Surface Acoustic Wave Technology based Temperature Monitoring of Rotating Machine Components

Summary

Acquiring temperature measurements from rotating machine components using conventional methods can be costly and technically challenging. Solutions involving thermocouples often include elaborate coupling mechanisms to ensure continuity of contact between the rotating thermocouple and the measuring instrument. Infrared thermal measurement solutions, while extremely accurate, do not provide the ability to measure temperature at critical and targeted locations on the rotating structure. The advent of wireless sensing technology holds the promise of providing cost effective and elegant solutions to the challenges of obtaining temperature measurements of rotating objects. Further, passive temperature sensors, which do not need an external power supply or batteries, provide the added benefit of a low maintenance and environmentally sustainable temperature measurement solution.

CHALLENGES OF ROTATING MACHINE COMPONENTS

The primary challenge with tracking temperature on a rotating machine component is the need to maintain contact between the sensor (e.g. thermocouple) and the measuring instrument. One option is to use a slipring, which is an electromechanical device that allows the transmission of power and electrical signals from a stationary to a rotating structure[1]. As shown in Figure-1, sliprings are mounted onto the rotating structure; carbon bushings are spring loaded to maintain contact with the sliprings as they rotate. The cost and complexity of using sliprings can be significant and in many instances, impractical.

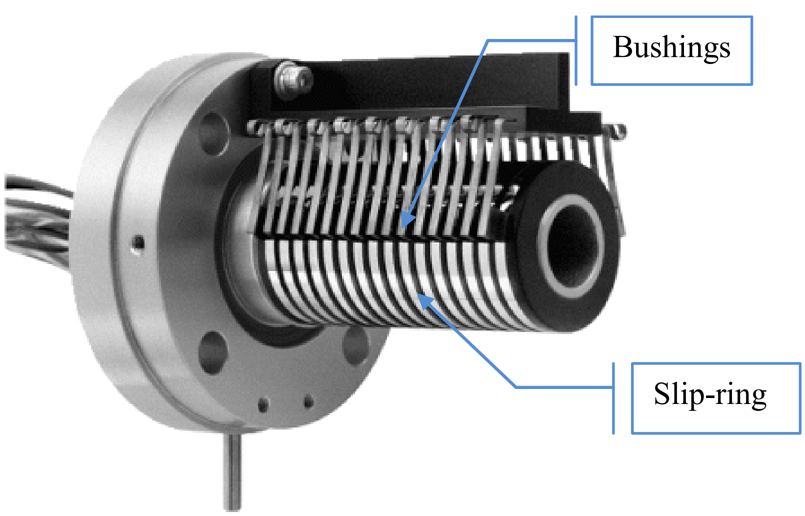

Figure 1: Sample Slip Ring Construction[2]

Infrared thermometers provide an alternative to complex mechanical solutions like sliprings. Due to their optical nature, infrared thermometers can be focused onto the rotating structure (with the use of a laser guiding device) and be appropriately setup to measure temperature. However, one significant disadvantage of this approach is the inability to obtain temperature measurements at specific target locations on the rotating structure. In some instances it is more important to measure, say the temperature of a specific machine component than it is to measure the rotating rim on which the component is mounted. Also, the infrared thermometer can, at best, indicate the presence of a temperature differential on the rotating component. It cannot specifically isolate the exact location of the temperature differential. Lastly, specific adjustments need to be made to the infrared thermometer to compensate for reflected and refracted radiation from the rotating structure. Although not insurmountable these add to the overall burden of setting up and maintaining an infrared thermometric solution.

Wireless temperature sensors address the disadvantages associated with sliprings and infrared thermometers:

- **Reduced Complexity**: Wireless temperature sensors do away with the complex electromechanical coupling mechanism of the slipring. Instead, an electromagnetic link between the sensor mounted on the rotating structure and the measuring system is used to provide a temperature sensing solution at greatly reduced costs.

