Smart Couplings Remove Guesswork from Measurements in Machinery Applications

Jack McGuinn, Senior Editor

Quite often, the collection of precise data in drive technology applications can be problematic. Data monitoring in a rotating drivetrain is difficult because a direct networking cable connection is often not an available option. Nothing sends shivers down the spine of for example, a production line manager or a system integrator like uncertainty. That's why achieving precise measurement of things like torque and other parameters in machinery applications is, while daunting, a dearly desired goal, especially if those measurements are only available at the drive and motor. Accordingly, couplings used in machinery and other applications today are being developed with a "smarts" and "intelligence" never seen before in such hardware. Coupling manufacturers are now producing couplings with leading edge measuring capabilities by virtue of adding sensors and software to the equation. These custom coupling are thus creating a new paradigm in manufacturing by enabling the wireless transmission of mechanical data from directly within components like, for example, a rotating drivetrain.

Call it "smart" or "intelligent" coupling (take your pick), this new technology provides a coupling system with measurement capabilities that are taken directly in the drivetrain, providing enhanced data acquisition and enhanced transparency in the drivetrain in a timely manner.

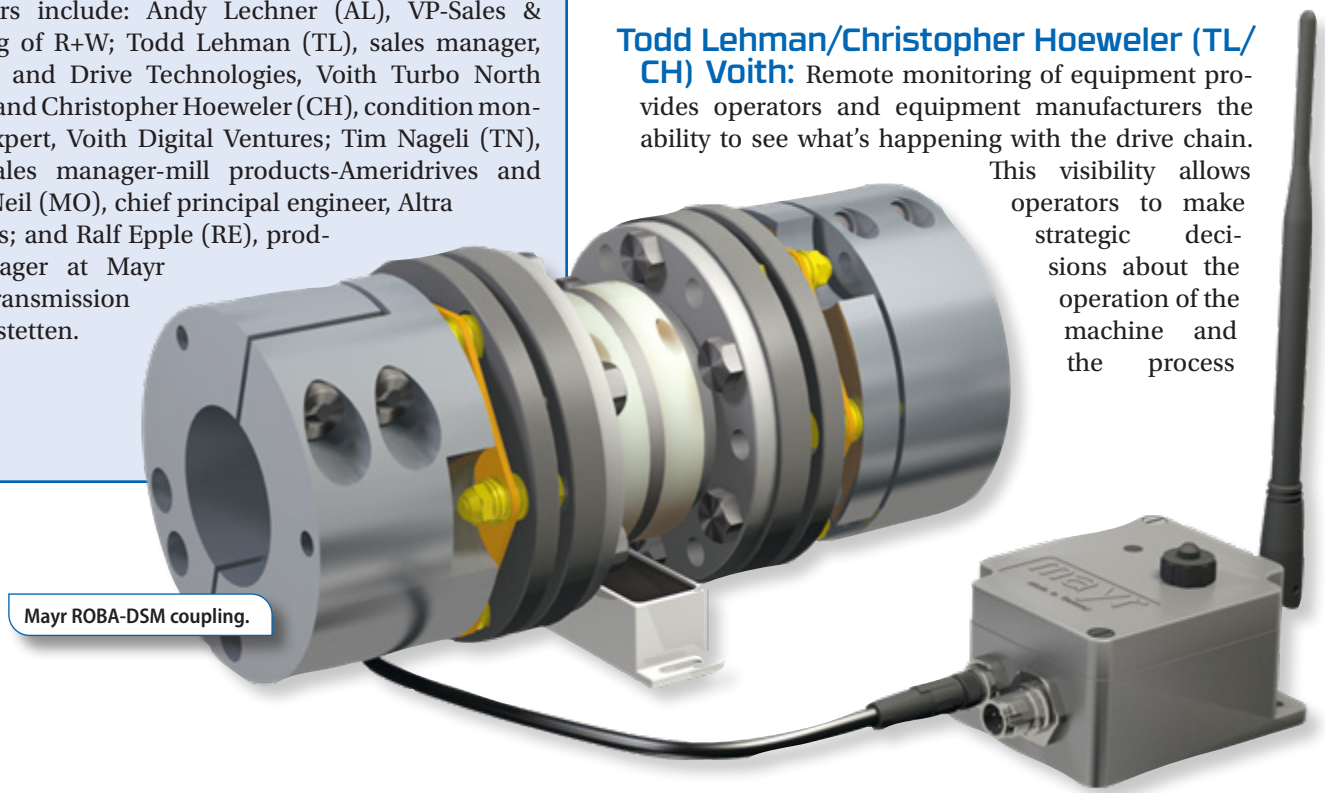
Following in much greater detail is a discussion regarding this latest advance in coupling technology. Our responders include: Andy Lechner (AL), VP-Sales & Marketing of R+W; Todd Lehman (TL), sales manager, Coupling and Drive Technologies, Voith Turbo North America and Christopher Hoeweler (CH), condition monitoring expert, Voith Digital Ventures; Tim Nageli (TN), global sales manager-mill products-Ameridrives and Mark O'Neil (MO), chief principal engineer, Altra Couplings; and Ralf Epple (RE), product manager at Mayr Power Transmission in Mauerstetten.

