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Wireless Surface Acoustic Wave Sensors

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Abstract: 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 afford the ability to measure temperature at critical and targeted locations on the rotating structure. The advent of wireless batteryless sensing using surface acoustic wave (SAW) technology holds the promise of providing cost effective and elegant solutions to the challenges posed by rotating machine components. Through use of independent frequency bands the sensors maintain unique identification within the system architecture. Further, passively powered SAW temperature sensors that do not need either an external power supply or batteries provide the added benefit of a low maintenance and environmentally friendly temperature measurement solution. *Copyright © 2009 IFSA.*

Keywords: Wireless passive temperature sensors, Batteryless temperature sensors, SAW sensors

1. Introduction

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 afford 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 posed by rotating machine components. Further, passively powered temperature sensors that do not need either an external power supply or batteries provide the added benefit of a low maintenance and environmentally friendly temperature measurement solution.

2. Challenges Posed by Rotating Machine Components

The primary challenge with tracking temperature on a rotating machine component is the need to maintain contact between the sensing elment (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]. Fig. 1 shows a typical slipring assembly. Sliprings are mounted onto the rotating structure; carbon bushings are spring loaded to maintain contact with the slip rings as they rotate. As can be surmised, the cost and complexity of using sliprings can be significant and in many instances, impractical. Wireless temperature sensors do away with the need to maintain a electromechanical coupling between the rotating structure and the measurement instrument. Instead, an electromagnetic coupling is created between the sensor and the measureing instrument thereby greatly reducing the cost and complexity of the overall solution.

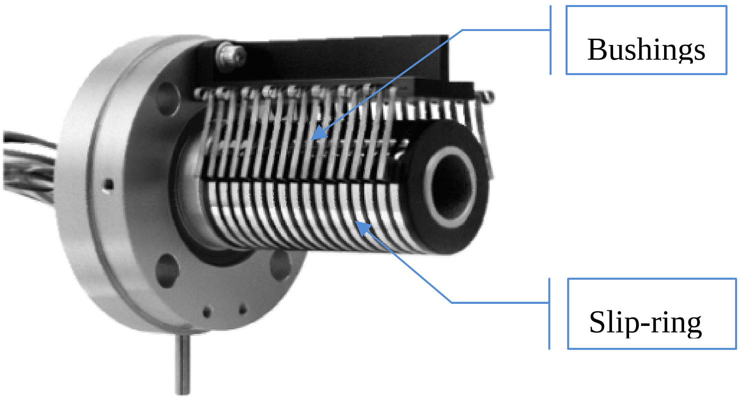

Fig. 1. Sample Slip Ring Construction[2].

Infrared thermometers offer a feasible alternative to thermocouples and sliprings. Due to their optical nature, these thermometers can be focussed onto the rotating structure with the use of a laser guiding device and be 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. Wireless temperature sensors offer the advantage of being able to be located at specific locations on the rotating structure. Further, there are specific adjustments that need to be made to the IR thermometer to compensate for reflected and refracted radiation from the rotating structure. Additionally, IR measurements require line of sight requirements and compenstations for the various emmisivity functions of the surface being measuremnt. Although not insurmountable, these add to the overall burden of setting up and maintaining an IR thermometric solution.

3. Wireless Surface Acoustic Wave (SAW) Based Temperature Sensing

Traditional methods of measuring temperature have relied on the temperature dependence of resistance (thermocouples), 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. Mechanical/acoustic waves, electrically induced into certain piezoelectric materials are known to be highly responsive to temperature changes. SAW based temperature sensing, which is described in detail below, involves electrically inducing acoustic waves and then reconverting the energy of the transduced wave back into an electrical signal for temperature measurement. One significant advantage of SAW devices is their low power consumption making them very amenable to wireless interrogation. A wireless SAW based temperature sensing solution consists of a Wireless Interrogator (RF Transceiver) that is electromagnetically coupled with a SAW sensing element as shown in Fig. 2. SAW wireless sensors are completely passive and do not need batteries or wires to transmit temperature information. Furthermore, through use of independent frequency bands the sensors maintain unique identification within the system architecture.

