METHODOLOGY OF THE DEFECT MAPS AND ITS APPLICATION FOR REPRESENTATION OF VIBRATIONAL EFFECTS OF BEARING MISALIGNMENT

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Summary

The essence of the present work is an innovative methodology consisting in creation and presentation of complex diagnostic relations in the form of "defect maps", which allow mapping the machine technical state in certain domain of random events represented by defects. In the case of the bearing misalignment defect, which is the subject of the present article, the "domain of events" is the area of possible bearing dislocations and the "technical state" may be expressed e.g. by vibrations of the machine elements. The effect of this work is complete set of maps, which present distribution of bearing vibration as functions of individual bearing displacements. Within this work various types of bearing misalignment maps were constructed, intended for various applications in the turbogenerator diagnostic system. The defect maps methodology applied here for presentation of the bearing misalignment effects has been generalized and proposed as the idea of presentation of a machine response to certain class of defects.

Keywords: technical diagnostics, rotating machine, mechanical vibration, misalignment.

METODYKA MAP DEFEKTÓW W ZASTOSOWANIU DO PREZENTACJI DRGANIOWYCH SKUTKÓW ROZOSIOWANIA ŁOŻYSK

Streszczenie

Istotą niniejszej pracy jest innowacyjna metodyka polegająca na tworzeniu i prezentacji złożonych relacji diagnostycznych w formie „map defektów", które pozwalają odwzorowywać stan techniczny maszyny w pewnym obszarze zdarzeń losowych reprezentowanych przez defekty. W przypadku defektu rozosiowania łożysk, który jest przedmiotem niniejszego artykułu „obszar zdarzeń" może być wyrażony np. przez drgania elementów maszyny. Efektem pracy jest kompletny zestaw map, które prezentują rozkład drgań łożysk jako funkcję indywidualnych przemieszczeń łożysk. W ramach tej pracy zostały utworzone różne rodzaje map skutków przemieszczeń łożysk, przeznaczone dla różnorodnych zastosowań w systemie diagnostycznym turbogeneratora. Metodyka map defektów, zastosowana tu do prezentacji efektów rozosiowania łożysk została uogólniona i zaproponowana jako sposób prezentacji odpowiedzi maszyny na pewną klasę defektów.

Słowa kluczowe: diagnostyka techniczna, maszyna wirnikowa, drgania mechaniczne, rozosiowanie.

1. INTRODUCTION

For turbo-generators of great power developed are extended diagnostic systems, which need proper diagnostic knowledge for safer operation. For continuous evaluation of the machine condition employed are self-acting diagnostic systems. The diagnostic systems need formulated previously "diagnostic relations", which link type and intensity of defects with their measurable effects [1-4].

We have worked for many years on the diagnostics of power turbo-generators, especially in the aspect of bearing misalignment defect. During this activity we found, that misalignment of bearings has great effect on the dynamic state of large rotating machines with a long shaft line supported in numerous bearings [5-8]. Location of particular bearings in relation to other bearings determines the bearing load distribution, therefore determines the shaft line shape and, as a consequence, operation of all bearings and, as a consequence, also rotors. The observations confirm numerous literature positions, e.g. [9-13]. According to Bognatz [14], the bearing misalignment defect may cause even 70% of vibration problems, which are recorded in rotating machines. Numerous phenomena observed in turbo-sets, which frequently grow stronger or vanish without a visible reason and are difficult to explain, are expected to have their origin in bearing misalignment [2, 5, 9-11, 14]. It is noteworthy and

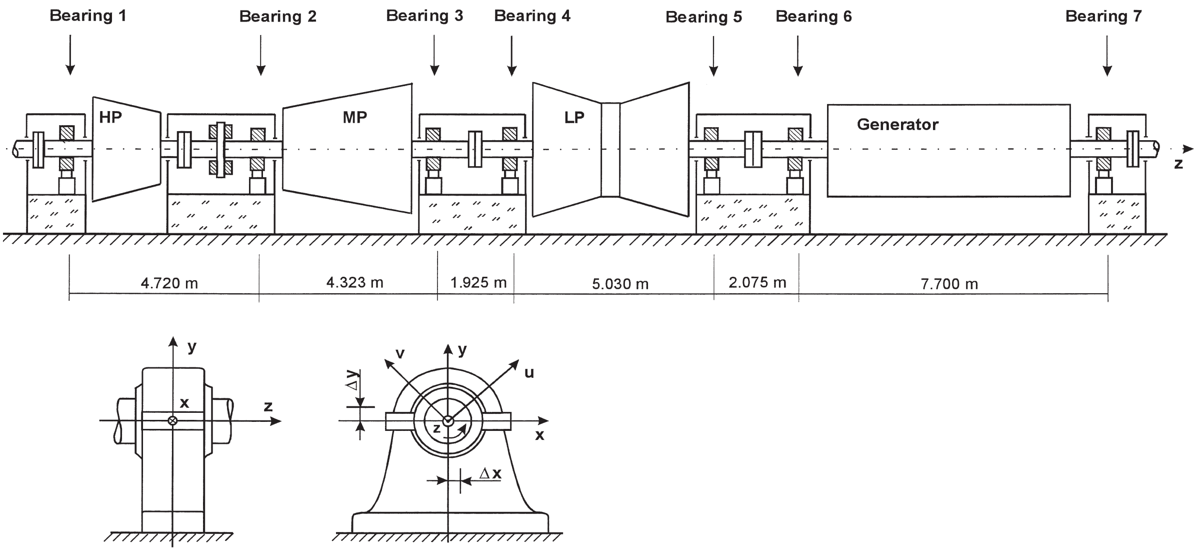

Fig. 1. Scheme of the 13K215 turbogenerator, which shows location of bearings and orientation of the machine in the coordinate system used in the analyses

