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STUDY OF VIBRATIONS CAUSED BY ROTARY MOVEMENT OF ELECTRIC MOTOR [1]

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Abstract: *The object of the study is devices and facilities in which the main purpose is realized by rotational motion. The vibrations as a signal of the excited vibrations caused by it are recorded in digital form. Transformation from time domain to frequency domein is made. The resulting spectrum i.e., the amplitude-frequency characteristics is analyzed. They provide rich information about the general condition of the object being investigated and the state of the individual nodes that make a rotating motion relative to a fixed axis, such as bearings. Conclusions and recommendations on the technical condition of the investigated objects were made.*

Keywords: *signal, vibration, spectrum, diagnosis.*

INTRODUCTION

The idea of studying the technical condition of machines and equipment through vibro-diagnostics is widespread, (Nafikov, A. 2004, Pozhidaeva, V. 2004, Rusov V.B. 2012, Brian P. Graney & Ken Starry, 2011). This benchmarking approach, especially of bearing assemblies for large-scale equipment such as stationary pumps, compressors, electric power generators and others, is standardized (IS0 10816-I, First edition 1995-l 2-15, GOST ISO 10816- 1-97). Based on the methodology in these standards and a number of author's publications (Shirman, A. & Solobev, 1996, Daniel Lynn., 2010, Saruhan, S. Sardemir, A. Çiçek, & H. Uygur, 2014, Upadhyay RK, LA Kumaraswamidhas, Md. & Sikandar Azam, 2013) extensive research work has been done. Their main focus is on the diagnosis of bearing assemblies, being one of the most important in rotating motion equipment and most often in need of replacement because of defects in them and their working capacity. Vibration measurement methods are by sensors with direct contact with the object (Saruhan, S. Sardemir, A. Çiçek, & H. Uygur, 2014) for the excited low frequencies, and for the high frequencies by acoustic measurements (Brian P. & Ken Starry , 2011). In the sources (Rusov VA 2012, Daniel Lynn, 2010), four diagnostic stages are introduced which give a clear idea of the state of a given bearing node according to the spectrum of the transmitted oscillations.

The object of attention in this study is to apply the digital recording approach to the vibration excited by electrical devices that are caused by the rotational motion of their parts and assemblies, such as: fan and abrazive tool. Performing a follow-up analysis of the amplitude-frequency characteristics obtained from which drawing conclusions about their condition in terms of workability and suitability for operation.

[1] Presented a plenary report of October 26, 2018 with the original title: ИЗСЛЕДВАНЕ НА ВИБРАЦИИТЕ ПРЕДИЗВИКАНИ ОТ ВЪРТЕЛИВОТО ДВИЖЕНИЕ НА ЕЛЕКТРИЧЕСКИ ДВИГАТЕЛИ

EXPOSITION

The vibrations occurring in the test objects are recorded by a 3D-BTA vibrosensor, which is a tri-axial accelerometer within ± 5g (where g = 9.8 m/s^2). The sensor is connected via LabQuest® Mini, to computer by electronic adapter of the company (www.venier.com), as shown in Figure 1.

