Basics of Control and Maneuvering a Multi-Wheeled Electric Motor Vehicle

Roman Kenkishvili
Department of Thermal Power Plants, LEPL Raphael Dvali Institute of Machine Mechanics
Tbilisi, Georgia
r.kenkishvili@gmail.com

Tamaz Natriashvili
Director. LEPL Raphael Dvali Institute of Machine Mechanics.
Tbilisi, Georgia.
t_natriashvili@yahoo.com

David Nizharadze
Department of Thermal Power Plants, LEPL Raphael Dvali Institute of Machine Mechanics
Tbilisi, Georgia
dnizharadze@yahoo.com

Giorgi Chilashvili
Department of Thermal Power Plants, LEPL Raphael Dvali Institute of Machine Mechanics
Tbilisi, Georgia
chilashvili.gia@gmail.com

Paata Dolidze
Department of Thermal Power Plants, LEPL Raphael Dvali Institute of Machine Mechanics
Tbilisi, Georgia
p.dolidze@yahoo.com

***Abstract*—At the LEPL Raphael Dvali Institute of Machine Mechanics has developed, created and is testing a new original construction of physical model of remote-controlled mobile machine-robot, hybrid type, special purpose, with high cross-country ability and maneuverability, with universal platform. The vehicle is eight-wheeled, with electric motors mounted directly in the wheels. The vehicle is supplied by independent balancer suspension with oscillating levers and torsional springing in the longitudinal and transverse planes. The vehicle is controlled and maneuvered on the principle of caterpillar driving, for which an appropriate algorithm has been developed and the relevant program has been created.**

Keywords — vehicle, mobile machine, hybrid vehicle, electric motor.

I. INTRODUCTION

Hybrid and electric vehicles are one of the new promising directions in the automotive industry today. The rapid development of this direction has led to the creation of new types of highly efficient electrical aggregates, units and their control systems. It has been processed in a short time and is currently in serial production brush less different power electric motor-generators with dual action. The characteristics of electric battery packs have been significantly increased. The works in this field continues today and some results have been obtained. From this can be distinguished electric vehicles by electric motors located directly in the wheels, in which there is a possibility of controlling each motor individually with appropriate programs adapted to the road conditions. All this gives great opportunities to create a new construction, wide-ranging highly efficient mobile machine-robots. Works on this topic at the Institute of Machine Mechanics are carried out since 2011. During this period, at the Institute were developed, created and tested different several types of a physical models of an operating mobile machine-robots.

II. MAIN PART

The object of control is the vehicle with an eight non-steering wheels and electric motors located directly in the wheels (Fig.1).

In vehicles with ungovernable wheels, in case of violation of wheel rotation frequency synchronization, namely at the time of turn, the wheel that rotates at a large radius of rotation starts working in a brake mode, which worsens the turning process as well as increases an energy losses also. According to the road conditions due to instant change of the vehicle's center of rotation and accordingly changing rotation of wheels, it is very important to work in a constant synchronization mode of the wheel rotation frequency ratios.

Fig.1. *Experimental sample of vehicle with eight non-steering wheels.*

All this are possible by modern vehicle electrical control technologies with proper algorithms and microprocessor control. Depending on the road conditions, the control of the wheels and their coordinated work, is carried out by the joint action of the operator and the microprocessor located on the presented vehicle board. The operator transmits commands to the microprocessor in the form of electrical signals via an intermediate link – joystick, from which the information obtained using the appropriate algorithm is also transmitted in the form of electrical signals to the control units of electric motors, from which each drive is controlled and powered (Fig. 2).

The vehicle is maneuvered by changing the rotation frequency ratios of the wheels located relative to the longitudinal axis of the vehicle. The wheels have a common center of rotation O and different radii of rotation - R_D, R_C, R_c, R_E (Fig. 3), which is why speeds both the left and right board of the vehicle and also the wheels are different, because the wheels move in different radius circles.

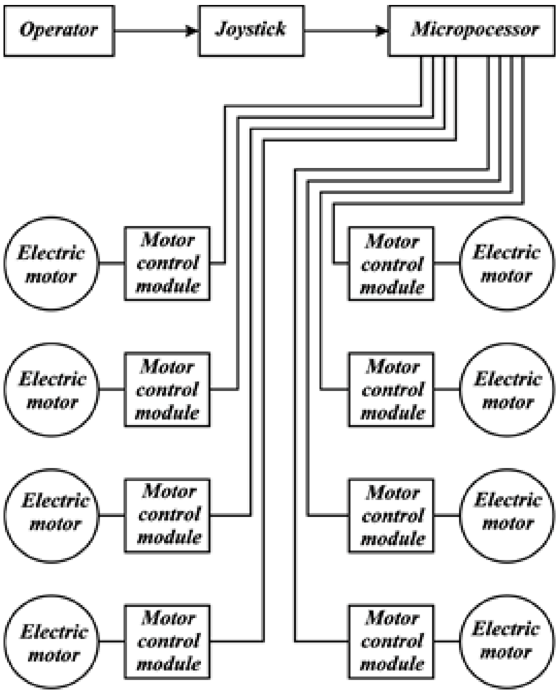

Fig.2. *Electrical control block diagram of the vehicle.*

Vehicle rotation maneuvering can be performed:

