14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

ANALYSIS OF OPERATION OF EXHAUSTERS 2,5 MW BY CONTINUOUS MEASURING OF VIBRATIONS

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ABSTRACT
This paper presents an approach of controlled and continuous condition monitoring of vibrations on slide bearings of process fans of high power and high rotational speed. This approach of such monitoring of vibrations, as the key operating parameter of slide bearings, has the benefit for planning and monitoring of maintenance expenditures, as well as understanding patterns of vibration changes on these machines. This kind of monitoring can be used for planning of period of correct operation of these machines, time of their shut down and overhauling, so as to conceive possibilities for improvements of operation and maintenance of such facilities.
Key words: vibrations, slide bearings, computer-based monitoring of vibrations

1. INTRODUCTION

In contemporary conditions of life production and use of steel, as a strategic metal in all spheres of the economy, has the most important role beside other materials. The process of obtaining the steel is done by the use of iron ore, coke, limestone, gas and heated blast in the metallurgical facilities of Sintering plant, Blast furnaces and Steel plant. In order to produce sinter which serves as the main component of burden in blast furnace, sinter machines (as a major metallurgical facilities) must have in their technological line have exhausters (fans) of 2.5 [MW] power, n = 1500 [rpm]. They are used for suction, enabling of combustion (sintering) of sinter in sinter machines and for dedusting of facilities through ESPs.

2. MECHANICAL ANALYSIS OF OPERATION OF EXHAUSTERS 5 and 6

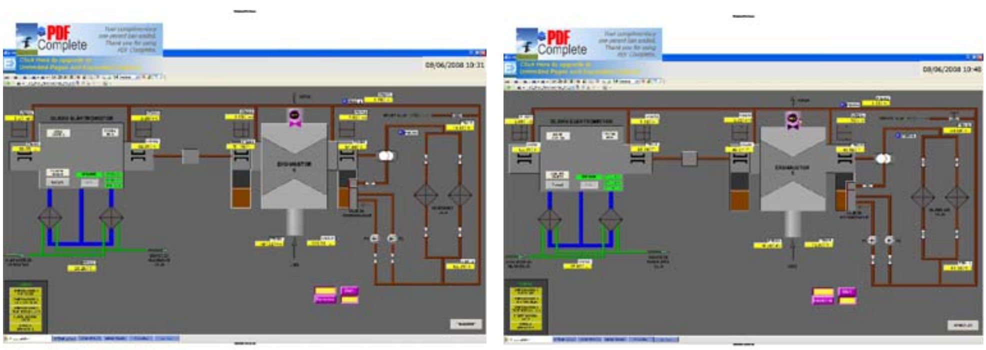
Exhauster type 6500 - II - 4 is a centrifugal fan that is designed and manufactured in Novska factory which produces machines VI Lenin, and is specified for the suction of air through the burden that burns in sinter machine and for removal of sinter machine generated gases at dry gas cleaning.
Exhauster main parameters are:

- volumetric capacity of the wet gas in relation to the basic conditions	6500 [m³/min]
- capacity of the dry gas compared to 0 º C and 1 bar of mercury column	3680 [Nm³/min]
- increase of pressure/ difference between the absolute static final and the initial pressure	0.1245 [bars]
- the required power	1700 [KW]
- the initial gas pressure on enterance into suction pipe	0.91 [bars]
- initial gas temperature on enterance into suction pipe	150 [º C]
- relative humidity	20 [%]

Exhauster has 4 bearing housings with slide bearings (el. motor is placed on two slide bearings and exhauster rotor on two slide bearings). The following if continuously measured on all bearings:

- temperature of bearings, waste gases on enterance into exhauster, water and oil at the entrance and exit
- vibration of bearings,
- subpressure of waste gases on enterance into exhauster,
- specific weight of dry gas in relation to 0 [^{o} C] and 1 [bar] 1,33 [kg / Nm^3]
- RPMs of exhauster rotor 1500 [o / min]
- sinchronus el motor, type 140/74-4, power 2500 [KW], voltage 6000[V], closed with air
- cooling and closed cycle blowing
- critical RPMs of exhauster rotor 2680 [o / min]
- rotating moment of exhauster rotor on el motor coupling 6550 [kgm^2]
- main oil pump – Q=60 [l/min], n=1500 [o/min], pressure p = 1 [bar]
- inlet and spare vertical pinion pump – Q = 18 [l/min], n = 1500 [o/min], p = 1 [bar], oil filter
- oil cooler, type M 0,5 – cooling surface P = 0,5 [m^2], max pressure p=1 [bar]
- water pressure p = 3 [bars].

Centralized lubrication system of exhausters is circulating and uses turbine oil 30 guest 32-53. The oil is brought into bearing housing (inserts) of el motor, exhauster and pinion coupling. Operating oil pressure is 0.7 to 1.0 [bars], and is maintained by safety valve that is mounted on the pressure line of oil piping. Starting and stopping of exhausters No. 5 and 6 have a separate procedure and are done by special technological manual/ instruction book on handling and maintenance of these facilities.



Picture 1. Schematic layout of exhausters No 5 and 6

3. COMPUTER PROCESSING OF OUTPUT PARAMETERS WHICH ARE RELATED TO VIBRATIONS IN EXHAUSTER 5 and 6

Vibration signals in duration of 3600 seconds from vibrational sensors VT5214 and VT6214 are taken from the ABB 800xA IndustrialIT HMI. Vibrational sensors are ProvibTech TM016 21.3. 2010. Output is from 4-20 [mA], proportional to the vibrations on the machine. Vibrational sensor TM016 measures the speed of vibration changes in mm/s. Continuous monitoring of the state (through the method of vibration measurements) of rotating machines (stationary and non-stationary) has two important aspects:

a) Financial- saving due to avoiding of breakdowns and delays in operation,
b) Life- critical conditions related to safety of people during the work on these facilities.