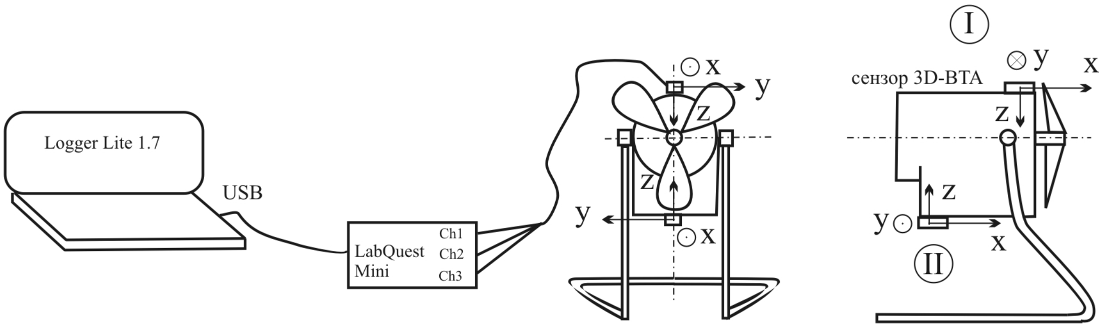

Fig. 1. Block shceem and positions of vibrosensor type 3D-BTA on fan

Figure 1 shows the way in which the vibrosensor is mounted when recording a vibrogram from a fan according to the requirements of IS0 10816-I, First edition 1995-1-2-15, GOST ISO 10816-1-97. The sensor does not need to be calibrated before starting the vibrogram recording. It is enough just to "reset" the Logger Lite 1.7 application with the "New" command from the "File" menu. The symbol ⊙ is the direction of the axis towards us from the plane of the figure, and the symbol ⊗ - from us t.

The recorded vibrogram with the Logger Lite 1.7 software is exported in a text format and after the corresponding processing with a special program in the MatLab environment the graphs shown in Figure 2 are obtained. In the Logger Lite program, the value $\mathbf{f_s}$ - sampling frequency is set beforehand. That is the record frequency that complies with Nyquist's condition to be twice as high as the maximum bandwidth we record. This value automatically determines the recording interval, **Δt** digitization, the vibrogram and the number of recordings **N**. For current measurements, a signal recording frequency is equal to the limit of 100 Hz, i.e. 100 Hz, is selected. The program measures the values of the signal at an interval of **Δt** = 0,01 s, which represents **N=**200 counts within 2 seconds (Figures 2 and 4).

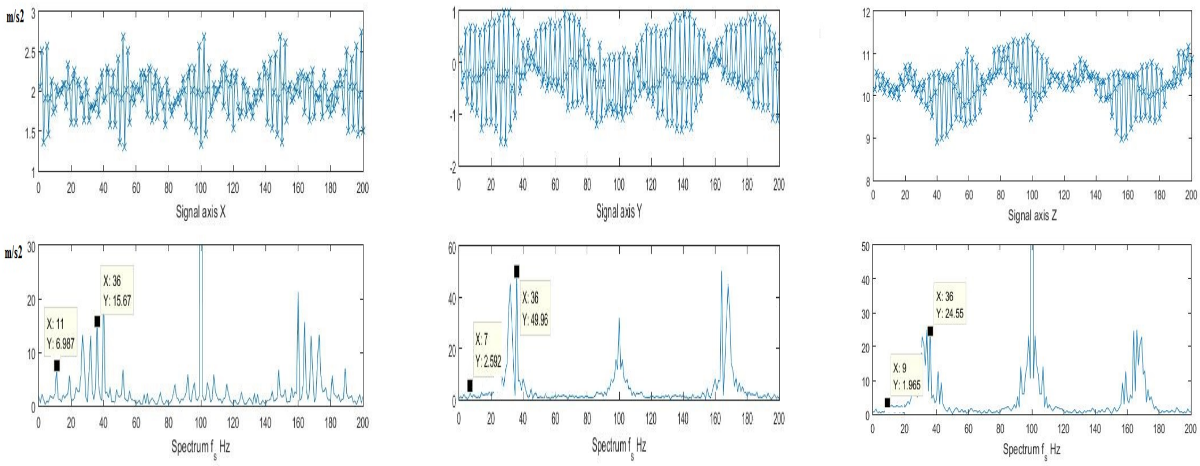

Fig. 2. Signal and spectrum at point I along axes X, Y, Z of the fan

Figure 3 shows the locations where the vibrosensor is mounted when removing the signal form abrazive tool. They comply with the recommendations in standard IS0 10816-I, First edition 1995-l 2-15, GOST ISO 10816-1-97.