underlined by majority of authors of papers on the subject that the literature on the bearing misalignment defect is anyway rather poor [9, 10, 13, 15, 16]. Especially Muszynska in [9] stresses it very strongly. In multi-support machines like the analyzed turbogenerator particular bearings are arranged in such a way that the shaft line consti-tutes a catenary. It helps to reduce shaft bending at the couplings. The catenary is determined theoretically in the design phase and then practically implemented in the process of machine assembly by proper positioning of axes of particular bearings with respect to the geodesic line [2, 9, 10]. Displacement of any turboset bearing from its optimum position, defined by the designed shaft catenary, changes conditions of operation of the hydrodynamic bearings and rotors supported on them. The distribution of the static load of particular bearings changes, and vibrations can be generated [2, 5, 9-11, 13-16]. Reasons for bearing displacements from the designed catenary can be of various natures, mainly connected with machine assembly and operation processes, and/or possible failures [7, 10].

During our work connected with the bearing misalignment defect we encountered troubles with gathering and interpreting great quantity of information, which were the results of computer simulation [6, 8]. The effect of seeking the method for proper arrangement of the acquired data is the idea of "maps of defect effects". The defect maps make possible presentation of response of a machine to defects in the comprehensible and easy interpretable form. The utilitarian effect of the work is the complete set of maps, which present distributions of the bearing vibration and the bearing load as a function of individual bearing displacements in relation to bearing proper position. The mapping may be regarded as the set of diagnostic relations or may be used for creation of the relations [1, 3, 4, 8]. Practical significance of the presented here investigations consists in possibility of direct application of the simulation results in a turbo-set diagnostic or advisory system, namely, the diagnostic relations may be included to the turbo-generator diagnostic knowledge base. Results of the work were intended for a certain specific 13K215 power turbo-generator, which works in the power station; therefore all results may find direct application to this real machine.

2. CALCULATION PROCEDURE AND OBJECT OF ANALYSIS

The object of calculations and following analysis is the 13K215 turbogenerator of 200MW power, which works in one of Polish power plants. The obtained results and conclusions may be directly applied to this specific machine as this machine was modelled and to this machine the model was tuned up. The machine consists of the three-stage steam turbine and the electric generator. Its scheme, showing the arrangement of shafts and distribution of bearings, is given in Fig. 1. Rotors of the four-casing machine are supported on seven bearings. Main dimensions and other characteristic features of the bearings are included in Table 1.

All calculations we carried out using a set of computer codes composing the system MESWIR. It is a package of codes, which has been developed for many years in the Institute of Fluid-Flow Machinery

Table 1. Characteristics of the turbo-set bearings and main operation parameters for the base case

Parameter	Denotation	Bear. 1	Bear. 2	Bear. 3	Bear. 4	Bear. 5	Bear. 6	Bear. 7
Diameter	D [m]	0.300	0.330	0.360	0.450	0.450	0.400	0.400
Length	L [m]	0.210	0.270	0.290	0.358	0.358	0.500	0.400
Clearance, horiz.	ΔR_H [mm]	0.643	0.650	0.745	0.880	0.885	0.885	0.245
Ellipticity ratio	m [-]	0.7309	0.700	0.7342	0.3886	0.3898	0.4520	0.0408
Eccentricity	ε [-]	0.3360	0.2684	0.3587	0.5226	0.5636	0.5095	0.3653
Attitude angle	γ [deg]	350.6	354.6	351.7	329.3	327.9	334.1	333.7
Oil abs. viscosity	μ [N*s/m^2]	0.0233	0.0276	0.0272	0.0296	0.0296	0.0283	0.0188
Bearing load – hor.	Q_x [N]	-1,042	-603	-7,133	7,473	-4,108	3,523	-741
Bearing load – vert.	Q_y [N]	41337	62351	164430	186740	255100	293520	253880
Relative vibr. – hor.	$A_{pp\ u}$ [μm]	49.3	60.8	29.8	30.7	31.7	44.2	17.9
Relative vibr. – vert.	$A_{pp\ v}$ [μm]	43.4	50.8	20.9	6.7	13.7	16.9	11.3
Absolute vibr. – hor.	V_x [mm/s]	0.54	1.04	0.80	0.18	0.39	1.51	0.87
Absolute vibr. – vert.	V_y [mm/s]	0.31	1.65	0.61	0.83	1.62	1.88	1.11

intended for calculating dynamics of rotors supported on oil bearings. The MESWIR is not specific for presented here calculations, but it was adopted for bearing misalignment simulation. Its detailed description and features are published among others in [17, 18] and its application to bearing misalignment is presented in [6-8]. Post-processing and visualisation were performed using MATLAB. The bearing static characteristics were obtained as a solution to the two-dimensional Reynolds equation by making use of Reynolds' boundary conditions. In the calculation model the bearings are treated as hydrodynamic oil bearings of finite width.

