Meaningful sensor signals to support AI

To prevent the major breakdown of the rotary kiln and high production losses, the addition of a few specialised sensor systems can boost the benefits of Artificial Intelligence (AI) and data analysis for machine learning and improved kiln reliability.

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In computer science, the phrase 'Garbage In, Garbage Out'(GIGO) implies that a bad input will result in a bad output. Today's control systems and data analysis in cement plants certainly take this problem into account and are able to identify false sensor signals, disregard them and notify maintenance teams should an issue need to be addressed.

Ensuring that the cement manufacturing process is kept stable and uniform, with the required quality, reduced energy consumption and the highest-possible level of alternative fuels (AF) usage has certainly become a key priority for data processing. Unfortunately, however, all these efforts, successes and savings can often be wiped away by just one or two major breakdowns, which result in high costs and production losses. In such instances, the following questions are raised: How did such a situation arise? Why was it not detected sooner? And what is the root cause?

A closer look at the major failures on a rotary kiln usually shows the following:

- no historical data available for prediction and tuning the control system because it is the first time the failure has occured
- operators and maintenance teams are overwhelmed by too many alarms on a daily basis, making it difficult to pay attention to them
- sensor signals are missing or wrong and could not be used
- there are no sensors installed that could detect the problem in advance.

Involved in analysing rotary kilns and damages for more than 12 years, TomTom-Tools clearly sees the increasing importance of continuous and reliable data on the mechanical kiln condition. Tyres that deform the kiln shell due to a lack of clearance, cranks that break roller shafts and tyres, overheated support roller bearings, etc, should not suddenly appear and bring production to a halt without the opportunity to react in good time. Therefore, TomTom-Tools' Mechanical Kiln Monitoring (MKM) system has been developed further in a more modular way to fit all kinds of rotary kilns or rotary dryers.

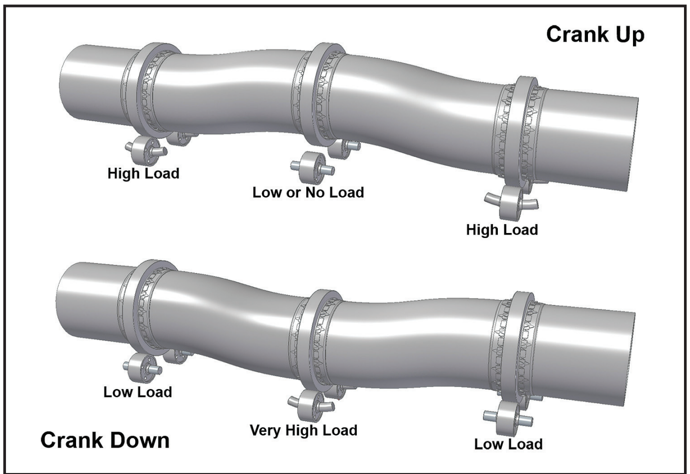

Figure 1: thermal cranks are caused by the process, coming from uneven coating or refractory thickness inside the kiln shell

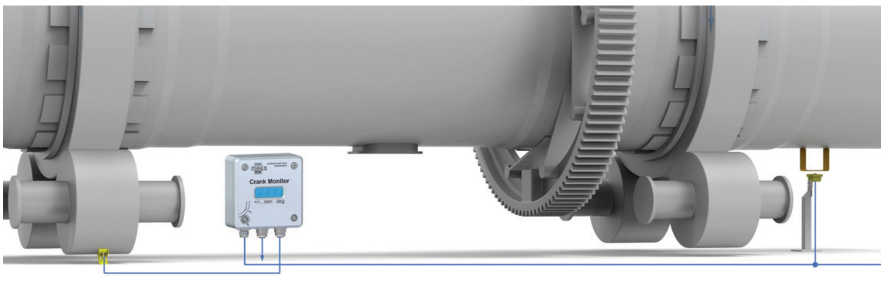

Figure 2: TomTom-Tools' Crank Monitor alerts operators to dangerous overload in the kiln pier

High priority monitoring

The highest areas of priority for continuously monitoring the mechanical condition of a rotary kiln are discussed below.

