Written by Rich Henry, Ron Sullivan, John Walden and Dave Zdrojewski, VibrAlign, Inc.
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Part three of a four-part series that will cover alignment fundamentals and thermal growth, and highlight the importance of field measurements through two case studies.

The previous article in this series, "Understanding Shaft Alignment: Thermal Growth" (*MT* 1/03, pg. 19), explained thermal growth and its affect on proper equipment alignment. A practical example involves a recent project at a wastewater treatment plant in Cleveland that needed realistic cold alignment targets for a 3600 rpm compressor.

This machine had a long history of coupling and bearing failures. Over a two-year period several attempts were made to calculate the thermal growth on the motor and compressor supports. The original equipment manufacturer's (OEM) technical manual gave a vertical thermal offset value of +0.04 in. (+40 mils). There were no recommendations for a target vertical angularity. Horizontal alignment changes were not mentioned.

Confusing data

There was some confusion with the OEM targets as provided. Maintenance personnel did not know if this value represented what the rim dial indicator should read when the cold alignment was completed (with a dial indicator mounted on the stationary shaft and indicating the motor coupling). Dial indicators indicate the total indicated runout (TIR) each time the shaft is rotated 180 deg. Half of the TIR represents the actual centerline offset; therefore the target should actually be +20 mils vertical offset.

The technician averaged temperature changes measured from the bottom of the support to the split line of the machine. This data was compared with hot alignment readings taken with a modern laser shaft alignment system. The result of all the data was a calculated vertical offset target of +19 mils and a target vertical angularity of +0.65 mil/1 in. No targets were calculated to compensate for horizontal alignment changes.

Laser-based system used

A laser-based monitoring system was installed on the machine and the shaft alignment was monitored as the machine was placed online and allowed to operate until it reached normal operating conditions. There were some interesting changes in the machine's operating characteristics. A set of machine vibration data was collected at 30 min intervals during the machine's warm-up period.

The graphs show data collected from the laser-based monitoring system.

The shaft alignment was set with a vertical offset value of +19 mils and a vertical angularity value of -0.65 mil/1 in. The vibration data collected on the machine bearings continued to improve, reaching a low of 0.13 in./sec (peak overall) until the change in the alignment reached the calculated targets. Unfortunately, the alignment continued to change past the calculated values; as the alignment moved farther away from zero, the vibration data trended back up to fairly high levels, 0.30 in./sec (peak overall). Spectral data indicated misalignment. The farther the alignment moved away from tolerance, the more clearly the signs of shaft misalignment became.

The laser-based monitoring system's data indicated changes in the horizontal alignment that would take the alignment out of tolerance in the horizontal plane as well. The total change in the shaft alignment was:

Vertical offset	+22.2 mils
Vertical angularity	-0.88 mil/1 in.
Horizontal offset	-4.42 mils
Horizontal angularity	-0.55 mil/1 in.

Based on the changes in the alignment as measured by the laser-based monitoring system, the cold alignment targets for this machine were:

Vertical offset	-22.2 mils
Vertical angularity	+0.88 mil/1 in.
Horizontal offset	+4.42 mils
Horizontal angularity	+0.55 mil/1 in.

Data was obtained from a startup; therefore, targets are opposite of the recorded change.

Lessons learned

So, what was learned from this example of thermal growth documentation? The first lesson learned is that no matter how many statistical calculations go into a thermal growth estimate, the best way to get thermal growth information is to measure it directly.

Another lesson is OEM-recommended cold alignment targets, while sometimes close, cannot accurately predict the actual operating conditions of a machine in its final installed state.

A third lesson can be learned from the changes in the horizontal alignment data. The dynamics of machines during operation force changes in the shaft alignment that cannot be measured during a hot alignment check. The machine examined in this example had a horizontal offset of +4.4 mils during operation. When the machine was shut down, the horizontal offset immediately changed by -3 mils, leaving a net horizontal change of +1.4 mils. The +1.4 mils is most likely due to temperature changes in the piping; however, 3 mils of the total change were most likely due to rotor torque and discharge pressure of the compressor.

