Misalignment Vibration Diagnosis of Fans used in Mining Industry
RIDZI MIHAI CARMELO, ITU VILHELM, DUMITRESCU IOSIF
Faculty of Mechanical and Electrical Engineering
Department of Mechanical, Industrial and Transportation Engineering
University of Petrosani
Str. Universitatii nr. 20, 332006 Petrosani, Jud. Hunedoara
ROMANIA
ridzim@yahoo.com, drituv@yahoo.com ,iosif_dumi@yahoo.com

Abstract: - Misalignment is a common cause of machinery malfunction. Considering the importance of alignment, the vibration spectrum of mining axial fan is not well documented. This paper is going research to determine the unique vibration signature for misalignment at varying operating and design conditions such as air flow, type and level of misalignment, coupling types and machinery dynamic stiffness. The mining axial fan was used in the study to create the varying mechanical conditions. Triaxial vibration measurements were taken at each end of the coupling on the motor and rotor bearing housings. Data was collected at several other locations of the fan. The results indicate that the air flow speed and the coupling type/stiffness have a strong effect on the vibration spectra. The level and type of misalignment had a significant effect on the vibration signature. No unique signature was observed, suggesting that care is needed to correctly diagnose misalignment.

Key-Words: Mechanical vibration, Mining axial fan, Alignment, Signal processing

1 Introduction
Underground mining safety and stability depend mainly on the ventilation system. The literature review showed that the axial fans used in mine ventilation system at a rate of 30 %.

Because the most important element that determines the life of a machine is the construction of various metal and mechanical assemblies is imperative to develop a methodology for real analysis of the dynamic system to determine the period of their safe use. Acting on the equipment while a number of factors such as overwork, shock, fatigue of materials, corrosion, etc., leading to their destruction.

The problem breaks fragile metal buildings began to be studied carefully only after developing serious technical accident when large machinery was destroyed.

The analysis of these accidents and failures, it appears that for complex welded construction, strength and stability calculations, although they are necessary, not sufficient to ensure the safety of construction is absolutely necessary that they should be supplemented by a series of measurements mechanical vibration.

Misalignment is a common cause of machinery malfunction. A poorly aligned machine can cost a factory 20 %...30 % in machine down time, replacement parts, inventory, and energy consumption. A large payback is often seen by regularly aligning machinery. Operating life is extended and process conditions are optimized.

Vibration signatures are widely promoted for studying machine malfunctions. However, the literature does not present a clear spectrogram of signature characteristics attributable to misalignment. Different authors report different signatures. There are no reports of systematic, controlled experiments with varying parameters.

The purpose of this paper is to establish modern methods of investigation weaknesses in the functioning of such VOD fans mining industry to make concrete proposals machinery vibration analysis, improve their alignment to increase performance and reliability. It presents a series of experiments designed to elucidate the consistent features, if any, of vibration signatures for misaligned. Two machines at the same mining plant were in study. The machine was fault-free with the exception of misalignment.
2 Experimental
All tests were conducted using a Russian manufactured VOD 30 axial fan, fig. 1. Paroseni Mining Plant is equipped with two identical axial fans.

Vibrations were monitored with piezoelectric accelerometers placed at 3 locations, fig.2, 3 and 4, were used to monitor three directions. In table 1 is lists locations and of measurement. The speed was determined automatically by the software using an optical tacho meter. The X, Y, Z coordinate system was used to show direction. In Fig.5. is presented the measurement devices.

The experimental design for this study included three different stiffness couplings. Four levels of offset were used on the left bearing housing to simulate a combination of angular and parallel misalignments. Equivalent offsets on the right bearing housing side gave parallel misalignment. The experimental design had 600 RPM speed of rotation. The goal of the study was to determine the effects of coupling stiffness, level and type of misalignment on vibration spectra.

Data was acquired with special custom hardware and software developed in University of Petrosani. The data was obtained for 500 Hz maximum frequency at 800 lines spectral resolution. Five data blocks were sum averaged to compute spectral functions. Newly developed software by us was used to analyze the vibration signatures. Typical spectra are

<table>
<thead>
<tr>
<th>Locations</th>
<th>Number</th>
<th>Coord.</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing (1)</td>
<td>1</td>
<td>X</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Y</td>
<td>Vertical</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Z</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Bearing (2)</td>
<td>4</td>
<td>X</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Y</td>
<td>Vertical</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Z</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Fan</td>
<td>7</td>
<td>X</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Y</td>
<td>Vertical</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Z</td>
<td>Horizontal</td>
</tr>
</tbody>
</table>
shown in figure 6...9. It shows the most prominent peak in the group. The figure shows magnitude spectra computed from four channel measurements.