Vibration signals in the time domain contain the noise coming from other machines and fluttering in the environment (work, passing vehicles, trucks, trains). It is necessary to eliminate the noise. This paper used the methods of wavelet decomposition and removal of noise. Two of the most appropriate wavelet bases for signals of vibrations on machines are Morlet and Coiflet. This paper used wavelet Coiflet 3 on level 3 of decomposition. Then, power cepstrum of clean signals is calculated, and on power spectrum signal power cepstrum (power cepstrum) is calculated. The procedure is visually presented in Figures 2. - 7. Power cepstrum is defined as dB / s. Power cepstrum is defined as the inverse FFT (Fast Fourier Transformation) of the logarithmic power spectrum:

$$C_p = P^{-1}\{\log F_{xx}(f)\},$$

where: $F_{xx}(f)$ is a power spectrum, and P^{-1} is an inverse FFT.
Method of power cepstrum on clean signals of vibrations can show the development of early failures in bearings and gear boxes. In addition to this method, there is a particle filter method, the method SOM of neural networks, eigenvector method and Gaussian Mixture Model. Diagnosis of early failures in bearings with threshold limits on the diagram of power cepstrum is done in two classes: normal operation and early failure (anomalies). If the power cepstrum is in interval Cp = (0-5) dB, then the messages on the HMI shows "**normal operation**". If the power cepstrum is Cp> 5 dB, then the messages on the HMI shows "**early failure (anomalies)**". This approach to the analysis of vibration on slide bearings of exhauster 5 and 6 impellor is called the inverse vibration periodogram or power cepstrum. In this way, in inverse way, we realize what is happening inside the machines based on the measurement of output parameters, such as in this case are vibrations, ie, we obtain power cepstrum (the inverse vibrations poriodogram).

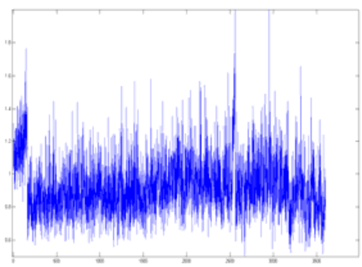


Figure 2. Vibration signal in time domain from sensor VT5214(mm/s)

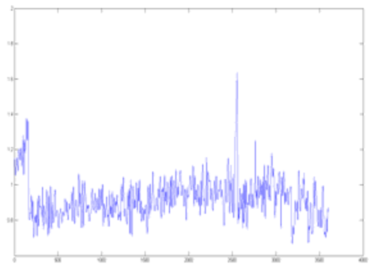


Figure 3. Vibration signal with removed noise from sensor VT5214 (mm/s)

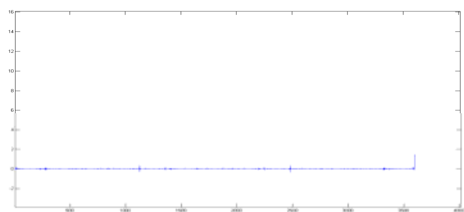


Figure 4. Power cepstrum on clean signal from sensor VT5214 (dB/s)

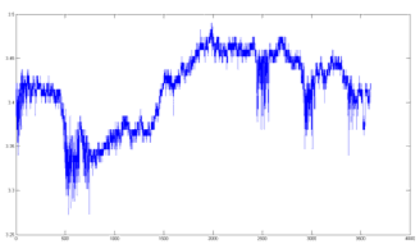


Figure 5. Vibration signal in time domain from sensor VT6214 (mm/s)

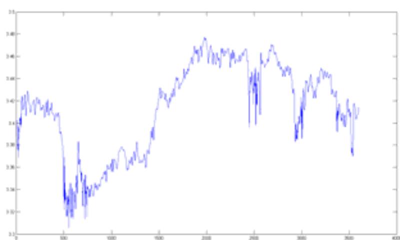


Figure 6. Vibration signal with removed noise from sensor Vt6214 (mm/s)

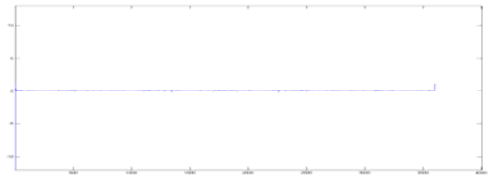


Image 7. Power cepstrum on clean signal from sensor VT6214 (dB/s)

4. COCLUSIONS

Based on the above modes of vibration monitoring using installed software and this approach of processing of output vibration values we can concluded the following:

- Causes of vibration on exhausters are: fan impellors imbalance, el motor axis shaft motor and fan impellor, inadequate stiffness of connections between exhauster and electric motor with foundation, sleeve shaft axis in relation to the bearing axis, shaft failure, deformation of motor rotor and impellor, incorrect amount and quality of oil for lubricating of slide bearings,
- Continuous monitoring of vibrations on synchronous electric motor slide bearings and high power fan impellors through the computer from operating center allows the timely detection of irregularities/ defects in operation of such aggregates, their stopping, repair and reduction of maintenance costs, considering that the parts of these facilities are very expensive to purchase,
- Monitoring of vibrations at the slide bearings, i.e. based on the trend of vibration increase can foreseen periods of the correct operation of these facilities, i.e. the legality of vibration changes on these facilities,
- This approach of vibration monitoring can be used for planning of shut down time and right time for refurbishment of these facilities, manpower who will be engaged in refurbishment, i.e. to plan maintenance costs of these facilities

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