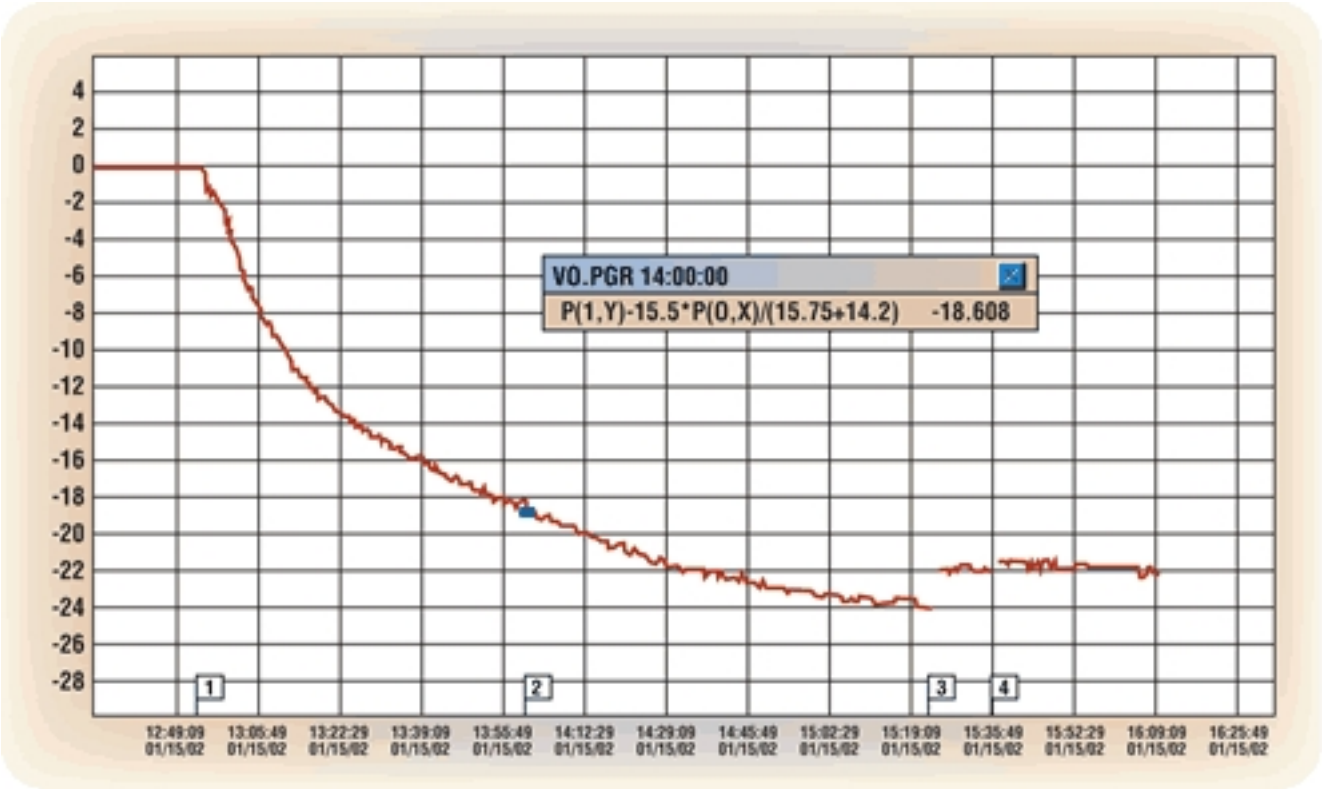
Knowing the initial alignment condition of the machine and the measured changes in the alignment allows us to estimate the current operating misalignment of this machine:

Vertical offset	-3.2 mils
Vertical angularity	-0.20 mil/1 in.
Horizontal offset	+4.4 mils
Horizontal angularity	+0.55 mil/1 in.

