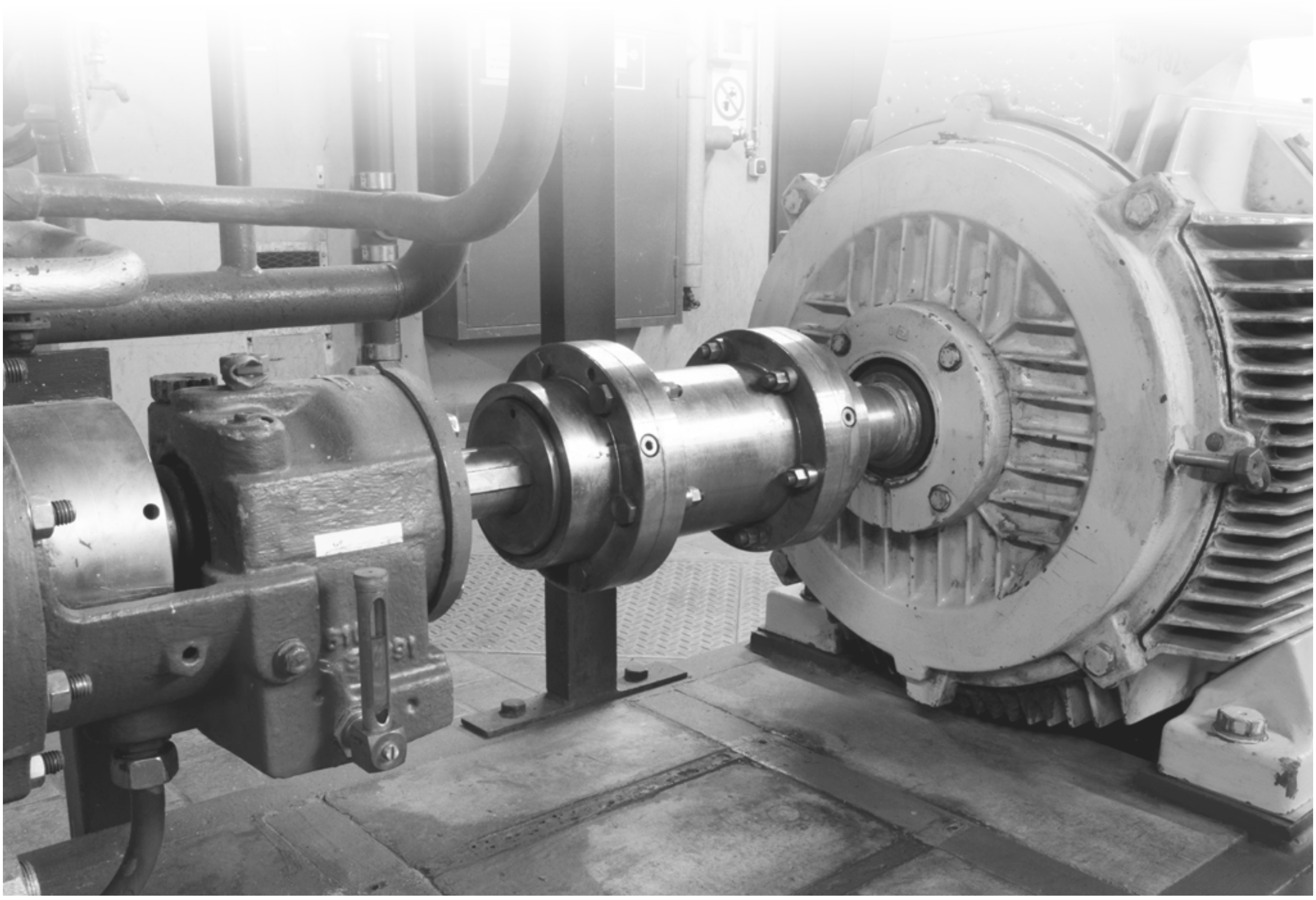
A Fluke Reliability White Paper

Adaptive Alignment

Next-generation technology for solving every shaft alignment challenge



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Executive Summary

The invention of laser shaft alignment revolutionized the industry by delivering measurements more precise by orders of magnitude than traditional methods.

