“Modelling of the machines damage detection for Polish mines”

Wojciech Okrasiński, Wrocław University of Science and Technology, Hugo Steinhaus Center,
Agnieszka Wyłomańska, Wrocław University of Science and Technology, Hugo Steinhaus Center,

“Models, Simulation, Optimization: Mathematical Technologies for Industrial Innovation in Europe”

Rome, Italy
19-21 December 2016
Accademia dei Lincei

Modelling of the machines damage detection for Polish mines

H2020 **SOCIETAL CHALLENGE**

The Industrial Problem

Technical diagnostics and mine machines damage detection

Mining

Research group

Hugo Steinhaus Center, Wrocław University of Science and Technology

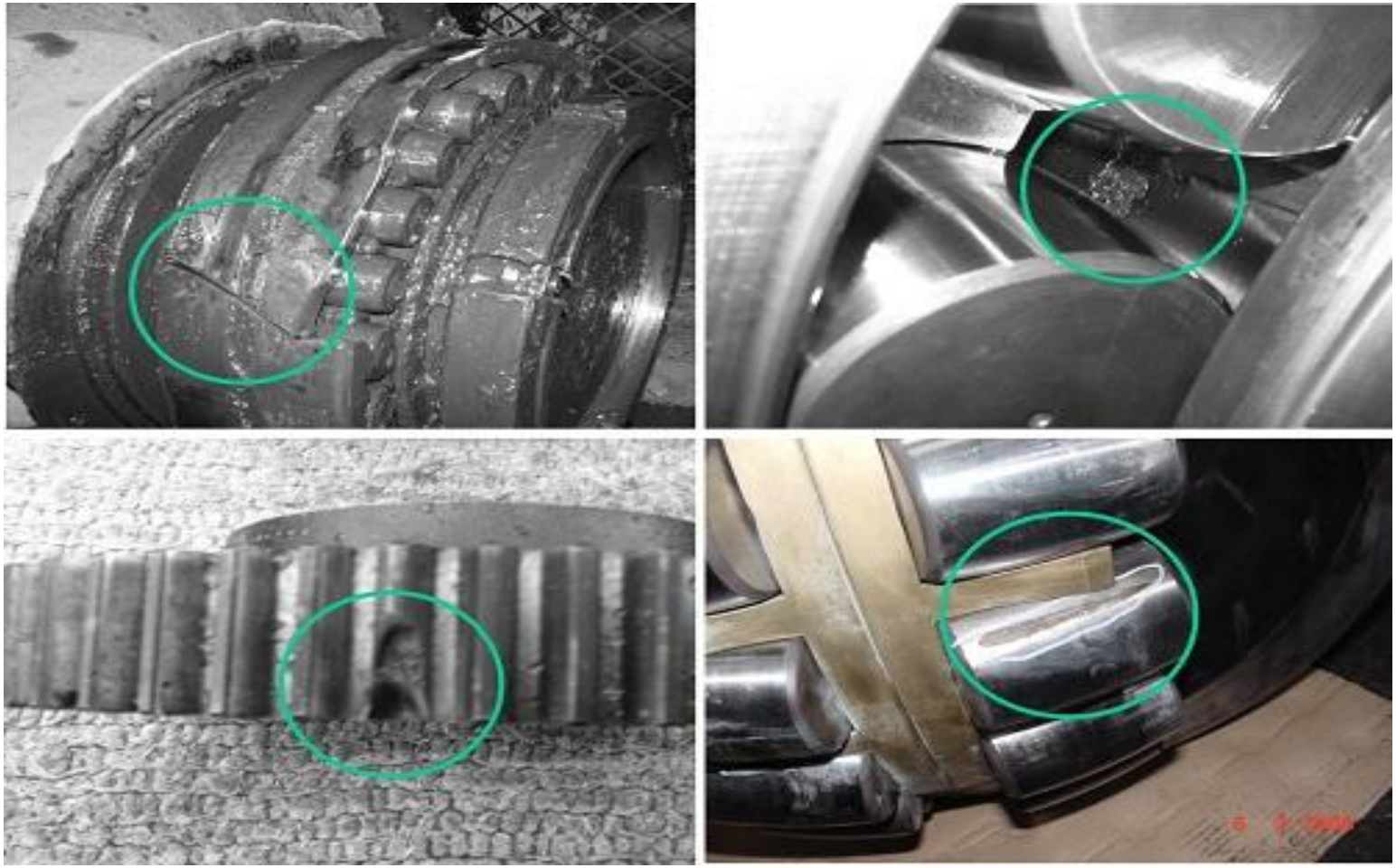
Company

KGHM Cuprum Research & Development Centre

Mining is still one of the key industries in Poland. Issues related to safety and efficiency are of particular importance in every mining operation. Nowadays, in the era of mechanization, automation and robotics, performance of miners increasingly relies on condition of the machines that they are operating. Such machines are often designed exclusively for particular application, taking into account specific environment in which they will work. For instance, loaders used in specific underground mines have to be low-profiled, but they still have to carry appropriate volume of mined rock.

In order to prevent from long and unexpected downtime the machines and structures are monitored using lots of sensors (temperature, pressure, current, tension, etc.).
The sensors might be attached on the machine and then the measurements are performed online. Sometimes, such frequent measurements are not necessary or they are even physically impossible and then measurements might be performed e.g. on daily or monthly basis. Although, there are also machines for which diagnostic methods are still under development.

One of the most investigated problems in diagnosis of rotating machines (gears, bearings) diagnostics is local damage detection. Mechanisms of damage development are rather complicated, but detection of a local damage might be simplified to searching for impulsive and cyclic (not necessarily periodic) content in the vibration signal. Such rapid and temporary increments of acceleration are related to contact between a damaged area (broken gear tooth, cracked bearing race etc.,) and other part of the gear or bearing. Since late detection can stop very complicated machinery and bring hudge loss of money by company, the fast detection of a local damage is very important to avoid so bad situation in mining industry.



Exemplary local damages in gears and bearings

From four years mathematicians from the Hugo Steinhaus Center at Wroclaw University of Science and Technology (WSUT), Poland, engineers from Faculty of Geoengineering, Mining and Geology WSUT and Polish Cooper Mining Company „CUPRUM" are cooperating in the area of application of mathematical methods to technical diagnostics.

These studies can be divided into four major groups. The first one is the study of local damage detection of mining machines (for example, the crusher)

A crusher – general view (note bearings with yellow housing)