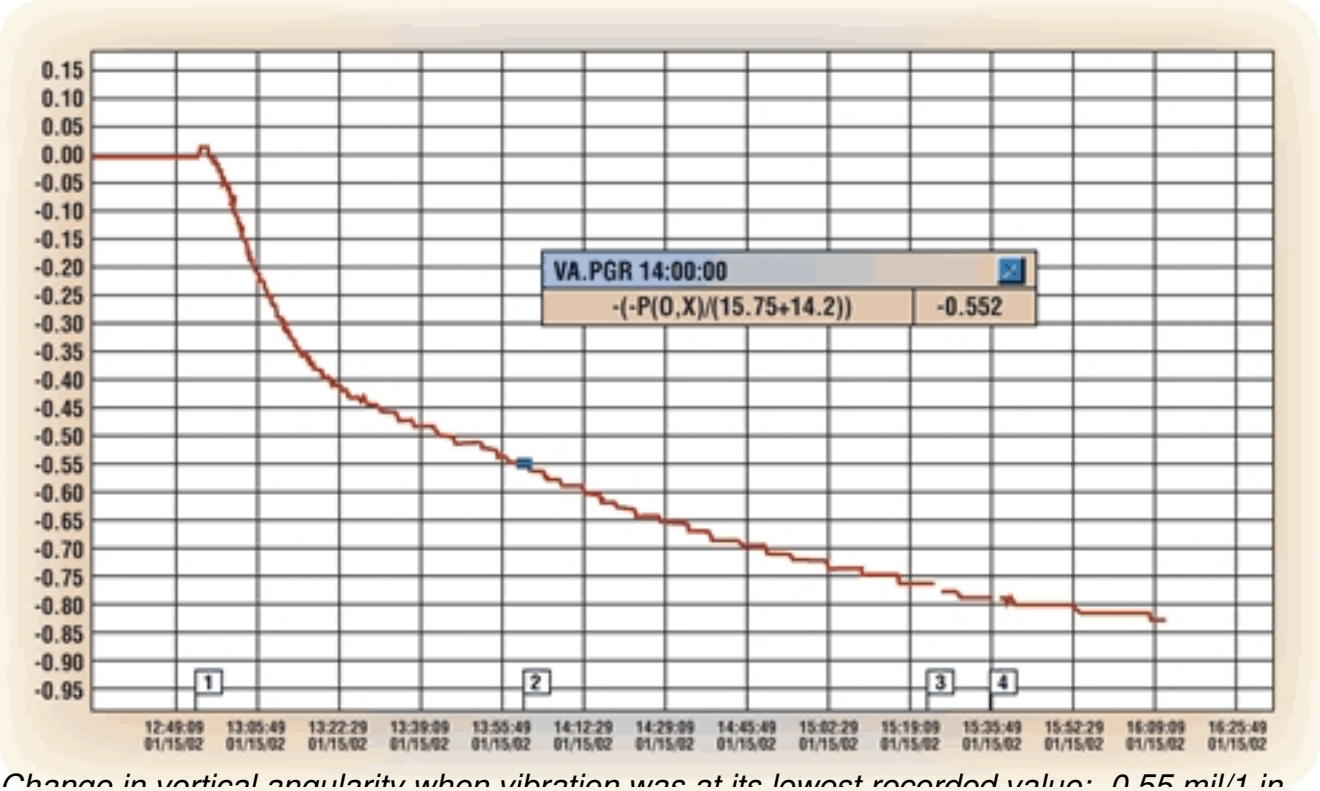
For a 3600 rpm machine, the offset values would be considered outside the acceptable tolerance, and the angularity values are also higher than would normally be considered acceptable. This also relates to shaft alignment tolerances based on shaft rpm rather than on maximum coupling alignment values. Many coupling manufacturers would consider the alignment data acceptable; however, the vibration data shows that considerable force can be applied to the machine bearings due to small amounts of shaft misalignment.

Next month this series will conclude with another case study discussing how identical machines may have different alignment targets. **MT**

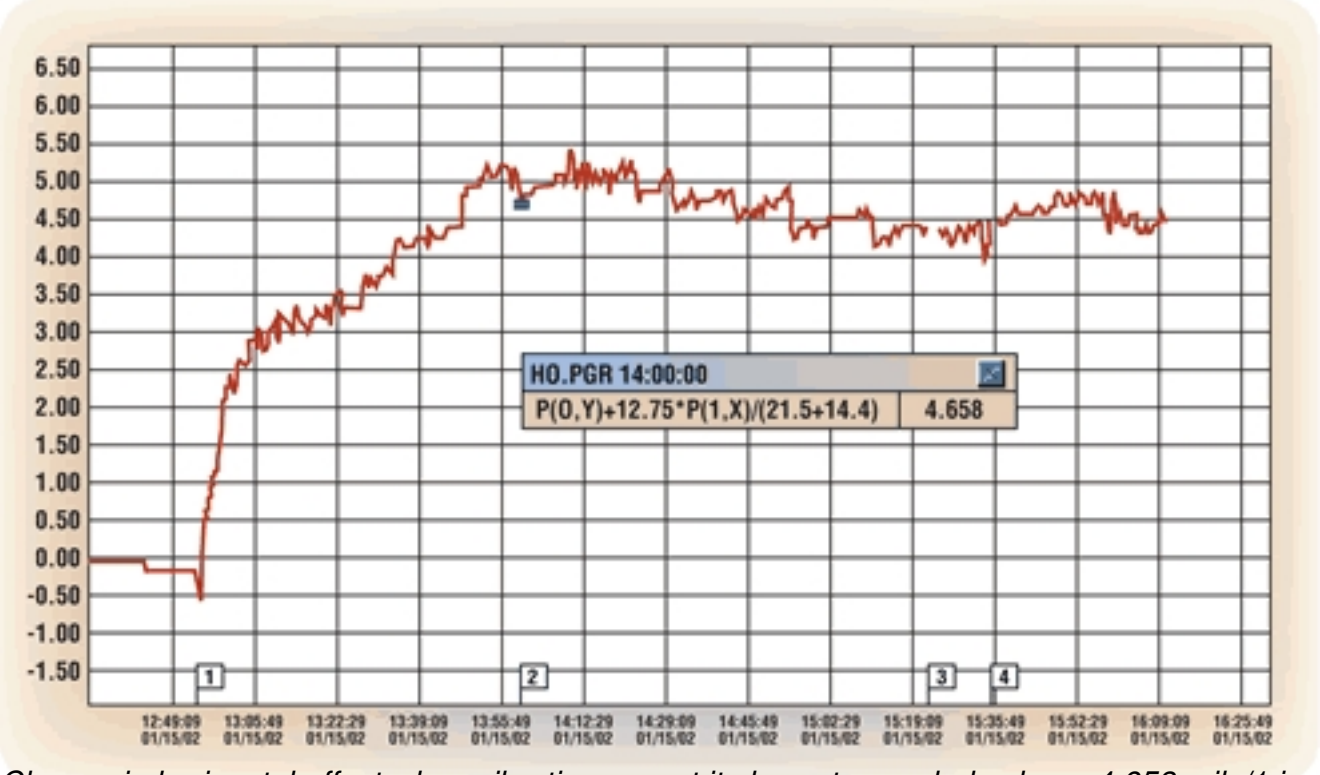
Contributors to this article include Rich Henry, Ron Sullivan, John Walden, and Dave Zdrojewski, all of VibrAlign, Inc., 530G Southlake Blvd., Richmond, VA 23236; (804) 379-2250; e-mail info@vibralign.com



