

Shaft Alignment White Paper

Despite the best efforts to precisely align rotating machinery shafts, dynamic movement (commonly believed to be due to the thermal growth of the machine casings) has resulted in machines operating at less than optimum alignment conditions. This vexing problem has plagued machine reliability professionals for decades.

What is shaft alignment?

Shaft alignment is the positioning of the rotational centers of two or more shafts such that they are co-linear when the machines are under normal operating conditions. Proper shaft alignment is not dictated by the total indicator reading (TIR) of the coupling hubs or the shafts, but rather by the proper centers of rotation of the shaft supporting members (the machine bearings).

There are two components of misalignment—angular and offset.

Offset misalignment, sometimes referred to as parallel misalignment, is the distance between the shaft centers of rotation measured at the plane of power transmission. This is typically measured at the coupling center. The units for this measurement are mils (where 1 mil = 0.001 in.).

Angular misalignment, sometimes referred to as "gap" or "face," is the difference in the slope of one shaft, usually the moveable machine, as compared to the slope of the shaft of the other machine, usually the stationary machine. The units for this measurement are comparable to the measurement of the slope of a roof (i.e., rise/run). In this case the rise is measured in mils and the run (distance along the shaft) is measured in inches. The units for angular misalignment are mils/1 in.

As stated, there are two separate alignment conditions that require correction. There are also two planes of potential misalignment—the horizontal plane (side to side) and the vertical plane (up and down). Each alignment plane has offset and angular components, so there are actually four alignment parameters to be measured and corrected. They are horizontal angularity (HA), horizontal offset (HO), vertical angularity (VA), and vertical offset (VO).

Shaft alignment tolerances

Historically, shaft alignment tolerances have been governed by the coupling manufacturers' design specifications. The original function of a flexible coupling was to accommodate the small amounts of shaft misalignment remaining after the completion of a shaft alignment using a straight edge or feeler gauges. Some coupling manufacturers have designed their couplings to withstand the forces resulting from as much as 3 degrees of angular misalignment and 0.075 in. (75 mils) of offset misalignment, depending on the manufacturer and style of the coupling.

Another common tolerance from coupling manufacturers is the gap tolerance. Typically this value is given as an absolute value of coupling face TIR (as an example, a specification might read "face TIR not to exceed 0.005 in."). This number can be deceiving depending on the swing diameter of the face dial indicator or the diameter of the coupling being measured. In fairness, it should be noted that the tolerances offered by coupling manufacturers are to ensure the life of the coupling with the expectation that the flexible element will fail rather than a critical machine component.

If this angular tolerance was applied to a 5 in. dia. coupling, the angular alignment result would be 1 mil/1 in. of coupling diameter or 1 mil of rise per 1 in. of distance axially along the shaft centerline. If the coupling was 10 in. in diameter, the

result of the alignment would be twice as precise (0.5 mil/1 in.). This would lead one to conclude that an angular alignment tolerance based on mils/1 in. would be something that could be applied to all shafts regardless of the coupling diameter.

Harmonic forces are dangerous

When shafts are misaligned, forces are generated. These forces can produce great stresses on the rotating and stationary components. While it is probably true that the coupling will not fail when exposed to the large stresses as a result of this gross misalignment, the bearings and seals on the machines that are misaligned will most certainly fail under these conditions. Typically, machine bearings and seals have small internal clearances and are the recipient of these harmonic forces, not unlike constant hammering.

Excessive shaft misalignment, say greater than 2 mils for a 3600 rpm machine under normal operating conditions, can generate large forces that are applied directly to the machine bearings and cause excessive fatigue and wear of the shaft seals. In extreme cases of shaft misalignment, the bending stresses applied to the shaft will cause the shaft to fracture and break.

