DETERMINATION OF PARAMETERS OF A TECHNICAL AND CONTROL STATES OF THE BUS ENGINE BY USING ITS DISCRETIZED OPERATION INFORMATION

WYZNACZENIE PARAMETRÓW STANU TECHNICZNEGO I STANU REGULACJI SILNIKA AUTOBUSU Z WYKORZYSTANIEM JEGO ZDYSKRETYZOWANEJ INFORMACJI EKSPLOATACYJNEJ

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Abstract: The paper presents fundamentals of an innovative diagnostic method using operation information (imported in the form of dimensionless number of points). This process consists in the fact that for any change in the signal (depending on the signal value and the time when the change occurs) appropriate number of points determined by the experts is assigned. The existing methods of assessing the operability include summing of all the points and then determining the current state and maintenance level [10]. The proposed method uses these signals expressed in the form of points to determine the coupled interaction equations [3] defining parameters of the control and technical states, which are the basis for the assessment of the plant's operability. In addition, the changes in control and technical states can be used to identify the parametric and momentary failures, and thus for the continuous monitoring of plants operability [7].

Keywords: diagnostic, safety, reliability

Streszczenie: W artykule przedstawiono założenia nowatorskiego sposobu wykorzystywania informacji eksploatacyjnej (sprowadzonej w postaci bezwymiarowej liczby punktów). Proces ten polega na tym, że każdej zmianie sygnału (w zależności od jej wartości i chwili pojawienia) przypisana jest odpowiednia ustalona przez ekspertów liczba punktów. W dotychczasowych metodach badania zdolności obiektów następuje sumowanie wszystkich punktów, a następnie określenie stanu, w jakim znajduje się obiekt oraz stopnia jego wyeksploatowania [10]. Zaproponowana nowa metoda polega na wykorzystaniu tychże sygnałów wyrażonych w postaci punktowej do wyznaczenia ze sprzężonych równań interakcji stanu [3] parametrów stanu regulacji i stanu technicznego, które są podstawą do oceny stanu zdolności obiektu. Dodatkowo ich przebiegi pozwolą na identyfikację uszkodzeń parametrycznych i chwilowych, a stąd pozwala to na ciągłą kontrolę stanu niezawodności obiektu w czasie eksploatacji [7].

Słowa kluczowe: diagnostyka, bezpieczeństwo, niezawodność

1. Introduction

Perfecting of exploitation systems of mass transport (public transportation) is an important problem, both from the point of people safety and economic benefits. In process of use and storage of technical object inevitable destruction occurs from maladjustment, wear and failure increase. Hence the importance of permanent observation from the point of operation and technical state changes. In order for object to be fully diagnosable, not only signals of its operation and environment should be considered, but also knowledge of people exploiting the object.

Apparently, only properly adjusted and “healthy” objects are reliable and may ensure required safety at any moment of use. [2,4,6,7]

Initial draft of new diagnostic method was created that would consider all the aforementioned signals and expression in form of points would be more eligible and simple for analysis.

Assumptions of an innovatory method of using diagnostic data (presented in form of points) is based on fact that for each signal change (depending on its value and moment of occurrence) proper amount of points set by the experts is assigned. In previous methods of object aptitude research the points are summed and the range in which object is as well as its status and wear extent is determined. Proposed method is based on using point signals for determining technical and control states and, subsequently, its reliability and safety from coupled interaction. This will allow for constant control of object reliability and safety conditions during exploitation. The described method may prove very useful due to presenting object global exploitation conditions using a_R , a_T , a_B , a_N parameters and hence allowing for forecasts on how the object should be used and when should it be serviced (repaired, refurbished).

2. Diagnostic research

Research was conducted on diagnostic station of Komunalne Przedsiębiorstwo Komunikacji Miejskiej w Białymstoku. Research was conducted on bus engines made by SOLARIS. The objective of research was obtaining diagnostic data concerning its technical state DK and signals concerning environment influence status U.

In order to obtain diagnostic data, the following devices were used:

- opacimeter – measurement of exhaust fumes fogging [1/m];
- sound level meter – noise measurement [dB];
- diagnostic station (chassis dynamometer) – fuel use measurement [l/100km], braking force of each bus axis [kN];
- expert knowledge.