Because laser systems have moved from being "state-of-the-art" years ago to "state-of-the-business" today, one might be tempted to think that all laser measurement systems are the same, and that there is nothing left to innovate in this important technology.

But that view is mistaken. It is true that some systems have remained the same, but others have continued to evolve.

This white paper introduces the latest advance: adaptive alignment. It is a combination of software and hardware innovations, enabling maintenance teams to address any type of shaft alignment task, from the standard, daily and simple alignment jobs through to the more complex and challenging tasks such as the alignment of cardan shafts, vertical flanged machines with right-angle gearboxes, or extensive machine trains with gearboxes.

Some alignment products emphasize the ability to make easy measurements. While ease of use is essential, "easy" is sometimes another word for "simplistic." Maintenance teams may get an easy tool that works for some simple jobs, but they bump up against limitations as soon as the job becomes less straightforward.

With adaptive alignment, maintenance teams have tools with a unique combination of hardware and software capabilities that adapt to virtually any situation in the field. Standard, daily or simple alignment jobs are performed much faster and with higher precision; more complex jobs involving challenging machine configurations, gross misalignments, or tight clearances are overcome with far greater ease of use and without having to resort to manual workarounds or time-consuming reworks.

Basic laser alignment systems actually introduce new errors, unnecessarily complicating the alignment process, frustrating technicians, and driving up operational cost. What maintenance leaders save with a cheaper system they lose in manual efforts and rework.

With adaptive alignment, the work is completed faster, results are more accurate, and team capacity is unlocked.

Every maintenance team faces unique alignment challenges. Adaptive alignment gives them a complete solution – without sacrificing ease of use. In fact, ease of use is strengthened in the many situations where basic laser alignment systems struggle.

Adaptive alignment eliminates human error while delivering new levels of accuracy and speed. This next generation in laser shaft alignment is made possible by two must-have underlying innovations: Single-Laser Technology and Active Situational Intelligence. Systems outfitted with these technologies deliver new levels of flexibility in three key areas:

- **Adapting to the Asset**
- **Adapting to the Situation**
- **Adapting to the Maintenance Team**

Foundational Enablers

Adaptive alignment achieves its results through two major innovations, which are integrated into one system. One is engineered into the hardware; the other includes patented algorithms, formulas, and intelligence built into the software.

Single-Laser Technology
With a single-laser system, users have just one sensor and one laser to set up. Not only is this faster, it eliminates the many frustrations and risk of inaccuracies that happen when working with two lasers firing in opposite directions.

Dual laser systems are challenging to coordinate through the entire measurement process. In particular, they suffer from a "divergence" phenomenon that happens when line-over-length between the laser and sensor is out of range … and contact between the laser and detectors is lost. This short video is helpful in understanding how this can happen.

Dual laser systems struggle with angular alignment in particular. Technicians cannot easily maintain the line to the detector – a fundamental problem that is magnified as the measurement distance increases, such as measuring across a spacer shaft.

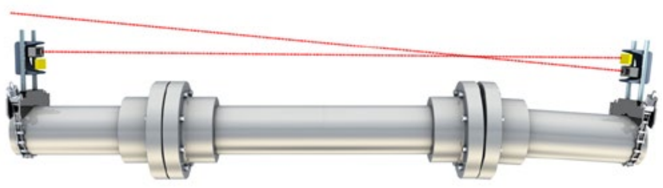


Figure 1: Dual laser technology over long distance: line-over-length divergence

Technicians have to restart measurements, which means stopping, loosening the feet, moving the machine, retightening the feet, and then hoping the detectors are now within range. This process may need to be repeated multiple times. Every one of these episodes adds significant time to the process and increases the potential for errors.