Bearing life expectancy

The most prevalent bearings used in machinery, ball and roller bearings, all have a calculated life expectancy, sometimes called the bearing's L-10 life—a rating of fatigue life for a specific bearing. Statistical analysis of bearing life relative to forces applied to the bearings has netted an equation describing how a bearing's life is affected by increased forces due to misalignment.

$$L_{10} = \frac{16700 \times \left[\frac{\text{dynamic capacity} \times \text{load rating}}{\text{force}} \right]^3}{\text{rpm}}$$

= hours of life

Formula notes: This formulation is credited to the work done by Lundberg and Palmgren in the 1940s and 1950s through empirical research for benchmarking probable fatigue life between bearing sizes and designs.

For ball bearings: $L_{10} = (C/P)^3 \times 10^6$; For roller bearings: $L_{10} = (C/P)^{10/3} \times 10^6$

where:

L₁₀ represents the rating fatigue life with a reliability of 90 percent

C is the basic dynamic load rating—the load which will give a life of 1 million revolutions which can be found in bearing catalogs

P is the dynamic equivalent load applied to the bearing

As the force applied to a given bearing increases, the life expectancy decreases by the cube of that change. For instance, if the amount of force as a result of misalignment increases by a factor of 3, the life expectancy of the machine's bearings decreases by a factor of 27.

Quite a bit of research in shaft alignment has been conducted over the past 20 years. The results have led to a much different method of evaluating the quality of a shaft alignment and to increasingly accurate methods of correcting misaligned conditions. Based on the research and actual industrial machine evaluations, shaft alignment tolerances are now more commonly based on shaft rpm rather than shaft diameter or coupling manufacturers' specifications. There are presently no specific tolerance standards published by ISO or ANSI, but typical tolerances for alignment are shown in the table.

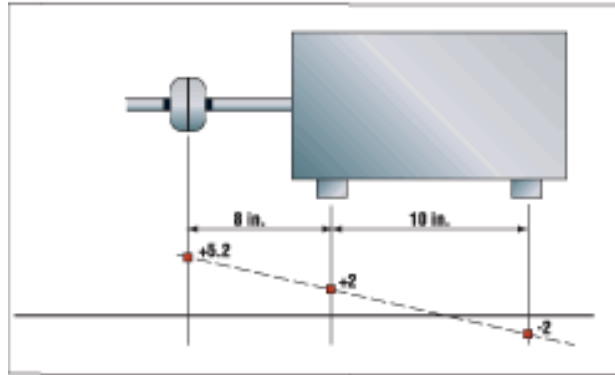
RPM	Angular Misalignment Mils per in. .001/1 in.		Offset Misalignment Mils .001 in.	
	Excellent	Acceptable	Excellent	Acceptable
3600	0.3/1 in.	0.5/1 in.	1.0	2.0
1800	0.5/1 in.	0.7/1 in.	2.0	4.0
1200	0.7/1 in.	1.0/1 in.	3.0	6.0
900	1.0/1 in.	1.5/1 in.	4.0	8.0

Typical Shaft Alignment Tolerances

Another common method of determining shaft alignment tolerances is to ensure the machine feet are within a specified distance from what is considered "zero". This method also can be misleading. If a machine is considered to be aligned when the foot corrections are less than 2 mils at both the front feet and back feet, serious misalignment can sometimes be present. As a general rule, the smaller the machine footprint (distance from front feet to back feet), the worse the alignment condition based on these criteria for alignment tolerance.

In Fig. 1, the motor foot distance front to back is 10 inches. The distance from the front feet to the center of the coupling is 8 inches. If the front foot of the motor is left 2 mils high and the back feet are left 2 mils low, the shaft alignment results will be as follows: vertical angularity of 0.4 mil/1 in. open at the top of the coupling, and a vertical offset of 5.2 mils high at the plane of power transmission. If this machine operates at 1800 rpm, it would be outside the acceptable shaft alignment tolerances. Again, this reinforces that a set of shaft alignment tolerances based on shaft rpm would apply to all machines regardless of their footprint.

MISALIGNMENT USING MACHINE FEET DISTANCES



Using machine feet distance to align a machine to acceptable tolerances can give misleading information.

Understanding Shaft Alignment: Thermal Growth

Machine conditions change from the time the machine is off line to when it is running under normal operating conditions. Some of these changes are due to process forces (e.g., fluid pressures, airflow, etc.). The most notable of these changes is the change in the temperature of the machine bearings and supports. This is called the machine's thermal growth.