The reference point for our analysis is the "base case" – a numerical model of the machine free of defects. The model particular description is described e.g. in [7, 8, 17, 18]. The base model was created and tuned based on the results of measurements done in a real power plant by the turbogenerator diagnostic system. The measurements were performed in steady state and nominal conditions of turbo-set operation, at the rotational speed 3000 rev/min and at full power output 211 MW. It was assumed that the data recorded in the power plant in these operational conditions illustrate the machine without defects, i.e. that they describe the reference case to be used for comparison with the machine with implemented defect. Table 1 contains most important parameters, which characterize operation of the turbogenerator for the base case. The bearing static loads and bearing shaft positions characterize the bearing operation and amplitudes of relative shaft vibration and RMS velocity of bush absolute vibration characterize the machine dynamic state.

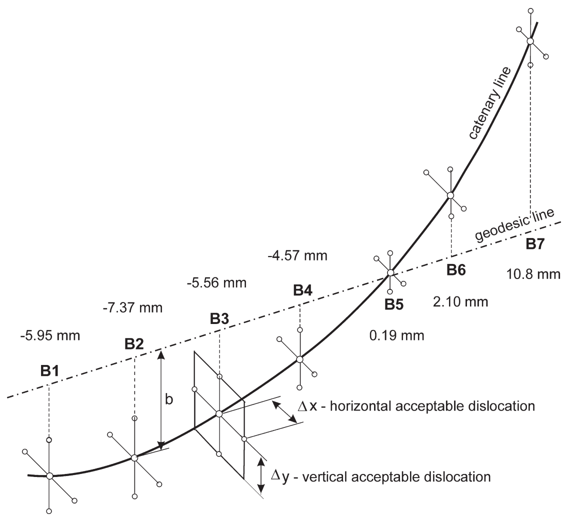

Fig. 2. Scheme of turboset shaft catenary on the background of the geodesic line, and the interpretation of bearing misalignment. *b* – displacement of a bearing positioned in the catenary with respect to the geodesic line, Δx, Δy – additional bearing displacement with respect to the catenary (defect)

An analysis concept of bearing misalignment defect is schematically shown in Fig. 2. The scheme presents the shape of the catenary line of rotors and against the background of the reference geodesic line. The bearing locations with respect to the geodesic line are denoted as "b" on the Fig. 2. Additional dislocations of the bearings, Δx, Δy representing the "defects" of the machine, were added to the basic dislocation values. In the codes used for calculations, the locations of particular bearings were introduced as their dislocations with respect to the geodesic line in the bearing data files [6, 17, 18].

For the purpose of creation the maps of bearing misalignment defect, which show vibrational effects of various bearing displacements, an area of simulated bearing dislocations has been defined. The area of possible bearing dislocations defined in the plane perpendicular to rotor axis is presented in Fig. 2 and the Fig. 3. The centre of this area is the base bearing position on the catenary line of the rotors, precisely defined by the turbo-set designer. Assuming the centre position as a base is justified by the fact that bearing dislocations reveal random nature, therefore dislocation of an arbitrary bearing in arbitrary direction is equally possible. Assuming that simultaneous dislocations in vertical and horizontal directions are possible, calculations of the effects of bearing dislocations were performed within the range:

–5mm < < 5mm, with 0,2mm horizontal step,

–5mm < Δy < 5mm, with 0,2mm vertical step.

Consequently, a 51 x 51 grid shown in Fig. 3 was defined, which gave 2601 possible positions of the bearing centre on the dislocation area. Distribution of the calculation points within the 10x10 mm square is marked in the figure with small circles. The base position of bearings on the shaft line catenary is represented in the Fig. 3 by the central point in of the dislocation square. Each point within the square represents a defect consisting in dislocation of a bearing from its base position to this point, that means dislocation of the bearing by Δx, Δy. For every of the 2601points the calculations of the turbogenerator numerical model were carried out by means of the MESWIR codes. For the needs of the present work the following quantities were calculated, every of them in two reciprocally perpendicular directions:

– A_u , A_v , the amplitudes of relative journal-bush vibrations, expressed by the p-p dislocation amplitude in two directions u and v, inclined by 45° to the vertical,

– V_x , V_y , the RMS velocities of absolute bush vibrations, expressed by RMS vibration velocities in the horizontal and vertical directions, x and y.

A machine works properly and safely, when some operation parameters, defined for a given machine as the most important, do not exceed permissible values. For the purpose of here presented work the following criteria are adopted:

A_u , A_v < A_{lim} = 165 μm, where A_{lim} is the limit of relative journal-bush vibrations,

$V_{RMS\,x}$, $V_{RMS\,y}$ < $V_{RMS\,lim}$ = 7,5 mm/s, where $V_{RMS\,lim}$ is the limit of absolute bearing vibrations.

