SELECTION OF EFFICIENT MONITORING METHODS FOR MACHINERY GENERATING HIGH VIBRATION SIGNAL DISTURBANCE

Tomasz BARSZCZ*, Jacek URBANEK*, Łukasz SZUMILAS**

*Katedra Robotyki i Mechatroniki, Akademia Górniczo-Hutnicza
Al. Mickiewicza 30, 30-059 Kraków, tbarszcz@agh.edu.pl
**EC Systems sp. z o.o., ul. Lublańska 34, 31-476 Kraków, lszumilas@energocontrol.pl

Summary

Monitoring and diagnostics systems of machinery are increasingly used in many industries. Generally, these systems are responsible for such a machinery like steam turbines, pumps, fans, etc. The increase in efficiency as well as the growing interest of diagnostics systems has expanded the potential markets to other related industries such as mining or metallurgy.

This paper presents efficient monitoring methods of machinery generating high vibration signal disturbances. The results have been developed by a diagnostic team, monitoring a reciprocating compressor, which is located on the Baltic Sea oil rig. Important feature of the compressor is existence of strong impacts in the vibration signals. These impulses introduce strong distortion to the signal spectrum.

The paper shows that different faults require specific diagnostic methods. The paper shows example of selection of such a method. It is the application of the enhanced resolution envelope analysis for detection of the bearing faults.

Keywords: diagnostics, reciprocating compressor, narrow band envelope analysis.

DOBÓR EFEKTYWNYCH METOD MONITORINGU DLA MASZYN GENERUJĄCYCH SILNE ZAKŁÓCENIA SYGNAŁÓW DRGANIOWYCH

Streszczenie

Systemy monitoringu i diagnostyki maszyn są coraz powszechniej stosowane w wielu gałęziach przemysłu. Są odpowiedzialne za pracę takich maszyn jak turbiny parowe, pompy, wentylatory i wiele innych. Powiększająca się skuteczność oraz wzrost zainteresowania systemami diagnostycznymi spowodował poszerzenie grona odbiorców na inne pokrewne gałęzie przemysłu takie jak przemysł wydobywczy i hutniczy.

Niniejszy artykuł przedstawia efektywne metody monitorowania stanu technicznego maszyn charakteryzujących się silnymi zakłóceniami sygnału drganiowego. Wyniki opracowane zostały przez zespół diagnostów monitorujących kompresor tłokowy, który znajduje się na platformie wiertniczej na Morzu Bałtyckim. Charakterystyczną cechą pracy kompresora jest obecność bardzo silnych impulsów. Impulsy te wprowadzają silne zakłócenia widma sygnałów drgań.

W artykule pokazano, że w zależności od typu uszkodzenia konieczny jest dobór specyficznych metod diagnostycznych. Artykuł przedstawia przykłady zastosowania analizy obwiedni o podwyższonej rozdzielczości do wykrywania uszkodzeń łożysk tocznych.

Słowa kluczowe: diagnostyka, kompresor tłokowy, analiza obwiedni.

1. INTRODUCTION

Monitoring and diagnostics systems of machinery are increasingly used in many industries. Generally, these systems are responsible for such machinery like steam turbines, pumps, fans, etc. The increase in efficiency as well as the growing interest of diagnostics systems has expanded the potential clients body to other related industries such as mining or metallurgy.

Modern machines, ubiquitous in our daily life, are characterized by a complex structure and a challenging technical state assessment. Monitoring and diagnostics systems are generally dedicated to rotating machinery with a relatively simple design (e.g. steam generators, fans, pumps). Such systems take advantage of commonly known vibration analysis in the time domain as well as in the frequency domain, which are prone to extraneous disturbances. Those disturbances can be results of both: external sources, operation of supporting machinery and the object nature of work.

One of the examples of machines, which require a custom diagnostic algorithms is gas compressor explored by the authors. The presence of strong impacts excited by the compressor's pistons causes the characteristic frequencies to be masked, and ultimately unrecognizable.