Basic laser alignment systems can't adapt. They recommend doing a "pre-alignment" before taking the first measurement. But this involves moving the machine from its as-found state – thus being unable to document it – and is really nothing more than a visual educated guess. In addition, only horizontal parallel movement is practically performed, overlooking the very real possibility of angular misalignment.

Single-Laser alignment systems eliminate all of these problems. Leveraging two optical detector planes in a single sensor, technicians never need to stop, loosen and retighten feet, or take multiple sets of measurements. Used in conjunction with Freeze Frame Measurement (explained below), long distances can be measured without any chance of the laser losing the target sensor.

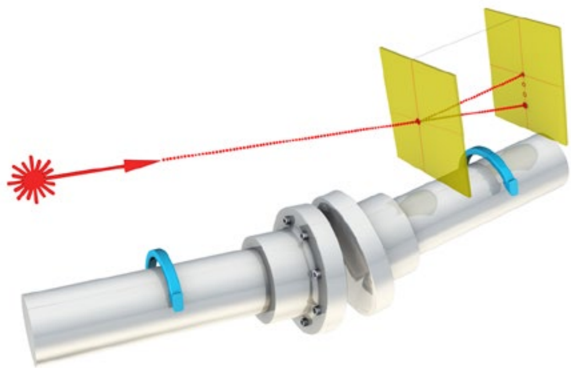


Figure 2: Single-laser dual detector technology solves the line-over-length divergence problem

Single-Laser Technology delivers rapid completion of alignment tasks while improving precision at the same time. Systems outfitted with this technology include a "Live Move" capability that enables technicians to literally see corrections in real time. They see updated results in vertical and horizontal planes simultaneously across the full range of the sensor detection surfaces. This overcomes the limitations inherent to non-adaptive, dual-laser systems that have the line-over-length divergence problem.

Click here to see how to align a machine in only one Live Move.

Active Situational Intelligence
Active Situational Intelligence (ASI) is software that provides real time, “in the moment” feedback and guidance. For instance, quality of measurement is tracked and displayed to the technician during a continuous sweep. Certain factors that can compromise measurement quality in non-adaptive systems, such as errors induced by coupling backlash or environmental vibration, are automatically detected and filtered out on the fly, enabling highly precise measurements even in challenging circumstances.

ASI is real time, actionable intelligence. It is situationally aware and delivered as work is being done. It dynamically reacts to everything involved in the alignment process. ASI also has predictive intelligence, enabling technicians to evaluate different possible courses of action before embarking on the time-consuming task of moving a machine.

With these two breakthroughs, advanced systems can deliver on the promise of adaptive alignment in all three critical areas common to every alignment task – the asset, the situation, and the maintenance team.

Adapting to the Asset

Basic laser alignment systems are not engineered to support a broad range of critical rotating asset types. They are very difficult to use with certain asset types. This becomes a costly and time-consuming problem for plants that rely on those assets or on certain specialized but common asset configurations. Capabilities for adapting to the asset include:

Simultaneous Machine Train Alignment
Adaptive alignment quickly and easily handles machine trains, measuring multiple machine couplings simultaneously via a unique multi-coupling measurement capability.

Machine trains are common with gearboxes, and are among the most challenging of all alignment scenarios. As soon as you get to 3 machines the combinations of angles and offsets become almost exponential, and far beyond the capabilities of dual laser systems without ASI.

With basic systems, a lot of trial-and-error happens with machine trains, and they often resort to mathematical projections in place of actual measurements. Because they use only one set of heads in this scenario, they only physically measure and monitor the live adjustment of one coupling at a time. But the movement of the gearbox affects simultaneously both couplings and all shaft positions. Only if both couplings are monitored in real-time can actual, not theoretical, changes be tracked.

