"Smart" Bearings are in Control—

BUT FULL POTENTIAL REMAINS UNTAPPED

Jack McGuinn, Senior Editor

To be clear, "smart" bearings—i.e., bearings and sensors integrated into a component to monitor bearing performance—are not new. They've been around for decades, dating back to military applications circa World War II. Since then, they have played a vital role, according to the Bearing Specialists Association (BSA), in the automotive, motion control, robotic control, paper and printing, web processing, wood processing, chemical, textile, agricultural and food processing industries. (*Ed.'s Note: Please see accompanying BSA sidebar on smart bearings.*)

Victoria Wikström, manager of SKF's industry applications segment group, provides some additional historical perspective.

A smart bearing from Dodge (courtesy Dodge Roller Bearings).

"(Smart bearings were developed) for applications where personal damage and safety are key, and the consequences of a bearing failure can lead to serious injury and even fatality, as opposed to 'merely' financial issues. Therefore, bearings in jet engines were first to be monitored by sensors (in flight), and by inspections and oil analyses on the ground. The automotive industry's adaptation of anti-lock brake systems (ABS) is probably the first large-volume sensorized bearings (position sensoring). Railway locomotives and cars have been using temperature warning sensors for some 20 years, even if these were not mounted as an integral part of the bearing but as an add-on through the housing.

"For industrial applications, use of sensorized bearings has not been as widely adopted as the opportunities and available benefits that are out there. But with higher demands on uptime and reducing maintenance costs, it is definitely increasing—load sensing (using strain gages) for paper machines, vibration- and temperature-condition monitoring for many industries, oil quality sensors for gearboxes. Today, for car applications, SKF has working prototypes of load sensing via sensor technology integrated into the wheel bearings."

Darin Davenport, product business manager for Dodge Roller Bearings, adds that in addition to the military applications, "Sensor technology was also likely improved through R&D dedicated to aerospace. We don't have proof of this though. Dodge only started offering smart products in 1995, when we leveraged Rockwell (Automation's) experience." He adds, "Sensor and monitoring capabilities are the primary value added features, but the bearing housings are modified to provide accurate sensor reading and proper sensor mounting."

Given that bearings are often one of the most important components in a machine, system, etc.—and are often one of the first to fail—having a reasonable expectation of their longevity is essential to maintaining peak performance cost. Smart bearings do just that in sensing vibration, temperature, speed, load and debris levels, to name just a few. Taken a step farther, they also are commonly used in industrial applications, in that the sensed data is extrapolated into condition monitoring systems for the monitoring of the aforementioned vibration and temperature issues. (*Ed.'s Note: For more on condition monitoring, please refer to our feature story on page 20.*)

According to the BSA, smart bearings have long played a big role in the automotive industry—in hub units, for example. That anti-lock braking system and traction control in your automobile are made possible by smart bearings.

Beyond automotive, smart bearings address a host of industrial applications, including the monitoring of speed, temperature (thermocouple) and vibration (accelerometer) levels.

All of which begs the question—can all bearings be "smart"?

"Yes, in principle," says SKF's Wikström, "but it also depends on what parameters are key to monitor. Anything can be basically sensed—the hard part is to know what to sense and what the output signals mean. When, for example, should an increase in temperature be considered dangerous and result in a 'red light' for the user? If occurring once or twice, and without an accompanying increase in vibration, probably not at all. If at the same time as the acoustic emission signal increase—right away.

"It is, however, difficult to use traditional vibration sensors (accelerometers) or temperature sensors and obtain sufficient information in very large, slow-moving bearings (slewing bearings or plain bearings). For these types of applications, one is better off using in-line oil analysis when looking for increasing trends in metallic wear."

Dodge's Davenport concurs that "Depending upon the bearing size, mounting style and housing type, (smart bearings) may be more practical with some (applications) than others."

Given the two distinctly different (yet ultimately compatible) components—sensors and bearings—one might reasonably ask a chicken-or-egg question, i.e., Where does the design for a smart bearing begin—with the bearing manufacturer or elsewhere?