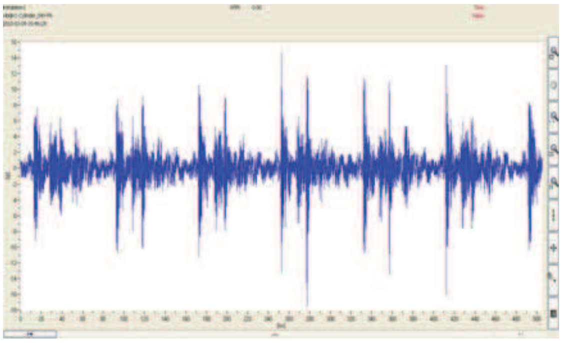


Fig. 1. Vibration signal from the gas compressor

Fig. 1 illustrates a fragment of a time vibration signal of the investigated large-dimension piston compressor. As stated above, a number of strong several impacts can be observed. Due to the number of compression levels, these disturbances occur at the rate of 0.04 s. Such a high impulse repetition rate totally hinders the analysis of signal's fragments recorded between the impulses, since these signals become too short. Therefore, in order to enable vibration analysis, a number of custom algorithms should be engaged.

2. OBJECT DESCRIPTION

The studied gas compressor of a type Dresser Rand C-VIP Compressor is 1000kW, operating between 600-1000 rpm, is a four-stage compression machine. Fig. 2 illustrates the layout of the compressor.

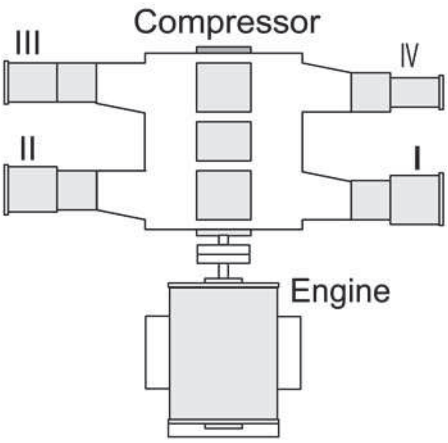


Fig. 2. Layout of the gas compressor

The machine is located on an oil rig in the Baltic Sea, and is responsible for a natural gas compression and transport (to the power plant 70 km away). Supporting machinery (hydrocarbon pumps, oilers, coolers etc.) has a strong influence on operational conditions of the described object. Due to very important function of the reciprocating compressor and high security requirements it is necessary to provide proper operation by scheduling repairs effectively. Location of the facility and the difficult weather conditions is the serious obstacle for frequent visit of maintenance team. This implies the need to reduce repairs to the minimum. Therefore, the decision of condition monitoring system has been made.

3. SYSTEM DESCRIPTION

The installed system of monitoring and diagnostics includes 20 vibration channels, four on every compression level. The remaining channels monitor rolling bearings, supporting the shaft. For every channel, a set of standard analysis has been defined. Apart from typical broadband analysis, a set of frequency analysis corresponding to particular machine parts has been configured in the system. Additionally, a phase reference sensor has been mounted, in order to obtain the speed information. Moreover, a set of process values is monitored, including pressures, temperatures, and flows. The highly-hazardous working environment (salt vapors, ATEX zone) has forced the designers to implement special solutions.

4. TYPICAL VIBRATION SIGNALS GENERATED BY GAS COMPRESSOR

The compressor operation is characterized by the generation of relatively strong vibrations, among which the piston and valves related impacts are the most dominant. These impacts in turn produce impulse responses, which induce vibrations in numerous machine components. It makes typical usage of frequency analysis almost impossible. Fig. 3 shows Fourier spectrum of vibration signal of gas compressor. Strong harmonic components of rotational speed caused by mentioned impacts can be seen.

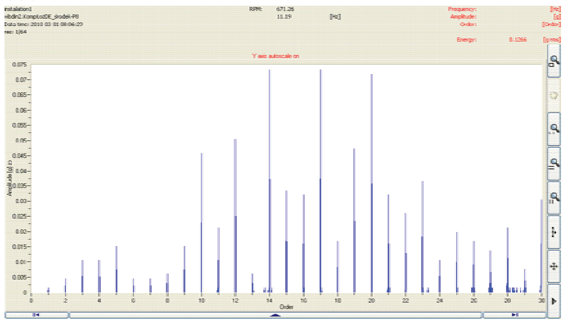


Fig. 3. Fourier spectrum of vibration signal of gas compressor

They are present in the whole range of analyzed frequencies (12kHz), which masks characteristics signals of other machine components. Another obstacle in vibration analysis is the influence of process parameters on the vibration signal generated by the machine. Fig.4 presents trends of the rms and the parameter of pressure at the inlet to the pipeline at constant speed operational conditions.

The installation tracks 22 process values, which together with aforementioned 20 vibration channels (about 6 analyses per channel, what gives altogether 120 analysis results), creates a complex correlation net.