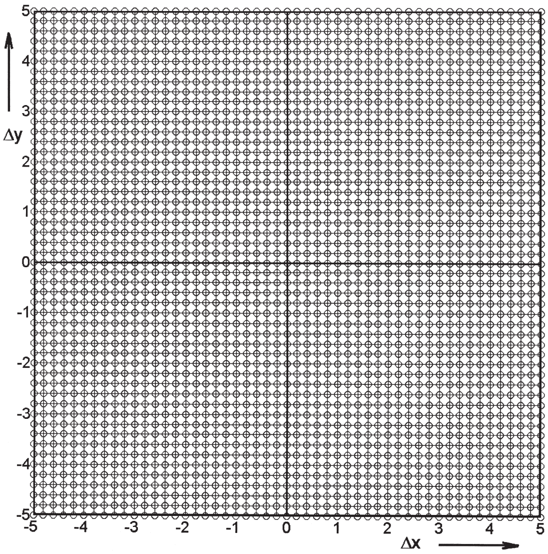

Fig. 3. The area of possible bearing dislocations with grid containing 51 x 51 nodes representing the bearing dislocations for which calculations were carried out

The axes x, y, u, v are interpreted in Fig. 1. The limiting vibration parameters and their values were taken from ISO standards: the relative vibration amplitudes from the standard 7919-2, and the absolute vibration velocities – from the standard 10816-2. The limits correspond to the „warning state". Table 1 shows that for the base case all vibration parameters are much lower than the defined above limits.

3. VARIOUS WAYS OF PRESENTATION OF THE BEARING MISALGNMENT DEFET

The maps of bearing misalignment effects are created automatically by special graphic software written in Matlab. Data for the maps consist of the results of simulating calculations of the machine model with implemented defects. To create a single map, the series of calculations for all the points shown in Fig. 3, which represent the defects, had to be done. Every single map presents distribution of only one vibration parameter concerning one particular bearing as the effect of dislocation of only one bearing within the defined area of dislocations. But vibrational effects of misalignment of a single bearing can be observed in every of seven machine bearings. This means that effects of misalignment of all seven bearings on all seven bearings characteristics can be presented using 49 maps showing the distribution of one single parameter. What is more, characterisation of the machine operation condition need a set of 4 graphs, presenting distribution of 4 parameters, defined in the previous section: A_u, A_v, V_x , V_y . The sample set of such graphs, which is one of the 49 possible sets, is given in Fig. 4.

Each set of graphs, like this in Fig. 4 contains four three-dimensional diagrams illustrating effect of dislocation of one particular bearing on the following parameters observed in one of the machine bearings:

$A_x=f(\Delta x, \Delta y)$ – u-dir. relative vibration amplitude,
$A_y=f(\Delta x, \Delta y)$ – v-dir. relative vibration amplitude,
$V_x=f(\Delta x, \Delta y)$ – x-dir. velocities of absolute vibration,
$V_y=f(\Delta x, \Delta y)$ – y-dir. velocities of absolute vibration.

To order the great number of maps, every particular figure is labelled by a pair of numbers {N_d N_e}, where:

N_d =1...7 is the number of the bearing, in which the defect is present,

N_e =1...7 is the number of the bearing, in which the response (effect) to the above defect is observed.

According to the above denotation the graphs presented in Fig. 4 are labelled by {5,5} and show the effect of dislocation of bearing 5 on the vibration parameters in the same bearing 5. In the diagrams the area of examined dislocations of a bearing is located in the x-y plane and is limited by the square –5mm < x < 5mm, –5mm < y < 5mm. In the Fig. 2 this area is seen as the square perpendicular to the shaft axis. The base bearing position on the catenary, (i.e. when the misalignment defect is missing), is marked in the Fig. 4 with the vertical line starting from the centre of the dislocation plane, Δx=0, Δy=0. To an arbitrary bearing dislocation by a vector [Δx, Δy] corresponds a certain value of the parameters: A_x , A_y , V_x , V_y . These values for the base case, i.e. for $\Delta x=0,\ \Delta y=0,$ are gathered in Table 1. On the vertical axis the level representing the corresponding parameter limit, A_{lim} , $V_{RMS\ lim}$ is marked. Crossing of the plane parallel to the x-y plane and situated at the limit level with the surface representing one of the functions *effect* = $f(\Delta x,\ \Delta y)$, gives the level line shown in each figure. The steep slopes noticeable on the vibration graphs testify that the gradient of vibration over the dislocation plane is high. The gradient is especially high in the vicinity of limit vibration level, which is marked in the figure with the thick line.

