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MULTICRITERIAL CONTROL SYSTEM OTHE TRACTION VEHICLE

Abstract: The development of the internal-combustion transport creates the threat of the offence of admissible values of noise levels, twitches and vibrations, and connected with the natural environmental pollution. Introduction of the vehicle with electric drive system or with hybrid drive system, should in the great manner limited their interaction. An optimal solution is application of the variant equipment of the petrol vehicle in additional electric drive system. It create a lower possibility a construction changes of the vehicle, enable obtaining a considerable exploitation providence, and also create possibilities a realization an ecological exploitation of traction transportation. The control of hybrid vehicle should assure the realization of established transport-assignments in the definite time, at the optimum of energy consumption. One can this realize using. the multi criteria control system. In the report introduced a mathematical models of the wheels vehicle, and chosen algorithms of the multi criteria control system. In the report one placed example-results of computer calculations for established functions of the target and control priority. Results of computer calculations became verified laboratory-research.
Keywords: traction vehicle, multi criteria control system, control algorithm

1. INTRODUCTION

The development of the internal-combustion transport creates the threat of the offence of admissible values of noise levels, twitches and vibrations, and connected with the natural environmental pollution. The application of vehicles with the electric drive or hybrid drive, should greatly limit this influence. The classical drive system of the wheel vehicle consists of the petrol engine with the electric starter and from system of the carriage of the drive, containing: the clutch, the gear-box, and the set of driving axles. In the report one proposed the introduction to system of the driving wheel vehicle, electric drive motors. The use of modernized drive, will permit to eliminate from the system of the drive vehicle: the electric starter and partly the multistage drive, and to diminish the engine power of internal-combustion. An optimum-solution is the introduction of the variant equipment of the car into the additional electro motion to the mass of internal-combustion cars. In the report one proposed the introduction to driving parley of the wheeled vehicle of inductive traction engines. The use of these engines to parley of drive vehicles, creates wide possibilities of changes a vehicle construction, and enable the obtainment of considerable petrol savings, and also creates certain possibilities of the realization of the ecological petrol of the road haulage. Total power of hybrid drive system will be equal power of the traction engine of the classical drive. The drive system of the wheel vehicle with the electro motion contains: one traction motor or system of traction electric motors, the block of converter supply system, and system of the drive carriage. The classical drive system of hybrid vehicle contains two tracks of the transformation of the energy: the thermo dynamical track, mechanical and electromechanical track. Track thermodynamically - mechanical contains the petrol engine and the battery of energy (the system of batteries, the ultra condenser, or the flywheel). Track electromechanical contains: set of electric traction motors (direct current motor, induction motors, or permanent magnets motor), the inverter supply system and drive carriage The configuration of the drive must assure the two-way flow energy [3, 4, 6].

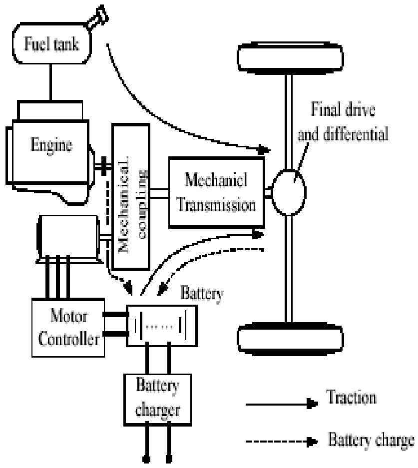

Fig.1 Scheme of the parallel hybrid drive system

The control system of hybrid vehicle should assure the realization of established transport-assignments in the definite time, at the optimum-consumption of energy. One can this realize using among other things the multi-level control. In the report presented a mathematical models of the wheels vehicle, and chosen algorithms of the multi criteria control system. In the report one placed example-results of computer calculations for established functions of the target and control priorities. Results of computer calculations became verified laboratory-research.

2. THE REVIEW OF SOLUTION A HYBRID VEHICLE DRIVE SYSTEM

In hybrid vehicles are applied different variants of drive parley: the series drive s, the parallel drive, the serial-parallel drive.[3, 4, 5]. In vehicles with the series drive, the petrol engine propels the electric generator, creating the current aggregate to the battery charge of batteries and to the partial power supply of the inverter supply system. The electric traction motor is supply by the block inverter supply systems, and propels driving axles of the vehicle, by the system of the carriage of the drive. In vehicles with the drive to parallels, driving units: the petrol engine and the electric motor, propel parallel driving axles of the vehicle. The summation of the mechanical power of each driving engines happens by the superposition of their driving torques on the common connecting shaft, or in the biaxial system by the superposition of their driving torques, at the utilization of the planetary [3, 4, 6] drive. The schema of the parallel drive system is introduced on fig.1.

