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ANALYSIS OF THE CONDITION OF A CAR DAMPER - IDENTIFICATION OF THE PARAMETERS OF DIAGNOSTIC PREMISES

Summary. The article presents the method of eliminating the number of diagnostic premises required for the purpose of diagnosing technical objects, as illustrated with a car damper. The method described in this article allows the extraction of components of a given technical object, selection of the diagnostic method, formalized notation of relations between the diagnostic premises and diagnostic inference simplification on the basis of the algorithms for searching graphs. For the purposes of preliminary identification of frequency range for further research, an analysis in the range 0÷10KHz was performed, with the use of estimator in the form of peak acceleration values.

ANALIZA STANU AMORTYZATORA SAMOCHODOWEGO - IDENTYFIKACJA PARAMETRÓW PRZESŁANEK DIAGNOSTYCZNYCH

Streszczenie. W artykule przedstawiono metodę eliminacji liczby przesłanek diagnostycznych wymaganych do celów diagnozy obiektów technicznych na przykładzie amortyzatora samochodowego. Opisana metoda umożliwia ekstrakcję podsystemów składowych badanego obiektu technicznego, wybór metody diagnozy, wykonanie sformalizowanego zapisu relacji pomiędzy przesłankami diagnostycznymi oraz uproszczenie wnioskowania na bazie algorytmów do przeszukiwania grafów. W celu wstępnej identyfikacji zakresu częstotliwości do dalszych badań wykonano analizę w przedziale 0÷10KHz, z użyciem estymatora w postaci wartości szczytowej przyspieszenia.

1. Introduction

Modern automated production is a source of many challenges posed to the quality control. Variability of production, product lifetime reduction as well as lowering downtime and costs produce a strong incentive to develop diagnostic methods based on the versatile devices with the possibility of implementing the advanced data processing algorithms.

Automatic quality control of car components requires a number of criteria to be met. The following are the most important: speed and reliability (due to particularly restrictive criteria laid down in a quality control standard ISO/TS 16949:2002);

resistance to external interferences and operating errors; possibility of fast learning, changing or modifying the applied algorithms.

There is a significant problem that occurs in case of the elements classified into the group of complex dynamic systems. Car dampers were used as an example of the verification of elements classified into this group.

Experimental tests involving car mufflers are usually carried out with regard to vibration and high-frequency acoustic emission with frequency lower than 1kHz [1÷4, 10÷12]. There is, however, no data concerning the automatic validation of damper condition on production lines.

The basic aim of the research is the identification of method of in-line damper diagnostics, estimation of the criteria for evaluating the condition on the basis of analysing diagnostic premises [5,6] obtained with the use of the available industrial methods and a proposal of formalization of the classifier contributing to the identification of failures.

In order to meet the requirements of the production process the following measures have been taken: configuration of the workbench based on pneumatic drives with electric control; one-time measurement of the condition of the examined element; tests aiming at the identification of damper defects [7÷9], reducing the range of defects to the valve disc defects and base valves (mechanical defects are inspected visually).

2. Selection of the measurement method and reducing the number of diagnostic premises

According to the definition of mechatronics, all technical systems (production lines, machines and their parts) can be divided into four main subsystems in the form of mechanical and electric structures, internal subsystem for data exchange and interface for data exchange between different devices in the system.

On the basis of the presented classification, a universal graph of subsystems being functional elements of the considered system and their mutual dependencies has been developed (Fig. 1a). The presented graph is used for the identification of relations between the determined elements and facilitates the use of the required level of structural analysis. Elimination of vertexes allows narrowing the list of elements in the collection of diagnostic methods, reducing the number of defects and facilitating the process of concluding. In case of the classic car damper system, according to the adopted constraints, it takes the form of the isolated vertex (Fig. 1b) corresponding solely to the mechanical structure.

The selection of measurement method and tools has been made according to the adopted method of reducing the available premises of the monitored systems, at the same time maintaining the required level of diagnosis quality.

The basic groups of car damper damages include three main premises allowing the condition diagnosis, i.e. oil leakages, mechanical damages and noise. Typical reasons of car damper damages may be divided into the following groups: contamination of hydraulic fluid (wear particles of a disc valve, metal chips, contamination of fluid as a result of low quality filtration); irregularities in opening or closing valve discs (resulting from material damages, construction defects or dirt deposits on disc surfaces); mechanical damages (piston rod buckling, cracks and dents on the hydraulic damper case) resulting from the wrong selection of methods or irregularities in the assembly process, as well as for operational reasons.

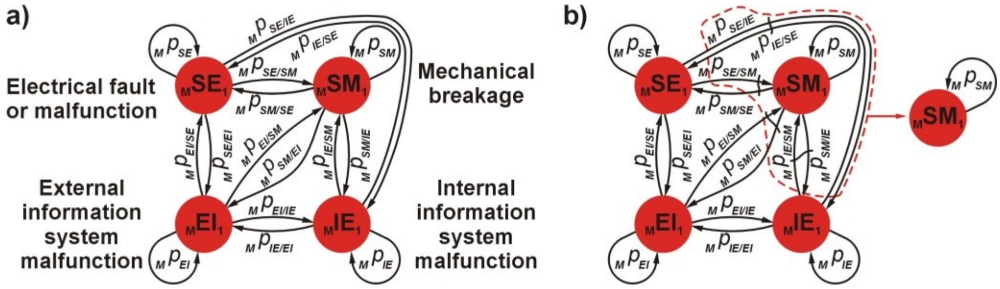

Fig. 1. General graph of the considered system: a) dependencies identified in relation to the development of defects, b) structures of the car damper; where: $_{M}SM$ – mechanical structure, $_{M}SE$ – electric structure, $_{M}IE$ – internal stream monitoring information exchange, $_{M}EI$ – external information exchange system, $_{M}p_{a(i,j)b(i,j)}$ – element $a_{(i,j)}$ on element $b_{(i,j)}$ impact coefficient