- **Localized Temperature Measurement**: Wireless temperature sensors offer the advantage of being able to be mounted at specific locations on the rotating structure thereby providing localized temperature measurement capabilities.

- **Low Maintenance Burden**: The overall effort required to maintain a wireless temperature system is nominal. Once installed, SAW based wireless temperature sensors require very little maintenance.

Wireless Surface Acoustic Wave (SAW) based Temperature Sensing

Traditional methods of measuring temperature have relied on the temperature dependence of resistance (thermisters or Resistance Temperature Detectors - RTDs), the temperature dependence of fluid expansion (thermometers) and the emission of infrared radiation from heated objects (IR thermometers). SAW based temperature sensors on the other hand take advantage of the piezoelectric effect. SAW based temperature sensing, which is described in detail below, involves electrically inducing a surface acoustic wave into a piezoelectric material and then reconverting the energy of the wave (influenced by the temperature to which the sensing element is exposed) back into an electrical signal for temperature measurement. One significant advantage of SAW devices is their low power consumption, which makes them very amenable to wireless interrogation. A wireless SAW based temperature sensing solution consists of a wireless interrogator (RF Transceiver) electromagnetically linked to a SAW sensing element as shown in Figure 2.

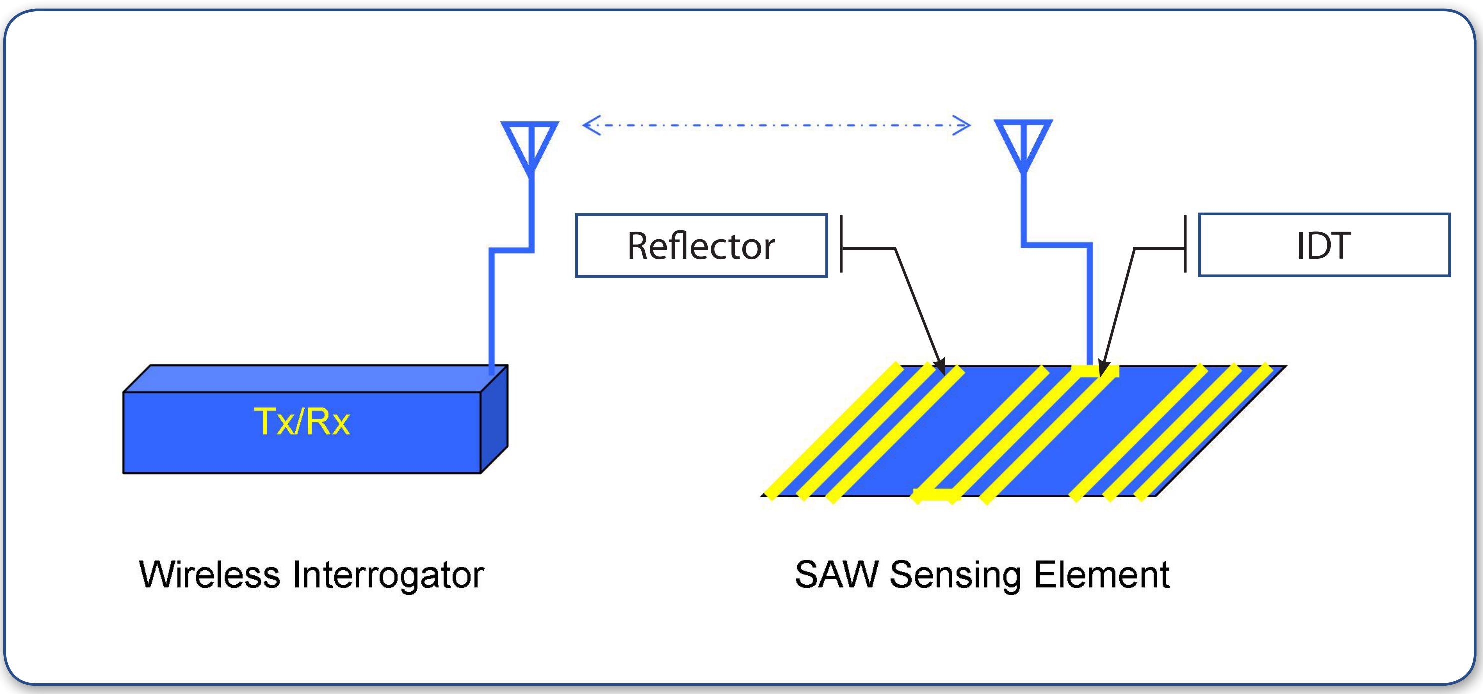

Figure 2: Wireless SAW Temperature Sensing System

A typical interrogation cycle includes the following steps:

- The wireless interrogator generates a Radio Frequency (RF) signal which is transmitted by the interrogator antenna.

- This signal is received by the sensor antenna and is used to induce a surface acoustic wave in the piezoelectric sensing element via an Interdigital Transducer (IDT).