3.TRACTION VEHICLE MATHEMATICAL MODEL

According with Hamilton's rule, in any holonomic system is realized vehicle move for which an energetic balance integral **w** score an extreme values.

$$w = \int_{t_0}^{t_1} (L + A)dt \tag{1}$$

where:

L – Lagrange function,

A – elementary work forces realized in the object

Solution of equation (1) is presented in the form of Lagrange equations (2):

$$\frac{d}{dt}\left(\frac{\partial L_L}{\partial q_i}\right) - \frac{\partial L_L}{\partial q_i} = Q_i \tag{2}$$

where:

q_i- generalization coordinates of the system

Q_i- generalization forces influence in the vehicle,

Lagrange function of the vehicle we can calculate with energy balance: **L= T- U**, where: **T** - kinetic energy of the vehicle, **U** – potential energy of the vehicle. Kinetic energy of the vehicle is an arithmetic sum of particular parts of the vehicle, drives revolving or progressive move, and energy accumulate in electromagnetic fields of drives motors of the vehicle. Total kinetic energy of the vehicle can be calculated using the relationship (3):

$$T = \sum_{k=1}^{K} \frac{1}{2} m_k \left(\frac{d^2 x_k}{dt^2}\right)^2 + \sum_{m=1}^{M} \frac{1}{2} J_m \frac{d\omega_m}{dt} + \sum_{n=1}^{N} \left(\int z_{nM,t} i_{nM,t} \varphi_{n,t,w} + \int z_{nM,w} i_{n,Mw} \varphi_{n,Mw,t} \right) \tag{3}$$

where:

m_k- weight of the k vehicle elements,

x_k- displacement of the k-th vehicle element,

J_m- moment of inertia of the m-th vehicle element about its rotation axis,

ω_m- rotational speed of the m-th vehicle element about its rotation axis,

z_{nMt}, $z_{n,Mw}$- number of armature coils and number of excitation coils, respectively, of the n-th motor,

$i_{nM,t}$,$i_{n,Mw}$- armature current and excitation current, respectively, of the n-th motor,

$\varphi_{nM,t}$, $\varphi_{n,Mw}$ – magnetic flux of the armature winding and excitation winding, respectively, of the n-th motor,

The potential energy of the vehicle can be calculated using the relationship (4):

$$U = \frac{1}{2}\left(C_{1,2}\,y_{1,2}^{2} + C_{2,2}\,y_{2,2}^{2}\right) + \sum_{i=1}^{p} E_i\left(x_i - x_{i+1}\right) \tag{4}$$

where:

$C_{1,2}$, $C_{2,2}$ – elasticity module of the mounting elements of the driving motors

$\sum_{i=1}^{p} E_i\left(x_i - x_{i+1}\right)$- energy accumulated in the elastic elements of the couplers with considering the effect of the coupling backlash,

$y_{1,2}$, $y_{2,2}$ – vertical displacement of the motors relative to the axes of the wheel set,

x_i – displacement of the i coupling element,

The generalized forces occurring in the wheel kinetic system include: driving motors' traction forces, weights of the motor casings, and dissipative forces associated with the motion resistance of the vehicle and with the vehicle track path. In case a vehicle with double motor driving system, the resultant traction force of the vehicle is a superposition of the force components produced by the drive vehicle motors: F_{P1} and F_{P2}, respectively, the traction motion resistance forces depending on the path configuration and inclination T_1 and T_2, respectively, and the force component of the traction motion resistance of the vehicle: F_{op}.

$$F_{wyp} = F_{P1} + F_{P2} + (T_1 + T_2)\,\mathrm{sign}\left(\frac{dv}{dt}\right) - F_{op} \tag{5}$$

The traction forces generated by the vehicle motors depend on the structure of the drive transmission system, and should be lower than the traction adhesion of the vehicle wheels F_{adh}, where: $F_{adh} = N_k.\alpha_k$, where N_k is the k driving axle load associated with the vehicle weight, α_K is the adhesion coefficient between the k wheel and the road.