Due to limiting the area of damage identification to the disc valve unit of the base, the cause and effect graph of the basic mechanical damages of the considered element has been created (Fig. 2). In the first stage, the industrial methods of diagnosing the condition of dampers on production lines (Fig. 2a), allowing controlling the mechanical subsystem of damper structure, have been compiled. Then, the graph has been reduced, with the objective function aiming at defining the method allowing for the unambiguous condition diagnosis with the minimal number of diagnostic premises in relation to the adopted constraints (Fig. 2b).

The graph analysis shows that the method of measuring the vibration parameters will enable fulfilment of the requirements. The increase of vibration may be explained by many phenomena connected with mechanical damages. The selection of vibration method has been made on the basis of the following features of mechanical damages in the phase of their development, causing: increase in the level of vibration and noise; increase of clearance; degradation of seals and oil leaks.

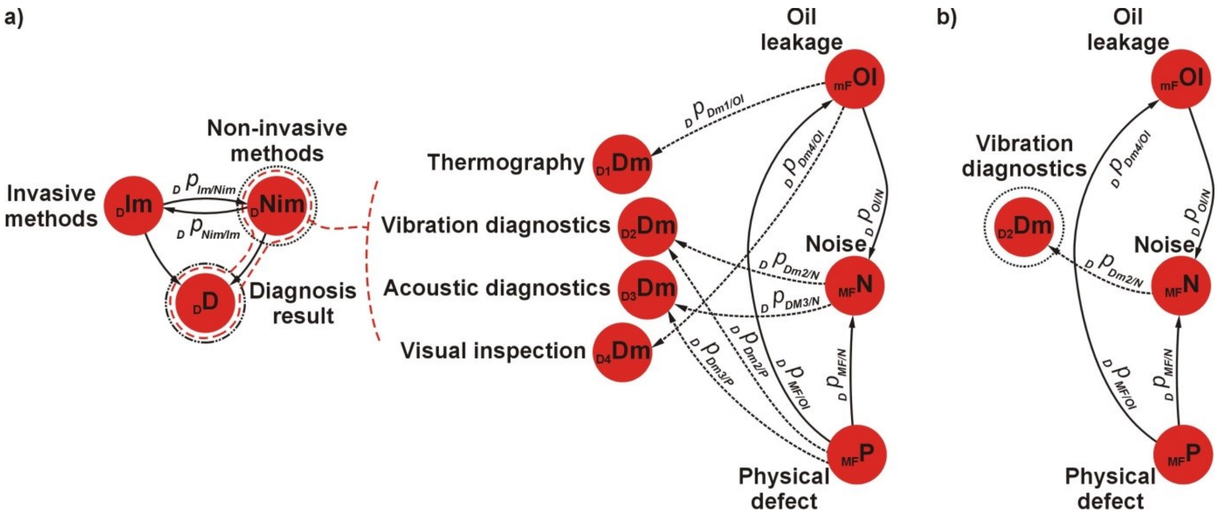

Fig. 2. A graph of available methods used for car damper diagnostics: a) complete graph, b) a graph after the reduction of paths

An identified graph is a formal notation of relations between the premises that enable the damage detection.

3. Configuration of a test workbench

Identification has been made at the preconfigured measurement station built on the basis of industrial elements, in full compliance with the requirements of the actual quality control process so as to minimize the influence of construction modifications and the nature of a driven force on the form of pre-determined condition classification thresholds.

The workbench (Fig. 3a) has been configured using the actuator being a UNIVER RPS0400002S double-acting pneumatic cylinder operated with the Parker 5/2 P2LAX511EENDDB49 bistable valve. The operation speed of cylinder movement in the direction of the measurement and the idle movement (retract) has been set using the throttle/check valves.

In order to minimize the effect of working medium compressibility and obtain the fixed value of driven force, a precise pressure regulator Parker R210G02C has been applied (controls output pressure to within 0.1% accuracy). Manometers have been used to control the pressure (set using the regulators and in cylinder chambers).

A damper has been mounted in the bush with the base on the lower surface (the damper axis positioned vertically, downward measurement movement (force induced by pressure on the sub-piston chamber of the cylinder). Configuration of electric control with actuator has been performed as cylinder indirect control.

