The key to hot kiln alignment

To achieve a long, trouble-free lifetime of the rotary kiln in a cement plant with reasonable running costs, kiln operators and the maintenance team need to take key mechanical factors into account. TomTom-Tools provides eight key kiln alignment guidelines.

■ *by **TomTom-Tools**, Switzerland*

Hot kiln alignment is a term widely used, and misused, in the cement industry. Therefore, an in-depth look at kiln mechanics and important kiln factors should dispel some of the myths. Several mechanical factors are worth considering to achieve a stable kiln operation without major issues, and to ensure a long lifetime of the pyroprocessing line.

Maximum shell temperature

To avoid fatigue cracks and plastic deformation of the kiln, it is recommended that kiln operators respect the maximum shell temperature of 450˚C and do not rely on the coating layer to protect the kiln shell as refractory bricks may be worn, damaged or have loosened. The coating can collapse at any time, tearing down the damaged refractory rings and exposing the kiln shell to the heat in the kiln. Turning off the burner immediately is often too late to avoid a red hot spot and plastic deformation.

Kiln shell deformation often results in:

• shortened refractory brick life and installation difficulties as a result of a warped kiln shell diameter
• high run-out of kiln tyres and girth gear as the straightness of the shell is affected
• risk for a permanent crank, which causes cyclic overloading of the support rollers and tyres, and leads to cracks in the roller shafts and tyres.

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Figure 1: thrust load meter BT at the support roller bearing of a rotary kiln

Correct kiln axis alignment

It is important that the kiln axis remains well aligned, with tolerances limited to a few millimetres. The centre of the kiln shell, at the tyre positions, needs to be in a straight line.

Deviations of the kiln axis lead to increased stresses in the kiln shell, which are cyclic and change direction at every turn of the kiln. This is why misalignment leads to fatigue cracks mainly in the circumferential welds of the shell near the middle tyre.

In addition, axis deviations also result in changes to the load distribution on the tyres, support rollers and bearings. Overloading the support rollers will damage the bearings and roller shafts.

The kiln axis can be easily and precisely measured with a kiln axis alignment system, based on a robotic theodolite in combination with some accessories and user-friendly software that calculates any deviation of the kiln axis.

Support rollers to neutral

It is also recommended that kiln operators adjust the support rollers close to the neutral position so they apply zero or only a light axial force to the kiln in an upward direction. Rollers should be prevented from pushing the kiln downwards as this increases the load on the thrust roller. Theoretically, a support roller is in neutral position, when the roller axis is exactly parallel to the kiln axis, but this is only true when the roller and tyre surfaces are perfectly cylindrical. As soon as the roller and tyre surfaces show uneven and conical wear, the axial force on the roller will not be zero anymore, despite the axis remaining parallel. To adjust the axial forces, the rollers are moved slightly away from their parallel position – an adjustment called 'skewing'.

To compare the axial forces on the different support rollers, the thrust load meter was developed (see Figure 1). It quickly identifies axially overloaded support rollers, so the necessary

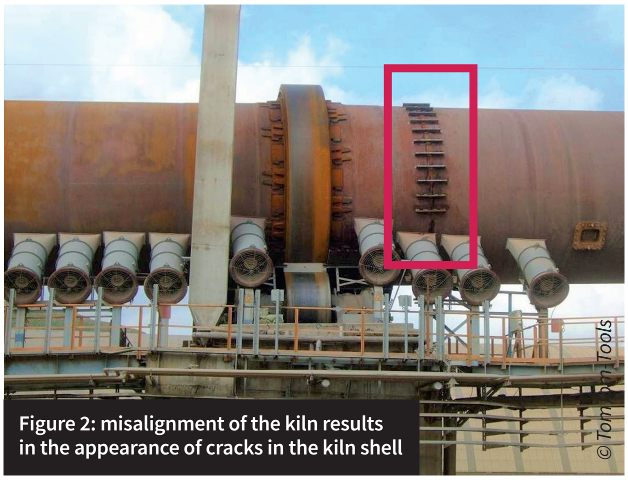


Figure 2: misalignment of the kiln results in the appearance of cracks in the kiln shell

adjustments can be carried out before the bearing fails due to a high load.

