

Comprehensive Kiln Alignment

Lou Lovas, North American Kiln, USA, describes how kiln stability can be maximised by aligning all interacting mechanical components.

Introduction

Most kiln alignment procedures fall far short of achieving optimum kiln stability because the applied scope of work is typically inadequate for the task. The purpose of this article is to detail a comprehensive kiln alignment work scope that achieves maximum mechanical stability.

Seven alignment-related procedures are generally always either omitted or are improperly implemented by alignment providers.

Support roller thrust load measurements

The alignment of support rollers relative to the kiln axis is a very important alignment requirement that is rarely addressed in relevant procedures. If a roller is not parallel to the kiln axis, the direction of rotation of the roller is slightly different from the direction of rotation of the kiln. The undesirable consequences are as follows.

In addition to the rotation of the roller along a line perpendicular to the kiln axis, there is an axial roller motion component, resulting in a) high bearing end cap pressures, or b) high roller shaft thrust collar pressures, depending on the bearing design. High thrust mechanism pressure in bearings generates heat and thus increases the bearing temperature. Most hot bearings are hot because of this pressure condition.

High support roller thrust load moves the kiln uphill or downhill, depending on the direction of the thrust load. The cumulative effect of thrust loads on several support rollers can overload a thrust roller. All thrust roller failures are caused by improper alignment between support rollers and the kiln axis.

Roller misalignment causes accelerated and uneven wear of tyres and rollers. Taper conditions arise that require grinding the tyre and roller surfaces.

The alignment of all rollers must be evaluated by measuring the support roller thrust loads. This requires the measurement of a) the bearing end cap pressures (AC and Fuller kilns), b) the measurement of the roller shaft thrust collar pressures (FLSmidth and KVS kilns), and c) the measurement of axial bearing pressures (Ahlstrom kilns). If a thrust mechanism pressure exceeds limits set by the OEM, the appropriate bearing

adjustments have to be made to lower the pressure. Very few kiln service providers have the technology to measure these pressures, and even fewer provide the alignment adjustments necessary to correct them. This important procedure is rarely included in alignments.

A very important note regarding support roller thrust loads: stable thrust roller load is not an indication that support roller bearing adjustments are not required. It is typically the case that some rollers that are misaligned push the kiln uphill, and some downhill. The net effect may be perfectly acceptable thrust roller load, with very inadequate overall kiln stability. Figure 1 shows a pier where one roller is pushing hard uphill and the other pushing downhill. The net effect on thrust roller load is zero, but both rollers are unstable. It is therefore important to measure and adjust the thrust load on every support roller as part of a kiln alignment.

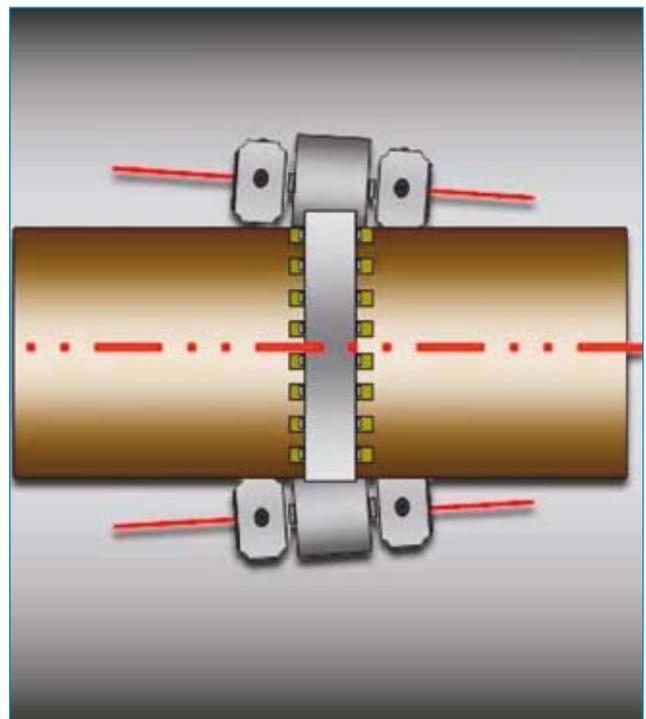


Figure 1. Rollers misaligned relative to the kiln axis are mechanically unstable. Stability requires that rollers be parallel to the kiln axis to within 0.008 in./ft. or less.

