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ANALYSIS OF OPERATION OF PROCESS FANS BY TREATMENT OF SOUND SIGNALS

Dr. Sc. Safet Brdarević, Dr. Sc. Mustafa Imamović, Dr. Sc. Sabahudin Jašarević,
University of Zenica, Fakultetska 1,72000 Zenica BiH

M.Sc. Alić Senad, B.Sc. Mech. Eng.
„ARCELOR MITTAL“ Zenica, Zenica

ABSTRACT
This paper describes technical diagnosing by monitoring of sound signals of el motor operation, impellor and sliding bearings on process fans which have high power and high rotating speed. By this type of monitoring of sound signals, using suitable sensors in the vicinity of el motor, impellor and slide bearings, gives an opportunity to monitor without any contact i.e. consideration of validity of change of sound signals on machine. This type of monitoring enables, in inexpensive and contactless way, consideration of time period when machines operation is correct. It also enables having a computer diagrams related to operation of these machines what provides consideration of possibilities for improvement of maintenance of these facilities. Also, in this way it is possible to provide continuous monitoring of sound signals and their tracking by computer. This approach and analysis of sound signals and conversion into diagrams can provide timely detection of anomalies in operation of such facilities; results can be compared with other types of diagnostics, feasibility of planned shutdowns as well as inspections, detection and maintenance. This type of diagnostics can identify critical events in some parts or complete facility. This is significant from the aspect of safety of employees who operate these facilities and from the aspect of importance of these facilities for production process.
Key words: sound signals, el motor, impellor, slide bearings, computer processing of sound signal

1. INTRODUCTION
In modern conditions of life, production and use of steel as a strategic metal in all spheres of the economy has, among other materials, the most important role. The steel making process is done by using iron ore, coke, limestone, natural gas and heated air in the metallurgical facilities such as sintering plant, blast furnaces and steel mills. In order to produce sinter in sinter machines, which serves as the main input in the blast furnace, they must have exhausters (fans) of power of 2.5 [MW], n = 1500 [rpm]. They are used for suction, enabling of burning process (sintering) of sinter in sinter machines and for dedusting through electrostatic precipitators.

2. MECHANICAL ANALYSIS OF EXHAUSTERS 4, 5 AND 6 OPERATION
Exhauster type 6500 - II - 4 is a centrifugal fan that is designed and manufactured in the Novska factory for producing of machines, VI Lenin, and is designed to suck air through the mixture in sinter machine which is burning, and removal of gases generated in sinter machine in case of dry gas cleaning.

Basic exhauster parameters are:
- volume of wet gas in relation to the basic conditions 6500 [m³ / min]
- capacity of dry gas compared to 0 º C and 1 bar of mercury column 3680 [Nm ³ / min]
- increase of pressure/ difference between absolute static final

pressure and initial pressure 0,1245 [bar]
- required power 1700 [KW]
- initial pressure of gas on the entrance into suction pipe 0,91 [bar]
- initial temperature of gas on the entrance into suction pipe 150 [° C]
- number of exhauster RPMs 1500 [o / min]
- synchronous el motor, type 140/74-4 power 2500 [KW], voltage 6000[V], closed with air cooling and blowing of closed type
- exhauster rotor moment on el motor coupling 6550 [kgm²]

Exhauster has 4 bearing housings with slide bearings (el motor is lined on two slide bearings and exhauster rotor on two slide bearings). The following is being continuously measured on this faciliyt: temperature of bearings, fume gases on the entrance into exhauster, water, oil on the entrance and exit, bearings vibrations, fume gases under - reassure on the entrance into exhauster.