The load transferred to the driving axles can be calculated from the relations (6, 7):

$$N_K = \frac{1}{2} m_{pK}\, g - \frac{H}{b} K_K(x) - \sum_{k=1}^{K} \frac{C_k}{b} Y_k(x) \tag{6}$$

$$N_{K+1} = \frac{1}{2} m_{pK}\, g + \frac{H}{b} K_K(x) - \sum_{k=1}^{K} \frac{C_k}{b} Y_k(x) \tag{7}$$

where:

m_{pK} – mass of the k element of the vehicle,

$K_K(x)$- the driving force at the vehicle coupler,

H - height at which the vehicle coupler is attached,

b – driving wheelbase,

$\sum_{k=1}^{K+1} \frac{C_k}{b} Y_k(x)$- forces produced from vertical conveyances of the vehicle driving motors,

The analysis of the dynamics movement of rail vehicle will require an assumption that the coordinates of the constraints associated with the Lagrange equations would be independent ones, hence the Lagrange equation describing the train movement can be can be written in the form (8):

$$L_1 = L + \sum_{k=1}^{K} \lambda_k f_k(y) \tag{8}$$

where:

λ_k- Lagrange multiplier,

$f_k(y)$ – equation that imposes the constraints,

The vehicle movement equation that incorporates the constraints can be can be written in the form (9)

$$: \frac{d}{dt}\left(\frac{\partial L_1}{\partial q_i}\right)-\frac{\partial L_1}{\partial q_i}=P_i \qquad (9)$$

$$f_k(y)=0$$

After elimination of the Lagrange multipliers, the system equation (9) can be presented in its expanded form (10):

$$m_0\frac{d^2x_0}{dt^2}+B_0\frac{dx_0}{dt}+K_0(x)=F_{1,1}+F_{1,2}-T_0 sign\left(\frac{dx_0}{dt}\right)-F_0$$

$$m_1\frac{d^2x_1}{dt^2}+B_0\frac{dx_1}{dt}+K_{10}(x)=-T_0 sign\left(\frac{dx_1}{dt}\right)-F_1$$

....

$$m_p\frac{d^2x_p}{dt^2}+B_0\frac{dx_p}{dt}+K_{p10}(x)=-T_0 sign\left(\frac{dx_p}{dt}\right)-F_p$$

$$(J_{1,1}+J_{1,3})\frac{d^2y_{1,1}}{dt^2}+(D_{1,1}+D_{1,3})\frac{dy_{1,1}}{dt}+C_{y1}y_{1,1}-\delta\left(J_{1,3}\frac{d^2y_{1,1}}{dt^2}+D_{1,3}\frac{dy_{1,1}}{dt}+C_{y1}y_{1,2}\right)=$$

$$rF_{1,1}-M_{1,1}sign\left(\frac{dy_{1,1}}{dt}\right)-M_{1,3}sign\left(\frac{dy_{1,1}}{dt}-\delta\frac{dy_{1,2}}{dt}\right)$$

$$(J_{1,2}+\vartheta_p^2J_{1,3})\frac{d^2y_{1,2}}{dt^2}+(D_{1,1}+D_{1,3})\frac{dy_{12}}{dt}+\vartheta_p^2C_{y1}y_{1,1}-\delta\left(J_{1,3}\frac{d^2y_{1,1}}{dt^2}+D_{1,3}\frac{dy_{1,1}}{dt}+C_{y1}y_{1,1}\right)=$$

$$\vartheta_pM_{1,3}sign\left(\frac{dy_{1,1}}{dt}-\vartheta\frac{dy_{1,2}}{dt}\right)-M_{12}sign\left(\frac{dy_{1,2}}{dt}\right)+k_{M1}\Phi_{Mw1}I_{M1}$$

$$(J_{2,1}+J_{2,3})\frac{d^2y_{2,11}}{dt^2}+(D_{2,1}+D_{2,3})\frac{dy_{2,1}}{dt}+C_{y1}y_{2,1}-\vartheta_p\left(J_{2,3}\frac{d^2y_{2,2}}{dt^2}+D_{2,3}\frac{dy_{2,2}}{dt}+C_{y1}y_{2,2}\right)=$$

$$rF_{2,1}-M_{2,1}sign\left(\frac{dy_{2,1}}{dt}\right)-M_{2,3}sign\left(\frac{dy_{2,1}}{dt}-\vartheta_p\frac{dy_{2,2}}{dt}\right)$$

$$\left(J_{2,2}+\vartheta_p^2J_{2,3}\right)\frac{d^2y_{2,2}}{dt^2}+(D_{2,1}+D_{2,3})\frac{dy_{2,2}}{dt}+\vartheta_p^2C_{y2}y_{2,2}-\vartheta_p\left(J_{2,3}\frac{d^2y_{2,1}}{dt^2}+D_{2,3}\frac{dy_{2,,1}}{dt}+C_{12}y_{2,,1}\right)=$$

$$\vartheta_pM_{2,3}sign\left(\frac{dy_{2,1}}{dt}-\vartheta_p\frac{dy_{2,2}}{dt}\right)-M_{2,2}sign\left(\frac{dy_{2,2}}{dt}\right)+k_{M2}\Phi_{Mw2}I_{212} \qquad (10)$$

$$U_{M1}=R_{M1}I_{M1}+L_{M2}\frac{dI_{M1}}{dt}+E_{M1_{M1}}$$

$$U_{M21}=R_{M2}I_{M2}+L_{M2}\frac{dI_{M2}}{dt}+E_{M2_{M1}}$$

The generalized forces occurring in the wheel kinetic system include: driving motors' traction forces, weights of the motor casings, and dissipative forces associated with the motion resistance of the vehicle and with the vehicle track path.