Kiln temperature

Each rotary kiln should be equipped with a thermal scanner. It provides a full picture of the temperature of the kiln shell, enabling operators to stop the kiln if the temperature becomes too high, therefore avoiding cracks in the kiln shell and deformation. Most kilns are already equipped with shell scanners, but sometimes the decision to stop the kiln is taken too late. When the shell temperature rises above 450˚C despite all efforts to cool it with fans, the kiln needs to be stopped. Spraying a high quantity of water onto the shell is also not a good solution because the thermal shock leads to cracks in the kiln shell. New scanners should enable the possibility of connecting to the control system, where AI can help identify 'dos and don'ts' to prevent undesired temperature patterns.

Kilns with more than two piers

Kilns with more than two piers should be equipped with a crank monitoring system. Thermal cranks are the main reason for broken roller shafts and cracks in kiln tyres. Cranks are divergences in the straightness of the kiln that cyclically affect the load on the support rollers and piers. It is the result of a slightly-bent kiln shell with tyres that are trying to rotate out of their centres.

Thermal cranks are caused by the process, coming from uneven coating or refractory thickness inside the kiln, which results in an uneven circumferential temperature distribution in the kiln shell. The areas with different temperatures have different thermal expansion and bend the kiln slightly. A strong crank can lift a tyre completely from its support rollers with each kiln revolution, which has a devastating impact on all affected kiln tyres, support rollers and foundations. Even smaller cranks that are not visible, can be very stressful for the whole kiln and will sooner or later lead to a breakdown. The cyclical load changes on the support rollers caused by the cranks push the rollers slightly out of the normal position whereas the roller shafts bend. This movement can be measured with inductive distance sensors under the rollers.

Alerting dangerous cranks, and also giving operators the confidence to maintain kiln operations at maximum capacity when there is no crank, were key reasons behind the development of the original MKM system. The Crank Monitor, (see Figure 2) part of the new modular MKM2 system, can now also be used on challenging kilns to counteract cranks with the Crank Elimination System by selective cooling of the kiln shell.

An even better and promising way to minimise the occurrence of cranks lies in machine learning. Data analysis can disclose unfavourable combinations and

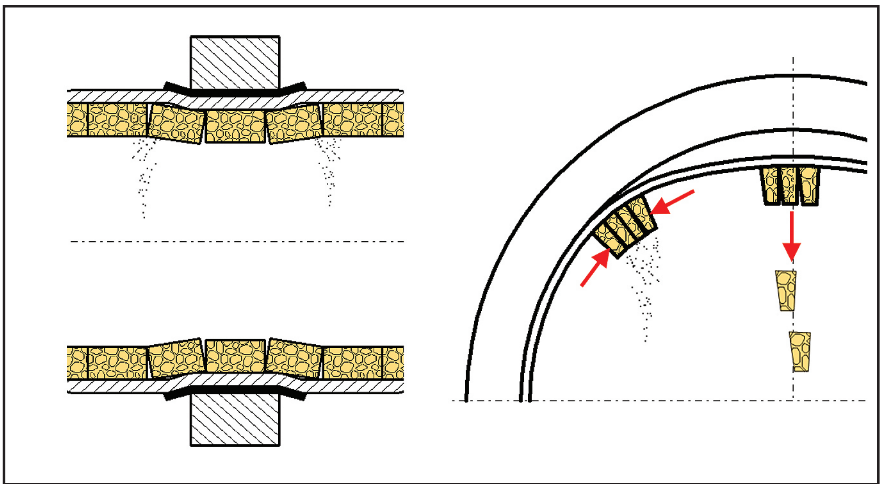

Figure 3: Correct clearance between tyres and kiln shell is the key. With insufficient clearance the tyre can lock and the shell constrict. With high clearance the bricks will get damaged due to high ovality

