1.8.12. NEW MACHINERY CONDITION MONITORING TECHNIQUE BASED ON MULTIDIMENSIONAL VISUALIZATION OF VIBRATION S-DISCRIMINANTS

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The standard approach to machinery condition monitoring is known to base on overall levels measurement data collected for specific frequency bands and subsequent comparing them with alarm thresholds. As a rule the common monitoring algorithms are not destined to machinery incipient fault detection and equipment parts deterioration prevention, but only for vibration protection aims.

The proposed new machinery vibration monitoring technique built upon usage of parallel narrowband S-discriminant analysis of clipped vibration signals [1] provides localization of machinery heightened "vibroreactivity" sources, in other words of frequency bands with signal dispersion dramatically grown in comparison with reference measurement data due to rising and then developing defects. Convenient for further interpretation of the multidimensional information presentation as a matrix where array cells are S-discriminants coloured meanings (in accordance with coloured bargraph) gives a good tool for incipient fault detection, primary (initial) identification of flaws and on-the-fly estimation its development rate.

Examples of the novel vibration monitoring technique practical application is given in the paper as for early detection of gas transportation compressor station avia-derivative gas turbine engine parts operation damages (bearing faults, damages of turbine gas generator nozzle and blade set) on GTU (gas turbine unit) case vibration measurement data.

Beneath there is the table with vibration velocity S-discriminants peak values colour presentation for case measurement point TGG-Hor (in quasioctave frequency bands) within operational dates Dec 26, 2006 through Jul 27, 2007 when nozzle set of HPT was burning up.

It follows from the data given in the table one that the burnout of the nozzle – fixed TVD unit, significantly changes vibration parameters in the high frequency band (3.0 – 4.0 kHz), with Max Id = 185. However, the narrow band 3.0 – 3.5 kHz with Max Id = 802.2 dated 13.05.07, i.e. in 2.5 before the engine stripping is the most. On the basis of a spectrum shape analysis it is possible to assume that the physical source of oscillations excitation at this band is the "whistle" – an autooscillation process created in gas flow eddy generation of a at the edges of a through hole in the design of the nozzle for cases of leakage under pressure.

Table 1. GTU hightened vibroreactivity sources localization when second stage HPT nozzle set of engine PS-90 was burning up

(1-2)	(3-4)	(5-8)	(9-16)	(17-32)	(33-64)	(65-128)	(129-256)	(257-512)	513-1024	1025-2048

<table>
<tr><td>ΔF</td><td colspan="8">S-discriminants peak value for case measurement point TGG-Hor within different frequency bands in time lag Dec 26, 2006 through Jul 27, 2007</td></tr>
<tr><td>4.0 kHz</td><td colspan="8">4.8</td></tr>
<tr><td>2.0 kHz</td><td colspan="4">2.2</td><td colspan="4">23.9</td></tr>
<tr><td>1.0 kHz</td><td colspan="2">2.7</td><td colspan="2">3.3</td><td colspan="2">2.0</td><td colspan="2">185</td></tr>
<tr><td>0.5 kHz</td><td>9.8</td><td>2.1</td><td>5.4</td><td>5.3</td><td>2.1</td><td>4.3</td><td>802.2</td><td>38.0</td></tr>
<tr><td>Date</td><td>20.05.07</td><td>17.04.07</td><td>04.07.07</td><td>05.05.07</td><td>15.07.07</td><td>25.04.07</td><td>13.05.07</td><td>31.05.07</td></tr>
</table>

F (kHz) 0.1 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

Table 2. Values trend of S- discriminants vibration velocity of GTU body in TGG in broad (0 – 4.0 kHz) and narrow (0.5 kHz) frequency bands in the operation period form 26.12.06 till 27.07.07 in case of a TVD nozzle burnout development

(1-2)	(3-4)	(5-8)	(9-16)	(17-32)	(33-64)	(65-128)	(129-256)	(257-512)	513-1024	1025-2048

Frequency band	ΔF ≈ 4.0 kHz	ΔF ≈0.5 kHz							
Dates	0-4.0	0.1-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0
26.12.06_18.02 - Referance	1	1	1	1	1	1	1	1	1
Out of operation (13.02-15.04.07)									
16.04.07_18.00 – Defect rise	2	2	1	2	3	1	1	45	2
17.04.07_18.02	1	4	2	1	1	1	1	382	2
18.04.07_18.00	1	2	1	2	2	1	2	106	1
27.04.07_18.00	1	2	1	2	4	1	2	428	2
10.05.07_06.00 – Full-blown defect	1	2	1	2	1	1	1	742	<1
13.05.07_06.00	1	2	1	3	1	1	<1	350	1
13.05.07_18.00 – Max defect дефекта	2	3	1	2	2	1	<1	802	1
14.05.07_06.00	2	3	1	3	1	1	<1	249	1
14.05.07_18.00	2	4	1	2	4	1	<1	560	1
20.05.07_18.00 – Secondary damages	1	10	1	2	2	1	<1	282	5
24.05.07_06.00	1	2	1	1	1	1	<1	150	2
Out of operation 25 .5 thru 27. 05.07									
28.05.07_08.32 – Secondary damages	1	5	0	2	2	1	1	107	17
29.05.07_06.00	1	2	0	3	3	<1	<1	122	33
31.05.07_18.00	2	4	1	2	3	<1	<1	20	39
06.06.07_18.00	1	1	1	3	<1	1	<1	465	1
12.06.07_06.00	1	1	1	3	<1	1	<1	16	2
12.06.07_18.00	1	1	1	2	1	1	<1	195	1
14.06.07_18.00	1	3	1	2	1	1	<1	598	3
Out of operation 19.06 thru 24.06..07									
25.06.07_18.00	1	1	<1	4	<1	2	<1	29	9
07.07.07_18.00	<1	<1	<1	3	<1	1	<1	278	1
11.07.07_06.00	<1	<1	<1	2	<1	1	<1	6	1
11.07.07_18.00	<1	<1	<1	2	<1	1	<1	240	1
18.07.07_18.00 – Multiple fault	<1	<1	<1	1	1	1	<1	4	1
Out of operation 19.07 thru 23.07.07									
27.07.07_18.00 – Engine shutdown	<1	<1	<1	1	1	1	<1	1	1

The given below table shows values trends of S-discriminants in broad and 8 frequency bands in development of the same defect (*selected data*).

Vibroreactivity tables allows to visually estimate cases of deviations of the object's technical condition from the norm and a speed of defects development for the purpose of making decisions concerning further operation.

Conclusions. The paper is one amongst others which show that to effectively monitor machinery conditions, to incipiently diagnose and localize heightened vibroreactivity sources, the condition monitoring procedure has to be built upon vibration features susceptible to vibration signal overshoots and even slight changes of its amplitude. These requirements are met the proposed vibration condition monitoring algorithm based on conception of non-dimensional S-discriminants presentation as multidimensional trend plot which is convenient tool for decision of different tasks:

– organization of automatic vibration monitoring;

– insipient condition monitoring;

– preliminary faults identification and definition of cause-and-effect relations along the operational time.

Reference:

1. **Соколова А.Г.** Алгоритм вибромониторинга машинного оборудования с адаптацией к базовому состоянию // Контроль. Диагностика. – 2005. – № 11. – С. 30 – 40.