Thermal growth is the change in the length of a particular metal as a result of the change in temperature of that metal. Typically, when a metal bar is heated, it will get longer. These changes can be very small (0.0005 in.) or they can be very large, depending on the length of the piece of metal and its coefficient of linear expansion.

Formula for thermal growth

The formula used for this calculation is often referred to as the $T \times L \times C$ formula. T represents the change in the material's temperature in degrees Fahrenheit, L represents the length in inches of the material, and C represents the material's coefficient of linear expansion. Different materials have different C values. Using the formula, we can anticipate the change in a machine's shaft alignment based on the expected changes in machine temperature. Below is a chart of the most common machine materials and their C values.

Consider the following example: A motor with a starting temperature of 70 F is perfectly aligned to the pump shaft it will be driving. For this exercise, the temperature of the pump will not change; however, the temperature of the motor will increase to 120 F under normal operating conditions. The motor end bell's material is cast iron with a C value of 0.0000059. The distance from the bottom of the motor feet to the center of the shaft is 15 in. We now can calculate the change in position of the motor from off line to running by multiplying the T , L , and C values. $T \times L \times C = \text{growth}$ (120 F – 70 F) \times 15 in. \times 0.0000059 = 0.0044 in.

Based on this information, the motor will grow 0.0044 in. or 4.4 mils. If the growth of the motor is the same for both ends, the result will be a change in the offset alignment of 4.4 mils but the angular alignment will not change. This motor shaft should be aligned 4.4 mils lower than the pump shaft which will allow the machine to grow into an aligned condition.

Temperature changes unequally

That was a fairly simple example and does not accurately reflect what will happen to an actual machine. In reality, the temperatures of all the machine supports will change; however, they will almost never change equally.

Using the above machine example, consider the change in shaft alignment if the outboard end (OE) bearing temperature changed by 20 F and the drive end (DE) bearing temperature changed by 50 F. The drive end bearing would grow by 4.4 mils; however, the outboard bearing would grow only by 1.8 mils. The result will be a change in both the offset and angular alignment. If the motor feet are 20 in. apart, the change in the angular alignment will be 0.13 mil/in. $[(4.4 - 1.8)/20 = 0.13]$ open at the top of the coupling. Changes in the temperature of machines from off line to running can have a significant impact on the shaft alignment.

These changes in the shaft alignment can be accommodated in a few different ways. One way is to align the machines to zero and then remove or add the amount of shim under the machine feet as determined by the temperature data. Another way is to gather the alignment data, graph the results, and predetermine the actual shim corrections based on the graph.

With today's modern laser alignment technology, accounting for thermal changes at the machine feet is actually a simple evolution. Most alignment systems on the market today have within them a function that allows the user to program the foot targets of the machine being aligned. For the previous example, the front foot target would be -4.4 mils and the back foot target would be -1.8 mils. After programming the determined foot target values at the machine feet, the user aligns the machines to zero on the display unit. The shaft alignment system will automatically calculate the required foot corrections to leave the feet at the prescribed positions. As the machine heats up, the shaft centerlines will grow into a properly aligned condition.

Gearboxes are difficult

Thermal changes in gearboxes can be especially difficult to calculate. Often the input shaft temperatures will be different from the output shaft temperatures. This causes the gearbox shaft alignments to change in the horizontal plane as well as the vertical plane.

Force-lubricated systems with an oil cooler also can have an effect on the final alignment condition of a machine. Higher oil temperatures out of the cooler will result in a hotter operating condition of the machine, therefore creating a more drastic change in the running alignment condition. A 10 F change in the operating temperature of a turbine from 105 F to 115 F can change the foot positions as much as 2-4 mils. The alignment condition of turbines and compressors that operate at very high speeds can be adversely affected by these relatively small temperature changes.

