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Method for Developing Classifications of Vehicles' Automated Power Systems Based on Their Generalized Mathematical Structural Models

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Abstract: The research paper presents a methods for developing classifications of various types of vehicles' automated power systems based on their generalized mathematical structural models (MSM). The great diversity of automobile designs now in production across the globe plus the variety of privately implemented design decisions for subsystems and subassemblies for the same functional application impose stringent requirements on the rigidity and objectivity of the latter's classification. This classification is a tool for expanding the information field of seeking extra sources of economic success in transportation business and of assured continuous re-engineering in business endeavors. Using an impressive multitude of essential schemes of private system arrangement, the method formulates a multitude of corresponding functional MSM. Following this, they are converted to the operational counterparts and further on to the structural form. Thus, by means of "a packaged addition" of all private model forms, a generalized structural MSM is created that applies to the class of systems under consideration. The model manifests all the distinctive features of the latter and ensures automation of compact procedures for evaluation of its functional properties.

Key words: Re-engineering · Auto vehicle · Key diagram · Functional property · Products' information support technology · Generalized mathematical structural system model · Design variety of auto vehicles' automated power systems · Structural classification of automated power systems

INTRODUCTION

At present, the Russian auto vehicle maintenance and road accident prevention enterprises are intensely introducing innovative technologies [1-3], including those in the area of re-engineering.

To assure the continuous improvement of the re-engineering mechanisms [4], every effort is made to use the expressly developed technologies of continuous and effective information support of the products being created. Such technologies are used all through the products' service life and after it (information support and CALLS technologies). The basis of the latter is made up of information business process models, facilities management models and enterprise control models in general. The models are being developed, investigated and adjusted strictly in compliance with the business demands. The special feature of the auto vehicles as objects of maintenance is at the moment the extreme diversity of their brands, types, models and modifications as well as the great variety of some complex automated systems used by vehicles in certain areas [5]. The availability of generalized models of the systems that have served to develop models for forming and algorithms for estimating the gauges of each of their functional property (stability, precision, ergonomics, etc.) in various operating modes, makes it possible to expand the enterprises' search for new commercial and other kinds of success. The techniques of integrating such models into the generalized systematic model of the enterprises' business activity, the model of organizing the production and support of steady improvement [6-10] and the examples of handover to computers of the tasks of automated study of intra-system structures [11] are well known and thoroughly described.

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MATERIALS AND METHODS

The first step in generalizing the complete multitude of private varieties of designs of automated power systems for the same purpose is the formation of their representative multitude in the form of key diagrams corresponding to a strict verbal description of their operating principle. This is an essential start-up principle of forming the said multitude enabling removal from the diagrams of their "non-key" features such as mass and size, geometrical shape and so on [12-13].

The second – analytical – technique of the strict generalization of information on the specifics of private designs of APS is the fundamental information product, i.e. the functional classification of their design features. The latter manifest themselves in the units of structurally presented isomorphic mathematical models (MM) of their functioning. Such a form of presentation is unique. It is visually (Fig. 1) perceived as an image of an internal arrangement of the modeled object equivalent to the initial differential equations of its movement and as a mechanism of transforming an entry signal into an exit one (here [alpha]$_{sw}$ and [alpha]$_{w}$). The generalization technique completely excludes subjectivity of the formed classifications which is important for their practical use.

The Main Part: Fig. 2 shows the start-up module of the method, where some APS key diagrams are presented, in which case it performs the steering function. Each of its private versions is a combination of a mechanical power channel driving the controlled wheels and a power channel of the automatic (tracking) drive with any type of amplifier and of any design. Due to the restricted space of the research paper, we shall omit the example of calculating any type of the system and differential equations of its functioning. The latter are fully presented in a research paper [13].

At the second stage of the procedure a database of movement equations is formed for all the known private versions of the system design. Those are subsequently transformed into operational and, further on, into a structural form of presentation.