3.1. Mathematical model of the wheel vehicle with electric drive

Mathematical model the wheel vehicle is a superposition of storage-models system of the drive. Occurrences reaching in each modules describe systems of non-linear differential equations. Except base equations appear also equations uniting each modules. In the report one limited himself to the mathematical description of occurrences happening in the driving engine and in the kinetic system of the vehicle. In parley of driving vehicles with the electric motor and with hybrid drive are practical motors: induction (compact or with the double rotor), motors with permanent magnets and synchronous motors: of hysteresis or SCR. [4, 5, 6]. The dynamics of the traction induction motor with the double rotor describes the system of differential equations (11):

$$u_s = R_s i_s + L_{\sigma s}\frac{di_s}{dt} + L_s\frac{di_s}{dt} + M_{s,r1}\frac{di_{r1}}{dt} + M_{s,r2}\frac{di_{r2}}{dt}$$

$$u_{r1} = R_{r1s} i_{r1} + L_{\sigma r1}\frac{di_{r1}}{dt} + L_{r1}\frac{di_{r1}}{dt} + M_{r1,s}\frac{di_s}{dt} + M_{r1,r2}\frac{di_{r2}}{dt}$$

$$u_{r2} = R_{r2s} i_{r2} + L_{\sigma r2}\frac{di_{r2}}{dt} + L_{r2}\frac{di_{r2}}{dt} + M_{r2,s}\frac{di_s}{dt} + M_{r1,r2}\frac{di_{r1}}{dt}$$

$$M_{M1} = i_s^T \frac{\partial}{\partial \phi_{M1}}\left[M_{s,r1}\right]\cdot i_{r1}$$

$$T_{M2} = i_s^T \frac{\partial}{\partial \phi_{M2}}\left[M_{s,r2}\right]\cdot i_{r2}$$

$$T_{M1} - T_{ob1} = J_{M1}\frac{d\omega_{M1}}{dt} + D_1\omega_{M1}$$

$$T_{M2} - T_{o21} = J_{M2}\frac{d\omega_{M2}}{dt} + D_2\omega_{M2}$$

where:

R_s, R_{r1}, R_{r2} – resistance of the stator and two rotor windings
L_s, L_{r1}, L_{r2} – individual inductive of the stator and two rotor windings
L_σ, $M_{s,r1}$, $M_{s,r2}$ – disperse inductive and coupled induction of the stator and rotor windings
T_{M1}, T_{M2} - electromagnetic torque of the individual rotor,
i_s, i_{r1}, i_{r2} – stator and rotor currents
u_s, u_{r1}, u_{r2} – supply voltage of the stator and rotor winding,

The force of traction resistances is dependent from the travelling speed of the vehicle in compliance with the relation (12):

$$W(v) = m_P g\left(a_1 + a_2 v + a_3 v^2\right)$$

An aim of the control a system is the assurance of the reproduction of given trajectory of the rotational speed of the motor ω and quasi norms of the stream ψ_d: $0{,}5(\psi_{rd}^2 + \psi_{rq}^2)$. Assumed that: ω and ψ_d are smooth, given trajectories, instead unknown parameters: J_z and T_{zobc} have a value a constant. At the selection of the adaptive regulator of the speed of the motor one founded that if $\mathbf{e_\omega = \omega_{M.} - \omega}$ it is an error of the tracking of the trajectory of the speed, if instead of real values of streams: $\boldsymbol{\psi_{rd}}$, $\boldsymbol{\psi_{rq}}$ will put himself their estimators: $\boldsymbol{\psi_{rd}^*}$, $\boldsymbol{\psi_{rq}^*}$, then the system of equations describing the quasi observer of the magnetic flux one can present in the equation (13):

$$B_0\frac{d\psi^*_{rd}}{dt}+B_1\psi^*_{rd}+B_2\psi^*_{rq}=i_{sd}+x$$
$$B_0\frac{d\psi^*_{rq}}{dt}+B_1\psi^*_{rq}+B_2\psi^*_{rd}=i_{sq}+y \qquad (13)$$
gdzie:
$$x=e_\omega i_{sq}, y=e_\omega i_{sd}$$
At the calculation adaptive of the regulation of the magnetic flux one receives the equalization (14):

$$B_0\frac{de_\psi}{dt}=B_0\frac{d\psi_d}{dt}-\nu_\psi+e_\psi\nu_\omega+B_1\left(\psi^{*2}_{rd}+\psi^{*2}_{rq}\right) \qquad (14)$$
gdzie
$$\nu_\psi=\psi^*_{rd}i_{sd}+\psi^*_{rw}i_{sq}$$

