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POLISH ACADEMY OF SCIENCES

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Aims and Scope

Transactions of the Institute of Fluid-Flow Machinery have primarily been established to publish papers from four disciplines represented at the Institute of Fluid-Flow Machinery of Polish Academy of Sciences, such as:

- Liquid flows in hydraulic machinery including exploitation problems,
- Gas and liquid flows with heat transport, particularly two-phase flows,
- Various aspects of development of plasma and laser engineering,
- Solid mechanics, machine mechanics including exploitation problems.

The periodical, where originally were published papers describing the research conducted at the Institute, has now appeared to be the place for publication of works by authors both from Poland and abroad. A traditional scope of topics has been preserved.

Only original and written in English works are published, which represent both theoretical and applied sciences. All papers are reviewed by two independent referees.

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Editorial

These Special Issues of the *Transactions of Fluid-Flow Machinery*, Nos. 113 and 114 contain selected papers from the International Conference on *Turbines of Large Output* devoted to commemorate 100$^{\text{th}}$ Birthday Anniversary of Prof. Robert Szewalski. The conference was held in Gdańsk, Poland on September 22-24, 2003.

The Conference is a continuation of previous conferences held at the Institute of Fluid-Flow Machinery PAS in former years dedicated to technology of steam turbines. Series of conferences bearing the same name took place in the years 1962, 1965, 1968, 1993. In 1997 organised has been a conference on steam turbines and related topics, but with a slightly amended title – *Problems of Fluid-Flow Machinery.* At present at the Institute of Fluid Flow Machinery there are conduced research of fundamental character encompassing both the issues related to steam turbines and fundamentals of power engineering.

Organisers of the present conference have returned to the traditional name, i.e. Conference on *Turbines of Large Output* to mark the respect to the memory of Professor Robert Szewalski (1903-1993), the founder and a director of the Institute of Fluid-Flow Machinery for several years, and initiator of the conference series devoted to the problems of steam turbines.

The Editors are very grateful to the referees of the papers presented in this issue of the *Transactions of Fluid-Flow Machinery*: J. Badur, W. Batko, E. S. Burka, J.T. Cieśliński, P. Doerffer, A. Gardzilewicz, B. Grochal, J. Kiciński, G. Kosman, T. Król, J. Krzyżanowski, J. Mikielewicz, A. Neyman, W. Ostachowicz, R. Puzyrewski, R Rządkowski, J. Świrydczuk, M. Trela, T. Uhl and Z. Walczyk.

We appreciate cordially the manifested authors interest in our conference. Special thanks are conveyed to Ms 'Maya' Bagińska, for her fruitful editorial help related to directing the papers to reviewers and correspondence with the authors of contributions.

Prof. Jarosław Mikielewicz
Editor-in-Chief

Dr Edward Śliwicki
Managing Editor

TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

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Influence of operational modes of a powerful turboset on its vibrational state

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Abstract

A correlation method for estimation of the influence of the change of turboset operational modes on its vibrational state using experimental data at post-analysis is used. For the solution of the problem in the automated operational mode of a system for vibrational diagnostics, the method using average value and current values of indexes of vibrational and technological processes is proposed. The results of full-scale investigations of vibrational state of the turboset at the change of power consumption are presented

Keywords: Correlation; Turboset; Vibration: Vibrational diagnostics

Nomenclature

K_S	–	parameter(index) of change of current vibrational parameter
K_T	–	parameter(index) of change of current technological parameter
M_S	–	average value of vibrational parameter
M_T	–	average value of technological parameter
N	–	width of the window, s
r	–	correlation coefficient
U_S	–	setting for vibrational parameters
U_T	–	setting for technological parameter

1 Problem definition

At transition to the maintenance of machines and equipment on their actual state, instead of under the rules it is necessary to check and to track the change

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not only vibrational state, but also to determine the causes of these changes. Occurrence and development of defects and faults of mechanical nature can be regarded as such causes. At the same time, the change of vibrational state can be caused by the change of operational modes of the set, which are characterized by technological parameters.

The development of methods permitting, in an automated mode, to recognize the change of vibration from the change of operational factors (technological parameters) is necessary for the estimation of the influence of operational factors on vibrational state This paper is dedicated to the solution of such problem.

2 Presentation of the main information

The automated system for continuous monitoring and analysis of vibrational parameters has been in operation for some years now on the extraction turbo-set T-250/300 of the Kiev thermo-electric plant No. 5 [1,2]. The systems consists of means for shaft and bearings supports vibrations measurement integrated by PC with driver. The system allows to record, analyse and indicate the vibrational measuring information, check the vibrational state of the turbo-set and give warning to operation personnel on accident situations.