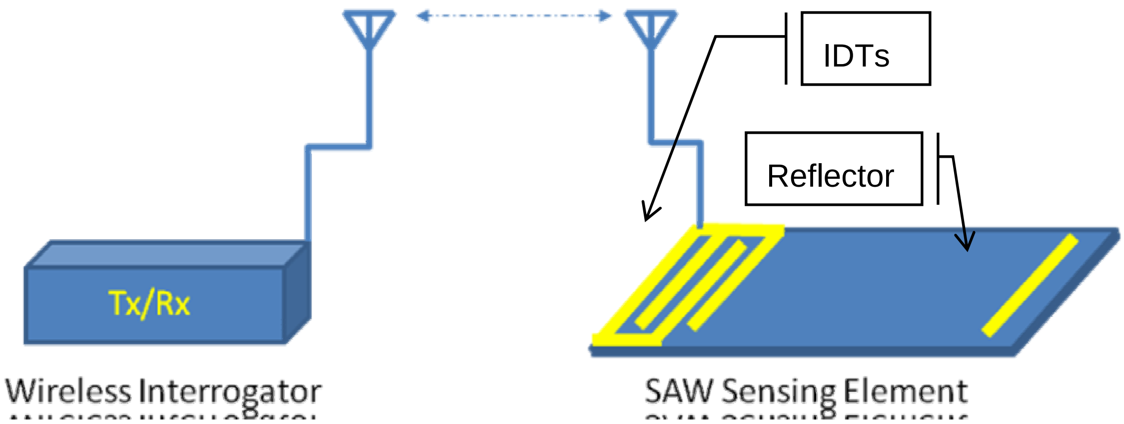

Fig. 2. Wireless SAW Temperature Sensing Solution.

A typical interrogation cycle includes the following steps:

- The wireless interrogator generates a Radio Frequency (RF) signal which is converted into an electromagnetic signal by the interrogator antenna (which operates in the ISM band).
- The electromagnetic signal is transmitted in free space and is trapped by the sensor antenna, which converts it back into an RF signal.
- The RF signal induces an acoustic wave in the piezoelectric sensing element via Interdigital Transducers (IDTs; the comb-like pattern of metal on the device that converts the electric field energy to mechanical wave energy and then back to an electric field)).
- This acoustic mechanical wave is reflected back to the IDTs by the reflector on the sensing element.
- The frequency of the acoustic wave 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 IDTs convert the reflected acoustic wave into an RF signal, which in- turn, is transmitted back to the transceiver via the same antenna set.
- A change in the frequency of the received RF signal is indicative of a change in the measured temperature.

A commercial SAW temperature sensor (see Fig.3) offered is a 433.78MHz one-port SAW resonator structure specifically designed to have a linear frequency versus temperature characteristic (see Fig. 3). With a temperature coefficient frequency of 16.2 ppm/°C (~7028 Hz/°C), it is operable from 0 to 120°C. The sensor has an unloaded Q of 8000, it is low loss (2.5dB max) and it is designed for a 50-Ohm system. When combined with an antennae and interrogation unit, this SAW sensor chip makes a great solution for numerous wireless temperature sensing applications.

The wireless sensors works within the ISM 433.92 MHz for the defined operating temperature range. The sensors are designed to provide instantaneous wireless temperature measurements for embedded real-time, in-line environments requiring high resolution and accuracy. A characteristic of the SAW temperature sensors is their exceptional stability characteristics, passing DIN IEC 68 T2-27 specifications for shock rating and screening according to DIN IEC 68 T2-6 standards for vibration rating. Temperature stability characteristics are assured by DIN IEC 68 Part 2 – 14 Test N standards.

Such wireless temperature sensors have been installed in commercial markets such as cooking ovens. And currently they continue to be evaluated for industrial applications, such as the determination of contact temperature in high voltage breaker boxes in the electrical power industry and monitoring of temperature in rotating equipment.

Customers in the marketplace are offered a starter kit that allows for the evaluation and validation of wireless temperature technologies and products (see Fig. 3). The starter kits are offered with an interrogation unit and standard off-the-shelf antenna which can be easily attached to a computer for data capture and visualization. The number of sensors that can be interrogated and the design of the antenna are application specific considerations that are addressed by modifying the interrogation electronics, sensor characteristics and antenna design.