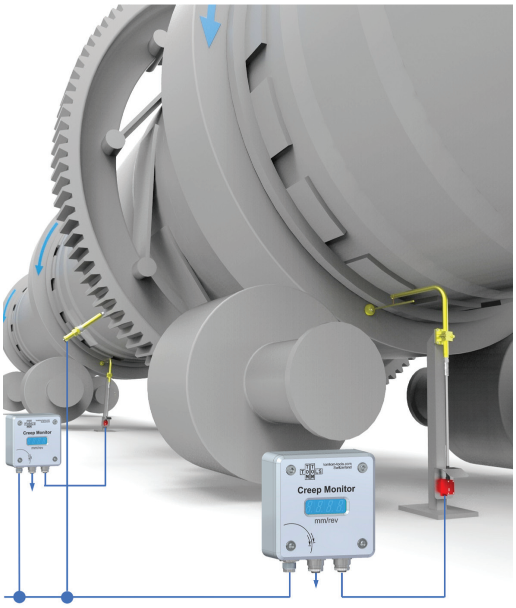

Figure 4: the Creep Monitor alerts operators to low clearance between tyre and kiln shell

fluctuations of the process parameters that lead to dangerous thermal cranks on a specific kiln.

Kilns with loose tyres

Kilns with loose, also known as migrating, tyres, should be equipped with an automatic measurement for tyre creep. The creep (also called migration) is the small, relative movement between a tyre and the kiln shell that takes place during each kiln turn. The creep indicates how much clearance exists to allow the kiln shell to expand by heat without getting constricted by the tyre.

Many kilns are equipped with a measurement system, but most use mechanical switches that have only a limited lifetime in such a hot environment and are not able to provide creep values during the heating phase when the kiln is not continuously rotated. During heating, the risk of losing the clearance is high because the shell heats and expands faster than the tyres. Therefore, a member of the plant team needs to go to the kiln frequently and check the relative movement manually by comparing chalk marks on the tyres.

Having received a number of requests to develop a new system that works also during start-up, TomTom-Tools developed its Creep Monitor, an easy-to-install solution that works precisely and in a stable manner, as required (see Figure 4).

Slide bearings

Support rollers are typically equipped with slide bearings made of bronze or white metal. At a certain kiln speed, the roller shafts have to get separated from the bearing bush by the hydrodynamic effect of the oil film. However, the oil film is rather thin, depending on speed, oil viscosity and bearing geometry. When the kiln is rotated slowly with the auxiliary drive, the speed is too slow to establish an oil film that could support the load. Hence the shaft touches the bearings and light wear occurs, depending on the roughness of the roller shaft.

After many starts and stops, the bearing will become worn, making the geometry no longer suitable. Then some areas of the shaft start to touch the bush even during normal kiln speed. At that speed the friction in the touching area will immediately generate heat and triggers the start of a vicious circle: the heat lowers the viscosity of the oil, lower viscosity means less thickness of the oil film, less thickness results in more contact, more contact in more heat, and so on.

In such a situation the temperature at the shaft surface increases fast – often in under a minute – and results in a dangerous situation, especially if detected too late. Often temperature indications in the control room are delayed because the temperature sensors are located too far away from the heat source – ie, somewhere in the bearing bush or they only measure the oil sump. On modern kilns with a high speed, the shaft temperature should be measured continuously. Timing is key, because running with a hot bearing will not only damage the bearing sleeve but also the roller shaft, which is difficult and time-consuming to repair or replace. Shaft temperature sensors are especially designed for such an application. They slide on the shafts and respond quickly to a problem. Contact thermometers have the advantage over pyrometers of not being affected by the oil or by the emissivity of the shaft and do not have optical lenses which get blind after some time.

The processing of temperature signals should trigger an alarm when the temperature increases (eg, >2˚C within a minute), not only when the maximum temperature of eg, 65˚C is reached. Artificial Intelligence (AI) should be trained so the time running the kiln on low speed and the number of starts and stops predicts failures of the bearing bushes on support rollers. Traditional condition monitoring using a vibration spectrum, as used on ball bearings, does not work on slide bearings.

Unlocking AI potential

Expectations on AI are high and benefits potentially huge. However, efforts should not be spent on compensating unavailable data with AI, which could easily be measured by reliable and proven sensor systems. Trending, analysing and combining relevant data opens significant opportunities to avoid major breakdowns and high production losses. Reliable and sound information can then unlock the meaningful use of AI and machine learning. ■

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Figure 5: The sliding sensors measure the temperature of the shaft and the thrust collar on support rollers