In 2012 years, there were three diagnostic tests buses U12 Solaris with numbers 301, 303 and 304.

During the research significant database concerning object – bus - diagnostic signals was collected (Tab.1.) D_{M1} – average fuel use without heating [l/100km], D_{M2} – average fuel with heating [l/100km], D_{M3} – fogging value in engine blow [1/m], D_{M4} – fogging value during engine operation [1/m], D_{M5} – noise peak value [dB], D_{M6} – noise average value [dB], D_{M7} – braking force value on front axis – left wheel [kN], D_{M8} – braking force value on front axis – right wheel [kN], D_{M9} –

percent value of difference between braking forces of left and right wheel of front axis [%], D_{M10} – braking force value on rear axis – left wheel [kN], D_{M11} – braking force value on rear axis – right wheel [kN], D_{M12} – percent value of difference between braking forces of left and right wheel of rear axis [%], D_{M13} – braking force value on middle axis (articulated bus) – left wheel [kN], D_{M14} – braking force value on middle axis (articulated bus) – right wheel [kN], D_{M15} – percent value of difference between braking forces of left and right wheel of middle axis (articulated bus) [%], D_{M16} – number of clatters, number of unattended stalls (on neutral gear), number of stalls (during operation), bus mileage [km] and environment data: U_{P1} – temperature [°C], U_{P2} – wind speed [m/s], U_{P3} – pressure [hPa], U_{P4} – precipitation [mm/12h] and, from questionnaire among drivers further environment signals – U_{K1} – job seniority [years], U_{K2} – number of hours of work in a month [h], U_{K3} – driving smoothness (braking, accelerating), U_{D1} – number of stops, U_{D2} – route length, U_{D3} – surface and lay of the land.

Tab. 1. Recorded signals of operation and environment

Signal s	Signals of operation											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
D_{M1}	35,7	35,7	35,7	35,7	35,7	35,7	33,66	33,66	33,66	35,1	35,1	35,1
D_{M2}	35,7	35,7	35,7	35,7	35,7	35,7	33,66	33,66	33,66	35,1	35,1	35,1
D_{M3}	0,37	0,37	0,37	0,37	0,37	0,37	0,45	0,45	0,45	0,42	0,42	0,42
D_{M4}	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03	0,03	0,03	0,03
D_{M5}	95	95	95	95	95	95	94	94	94	91,9	91,9	91,9
D_{M6}	92	92	92	92	92	92	90	90	90	91	91	91
D_{M7}	12	12	12	12	12	12	11,4	11,4	11,4	8,8	8,8	8,8
D_{M8}	13,2	13,2	13,2	13,2	13,2	13,2	12	12	12	12,6	12,6	12,6
D_{M9}	9	9	9	9	9	9	5	5	5	29	29	29
D_{M10}	15,8	15,8	15,8	15,8	15,8	15,8	12,5	12,5	12,5	11,9	11,9	11,9
D_{M11}	14,7	14,7	14,7	14,7	14,7	14,7	12,3	12,3	12,3	13,3	13,3	13,3
D_{M12}	6	6	6	6	6	6	1	1	1	10	10	10
D_{M13}	0	0	0	0	0	0	0	0	0	0	0	0
D_{M14}	0	0	0	0	0	0	0	0	0	0	0	0
D_{M15}	0	0	0	0	0	0	0	0	0	0	0	0
D_{E1}	0	0	0	0	1	0	0	0	0	3	0	0
D_{E2}	0	1	0	0	0	3	0	0	0	3	0	0
D_{E3}	0	0	0	2	0	0	0	0	0	3	0	0
D_{E4}	215582	217982	220102	222669	225125	227358	229758	235776	238074	240202	242550	244895
U_{K1}	4	24	24	10	10	16	16	16	16	4	4	4
U_{K2}	125	164	160	179	146	187	110	144	170	144	154	185
U_{K3}	5	5	5	5	5	6	6	4	4	4	7	7
U_{D1}	33	21	21	21	40	40	40	40	40	29	29	29
U_{D2}	15	9,4	9,4	9,4	16,9	16,9	16,9	16,9	16,9	14,6	14,6	14,6
U_{D3}												
U_{P1}												
U_{P2}												
U_{P3}												
U_{P4}												