"The design starts with the manufacturer, but it is customer-driven," says Davenport. "Customer needs will dictate the features to monitor, the signal type and the sensor type. Environment and operation will also influence the design."

Asked the same question, SKF's Wikström replies, "Mostly, yes (the bearing manufacturer). Bearings are at the heart of all rotating applications, and rotational speeds, vibrations, forces and moments all go through the bearings in some way or other. Therefore, the bearing is an ideal point to monitor; there are bearings that come pre-sensorized from the factory that measure position and/or speed, temperature and vibration within a given range.

"For application-specific needs, close cooperation and joint product development between bearing manufacturer and machine builder is always a good solution."

Smart bearing technology can also play a central role in predictive facility maintenance. There remain, however, impediments to smart bearing systems in some scenarios.

"Typically, barriers to entry include the costs of the measurement equipment, software and any associated operator training," says Davenport. "These costs will also be related to the types of measurements desired, as well as the quantity and number of bearings intended for smart features. For example, installing a single thermocouple or RTD (resistance temperature detector) onto a bearing housing is fairly simple and the data retrieval and analysis software are fairly straightforward.

SKF's "smart" steering unit for warehouse and off-highway vehicles (courtesy SKF).

"However, if vibration measurements are required, then accurate results will require three accelerometers or velocity pickups per bearing or shaft-mounting location. Additionally, interpreting the results is a bit more complicated than trending temperatures. But vibration analysis provides detail of the entire machine rather than just the trend of temperatures on a bearing. The bearing is simply the most accurate location for obtaining the vibration."

Davenport goes on to explain that any decision to incorporate smart bearings must "weigh the costs of entry against the costs of downtime and costs of product replacement" due to failure, etc. He adds that often a machine component will fail, yet continue to operate and in turn wreak damage on nearby components, thus compounding replacement time and overhaul cost. All of which leads him to conclude, "A good preventive maintenance program will prolong the life of machine components as well as identify components to be replaced prior to a costly, catastrophic failure. Some smart features will also shut a system down upon alerts from the bearing that operation is faulty."

And given those start-up costs, SKF's Wikström points out that "Smart bearings with integrated sensors are not as widely deployed as they could or should be. But externally attached sensors are used in many process and manufacturing plants, as well as in mining, oil and gas, etc. All critical rotating machines are candidates—pumps, fans, motors, gearboxes, machine tool spindles, etc."

Considering for the moment that cost is no object, Wikström lays out a typical scenario for implementing smart technology in a manufacturing facility.

"Step one is to go through which applications in a plant are critical for operations. Usually, it is the 'driveline' applications: a motor, gearbox, coupling system driving a fan, pump or roll. Then, the weak links in these critical drivelines need to be identified—Which part is likely to fail first or most often? Third is to identify what can be monitored on these weakest links and to consider if relevant information (for decision making) would be obtained. Once this is done, the optimum methods for sensorizing can be decided upon—selecting pre-sensorized bearings, mounting sensors in bearing housings, or if it is just as effective and more cost-efficient to make hand-held vibration analysis instruments and/or oil analysis online or in the laboratory. The extent of a retrofit is dependent on the plant size and the above considerations.

"I find it a useful exercise to think, 'What if I knew exactly how the temperature/vibration of this point looked like all the time? What would I do with the information? Would it be data, or would it be information? And how would I make decisions based on that information."

To close the loop, we asked both

continued

contributors for examples of how smart bearings perform a specific function.

Dodge's Davenport cites a mining application in which head pulley bearings are equipped with speed sensors on a bulk material handling transport conveyor.

"A coal transport train is expected to arrive at the mine in two hours when a catastrophic failure occurred on the drive coupling at the head pulley. The speed sensors on the head pulley bearing were able to communicate through a PLC, switch or data acquisition system combined with an alarm to the mine operators. Resources were directed to replace the coupling before the train arrived, saving a $50,000/hr fine by the transportation company."

For another example, Davenport cites a critical exhaust fan in a steel processing plant using a thermocouple/transmitter in tandem with exhaust fan roller bearings.