Figures of this type may be presented also in a modified form. Fig. 5 presents sample of the modified diagrams, which correspond to the diagrams shown in Fig. 4 after cutting them off at the level of the adequate parameter limit. The vertical axes of these graphs are properly rescaled. The areas limited by the level lines are marked dark. In these graphs the prohibited bearing dislocations are better visible and distribution of the analysed

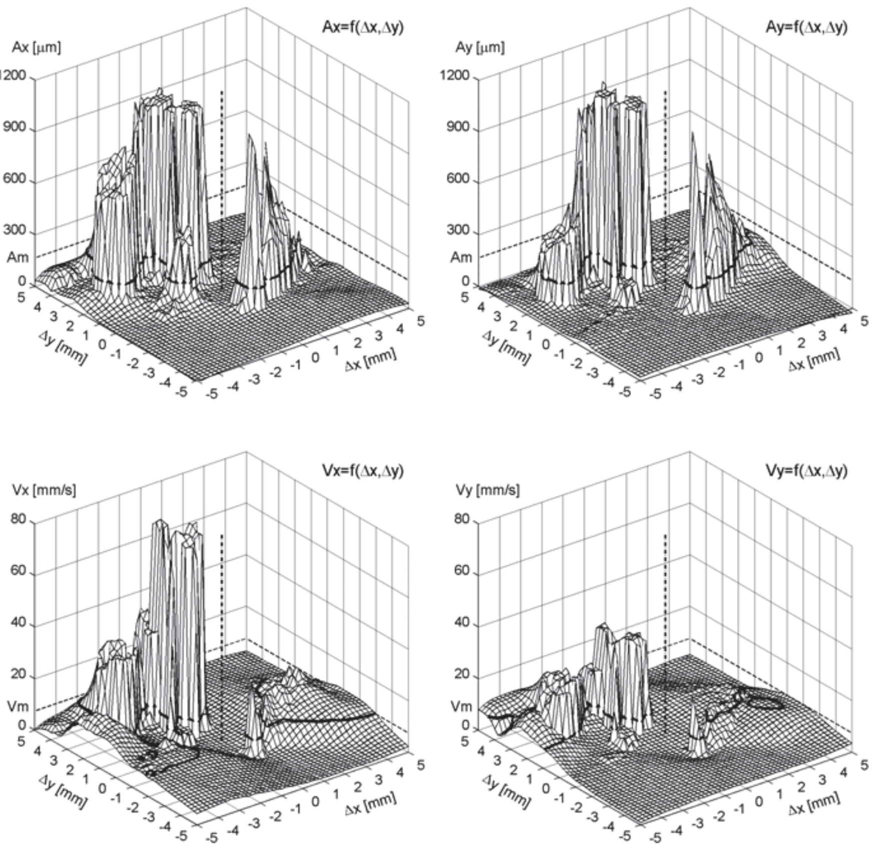

Fig. 4. The set of six three-dimensional diagrams, coded {5,5}, which illustrates effects of dislocation of the bearing 5 on the bearing 5 parameters: amplitude of relative vibration and velocity of absolute vibration, all in horizontal and vertical directions

parameters on the *x-y* plane is more readable. Projection of the limit level lines onto the dislocation plane x-y defines the region of prohibited bearing dislocations. When, in any way, the bearing bush centre falls into this prohibited region (marked dark in the figure), the machine should be stopped from operation as it means that the permissible limit for one of operating parameters was exceeded in at least one bearing.

Fig. 6 presents 2-dimensional but multiple valued graphical representations of the graphs presented in Figs. 4 and 5. The graphs have the form of contour lines filled with colours like geographical maps. Broken lines in the maps envelope the area, where appropriate parameters are greater then limiting values defined in Section 3.

From the practical point of view, of high usability are simplified figures of this type, showing the division of the area of the expected bearing dislocations into only two sub-areas: permissible dislocations and prohibited dislocations. Samples of such diagrams are shown in Fig. 7. The prohibited and permissible dislocation areas are separated by lines, which are the projections of the limit level lines drawn in Figs. 4 and 5 onto the x-y dislocation plane. In Fig. 7 the areas of prohibited bearing dislocations are marked dark, while the white area represents permissible dislocations. Dislocating the bearing to an arbitrary point located within the white area does not provoke effects, which could be considered unacceptable from the point of view of machine operation.

It is seen, that many miscellaneous representations of the defect maps can be created, depending on needs. Figs 4-7 present the maps of bearing misalignment effects in various degree of complexity. Figs. 4 and 5 present the 3-dimensional graphs and Figs. 6 and 7 present their two-value plane representations. It should be added, that all defect maps in their original version are colourful.