To the estimation of the stability of the system: the adaptive regulator- the motor- the observer one can use the Lapunov function (15):

$$V=\frac{1}{2}\left[J^*e^2_\omega+\Theta^{*T}\Gamma^{-1}\Theta^*+B_0\left(\psi^{*2}_{rd}+\psi^{*2}_{rq}\right)\right] \qquad (15)$$

3.2. Mathematical model of the kinetic wheel vehicle system

The classical kinetic system of the wheeled vehicle is composed with: drive motors, the clutch, the system of the carriage of the drive (the gear-box) and driving axles. The visual schema of the system of the kinetic vehicle is presented on fig.2

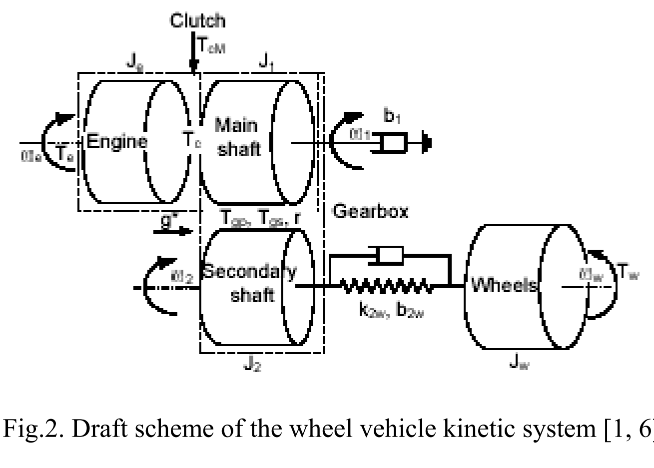

Fig.2. Draft scheme of the wheel vehicle kinetic system [1, 6]

Mathematical model of the kinetic vehicle system describes the system of equations (16):

$$
\begin{aligned}
J_e\dot{\omega}_e &= T_e - T_c(\mathbf{q},\mathbf{x},\mathbf{u}) \\
J_1\dot{\omega}_1 &= -b_1\omega_1 + T_c(\mathbf{q},\mathbf{x},\mathbf{u}) - T_{gm}(\mathbf{q},\mathbf{x},\mathbf{u}) \\
J_2\dot{\omega}_2 &= T_{gs}(\mathbf{q},\mathbf{x},\mathbf{u}) - T_{2w} \\
J_w\dot{\omega}_w &= T_{2w} - T_w \\
\dot{\theta}_{2w} &= \omega_2 - \omega_w .
\end{aligned}
\tag{16}
$$

where:

$$T_{2w} = k_{2w}\theta_{2w} + b_{2w}(\omega_2 - \omega_w)$$

T_{2e}- resistance torque of the elastic element

In hybrid vehicles a drive unit is: the system of electric motors and the petrol engine. The control of the work an petrol engine is realized impromptu automatic from the driver (the microprocessor chip), affecting the carburetor the electronic regulative fuel feed and airs to the engine. The simplified circuit diagram of the steering with the composition of the petrol engine are presented on fig.3

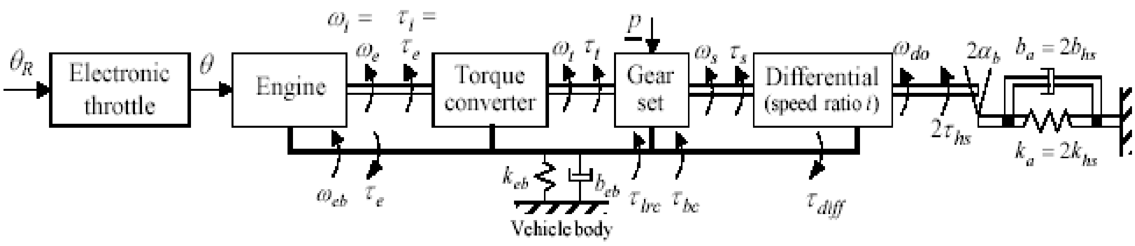

Fig.3. Draft scheme of the wheel vehicle drive system

3.3. Petrol engine mathematical model

Mathematical model of the system describes thermo dynamical reactions happens in the petrol engine and their influence on parameters kinetic units of drive.[2, 6]. Occurrences happening in the system of the carriage of the drive of the wheel vehicle with the petrol engine describes equations (17, 18, 19).