The differing parts of the complete structural forms of presenting the MM of steering wheels of Ikarus, MAZ-6422 and Wolseley 18/85 are shown in Fig. 3. The generalized structural mathematical model of the system under consideration obtained by projecting the structural models of all private construction versions onto the common plane is shown in Fig. 4. The model formally, i.e. analytically, allows the classification of signs as per the difference in some of its units' contents. Based on this

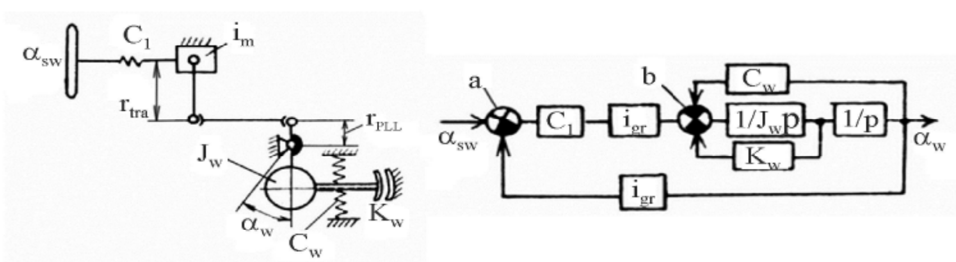


Fig. 1: Computing pattern of the mechanical steering system and the structural form of presenting MM and its movement: p - Laplace operator; C_1, i_m, - rigidity and gear ratio of the steering mechanism; C_w, K_{dw}, J_w - rigidity, damping coefficient and inertial moment of the load node; r_{tra}, r_{PLL} - lengths of steering wheels' drive levers.