COMMON MATERIALS AND THEIR C VALUES

Material	C (in./in./F)
Aluminum	0.0000126
Bronze	0.0000101
Cast iron	0.0000059
Copper	0.0000092
Mild steel	0.0000063
Stainless	0.0000074

Different materials have different C values (coefficient of linear expansion).

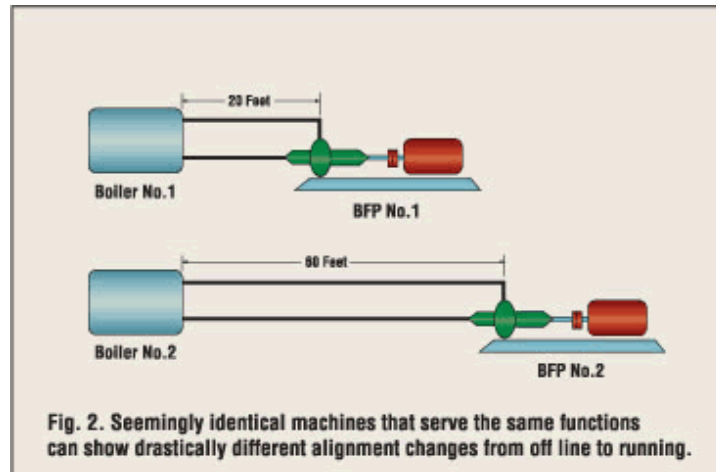
Pipe strain

Another condition that changes is the increase or decrease in temperatures of the suction and discharge piping attached to pumps and compressors. Some compressors may actually form ice on the suction end while the discharge piping is too hot to touch. Conditions such as these can force major changes in the operational alignment condition of machines.

While original equipment manufacturers might be able to anticipate the nominal changes in operating temperatures of a piece of equipment, they cannot accurately anticipate the effects of the piping configurations of the final machine installation or the changes in the temperature of the piping runs. Piping runs are typically very long and can have a tremendous impact on the change in the shaft alignment from off line to running condition. In addition, piping connections act as fixed (or restraining) points with respect to the tendency of machines to move/grow when on line. The effect of these fixed points on the final position of the machines is almost impossible to calculate or predict.

Depending on the piping configuration, these changes may be in the vertical plane or in the horizontal plane and are extremely difficult or impossible to accurately calculate based on the TLC formula above.

Consider two identical boiler feed pumps (BFP) as shown in [Fig. 2](#). BFP #1 feeds boiler #1 which is 20 ft away and BFP #2 feeds boiler #2 which is 60 ft away. The length of the discharge piping on BFP #2 will be approximately three times longer than that on BFP #1. This will result in the two "identical" machines showing drastically different alignment changes from off line to running. A great deal of care must be taken when calculating the changes in the alignment condition of these machines. Just because two machines appear identical and serve the same function does not ensure they will exhibit the same operational characteristics.



Determining alignment changes

In the past, there have been several methods used to attempt to measure the changes in the shaft alignment of two or more machines. One of these methods involves measuring the changes in machine temperatures at each machine support and performing the target alignment based on mathematical calculations.

Another method relies on tooling balls mounted on machine bearings. Typically an optical transit (scope) is used to measure the off line positions of the tooling balls. Once the machine is at operating conditions, another set of measurements is made; the positional changes are compared to the "stationary" tooling balls. These changes are triangulated to calculate the change in the position of the shafts.

There is a variant to the above technique, the Acculign method, which involves installing tooling balls in the foundation as well as at the bearings. The distance between the fixed tooling balls (mounted in the foundation) and the bearing-mounted tooling balls is measured off line and then on line. Precise measurements of the distances and angles are required to make the calculations of the growth.

Doing hot alignment checks

Another way to gather this data is to perform a hot alignment check of the affected piece of equipment. The procedure for this is relatively simple. The machine is aligned off line and the results of the alignment are documented (horizontal angularity, horizontal offset, vertical angularity, and vertical offset). The machine then is placed on line and allowed to reach normal operating conditions. At this point, the machine is shut down and allowed to stop rotating.

