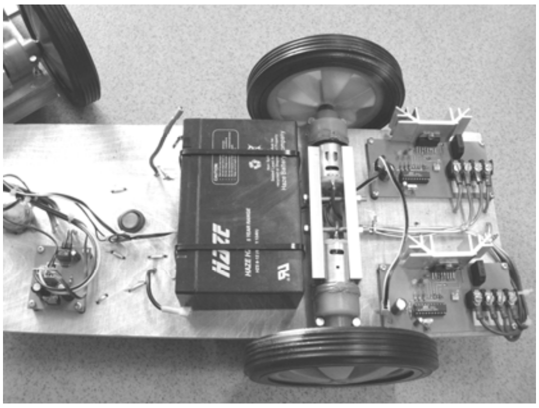

Fig.3. Power supply in electric vehicle model the second generation

6. CONTROL SYSTEM

The Vehicle Control System becomes divided to two parts. The first part is built in vehicle and operates as Vehicle Main Control System (VMCS), and second is built in Steering Bracket and operates as Main Control Steering System (MCSS). VMCS is responsibile on communication and measuring the analog data from input devices controlling UART.

Steering Bracket is input device of vehicle. It is contains steering wheel with push buttons (forward drive, backwards drive, stay), accelerator and brake. Analog data there are:

- angle of steering wheel position,
- shift accelerator and brake,temperature at the Steering Bracket.

Wheel Logitech WingMan Formula Force GP has „ForceFeedback" system with direct current motor 24 V. Feedback controls turn angle and tries to set up steering wheel in accordance with angle of articulated joint. When power supply and Steering Bracket are turn on the steering wheel is put at the same angle as vehicle model. It makes impossible straightening vehicle after power supply turn on. The main motor of „ForceFeedback" system is controlled by Main Control Steering System (MCSS) with PWM unit include in processor and bridge circuit controller of direct current motors L298.

Vehicle Main Control System (VMCS) is built from processor ATmega128 which has two series transmission UART units and eight A/C converters with 10-bit resolution. One of UART units is responsibile on communication Steering Bracket, the second with steering modules and position measuring systems assemble internal area network of vehicle.

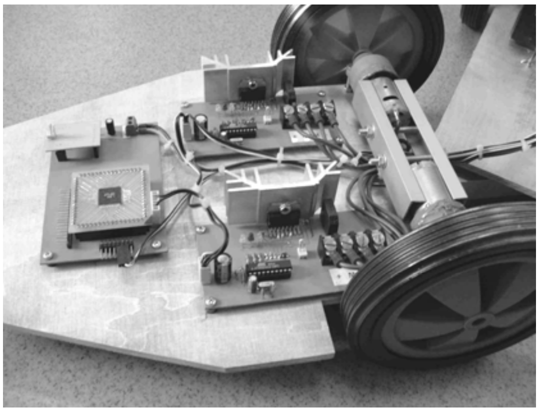

Fig.4. Control system in electric vehicle model the second generation

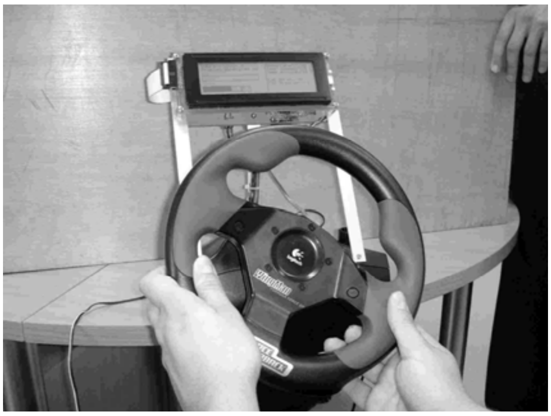

Fig.5. Wheel Logitech WingMan Formula Force GP has „ForceFeedback" system

Main Control Steering System (MCSS) is the processor ATmega128, identical as built in vehicle. The main task of its operation is communication with vehicle, data transmitting and operating under steering algorithm. The reason of location of the work algorithms in Steering Bracket comes from research, which has been made in the first generation model of vehicle. If algorithms put in the vehicle processor communication between Steering Bracket and MCSV it would slowing down.

Modules, which we could add to MCSV design, are laser position measuring systems and radio frequency communicator TLX901 that replace wire transmission system in RS-485 standard. Designed and made interface RS-485 is characterized by simple structure, dependability and high speed (to 4 Mbit/s) data transmission and spiral structure with long to 1200 m. There standard is similar as CAN-bus which is willingly using in cars.

Actual data like: battery voltage, turn angle, speed, driving forward, driving backwards and temperature are shown on display panel with 240x64 points resolution. Analog data are representing as analog rulers. This method is easier to valuation by driver.