3 Results
The purpose of this study is to examine the spectra due to misalignment between the motor and the rotor shafts. Spectral comparisons were made across coupling measurement points on left bearing housing and the motor. The data were compared in vertical, horizontal and axial directions. The results are limited only to 600 RPM.

Figures 6 to 7 illustrate typical spectra for two identical fan at the same plant, operating in identical conditions. In fig.8 to 9 are typical spectra after misaligned corrections (combination misalignment). In each graph is represented four spectra measured in vertical and axial directions on front top of the motor and top of the right bearing (2). In each figure, the green graphs are for the motor axial vibration, blue color for vertical vibration. Red color is for Bearing in vibration in axial directions and black for the horizontal vibration. Horizontal scale is frequency in orders of RPM. Vertical scale is acceleration in G, (9.81m/s²).

A correlation between misalignment and vibration signature could not be discerned. The data for all cases contained several harmonics. Both axial and lateral vibration was present in all cases. The dominant harmonic varied from condition to condition. As a general rule, as expected, increased misalignment yielded increased vibration peaks. However, an exception to this rule was observed.

As a general rule, higher speeds generated increased vibration amplitude and number of harmonics. Often 1X vibration had higher peaks, but in many other cases 2X and 4X seemed to have the largest amplitude. The motor accelerometer revealed higher frequency vibration than the bearing housing. Some frequency modulation was also noticed at higher harmonics.

Coupling stiffness also appears to have a dramatic effect on misalignment vibration spectra. For a given speed and misalignment level, the steel coupling produced the highest vibration than the rubber coupling. Thus, it can
be deduced that at a given condition a stiffer coupling produces more vibration than a softer coupling. The correlation does not seem to be linear and simple.

The effect of the amount of misalignment was not as significant except for the steel coupling. But the steel coupling, very stiff, showed high levels of vibration even below 0.508 mm misalignment. No significant difference was observed between parallel and combination of parallel and angular misalignment. The study did not include pure angular misalignment.

4 Conclusions

The results clearly indicate a significant variation in vibration spectra as a function of misalignment conditions. Both amplitude of the dominating peak and its location along the frequency axis changes in a complex manner. The data indicate that it is not possible to conclude that the cause of real world machinery malfunction is shaft misalignment just by looking at a single vibration spectrum at an operating condition. A careful examination is essential to differentiate misalignment from other sources of vibration. Some experimentation and cross correlation analysis along with a rotor dynamics model may be necessary to fully diagnose a problem.

Since misalignment vibration seems to be a strong function of coupling type (stiffness) and rotational speed, a detailed rotor dynamics model is needed to develop a predictive model for misalignment vibration spectra. The misalignment phenomenon is non-linear and much more complex.

The results of this study confer with common sense that when two misaligned shafts are joined together by a coupling, the machine structure is subjected to deformation (strain). The deformation will be different at each angle of rotation depending upon the amount and type of misalignment. The corresponding stress will depend upon the stiffness of the machine structure. Now when the machine starts turning, the angularly varying stress will produce vibration at each of the Fourier components, assuming a linear relationship. The problem is complicated further due to the inherent non-linearity of a machine.

For predictive maintenance applications where the goal is machinery health monitoring, it is sufficient to realize that the problem is complex. One can routinely trend the vibration spectra until it becomes severe. But for root cause analysis, one must exercise caution and perform a detailed analysis.

The observed changes that occurred with shifts of speed and misalignment do not show a typical signature for misalignment vibration spectra.

Misalignment induced vibration is very complex.

The data show that a machine can have parallel misalignment without exhibiting 2X vibration.

A single point vibration spectrum for a given operating condition does not provide a good, reliable indication of machinery misalignment. Orbital plots of vertical and horizontal measurements in the time domain are also needed. Non-linear dynamic modeling may be required for a full understanding of misalignment effects. More work is needed to develop simple rules for diagnosing machinery shaft misalignment.

References:
2) Ridzi, M.C, Diagnostica vibromecanica a masinilor industriale, Editura Militara, Bucuresti, 1999
5) Zoller C., Fotău I., Ridzi M., Dobra R., Păsculescu D., Sistem de telemăsurare tensiometrică a tensiunilor mecanice de pe cuțitele cupelor excavatoarelor din carierele de lignit” UNIVERSITARIA SIMPRO Petrosani, 14-15 octombrie 2005