In drive technology, why is accurate measurement of torque and other parameters in machinery (drivetrain) applications so important?

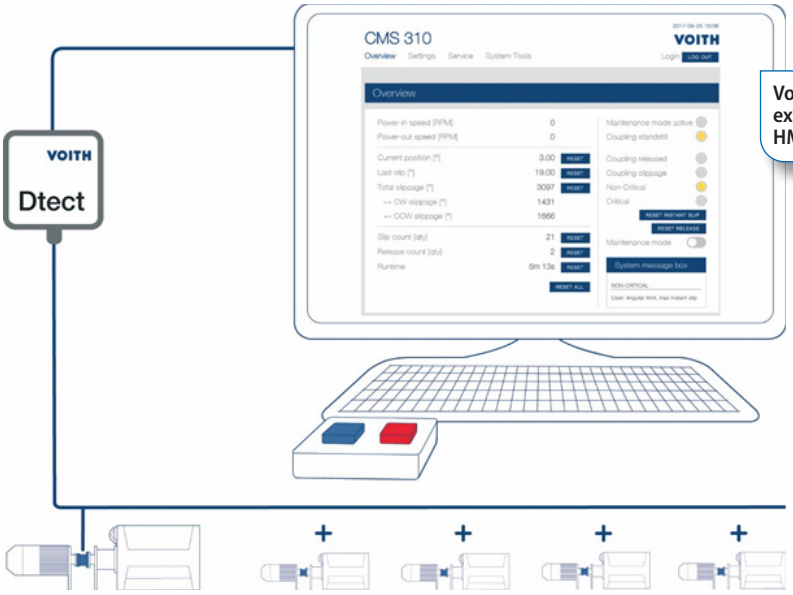
Andy Lechner (AL)/R+W: All components in a mechanical drive line have limits to the amount of torque they can withstand before failure, and as machine designs are continually optimized for size and weight, while running faster, the margin of safety from torque overload is becoming smaller. Conditions detrimental to machine performance such as wear, misalignment, loss of lubrication and binding of workpieces all increase the amount of torque required to make the machine move. So an accurate measurement of the torque being applied at key locations in the drive line can be essential to condition monitoring and predictive maintenance. Similarly, vibration can be caused and exacerbated by these same detrimental conditions, as can the axial force applied to shafting as a result of movement and heat generation. Having the ability to measure changes in these parameters is also useful in monitoring the overall health of rotating equipment.

In other instances, particularly in the process industry, changes in the density and viscosity of materials being mixed, pressed, pumped or extruded can manifest themselves as changes in the torque required to drive the process. Here too, accurate measurement of torque can aid engineers in optimizing quality and throughput.