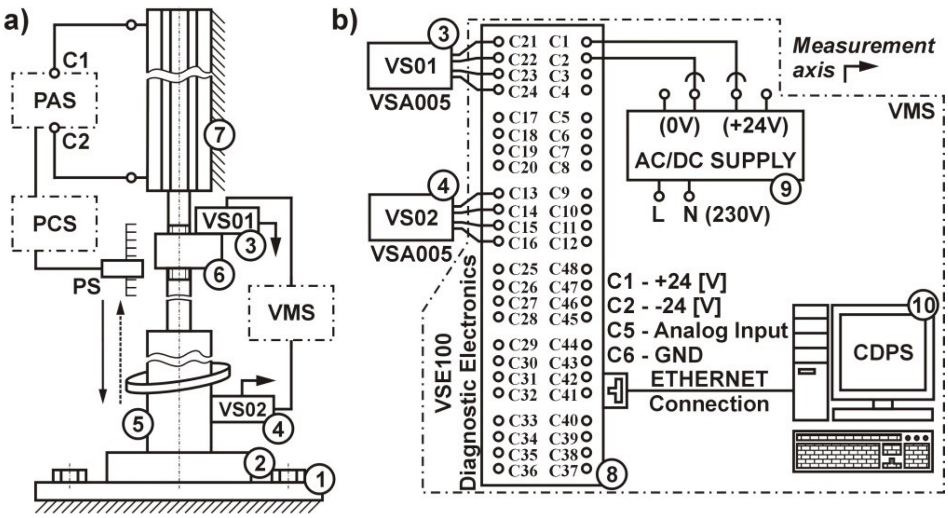

Fig. 3. Schematic diagram of a measurement station to determine amplitude characteristics of the dampers: a) mechanical structure, b) configuration of the measurement system, where: 1 – mounting plate, 2 – adapter, 3, 4 – vibration sensors (VS01, VS02) , 5 – damper, 6 – connector, 7 – pneumatic cylinder, 8 – measurement unit, 9 – power supply, 10 – computer with software, VMS – vibration measurement system, PAS – pneumatic actuator system, PCS – pneumatic control system, CDPS – computer data processing system, PS – position sensor

As a result of the analysis, it has been decided to use the measurements of vibration characteristics of the examined element enabled by the four-channel vibration measurement module VSE100 with interface Ethernet TCP/IP and two sensors VSA003 (by the IFM). The data obtained in the measurements has been registered using the software OCTAVIS VES003.

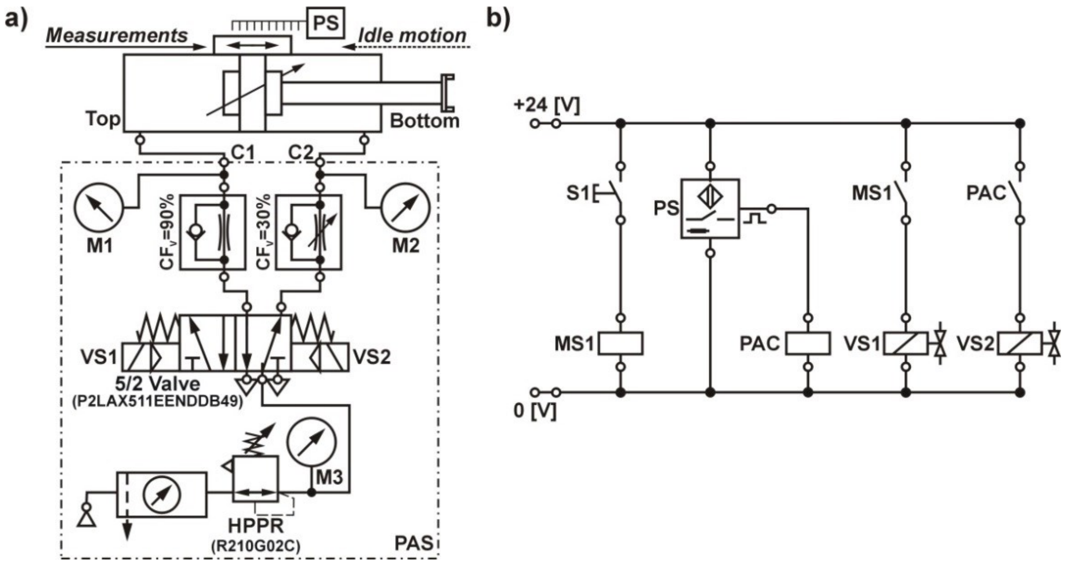

Fig. 4. Schematic functional diagram of the configuration: a) of the pneumatic drive, b) of electric connections to control the actuator

The measurement of vibration has been performed using two sensors (Fig. 3a) mounted according to the orientation of axes in the following directions: vertical (sensor VS01) – mounted using a screw attached to the support at the end of the pneumatic cylinder piston rod; horizontal (sensor VS02) – mounted on the cylindrical surface of the damper tube (bipolar magnet).

In order to extract the values of diagnostic identifiers, the analysis of vibration parameters for 65 dampers of the same production batch (including 10 dampers with defects) has been performed. Then, a classifier with two parameters has been identified: frequency range (identification of defect source); amplitude values (determining the threshold of classification into the group of products of full value or damaged products).

A classifier may be presented as a formula:

$$C_{OS} = \langle O, A, V_s, f_C \rangle \tag{1}$$

where:

O – a finite set of objects,

A – a finite set of attributes,

$V_s = \bigcup_{a \in A} V_a$ - set of attribute values,

V_a – domain of the "v" attribute,

f_C – the decision function, defined within the following rules:

$$f: O \times A \rightarrow \delta(V_s), \textit{ where: } \bigvee_{\substack{o \in O \\ a \in A}} f(o, a) \in V_a \tag{2}$$

4. A broad analysis of characteristic frequencies of a damper

On the basis of the analysis of the available frequency range 0÷10 kHz (constraints of the available measurement track), 31 characteristic frequencies (so called factors) with window width equal to 15% of the selected central frequency (Fig. 5) have been defined.