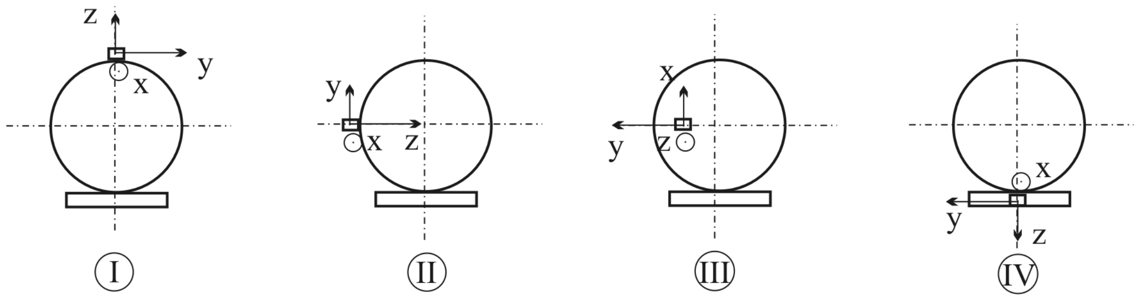

Fig. 3. Position of vibrosensor type 3D-BTA at point I, II, III and IV on abrasive tool.

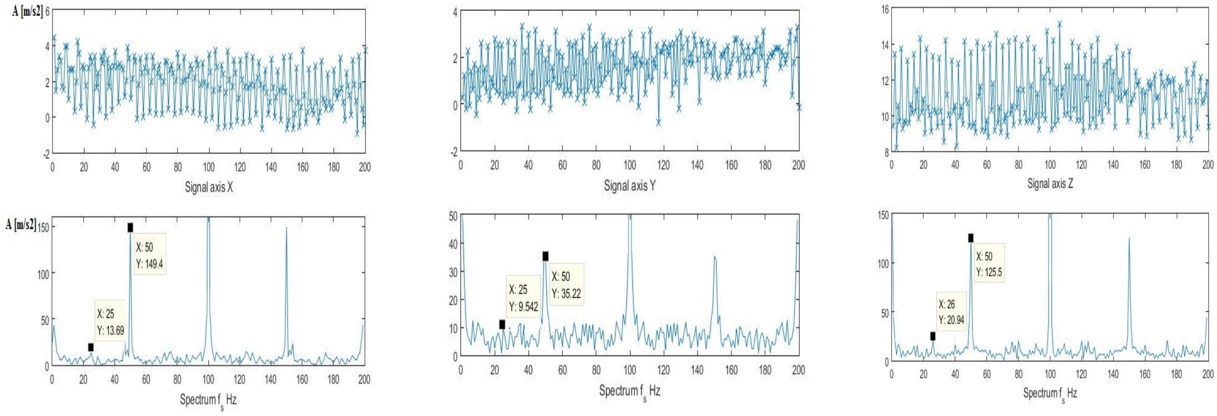

Fig. 4. Signal and spectrum along axises X, Y, Z at point I of the abrasive tool.

Table 1 gives data about the values obtained after applying the Fourier Fast Transform to the frequencies and amplitudes of the harmonics involved in the measured signals in points I, II, III, IV on the X, Y and Z axes of the fan, (Fig. 1.) and abrazive tool, (Fig. 3.).