As work progresses sequentially on the train using a basic system, wrong moves can easily be made early in the process but not discovered until later. Assets can become bolt-bound or base-bound, and technicians cannot move them any further in the desired direction. When this happens, they must change the fixing point and start over. With no situational intelligence, rework becomes the order of the day.

Adaptive alignment systems can measure a machine train in one go. Unique ‘under-constrained’ and ‘over-constrained’ asset support enables the system to operate accurately with no fixed feet, one fixed foot, or two or more fixed feet – so technicians can get the optimum alignment incorporating real-world machine constraints.

Used in conjunction with the Virtual Move Simulator (described below), Simultaneous Machine Train Alignment enables technicians to test a range of tolerances and proposed movements on the complete machine train, eliminating the trial-and-error and consequent rework common to basic laser alignment systems.

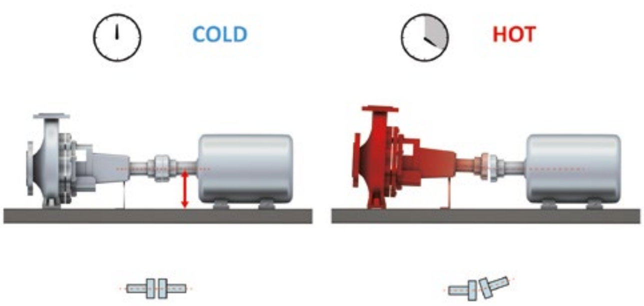
Total Thermal Coverage

In operating condition, most assets change their relative position due to increased temperatures and therefore need special presets during alignment. Since alignment can only be done when the machine is stopped, it's essential to fully anticipate and account for real operating temperatures.

Basic systems only measure the coupling changes. Unfortunately, this is only half of the thermal picture, ignoring machine feet measurement changes. By not calculating and displaying the feet, maintenance technicians using these systems do not have complete information, and thermal impact becomes a matter of guesswork.

Some systems attempt to compensate by enabling entry of one set of presets and attempt to derive the others. But this does not give technicians the full range of adaptability and control they want.

Adaptive alignment systems deliver total thermal coverage that includes dynamic changes at both the coupling and the feet. This enables the maintenance team to enter thermal presets at both the coupling and/or machine feet.

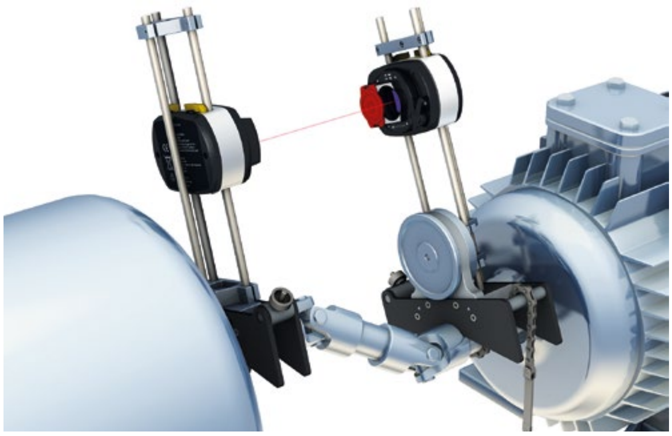


In-Situ Cardan Shaft Alignment

Not every industry has cardan shafts, but those that do face extreme alignment challenges. Standard practice for these assets is to take the cardan shaft out in order to accomplish alignment. This means dismantling and removing the cardan shaft, which may require a hoist or crane just to undertake an alignment measurement check.

Adaptive alignment includes breakthrough technology that enables measurement with the cardan shaft in place – so no removal is needed. This video helps understand how in-situ cardan shaft alignment works.

For critical assets that have rollers, In-Situ Cardan Shaft Alignment is an innovation that saves tremendous amounts of time and money – while delivering a high-precision result.



When laser alignment supports the widest range of assets and configurations, it is a more complete solution that eliminates the manual workarounds and accuracy problems common to basic laser alignment systems.

