Simple, Low-Cost Vibration Monitoring of Air Handlers

By Doug Ausbon, Johnson Controls, Inc., and Tom LaRocque, CTC, Inc.

Monitoring the vibration of rotating components of enclosed air handling units presents a unique challenge for predictive maintenance programs. The air handling units are expected to maintain consistent environmental conditions, such as flow rate, temperature, and humidity, and often to extremely limited tolerances.

At a large pharmaceutical company, even a seemingly insignificant deviation in any of these operating parameters can void a laboratory experiment or ruin the production of an entire batch of product. As a result, opening a unit to access the rotating components to collect vibration data, or even to perform a visual inspection, is impractical because of the potential for ambient air to affect conditions or introduce contaminants. Safety is a concern as well, and because many of the enclosures are small, reaching across belts and shafts poses obvious hazards. With all of these considerations, however, these units are expected to operate continuously, with no breakdowns, and minimal scheduled shutdowns.

Figure 1 *- Cables have been run from the accelerometers to a switchbox mounted outside of the enclosure.*

In order to include enclosed air handling units in their vibration analysis program, accelerometers have been permanently mounted to fan and motor bearings, and cables have been run from the accelerometers to a switchbox mounted outside of the enclosure (Figure 1). This application has been successfully implemented for over 160 air handling units, serving a wide range of laboratory, manufacturing, and critical warehousing spaces. The majority of the air handling units monitored are belt driven. Data collection performed on monthly routes yields many indications of wear, including bearing degradation, sheave wear, misalignment, belt condition, and the build up of debris on fan blades.

Sensor Location

Due to the many potential failure modes of these units, the desire was to monitor each bearing in the horizontal and vertical directions, and monitor one axial direction per shaft. Ideally, this would include ten points per belt driven unit:

Motor
Outboard (free end) bearing - horizontal and vertical.
Inboard (sheave end) bearing - axial, horizontal and vertical.
Fan
Inboard (sheave end) bearing - axial, horizontal and vertical.
Outboard (opposite sheave end) - horizontal and vertical.

For some units, the actual configuration prevents all ten measurement locations from being accessed. It is not always physically possible to install axial accelerometers on the inboard bearings. During installations, each unit was evaluated to determine the best locations to ensure the most reliable vibration data would be collected.

Vibration Analysis Hardware Selection Criteria

The air handling units have fairly typical rotating elements, composed of two shafts supported by rolling element bearings, connected by a sheave-and-belt combination (Figure 2). Most are mounted on a spring support system. Expected failure modes requiring monitoring include:

- Bearing defect frequencies
- Worn, damaged, or broken belts
- Worn or damaged sheaves
- Misalignment between the sheaves
- Mechanical looseness
- Motor electrical, including rotor bar faults

Figure 2 *- The air handling units have fairly typical rotating elements, composed of two shafts supported by rolling element bearings, connected by a sheave-and-belt combination.*

Most of the motors operate near 1800 RPM, but some applications have 1200 or 3600 RPM motors. Horsepower ranges from 1 to 200 HP. Fan speeds range from 480 RPM to nearly 3500 RPM, depending on the application.

To detect the potential defects, analysis ranges typically include a lower limit of 2 Hz, and an upper limit of 40 to 50 times the component rotational frequency (the maximum expected frequency would therefore be 3600 X 50=180000 CPM, or 3000Hz). Stress wave analysis is also being used to detect very early bearing degradation, and to evaluate lubrication, so a frequency response up to or greater than 10,000 Hz is also necessary. These maximum ranges are considered sufficient to accurately diagnose and monitor trends to effectively plan repairs for this type of equipment and the applications for which they support.

Based on these requirements, a general purpose accelerometer will meet the needs of these air handling units. And an accelerometer with a side connector is especially suitable for the limited access areas, such as the axial readings near belt guards.

Mounting Hardware Selection

To provide the optimum vibration transfer between the machine surface and the accelerometer, a mounting system that utilizes the full frequency span of the accelerometer needed to be considered (Figure 3). A mounting target attached to the prepared machine surface (using a tool kit that can be re-sharpened for multiple installations) with an adhesive was selected. The adhesive mounted target facilitates vibration transfer, and the

Figure 3 *- To provide the optimum vibration transfer between the machine surface and the accelerometer, a mounting system that utilizes the full frequency span of the accelerometer needed to be considered.*

full frequency range of the accelerometer can be utilized. Another advantage to the adhesive mounted target is the machine surface does not have to be drilled and tapped. A flat mounting target with a threaded hole was selected for this function.

Cable Selection

Due to the environment within the air handling unit, the cable connecting the accelerometer to the switch box needed to be robust, chemical resistant, moisture resistant and reliable in a potentially caustic environment. A low-cost, composite connector with a silicone o-ring and threaded locking ring (type "A" connector) provides the seal required to protect against the environment. A flexible, twisted shielded cable was chosen to carry the signal from the accelerometer to the switch box, due to it's low-cost and performance in air handler unit applications.

Figure 4 *- Cables should be tied together so they cannot be damaged by rotating equipment, and should exit from the air handler unit in a centralized location.*

Junction Box Selection

A junction box provides convenient, direct access for the analyst to the vibration data. It can be located outside, exposed to the environment. A NEMA 4X enclosure with a water-tight cable entry into the enclosure is recommended to ensure that water will not collect inside the switch box. A switch box was selected due to the ease of use and to limit connections to the junction box. The enclosure selected is fiberglass and features factory installed cord-grips that provide water tight entry of the cable into the junction box.