"Trending data over the last 18 months have yielded bearing temperatures within 10 percent from nominal operating temperatures. Over the last three days, the bearing temperatures have been climbing 15 percent per day. Although these bearings were not scheduled for replacement during the next scheduled downtime, the preventive maintenance manager was able to obtain replacement bearings and include their replacement in the weekend's scheduled downtime. This helped avoid a costly delay in unexpected downtime and extended lead times."

For anyone missing the trend developing here (cost containment), SKF's Wikström offers a couple of examples of her own.

"Paper machines use load sensing to set the roll pressure, and temperature and vibration sensing to ensure all parts of the machine are OK. In a paper machine, all points related to moving forward are key—if one fails, the paper breaks and there is an expensive and undesired stop—a disaster if you are making paper for (or printing) tomorrow's newspaper. Also, because paper mills are among the most efficient plants in the world, vibration monitoring is most often applied and is done on critical drivelines and auxiliary machinery."

Wikström's second show-and-tell

Smart Bearing

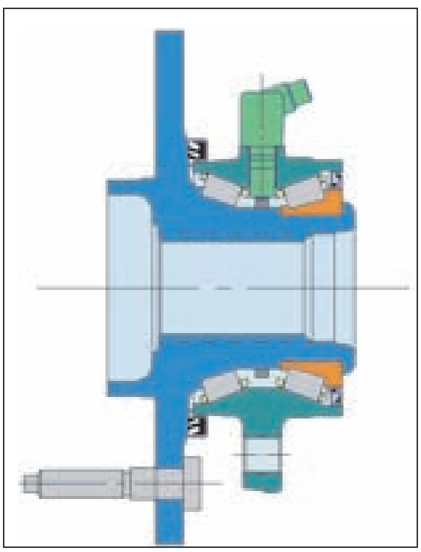

Figure 1—Gen 3 hub unit bearing with speed sensor (courtesy of The Timken Company).

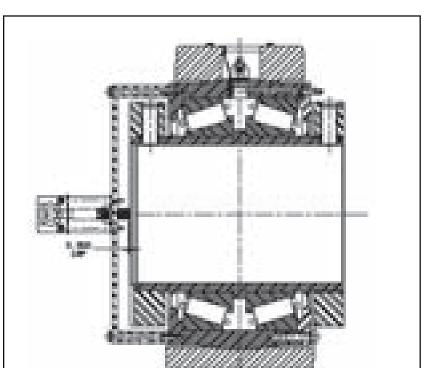

Figure 2—Smart bearing with speed proximity switch (courtesy of Baldor-Dodge-Reliance).

Proper bearing analysis is the key to keeping equipment running efficiently, reliably ,consistently and cost effectively. Monitoring for and preventing costly bearing damage can enhance productivity, ensure peak performance and ultimately affect the bottom line.

Use of "smart" bearing technology is one method manufacturers can use to monitor bearing operation. Smart bearings are instrumented with sensors to provide information about their surrounding environment, including speed, direction, temperature, vibration, load, levels of debris and other factors. The integration of sensors and bearings is what gives smart bearings their name.

Once smart bearings gather the data, they feed it to a control unit that is used to monitor the particular bearing operation. For example, smart bearings used in automotive wheel applications collect speed data used to operate anti-lock brakes.

Further, in industrial applications, the data collected by smart bearings is often matched with condition monitoring programs where being aware of temperature and vibration levels is essential to preventing bearing failures.

Smart bearing technology is used in a variety of industries, including automotive and industrial. Specific applications include, but are not limited to: automotive wheel speed and direction feedback, machine control, robotic control, printing industries, paper converting, web processing, wood processing, chemical production, textile, agriculture machinery and food processing.

Smart Bearing Types

The most popular smart bearings are found in automotive wheel applications. Most automotive "hub unit" bearings commonly include speed sensors which send wheel speed data to the ABS (anti-lock brake system) and traction control units of light vehicles. Figure 1 shows one such hub unit bearing.