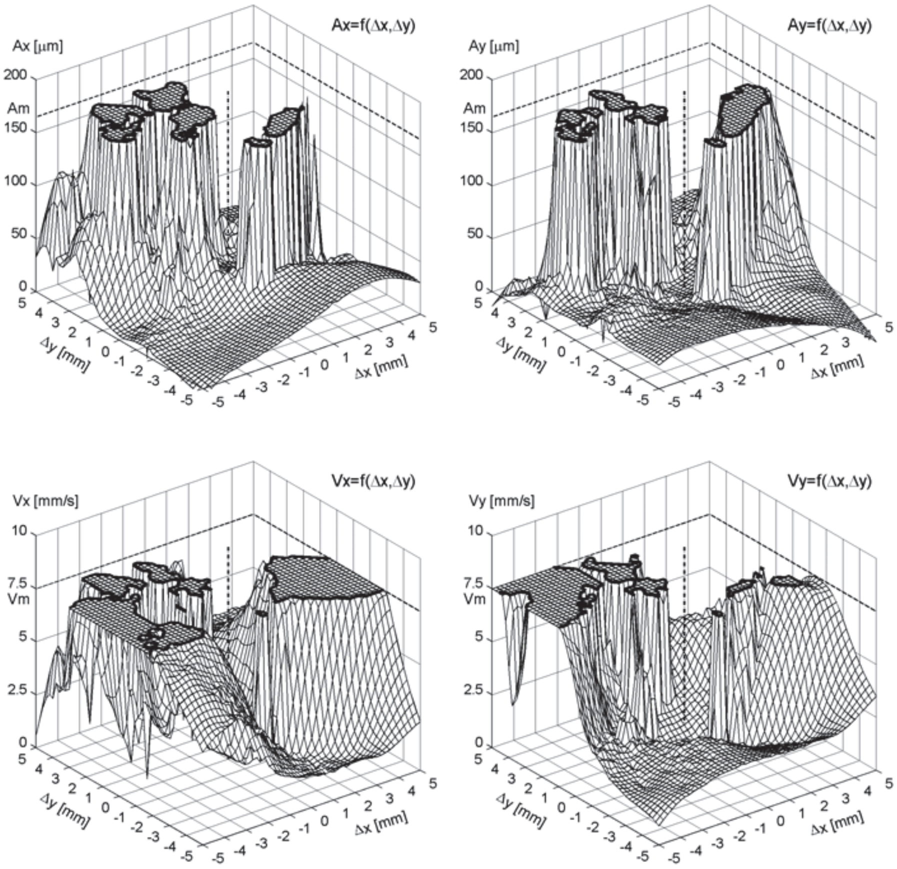

Fig. 5. The set of three-dimensional diagrams corresponding to the graphs from the Fig. 3, cut off at the level of the adequate parameter limiting value

4. ANALYSIS OF THE BEARING MISALIGNMENT DEFECT MAPS

The three-dimensional maps of bearing dislocation effects shown in Figs. 4 reveal that the amplitudes of relative vibrations of the bearing journals as well as velocities of absolute vibrations of the bearing bushes rapidly increase in some areas of bearing dislocations. Comparison of the vibration magnitudes with the contour lines drown on the permissible levels shows, that vibration may exceed many times the permissible limits. It is seen also in the Fig. 4 that the amplitudes of relative vibrations of the bearing journals are limited to about 1000 μm (peak to peak). The diagrams are cut off at this level. The maximum double vibration amplitude A_{pp} = 1000 μm seen in Fig. 4 corresponds approximately to the average bearing clearance in the direction of vibration measurements (vibration amplitudes are calculated here in the directions being the bisectors of the coordinate axes). Limitations placed on the amplitudes of the relative journal-bush vibrations result from physical limitations of the bush surface, since journal movements are limited to the bearing clearance circle. This testifies to the fact that after reaching the maximum amplitude the journal slides along the bush surface, or hits into it.

This suggest the presence of vibrational instability of the rotors or bearings, manifesting itself in the fact that relatively small intensification in bearing misalignment in some directions leads to rapid increase in vibration. The appearance of the instability in bearing operation due to the bearing misalignment is confirmed by shapes of trajectories of the bearing journals. Analysis of the bearing journal trajectories corresponding to bearing misalignment directions and magnitude was the subject of the author earlier papers [7].

The bearing misalignment defect maps can be useful for the diagnostic purposes in two ways:
- they can provide information on machine vibrational state if the bearing misalignment is known,
- they can provide opportunities for drawing conclusion on the location and magnitude of the bearing misalignment basing on the recorded vibration patterns of the bearing journals and bushes.