Situational Adaptability

Although alignment seems to be a simple process – measure ➡ move ➡ remeasure, maintenance technicians know it is deceptively simple. They have to deal with many variables that come into play: asset type, asset location, installation or maintenance project, measurement setup, movement options, etc.

Perhaps the strongest attribute of adaptive alignment is Active Situational Intelligence – its ability to adjust to these many different variables while delivering a smooth, rapid, and accurate alignment experience.

The concept of adaptive alignment applies throughout the process and is driven by ASI. Here are a few of the innovations that come into play:

Uncoupled Shaft Awareness

When installing machines, the alignment should commence with uncoupled shafts, to remove any residual forces in the machine train. But basic systems don't have optimized measurement procedures for uncoupled shafts. Technicians have to manually hold shafts to make sure both are at the same relative angle, then manually take the point, then manually move them. This greatly increases the risk of errors.

With adaptive alignment, uncoupled shafts can be in any position; the laser just needs to hit the detector. During the measurement, shafts can be freely moving while the adaptive system works out the angles and obtains the measurement.

This capability delivers high ROI when teams are installing an asset, because accurate results and required machine movements are obtained in the fastest possible time.

Freeze-Frame Measurement

Laser alignment systems, when confronted with a big initial misalignment, will come to the end of the detector range before completing the shaft rotation. The alignment cone is so big that the laser exceeds the measurement range, and a complete measurement is not possible.

In cases like this, and because they lack adaptability, the standard advice for basic systems is to do a "pre-alignment" or "rough align" so that subsequently the laser and detector can operate within their limited range.

Of course, this pre-alignment is done without any measurement help – technicians don't know how much shimming or horizontal movement to do. They are estimating without knowing what the underlying problem is. Plus, in a practical sense these systems only show visual indications of horizontal position. Although some acknowledgement of the need for vertical positioning is made, no practical process for obtaining vertical position, such as shim correction amounts, are given – so technicians operate in the dark.

Adaptive alignment solves the problem with Freeze-Frame Measurement. It handles any misalignment, no matter how big, over any practical distance.

Technicians are automatically alerted when getting towards the detector edge during a continuous sweep measurement, and can freeze the measurement, reposition the laser, and continue with the continuous sweep. Built-in algorithms connect the sectors when the measurement is finished, "stitching" them together. The result is complete knowledge and documentation of the misalignment: where the problem actually is, and therefore what to do about it, without resorting to guesswork.

Automatic Multi-Factored Quality Enhancement

An advanced innovation built into Active Situational Intelligence is the ability to detect and compensate for many factors that might negatively influence a measurement. ASI applies these quality enhancement factors in real time, during the continuous sweep. Technicians get immediate feedback, and in cases where automated corrections are not enough to produce a highly precise result, the technician is told exactly what to pay attention to when doing a new continuous sweep.

This means that even less experienced technicians can take high-quality measurements by just following the steps and tips displayed on the screen.

ASI evaluates many quality factors simultaneously in real time, such as rotation angle, speed, and evenness, providing instantaneous feedback. Included among those factors are these common issues:

- **Instant Coupling Backlash Filtering**
  Basic laser alignment systems advise and/or warn users to "eliminate coupling backlash to obtain accurate measurement." That's easy for the vendor to say but not so easy for the technician to do.

  In contrast, ASI assumes that coupling backlash is going to happen. Built-in intelligence automatically detects backlash during the continuous sweep and filters it out. By recognizing coupling backlash and eliminating the appropriate measurement data, ASI delivers a clean measurement even when coupling backlash is present.

- **Environmental vibration**
  Another automatic adjustment happening in the background during the measurement is the filtering out of the low-quality measurement points induced by environmental vibration – which commonly happens when a nearby machine is operating and producing such vibrations.