The alignment system is remounted on the machine and the shaft alignment is re-measured and documented. Now the machine may be aligned hot by re-shimming and repositioning the moveable machine as quickly as possible. One drawback of this method is that the machine will begin to cool as soon as it is shut down, adversely affecting the accuracy of the hot alignment check.

If the two sets of alignment readings were documented, a set of cold alignment targets can be calculated.

Alignment results (hot) – alignment results (cold) represents the change in the alignment condition of the machine from cold to hot. The alignment targets for this machine will be the opposite of the changes in the alignment parameters.

While this is currently a widely used method of hot-aligning machines, it will measure only the changes in the shaft alignment due solely to the changes in the machine's temperatures. Discharge pressure, shaft torque, multiple machines operating in parallel, electrical loading of a generator, etc., also can play a large role in the change in the alignment condition from off line to running. These changes most often will be seen in the horizontal plane, but could affect the vertical alignment as well.

Yet another factor to consider is the location of the machine. If a machine is located indoors in a controlled environment, the operating characteristics should be relatively constant throughout the year. A machine that operates outdoors and is exposed to large changes in temperature also could exhibit extreme changes in its shaft alignment as the temperature changes (as in the change of seasons).

On line positional change measurements

One method used to measure the change in the alignment of two pieces of machinery is to document their bearing cap positions in both the horizontal and vertical planes relative to some fixed points in space while the unit is off line. After the data has been documented, the machine is started and placed on line. When the machine has reached its normal operating temperature, the positions of the bearing caps are measured again and compared to the points that are stationary. The movement of the machines and the changes in the shaft alignment then can be either calculated or graphed.

In the past, there have been problems obtaining on line readings using this method. A nominal amount of vibration can make an optical scale very hard to read through a transit or theodolite. Care must be taken that the scale is placed back in the exact location for each measurement at each point. Bearing caps are not typically precision machined on the outside surfaces. A very small deviation in the position of the detector can lead to a very large error if the surface that is being measured is not flat and smooth.

Modern laser-based measurement systems designed to measure flatness and surface parallel also can be used in this manner. One benefit of the laser-based positional measurement systems is that the data can be averaged, eliminating the potentially large errors when measuring machines that are running. When the laser beam strikes a vibrating detector surface the data will appear to bounce slightly. A simple function in the display unit will sample the data for the desired amount of time, locate the maximum and minimum values on the detector, and average the data accordingly. Since vibration, by definition, is cyclic and repeatable, very good results can be obtained.

Laser measurement systems

In the 1980s, a laser-based system became available that mounted to the drive end bearings of a machine to monitor the changes in the machine's alignment from cold to hot or from hot to cold. Two laser transmitter/detectors are mounted on the stationary machine drive end bearing. One of these transmitter/detectors must be positioned in the 12 o'clock position (to monitor vertical offset and horizontal angle changes) and the other must be positioned in the 3 o'clock position (to monitor horizontal offset and vertical angle changes). The transmitter/detectors are positioned coaxially with the stationary shaft centerline and level. Corresponding prisms are mounted on the moveable machine drive end bearing. They are positioned to reflect the laser beam back to the detectors mounted on the stationary machine.

The transmitter/detectors are hooked up to a computer running the measurement software. The user can now program the alignment monitoring equations into the software and have the system monitor all four alignment parameters simultaneously. The values are auto-zeroed and the data collection begins. When the machine is started and the

alignment changes, it is recorded in the system software. When the machine reaches normal operation, the data collection is stopped and the alignment changes calculated. The results are displayed as a graphical trend.

The cold alignment targets will be opposite of the measured change in the machine alignment if the data collection was started when the machine was cold. If the cool down was monitored, the targets are equal to the values displayed in the software. While this system can be very effective for diagnosing alignment problems, it also can be very time consuming and frustrating to set up and monitor. Any change in the bracket position during the data collection will introduce errors into the results. This system also requires the user to purchase a PC to use for the data collection.

Determining Accurate Alignment Targets

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 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.