Table 1

Values of the characteristic parameters of the defined frequency factors; where: $b_{na}=F_{Upper\_(n-1)}-F_{Lower\_(n)}$, n – ordinal number of the frequency factor, F_F – Frequency factor, F_{width} – frequency window width

F_F No.	Frequencies [Hz]			Spectral lines			F_{width} [Hz]	b_{na} [Hz]
	$F_{Central}$	F_{lower}	F_{Upper}	$L_{Central}$	L_{Lower}	L_{Upper}		
1st	14	11,9	16,1	1,15	0,97	1,32	4,2	-11,9
2nd	25	21,3	28,8	2,05	1,74	2,36	7,5	-5,2
3rd	37	31,5	42,6	3,03	2,58	3,49	11,1	-2,7
4th	49	41,7	56,4	4,01	3,41	4,62	14,7	0,9
5th	62	52,7	71,3	5,08	4,32	5,84	18,6	8,4
6th	74	62,9	85,1	6,06	5,15	6,97	22,2	12,0
7th	86	73,1	98,9	7,05	5,99	8,10	25,8	15,6
8th	98	83,3	112,7	8,03	6,82	9,23	29,4	19,2
8th	110	93,5	126,5	9,01	7,66	10,36	33,0	7,5
10th	140	119,0	161,0	11,47	9,75	13,19	42,0	15,7
11th	171	145,4	196,7	14,01	11,91	16,11	51,3	19,9
12th	208	176,8	239,2	17,04	14,48	19,60	62,4	31,0
13th	245	208,3	281,8	20,07	17,06	23,08	73,5	21,7
14th	306	260,1	351,9	25,07	21,31	28,83	91,8	40,0
15th	367	312,0	422,1	30,06	25,56	34,57	110,1	37,9
16th	452	384,2	519,8	37,03	31,47	42,58	135,6	52,3
17th	550	467,5	632,5	45,06	38,30	51,81	165,0	61,3
18th	672	571,2	772,8	55,05	46,79	63,31	201,6	77,5
19th	818	695,3	940,7	67,01	56,96	77,06	245,4	89,8
20th	1001	850,9	1151,2	82,00	69,70	94,30	300,3	113,3
21st	1221	1037,9	1404,2	100,02	85,02	115,03	366,3	127,5
22nd	1502	1276,7	1727,3	123,04	104,59	141,50	450,6	170,1
23rd	1832	1557,2	2106,8	150,08	127,57	172,59	549,6	196,9
24th	2247	1910,0	2584,1	184,07	156,46	211,69	674,1	249,1
25th	2747	2335,0	3159,1	225,03	191,28	258,79	824,1	305,6
26th	3357	2853,5	3860,6	275,01	233,76	316,26	1007,1	373,8
27th	4102	3486,7	4717,3	336,04	285,63	386,44	1230,6	463,1
28th	5005	4254,3	5755,8	410,01	348,51	471,51	1501,5	547,0
29th	6128	5208,8	7047,2	502,01	426,71	577,31	1838,4	675,6
30th	7496	6371,6	8620,4	614,07	521,96	706,18	2248,8	837,8
31st	9156	7782,6	10529,4	750,06	637,55	862,57	2746,8	-

Peak values of the registered acceleration have been obtained on the basis of band pass filtration within the range of the defined scopes.

The adopted assumption of the fixed percentage value of the window width makes the width of frequency range increase according to the increasing value of central frequency.

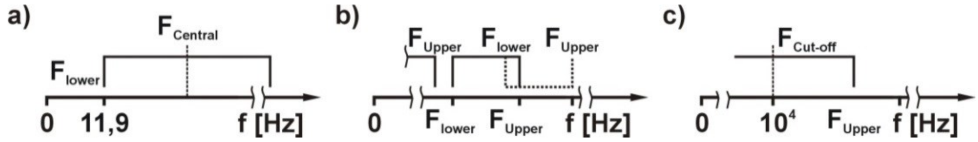

Fig. 5. Possible solutions of frequency range set for the measurements: a) at the beginning of the measurement range, b) within the range 0÷10kHz, c) at the end of the measurement range

Bands in the defined frequency ranges have been determined in a way enabling covering the entire frequency range 0÷10KHz (14Hz for the first sub-object and 9156Hz for the last one).

The actual range of the monitored frequency values falls within the range 11.9Hz÷10kHz (Tab. 1). The blind spots between the identified frequency factors do not influence the result of the defect identification due to reducing the search area to defects of valve disc and valve components, whose characteristic defect premises are expected within the frequency range 600÷1200Hz.

5. Results of the tests at workbenches

In order to identify the characteristic frequency range, a test involving 55 dampers without damages and 10 dampers with the identified disc valve damages has been undertaken in two independent measurement series. In each series, the measurement was taken with a time interval enabling stabilizing the temperature of hydraulic fluid and preventing the influence of oil foaming.

A peak value of vibration acceleration has been chosen as the parameter to be measured, due to the nature of the examined phenomena and the possibility of identifying the irregularities of the disc valve operation that directly influences the fluency of piston rod movement.

The presented test results have been obtained by means of averaging the single unit measurement values, in order to achieve the classification thresholds for damaged products and characteristic frequency range for the considered type of damage.

For the purpose of preliminary verification of test results reproducibility in particular measurement series, calculations of correlation coefficient have been performed. The reproducibility verification test has been carried out in order to select the optimal place to mount the measurement sensor.

The analysis indicates that the characteristics curves registered by sensor VS01 are characterized by greater reproducibility of curves obtained in the measurement phase of dampers with defects (Tab. 2, 3).