Tab. 2. Expert assessment of state of engine, environment and driver (expert – driver)

Signals	Signal name	group weight	weight in group	number
D _{M1}	average fuel consumption without heating [l/100km]	1	6	3
D _{M2}	average fuel consumption with heating [l/100km]		5	4
D _{M3}	fogging value in engine blow [1/m]		4	3
D _{M4}	fogging value in engine operation [1/m]		3	3
D _{M5}	noise peak value [dB]		2	5
D _{M6}	noise average value [dB]		1	6
D _{E1}	clatter	2	1	3
D _{E2}	unattended stall		2	2
D _{E3}	stall		3	4
D _{E4}	mileage		4	1
U _{K1}	job seniority [year]	3	3	2
U _{K2}	number of work hours in month [h]		2	1
U _{K3}	driving culture (smoothness)		1	1
U _{D1}	numbers of stops	4	1	1
U _{D2}	route length		2	2
U _{D3}	surface and lay of land		3	1
U _{P1}	environment temperature	5	4	1
U _{P2}	wind		3	1
U _{P3}	air pressure		2	1
U _{P4}	rainfall		1	1

Signals U_{P1}÷ U_{P4} are empty in Tab.1., filled values are in Tab.4. (reduced to point value). Expert assessments of engine, driver and environment states (experts are driver and diagnostician) were obtained through questionnaire. Questions were asked on the most important phenomena, processes, signals and other facts concerning object and its environment – Tab.2. and 3.

Interviewees (among bus drivers) answered the questions by putting values from 1 to 6 concerning importance of information (1 – least important information).

Tab. 3. Expert assessment of state of engine, environment and driver (expert – diagnostician)

Signal s	Signal name	Ewp 1	N	N+5 %	N+10 %	N+15 %	N+20 %
D _{M1}	average fuel consumption without heating [l/100km]	6	1	2	4	8	20
D _{M2}	average fuel consumption with heating [l/100km]	5	1	2	4	8	20
D _{M3}	fogging value in engine blow [1/m]	4	1	2	4	8	20
D _{M4}	fogging value in engine operation [1/m]	3	2	4	6	8	20
D _{M5}	noise peak value [dB]	2	1	2	3	4	5
D _{M6}	noise average value [dB]	1	5	7	10	15	30

Signal s	Signal name		Ewp 1	<1 %	1- 10%	10- 20%	20- 30%	>30 %	
D _{M7}	braking force value on front axis - left wheel [kN]		-	-	-	-	-	-	
D _{M8}	braking force value on front axis - right wheel [kN]		-	-	-	-	-	-	
D _{M9}	percent difference between D _{M7} and D _{M8} [%]		3	1	2	3	10	20	
D _{M10}	braking force value on rear axis - left wheel [kN]		-	-	-	-	-	-	
D _{M11}	braking force value on rear axis - right wheel [kN]		-	-	-	-	-	-	
D _{M12}	percent difference between D _{M10} and D _{M11} [%]		3	1	2	3	10	20	
D _{M13}	braking force value on middle axis - left wheel [kN]		-	-	-	-	-	-	
D _{M14}	braking force value on middle axis - right wheel [kN]		-	-	-	-	-	-	
D _{M15}	percent difference between D _{M13} and D _{M14} [%]		2	1	2	3	10	20	
Signals	Signal name		Ewp1	0-2		2-5		>5	
D _{E1}	clatter		2	1		5		20	
D _{E2}	unattended stall		4	1		5		20	
D _{E3}	stall		6	1		5		20	
Signals	Signal name		Ewp1	< 500 k		500 k - 1 mln		>1 mln	
D _{E4}	mileage		8	0,2		0,4		0,6	
Signals	Signal name		Ewp1	< 5 years		5-12 years		>12 years	
U _{K1}	job seniority [year]		9	0,3		0,1		0,2	
Signals	Signal name		Ewp1	< 140 h		140-180 h		>180 h	
U _{K2}	number of work hours in month [h]		6	0,2		0,1		0,3	
Signals	Signal name		Ewp1	<10		10-15		>15	
U _{K3}	driving culture (smoothness)		3	1		4		10	
Signals	Signal name		Ewp1	<15		15-30		>30	
U _{D1}	numbers of stops		4	0,1		0,2		0,3	
Signals	Signal name		Ewp1	<4 km		4-8 km		> 8km	
U _{D2}	route length		8	0,1		0,2		0,3	
Signals	Signal name		Ewp1	good surface		medium surface		poor surface	
U _{D3}	surface and lay of land		12	0,1		0,3		0,5	
Signals	Signal name		Ewp1	< -10 °C	-10 -10 °C	10-20 °C	20-30 °C	>30 °C	
U _{P1}	environment temperature		20	0,3	0,2	0,1	0,2	0,3	
Signals	Signal name		Ewp1	<28,4 km/h		28,4-61,56 km/h		>61,56 km/h	
U _{P2}	wind		15	0,1		0,5		1	
Signals	Signal name		Ewp1	<994,66 hPa		996,66-1020 hPa		>1020 hPa	
U _{P3}	air pressure		10	0,1		0,5		1	
Signals	Signal name	Ewp1	no precipitation	without significant rainfall		light rain	rain	light snow	snow
U _{P4}	rainfall	5	0,1	0,2		0,3	0,4	0,5	0,6