Todd Lehman/Christopher Hoeweler (TL/CH) Voith: Remote monitoring of equipment provides operators and equipment manufacturers the ability to see what's happening with the drive chain. This visibility allows operators to make strategic decisions about the operation of the machine and the process



Mayr ROBA-DSM coupling.



Voith Dtect torque limiting coupling expandable monitoring system with HMI (Courtesy Voith).

that it is performing. The accuracy and timeliness of the measurement will provide the operator the ability to maximize machine productivity without exceeding individual drive chain component capacities. In addition, equipment monitoring can provide the ability to produce trend data for each monitored component of the drive chain. This can help operators make decisions about the health of each drive component allowing them to order spare parts in preparation for repair.

A good example is our OnCare.Health ACIDA — Report generator. The measurement is not only dependent on the accuracy but also on the reliability of gathering the data. It is important to trust the data to make decisions on actions improving maintenance or operations.

It is also noted that the torque signal is also carrier of health information of the driveline. Tracking natural frequencies, for instance, allows the ability to pinpoint changes in the system characteristics which may have been caused by rotor cracks.

Tim Nageli/Mark O'Neil (TN/MO) Altra: Measuring torque, vibration and other machinery conditions significantly reduces machine failures, downtime for repairs and stock of spare parts while increasing efficiency, production and component service life.

O'Neil/Altra: On turbomachinery in a petrochemical plant, for example, a single day of an individual out-of-service compressor can shut down the entire process and cost millions of dollars. Monitoring systems can identify performance deterioration. A decrease in torque indicates a problem such as excessive turbine or compressor wear that causes an efficiency loss. Proper monitoring allows users to trend the torque transmission and performance of their equipment. The data collected allows the user to schedule and perform any required preventative maintenance in a more controlled time frame versus the stress associated with a costly, unplanned equipment failure.

MO/Altra: Special precautions are often taken in oil refineries, petrochemical plants and other potentially explosive environments, where torque monitors and strain gages are installed. Couplings are often positioned within isolated enclosures that can be gas purged since these monitoring systems require electric current to operate and can potentially emit a spark. Incorporating "intrinsically-safe" ATEX-approved equipment that does not cause sparks is preferred.

Continuous-duty torque monitoring is often a requirement on natural gas pipelines. Compressor stations, typically placed 40 to 70 miles apart along the pipeline, are required to boost/maintain proper pressure through the pipeline's entire length. To control costs, usually only every 4th or 5th station is manned. The remaining stations utilize continuous torque and vibration monitoring systems that relay data to a central pipeline control room. In this way, the performance of all turbine/coupling/compressor drivetrains along the pipeline can be viewed in real-time to identify any potential problems as they arise that can lead to a potentially catastrophic system failure.

Ralf Eppel (RE)/MAYR: Only accurate measurement allows us to carry out a realistic analysis of the data. Only in this way, the data can be used for an analysis or wear and maintenance models and provide a meaningful overall picture of the system.

Why are measurements taken at the drive and motor in drive technology often insufficient?

AL/R+W: Monitoring the amperage drawn by the motor is a great starting point for letting the user know approximately how much torque the motor itself is generating. But these measurements become less sensitive the further one travels down the drive line. In many cases a main drive motor is used to power multiple rotating axes in a machine, separated by different types of gearing and belts, making it impossible to use amperage to monitor the torque being applied to a single branch axis. Estimating torque at the motor also fails to consider the flywheel effect of downstream equipment, where a rotating mass that has already been powered by the motor can apply large torques to components further yet down the driveline, with no evidence of this applied torque available at the drive. Depending on the speed of the application, even the inertia of the motor shaft can serve to conceal variations in mechanical torque when measured only by the real time power consumption of the motor.