Table 2
Correlation coefficients for the measurements of dampers with defects (sensor VS01)

	1-st measurement serie					2-nd measurement serie				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
No. 1	x	0,820	0,881	0,894	0,900	x	0,949	0,900	0,939	0,940
No. 2	0,820	x	0,863	0,859	0,824	0,949	x	0,892	0,946	0,960
No. 3	0,881	0,863	x	0,863	0,805	0,900	0,892	x	0,884	0,864
No. 4	0,894	0,859	0,863	x	0,874	0,939	0,946	0,884	x	0,937
No. 5	0,900	0,824	0,805	0,874	x	0,940	0,960	0,864	0,937	x

Table 3
Correlation coefficients for the measurements of dampers with defects (sensor VS02)

	1-st measurement serie					2-nd measurement serie				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
No. 1	x	0,897	0,868	0,883	0,914	x	0,895	0,891	0,938	0,901
No. 2	0,897	x	0,911	0,889	0,865	0,895	x	0,936	0,937	0,930
No. 3	0,868	0,911	x	0,861	0,857	0,891	0,936	x	0,924	0,930
No. 4	0,883	0,889	0,861	x	0,886	0,938	0,937	0,924	x	0,957
No. 5	0,914	0,865	0,857	0,886	x	0,901	0,930	0,930	0,957	x

Table 4
Correlation coefficients for the measurements of dampers without defects (sensors VS01 and VS02)

	1-st measurement serie					2-nd measurement serie				
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5
No. 1	x	0,852	0,847	0,894	0,857	x	0,866	0,858	0,917	0,859
No. 2	0,852	x	0,857	0,866	0,781	0,866	x	0,866	0,906	0,901
No. 3	0,847	0,857	x	0,868	0,882	0,858	0,866	x	0,899	0,860
No. 4	0,894	0,866	0,868	x	0,883	0,917	0,906	0,899	x	0,903
No. 5	0,857	0,781	0,882	0,883	x	0,859	0,901	0,860	0,903	x

A opposite dependency may be observed in case of the accuracy of reflecting the characteristics of dampers classified as damage-free components and being the classification benchmark for the condition assessment (Tab. 4).

Figures 6, 7 present the results of a broad frequency analysis for two independent measurement series of the same dampers with defects and classified as fully functional.

The test has been carried out with the purpose of evaluating the reproducibility of measurements (in accordance with the agreed workbench design and environmental conditions) and verification of the peak values of acceleration in particular frequency ranges for the purposes of further FFT-based analysis.