Roller bearing adjustments

The support roller bearing adjustments required to correct the misalignment of all interacting kiln components are the most difficult and most important part of an alignment. Most plants make the serious mistake of awarding alignment contracts without demanding bearing adjustments as part of the scope of work. A kiln alignment without roller adjustments is no different than a front-end alignment on a car without wheel adjustments. It makes no sense.

It is rare that a kiln alignment does not require several bearing adjustments in the $\frac{1}{4}$ - $\frac{1}{2}$ in. range. Some adjustment requirements are in excess of 1 in. Large adjustments on a roller often require the simultaneous use of two high-capacity hydraulic torque wrenches. Plants do not have such resources. Furthermore, large adjustments are too infrequent to be a routine maintenance responsibility. Plant maintenance personnel therefore cannot be expected to reliably make numerous, sometimes large adjustments without the high risk of causing a major breakdown. The stability of a kiln is obviously at risk during the adjustment procedure. Bearings may burn up, thrust rollers may fail, and the kiln drive stability may be seriously jeopardised by inadvertent changes to the pinion to gear root clearance. For these reasons, the adjustments need to be made by highly-trained technicians that align kilns and adjust bearings for a living. Common sense dictates the need for this service. Despite the obvious need, very few kiln service companies provide adjustments.

Shell ovality assessment

All kiln maintenance service providers measure shell ovality in the process of evaluating the alignment of kilns. However, the information is rarely put to proper use. The rationale for aligning a kiln axis, properly understood, is to optimise ovality distribution over the length of the kiln. If, for example, the ovality at a pier near the burning zone is high because of buildup, the tyre should be lowered up to $\frac{3}{8}$ in. below the shell axis to lower the ovality. The resulting pier load distribution change will transfer load (and ovality) from the high ovality pier to the adjacent piers.

In defense of this alignment strategy, one should consider: if a tyre is $\frac{3}{8}$ in. misaligned relative to the kiln axis and the adjacent tires are 80 ft. away, the resulting shell flexing per unit area is small compared to the very high localised shell flexing associated with ovality. Shell flexing is, in other words, spread out over a large area where it is negligible on a per unit area basis. The maximum ovality can be increased because the maximum stress is decreased. A lowered maximum ovality means that the kiln will run longer before brick loss occurs.

The counterintuitive conclusion of this line of reasoning is that a properly-aligned kiln does not necessarily have a straight axis. The kiln axis often has to be misaligned to guarantee optimum mechanical stability, with emphasis on better ovality distribution.

There is of course a limit to the pursuit of optimum ovalities via pier load distribution changes. Limits on hertz pressures and bearings pressures have to be considered; but kiln axis misalignments less than $\frac{1}{2}$ in. will not cause hertz and bearing pressure problems on properly

designed kilns. To prove this point, one should consider what happens when a tyre lifts off support rollers because of a dogleg. The load variation on an affected pier is very high. The maximum bearing pressure and hertz pressure significantly exceed pressures caused by a $\frac{1}{2}$ in. axis misalignment. Yet, such dogleg-induced bearing and hertz pressures rarely, if ever, cause a breakdown.

It should be noted that high ovality is often caused by excessive tyre clearance. A tyre with high clearance is not tight enough to provide the structural support necessary to maintain a circular shell cross section. This condition results in high ovality. Pier load distribution changes will not correct ovality problems caused by this mechanism.

Ovality is measured at three places 120° apart on the circumference at each pier. The average of the three measurements is often presented as the ovality at a particular pier. The representation of ovality data in this manner can be misleading in the following sense. A pier with high load variation may have ovality measurements ranging from near zero to very high, with an average that is perfectly acceptable. A brick residing at the point of maximum ovality however is not affected by the average ovality; it is affected by the maximum ovality, and it will fall out. For this reason, the effective ovality for stability purposes is not the average ovality, but the maximum ovality measured at each pier.