TL/CH/Voith: The accuracy of measurements taken at the prime mover and the machine can provide a view to issues that may exist within a driveline. However, the view will not be complete unless all of the components of that driveline are measured. Many times, drivelines are monitored and controlled via the target speed of the engine or current draw of the motor without consideration for monitoring of the reaction of the connecting coupling or the driven machine. Connecting couplings include mechanical rubber, grid, gear, disc and diaphragm couplings as well as universal joint shafts, torque limiting and hydrodynamic fluid couplings. In such cases, the set target speed or monitored current provides limited information about the true load seen by the driven machine. Voith field service technicians have diagnosed issues, such as a failing machine bearing, which will only appear to the operator as additional load seen by the increase in engine fuel consumption or motor amperage demand. The operator could view this as additional production throughput when in reality the added demand is caused by potentially imminent machine failure.

TN/Altra: On metal mill applications, U-Joint and gear spindle measurements taken at the motor are often a motor current reading average over a certain length of time. It has been proven that within that time length, the mill can experience significant torque spikes at the roll end that are averaged out with the current or not read as high as they are. Also, the gearing and equipment through the complete drivetrain dampens the torque spikes.

RE/MAYR: Quite frequently the measurement is carried out at the wrong position and at an insufficient sampling rate.

How sophisticated is the software used in conjunction with the sensors?

AL/R+W: The software is quite simple and can be run on any Android based mobile device. It provides for real time monitoring of multiple couplings simultaneously and offers a data log output in the form of a CSV file. R+W is also in the process of developing a gateway with a USB, RS232 and an analog output, allowing the user to transfer the information to their own data acquisition software or control systems. IO-Link is next.

TL/CH/Voith: The level of software sophistication will normally be determined by the needs of the customer and the application, and it typically relates to the value of the equipment that is to be monitored. The software can be as simple as some added lines of code to the existing plant PLC for simple alarm or shutdown settings. In contrast, software can be developed for the collection of operating data, or the complete operation, monitoring and control of the machine. Once the scope and requirements of our customer's application is known, Voith will work to define and create the software for the collection and evaluation of the incoming data. The sophistication of the software will be determined first by the components of the drive chain, second by the number of sensors and data points that are to be evaluated and third by the process and how this data is to interface with the overall operating process of the machine.

TN/Altra: Permanent systems that can be measured remotely in real time can be quite elaborate. Temporary systems, installed for troubleshooting certain applications that aren't as sophisticated, collect data that is read and analyzed later.

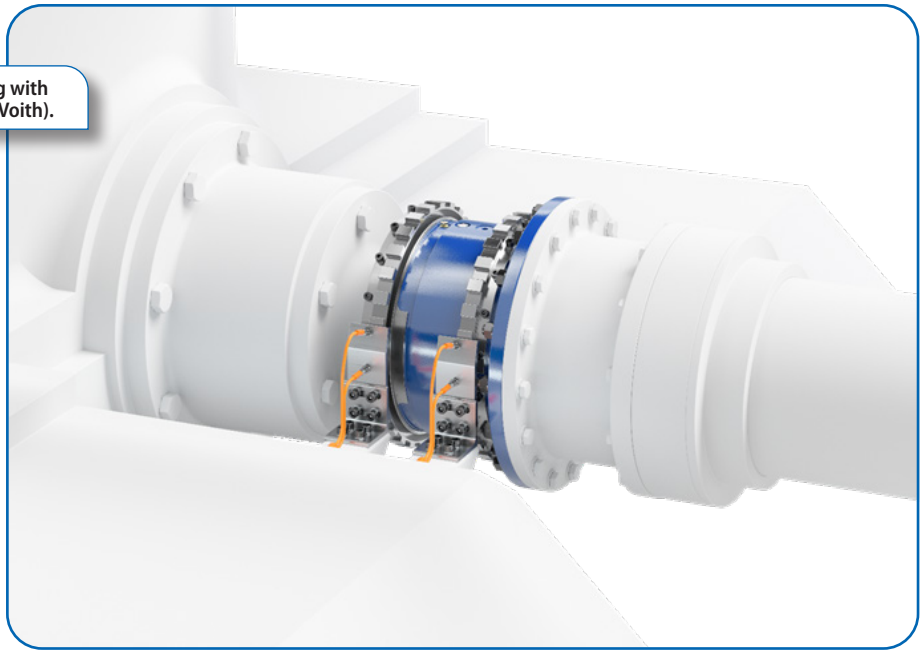
MO/Altra: Many drivetrains utilize sophisticated VFD/AFD controls. Care must be taken when monitoring equipment in these applications since these types of variable frequency drives can cause a 20% variation in torque in extreme cases. Special software with very high data sampling rates are required to evaluate these types of applications.