Kiln shell corrosion

Alternative fuel usage increases the sulphur and chlorine content in the kiln system. The highly corrosive sulphur and chlorine infiltrate the refractory down to the kiln shell. Under certain conditions, the shell corrodes quite quickly and loses its original thickness, leading to high bending stresses and ultimately to dangerous cracks.

To avoid shell failure, the first priority is to protect the kiln shell from corrosion by using refractory bricks that are more resistive to infiltration or by installing a thin layer of sacrificial stainless steel sheets between the bricks and the shell.

However, it is also important to know the thickness limits throughout the kiln shell as this will indicate when and where the corrosion becomes dangerous and the affected shell section needs to be replaced. To help gauge this, kiln producers can provide a graph that shows the nominal stress along the kiln shell. When corrosion takes place in an area that is subject to low stresses, thickness reduction up to 30 per cent may not be dangerous. However, in an area that undergoes high stresses, a loss in thickness of only 20 per cent can become dangerous and result in cracks.

To help kiln operators calculate and visualise the stress in the kiln shell, they can use the newly developed kiln calculator, an online finite element analysis (FEA) for rotary kilns. It is an easy-to-use tool that does not require special knowledge in mechanical engineering. After entering the kiln geometry and loads, it calculates and visualises the stresses in the kiln shell and tyres, and provides the load on the support rollers. The strong impact of a misaligned kiln axis can be simulated as well, which proves the need for alignment in an impressive way.

Figure 2 shows a kiln where the shell cracked due to misalignment. As the maintenance team did not know about the importance and tight tolerance of the kiln axis, they tried to reinforce the kiln shell by welding stiffener plates – without success.

The calculation with the kiln calculator confirmed that even the small deviation caused a significant increase in the bending stresses in the kiln shell (see Figure 3).

By aligning the kiln axis to less than 5mm deviation in vertical direction and less than 3mm in the lateral direction and by a proper repair welding, the problem was solved, and the reinforcement ribs could be removed. The correct alignment of the kiln led to very low stress levels and the risk of cracking disappeared (see Figure 4).

Tyre clearance

It is recommended that tyre clearances are kept in an optimal range. Some clearance between the tyres and the kiln shell is essential to allow thermal expansion of the shell, but too much has a negative impact on the roundness of the shell. This effect is called ovality and high ovality values

Figure 3: the kiln calculator shows that the small deviations of 5mm vertical and 3mm lateral at tyre 2 already cause a significant increase of the stress in the kiln shell

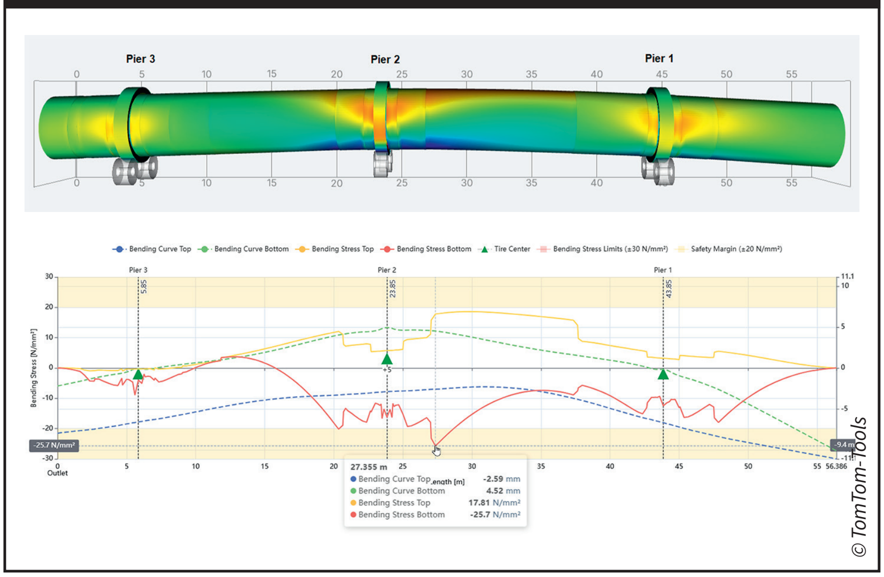


Figure 4: the kiln calculator shows low stresses, when the kiln axis is precisely aligned

