Condition Monitoring Methods for Vane Axial Fans

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This article outlines a comparison of results from five different test methods to detect common faults in vane axial fans. Testing is based on inducing faults in ball bearing races and unbalancing the fan, then measuring the results to determine the effects of the faults on known parameters. The results indicated that vibration measurements on the fan shroud do not accurately detect faults, but that vibration measurements on motor bearing caps and analysis of motor current can correctly indicate their presence.

Vane axial fans present a real challenge to the traditional vibration analyst when it comes to making routine measurements for condition monitoring. The vibration path from the motor bearings to the cowling is simply too long to permit accurate assessments for all but the largest “near death” faults. The vibration must travel through the outer bearing race to the motor frame, through struts to eventually arrive at the cowling, greatly attenuated. This long path especially limits high frequency transmission, as it includes no less than two mechanical interfaces. A better approach is to enter the fan’s flow path and attach vibration sensors to the motor frame; however, doing so involves two severe risks. The more serious is an inadvertent start of the fan while the technician is exposed to moving parts or air currents that could force him into moving parts. The other is that the sensor could become dislodged and damage the fan during testing. Another method of fault detection is motor current analysis. This involves connecting current probes at the motor control center – well away from moving parts, but potentially in proximity to high voltages.

Monitoring Methods

The advent of high resolution 24 bit A/D converters, demodulation techniques and superior notch filters have made possible the detection of some faults through analysis of motor current.[7] These faults cause small changes in the motor torque and current which can only be detected if a high level of discrimination against the current frequency is possible. It is the cumulative improvement in signal analysis that makes this work and advance possible.

Figure 1 shows the test fan with accelerometers attached to the motor case and fan shroud. The fan is characteristic of many used in the electric power industry for both ventilation and component cooling. The fan is an eight bladed stamping 24 inches in diameter powered by a 5 hp motor using 460 VAC, 3 phase power. The fan operates at 1778 rpm.

This study utilized instruments from five different manufacturers to measure either current- or vibration-based indications of faults. Table 1 summarizes the characteristics of each instrument. The Swantech analyzer is a dedicated stress wave analyzer. The PdMA Emax and Baker MPM are dedicated instruments for measuring motor current signatures. The Cognitive Vision CV395B and the Bentley Nevada ADRE are general purpose spectrum analyzers commonly used for machinery vibration analysis.

Table 1. A comparison of instrument characteristics.

Manufacturer	Frequency Range (kHz)	A/D bits	FFT Resolution Lines	Dynamic Range With Internal Amplification
PdMA EMax	100	16	100-12,800	138 dB
Baker MPM	100	12	100-1,200	138 dB
Cognitive Vision CV395B	100	16	100-2,400	90 dB
Bentley Nevada Adre	10	12	100-1,200	66 dB
Swantech	40	N/A	N/A	N/A

To establish a baseline against which all measurements were compared, the fan was first balanced to a level that indicated only a very small vibration at the rotating speed. Then the fan was installed vertically into a test facility that was used for all tests. The baseline measurements were made from this initial setup. The facility was carefully controlled to assure that the fan installation was consistent between tests and that the airflow impedance was the same for all tests. Examples of the controls on the facility were that all bolts were torqued to the same level in each installation and no changes in flow path were permitted. Fan speed was monitored using a laser tachometer.

Three types of faults were introduced into the system. The first two are 1/16 in. by 1/16 in. slots cut into the inner and outer races of the motor bearing, introduced one at a time. A grinding wheel was used to cut the slots. The third fault was a small imbalance (0.54 oz/in.) of the rotor that approximately

Table 2. Data collection system comparison ratios.