RE/MAYR: In our opinion a reasonable measurement signal (sampling rate/resolution/accuracy) is most important and in a second step suitable software is required. Bad or inaccurate measurements cannot be compensated even by the best software.

How are the sensors incorporated into the couplings?

AL/R+W: The sensor package consists of a steel frame, to which strain gauges are applied for torque and force measurements, an accelerometer (like those used in smart phones) for vibration measurement, and a gyroscope to provide speed measurements. This steel frame is pressed into an intermediate spacer in the center section of the coupling and sealed off with resin.

TL/CH/Voith: Incorporation of sensors onto or into couplings vary. Sensors are typically externally mounted onto the coupling or the corresponding shaft that supports the coupling and remotely monitored since in most cases the coupling is rotating. However there are situations where a sensor may be incorporated within the coupling. Measurements typically include torque, speed and temperature. If the coupling is operated within a stationary housing, sensors will be applied to the housing for the monitoring of data such as vibration, temperature, fluid level and flow, and relative position of essential components. In certain



Voith SmartSet torque limiting coupling with Dtect slip detection sensors (Courtesy Voith).

situations, caused by physical access limitations to the coupling, Voith has incorporated sensors within the flexible element of the coupling to collect operating data for a temporary period since battery life is limited. We have used these types of units to record driveline operation behaviors for analysis and verification of proper coupling selection in situations where published machine data was not matching the actual operational data.

In addition to the direct torque measurement, rapid torque changes can be captured allowing customers to see maximum torque levels in drivelines which may be unseen on calculated motor torque. Also since strain gauges are directly mounted on driveline equipment, dynamic driveline characteristics can be made visible, which may have been isolated in the calculated torque measurement. By measuring torque precisely, operators and engineers are able to make strategic decisions that reduce downtime, increase efficiency, and save money.

TN/Altra: In mill applications, strain gages are added to the spacer section of universal joints or gear spindles along with a protective casing, power, and remote antenna. Strain gages are a good diagnostic tool. There are cost-effective short-term systems and more robust long-term continuous-duty systems available.

Are torque, rotational speed, vibration and axial forces the parameters requiring precise measurement?

TL/CH/Voith: The determination of measurement accuracy requirements will vary among industries, applications, and customers. The precision of all those measurements mentioned can be very important. At Voith, we place importance on not only high resolution in amplitude, but also on frequency of the signal. A lot of information is found in the frequency content of a signal. Measurement of these Eigen frequencies in a drive line might be correlated to a cracking shaft or other issue if there is a change in the monitored frequency. The cause of such a frequency change needs to be identified as soon as possible to safeguard the environment. Other precise measurements, for example, temperature, can also be required to enable to safe and stable operation of a drivechain.

RE/MAYR: The parameters mentioned in the question are certainly not the only parameters that play a role, but the most important ones. In addition, the temperature and the angular position of the acceleration are also important parameters for us. But what's really crucial are the accuracy and reproducibility of the measurement signals - these factors are more important than the total number of possible recordable parameters.

Is this enhanced measurement regimen IIoT-driven?

AL/R+W: The need for simple and cost-effective measurement of mechanical behaviors in drive lines precedes IIoT, but related technological advancements have facilitated the development of this product, and certainly help drive demand for it.