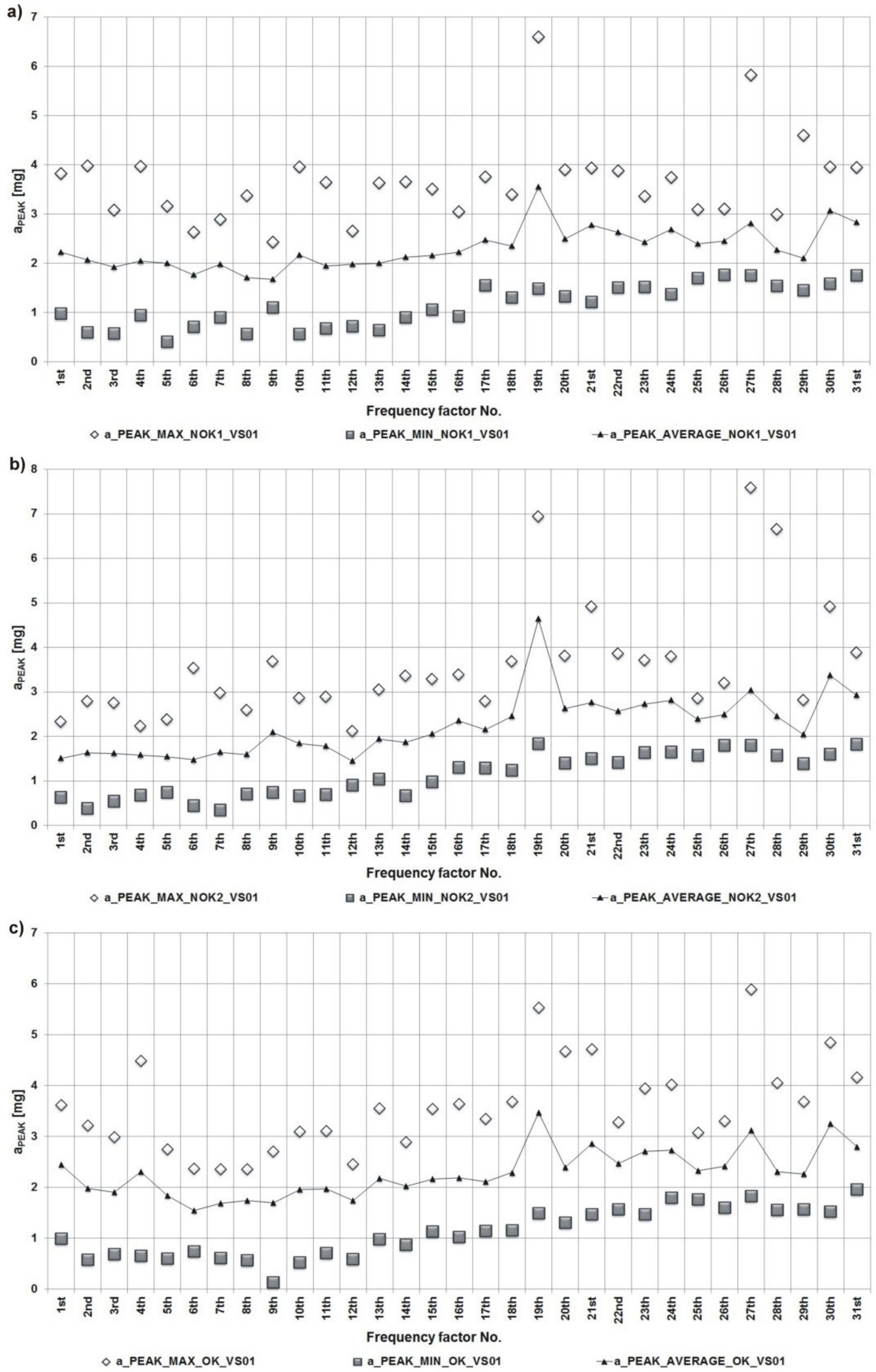

Fig. 6. Comparison of average values of acceleration from two independent measurement series in the defined frequency ranges measured by the sensor VS01 for the dampers: a) with defects (the first measurement series), b) with defects (the second measurement series), c) fully functional (the summary result from the two measurement series)

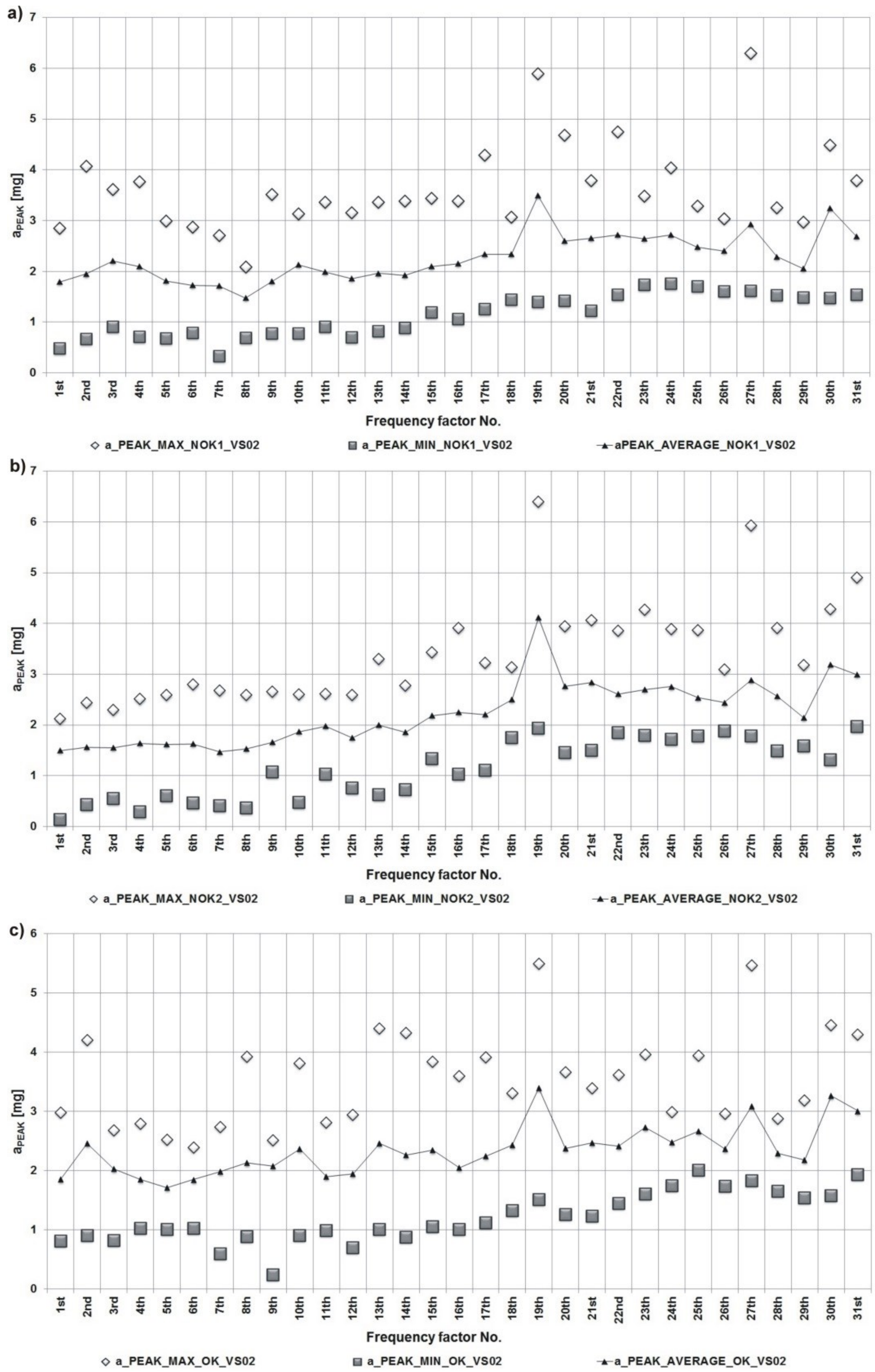

Fig. 7. Comparison of average values of acceleration from two independent measurement series in the defined frequency ranges measured by the sensor VS02 for the dampers: a) with defects (the first measurement series), b) with defects (the second measurement series), c) fully functional (the summary result from the two measurement series)

The results obtained from the VS02 sensor measurements are characterized by greater value of dispersion of amplitudes as compared with the other sensor. In case of inspecting the condition of the damper, it facilitates achieving greater selectivity of acceleration amplitude peak values in the defined frequency ranges and the reduction of measurement error.