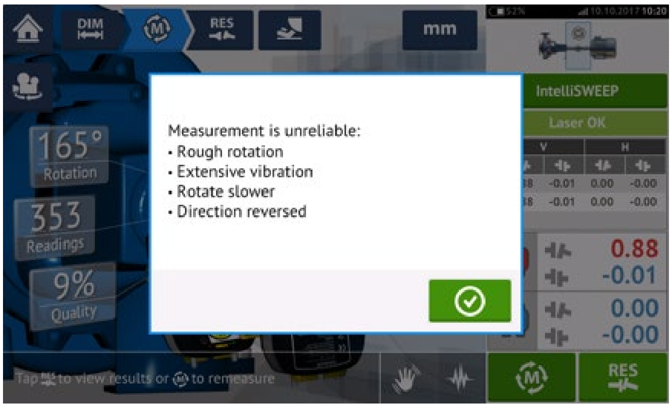


Figure 5: Automatic Multi-Factor Quality Enhancement Provides Immediate Feedback

Adapting to the Team

Adaptive alignment has the intelligence to remove many errors a technician may inadvertently make. It utilizes analytics in real time, removing erroneous data.

With basic laser alignment systems, experienced and inexperienced technicians often obtain different results. Adaptive systems unlock team capacity: even if an inexperienced technician is doing the alignment, the system corrects common errors to enable the technician to obtain the same high-quality results as a more experienced engineer.

Some adaptive alignment facilities designed to enhance team performance include:

Virtual Move Simulator (VMS)
Moving the machine is often the costliest part of alignment, carrying with it the risk of even more cost and time if it turns out to be the wrong move.

VMS has saved technicians thousands of hours across many industries around the world. It enables them to model different options for a move, see the results, and refine choices before actually doing the physical movement.

VMS confirms whether the move will work or not, within machine tolerances. It analyzes the horizontal and vertical directions, providing detailed guidance for foot movement and shim corrections/adjustments.

VSM pays off by identifying problems like not having enough clearance for the move (e.g., you need 5 mm and there are only 2 mm of physical clearance). Technicians avoid commencing time-consuming moves only to find out they won't work. They can change assumptions to find an alignment solution that will work and do it all before committing to the physical move.

Although basic laser alignment systems may offer some simulation, their inability to adapt to long distances, specialized asset types, and gross misalignments means the simulations can only follow the usual guesswork and work-arounds such as pre-alignment moves.

Measurement Sharing & Collaboration
Technicians can invoke a Cloud Transfer facility to send measurements to other team members, whether they are in the same plant or on the other side of the world. With the software application running on a desktop computer, managers and experienced technicians have advanced collaboration facilities at their fingertips. [This video](#) shows an example of measurement sharing & collaboration.

For instance, post-processing of the measurement is possible. The measurement can be replayed on video. Changes can be made on the desktop, and specific guidance can be sent back to the technician at the machine.