TL/CH/Voith: Once again, it will depend upon the industries, applications, and customers. It will also depend upon the function and value of the equipment. Generally, IIoT-driven architectures are increasingly being focused upon by companies. Voith, like many companies, is constantly working to develop intelligent equipment technologies so that they can be operated and monitored within unmanned facilities or stations remotely. To Voith, this increases the need for and importance of accurate and reliable instrumentation for measurement of all of the drive chain components.

MO/Altra: Torque monitoring systems have been available and widely used throughout various industries for many years. The growth of the IIoT has raised awareness of these types of remote performance monitoring devices. While most large couplings could benefit from torque monitoring, the reality is that many of the sophisticated torque monitoring systems currently on the market have associated costs that exceed the cost of the actual coupling being monitored. Hopefully, as newer technologies evolve, the cost of these important devices will begin to come down.

RE/MAYR: We have been working on the topic process monitoring for more than 15 years. During all this time, we have continuously further developed our product, the ROBA-DSM coupling. But it is only with the possibility of faster data acquisition and processing and the resulting analysis systems that possibilities have arisen here to make this information widely available. Of course IIo

Are the mechanical properties of "smart couplings" affected by the integrated sensors?

AL/R+W: The sensor package occupies approximately 75mm of length within the coupling, which depending on the individual application, could require that the coupling be slightly longer than it would otherwise be. The focus has been primarily on flexible disc couplings in the capacity range of 350 to 2,500 Nm, though plans to integrate into larger coupling sizes are also being implemented. The larger the coupling is, the less of an impact the sensor package has on its mechanical properties.

TL/CH/Voith: There are many factors that must be considered when evaluating the integration of sensors onto a coupling. Factors include, but are not limited to, the method of attachment, the sensor weight and the impact of the sensor on the normal function of the coupling. We present all these factors for customer consideration prior to sensor installation to maintain the longevity and reliability of the coupling.

Voith SVTL variable speed hydrodynamic coupling with housing mounted sensors. (Courtesy Voith)

RE/MAYR: In some cases it will not be possible to avoid that rigidity, maximum torques and displacements have to be changed or limited due to the implementation of sensors. But this is exactly where our know-how as a clutch/coupling manufacturer comes into play: We select the type of sensors in such a way that this plays a subordinate role for the application. And this is the reason why we will not focus on a specific measurement system or sensor type. Our applications are too diverse. Not every application requires the same data and the same sensor technology. And the costs should also always be kept in mind here. In the area of process monitoring or analysis, the additional cost is often a decision criterion whether certain processes are monitored or not.

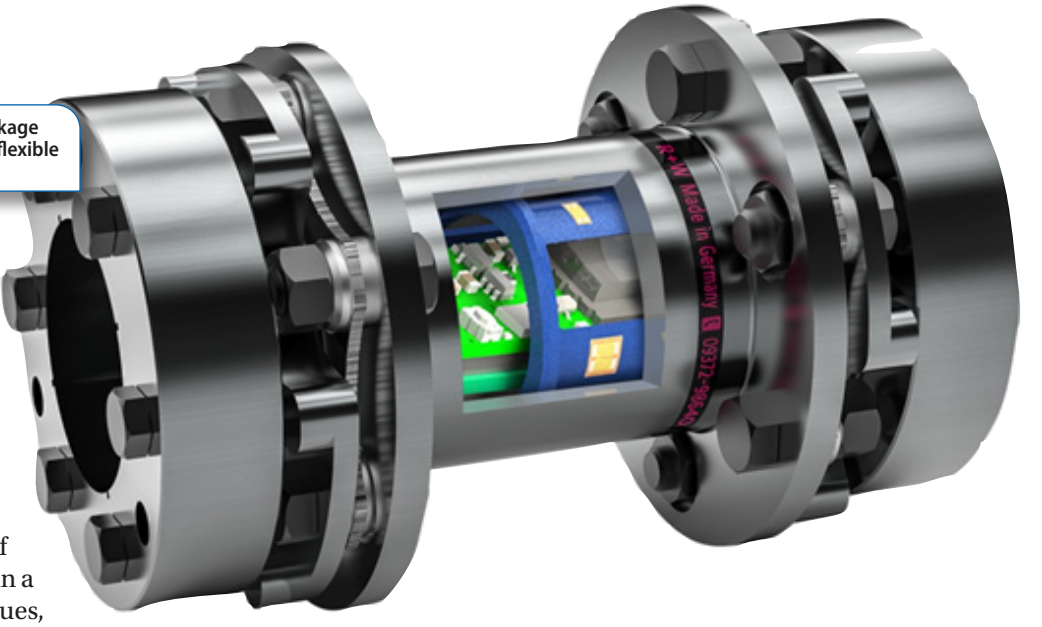
How is the information provided by the sensors processed and applied in real time?