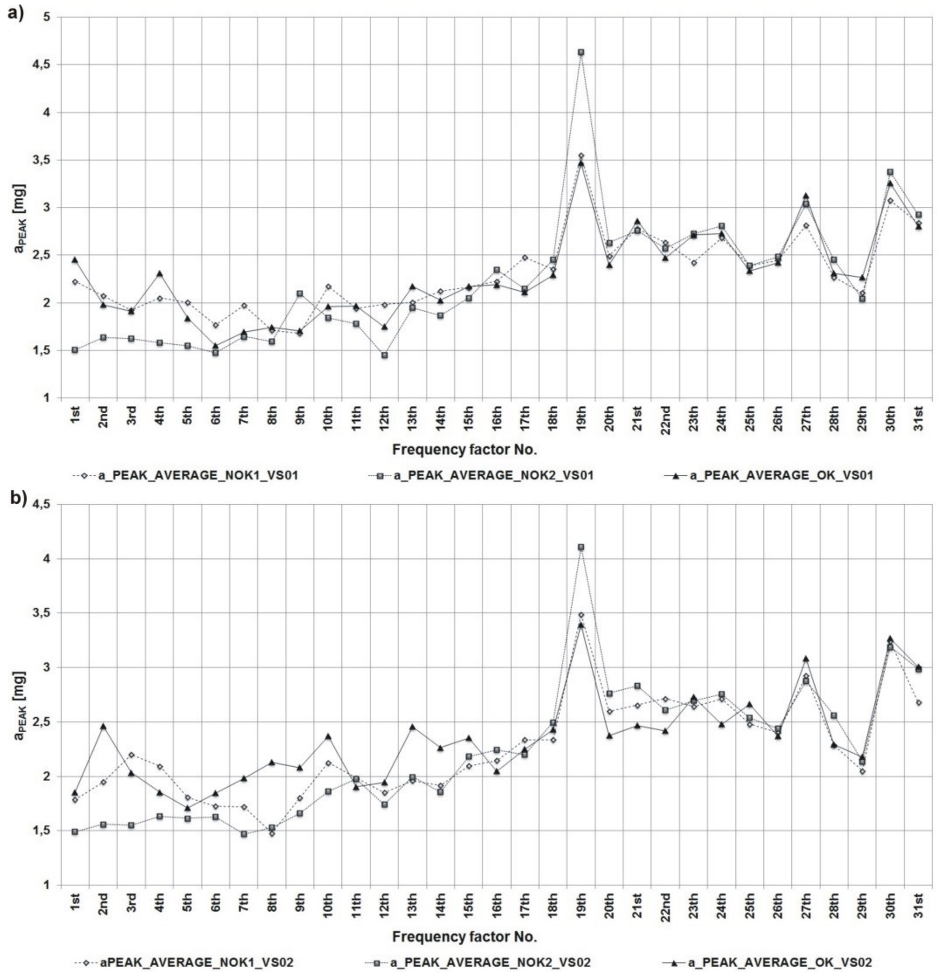

Fig. 8. Comparison of average acceleration values in the defined frequency ranges in two independent measurement series of the examined dampers with and without damages measured by the sensor: a) VS01, b) VS02

In the group of parameters, the greatest selectivity of identification is achieved by observing the values of acceleration in the frequency range 0÷1,5kHz (1÷22 frequency factor), which enables applying Fourier transformant for further analysis of the condition.

In the presented case of analysing different samples (selected from the same production batch), a relatively large dispersion of measurement values has been observed, which indicates no reproducibility of the results in different measurement cycles despite maintaining the stability of measurement conditions and environmental parameters (Table 5). Another factor influencing the results is low dynamics of parameter changes of damper acceleration induced by stabilized speed and the complexity of phenomena occurring in the examined system.

Table 5
The results of the frequency factors analysis, in case of the selected groups of dampers classified as properly assembled (no defects or irregularities, sensor VS02)

F_F No.	$F_{central}$ [Hz]	a_{PEAK} [mg] in measurement series					$a_{PEAK\_AVERAGE}$ [mg]	Standard deviation a_{PEAK_SD} [mg]
		No. 1	No. 2	No. 3	No. 4	No. 5		
1st	14	2,008	1,608	1,928	1,838	1,879	1,852	0,150
2nd	25	2,426	2,623	2,485	2,447	2,327	2,461	0,107
3rd	37	2,188	1,655	2,066	2,093	2,166	2,034	0,218
4th	49	1,957	1,916	1,917	1,835	1,647	1,854	0,124
5th	62	1,938	1,415	1,687	1,904	1,604	1,710	0,217
6th	74	1,705	1,890	2,007	1,706	1,925	1,847	0,136
7th	86	2,176	1,963	1,893	1,962	1,913	1,982	0,113
8th	98	2,084	2,255	2,011	2,177	2,128	2,131	0,092
8th	110	2,114	2,039	1,750	2,253	2,239	2,079	0,204
10th	140	2,534	2,550	2,196	2,392	2,178	2,370	0,178
11th	171	2,115	1,907	1,727	1,912	1,851	1,902	0,140
12th	208	1,926	1,973	1,914	2,041	1,874	1,946	0,064
13th	245	2,532	2,431	2,301	2,463	2,551	2,456	0,099
14th	306	2,149	2,189	2,354	2,282	2,340	2,263	0,091
15th	367	2,309	2,124	2,678	2,433	2,211	2,351	0,216
16th	452	2,153	2,066	1,925	1,999	2,100	2,048	0,089
17th	550	1,895	2,483	2,145	2,373	2,345	2,248	0,232
18th	672	2,646	2,591	2,177	2,351	2,383	2,429	0,191
19th	818	3,546	3,438	3,176	3,452	3,361	3,394	0,139
20th	1001	2,480	2,264	2,256	2,554	2,313	2,373	0,135
21st	1221	2,515	2,701	2,392	2,457	2,266	2,466	0,161
22nd	1502	2,258	2,440	2,266	2,352	2,763	2,416	0,208
23rd	1832	2,608	2,837	2,936	2,774	2,485	2,728	0,181
24th	2247	2,510	2,595	2,528	2,292	2,467	2,478	0,114
25th	2747	2,932	2,537	2,766	2,568	2,523	2,665	0,178
26th	3357	2,367	2,448	2,380	2,307	2,334	2,367	0,053
27th	4102	3,138	3,143	3,012	2,923	3,207	3,085	0,115
28th	5005	2,357	2,325	2,289	2,304	2,195	2,294	0,061
29th	6128	2,176	2,061	2,406	2,226	2,027	2,179	0,151
30th	7496	3,074	3,424	3,200	3,013	3,622	3,267	0,253
31st	9156	3,014	2,920	3,029	3,053	3,016	3,006	0,051