Table 1. Values of the frequancies and amplitudes of the harmonics

Pos.	**Axis**	**Harmonics of fan - Frequency/Amplitudes [Hz/m.s^{-2}]**									
		F_{x1}	F_{x2}	F_{x3}	F_{x4}	F_{x5}	F_{x6}	F_{x7}	F_{x8}	F_{x9}	F_{x10}
I	X	11/6,98	19/5,66	27/13,29	32/12,98	36/15,67	40/21,16	52/6,7	67/2,3	84/4,03	92/5,7
	Y	7/2,6	14/2,76	32/45,06	36/49,96	40/8,15	45/4,33	54/2,003	86/2,96	-	-
	Z	9/1,96	27/7,36	31/22,84	36/24,55	41/12,58	43/9,26	93/14,01	-	-	-
II	X	11/6,98	19/5,66	27/13,3	32/12,98	36/15,67	40/4,77	44/3,02	52/6,11	76/2,8	88/3,51
	Y	7/1,09	15/3,34	19/4,59	23/7,35	32/13,71	36/4,77	44/3,026	52/6,11	76/2,8	88/3,51
	Z	7/1,3	11/2,53	15/2,85	23/8,16	32/7,17	36/14,05	40/5,54	52/9,64	79/5,88	96/,49
		Harmonics of abrzive tool - Frequency/Amplitudes [Hz/m.s^{-2}]									
I	X	25/13,69	50/149,4	76/14,6	86/11,8	-	-	-	-	-	-
	Y	7/12,26	25/9,5	50/35,2	67/11,6	78/11,07	92/11,93	-	-	-	-
	Z	4/16,89	16/15,8	26/20,94	40/15,85	50/125,5	76/19,52	80/19,8	91/17,28	-	-
II	X	5/18	14/10,8	26/11,47	50/44,75	73/25,1	95/21,6	-	-	-	-
	Y	5/33,78	26/5,4	50/34,52	63/12,82	75/10,73	80/9,8	96/12,11	-	-	-
	Z	5/33.01	32/13,7	50/110,1	68/12,33	85/14,4	94/20,19	-	-	-	-

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III	X	25/16,95	37/13,55	50/110,3	74/14,19	89/13,42	-	-	-	-	-
	Y	8/30,3	25/45,27	50/155	76/16,52	93/51,24	-	-	-	-	-
	Z	25/13,44	50/181,4	74/20,43	87/16,99	-	-	-	-	-	-
IV	X	5/15,53	26/13,9	49/27,13	66/10,45	73/11,2	84/8,5	95/18,3	-	-	-
	Y	14/9,8	25/9,6	50/70,85	72/10,5	95/21,78	-	-	-	-	-
	Z	4/16,5	12/12,73	28/14,52	50/153,4	74/17,19	81/17,82	95/25,9	-	-	-

Table 2. gives the values of vibration acceleration, vibration velocity and the amplitude of vibrationts along the X, Y, and Z axes of the sensor in the points, (Fig. 1, and 3) where it is placed of the various objects studied.

The vibrations graphs and amplitude-frequency characteristics shown in Figures 2 and 4 are for the vibration acceleration, whith dimension is m/s^2. According to standard GOST ISO 10816-1-97 Annex A, the vibration state of the machines is assessed by the mean-square magnitude of the vibration velocity. In order to obtain this magnitude, it is necessary to divide the acceleration value into $\mathbf{2\pi F_1}$, taking into account the fact that the velocity is measured in the dimension [mm/s], where $\mathbf{F_1}$, (see Table 3) is the base frequency from the revolutions of the rotating shafts. The vibrational amplitude is calculated in a similar way in [μm].

Table 2. The values of vibroacceleration, vibrovelocity and the amplitude of vibrationts

Object	**Point №**	**Axis**	**a [m/s²]**	**v [mm/s]**	**s [μm]**	$\mathbf{v_{max}}$ **[mm/s]**
Fan	I	X	2,003	11,81	69,67	
		Y	0,664	3,91	23,11	
		Z	10,32	60,92	359,9	60,92
	II	X	5,84	34,44	203,14	
		Y	4,27	25,19	148,57	
		Z	8,7	51,35	302,86	51,35
Abrasive tool	I	X	2,23	13,16	77,63	
		Y	1,89	11,2	66,06	
		Z	11,25	66,37	391,47	66,37
	II	X	2,3433	13,8197	81,5031	
		Y	9,3426	55,0991	324,9537	55,0991
		Z	1,6855	9,9406	58,6256	
	III	X	8,8023	51,9126	306,1609	51,9126
		Y	3,6090	21,2825	125,5337	
		Z	2,5923	15,2885	90,1657	
	IV	X	1,2669	7,4715	44,0640	
		Y	2,9361	17,3163	102,1248	
		Z	9,7941	57,7621	340,6588	57,7621

