Transense SAW Sensors for Torque and Temperature Measurement in next-generation smart electric drive systems

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Abstract. The accurate measurement of torque and bending loads on rotating shafts is essential for the validation, optimisation, and safe operation of mechanical systems across a wide range of industrial sectors, including automotive, aerospace, marine, energy generation, and industrial power transmission. Traditional shaft instrumentation approaches typically rely on strain gauges combined with slip rings or active telemetry systems, introducing challenges related to wear, signal integrity, power supply, and long-term reliability [1]. Surface Acoustic Wave (SAW) based sensing technology provides a passive, wireless alternative for measuring torque and temperature directly on rotating components. These sensors respond to strain induced on the shaft surface and are interrogated using radio-frequency signals, eliminating the need for rotating electrical connections. This extended abstract presents a practical overview of the complete instrumentation process for a SAW based measurement system created by Transense Technologies PLC, including component strip-down, sensor installation, shaft reassembly, calibration, and testing. System performance, and application benefits are also discussed.

Introduction

Transense develops and manufactures advanced Surface Acoustic Wave (SAW) wireless and passive sensor systems to measure torque, force, pressure, and temperature [2] enabling our customers to accurately measure application-critical parameters in real time. The SAW sensors are passive elements, which do not need power supply, and can be accessed wirelessly, enabling remote monitoring in harsh environment. The SAW sensors are interrogated by an RF signal produced by a dedicated and proprietary ASIC developed by Transense enabling a highly accurate and compact sensor solution that can be deployed in a cost-effective manner at scale.

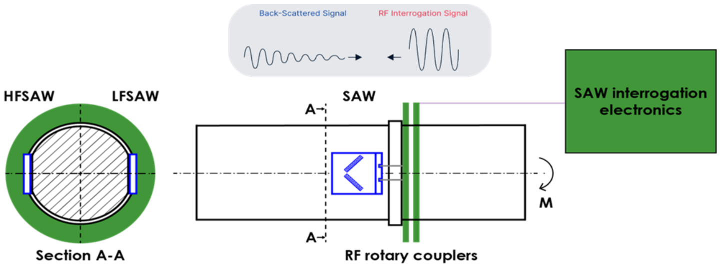
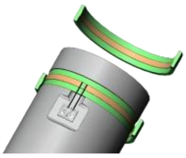


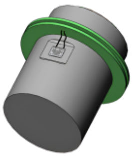
Fig.1. Diagram shows an example of the setup of a typical shaft application measuring torque.

The sensor design usually involves some modifications of the standard shaft to provide flat spots for attaching the SAW sensing elements and ensure the optimum nominal strain level of 350 - 400 microstrain depending on the trade-off between the resolution and the over torque. The modifications require a careful finite element analysis of the component [3].

Components required on the part being measured: All Quartz Package (AQP) bonded to a flat surface and RF Rotary coupler. Components used for coupling: stationary coupler, ASIC for generating and receiving the RF signal, and MCU for signal processing.

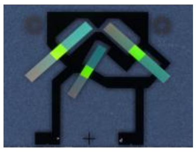


(a)



(b)

(c)



(d)

Figure 2 (a) and (b) showcasing examples of radial and planar style rotary and stationary coupler arrangement for transmission of RF signals. (c) showcase an IndyCar torque transfer shaft with SAW sensor and a radial style rotary coupler. (d) showcase AQP 40 times magnified under a microscope.

The SAW-based torque and temperature system consists of HFSAW (contains three one-port resonators) and LFSAW (contain two one-port resonators) elements each positioned at ±45° to the shaft axis, opposite to each other hence they are sensitive to torque and insensitive to the bending force applied in both planes [4]. Instrumentation of an existing component begins with a complete strip-down of the shaft assembly to provide access for surface preparation and sensor installation. Shaft surfaces are cleaned, prepared, and inspected to ensure optimal bonding conditions. AQP and mechanical couplers are installed as required to support the sensing architecture. An oscillating electric field is utilised in piezoelectric acoustic wave sensors to create a mechanical wave, which propagates through the substrate, then transformed back to an electric field for measurement [5].

Calibration is performed by applying known torque [6] at a known temperature across the operational range of the shaft. Calibration matrices are generated to relate sensor response to applied loads and temperature. This process is essential for achieving accurate and repeatable measurements, particularly in applications where combined loading occurs. Dynamic testing is conducted under rotating conditions to verify signal stability, noise performance, and frequency response.

Graph in Figure 3 shows measurement uncertainty which is the average measurement error at a given applied torque using SAW based sensor on a high-speed motorsport application. Maximum error was 0.46% at 100oC and -296.7Nm, an accuracy of <0.5% could be claimed.

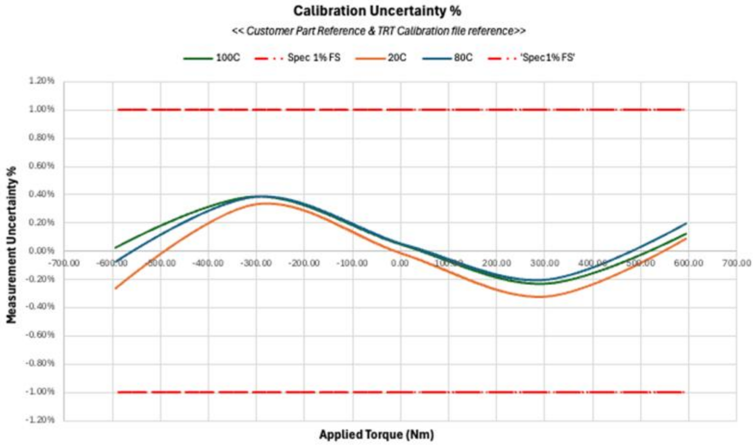


Figure 3

High temperatures lead to frequency shift. The SAW sensor's resonant frequencies have a linear relationship with strain at fixed temperatures however strain sensitivity is significantly impacted by temperature [1].

Conclusion

SAW-based shaft instrumentation provides a robust, accurate, and practical solution for wireless torque measurement and orthogonal bending moments on rotating components. The described instrumentation process demonstrates that complete re-instrumentation can be achieved efficiently while maintaining mechanical integrity and measurement fidelity.

This technology is well suited to laboratory testing, field trials, and operational monitoring where conventional approaches are impractical or unreliable. Unlike magneto-elastic and Hall effect sensors, these devices are tiny, lightweight, and low-cost. They are insensitive to stray magnetic fields and can withstand variations in distance from the reader antenna. Additionally, their great strain sensitivity makes them suitable for normal or minimally modified parts [3]. Ongoing research is directed toward the development of multi-degree-of-freedom sensing systems capable of simultaneously measuring forces, loads, and bending moments across multiple axes.

References

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