In the industrial markets, housed bearing units can be equipped with sensors that monitor bearing speed, vibration, temperature or a combination of all three. Figure 2 shows a smart bearing that is using a speed pickup proximity switch. The speed pickup proximity switch senses the presence of two targets on a special collar or locknut inside the sensorized bearing housing. When a target comes into range the proximity switch closes, involves the robotics industry.

"Robotic control and electric motors for positioning use position sensors on bearings to know where a shaft is, and for remembering where it was before shutting off power. In the near future, robotic or semi-automated excavators and motor graders will be used, making it possible for less-experienced drivers to reach desired performance levels quicker. In warehousing vehicles, SKF has produced a prototype, called the SKF E-Truck, where all functionality is powered by electric systems and the lift positioning height is displayed on a screen in the driver's cabin by virtue of a sensorized bearing."

Given the evidence to date, it appears that smart bearings provide benefits both documented and yet to be realized.

For further projections regarding smart bearings, we went to the experts.

"Wireless transmission is likely one of the next big steps," says Davenport. "Some sensor manufacturers have already been offering these features, but they are not widespread or (sufficiently) inexpensive as yet. Battery life on wireless transmitters would also need improvement."

At SKF, Wikström has a somewhat guarded take.

"Besides the examples given above, sensorized bearings are still far from being used to the extent that they could be, and the enabling technology is continually developing."

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Technology

allowing the supplied voltage to pass through. The time between the two pulses per revolution may be measured to determine the shaft speed.

Available Sensors

The types of sensors that create smart bearings also range in capabilities and usage. For industrial applications, sensors are available to measure speed, direction, temperature (thermocouple) and vibration (accelerometer).

Condition Monitoring

Manufacturers continue to further explore the benefits and uses for smart bearings in specific applications. Currently, smart bearings are evolving to have the ability to measure bearing system performance and predict the remaining useful life.

Condition monitoring units are yet another option in predictive bearing maintenance technology and can be used in conjunction with smart bearing sensors. Just as sensors are being used to transmit data to a source, condition monitoring units are external devices that can receive data on the operating conditions of equipment to ensure peak performance. Together, these devices can communicate to an operator when critical machine elements have become worn, contaminated, damaged, improperly lubricated or experience a rise in temperature or vibration—all leading to potentially costly downtime and repairs. Figure 3 shows an example of combining smart bearings into a system and feeding data to a PC as part of a condition monitoring program. Smart bearings can send the performance data via wireless or wired arrangements.

As industries continue to grow and develop, additional smart bearing sensor data is needed to more closely monitor proper bearing function, which is so essential to optimal operation. Advancements in bearing technology, including data sharing and maintenance tracking, will continue to be researched and developed for more applications.

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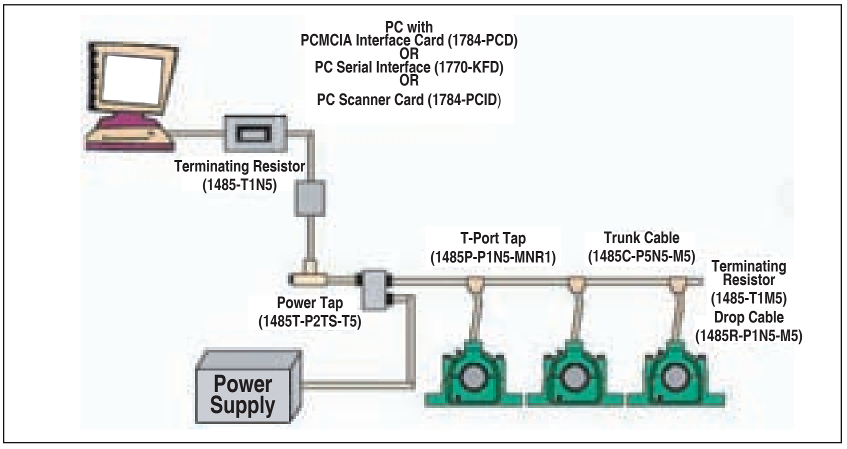

Figure 3—Condition monitoring system set-up (courtesy of Baldor-Dodge-Reliance).

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