Assessment of shell dogleg conditions

If a kiln shell axis is warped, there are load variations on effected piers in the course of kiln rotation. High pier load variations place massive stresses in the roller bases and anchor bolts, often breaking a base loose from the pier cap. Another frequent adverse consequence is unacceptably high ovality at the point of maximum pier load.

If the load variation on a pier is of sufficient magnitude, the tyre centre and the pier will move to the right and to the left of the kiln axis with every kiln rotation. This lateral movement exceeds $\frac{1}{2}$ in. at times. The lateral motion of each tyre has to be measured as part of a kiln alignment to assess the severity of dogleg conditions.

In case of a seriously warped shell axis, three adjacent piers will exhibit lateral tyre motion. The motion of the centre tyre will be 180° out of phase with the motion of the other two tyres. One of the three ovality measurements at each pier has to be at the maximum pier load location. That location has to be found via the tyre motion measurements.

→ "Shell Radial Runout Analysis", often marketed in conjunction with kiln alignments to identify and locate doglegs, is not a useful procedure for its intended purpose. The procedure consists of measuring the shell radial runout every 10 ft. along the kiln axis and without exception, divining unsupportable conclusions from the measurements. The problem with the misunderstood and misrepresented procedure is that dogleg-induced pier load variations cause major cyclical changes in the shell stress distribution as the kiln rotates; these changes, in turn, dampen the shell radial runouts that are being measured. The dampening effect is nearly absolute at a tyre section, where the shell runout is almost always zero, even on kilns with significant doglegs. Unless shell stress distribution variations are

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calculated and the radial runout measurements are accordingly adjusted, the runout readings are useless for diagnostic purposes. The complex calculations necessary to quantify constantly changing shell stress distributions and to correlate these calculations with the radial runout readings would be a challenge for NASA, and is guaranteed to be beyond the capability of any kiln OEM or kiln service company. The bottom line and the gauntlet: reading tealeaves is inexpensive, requires little training, and has the same predictive value in assessing dogleg conditions as shell profile analysis. Measuring tyre lateral movement in the course of kiln rotation, on the other hand, is very predictive insofar as dogleg effects are concerned. Such measurements are therefore required as part of a comprehensive kiln alignment.

A short, but very important digression from our main theme: it is worth noting that the vast majority of dogleg conditions are not caused by defective kiln shell; they are almost always caused by the misalignment of perfectly good shell relative to the rotating axis of the kiln. Shell section replacement therefore is never necessary to correct doglegs. What functional differences can there possibly be between an undamaged shell section that is removed for the purpose of correcting doglegs and the new section that is installed? It should be obvious that there are no functional differences. The old shell could be put back and have the same corrective effect on doglegs as is the case with the installation of the new shell.

The proper way to remedy mechanical instabilities caused by doglegs is a) cutting the kiln shell at two to three locations and b) making adjustments on the cuts as necessary to eliminate pier load variations in the course of kiln rotation. This procedure is more reliable in eliminating dogleg symptoms than is shell section replacement because the joint adjustments are based on actual measurements of pier load variations. In addition, cost savings are substantial: a) new shell need not be purchased; b) refractory removal is minimal; c) crane costs are eliminated; d) downtime is cut in half.

Kiln axis alignment assessment

All kiln service providers are capable of establishing the coordinates of the shell axis at each pier. This information is then used to calculate the kiln axis misalignment. There are two competing models to accomplish this task. One procedure determines the location of the "shell centre of rotation" at each pier and the other procedure determines the tyre centre locations. Much is made by competing companies of the alleged advantage of one approach over the other, but the technical reality is that there is no measurable difference between the two methodologies. The standard deviation of alignment measurements is high enough so that the probable measurement errors are far greater than any possible difference between the shell rotating centre coordinates and the corresponding tyre centre coordinates. How can the shell centre line not be very close to the tyre centre line on a pier? Excluding the very small and easily quantified tyre clearance effect, how can a tyre rotate on a centre that is measurably different from the shell centre of rotation directly at the tyre? One must resort to quantum tunneling considerations to rationalise such hypotheticals.