The same tests (Tab. 1.) were carried out two other buses.

3. Determination of parameter of technical and control states

Signals $D_{M1}, D_{M2}, D_{M3}, \dots, D_{M15}, D_{M16}$ and $U_{P1}, U_{P2}, U_{P3}, U_{P4}, U_{D1}, U_{D2}, U_{D3}, U_{P1}, U_{P2}, U_{P3}, U_{P4}$, are of various physical nature, and hence must be reduced to a homogenous form $D_{M1P}, D_{M2P}, D_{M3P}, \dots, D_{M15P}, D_{M16P}$ and $U_{K1P}, U_{K2P}, U_{K3P}, U_{K4P}, U_{P1P}, U_{P2P}, U_{P3P}, U_{P4P}$. Basing on expert knowledge (driver, diagnostician, Tab.2. and 3.) all signals might be reduced to „point form” (number). The possibility exists to determine net (complex) signals of object and environment [8].

$$D_k = \sqrt{D_{M1P}^2 + D_{M2P}^2 + D_{M3P}^2 + D_{M4P}^2 + D_{M5P}^2 + \dots + D_{M16P}^2} \quad (1)$$

$$U = \sqrt{U_{K1P}^2 + U_{K2P}^2 + U_{K3P}^2 + U_{K4P}^2 + U_{D1P}^2 + U_{D2P}^2 + U_{D3P}^2 + U_{D4P}^2 + U_{P1P}^2 + U_{P2P}^2 + U_{P3P}^2 + U_{P4P}^2} \quad (2)$$

Such obtained knowledge and database (Tab.1.) including expert weights (Tab.2. and 3.) might be reduced to homogenous point form – Tab.4. (such form was used in USA in helicopter diagnostic process). Correlation of all data, i.e. engine, pilot and environment state gives total point assessment of bus state. Hence the pilot knowing that his aircraft has a total of 40 points will know that system of aircraft + pilot + environment is insusceptible to undesired failure accidents. [10]

After processing all the signals, general point table is obtained – Tab.4. that is a base for calculations connected to determining diagnostic parameters and use quality (diagnostic and utility signals are reduced to diagnostic parameters and use quality parameters from coupled interaction equations). In coupled interaction equations a fact is used that use is an environment for technical state and technical state is an environment for use [1,2,9,11].

$$\frac{dD_k}{dt} = a_T D_k + b_T U \quad (3)$$

$$\frac{dU}{dt} = a_R U + b_R D_k \quad (4)$$

where: U – operation status variable (use signal), D_k – bus technical state signal (environment), a_R – operation status parameter, b_R – parameter of influence of technical state on control state, a_T – bus technical state parameter, b_T – parameter of influence of control state on bus technical state.

According to rules of static and dynamic identification [9], the following is obtained from equation (3):

$$\hat{a}_T = \frac{\sum \Delta D_k \Delta U}{\sum U^2} \quad (5)$$

$$a_T = \frac{\Delta D_k}{\frac{\Delta \Theta}{resurs} (D_k + \hat{a}_T U)} \quad (6)$$

Parameter a_T describes system technical state and depends on diagnostic signals and signals resulting from driver actions and environment.

