Precise Coupling Alignment

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Turbomachinery reliability is considerably affected by the coupling alignment within the machinery train. Sulzer Hickham, a company of Sulzer Turbomachinery Services, is very experienced in the precise alignment of machinery trains. This leads to enhanced reliability and increased plant availability.

Much has been written and discussed over the years concerning how coupling alignment affects machinery reliability, yet most turbomachinery trains are still operating well beyond acceptable tolerances even today. The results include shortened coupling and bearing life, unplanned machinery shutdowns, and even complete destruction of machines, plant fires, or personnel injury or death.

A Simple Problem?

Initial alignment recommendations found in most machine manuals are often incorrect, sometimes drastically. Coupling alignment is not well understood throughout the industry, and most plants do not have the in-house expertise to properly diagnose excessive misalignment.

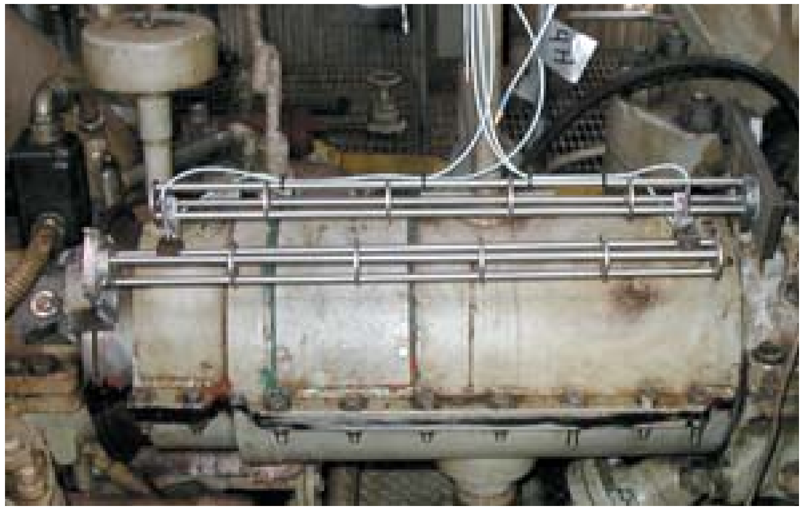
Sulzer Hickham has the experience and expertise to perform independent alignment calculations on entire machinery trains and to precisely measure the difference in ambient and service condition alignment. These tried and proven methods assure collinear alignment of machinery shafts, leading to optimized reliability and increased plant availability.

In the early 1970s, a number of mechanical people were striving to find a better way of assuring that their machines operated with good coupling alignment. Several innovations came out of this, including an accurate means of measuring relative machinery centerlines using proximity probes. The author was intimately involved with the manufacturing and use of alignment bars utilizing proximity probes, a system that has now been in use at Sulzer Hickham for the last twelve years.

Alignment Calculations

Most initial estimates are significantly in error. To be proficient at calculating how machines will move between ambient and service conditions requires much field experience in the actual alignment tracking of machines, a function at which even experienced field engineers have very little, if any, experience at doing.

Several factors must be considered when estimating how machines are likely to move, including average ambient temperature, inlet and outlet temperatures of the machines, piping arrangement, distances between measurement planes and the machines' feet, etc. The simple coefficients of thermal expansion won't give satisfactory results, because the steel between the centerline of a machine and its feet will not have an even temperature equal to the service temperatures. After years of tracking turbomachinery alignment on many trains, one can develop a feel for how these machines generally move between cold and hot, and can also develop certain "fudge factors" that are helpful in estimating what the initial ambient offsets should be. There is no doubt that this ability is more of an art than it is science.



1 Alignment bars allow for an exact measurement of the centerlines of a machinery train. When the tolerances are met, coupling and bearing life are extended.