Picture 1. Layout of exhauster 4, 5 & 6 hall

3. COMPUTER PROCESSING OF SOUND SIGNALS DURING OPERATION OF EL MOTOR, IMPELLOR AND SLIDE BEARINGS ON EXHAUSTER No 6

The sound signals for the analysis of these facilities operation were collected through limited sensors, cell phones, Sony Ericsson K800i, which converts the analog signal into a digital signal with a sampling frequency of 8 kHz. Signals received in this way are converted through a computer software package into a visual diagram, based on which we come to knowledge about the nature and patterns of sound vibrations. Installation of continuous monitoring of the situation of this type of rotating machinery (stationary and non- stationary) can help to achieve the following:

a) by cheap approach in financial sense, we are coming to the knowledge of machine status and we achieve saving in avoiding of failures and downtime,
b) safer conditions related to people who are servicing these facilities (handling, maintenance),
c) this approach can improve possibilities of technical diagnostics, with the restrictions that this way of perceiving of status of these rotating machines is carrying.

This new method of technical diagnosing of condition of rotating machines of high power and high rotating speed allows us to know when is a state of "normal operation", and when a state of "early failure (anomalies).

In this way, by the sound (which is on the complex fan facility produced by slide bearings), sound (which is produced by the rotation of electric motors) and the sound of the spinning impeller, we come to realize what is happening inside the machines (which in this case turns into a diagrammatic form i.e. which is obtaining legality of sound vibrations), and thereby we find out whether these rotating parts are in normal mode.

The sound signal is converted into a frequency domain with a short-time Fourier transformation (STFT) in order to obtain a spectrogram. Spectrogram is actually FFT Fast Fourier transformation of sound signal in a very short time intervals (windows) of 128-256 ms. On the STFT spectrogram, three statistical indicators are being computed in parallel:

1. Spectral kurtosis is defined as moment of 4^{th} raw

$$K = E(X - u)^4 / \partial^4 \qquad (1)$$

where: X- is a value of sound samples,
u – is medium value of X sound samples,
∂- is standard deviation of X sound samples,

E – is expected value of expression in brackets.

Spectral kurtosis (STFTk) is calculated as K kurtosis in frequent domain.

2. Spectral RMS, Root Mean Square of sound signal is defined as:

$$RMS = \sqrt{\sum X / M} \qquad (2)$$

where: X – is a value of sound samples

M – is a number of sound samples.

Spectral RMS (STFTrms) is calculated as RMS in frequent domain.

3. Spectral skewness is calculated as a moment of 3rd raw and is defined as:

$$S = E(X - u)^3 / \sigma^3, \qquad (3)$$

where: X- is a value of sound samples

u - is medium value of X sound samples,

σ - is standard deviation of X sound samples,

E – is expected value of expression in brackets.

Spectral STFTskewness is defined as S in frequent in the domain. Techniques of multivariable statistical process control (MSPC) are applied. MSPC has a series of diagrams (control charts) and the control of rules. For audio signals of noise and monitoring of these three spectral indicators defines the control rule WE10 (Western Electric 10):

R = control rules (we10,STFTkurtosis,STFTrms,STFTskewness,cl,se) (4)

where: R - are identified alarm values in which defined limit is being exceeded,

we10 - Western electrical control rule which defines limits for value 10,

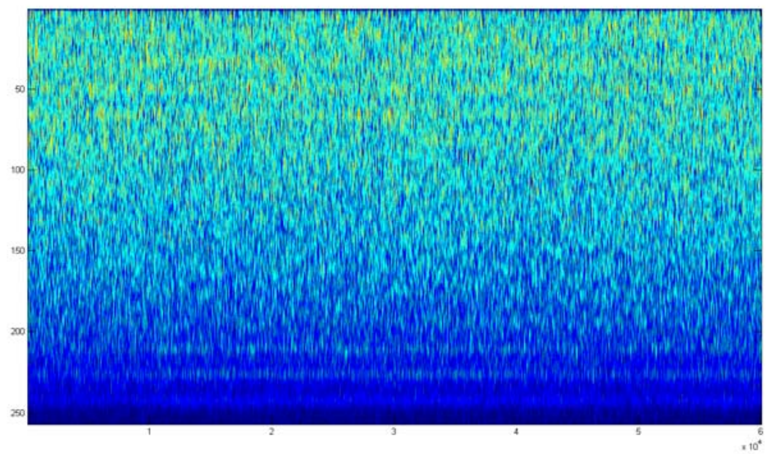
STFTkurtosis – value of sound signals kurtosis in frequent domain,