Tab. 4. Point signals of operation and environment

Point signals of operation												
Signals	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
D _{M1P}	6	6	6	6	6	6	6	6	6	6	6	6
D _{M2P}	5	5	5	5	5	5	5	5	5	5	5	5
D _{M3P}	4	4	4	4	4	4	4	4	4	4	4	4
D _{M4P}	6	6	6	6	6	6	6	6	6	6	6	6
D _{M5P}	2	2	2	2	2	2	2	2	2	2	2	2
D _{M6P}	5	5	5	5	5	5	5	5	5	5	5	5
D _{M9P}	6	6	6	6	6	6	6	6	6	30	30	30
D _{M12P}	6	6	6	6	6	6	3	3	3	6	6	6
D _{M15P}	0	0	0	0	0	0	0	0	0	0	0	0
D _{E1P}	2	2	2	2	2	2	2	2	2	10	2	2
D _{E2P}	4	4	4	4	4	20	4	4	4	20	4	4
D _{E3P}	6	6	6	6	6	6	6	6	6	30	6	6
D _{E4P}	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6
U _{K1P}	2,7	1,8	1,8	0,9	0,9	1,8	1,8	1,8	1,8	2,7	2,7	2,7
U _{K2P}	1,2	0,6	0,6	0,6	0,6	1,8	1,2	0,6	0,6	0,6	0,6	1,8
U _{K3P}	3	3	3	3	3	3	3	3	3	3	3	3
U _{D1P}	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
U _{D2P}	1,6	0,8	0,8	0,8	2,4	2,4	2,4	2,4	2,4	1,6	1,6	1,6
U _{D3P}	3,6	1,2	1,2	1,2	3,6	3,6	3,6	3,6	3,6	3,6	3,6	3,6
U _{P1P}	4	5	3	3	3	4	5	4	3	3	4	4
U _{P2P}	2	2	2	2	2	2	2	2	2	2	2	2
U _{P3P}	3	3	4	2	4	2	3	4	4	3	3	3
U _{P4P}	2	3	2	2	2	3	2	2	1	2	1	2

According to rules of static and dynamic identification [9], the following is obtained from equation (4):

$$\hat{a}_R = \frac{\sum \Delta D_K \Delta U}{\sum D_K^2} \quad (7)$$

$$a_R = \frac{\Delta U}{\frac{\Delta \Theta}{resurs} (U + \hat{a}_R D_K)} \quad (8)$$

Parameter a_R describes operation status of control states of engine-environment system and depends mostly on driver actions and influence of object technical state on this action.

As seen in presented results (Tab. 5, 6, 7), both a_T and a_R parameters changes. This may be interpreted that state parameters are “chosen” from base value and will approach 0. The harder are the conditions in which object (bus) is operating, the faster will be the decrease of technical state parameter as well as adjustment parameter until it is fully exhausted.