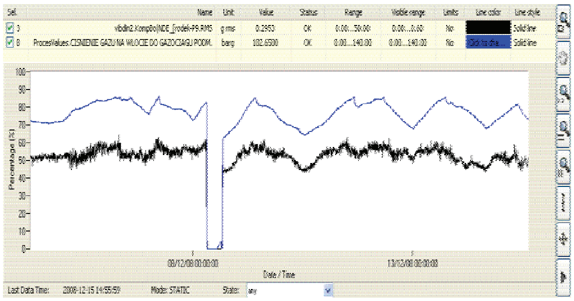


Fig. 4. Trends of the rms and pressure

5. BEARING FAULT DETECTION

Over a several years of the compressor continuous monitoring, a number of malfunctions was experienced by the authors. Generally, the malfunctions concerned bearings' races, raptures of elements connecting mid-chambers with the body, and breakage of bolts mounting cylinders' covers.

Due to harsh operating conditions, in all of these cases, the classical vibration analysis din not meet the customer's expectations.

In order to enhance the risk assessment efficiency, a number of extra vibration algorithms has been developed and implemented (including order analysis and custom envelope analysis). Typical method for detecting bearing faults is wideband envelope analysis, insufficient in describe case. Envelope spectrum calculated in tradition method shows only rotational speed components. It is necessary to apply more selective diagnostic methods.

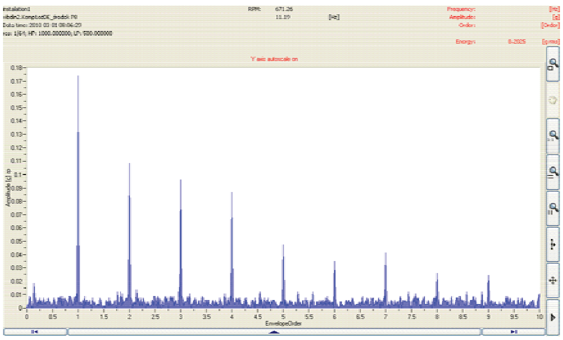


Fig. 5. Envelope order spectrum

The first method was the high resolution envelope analysis. In this method, we have calculated the envelope spectrum after signal resampling, which improves peakidness of spectral lines from synchronous sources. Then, the spectrum had sufficient line resolution to detect spectral lines from the sought bearing fault. The fig. 6 presents the high resolution envelope spectrum. As shown, the sought fault signature is visible, but the magnitude of the responsible spectral lines is low and the fault is still hard to detect.

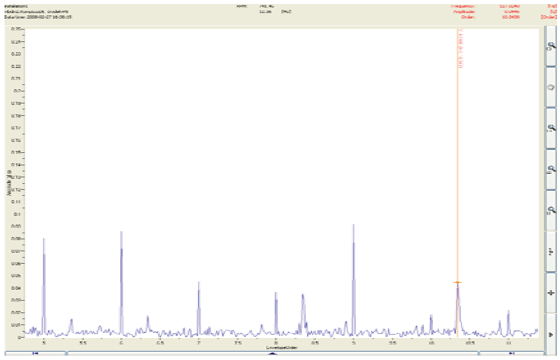


Fig. 6. High-resolution envelope spectrum. Two lines caused by the innerring bearing fault are visible

The second method was the narrowband envelope analysis (NEA) based on the Hilbert transform [1]. For a proper parameters selection, the method enables identification of rolling-element bearings' characteristic components.

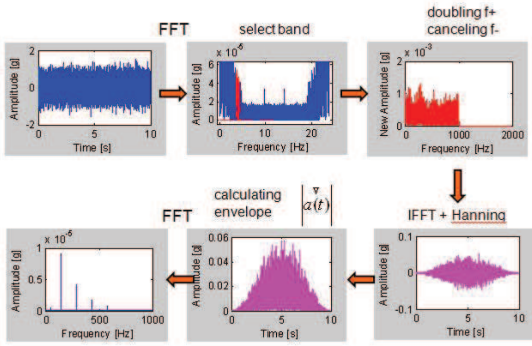


Fig. 7 The algorithm of envelope spectrum generation [1]

The principle of the NEA algorithm is the selection of the band, in which the vibration signal is to be demodulated. The band selection problem was discussed in a number of contributions [2] of which the kurtogram proposed by Antoni [3] deserves a special attention. This powerful method is based on the kurtosis of the vibration signal processed by several filterbanks, modifying both, the center frequency (*CF*), and the filter bandwidth (*dF*). Nevertheless, this approach is sensitive to strong impulsive noises, which are present in the case of the reciprocating compressor. The Fig. 8 presents the Fast Kurtogram calculated for the vibration signal with the bearing fault. The presence of such disturbances may cause the kurtogram to miss the optimal solution, which in fact results in magnifying impulses not related to the fault.