1. By synchronizing the rotation frequency of the wheels located on the vehicle board while braking the rear D wheel.
2. By synchronizing the rotation frequency of the wheels located on the vehicle board while braking the rear D and F wheels.
3. With synchronized control of the rotation frequency ratios of the wheels located on opposite sides of the vehicle.
4. By changing the direction of rotation of the wheels located on opposite sides of the vehicle (turning of the vehicle in relation to its own geometric axis).

To develop a vehicle control and maneuvering algorithm let's consider point 3, vehicle control and maneuvering with synchronized control of the rotation ratios of the wheels located on opposite sides of the vehicle. In this case the turning radius of the vehicle will pass through the middle points A and B of its wheel base b, with center of rotation radius O, which is permanently changing due to road conditions and depends on the ratio of the vehicle outer and inner wheels rotation frequencies. The location of the O center of rotation in relation to the boards of vehicle determines of its rotation direction (left, right). To determine the center of rotation O, consider the triangle ANO (Fig. 4) where $\vec{V}_A = \overline{[AN]}$ is the outer board motion instant velocity at point A and $\vec{V}_B = \overline{[BM]}$ – is the inner board motion instant velocity at point B.

Based on the similarity of the ANO and BMO triangles we will have:

$$\frac{V_A}{V_B} = \frac{AO}{BO} = \frac{AB + OB}{OB} \qquad (1)$$

where,

AB = l - is the track of the vehicle;

OB = R_x - is the vehicle turning inner radius.

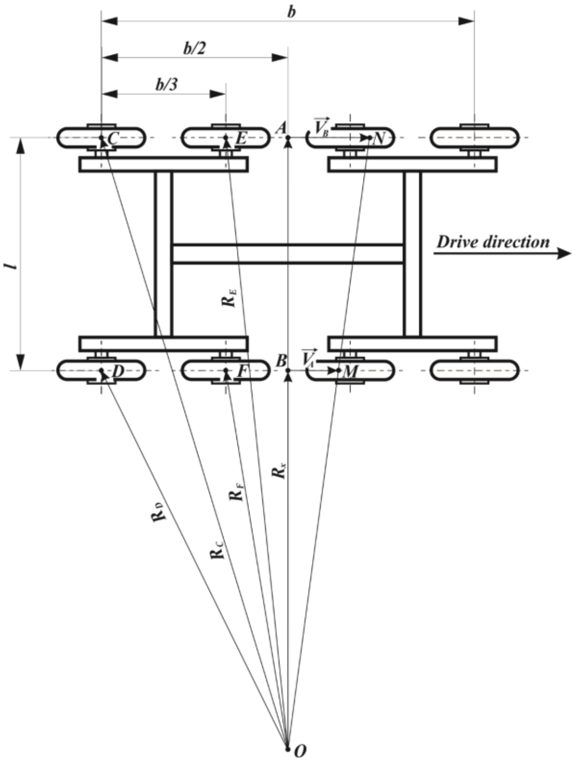

Fig. 3. *Scheme of vehicle with eight non-steering wheels.*

If we place at the points A and B the imaginary wheels identicals of the wheels on the vehicle then the velocities at these points will be equal:

$$V_A = 0{,}1R_A \cdot n_A$$

$$V_B = 0{,}1R_B \cdot n_B$$

here,

R_A and R_B - are the radiuses of the imaginary wheels placed at points A and B, accordingly;

n_A and n_B - are the rotation frequencies of the imaginary wheels placed at points A and B, accordingly.

LEPL Raphael Dvali Institute of Machine Mechanics.

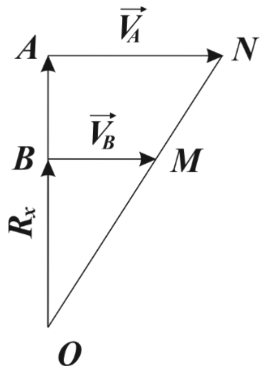

Fig. 4

By entering obtained values in the equation (1) we will have:

$$\frac{0,1R_A \cdot n_A}{0,1R_B \cdot n_B} = \frac{l + R_x}{R_x}$$

and based on the:

$$R_A = R_B$$

we will have:

$$\frac{n_A}{n_B} = 1 + \frac{l}{R_x} \qquad (2)$$

from where:

$$R_x = \frac{l \cdot n_B}{n_A - n_B} \qquad (3)$$

As can be seen from equation (2) when R_x=∞ then n_A= n_B and the vehicle moves by a linear motion type, and when R_x = 0 then n_B= 0 and the one side of the vehicle brakes and it is turned like a caterpillar.