$$
\begin{aligned}
\dot{p} &= \frac{\kappa R}{V}\left(W_i T_a - W_o T + \frac{\dot{Q}}{c_p}\right) , \\
\dot{T} &= \frac{RT}{pV}\left[\kappa(W_i T_a - W_o T) - T(W_i - W_o) + \frac{\dot{Q}}{c_v}\right]
\end{aligned}
\tag{17}
$$

$$
\begin{aligned}
\dot{Q} &= hA_w(T_w - T) \\
h &= K_h\left(\frac{W_i + W_o}{2}\right)^{0.75}
\end{aligned}
\tag{18}
$$

$$\frac{dh}{dt}=v\left(\dot{p}_{app}\phi(h)\left[\frac{1}{g(h)}\phi(h)\left(1+3\eta_{BJ}(h)+\frac{12\Phi d}{h^3}\right)\right]\right)*\left(F_{app}-\frac{N_g\Theta_0}{2\pi}Ap_c(h)\right)\frac{h^3}{12\eta Q} \tag{19}$$

$$T=T_c+T_v=N_f N_g\Theta_0\frac{b-a}{3}\mu p_c\,\mathrm{sgn}(\omega)+N_f N_g\Theta_0\frac{b^4-a^4}{4}\eta\omega\frac{\phi_f-\phi_{fx}}{h}$$

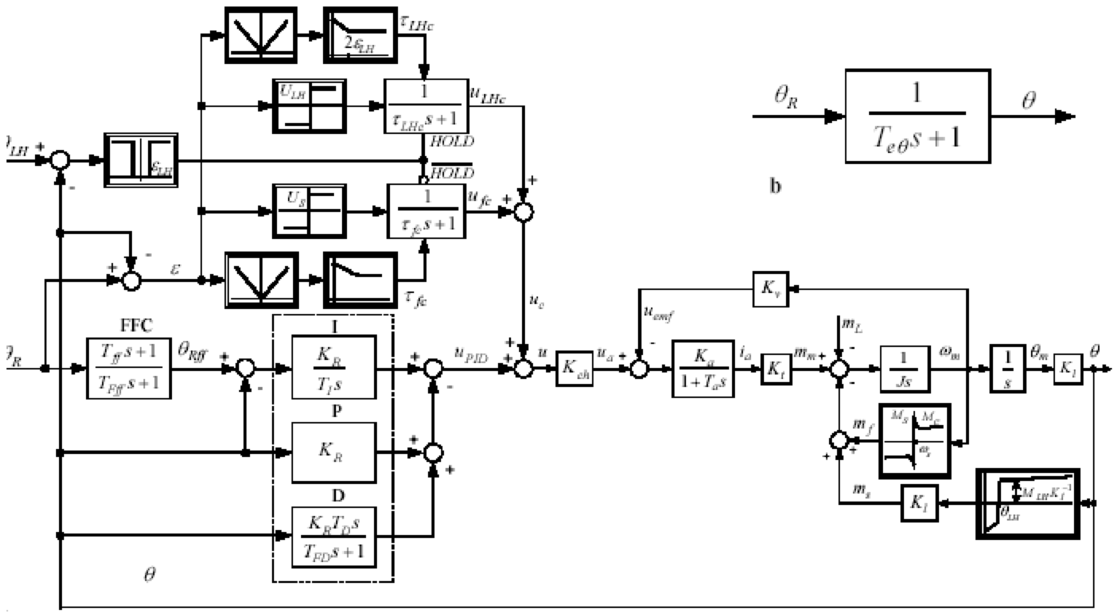

Fig.4. Block scheme of the wheel vehicle kinetic model

4. ALGORITHM OF THE MULTI CRITERIA CONTROL OF THE TRACTION VEHICLE

The multi-criteria control system must assure the realization of established transport assignments in the definite time, at given quantity of transport, and the minimum-consumption of energy. Transport-assignments should be realized at minimum- economic costs. Accordingly belongs to use driven transport with energy-saving traction motors, controlled adaptive, impromptu non-slip, in the optimum-working period. The selection of optimum-parameters of the control a wheel vehicle one can realize basing on probabilistic models of the intensification of the traffic and the thickness of the probability of the pronouncement of definite masses of vehicles in the given time slice.[4, 6]. Accordingly the resultant gathering of the decision size, belongs to assign to n of temporary sections, (at the regard of exploitive real terms and to the delimitation of coefficients of the weight of each events). The product resultant objective function will be a sum of products of local optimization functions, coefficients of the weight and the thickness of the probability of masses of vehicles. To the harvest decision variable one can number: exploitive parameters of the vehicle (the mass of the vehicle, the load capacity of the vehicle, the maximum speed, the traction power), analyzed communication system, and parameters of the power supply of the vehicle. The function of the thickness of the schedule a mass of the vehicle one can present in the form of the normal distribution, instead the probability of the appearance of the vehicle **P_i** about the mass m in i section of the route one can mark from the relation (20):