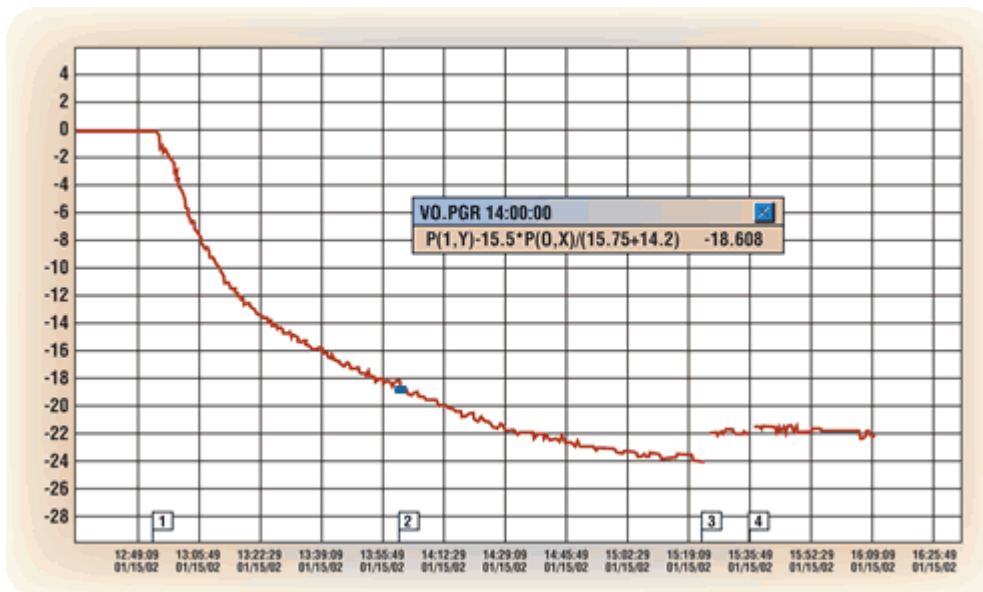
Another lesson is OEM-recommended cold alignment targets, while sometimes close, cannot accurately predict the actual operating conditions of a machine in its final installed state.

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.

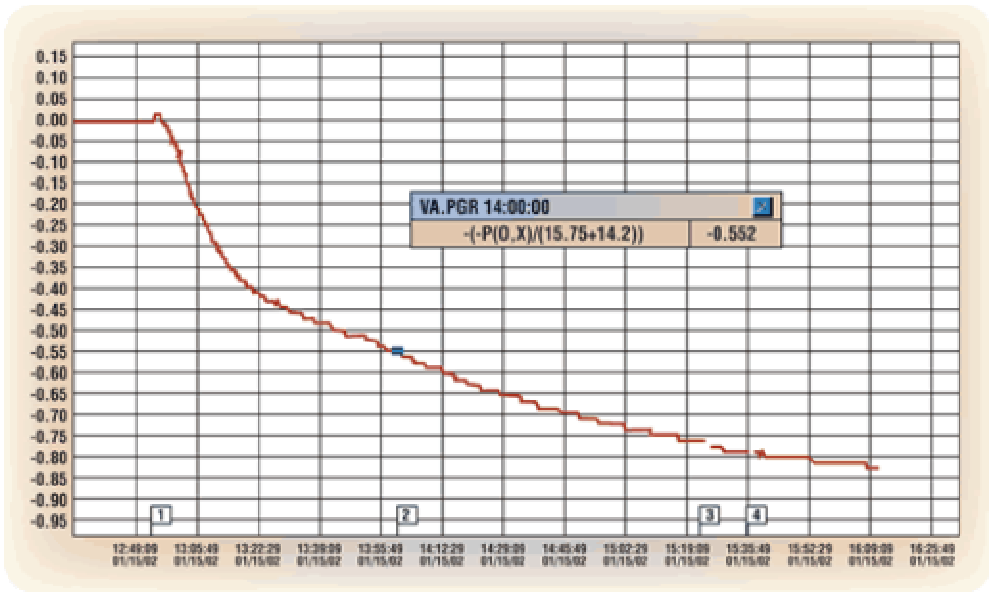
Knowing the initial alignment condition of the machine and the measured changes in the alignment allows us to estimate the current operating misalignment of this machine:

Vertical offset: -3.2 mils
Vertical angularity: -0.23 mil/1 in.
Horizontal offset: +4.42 mils
Horizontal angularity: +0.55 mil/1 in.