On the other hand, the rotational numbers n_A and n_B of the imaginary wheels are formed by two electrical signals U_A and U_B supplied from the joystick, which must meet the following condition:

$$\frac{n_A}{n_B} = \frac{U_A}{U_B} = k$$

Where k is not a constant and varies depending on the control signal ratio $\frac{U_A}{U_B}$ received from the joystick.

Considering this the equation (2) will look like:

$$k = 1 + \frac{l}{R_x} \qquad (4)$$

or

$$R_x = \frac{l}{k-1} \qquad (5)$$

By determining R_x we can find the O center of rotation of the vehicle, according to which the radiuses of rotation of all the wheels are formed:

$$R_D = \sqrt{\left(\frac{b}{2}\right)^2 + \left(\frac{l}{k-1}\right)^2}$$

$$R_C = \sqrt{\left(\frac{b}{2}\right)^2 + \left(\frac{l}{k-1} + l\right)^2}$$

$$R_F = \sqrt{\left(\frac{b}{3}\right)^2 + \left(\frac{l}{k-1}\right)^2}$$

$$R_E = \sqrt{\left(\frac{b}{3}\right)^2 + \left(\frac{l}{k-1} + l\right)^2}$$

After determination of the rotation radius of each wheel, and known that the angular velocity of rotation of all wheels is equal when turning the vehicle, the following can be written for each wheel:

$$\frac{n_D}{n_{R_x}} = \frac{R_D}{R_x} = \frac{U_D}{U_B}$$

$$\frac{n_c}{n_{R_x}} = \frac{R_c}{R_x} = \frac{U_C}{U_B}$$

$$\frac{n_F}{n_{R_x}} = \frac{R_F}{R_x} = \frac{U_F}{U_B}$$

$$\frac{n_E}{n_{R_x}} = \frac{R_E}{R_x} = \frac{U_E}{U_B}$$

where,

n_D,n_c,n_F, n_E are the rotation frequencies of the wheels D, C, F and E, accordingly;

n_{R_x} – is rotation frequency of imaginary wheel at the point B;

R_D, R_c, R_F, R_E - are the rotation radii of the wheels D, C, F and E, accordingly;

R_x - internal turning radius of the imaginary wheel;

U_B - is the support signal on the imaginary wheel obtained by calculation.

Based on all the above equations, the electrical signals supplied to the control block of wheels D, C, F and E were determined:

$$U_D = \frac{R_D}{R_x} U_B$$

$$U_C = \frac{R_C}{R_x} U_B$$

$$U_F = \frac{R_F}{R_x} U_B$$

$$U_E = \frac{R_E}{R_x} U_B$$

Thus, a generalized algorithm for control and maneuvering an eight-wheeled electric vehicle with electric motors was developed.

III. CONCLUSIONS

1. The performed work allows in the process of maneuvering to take individually into account the each wheel rotation frequency of the vehicles with electric motors directly mounted in the wheels . All this ensures maximum maneuverability of the vehicle and minimal energy losses.

2. In case of wheels with the different diameters depending on the type and construction of the vehicle, the proposed method can ensure the normal functioning of the vehicle.

REFERENCES

[1] Dvali R. The theory of the performance properties of the car. Tbilisi, Tbilisi State University, 1986. (In Georgian).

[2] Гладов Г. И. и др. Конструкции многоцелевых гусеничных и колесных машин. Москва, «Академия», 2010.

[3] Иванов В. В., Иларионов В. А., Морин М.М., Мастиков В.А. Основы теории автомобиля и трактора. Москва, «Высшая школа», 1970.

[4] Литвинов А. С., Фаробин Я. Е. Автомобиль. Теория эксплуатационных свойств. Москва, «Машиностроение», 1989.

[5] Платонов В. Ф., Азаев В. С., Александров Е. Б. и др. Энциклопедия. Колесные и гусеничные машины. Т. IV. Москва, «Машиностроение», 1997.

[6] https://www.youtube.com/watch?v=zlsJXYdyBOE

[7] https://www.youtube.com/watch?v=GPz2e-SLgjE

[8] https://www.youtube.com/watch?v=_1JmfoD2_lA

[9] https://www.youtube.com/watch?v=qblfZ63LBrI

[10] https://www.youtube.com/watch?v=dVGVkkpaWIc

[11] https://www.youtube.com/watch?v=l9coMQIcVfw