Tab. 5. Determination of technical and control parameters bus No. 301

Month	Work time θ	D_K	U	$\Delta\theta$	ΔDK	AU	$AD_K \cdot AU$	$\Sigma AD_K \cdot AU$	U^2	ΣU^2	D_K^2	ΣD_K^2	$a \cdot T$	$a \cdot R$	a_T	a_R	a_T^*	a_R^*	
I	215582	16.51	8.35	0	0	0	0	0	69.68	69.68	272.56	272.56	0	0					
II	217982	33.02	16.11	2400	16.51	7.76	128.11	128.11	259.44	329.12	1090.24	1362.80	-0.39	-0.09	257.16	248.64	0.26	0.25	
III	220102	49.53	23.34	2120	16.51	7.23	119.43	247.54	544.81	873.94	2453.04	3815.84	-0.28	-0.06	181.45	169.53	0.18	0.17	
IV	222669	66.04	29.00	2567	16.51	5.66	93.37	340.91	840.82	1714.76	4360.96	8176.80	-0.20	-0.04	106.70	83.95	0.11	0.08	
V	225125	82.55	36.95	2456	16.51	7.95	131.29	472.20	1365.25	3080.00	6814.00	14990.80	-0.15	-0.03	87.43	94.27	0.09	0.09	
VI	227358	108.17	44.93	2233	25.62	7.99	204.61	676.81	2019.12	5099.12	11700.83	26691.63	-0.13	-0.03	112.27	84.76	0.11	0.08	
VII	229758	123.84	53.38	2400	15.67	8.45	132.42	809.23	2849.95	7949.07	15336.53	42028.16	-0.10	-0.02	55.14	69.04	0.06	0.07	
VIII	232273	139.51	61.62	2515	15.67	8.23	129.04	938.27	3796.97	11746.04	19463.34	61491.50	-0.08	-0.02	46.29	55.04	0.05	0.06	
IX	234571	155.18	69.42	2298	15.67	7.80	122.30	1060.57	4819.69	16565.73	24081.28	85572.79	-0.06	-0.01	45.24	50.31	0.05	0.05	
X	236699	204.99	76.78	2128	49.81	7.36	366.35	1426.91	5895.10	22460.83	42019.53	127592.32	-0.06	-0.01	116.96	46.40	0.12	0.05	
XI	239047	238.70	84.59	2348	33.71	7.81	263.33	1690.25	7155.57	29616.40	56977.49	184569.80	-0.06	-0.01	61.39	40.37	0.06	0.04	
XII	241392	272.41	93.01	2345	33.71	8.42	283.87	1974.12	8651.01	38267.42	74208.56	258778.36	-0.05	-0.01	53.72	39.49	0.05	0.04	
													Σ			1123.78	981.80	1.12	0.98

Tab. 6. Determination of technical and control parameters bus No. 303

Month	Work time θ	DK	U	$\Delta\theta$	ADK	ΔU	$\Delta DK^* \Delta U$	$\sum \Delta DK^* \Delta U$	U^2	$\sum U^2$	D_K^2	$\sum D_K^2$	a^*T	a^*R	aT	aR	aT^*	aR^*
I	208928	33,71	6,30	0	0	0	0	0	39,68	39,68	1136,56	1136,56	0	0				
II	211052	67,43	14,13	2124	33,71	7,83	263,94	263,94	199,61	239,29	4546,24	5682,80	-1,10	-0,05	306,17	335,19	0,31	0,34
III	213208	101,14	20,52	2156	33,71	6,40	479,55	479,55	421,22	660,51	10229,04	15911,84	-0,73	-0,03	181,32	169,74	0,18	0,17
IV	215729	134,85	25,32	2521	33,71	4,79	161,63	641,18	641,00	1301,51	18184,96	34096,80	-0,49	-0,02	109,27	83,48	0,11	0,08
V	218085	168,56	33,42	2356	33,71	8,10	273,20	914,38	1117,01	2418,53	28414,00	62510,80	-0,38	-0,01	91,77	111,11	0,09	0,11
VI	220518	202,28	41,22	2433	33,71	7,80	263,06	1177,44	1699,48	4118,00	40916,16	103426,96	-0,29	-0,01	72,74	82,40	0,07	0,08
VII	223018	225,72	50,72	2500	23,44	9,50	222,60	1400,04	2572,56	6690,56	50949,58	154376,54	-0,21	-0,01	43,59	78,04	0,04	0,08
VIII	225517	249,16	60,08	2499	23,44	9,36	219,47	1619,52	3609,91	10300,47	62082,11	216458,65	-0,16	-0,01	39,13	64,35	0,04	0,06
IX	228308	272,61	69,07	2791	23,44	8,99	210,66	1830,17	4770,46	15070,93	74313,77	290772,42	-0,12	-0,01	31,79	47,80	0,03	0,05
X	230663	290,43	74,09	2355	17,82	5,02	89,43	1919,60	5488,88	20559,81	84347,11	375119,53	-0,09	-0,01	26,69	29,35	0,03	0,03
XI	232945	308,25	87,36	2282	17,82	13,27	236,47	2156,08	7631,24	28191,05	95015,56	470135,09	-0,08	0,00	25,90	67,66	0,03	0,07
XII	235336	326,07	100,99	2391	17,82	13,64	243,02	2399,10	10199,87	38390,92	106319,14	576454,23	-0,06	0,00	23,31	57,24	0,02	0,06
										$\sum$					951,68	1126,36	0,95	1,13