STFTrms – value of RMS sound signals in frequent domain,

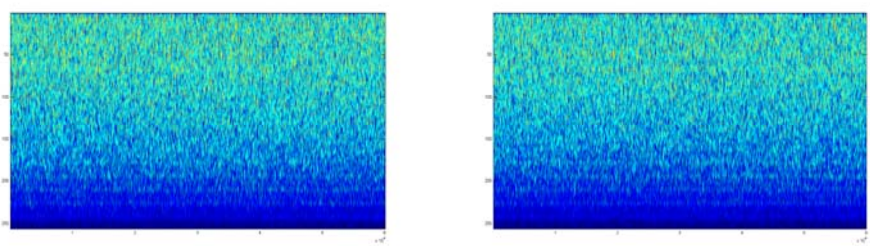
STFTskewness – value of skewness in frequent domain,

cl – vector of values around central,

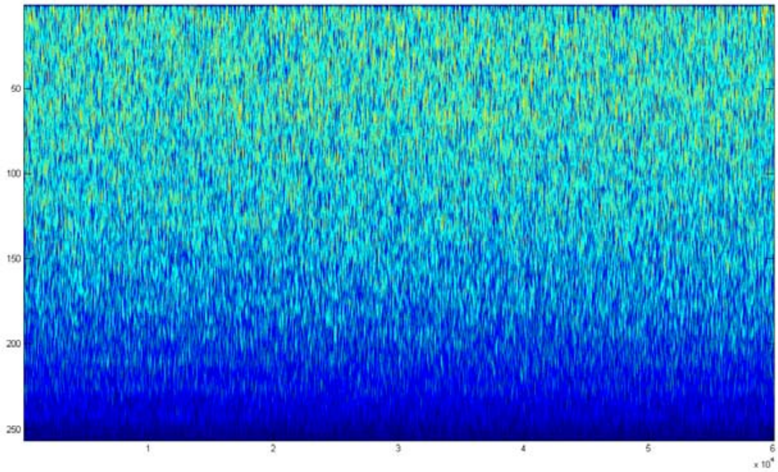
se - vector of values of standard errors.



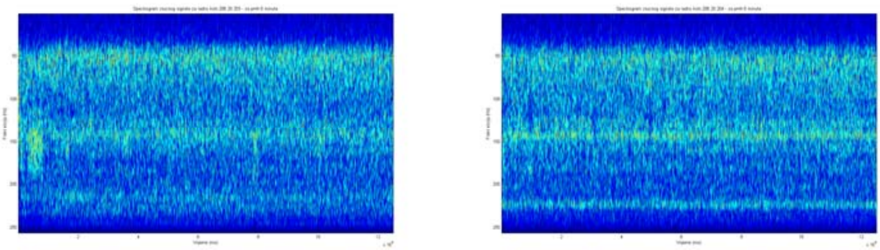
Picture 2. Spectrogram of sound signal of el motor P = 2,5 MW



Picture 3. Spectrogram of sound signal of slide bearing No. 1 & 2 on el motor P = 2,5 MW



Picture 4. Spectrogram of sound signal of impellor P = 2,5 MW



Picture 5. Spectrogram of sound signal of slide bearing No 3 & 4 on impellor P = 2,5 MW

4. CONCLUSIONS

Based on the above ways of consideration of signals using such a limited sensors and by conversion using software in the form of diagrams we can conclude the following:

- This method of technical diagnostics enables realizations and consideration of the character and behavioral patterns of the sound i.e. slide bearings operation, el motor and fan impellor of such great strength and great speed of rotation
- This approach may help to receive information about the functionality of these facilities and thus enables planning of appropriate maintenance procedures, all with the aim of improving the quality of maintenance of these facilities
- By monitoring of sound signal and by converting into numerical and diagrammatic form on slide bearings, el motor and impellor, we can detect irregularities in operation of this equipment, i.e. to plan shut down and refurbishment time, manpower for refurbishment i.e. to plan maintenance costs for these facilities.

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