- The IDT consists of two interlocking comb-shaped metallic patterns applied to a piezoelectric substrate for the specific purpose of converting microvoltages to surface acoustic waves and converting surface acoustic waves back into microvoltages.

- The surface acoustic wave is reflected back to the IDT by structures called reflectors, thereby creating a resonator.

- The resonant frequency of the surface acoustic wave resonator is influenced by the temperature to which the sensing element is exposed. It is this phenomenon that is exploited to obtain a temperature measurement.

- The IDT converts the natural oscillation of the surface acoustic wave resonator into an RF signal, which in- turn, is transmitted back to the interrogator via the same antenna set.

- A change in the frequency of the received RF signal is indicative of a change in the measured temperature.

SAW Based Temperature Sensing for Rotating Applications

SenGenuity has developed a wireless temperature measurement solution that makes use of passive SAW temperature sensors to obtain temperature measurements at specific points on rotating machine components. The sensors are interrogated by a wireless SAW interrogation device via a capacitive plate as shown in Figure 3. The measurement of the sensor is synchronized with the speed of the rotating component thereby ensuring accurate temperature measurements. The temperature as well as the identity of the sensor is tracked by the wireless sensing system. Temperature data is obtained either via a PC based application or via the CAN communication protocol.

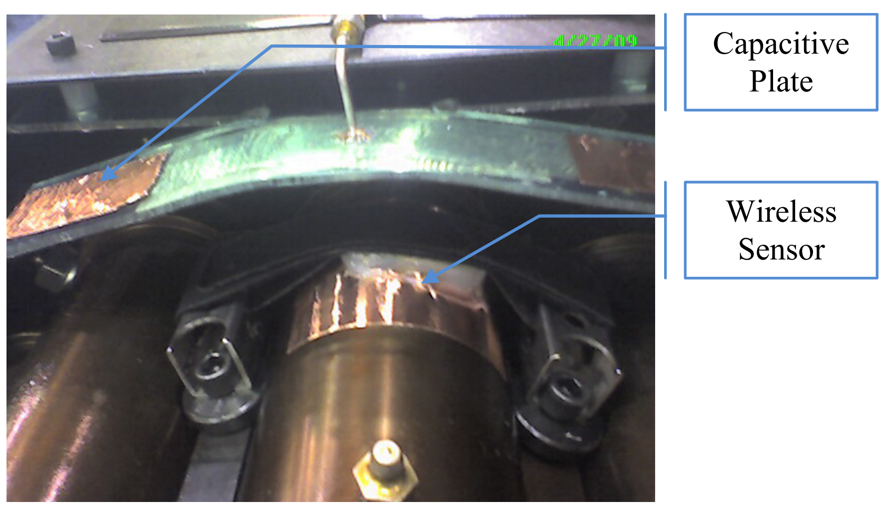

Figure 3: Typical Installation on Rotating Machine Component

Contact Information

Please contact our Application Engineering group at support@sengenuity.com for more information about this product.

References

1. www.polysci.com/sliprings/slipring.html, 2009
2. www.fabricast.com, 2009

- Rev. A