Tab. 7. Determination of technical and control parameters bus No. 304

Month	Work time θ	DK	U	$\Delta\theta$	ADK	ΔU	ADK $\cdot\Delta U$	Σ ADK $\cdot\Delta U$	U^2	ΣU^2	D_K^2	ΣD_K^2	a^*T	a^*R	aT	aR	aT*	aR*
I	212915	15.67	7.91	0	0	0	0	0	62.63	62.63	245.56	245.56	0	0				
II	215438	31.34	15.83	2523	15.67	7.92	124.12	124.12	250.73	313.36	982.24	1227.80	-0.40	-0.10	247.76	247.85	0.25	0.25
III	217535	47.01	29.94	2097	15.67	14.10	220.98	345.09	896.16	1209.51	2210.04	3437.84	-0.29	-0.10	194.25	266.67	0.19	0.27
IV	220058	62.68	37.08	2523	15.67	7.15	111.97	457.06	1375.01	2584.53	3928.96	7366.80	-0.18	-0.06	110.67	85.32	0.11	0.09
V	222527	78.35	45.18	2469	15.67	8.10	126.99	584.05	2041.68	4626.21	6139.00	13505.80	-0.13	-0.04	87.37	78.53	0.09	0.08
VI	224882	94.02	52.99	2355	15.67	7.80	122.27	706.32	2807.71	7433.92	8840.16	22345.96	-0.10	-0.03	74.78	66.25	0.07	0.07
VII	227238	111.84	61.03	2356	17.82	8.04	143.34	849.66	3724.83	11158.75	12508.71	34854.67	-0.08	-0.02	70.56	58.56	0.07	0.06
VIII	229693	129.66	68.98	2455	17.82	7.95	141.73	991.40	4758.92	15917.67	16812.38	51667.05	-0.06	-0.02	57.90	48.72	0.06	0.05
IX	232041	147.48	82.78	2348	17.82	13.79	245.81	1237.21	6852.38	22770.05	21751.17	73418.21	-0.05	-0.02	53.08	73.17	0.05	0.07
X	234410	163.90	96.29	2369	16.42	13.51	221.87	1459.08	9272.34	32042.39	26863.55	100281.77	-0.05	-0.01	43.45	60.75	0.04	0.06
XI	236897	180.32	103.04	2487	16.42	6.75	110.79	1569.87	10617.39	42659.78	32515.06	132796.83	-0.04	-0.01	37.40	26.89	0.04	0.03
XII	239384	196.74	110.89	2487	16.42	7.84	128.80	1698.67	12295.59	54955.37	38705.69	171502.51	-0.03	-0.01	34.15	28.96	0.03	0.03
Σ													101135	101.64	1.01	1.01	1.04

A comparison of the sum of the parameters a_T (Tab. 5, 6,7) can be said that the bus number 303 has the largest supply of technical condition (Σa_T is the smallest).

A comparison of the sum of the parameters a_R (Tab. 5, 6,7) can be said that the bus number 30 has the largest inventory of control or that the quality of life is the best - it is better for the driver (Σa_R is the smallest).

Knowing control a_R and technical a_T parameters as well as their dynamics, further parameters may be determined that may be connected to reliability and safety of engine (which may be continued in further works).

Due to collecting such extensive database in form of parameters a_R and a_T set, determination of reliability parameter $E(T)$ will be possible (what will significantly increase safety of people travelling and driving the vehicle).

4. Conclusion

Assumption of innovatory method of using diagnostic data (presented in form of points) was presented in the article. For each change of signal (depending on its value and moment of occurrence) proper amount of points set by the experts is assigned. In previous diagnostic method points are summed and, subsequently, range to which the object belong is determined as well as its state and exploitation extent [10]. Proposed method is based on using signals in form of points to determine parameters of technical and control states from coupled interaction equation [5,8,9].

Suggested point assessment allows greater group of people to make decisions on further fate of object, e.g. setting certain value limit for parameters a_T and a_R may lead to directing object for technical inspection. Assessment in form of points is simple and unequivocal for user (driver) and service (mechanic – diagnostician).

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