$$p(m)=\frac{1}{\sigma\sqrt{2}}\exp\left(-\frac{(m-m_s)^2}{\sigma^2}\right) \tag{20}$$

$$P_i=\int\frac{i}{\sigma\sqrt{2}}\exp\left(-\frac{(m-m_s)^2}{\sigma^2}\right)dm$$

where :

m_s - average mass of the vehicle,

σ - the standard deviation

Objective function the traction drive engine must enable problems of energy-saving, costs of the use and product of the motor. There must be realizing following conditions (22):

$$\forall M\left\{\max\eta_n\left(x\in X(y)\ ,y\in Y\ ,C_m\left(x,y\ \le 1{,}3C_m^0\right)\right)\right\} \tag{21}$$

$$\min\ \{C_m,C_0\},\ \ dla\quad x\in Y(y_1)$$

where:

$C_m = m_{Cu}\,c_{Cu} + m_{Al}\,c_{Al} + m_{Fe}c_{Fe} + m_{iz}\,c_{iz,,}$

C_m - the cost of the use of active materials

C_o - the cost of the use of the motor,

$C_m^{\,o}$ - the cost of the use of the motor performed from definite materials,

η_n – birth-mark efficiency of the motor,

x, y - coordinates of vectors being variable of optimization,

X, Y - crops of admissible sizes

Assure limited conscription of the energy by drive motors of the vehicle must be the realized condition (22):

$$\mathop{\exists}_{k=1}^{n}\mathop{\forall}_{j}\left[I_k\cdot j\le I_{k\max}\right]\cap\max\left[\eta_k\cdot\cos\varphi_k\right]\text{przy }\omega\in\left(0,\omega_{M\max}\right) \tag{22}$$

where:

I_k – the current input k traction motor**,**

ω_{Mmax}- maximum rotational speed k of this traction motor

The traffic of vehicles can take place after routes about different configurations and to the structure. To assure the realization of transport- exercises one ought to count the minimum of the quality coefficient (23) :

$$J_1=\int_0^{t_j}\left\{q_E\left[(1-k_H)F_P(t)+(1+k_H)\left|F_P(t)\right|\right]\upsilon_p(t)+q_R F_P^2(t)\right\}\,dt \tag{23}$$

where:

t_j - time of the ride of the given section of the route,

$\mathbf{k_H}$- the relation of work costs of necessary to the drive to the sum of costs of the drive and applying of the brake

$\mathbf{q_E, q_R}$ - coefficients of the balance denominative the participation of costs of the conscription of energies and power losses in the balance of energy system

To limit errors of the control suboptimal: adaptive or predictive, we should calculate the minimum coefficient of quality defined as (24):

$$J_n = f_l \varepsilon_l^2(t) + f_v \varepsilon_v^2(t) + \int_0^{t_j} \left[q_l \varepsilon_l^2(t) + q_v \varepsilon_v^2(t) + q_R F_P^2(t) \right] dt \tag{24}$$

where;

$\varepsilon_l(t) = l_z(t) - l_R(t)$ – he difference between given and with the real change way

$\varepsilon_v(t) = v_Z(t) - v_R(t)$ - the difference between given and with the real travelling speed of the vehicle,

f_l, f_v, q_l, q_R, q_v - coefficients of balance of each parameters of the drive

Conditions (20-24) describe local functions of the target, taking into account problems electromagnetic, electromechanical and kinetic and forwarding. The product resultant objective function consequential from requirements of the multi-level control system, enable also coefficients of the weight and functions of the penalty [3, 6]. Detailed algorithms of the control will be presented in further publications [6].

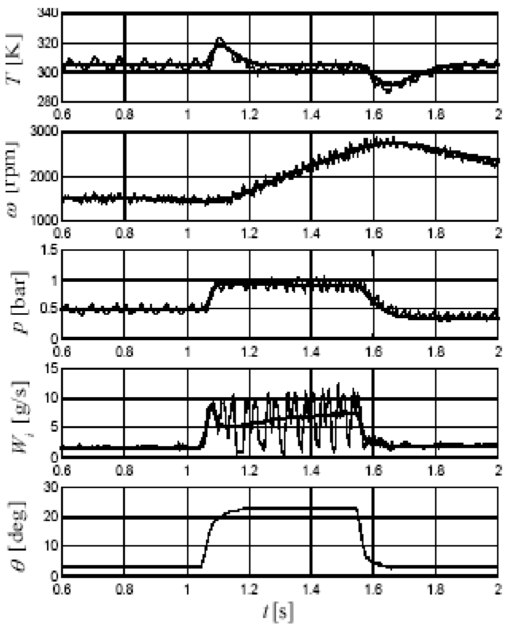

Fig.5. Calculations results of combustion drive system of the vehicle [2, 6]