Cable Routing

Cables should be tied together so they cannot be damaged by rotating equipment, and should exit from the air handler unit in a centralized location (Figure 4).

Cables Exiting from Air Handling Unit

Depending on the application and location of the fan-motor set, some units are under pressure and some create a vacuum. Cables exiting the air handling unit enclosure must be properly sealed to prevent air from escaping from the unit (which reduces unit efficiency), or to prevent unconditioned and possibly contaminated air from entering the unit. One option used for this was to drill a hole in the side of the housing for installation of a cord grip (Figure 5), and then seal it upon installation with silicone RTV. This maintained the integrity of the air-tight seal. Another option is to mount a conduit fitting to the side of the housing (Figure 6) and run the wires through conduit.

Figure 5 *- One option used for this was to drill a hole in the side of the housing for installation of a cord grip and then seal it upon installation with silicone RTV.*

Mounting of Vibration Switch Box

The switch box should be located as close to the sensors as possible to reduce the length of cable needed (for cable cost reasons). The unit housing provides an excellent mounting surface.

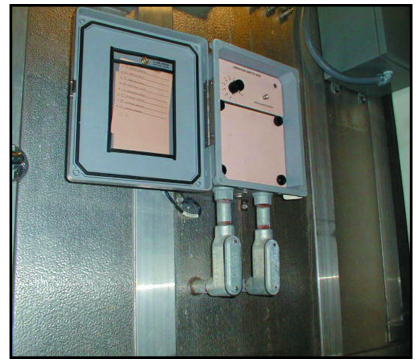

Figure 6 *- Another option is to mount a conduit fitting to the side of the housing and run the wires through conduit.*

Results

The investment made in these air handling units has been returned by successfully detecting and correcting many bearings needing lubrication, detecting bearing degradation in early stages so bearings could be changed prior to failure, and detecting cracked or broken belts requiring replacement before the next scheduled shutdown inspection.

Because of these successes, permanent installations are now included in design packages for upgrades and for the addition of new facilities. The vibration monitoring equipment is installed during fabrication of the air handling units at the fabricators shop. This is especially valuable during equipment commissioning, and to establish an initial baseline.

Future Plans

Although there has been remarkable success in improving equipment reliability by including air handling units in the monthly monitoring program, there is one major pitfall which long term trends usually do not detect. This is the abrupt, unexpected effects caused by a sudden change in mechanical condition.

For belt driven units, this is typically a broken belt. Murphy's Law has demonstrated that a belt will break within a week after the monthly data collection. Obviously, for a single belt unit, the airflow stops immediately, but for a multi-belt unit, it may continue to run, but the remaining belts typically break soon due to the increased and often uneven loads on them.

A missed failure occurred when the bolted connection supporting a fan shaft outboard bearing came apart as a bolt vibrated loose and fell out. The monthly route data showed no indication of looseness, but about three weeks later, the connection failed and the entire side of the fan collapsed, destroying the fan wheel and causing major damage to the fan housing. This was an old unit, which required the replacement parts be custom fabricated - a lengthy and expensive process.

Another failure occurred when a fan shaft broke in two during a weekend. The motor continued to run, and the belts continued to turn on the now immovable fan sheave. The belts overheated, melted, burned and smoked. The smoke filled the spaces, setting off smoke alarms, and filling the space with the smell of the burned belts. The fire department responded to the smoke alarms. While it is not possible to know for sure if the shaft failure could have been detected before it broke in two, it is certain a significant change in vibration occurred when the shaft broke. Having detected this, the unit could have been shut down much earlier, preventing the smoke damage.

For these prior examples, a method of monitoring an obvious change in overall vibration levels would have triggered a need for an immediate investigation. The loss in air supply, the catastrophic failure, or smoke problems would have likely been avoided.

In order to account for the sudden changes and provide a low cost monitoring solution, one of the already installed accelerometers will be rewired to a vibration transmitter which will be located on the air handling unit exterior adjacent to the existing switchbox. (This, too is now being provided with new equipment installations.)

The transmitter provides a BNC connection so the monthly route data can still be collected from the same accelerometer. The transmitter also provides the capability to convert the accelerometer output to a proportional 4-20mA signal acceptable to most PLC or DCS systems. In this way, the trends can be "watched' by the control signal, and alarms generated when a preset level is exceeded.

Conclusion

The following four factors have proven the success of permanently mounted vibration monitoring of air handling units:

• Reduced or eliminated exposure to safety hazards.

• Reduced data collection time while increasing repeatability and data accuracy.

• The ability to collect data on previously inaccessible fan components.

• A low-cost solution to prevent potentially high cost failures.

The previously dangerous and difficult task of monitoring enclosed components of air handling units is now highly accurate and efficient. Equipment once rarely or never monitored is now incorporated into a regularly scheduled Predictive Maintenance Program.

Contact Tom LaRocque, CTC, 590 Fishers Station Drive, Victor, NY 14564; (716) 924-5900; www.ctc-online.com.

About the Authors

Doug Ausbon works with Johnson Controls, Inc., a provider of facilities management services. He began work in the field of vibration analysis in 1978, and is currently a Level III Certified Vibration Analyst. He holds a BS in Mechanical Engineering from North Carolina State University, and is a member of the Piedmont Chapter of the Vibration Institute.

Tom LaRocque is an Engineering Manager for CTC. He is a Certified Vibration Specialist II, holds a BS in Civil Engineering from Clarkson University. He is a member of the Central New York Chapter of the Vibration Institute.