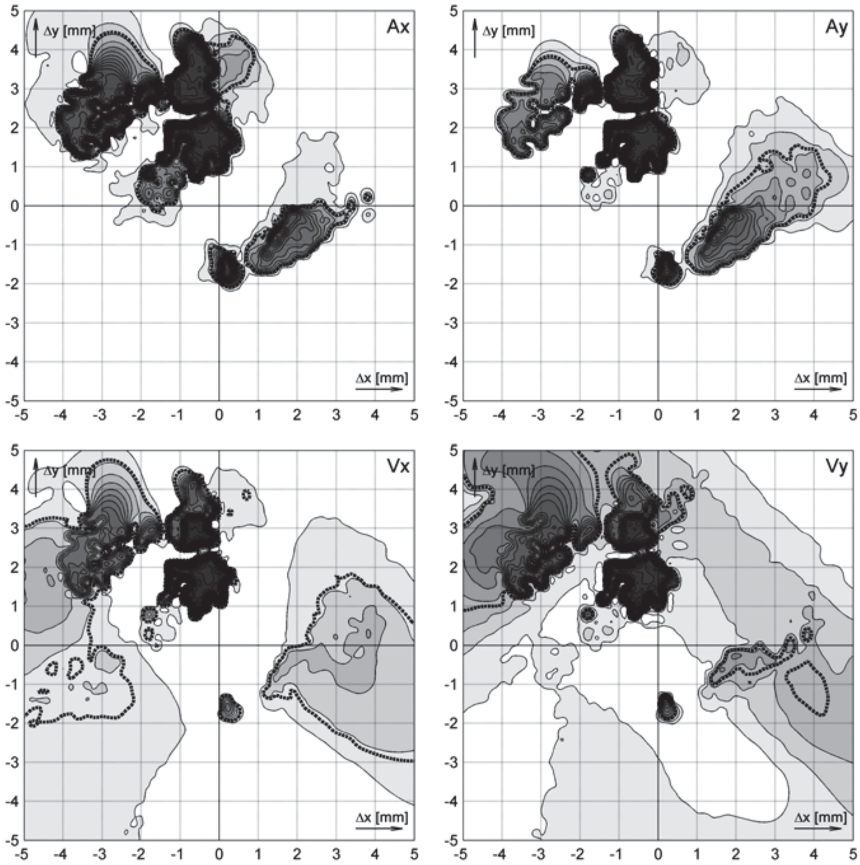

Fig. 6. The two-dimensional representations of the diagrams from the Fig. 3 in the form of contour lines. The broken lines link the points where presented parameters are equal to the limiting values

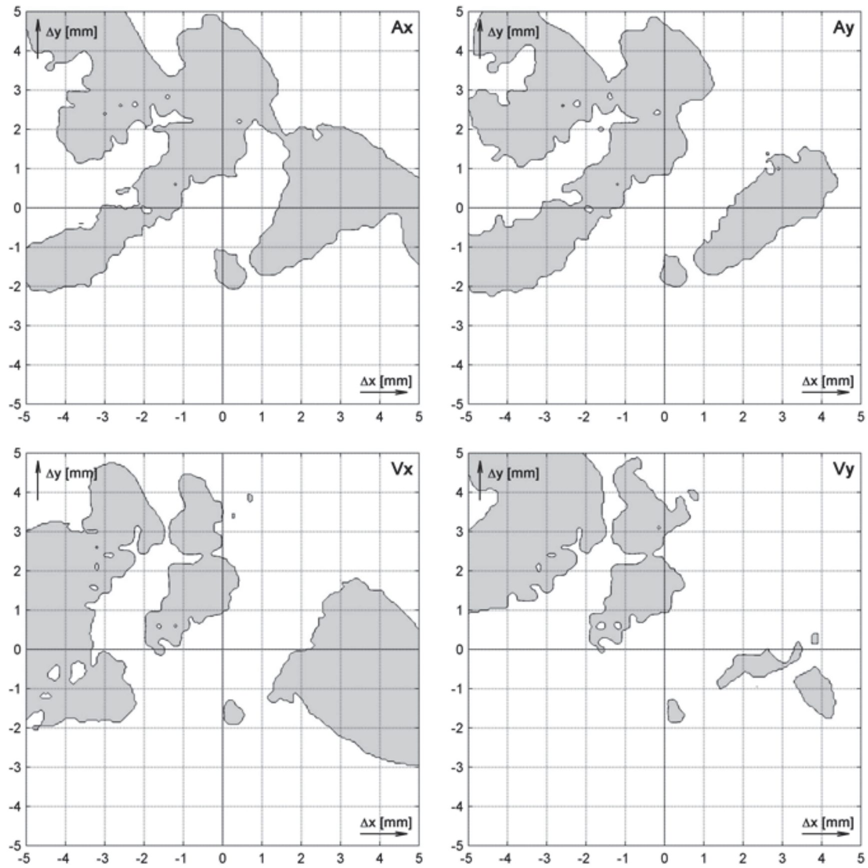

Fig. 7. The two-value, two-dimensional graphs, which show the division of the possible bearing dislocation area to the area of prohibited dislocations (marked dark) and area of permissible dislocations (white)

In the former case, an assessment is possible whether the known bearing misalignment, e.g. bearing dislocation measured by the diagnostic system, is safe, and, what effects generates this misalignment. In the latter case we can conclude about the scale and form of a bearing misalignment by comparative analysis of the machine vibration pattern recorded by the diagnostic system with vibration magnitude characteristics for a given misalignment readout on the maps. Moreover, the set of bearing dislocation maps enables distinction between bearing misalignment and other defects manifesting themselves in bearing vibrations despite the fact, that effects of bearing misalignment are not specific for this defect. The correct distinction is more possible if vibration parameters of many bearings may be analyzed altogether. Probability of the right diagnosis is very high if vibration patterns of all bearings agree with samples, which are readout from bearing misalignment maps. The distinction is also easier if additional symptoms may be taken into account, e.g. bearing oil temperature.