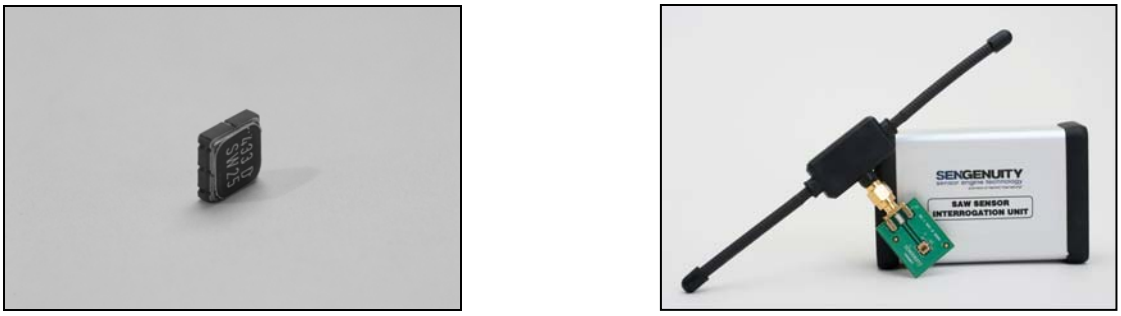

Fig. 3. Wireless temperature sensor and TempTrackr™ wireless temperature measurement system.

The TempTrackr™, SenGenuity's suite of wireless temperature sensing products, can be used to determine the viability of offered wireless temperature sensing solution for applications such as rotating machine components. The TempTrackr™ platform for example specific to rotating machines, includes a single wireless interrogator, a capacitive antenna and capacitively coupled wireless sensors mounted on a rotating surface.

The wireless interrogator excites the sensing element within each sensor as it passes by the capacitive plate. The response generated by each sensor is fed back to the interrogator in a timeframe that is a fraction compared to the total time the sensor is within the vicinity of the capacity plate. Rotation speeds of up to 100 rpm have been achieved.

The wireless interrogator is controlled by PC based software shown in Fig. 4. The software can be configured to record the maximum noted temperature, the minimum noted temperature, the average temperature and standard deviation. Tracking these metrics over time can yield to early warning indications of problems within the rotating component. The wireless interrogator can be seamlessly interrogated with a CAN enabled instrumentation platform.

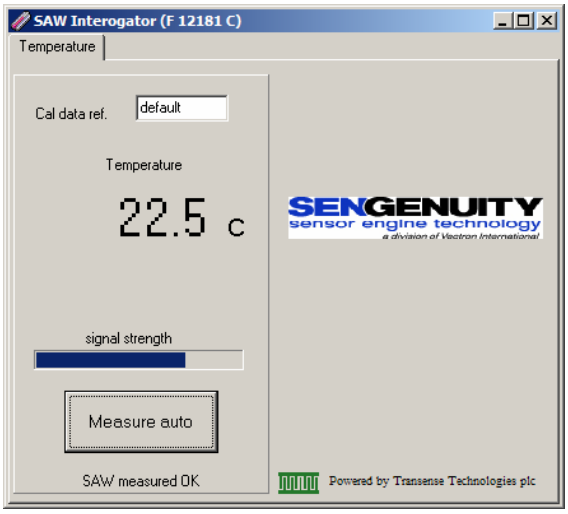

Fig.4. TempTrackr™ Software Interface.

Because the SAW sensors are passively energized, they do not require batteries, and the interrogation electronics can be such that allows for easy integration into any host control or data acquisition system.

Also given the advanced packaging and manufacturing techniques are well-established for acoustic wave devices, they are an attractive candidate for wireless sensor applications where a small footprint coupled with cost-effectiveness, and robust/reliable design with very low power requirements are critical for wide-scale implementation.

In conclusion, wireless acoustic wave temperature sensors have unique features that allow customers to address specification needs and requirements that otherwise may not have been possible due to design constraints and sensor suppliers are well poised to provide solutions for these multiple applications.

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[2]. http://www.fabricast.com, 2009.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

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