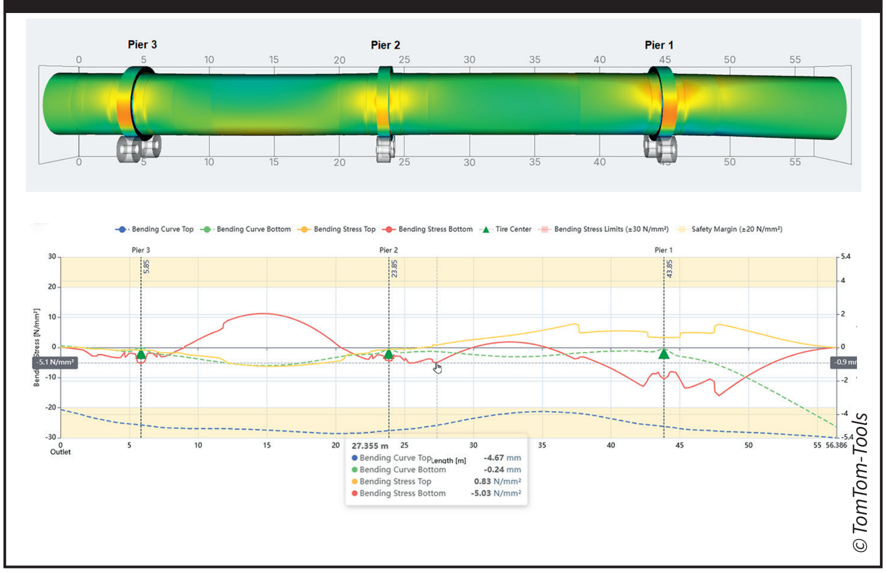
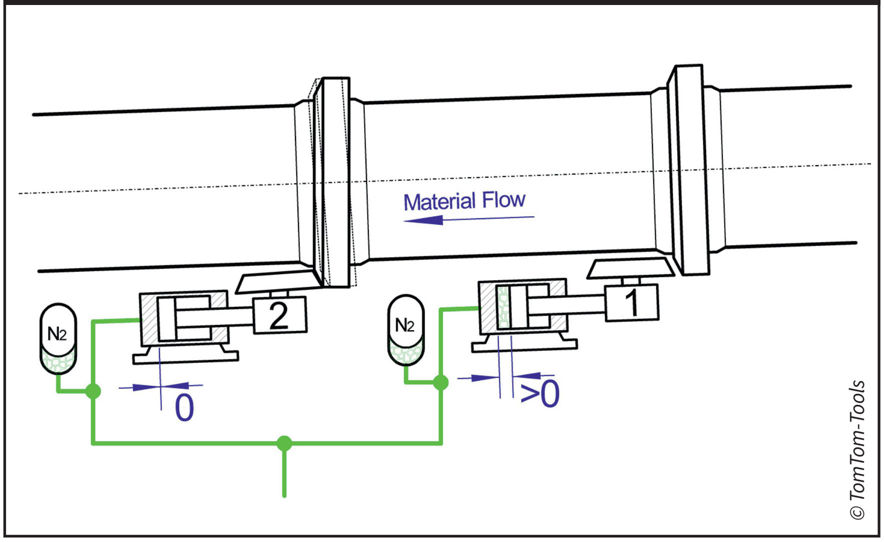


Figure 5: Thrust Roller No 2 is at its end position. It can not absorb any wobble of the tyre and gets overloaded because the Thrust Roller No 1 lost the contact to its tyre



reduce the lifetime of the refractory bricks.

Tyre clearance is monitored and maintained by measuring the tyre creep, the relative movement between the tyre and the shell. The creep can be measured manually, but the better way is to use a creep monitor, which continuously measures the creep and provides the values to the plant's control system. Values can be monitored over a long period of time and alarm levels can be set. A modern creep monitoring system must be able to provide reliable values as soon as the kiln heats up and not yet continuously rotating, because the heating phase is the most critical period for losing the tyre clearance.

Bearing maintenance

It is important to ensure that the bearings of the support rollers are kept clean and in good shape.