It is quite obvious, that a rotating multi-bearing machine should be considered unserviceable as a whole when only a certain single parameter is exceeded even in only one bearing due to misalignment of any bearing. But a single set of maps, like the sets shown in Figs 4 – 7, contain graphs for only one vibration parameter and for only one particular bearing. Moreover, the graphs present functions of displacements of only one particular bearing. The problem may be overcome on the ground of operations on sets. It is easy to note, that in the sense of the algebra of sets the area of prohibited dislocations of a given bearing is the sum of the areas of prohibited dislocations of this one bearing calculated with the viewpoint of fulfilment of given criterion in every particular bearing separately. For instance, when taking into account only the relative vibration criterion, the area of prohibited dislocations of the bearing 5 covers all these dislocations of the bearing 5, which generate unacceptable relative vibrations in any of bearings 1… 7. In similar way, the area of allowable and prohibited dislocations can be linked together via the abovementioned operations on sets also with respect to other criteria. Thus, based on numerous detailed maps, it is possible to find areas of bearing dislocations provoking certain generalised effects. Such operations on sets are very easy in relation to the defect maps in the numerical form. What is more, the maps in numerical form may be easy put into use in automatic diagnostic systems. Basing on so created numerical maps also graphical maps can be created for different combinations of criteria, for example with respect to vibration in one particular bearing, or with respect to particular kind of vibration. However this cause, that the number of graphs grows and their analysis becomes difficult.

5. THE GENERAL IDEA OF DEFECT MAPS

The primary idea of the presented work consists in specific methodology of presentation of the machine response to a certain class of defects. The idea of defect maps consists in mapping a machine technical state in certain domain of random events, which are represented by defects. In relation to the presented here defect of bearing misalignment the "domain of events" is an area of possible dislocations of bearings in relation to their base location. The "technical state" may be expressed e.g. by vibration intensity of the machine elements, which is subject of this article, but also by the bearing oil temperature, by the bearing load etc.

In general approach the "maps of defects" are represented by ordered sets of parameters, which determine technical status of the machine as the function of parameters, which ambiguously characterise defect in respect of type, location and intensity. The maps express intensity of machine reaction to defect as the function of parameters, which characterize the defect. According to this approach maps may be of graphical or numerical form. The numerical maps are the matrixes, which contain discrete parameter values but may be approximated for intermediate parameter values characterizing a defect. Maps in this form may find application in self-operated diagnostic and expert systems. The graphical maps are the plots made on the basis of the corresponding numerical maps. The form of graphical maps may be adapted to the intended application. The graphical maps may have a form of two- or three-dimensional plots illustrating intensity of analysed parameters. A level of the parameter may be shown in the maps e.g. as the diagram ordinate or using a colour scale. Various types of the graphical maps are illustrated in Section 4.

The method of the defect maps is especially suitable in the case of complex mechanical systems, where reducing diagnostic relations to simple logical sentences of defect-symptom type is not possible in practice. What is more, in some cases creation of predefined defect maps is the only possible solution. This is why methodology of the defect maps has been practically applied to bearing misalignment defect of the real power turbo-generator. In this particular application the maps characterize relative and absolute vibration of bearings as a function of bearing displacements in relation to their proper, base position. The practical result of the described above investigations is complete and ready to use knowledge base on the defect consisting in misalignment of all bearings of the 13K215 turbogenerator.

It should be remembered, that the knowledge base that is the object of this paper contain the effects of an individual bearing dislocations, i.e. situation in which the misalignment defect takes place in only one bearing, while the remaining bearings are still in their base positions. The defects consisting in simultaneous dislocations of two or more bearings couldn't be presented in the form of the ready-to-use base of knowledge, as the expected volume of resulting base and corresponding effort for its preparation would be too high. If necessary, however, arbitrarily selected individual cases of simultaneous dislocations of a number of bearings may be calculated and interpreted.

CONCLUSIONS

- The idea of presentation of a machine response to defects in the form of defect maps has been proposed. The maps allow presentation of the machine response to a set of defects in comprehensible, easy readable and usable form. The maps express intensity of machine reaction to defect as the function of parameters, which characterize the defect.
- The complex set of maps, which present response of the turbo-generator to the bearing dislocations has been created by computer simulation of the defect implemented in numerical model of the machine. The maps present relative journal vibrations and absolute bush vibrations, thus giving a general view on the machine resistance to misalignment of particular bearings from the viewpoint of defined criteria.
- The maps of bearing misalignment defect reveal, that vibrational response of the complex machine to the bearing misalignment is difficult to predict intuitively, as it can be rapid and unexpected. Vibration intensification gradient is especially high at the border between the areas of permissible and prohibited bearing dislocations.
- In some areas of possible bearing misalignments small increase in bearing displacement may lead to sudden appearance of extremely high vibrations, which many times exceed the permissible limits. In those situations the limitations for relative vibration amplitudes are physical restrictions resulting from the size of bearing clearance. This suggests the presence of vibrational instability of the rotors or bearings.
- The set of maps containing information on effects of the tutbogenerator bearing misalignment can be interpreted as the base of knowledge on this defect and may be implemented in the turbogenerator diagnostic system. The presented work is an example of practical realisation of a concept of creating a pre-defined base of diagnostic

knowledge using the model based computer simulation.

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