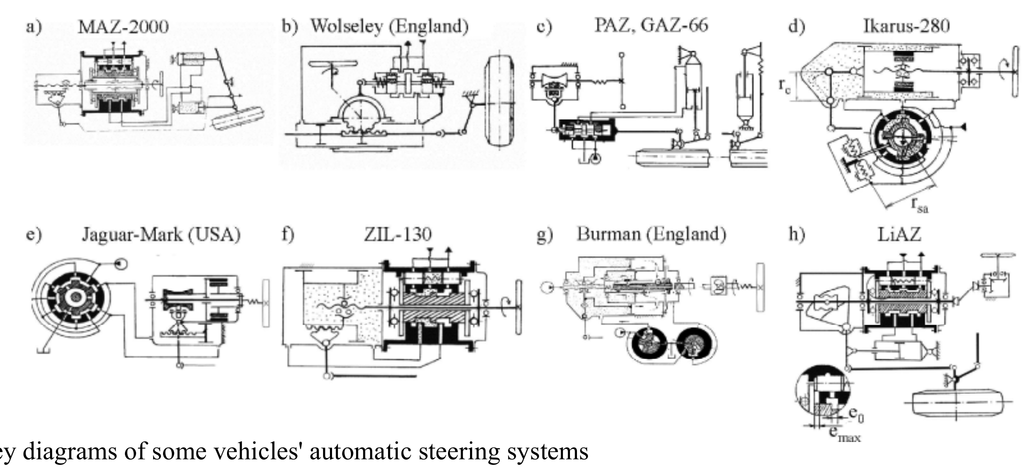


Fig. 2: Key diagrams of some vehicles' automatic steering systems

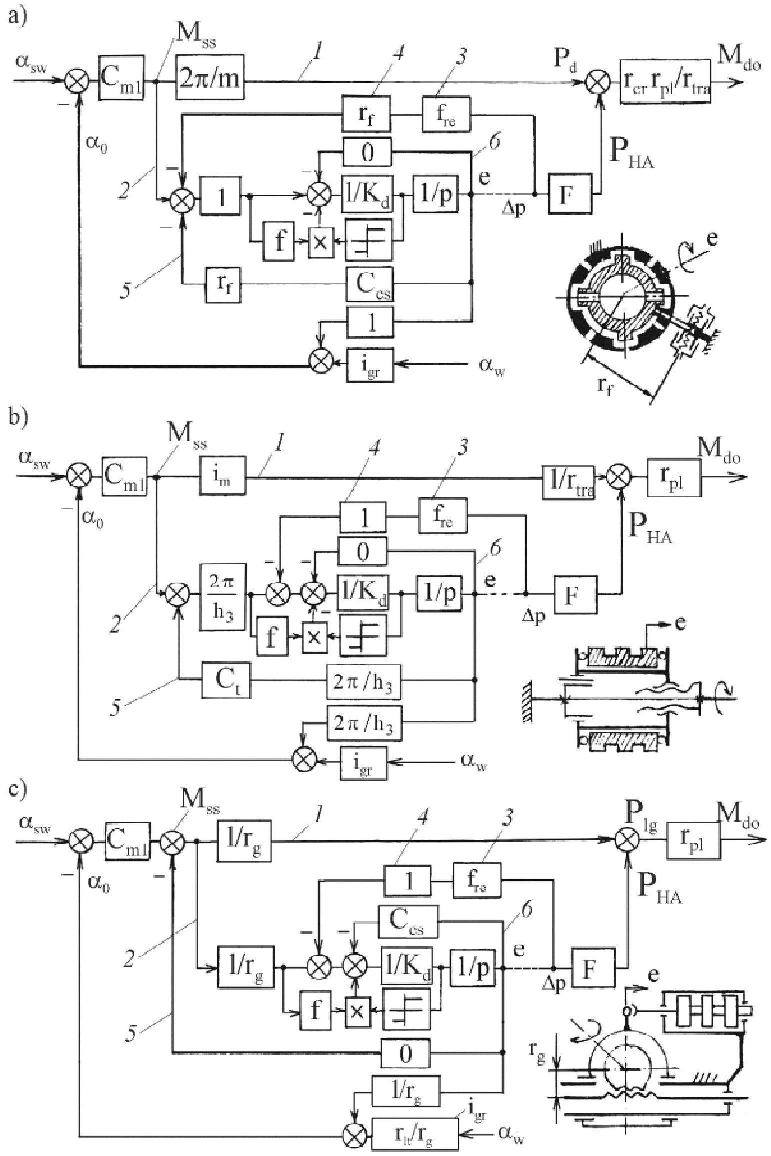
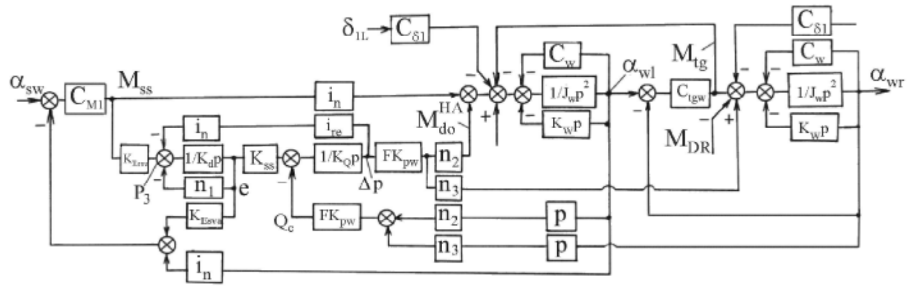


Fig. 3: Structurally different versions of steering systems' MM: a - Ikarus; b - MAZ-6422; c - Wolseley 18/85; *1* - mechanical channel; *2* - amplifier channel; 3 - valve resilient centering channel relative to conjugated sleeves; *4* - functional units of feedback tactile channels for amplifier-developed pressure; C_{ml} - “direct” rigidity of steering mechanisms (SM); h_m, h_{sva} - steps of SM screw couples and valve gear; F, f - areas of hydraulic cylinder pistons and reactive elements; i_m, i_n - SM and steering gear ratios; P_d, P_{HA} - a strain developed via the mechanical channel and HAC (hydraulic amplifier channel); M_{do} - steering systems driving torque

model and using the well known techniques of convoluting the structural schemes it is possible to produce a database of measuring criteria for all functional properties for all operating modes, including those on the test-bench. The model, if necessary, can be easily docked with models like "the driver", "the steerable axle" and a vehicle model functioning as a steerable object of the "driver-steering system-vehicle-road medium" arrangement [13]. This manifests all the classification signs (Table 1), including a sign that determines the connection between the actuator and the hydraulic cylinders with a loaded steering system whilst the links n_2 and n_3 ensure the connection of hydraulic amplifier channel (HAC) to the left (adder 1) or right (adder 2) steering wheel of the vehicle.



	ZIL-130	Volvo	URAL-375	MAZ-6422	IKARUS	Wolseley	MAZ-500	Mech SG
K_{Esva}	$2\pi/h_M$	$1/r_{sva}$	$2\pi/h_M$	$2\pi/h_{sva}$	1	$1/r_g$	i_M/r_{tra}	0
Kf	1	0	1	1	r_{sva}	1	1	0
K_{pw}	$r_{gs}r_{pl}/r_{tra}$		r_{pl}	r_{pl}	$r_{cr}r_{pl}/r_{tra}$	r_{lt}	r_{pl}	0
n_1	C_{cs}	$C_\tau r^2_{sva}$	C_{cs}	$C_\tau 4\pi^2/h^2_M$	$C_{cs}\ r^2_{sva}$	C_{cs}	0	0
n_2	1	1	0	1	1	1	1	0
n_3	0	0	1	0	0	0	0	0

Fig. 4: Generalized structural mathematical model of vehicles' automatic steering system (a) and a table of design's parameters in the private versions (b): K_{Esva}, K_f, K_{pw} - coefficients of torque actuation on the M_{ss} steering shaft for the power application of P_{sva} on the HA valve, power application on the reactive elements side towards the valve entry, strains on the power cylinder piston towards the steering wheel.