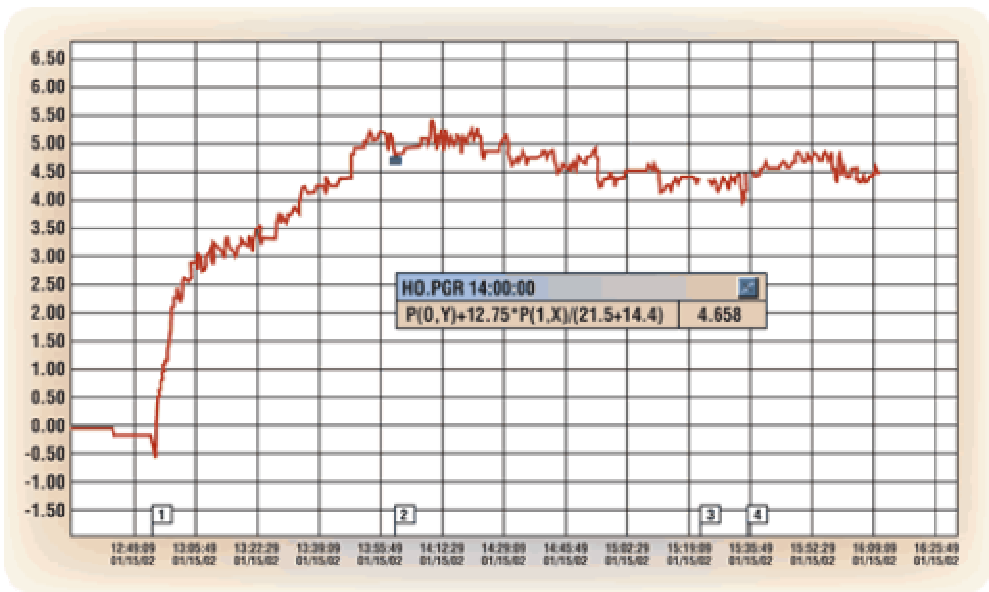
For a 3600 rpm machine, the offset values would be considered outside the acceptable tolerance, and the angularity values are also higher than would normally be considered acceptable. This also relates to shaft alignment tolerances based on shaft rpm rather than on maximum coupling alignment values. 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.



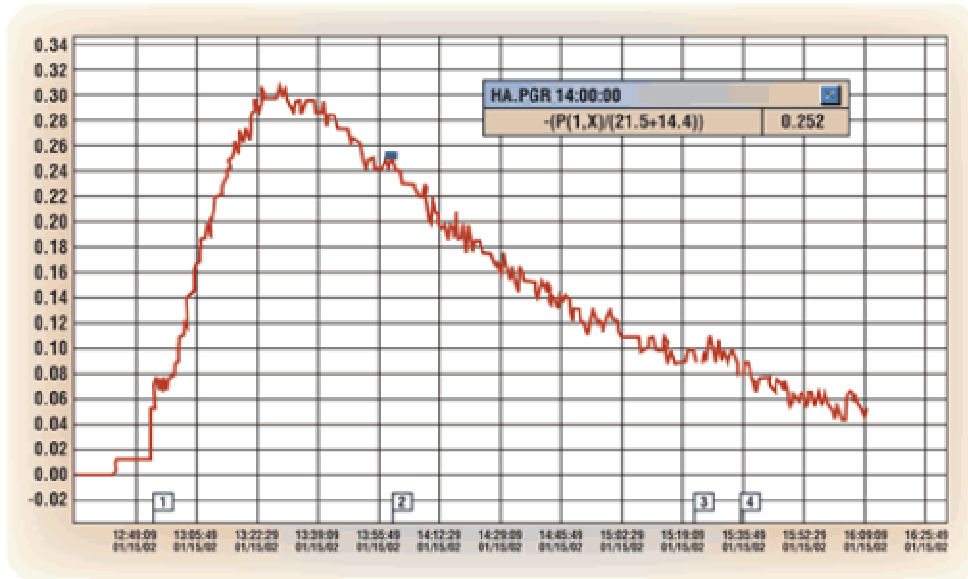
Change in vertical offset when vibration was at its lowest recorded value: -18.61 mils