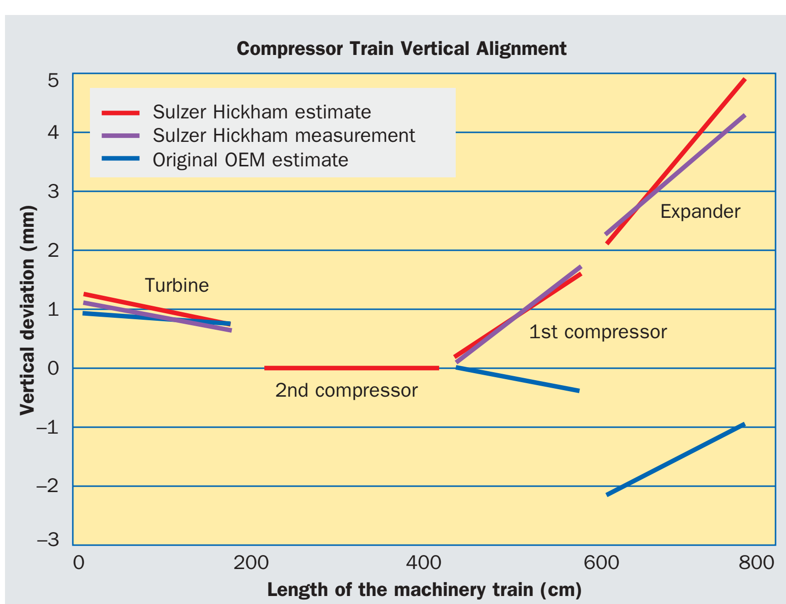
Alignment Tolerances and Tracking

After the initial alignment estimates are completed, the machines are aligned to tolerances. The factors that actually determine alignment tolerances for flexible couplings are coupling span and speed. For most turbomachines, a practical alignment offset tolerance is derived as follows:

$$\textit{tolerance} = \frac{\textit{coupling span}}{\textit{speed (rpm)}} \times 5.66$$

An example: If the distance between the measurement planes on the two coupling hubs is 16" (400 mm) and the machine speed is 10 000 rpm, the tolerance is 0.009" (0.23 mm). This is the amount that the machine's centerline can be allowed to differ from the actual desired position, either vertically or horizontally.

After the alignment is completed and the coupling guards are installed, alignment bars (Fig. 1) are mounted on the machine bearing housings using Invar 36, which is a high-nickel alloy with a very low coefficient of thermal expansion.



2 Alignment estimate and measurement on a compressor train. The original OEM estimate differs significantly from Sulzer Hickham's estimate, which is very close to the measured values.

For example, a 6" (150 mm) long bracket at 150 °F (83 °C) over ambient will only grow 0.0015" (37.5 µm). If the bars are mounted in an especially hot area, such as a hot-gas expander coupling, they are air-cooled through flexible tubing to minimize distortion. The bars utilize four proximity probes that have been calibrated to the 4140 steel targets*, one probe for each plane (vertical and horizontal at each coupling). The bar with the probes installed mounts on the "stationary machine" (the machine that is not to be moved), and the bar with the 4140 targets is mounted on the "moveable machine". Then, the probes are set to voltages that represent the existing alignment. From that point on, the exact alignment at the two coupling hubs is known under any condition.

Typical Alignment Example

Sulzer Hickham has done the alignment calculations and tracking on many different turbomachinery trains in various operating plants and on various types of machines, including steam turbines, centrifugal, axial and screw compressors, hot-gas expanders, gearboxes, etc. One example is given in Figure 2, on a train consisting of a steam turbine, two centrifugal compressors, and a hot-gas expander (Fig. 3). In this example, the second compressor was the "stationary machine", and the remaining machines were aligned to it. The red lines are the Sulzer Hickham original alignment estimate, whereas the violet lines are the actual desired centerlines measured with the alignment bars. The original OEM estimates are shown in the blue lines. As can be seen, the Sulzer Hickham estimate and the actual desired centerlines are well within tolerances, and both of these are significantly different from the original OEM estimate.

Sulzer Hickham is very experienced in coupling alignment calculations, alignment of the machines, and in the actual tracking of the centerlines to verify that all couplings are operating within acceptable tolerances. In one case, this was performed for all the trains in a new ammonia plant installation with a total of eleven machines, and all tracked to be operating within acceptable tolerances. In that case, all machines had also been retrofitted with diaphragm couplings, which necessitated pre-stretch calculations and field measurements for verification, and the calculated pre-stretch values also proved to be correct as calculated. ◀

* Common and alloy steels have been numbered by the American Iron and Steel Institute (AISI). AISI 4140 is the standard material that probes are calibrated to.

3 Machinery train whose vertical alignment is shown in Figure 2.

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