7. DATA TRANSMISSION

The data transmission protocol between MCSV and MCSS is supported by protocol S.N.A.P. what simplify communication between all parts of vehicle system. Free software, source codes and tools facilitate making steering software on PC.

	Transmission direction	
	To MCSV	To MCSS
Transmission speed	115200 bit/s	115200 bit/s
Number of data bytes	8	16
Errors correction	CRC16	CRC16

8. SOFTWARE

In the programming vehicle model used BASCOM-AVR software for microcontrollers AVR and BASCOM-8051 for AT89C2051. Language BASIC is chosen because of a few reasons. The simplicity and characteristic features of AVR processors make possible fast modernization steering software. As well searching of errors in steering programs is easier because of built-in simulation procedures in compilators of BASCOM.

9. CONTROL ALGORITHM

When steering algorithm has created following parameters were taken into consideration: axle base, wheel track, angle of turn and vehicle speed. On bases of this data there are calculated adequate rotational speeds for the particular wheels.

Turn force in articulated joint during drive requires rotational speeds correction for each driving motor. In case of the model is driving forward there are corrections of all wheels.

Forward driving algorithms in dependent on turn angle change is steering adequate vehicle wheels. Wheel, which should go on the shorter way reduces rotational speed in case of speed of vehicle and the second wheel on the same axle should accelerate speed. Differences between speeds are proportional to value of difference of demanded turn angle and measure real vehicle angle. During driving backwards the algorithm is similar with difference that concern rear axle and the front wheels are moving by the straight way. In this case this state goes on to moment when turn angle is achieved. Another algorithm controls the turn of vehicle when model is immovable. In this case MCSS put reverse rotational speeds of weels in each axle dependent on drive direction If forward direction is chosen it would be front axle, when backward direction it would be rare axle. In the event when turning of the vehicle should be performed in neutral gear both axles react in the same time.

10. CONCLUSION

Carried on researches of first generation model had admitted that the best way is putting microcontroller with steering algorithm to vehicle and equip driving motors in own microprocessor control systems. In result researches with second-generation model we changed ours opinion about design and we saw that putting control system is the better way. In this new configuration one microprocessor responsible for measure analog data and control data transmission, whereas second one, built in MCSS, has steering algorithm and supervision system.

In order to maintain correct operation the system has to used fast bi-directional data transmission between parts of system. In the beginning we thought about communicate by using radio with frequency 433 MHz. For that purpose we have TLX401 communicators which are operating with 433,93 MHz or 434,33 MHz and has data range up to 800 m with 19,2 kbit/s transmission speed. In the consequence of experiments on present construction level we don’t have corectly transmission between MCSV and MCSS. The reason of this case is known. It is uncorrect synchronicity of beginning transmission data of microprocessors. In the next stages of vehicle development we want to work with this problem and use special decoding and filtering algorithms.

The preliminary design of vehicle model makes an assumption about using optical measuring systems to describe position parts of vehicle. Our experiments showed us that these systems are very sensitive on assembly.

At present level of design development we do not use these sensors but we made control system with processors family ’51 for using optical measuring systems. In the next stages of development we would use these optical measuring units.

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MODEL POJAZDU ELEKTRYCZNEGO Z CZTEREMA SILNIKAMI ELEKTRYCZNYMI WBUDOWANYMI W KOŁA

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STRESZCZENIE *Artykuł dotyczy modelu pojazdu, który ma cztery silniki elektryczne wbudowane w koła. Pojazd ten jest modelem ciągnika holowniczego używanego w górnictwie rud metali (np. rud miedzi). Głównym zadaniem takich ciągników holowniczych jest transport urobku lub maszyn w kopalniach. W czasie tej pracy wykonano dwa modele pojazdu (rys.1, rys.2). Zaprojektowano również i wykonano mikroprocesorowy układ sterowania. Pojazd jest kierowany z Konsoli Sterowania (rys.5), na której znajduje się kierownica z układem sprzężenia zwrotnego siły, przyciski, przyspieszacz i hamulec. Konsola Sterownicza jest połączona z modelem poprzez interfes RS-485. Model pojazdu jest wyposażony w komutatorowe silniki prądu stałego o magnesach stałych. Zasilanie prądem nastę-*

puje z baterii kwasowej umieszczonej w pojeździe. Układ Sterowania Pojazdu jest podzielony na dwie części. Pierwsza część jest wbudowana do pojazdu (rys.4) i pracuje jako Główny Układ Sterowania Pojazdu, a druga część jest wbudowana do Konsoli Sterowania i pracuje jako Główny Układ Sterowania.