Since the aforementioned method of the optimal band selection did not yield useful results, the authors have started to investigate the problem thoroughly starting from the basic approach. On one hand, a number of cases has been encountered, when "trial & error" approach gave relatively satisfactory results. On the other hand, it is obvious that such approach is (to a degree) based on pure luck. Moreover, it would require to assess a number of combinations manually. Therefore, another methods have been used in order to limit the number of possible *CF-dF* [1].

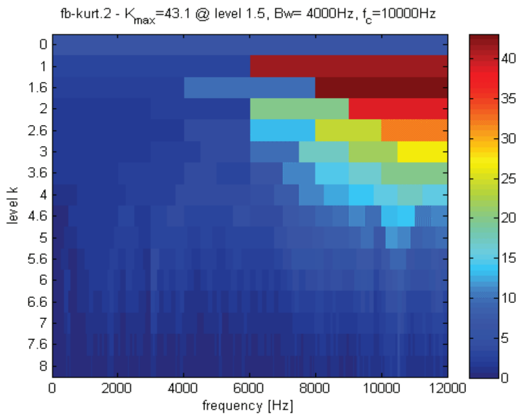
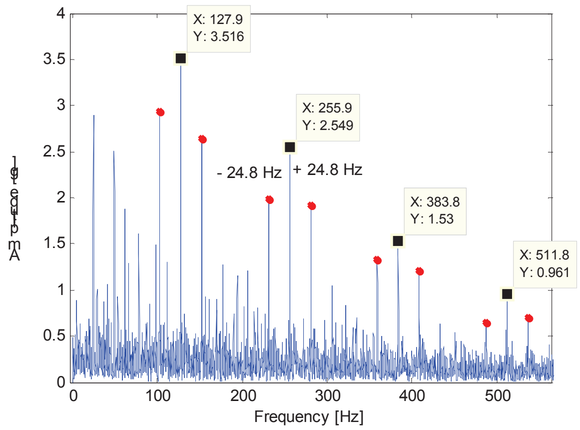


Fig. 8. Fast Kurtogram obtained from the signal with the fault. Detected maximum is not related to the fault, but to the operation induced impacts



Rys. 9. Narrowband envelope spectrum (CF=8900 Hz, dF=600 Hz)

Fig. 9 illustrates the narrowband envelope spectrum with marked bearing inner race characteristic component. The figure was calculated for the center frequency *CF* equal 8900 Hz, and the bandwidth *dF* 600 Hz. The first four harmonics from the bearing fault BPFI are clearly visible along with the sideband components spaced at 2 times the machine speed.

6. CONCLUSIONS

The proposed methods have enabled to extract diagnostic information from the vibration signals, despite of the high disturbances. However, the selection of the optimal parameters for the developed algorithms is yet to be improved. The further work of the authors will also be directed towards signal separation. Even though the latter topic is popular topic in the signal processing literature, the high repetition rate of the impulses remains a challenge to both, scientists and engineers.

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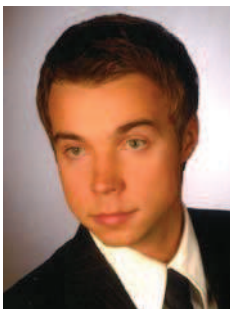
dr hab. inż. **Tomasz BARSZCZ**. Graduate of Electronic Eng at Politechnika Gdańska (1993r.). Received PhD in mechatronics in 1997r. (AGH). Has long experience of working with companies like ABB Zamech and ALSTOM Power. Author of many papers and books on machinery diagnostics. Monitoring systems developed under his supervision were installed on several hundred machines worldwide.

mgr inż. **Jacek URBANEK** PhD student in the Department of Robotics and Mechatronics, AGH University of Science and Technology, Kraków, Poland. His scientific interests are focused on practical application of machine diagnostics. Co-author of hand book on vibrodiagnostics (2008).



mgr inż. **Łukasz SZUMILAS**. Graduate of Department of Robotics and Mechatronics, AGH University of Science and Technology, Kraków, Poland. (2008). Currently working as a diagnostics engineer in EC Systems in Kraków. His scientific interests are focused on difficult cases of fault detection in compressors, wind turbines and printing machines.