Table 1: Structural classifications of vehicles' automatic steering systems

No.	Classification sign	Subclasses and modifications	Examples (models, companies)
1	Point of man-made power circuit tear	1.1. Steering gear shaft's (SGS) ball bearing support tear - steering box	
		1.1.1. Distributor on the SGS upper support side	ZIL, URAL, LiAZ, Kalconi, Fulmina, Chrysler, Burman
		1.1.2. Distributor on the SGS lower support side	K700, MTZ50
		1.2. SGS tear	MAZ 6422, Ikarus, Ford, Jaguar_Mark, Volvo, Bendix
		1.3. Tear in the conjunction of SG box and frame	Wolseley 18/85
		1.4. Leverage system tear	MAZ 500, GAZ 66, PAZ 672, Tatra, Fiat, Bendix, Vickers
2	Method for centering the tear elements	2.1. Via valve	ZIL 130, LiAZ, URAL, KAMAZ
		2.2. Directly tear elements	MAZ500, GAZ 66, Ford, ZRF, Jaguar Mark
		2.3. Mixed	ZIL 111, MAZ 6422, Chrysler
3	Type of tear elements centering mechanism	3.1. Resilient element	Volvo, Ford, Bendix, Magirus-Deutz
		3.2. Service fluid pressure	MAZ, GAZ, PAZ, SK 4, Ford
		3.3. Resilient element and pressure	MAZ 6422, ZIL, LiAZ, KAMAZ
		3.3.1. Centering by pressure in the delivery line	Ikarus, ZIL, KAMAZ
		3.3.2. Centering by pressure in the power cylinder chamber	MAZ, GAZ, Wolseley
		3.3.3. With pressure restriction	ZIL 111, Chrysler
		3.3.4. Without pressure restriction	ZIL 130, MAZ, GAZ
4	Coincidence of the movement pattern of the leading element tear and the valve	4.1. Corresponding forms of movement of the drive tear element and valve	
		4.1.1. Angle to angle	Jaguar Mark
		4.1.2. Axis to axis	ZRF 7400, MAZ 500, GAZ, ZIL 130
		4.2. Not corresponding forms of movement of steering element of the tear and valve	
		4.2.1. Angle to axis	Volvo, Daimler Benz, Ford, Magirus-Deutz, MAZ 6422
		4.2.2. Axis to angle	
5	The valve drive mechanism transfer factor value	5.1. Coefficient is equal to a unit	ZIL 130, LiAZ, URAL, Fiat, Ikarus
		5.2. Coefficient is not equal to a unit	ZIL 111, MAZ 6422, ZRF 8000, Chrysler, Ford
6	Feedback channel arrangement under load	6.1. By alignment with the centering mechanism	ZIL, MAZ, GAZ etc.
		6.2. Self-sustained feedback channel	
		6.3. Without feedback channel under load	Magirus, Volvo, Ford, Lincoln
7	Means of linking the actuator with a driven element of the power chain tear	7.1. Directly rigidly linked	MAZ 500, PAZ
		7.2. Via transmission gear	
		7.2.1. Mechanical	URAL, ZIL 111, Chrysler, Ford
		7.2.2. Hydraulic	ZRF, Orbitrol
8	Means of linking the actuator to the steering wheel load	8.1. Linked to the left steering wheel	MAZ, ZIL, GAZ, Fiat, Ford
		8.2. Linked to the right steering wheel	URAL
		8.3. Linked to the bar connecting the wheels	GAZ-66, ZRF, Wolseley
		8.4. Linked to swivel axis	MAZ 2000, MAZ 529

Note: ZIL, URAL, LiAZ, MAZ, Ikarus, GAZ, PAZ, KAMAZ are names of motorworks located respectively in Moscow, Mias, Likino, Minsk, Sekeshfehervar (Hungary), Gor'kij (now Niznij Novgorod), Pavlovsk and Naberezhnye Chelny.