Conditions (20-24) describe local functions of the target, taking into account problems electromagnetic, electromechanical and kinematic and forwarding. The product resultant objective function consequential from requirements of the multi-level control system, enable also coefficients of the weight and functions of the penalty [3, 6]. Detailed algorithms of the control will be presented in further publications [6]. For models of wheel vehicles: with the electric drive and with the drive hybrid, composed from the explosion engine about the power 6 kW, the electric motor about the power 5 kW, laden with the machine of the direct current, one worked out the simulation model, algorithms of the control and the computer software. Chosen results of simulation calculations presented on the fig.(5 , 6, 7). [1, 2, 6]. On fig.5 is presented a results of the simulation of occurrences happening in the explosion engine, at the change of the mixture swimming to the carburetor of the engine. On the fig 6 is presented a temporary courses of the driving torque and on fig.7 courses of changes of the rotational speed in the kinematic system of the vehicle. New model of the multi-level control system became partly verified laboratory-research. Findings confirmed the advisability of the introduction of the multi-level control system to the control with the wheel vehicle with the electric drive and with hybrid drive.

6. CONCLUSION

The control with the wheel vehicle should enable: the kind of the drive (the internal-combustion drive, the electric motor, or hybrid drive), the kinetic system of the vehicle (the kind of the ignition, system of the carriage of the drive), and exploitive (the configuration of the ground, maximum speeds and accelerations) parameters. These factors are taken into account by in a manner the multi-criteria control.

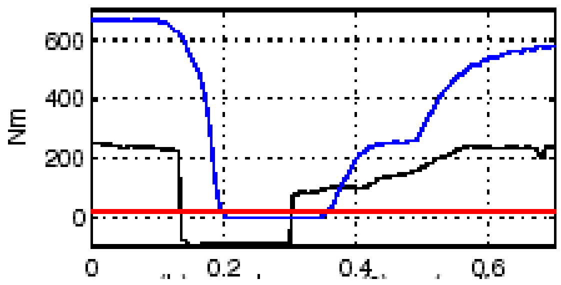

Fig. 6. Timing run of the torques: T_e, T_{cM}, T_w

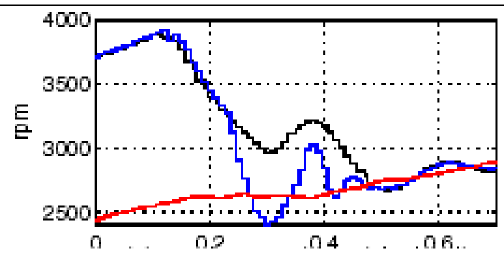

Fig. 7. Timing run of the rotational speed: ω_e, ω_1, ω_w

Depending on accepted priorities, one obtains the suitable total function of the aim. At rough estimates enable only chosen algorithms of the control, accepting remaining parameters as constants. The use of deck-computers in the wheel vehicle will assure the realization of complicated algorithms of the control, aside from of the interference of the driver.

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STEROWANIE MULTIKRYTERIALNE POJAZDU TRAKCYJNEGO

Streszczenie: Rozwój transportu spalinowego stwarza zagrożenie przekroczenia dopuszczalnych wartości poziomów hałasu, drgań i wibracji, oraz wskaźników związanych z zanieczyszczeniem środowiska naturalnego. Wprowadzenie pojazdów z napędem elektrycznym lub hybrydowym, powinno w znacznym stopniu ograniczyć to oddziaływanie. Optymalnym rozwiązaniem jest wprowadzenie wariantowego wyposażenia pojazdu spalinowego w dodatkowy napęd elektryczny. Stwarza to szerokie możliwości zmian konstrukcyjnych pojazdów, umożliwia uzyskanie znacznych oszczędności eksploatacyjnych, a także stwarza możliwości realizacji ekologicznej eksploatacji transportu trakcyjnego. Sterowanie pojazdem hybrydowym powinno zapewniać realizację założonych zadań przewozowych w określonym czasie, przy optymalnym zużyciu energii. Można to zrealizować stosując. sterowanie multikryterialne. W referacie przedstawiono modele matematyczne pojazdu kołowego, oraz wybrane algorytmy sterowania multikryterialnego. W referacie zamieszczono przykładowe wyniki obliczeń komputerowych dla założonych funkcji celu i priorytetów sterowania. Wyniki obliczeń komputerowych zostały zweryfikowane badaniami laboratoryjnymi.
Słowa kluczowe: pojazd trakcyjny, sterowanie multikryterialne, algorytm sterowania