A common error in kiln axis misalignment corrections

is to compensate for tyre clearance differences on piers. The conventional wisdom correctly dictates that if a tyre clearance on Pier A is $\frac{1}{2}$ in. greater than the tyre clearance on Pier B, then other things being equal, the shell centre at A is $\frac{1}{4}$ in. below the shell centre at B. It is however a mistake to make alignment corrections based on this difference in elevations. Ovality is, in part, a function of tyre clearance, so other things being equal, the ovality is greater at A than at B. Correcting the misalignment requires that tyre A be raised. This will increase the ovality at A, which is already high because of the high tyre clearance. The proper course of action is to ignore tyre clearance differences when aligning a kiln axis. Kiln stability is thereby enhanced because ovality is minimised.

Alignment of tyres

As depicted in Figure 2, if the plane of a tyre is not perpendicular to the kiln axis, the direction of rotation of the tyre is not the same as the direction of rotation of the shell. Given that condition, the tyre creep has a horizontal motion component, which is the cause of high tyre retainer pressure. This pressure is always caused by the misalignment of the tyre plane relative to the kiln axis. Contrary to conventional wisdom, it is never caused by improperly adjusted support roller bearings; consequently, high tyre retainer pressure cannot be corrected with bearing adjustments. Correcting the problem requires changing the support roller slopes and thereby tilting the tyre plane relative to the kiln axis. The magnitude of the necessary roller slope changes should be ascertained as part of a kiln alignment. Corrective measures can then be implemented during a shutdown.

An interesting digression: it is possible to have two rollers push a tyre uphill, and have the tyre exert high pressure on the downhill tyre retainers, and vice versa. This occurs if the horizontal motion component of the tyre creep is in the direction opposed to the support roller thrust load direction.

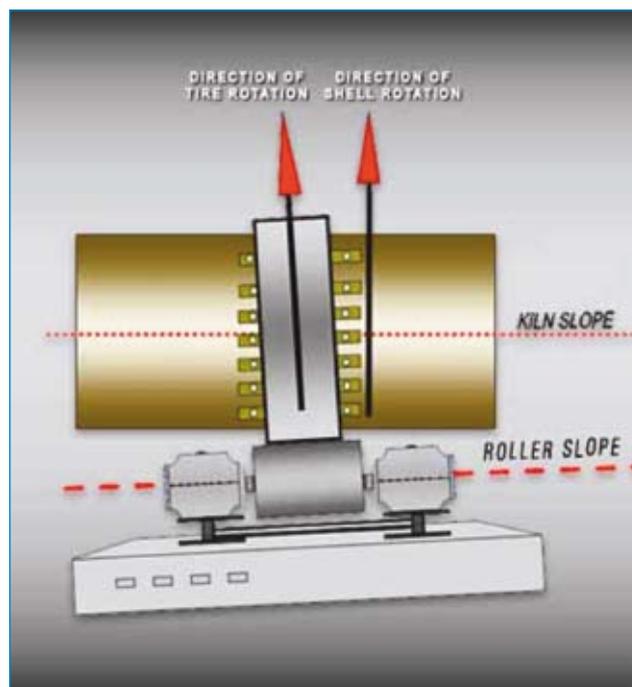


Figure 2. Tyres must be aligned perpendicular to the shell axis to assure low tyre retainer pressures. This can only be done by adjusting the roller slopes.

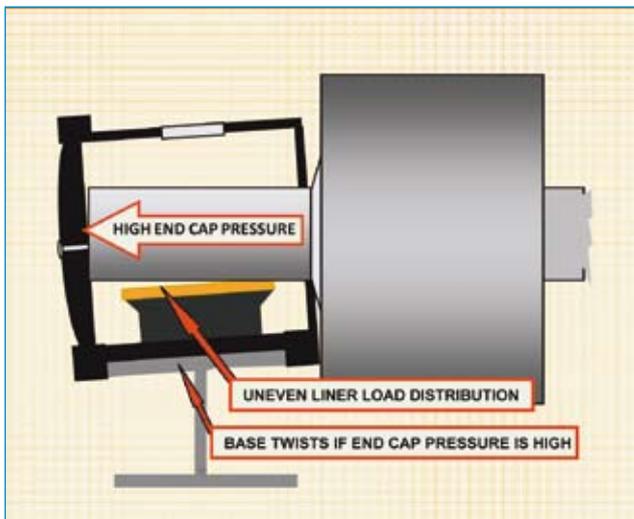


Figure 3. Misalignment of bearing relative to roller shaft. The root cause is high end cap pressure caused by roller axis misalignment relative to the kiln axis.