For diagnostics of vibrational state of the machine and finding of the causes of increased vibrations it is important to determine whether the increase of vibrations is caused by the development of defects and damages or by changes of operational factors. For the solution of the problem on the estimation of influence of operational factors on vibrational state of the turboset we use standard methods of statistical data processing. As a measure of interdependence between operational parameters of the turboset and its vibrational state it is proposed to use a correlation coefficient r [3]

$$r = \frac{1}{N}\frac{1}{c_S c_T}\sum_{i=1}^{N}(S_i - m_S)(T_i - m_T), \tag{1}$$

where S_i – vibrational parameter; T_i – technological parameter; N – width of the window; c_S, c_T – root-mean-square values of samples; m_S, m_T – arithmetical averages of samples. For example, at the determination of r (see Fig. 1, graph 4) S – maximal modulus of shaft neck of vibrational displacements (see Fig. 3, graph 2); T – active power of the generator (see Fig. 3, graph 1); N – 2700 s; c_S, c_T are calculated by formulas $c_S = \sqrt{\frac{1}{N}\sum\limits_{i=1}^{N}(S_i - m_S)^2}$, $c_T = \sqrt{\frac{1}{N}\sum\limits_{i=1}^{N}(T_i - m_T)^2}$; and m_S, m_T respectively $m_S = \frac{1}{N}\sum\limits_{i=1}^{N} S_i$, $m_T = \frac{1}{N}\sum\limits_{i=1}^{N} T_i$.

By the data of continuous measurements of vibrational and technological parameters in the mode of a slipping window (with each new input value of parameters in time the process of calculation is carried out again) the correlation coefficients are determined. Thus the value r depends on the width of the window N, that is confirmed by presented in Fig. 1 graphs of the change of correlation coefficients obtained at different N [4]. Let's mark, that at small values N the error of calculation increases, and also the share of random components increases, that can result in inadequate estimation of the situation. At increase of N the accuracy increases, but the "lag" of definition of the correlation coefficient increases also. That results in the time lag of the estimation of influence of the operational factors on the vibrational state of the turboset. It is necessary to take it into account when using the algorithm in real-time mode by assigning a large N. Let's notice also, that alongside with the "lag" of the estimation of the correlation coefficient the time lag of reaction of vibrational state of the turboset on change of technological parameters can take place, that also complicates the selection of N.

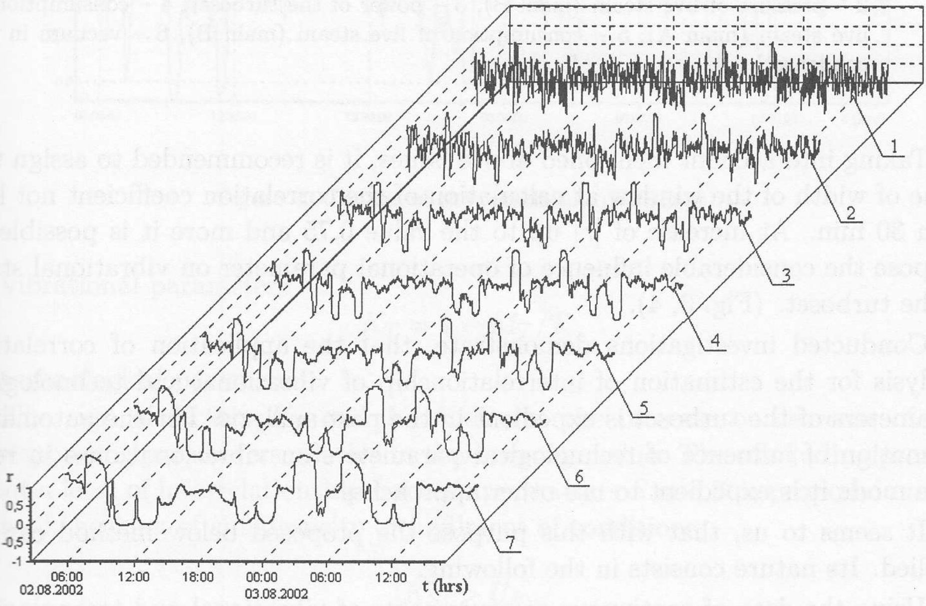

Figure 1. Change of the correlation coefficient in time at different width of the window N (1 – $N = 450$ s, 2 – $N = 900$ s, 3 – $N = 1800$ s, 4 – $N = 2700$ s, 5 – $N = 3600$ s, 6 – $N = 5400$ s, 7 – $N = 7200$ s).