The bearing sleeve requires a clearance of 0.3-0.4 per cent of the shaft diameter. However, there are still many bearing drawings that indicate less clearance and therefore, require manual scraping on site. Manual scraping is no longer recommended as a much higher precision can be reached by machining than by manual work. Roller shafts should also be polished and free of any grooves.

Other measures that support effective bearing maintenance include:

- the installation of reliable and fast-reacting shaft temperature sensors, which send an early alert in case of problems with bearings.
- the use of high-viscosity oil to build a strong oil film (eg ISO 680mm^2/s in areas where the ambient temperature can go below 0˚C and ISO 1000mm^2/s in hot countries).

Uniform gear meshing

It is essential to maintain proper gear meshing on the open gear drive. Uniform

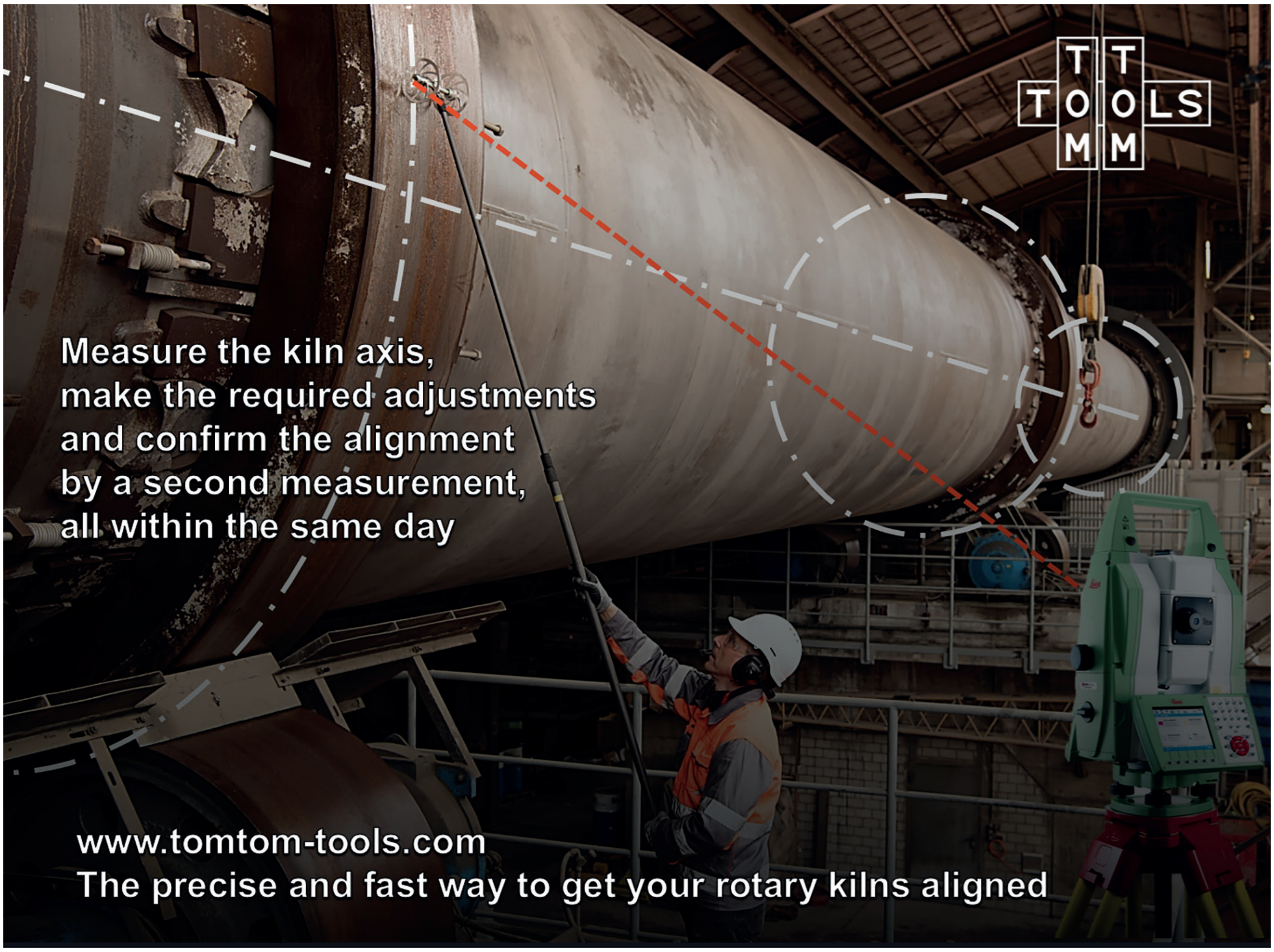


Table 1: the symptoms matrix helps finding the root cause of a problem in a rotary kiln