Table 3. shows the datas for the bearings that are embedded in the study objects. The fan (*) has sliding bearings, **6202** is the bearing number of the abrasive tool. The indications in the table are as follows: **D** - diameter of the outer ring, **dp** - diameter of the separator, **din** - diameter of the inner ring, i.e. of the rotating shaft, **db** diameter and **Nb** number of rolling bodies. There are also included: **RPM**, referred to as the base frequency $\mathbf{F_1}$ in [Hz], the types of frequencies that the bearings generate: **BPFO** - Ball Pass Freguency of Outer Ring, **BPFI** - Ball Pass Freguency of Inner Ring, **FTF** - Fundamental Train Freguency and **BSF** - Ball Spin Freguency.

Table 3. Dimentions and frequencies of the bearing

Bearing Number	Dimentions [mm]				Nb [num]	RPM [min^{-1}]	Fequencies [Hz]				
	D	dp	din	db			F_1	BPFO	BPFI	FTF	BSF
*	-	-	5	-	-	2230	37	-	-	-	-
6202	35	25	15	6,4	8	1494	24,9	74,10	125,09	9,3	18,17

CONCLUSION

The analysis of the received vibrations and their respective amplitude-frequency characteristics for the fan show that:

1. Axis X longitudinally to a fan has a frequencies of 7 to 11 Hz, which are caused by the solid base on which it is placed;
2. From the measured oscillations on each of the three axes X, Y, Z (Fig. 2.) of the fan respective the sensor axes, the basic frequency of 36 Hz (see Table 3) is recorded, which is excited by the velocity of the blade rotation. The blade is not dynamically balanced and this is why this frequency is dominant.
3. The maximum speed is 60.92 mm/s, (see Table 2.). That is vibrospeed that according to IS0 10816-I is unacceptable for industrial facilities, but here it is not a machine of these types!

The analysis of the results of the vibrograms and the resulting amplitude-frequency characteristics of the abrzive tool placed on a rigid base show that in all the vibrograms the phenomenon "beating" is observed, which is an indication of the presence of a defect in the bearings and disbalance of the abrazive disk. These facts are grounds for believing that there is a developed defect in the bearings in the second diagnostic stage, (Rusov V.A. 2012).

1. A low frequency is recorded in the range of 4 Hz with amplitude of 16.5 m/s^{-2} to 8 Hz with an amplitude of 30.9 m/s^{-2}, which is caused by the corps of abrazive tool due to the hard foundation;
2. Frequancies are meazured in the range from 25 to 28 Hz with amplitudes ranging from 9 to 45 m/s^{-2} on all the vibrograms. The basic frequency is **F_1 = 24.9 Hz**, of the rotor speed of the electric motor (see Table 3.);
3. The greatest amplitude in the range of 27.13 to 181.4 m/s^{-2} is the frequency of 50 Hz. This is the doubled value of the base frequency that is obtained from the unbalanced masses in the planes of the two bearings of the rotor of the electric motor, (Pozhidaeva, V. 2004);
4. Frequencies ranging from 12 to 16 Hz are also recorded with amplitudes ranging from 9.8 to 15.8 m/s^{-2}. They are close to the calculated bearing frequency of the bearing **BSF = 18.17 Hz**, (See Table 3.);
5. The calculated bearing frequency **BPFO = 74 Hz**, (See Table 3) is recorded in the range of 72 Hz / 15.5 m/s^{-2} to 78 Hz / 25.1 m/s^{-2}, (See Table 1.);
6. The calculated bearing frequency **BPFI = 125 Hz** is outside the range of frequencies the sensor can measure.
7. No frequency indications **FTF = 9.3 Hz**, (See Table 3.);

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