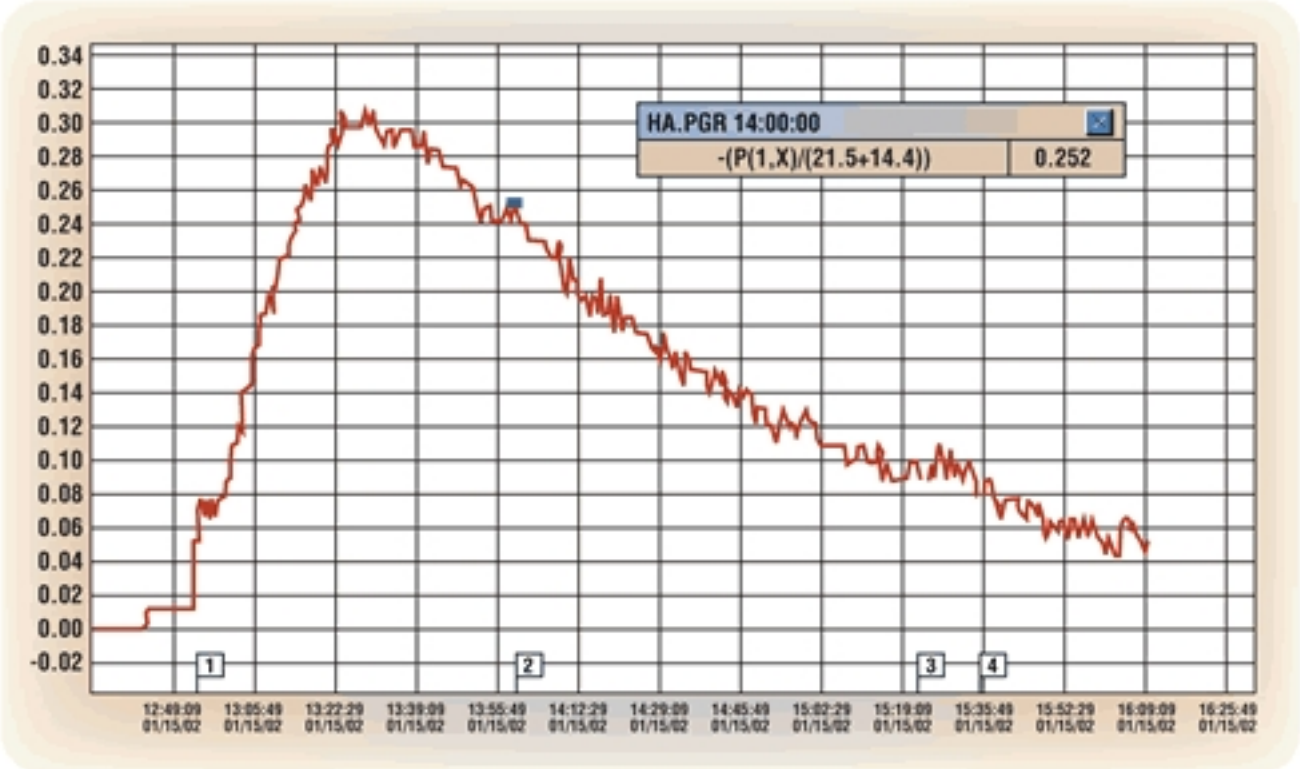
Change in vertical offset when vibration was at its lowest recorded value: -18.61 mils



Change in vertical angularity when vibration was at its lowest recorded value: -0.55 mil/1 in.



Change in horizontal offset when vibration was at its lowest recorded value: +4.658 mils/1 in.



Change in horizontal angularity when vibration was at its lowest recorded value: +0.252 mil/1 in.

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