As a rule, the change of operational parameters such as power of the turboset, consumption and pressure of live steam, vacuum in the condenser decreases stepwise during 10-30 minutes (Fig. 2).

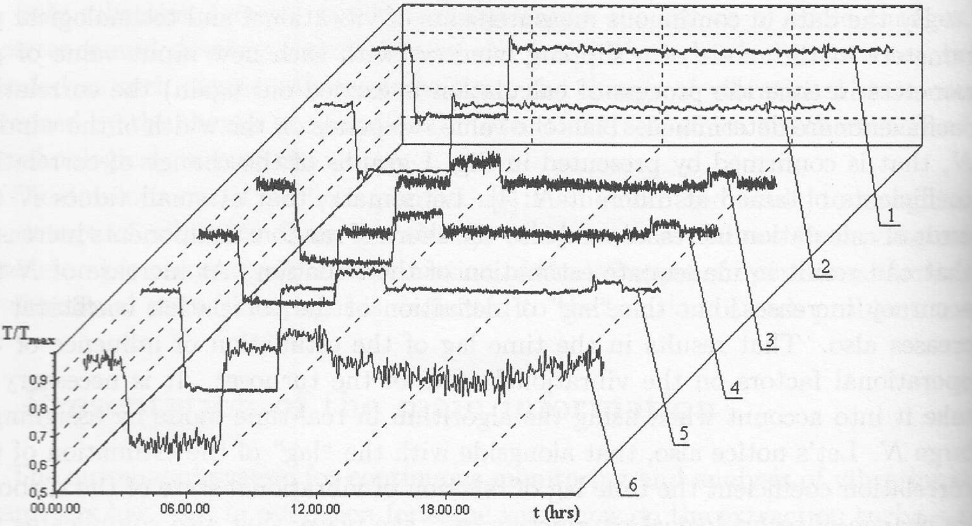

Figure 2. Change of operational parameters for one day (1 – pressure of live steam (main A), 2 – pressure of live steam (main B), 3 – power of the turboset, 4 – consumption of live steam (main A), 5 – consumption of live steam (main B), 6 – vacuum in the condenser).

Taking into account mentioned above issues, it is recommended to assign the value of width of the window at calculation of the correlation coefficient not less than 30 min. At increase of $|r|$ up to the value 0.75 and more it is possible to suppose the considerable influence of operational parameter on vibrational state of the turboset. (Fig. 3, 4).

Conducted investigations demonstrate, that the application of correlation analysis for the estimation of interrelationship of vibrational and technological parameters of the turboset is expedient in the post-analysis. For the automated estimation of influence of technological parameters on vibrational ones in real-time mode it is expedient to use other approaches.

It seems to us, that with this purpose the proposed below method can be applied. Its nature consists in the following.

Using the data of continuous measurements of vibrational and technological parameters of the turboset the average value M_S and M_T are calculated in the mode of slipping window. They are used for calculation of the index of change of current values of operational and vibrational parameters. Factors K_S and K_T are applied, as an index of change of current values of parameters S and T, respectively. They are determined as follows:

$$K_S = 1 - M_S/S \tag{2}$$

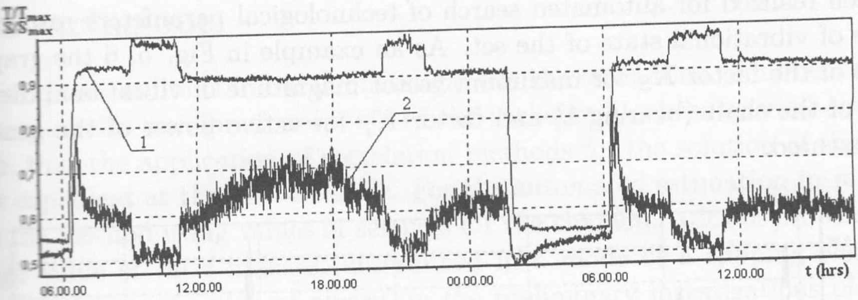

Figure 3. Change of active power of the generator (1) and maximum modules of vibrational displacements of the shaft neck (2).

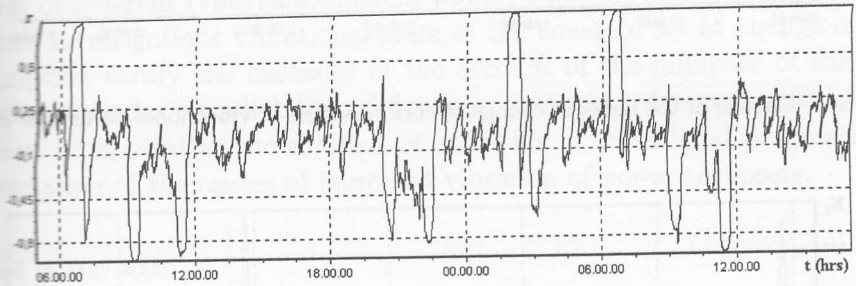

Figure 4. Change of the correlation coefficient.

for vibrational parameters

$$K_T = 1 - M_T/T \tag{3}$$

for technological parameters.