Alignment of bearing housings

An important alignment consideration is the alignment of support roller bearings relative to the roller shafts they support. As illustrated in Figure 3, a base plate often twists as a result of high bearing end cap pressure. If such base distortion occurs, the bearing liner will be misaligned relative to the roller axis. The condition causes uneven liner load distribution. The liner area sustaining the maximum load can generate too much heat for the cooling system to dissipate. Unstable bearing temperatures often result. The problem can be detected by measuring the slope of the bearing housing and comparing this slope to the roller axis slope. If the two slopes differ by more than 0.003 in./ft., the housing has to be tilted using shims. The need for such alignment correction should be identified as part of a kiln alignment.

Note: this procedure does not apply to kilns where the brass liners are supported on self centering spherical sockets. The ball and socket support system in such bearings automatically adjusts the brass liner slope if load distribution irregularities occur.

Alignment of two pier kilns

If one makes the mistake of accepting that a kiln alignment is limited in scope to the alignment of the kiln axis, there is no compelling argument in favour of aligning two pier kilns. It is not possible, after all, to have two tyre centres that are not on a straight line. If, however, one accepts the premise of this article, that a comprehensive alignment has to address the alignment of all interacting moving components, the need for periodic alignment of two pier kilns is obvious. Thrust loads on support rollers will change over time, as will thrust roller pressures. End cap pressures and thrust collar pressures are subject to change and need to be measured and corrected periodically via bearing adjustments. Vertical shell deflection changes attributable to buildup will change the shell axis slopes at a tyre - these changes will affect tyre retainer pressures

and may require bearing elevation adjustments. Roller bases may distort in response to high-end cap pressures, so bearing housing slopes need to be compared to the roller slopes periodically. The prudent conclusions are that a) the alignment of two pier kilns needs to be checked annually and b) the scope of work must be far more comprehensive than is the case with most kiln alignments.

Conclusion

To get the maximum return for an alignment investment, plants must demand a comprehensive alignment work scope as follows:

- Locate the coordinates of the centre of the shell on all piers. Laser-based technology is preferred to assure maximum accuracy.
- Determine the kiln axis misalignment by calculating the distance and angle between the shell centre at each pier and the desired kiln axis. All calculations should be computer generated to minimise errors.
- Measure the shell ovality on all piers.
- Adjust all support rollers to straighten the kiln axis. The priority is to fine-tune pier load distribution in a manner that optimises shell ovality (without exceeding limits on bearing pressures and hertz pressures).
- Measure all roller shaft thrust collar pressures and bearing end cap pressures, depending on the bearing design. Adjust bearings as necessary to lower high thrust mechanism pressures. Properly done, these adjustments will assure that all support rollers are parallel to the kiln axis to within 0.008 in./ft. or less.
- Measure the lateral tyre movement on all piers to detect and quantify the effects of dogleg conditions that are of sufficient magnitude to jeopardise kiln stability.
- Determine what support roller slope changes are necessary to align the plane of each tyre perpendicular to the kiln axis. This procedure is necessary to eliminate high tyre retainer pressures.
- Assess the need to correct improper bearing liner load distributions by comparing bearing housing slopes to roller axis slopes.
- Inspect all kiln components. Make prioritised written recommendations to improve kiln mechanical performance.

Unless the above procedures are specified in quotation requests and purchase orders, they will not be provided and kiln stability will be less than ideal. There are companies that are capable of providing a comprehensive alignment work scope; they should be given preference over companies whose alignment expertise is not sufficiently advanced.

If readers would like elaboration or justification for any of the above technical claims, they can contact the author via the editor (pmc@worldcement.com). Challenges to the above opinions are welcome.