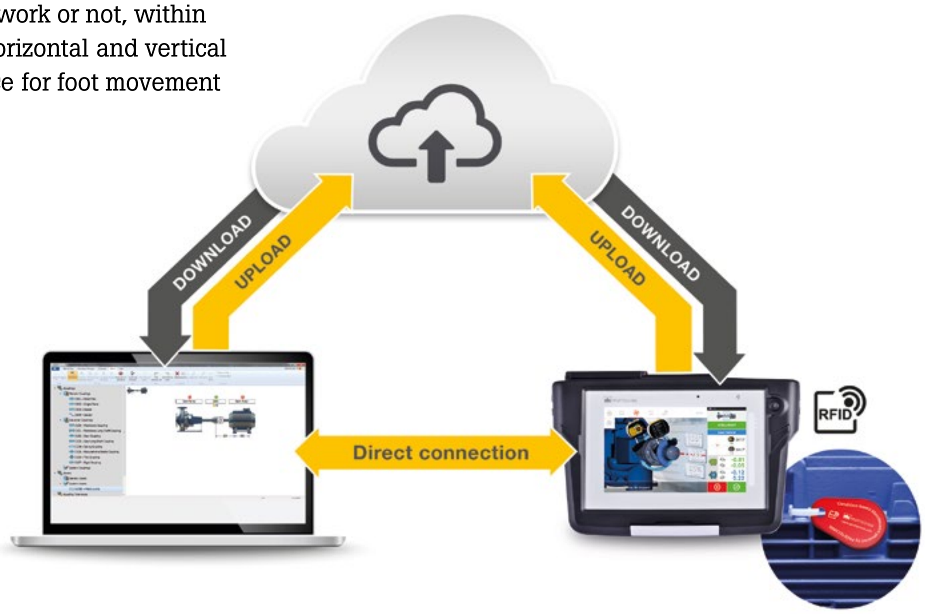


Figure 6: PRUFTECHNIK's Alignment Reliability Center® 4.0 is an example of collaborative communication

This is how team capacity in unlocked: a technician does a measurement but then doesn't know what to do next. Instead of waiting to get back to the office, he can send the measurement to a senior engineer who can then provide directions. This optimizes time for both parties.

RFID Integration
This facility automatically reads the machine RFID tag and saves relevant information. This ensures technicians are measuring the right machine. Software enables technicians to see the whole history of the alignment and to track the alignment condition over time and investigate deeper causes of frequent misalignments.

Alignment Frequency Calculation
A formula calculates how often to check the alignment of a given machine, and aids in work scheduling. It enables users to include asset criticality into the formula, yielding an alignment interval will be shorter, and thus optimizing the life of the machine.

Asset-based alignment with ALIGNMENT RELIABILITY CENTER® 4.0 software
Using adaptive alignment systems and software, maintenance and reliability leaders can leverage alignment data as a dynamic machine condition monitoring parameter.

Adaptive systems with asset-based alignment software can track the alignment condition of an asset over time and deliver relevant data to diagnose recurring machine misalignment.

Using Cloud Transfer facility, engineers can create and send asset-based measurement tasks to technicians in the field. Embedded RFID technology automatically identifies the right asset to measure. After the measurement, the results are transferred back to the software. They can be replayed, analysed, archived, or used to create alignment reports.

Asset-based alignment software is designed specifically to help maintenance and service professionals manage multiple assets across the plant or remote sites.

ALIGNMENT
RELIABILITY CENTER 4.0

Conclusion

Maintenance leaders in plants with rotating assets know that shaft alignment is one of the most important factors in asset life, cost of operation, and ultimate value to the business.

First, highly precise alignment at installation time is a proactive maintenance technique that ensures high performance, high efficiency, and longer machine life right from the beginning of its active use.

During operation, alignment is the first measure to take after a machine was diagnosed with high vibration. In fact, over 50% of machine failure is caused by misalignment.

Over three decades ago, laser alignment systems revolutionized the industry. They have accelerated the measurement process, made it far more effective than traditional methods, and accessible to non-specialists.

But the only thing laser alignment systems have in common is that they all use lasers. There is a great gulf between basic and adaptive systems.

Maintenance leaders also know that every plant is unique, with its own physical layout and critical asset list. Increasingly, they are demanding alignment systems that are more complete and can adapt to their assets, their alignment challenges, and their team.

PRUFTECHNIK pioneered laser shaft alignment over 35 years ago. Now part of Fluke Reliability, PRUFTECHNIK has continued to innovate.

We have introduced the next generation of laser alignment: Adaptive alignment systems. Incorporating patented breakthroughs in both hardware and software, these are the only systems that combine Single-Laser Technology with Active Situational Intelligence.

With PRUFTECHNIK systems, maintenance teams easily handle a wide range of alignment challenges – from simple to complex scenarios, avoiding the rework that comes with more basic systems. Adaptive alignment works faster, eliminates errors, and unlocks team capacity, enabling maintenance and reliability teams to ensure maximum operational life and efficiency for critical assets entrusted to their care.

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