Change in vertical angularity when vibration was at its lowest recorded value: $-0.55 \text{ mil}/1 \text{ in.}$



Change in horizontal offset when vibration was at its lowest recorded value: $+4.658 \text{ mils}/1 \text{ in.}$



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

Understanding Shaft Alignment: Identical Machines

Another example is a project that involved performing off-line-to-running examinations on two identical machines at a cogeneration facility in Virginia.

The machines are gas turbine generator units that experienced high vibration issues at particular times along their operating cycles. These units were considered identical in terms of manufacturer, size, containment structure, load rating, installation, rpm, etc. A laser-based monitoring system was set up on both units and the setup dimensions were programmed into the computers. Data collection was started and the machines were placed into their startup modes at approximately the same time.

Dramatic difference seen

While the trended changes in the alignment had the same basic shape to the graph, one of the units showed a dramatically different change in the vertical offset alignment. Both machines are supposed to operate at the same temperature and both machines were set to the OEM-recommended cold alignment targets.

Unit No. 5 showed approximately a +20 mil maximum change in the vertical offset and settled around +10 mils at normal operating conditions.

Unit No. 6 showed approximately a +30 mil maximum change in the vertical offset and settled around +20 mils at normal operating conditions.

The OEM technical documentation states that the generator will grow 20 mils evenly front to back and the clutch will grow 22 mils evenly front to back. That results in a +2 mil change in the alignment from off-line-to-running at normal operating conditions. As noted, this value is not accurate and does not reflect the actual operating condition of either machine.

Compared to the recommended tolerances for the 3600 rpm machine, ± 2 mils vertical offset misalignment, Unit No. 5 is operating with a vertical offset of +8 mils and Unit No. 6 is operating with a vertical offset of +18 mils. These particular machines have been operating under these conditions since their installation more than a year prior and have a history of high vibration readings and premature clutch failures since their first day of operation. The test on both units required less than one day to complete.

Consider dynamic movements

The cost of a precision alignment is typically small when compared with the loss of production should a critical piece of equipment fail. Even with the introduction of portable vibration monitoring equipment and easy-to-use laser alignment systems, alignment still ranks as one of the leading contributors to premature rotating machinery failure and lost production. One reason is the neglect or miscalculation of machinery dynamic movements. It has been shown that besides cold alignments, the actual dynamic movements of machinery need to be considered when aligning.

The problem of ignoring dynamic changes in the shaft alignment of two machines from off-line-to-running condition needs more attention. There is mounting evidence that long-standing assumptions are leading to machine reliability problems—assumptions such as believing identical machines have identical dynamic movements, relying solely on OEM recommendations, ignoring the possibility of horizontal movement, assuming growth will be symmetrical, and accounting only for thermal effects. These assumptions need to be challenged and behaviors changed.

The options available on the market today until very recently have not been enticing. Optical methods, mechanical methods, and laser-based monitoring systems all require some special skills and expertise to obtain good results. It may be prudent to contract these services for critical equipment rather than attempting to develop the skills in-house since the learning curves can be steep. A Swedish manufacturer has introduced a device that greatly facilitates in-house measurement of machinery dynamic movement.

Regardless of the approach, coupled machines need to be set to cold alignment targets that will reflect the actual changes in the shaft alignment. This will lead to lower vibration levels, increased mean time between failures, decreased maintenance expenditures, and increased production. Much like the philosophical change from aligning shafts with dial indicators to aligning shafts with laser-based systems, these types of measurements will take some time to be generally accepted and routinely practiced. While some of the current technology may be relatively expensive, a simple cost/benefit analysis will help with the right decision, which can yield a significant increase in machine availability and profit.