The Table of Fig.4 shows the coefficients of some vehicle models which are determined by the specific features of an individual key diagram of the steering system. In the structurally generalized MM (mathematical model) the zeroed coefficients n_2 and n_3, "cut off" the links between the hydraulic amplification channel and the elements of the mechanical steering system if those need to be investigated separately. Also, the points have been singled out in it for introduction of new structural links arising in interaction between the steering system (SS) and the controlled object SS as well as between the latter and the road irregularities: deflection angle introduction channel $[delta]_{1l}$ and $[delta]_{1r}$ of the front wheels and of the disturbing moments M_{dl} and M_{dr} applied to them by the road irregularities. The docking pattern for the steering system's mathematical model and the controlled object is also shown in [13].

By performing a simple correction of the load angle on the controlled wheels the model can also consider the existence in the system of more than two steering wheels, a draft linkage to them and other specifics of its particular design. The information on operational capabilities of private APSs and recommendations for their adequate use in various vehicle models are supplied in the relevant technical literature, e.g. in [14-17].

CONCLUSIONS

The paper presents a method for developing a classification of vehicle APS which makes it possible to include the redundant unused system information into a generalized compact and technologically convenient medium of different business models, to reduce the requirements for the personnel skills and to essentially improve the enterprises' general efficiency and their personnel's technological culture and performance.

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List of abbreviation

Fig. 1:
M_{dl} & M_{dr} – the disturbing moments on the left and right wheels
[alpha]$_{sw}$ – steer angles of steering and steerable wheels
a, b – adders
i_{gr}, i_m* – steerable wheels gear ratio
i_{gr} – gear ratio of the steering mechanism
r_{pll} & r_{tra} – radii of pivoted lever and tie-rod arm
Fig. 2:
e_0 – depth of throttle gaps of hydraulic amplifier (HA) in neutral
e , e_{max} – current and maximum displacement of slide valve relative to hydraulic amplifier HA
r_c , r_{sva} – radius of crank and slide valve actuator arm
Fig. 3:
1 – mechanical channel
2 – connecting link providing application of hydraulic amplifier channel in parallel with mechanical channel of hydraulic amplifier
3 – arm putting in action feedback channel by load to driver
4 – arm adjusting mode of force action on the part of reactive components with the movement mode of driving element of breaking power circuit PC
5, 6 – arms of slide valve elastic aligning via running gear and slide valve directly
f – power factor of hydraulic amplifier cushioning – drive torque (a) and force (b, c)
M_{ss} & M_{do} – drive torques on steering shafts and at the output of steering gear (SG), steering systems driving torque
K_d – coefficient of damping
[alpha]$_0$ – value of actual angle of operation of SG
Δp – value of driving pressure on the rod of the HA hydraulic cylinder
r_{cr} , r_g , r_{pl} , r_{tra} – radii of crank and gear of steering mechanism (SM) of pivoted lever , tie-rod arm
F, f_{re} – areas of hydraulic cylinder pistons and reactive elements, f_{re} – reactive element area
i_M , i_n – SM and steering gear ratios
P_d & P_{HA} – a strain developed via the mechanical channel and HAC (hydraulic amplifier channel), force of the driver and hydraulic amplifier (HA)
C_{m1} , C_{cs} , C_t – "direct" rigidity of steering mechanisms (RM), C_{M1} – rigidity of steering mechanisms (SM), reduced to steering wheel, C_{cs} -centering spring rigidity, C_t – torsion bar rigidity
Fig. 4.
r_{gs}, – radius of gear sector of steering mechanism SM
J_w – inertial moment of the steering wheel
Q_c – fluid consumption by the cylinder
M_{do}^{HA} – drive torques developed by the HA channel
M_{tg} – moment by transverse gear
K_{Esva} – transition factor of pair "slide-steering wheel"
K_w – decay coefficient of wheel load
K_Q – HA flow coefficient
r_{lt} – radius of trapezium lever
C_w – rigidity equivalent to load on wheel
K_{pw} – transition factor of pair "piston-wheel"
K_f – reduction coefficient of reaction force to rotational power
P_{tf} = P_{lg} – total force on draft link
F = piston area
C_{tgw} – rigidity of transverse tie rod reduced to steering wheel