Probability	Symptoms/damages								
	Kiln shell *		Support roller			Tyre *		Wear	
	Longitudinal	Circumferencial	Shaft	Body	Surface	Body	Surface	Between tyre and kiln shell	On rolller/ tyre surface
A	Ovality	Kiln axis	Crank	Crank	Tyre wobbling	Crank	Tyre wobbling	Lubrication	Dust
B				Design	Cylindricity	Tyre wobbling	Cylindricity	Relative movement	Lack of lubrication
C		Corrosion	Kiln axis		Inclination		Inclination		Skewing
D		Crank		Kiln axis	Oil on surface	Kiln axis	Kiln axis		Inclination
E					Kiln axis	Heavy coating			
F									

Probability	Refractory failure		Hot bearing – support roller		Drive problems – girth gear		Thrust roller	
	Between tyres	Near a tyre	Radial Axial	Axial	High vibration	Pitting/wear	High Wear	Failure of shaft or bearings
A	Shell deformation	Ovality	Geometry	Skewing	Tooth profile	Contamination	Incorrect angle	Reach stopper
B	Installation	Installation			Gear split	Lubrication	High offset	Accumulated damage
C	Thermal shock	Shell deformation	Contamination	Contamination	No backlash	Alignment	Tyre wobbling	Wear step
D	Unstable coating	Thermal shock	Kiln axis	Wear on roller	Alignment		High load	Tyre wobbling
E	Chemical attack	Unstable coating	Lubrication	Lubrication	Crank	Crank		High offset
F		Chemical attack	Crank	Wobbling				High load

** significantly increased in combination with high temperature*

gear meshing, reliable lubrication and cleanliness are key for the smooth operation of the pinion and girth gear drive. Wear on the tooth flanks, usually caused by dust contamination, generates vibration, which leads to cracks in the fixation of the girth gear and, in the worst cases, to teeth breakage. In case of spray lubrication, it might be preferable in terms of cleaning to apply higher quantities of proven grease with solid additives than to change to modern grease types that claim to reduce the consumption of lubricants.

Overheating the kiln shell is a typical root cause for high run-out of the girth gear, which affects the gear meshing. The run-out of the ring gear can be measured with inductive distance sensors while the kiln is in operation, or by feeler gauges and dial indicators when the kiln is stopped. It is essential to maintain a minimum clearance between the girth gear and the pinion to avoid a hard contact causing excessive pressure on the tooth flanks.

Thrust roller position

In addition to a proper alignment and contact to the tyre, it is recommended that operators ensure that the hydraulic thrust rollers never reach their end positions and the guide rods are well lubricated. When the roller is frequently pushed against its mechanical stoppers, at its end of range, or if the guiding rods are jammed, there is a high risk of breaking the roller, its shaft and bearings.

Kiln tyres never run perfectly straight and therefore, the axial movement of the tyre needs to be absorbed by the hydraulic cylinder of the thrust roller. That is only possible when the thrust roller can freely move in the axial direction and is not blocked. The stoppers should only act as a limitation in emergencies, to prevent the kiln moving too far downwards, for example, when the hydraulic system is leaking. During normal operation, the axial kiln movement should be floating ~25-50mm between the limit switches that control the hydraulic pump. When the kiln is equipped with two thrust rollers, this becomes even more important, because the two rollers are supposed to share the axial load. However, the load distribution will only work as long as both rollers move freely. As soon as one of the rollers is jammed or runs against a stopper, one of the rollers will lose the contact to the tyre and the full axial load of the kiln is shifted to the roller that remained in contact with the tyre. When this situation happens often and goes undetected, a failure of a thrust roller is just a question of time.

Conclusion

Kiln alignment is part of an overall kiln maintenance strategy. Monitoring a range of kiln mechanical factors is key to ensuring a stable kiln operation, free of any major problems. ■