The sign of factors K_S and K_T indicates the increase or decrease of the corresponding parameters relative to their average value. *The concluding process about a level of interrelationship between parameters S and T is proposed on the* basis of checking of simultaneity of fulfilment of conditions

$$|K_S| > U_S, \tag{4}$$

$$|K_T| > U_T. \tag{5}$$

It is recommended to assign the values U_S, U_T from the condition of "sensitivity" of the algorithm. Thus, it is necessary to *take into account the results of preliminary investigations of the range of change of factors K_S and K_T for the concrete set. The preliminary statistical data are necessary also at definition of the width of the window N* for calculation of M_S and M_T. The algorithm has been realized for automated search of technological parameters resulted the change of vibrational state of the set. As an example in Fig. 5, 6 the graphs of change of the factor K_S for maximum vector magnitude of vibrational displacements of the shaft (bearing 1) and factor K_T for active power of the generator are presented.

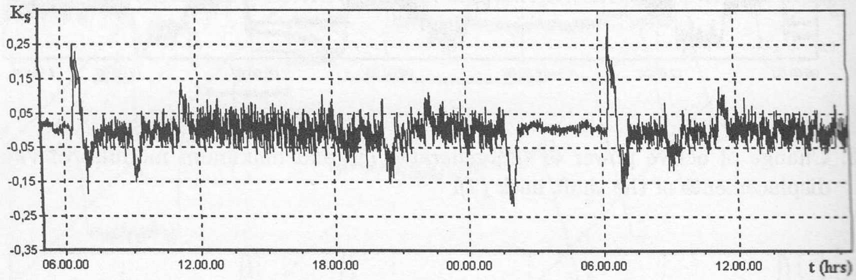

Figure 5. Change of the index of change of current values of vibrational parameter K_S.

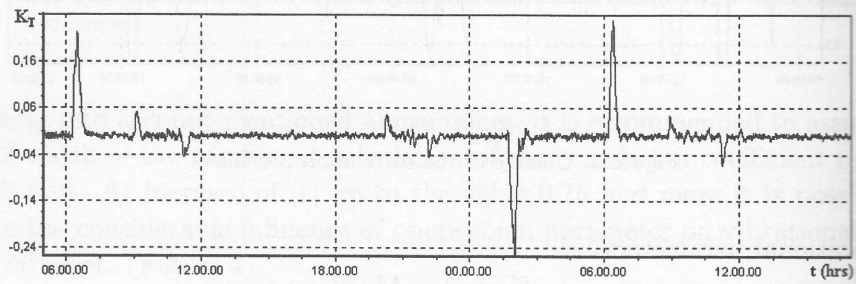

Figure 6. . Change of the index of change of current values of technological parameter K_T.

At excess of the setting K_S the search of operational parameter, for which K_T reaches the value of the setting, is carried out. Analysing the results it is possible to determine the statistical relationship between vibrational and technology factors. It is necessary to take into account, that determination of the interrelationship between operational and vibrational indexes indicates on the possibility of change of vibration from the change of operational modes and does not exclude the possible contribution of the high-developing defect of mechanical nature on increase of vibration. At the same time, the factor K_S can be used as a diagnostic indication of a developing defect, because the range of change K_S for the separate set practically does not change in the overhaul period. The departure beyond the limits of range of possible K_S values can serve a signal about the development of a defect.

3 Conclusions

Using the results of full-scale investigations the estimation of influence of operational modes on vibrational state of the turboset has been carried out. It is shown, that the application of correlation methods for the solution of this problem is expedient at the post-analysis. For the automated estimation in real-time mode the method using values of settings for the characteristics of processes and average value of their indexes, determined in a mode of a slipping window is proposed. For application of algorithm the preliminary investigations of ranges of change of factors K_S and K_T for the concrete set and duration of transients are expedient. It is necessary to take into account their results at assigning the values of settings and width of a window of observations, which can be different for sets of different types and different power. Presented in the paper results of full-scale investigations vibrational state of the concrete set at change of power consumption testify the necessity of the account of the influence of changes of operational modes on reliability of dynamic operation of power units. The results can be applied at the solution of problems of vibrational diagnostics and determination of the causes of increased vibration of power turbosets.

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