Imbalance	**Baseline**	**Imbalance**	**% Change**	**dB Change**
Vibration on bearing housing	9.2×10^{-4}	1.4×10^{-3}	57	3.9
Vibration on fan cowling	2.9×10^{-4}	3.0×10^{-4}	5.3	0.45
Baker	1.4×10^{-4}	2.0×10^{-2}	14,000	44
PdMA	0.54	0.73	34	2.6
SWANtech bearing housing	3800*	3800*	**0.00***	**0.00***
SWANtech fan cowling	350*	350*	**0.00***	**0.00***
BPOR	**Baseline**	**BPOR**	**% Change**	**dB Change**
Vibration on bearing housing	6.1×10^{-5}	5.4×10^{-4}	790	19
Vibration on fan cowling	8.0×10^{-5}	2.6×10^{-5}	**–67**	**–9.8**
Baker	1.6×10^{-2}	1.7×10^{-2}	7.0	0.59
PdMA	–	–	–	–
SWANtech bearing housing	2.0×10^{-3}	1.0×10^{-2}	400	14
SWANtech fan cowling	7.9×10^{-5}	7.1×10^{-4}	790	19
BPIR	**Baseline**	**BPIR**	**% Change**	**dB Change**
Vibration on bearing housing	1.4×10^{-4}	1.5×10^{-3}	1,000	21
Vibration on fan cowling	2.0×10^{-4}	2.6×10^{-5}	**–870**	**–18**
Baker	–	–	–	–
PdMA	0.12	0.15	21	1.7
SWANtech bearing housing	–	–	–	–
SWANtech fan cowling	–	–	–	–

– Data not collected for this technology
* Data from an overall value number from SWANTECH

Figure 1. Fan cowling vibration transducers (left) and motor bearing housing transducers (right).

doubled the vibration level measured at rotating speed on the outboard bearing. Figure 2 shows the bearing defects as seen in a post-test analysis and Figure 3 shows application of the imbalance weight.

Results

The results are presented in Table 2 as a ratio of selected spectral lines of the faulted condition to the same spectral lines of the original (unfaulted) condition. This was taken as an indication of the sensitivity of the measurement technique to detect the fault. In all circumstances the motor current analysis method and the vibration analysis performed on bearing caps were capable of detecting the faults. At least 30% changes in the amplitude of the spectral line were observed as an indicator of fault development.

Vibration analysis of the fan cowling was not capable of measuring faults at the levels of these tests. In some cases the vibration level actually went down substantially after the fault was introduced. Data were not available for all instruments for all conditions because the instruments were pressed into service for other applications.

Conclusions

Electric motor current analysis offers substantial sensitivity in detecting common faults of axial vane fans. Axial vane fans, as a class of machines, have been notoriously difficult to analyze for faults due to the loss of sensitivity in measurements on the cowling. Vibration analysis at the bearing caps of the motor is also sensitive, but difficult to perform because of the difficulty in placement of sensors. Vibration measurements on the cowling of the fan are insensitive to any of the faults induced on the fan and bearings for this study. This is consistent with a large body of field experience.

Motor current analysis shows promise for fault detection in other types of machinery. A library of faults, similar to those of this work, must be built to support the extension to other machines. The additional safety benefits of motor current analysis for condition monitoring suggest that progress in this technology is highly desirable from a human standpoint. The sensitivity of the method also makes progress desirable from a technical basis.

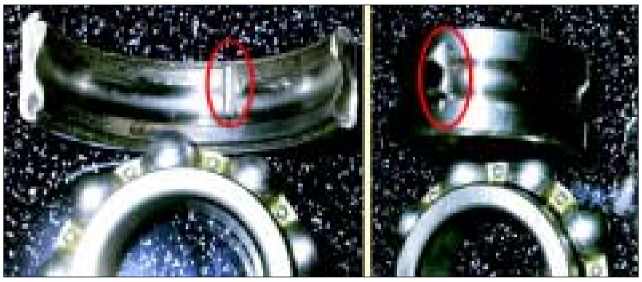

Figure 2. SKF® 6503 and 6502 deep grooved bearings with race defects.

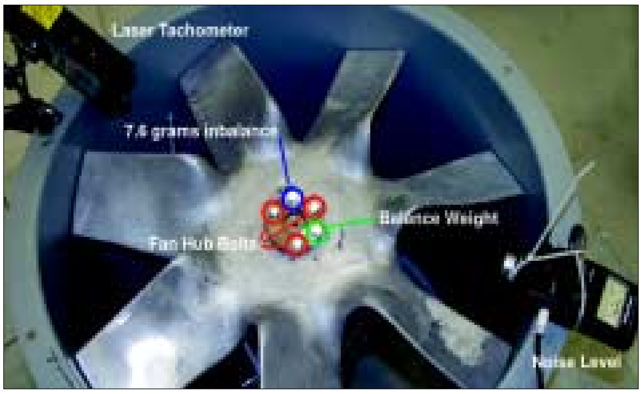

Figure 3. Fan with imbalance weight.

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