AL/R+W: This depends on the type of process being monitored and how the information is being used. It could be used to trigger warnings in case of torque and vibration increases beyond a certain threshold in manufacturing equipment, or to verify the consistency of media in processing equipment and advise that other mechanical adjustments be made, or simply to confirm that a device is producing or receiving sufficient torque in test and measurement equipment. Ultimately the way the information is processed and applied is up to the user.

TL/CH/Voith: The machine monitoring system or PLC will process the data according to how the machines process lines of code dictates. The data transfer from the sensor to the PLC for evaluation happens within milliseconds. The result of the sensor data causes the PLC to control the machine normally or make adjustments to the machine operation, again within milliseconds.

Can the smart coupling be integrated in existing systems?

TL/CH/Voith: Customer demand is there and we are capable of adding sensors and related supporting equipment to an existing system. However, we have found physical dimensions and layout of the system along with the desired sensor array will ultimately determine what is and what is not possible. In other words, sensor integration into existing systems can be done to varying degrees on a case by case basis.



iLP3: rendering of R+W sensor package installed into the spacer of an LP3 flexible disc coupling. (Courtesy R+W.)

Regarding torques and axial forces, how do the smart couplings-sensors help reduce or prevent failure and/or downtime?

TL/CH/Voith: Drivelines that experience over torques and / or excessive axial forces typically do not last a long time. The integration of strain gauges at various places within a driveline that experiences such issues, at least on a temporary basis, can identify the magnitude of the torque or axial forces and allow the machine owner to make educated decisions. For example, in one case, a universal joint shaft in a scrap metal recycling shredder application experienced over torques that could have led to the premature or catastrophic failure of the universal joint shaft. Sensor feedback in this application showed the machine owner the amplitudes and durations of the torque spikes and indicated the need for the addition of a torque-fuse coupling, such as a hydrodynamic fluid coupling or a torque-limiting safety coupling, to the machine drive chain. Such a torque-fuse coupling would act as the soft element in the drive system with built-in safety and release features. They then also had the ability remotely monitor the system for over-temperature and release conditions.

Torque, axial forces and radial forces are part of the design of machinery and integrated in the game of engineering. However things can be overseen during design phase or machinery is operated out of allowed operating points. In such cases, dynamic forces can rise quickly and damage machinery or civil structures prematurely. Measurement of dynamic forces is therefore a great tool to understand the system characteristics to avoid premature failures and also to identify the root cause of vibration problems.

RE/MAYR: Monitoring in the drive line provides the opportunity to detect errors and wear that are gradually becoming apparent at an early stage and then to act with foresight.

Also, when planning maintenance periods, for example, the parts which are subject to wear can be ordered in advance. This reduces the maintenance time and thus the overall downtime of the system. In particular changing vibration patterns or torques with always the same process sequences are ideal signal generators or indicators. Also load conditions that are recorded by the sensors (torque/temperature/speed) in the drive line enable the system operator to carry out the maintenance interval sooner or later if necessary and to plan it better.

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