In the test result, the frequency range of the classifier has been narrowed. The subsequent phase of research will be developing algorithms for the identification of characteristic frequencies in the frequency spectrum and classification of defects on the basis of the FFT spectrum analysis.

Table 6
The results of the frequency factors analysis, in case of the selected groups of dampers with defects (sensor VS02)

F_F No.	$F_{central}$ [Hz]	a_{PEAK} [mg] in measurement series					$a_{PEAK\_AVERAGE}$ [mg]	Standard deviation a_{PEAK_SD} [mg]
		No. 1	No. 2	No. 3	No. 4	No. 5		
1st	14	1,653	1,657	1,748	1,649	1,491	1,640	0,258
2nd	25	1,925	1,924	1,627	1,686	1,605	1,753	0,308
3rd	37	1,870	1,637	1,997	1,924	1,958	1,877	0,383
4th	49	2,139	1,588	1,772	1,818	2,003	1,864	0,327
5th	62	1,629	1,587	1,995	1,635	1,707	1,711	0,191
6th	74	1,776	1,701	1,509	1,685	1,714	1,677	0,231
7th	86	1,620	1,517	1,647	1,452	1,729	1,593	0,204
8th	98	1,454	1,540	1,473	1,593	1,454	1,503	0,206
8th	110	1,971	1,746	1,679	1,623	1,631	1,730	0,228
10th	140	2,131	2,026	2,078	1,841	1,896	1,995	0,208
11th	171	1,943	1,971	1,829	2,006	2,152	1,980	0,137
12th	208	1,818	1,880	1,669	1,876	1,746	1,798	0,179
13th	245	2,003	2,027	1,989	1,861	2,004	1,977	0,088
14th	306	1,931	1,758	1,792	2,016	1,943	1,888	0,158
15th	367	2,232	2,058	2,084	2,066	2,261	2,140	0,163
16th	452	2,192	2,215	2,028	2,253	2,288	2,195	0,153
17th	550	2,251	2,248	2,366	2,119	2,362	2,269	0,133
18th	672	2,411	2,216	2,433	2,563	2,454	2,416	0,246
19th	818	3,421	3,896	3,999	3,695	3,989	3,800	0,423
20th	1001	2,853	2,585	2,498	2,655	2,818	2,682	0,208
21st	1221	2,807	2,908	2,576	2,715	2,716	2,744	0,213
22nd	1502	2,621	2,656	2,808	2,644	2,578	2,661	0,156
23rd	1832	2,622	2,679	2,718	2,812	2,515	2,669	0,123
24th	2247	2,697	2,838	2,783	2,624	2,729	2,734	0,130
25th	2747	2,446	2,488	2,625	2,453	2,531	2,509	0,083
26th	3357	2,407	2,402	2,360	2,398	2,538	2,421	0,124
27th	4102	2,701	2,999	2,962	2,948	2,896	2,901	0,145
28th	5005	2,505	2,463	2,407	2,345	2,402	2,424	0,183
29th	6128	2,134	2,167	2,132	2,043	1,992	2,094	0,095
30th	7496	3,269	3,111	3,194	3,203	3,301	3,216	0,151
31st	9156	2,717	2,751	2,864	2,789	3,044	2,833	0,217

5. Summary

The final evaluation of product should be based on the comparison of results from the single measurement cycle with the average of vibration parameter values obtained from averaging the results of measurements taken with fully functional products.

The main assumptions of the undertaken tests are as follows: applying the peak value of acceleration for the identification of frequency range of defects characteristic for dampers, without the positive identification of the defect source; a necessity of identifying the thresholds for the classification of the examined dampers into the groups of fully functional of defective products; using for measurements workbenches with minimum cost, integration and return on investment period; automatization of the measurement method in order to reduce the influence of the human factor.

The measurements have been carried out maintaining the values of key parameters (actuating conditions, environmental parameters and the level of external interferences).

Hydraulic fluid foaming has significant influence on the measurement results. Repeated damper actuation indicates that there is no reproducibility of measurement results, which makes it difficult to assess the condition of the examined element.

The presented frequency analysis enables obtaining partial information about the nature of phenomena occurring in car dampers. Nevertheless, there still aren't sufficient conditions for the analysis of assembly errors and faulty operation of the examined dampers.

The presented measurements cannot be the basis for the classification of the examined damper. Further tests aiming at the development of state classifiers shall be carried out with regard to the development of the advanced algorithms enabling identification of defects and their sources on the basis of the frequency spectrum analysis.

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