In the literature one can find some unconventional methods useful for damage detection in machines for which the signals are very complex and for which classical methods do not give the expected results. The new methods using the statistical properties of the analyzed signals allow detect damages in mining machines even in presence of a high level of noise with different nature. The bassis is the decomposition and then adaptation of known methods and developing new ones. Novel methods developed for damage detection are based on the fact that for the sub-signals obtained for healthy machines the probability distribution is close to the Gaussian distribution, whereas in the case of damaged machine this property is not satisfied. They were proposed some new measures of impulsiveness on the basis of which it is possible to detect damages also for such signals, for which the classical method based on kurtosis did not give the expected results.

The second group of the studies is based on application of time series methods to modeling of vibration signals in varying operating conditions. In this case the signals are amplitude and frequency modulated and have no constant structure of the spectrum, and therefore classical models (like ARMA) can not be applied here. The study was focused primarily on the ARMA models, for which the coefficients are time-varying. Such systems are an extension of the classical ARMA models (with constant coefficients), which were used to model the vibration of machines working in constant operation conditions. It was shown that such reflect character of the analyzed vibration signals is observed, for example, in the driving system for bucket wheels of bucket wheel excavator,

Bucket wheel excavator

The next area of the interest is the modeling distributions of diagnostic features for determining the decision thresholds. To describe the distribution of such features it is proposed here to use other than Gaussian distributions. Such distributions are for example Pareto or Weibull. On the basis of estimated parameters of these distributions for the diagnostic features and characteristics of the speed it was possible to determine the decision thresholds that allow to classify the condition of given machine. In this area it was proposed to use also another distribution, the alpha-stable, which perfectly reflects the nature of physical phenomena, related to diagnostic machines.

The last group of the studies in the context of technical diagnostics is related to the signal segmentation for operating conditions detection of machine. They were proposed two methods based on statistical properties of the signal, which allow to segmentation of data describing the machines speed. In addition, there was proposed a test for testing if in given signal some statistical properties change. Such behavior with different regimes are observed in fluctuations in relative speed. In addition, there also was analyzed the problem of data description in which there are visible the so-called "traps", i.e. the intervals at which the signal remains at the same level. Such behavior is observed also for example in speed when the engine is in the idle model.

The main objectives of the common research in the field of technical diagnosis are:

a) to show that the statistical and stochastic methods can be applied to adapt the methods previously used in the analysis of vibration signals,

b) to demonstrate that the proposed frequency band selection criteria have very good properties and can be an alternative to the widely used spectral kurtosis, and in some cases they give better results,

c) to show that the classical time series models are inadequate to describe the signals for machines working in nonstationary operating conditions therefore it is necessary to propose more advanced models,

d) to indicate that the commonly used Gaussian distribution is insufficient to describe the data related to the mining machines, therefore it is necessary to use other distributions,

e) to determine the methods of signal segmentation for detection the state of the machine by using its statistical properties.

References:

Obuchowski Jakub, Zimroz Radoslaw, Wylomanska Agnieszka: Identification of cyclic components in presence of non-Gaussian noise application to crusher bearings damage detection, JVE INTERNATIONAL LTD. JOURNAL OF VIBROENGINEERING 17, 1242-1252, 2015

Wyłomańska Agnieszka, Obuchowski Jakub, Zimroz Radosław, Hurd Harry: Influence of different signal characteristics to PAR model stability, Applied Condition Monitoring. Cyclostationarity: Theory and Methods - II (Chaari et al. ed.), 89-104, 2015

References:

Stefaniak Paweł, Wyłomańska Agnieszka, Obuchowski Jakub, Zimroz Radosław: Procedures for decision thresholds finding in maintenance management of belt conveyor system statistical modeling of diagnostic data, in: Lecture Notes in Production Engineering, Christian Niemann-Delius ed., 391-402, Springer, 2015

Obuchowski Jakub, Wyłomańska Agnieszka, Zimroz Radosław: Two-stage data driven filtering for local damage detection in presence of time varying signal to noise ratio, Vibration Engineering and Technology of Machinery Mechanisms and Machine Science Volume 23, 401-410, 2015

References:

Obuchowski Jakub, Wyłomańska Agnieszka, Zimroz Radosław: Recent developments in vibration based diagnostics of gear and bearings used in belt conveyors, Applied Mechanics and Materials 683, 171-176, 2014

Obuchowski Jakub, Wyłomańska Agnieszka, Zimroz Radosław: Selection of informative frequency band in local damage detection in rotating machinery, Mechanical Systems and Signal Processing 48, 138--152, 2014

„Modelling of the machines damage detection for Polish mines”

Results & Benefits to the company

1. **Better safety and efficiency**
2. **Prevention from long and unexpected downtime the machines even destruction of the very expansive machinery**
3. **Avoiding the loss of hudge amount of money by the company (the exact amout is not known)**

Better safety, efficiency and more stable economic results to the company

Instead of epilogue

In 1964 Hugo Steinhaus in his Reccolections and Notes wrote (free translation):

Instead of epilogue

In 1964 Hugo Steinhaus in his Reccolections and Notes wrote (free translation): „It is not so known but Wroclaw mathemticians saved Polish charcoal open mine and electric power station Turow from the economic collapse.

Instead of epilogue

In 1964 Hugo Steinhaus in his Reccolections and Notes wrote (free translation): „It is not so known but Wroclaw mathemticians saved Polish charcoal open mine and electric power station Turow from the economic collapse. Directors and clever engineers from that company could not find solution how to avoid very frequent breaks at work of belt conveyors transporting the coal.

Instead of epilogue

In 1964 Hugo Steinhaus in his Reccolections and Notes wrote (free translation): „It is not so known but Wroclaw mathemticians saved Polish charcoal open mine and electric power station Turow from the economic collapse. Directors and clever engineers from that company could not find solution how to avoid breaks at work of belt conveyors transporting the coal.

Mathematician dr Gladysz applying stochasic processes solved that problem. Thanks to this solution the costs of electric energy producing were lower about 10%.

Because of that company Turow had saving counted at many of millions PLN.

Instead of epilogue

Dr Gladysz become the adviser of company Turow with the salary 2000 PLN.

Instead of epilogue

Dr Gladysz become the adviser of company Turow with the salary 2000 PLN. That salary was much more lower than the salary of an ordinary worker at this mine".

Thank you for your attention!