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Heavy-Duty Telemetry Systems based on SAW Sensors

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Abstract:
The suitability of telemetry systems based on surface acoustic wave sensor technology for applications like temperature measurement within the electric motor on a system level is demonstrated.

Key words: SAW, rotor temperature, wireless sensing

Problem

The challenge of the application of wireless telemetry systems lies in the elevated temperature and the very limited space available within engine and transmission components. Current telemetry systems are bulky and consist of active components, especially amplifiers, usually with a limited resistance towards temperatures beyond 125°C and fast changing electromagnetic fields.

As a result, new approaches come into consideration, to speed up and improve the development process of hybrid and full-electric drivetrains. One such approach is based on surface acoustic wave (SAW) technology.

Technology

Sensors based on SAW technology, are already known to be suitable for wireless sensing under industrial conditions [1]. The sensors are robust, work passively and due to a batteryless function, the sensors can be applied under fairly high temperatures.

The system configuration described in this paper is based on the principle, where the specific change in resonance frequency of the SAW device, brought about by a temperature change, is being measured and converted into a temperature value [2].

System Solution

Such systems are ideally suited for the digitalization of hot and fast rotating objects that are difficult to access as for example the rotor within an electric motor. As no pre-amplifier or similar electronic circuitry is needed on the rotating part, the transmitter and receiver modules are significantly smaller and more robust than in conventional telemetry systems.

The applied telemetry system (Fig. 1) uses a modular design consisting of a SAW sensor, a sensor antenna, a reader antenna and the reader electronics. The reader unit consists of a continuous wave radar operating at 2.4 GHz. Both, the reader unit as well as the resonating SAW sensor are connected to a fiberglass enforced printed circuit board antenna in form of a ring. All components are tailored flexibly to meet the geometrical requirements of almost any engine design, no matter the rotor diameter, magnet type, rotational speed, oil cooling or electromagnetic interference.

Due to the minimalistic design, the entire system gets mounted inside the engine housing without influencing oil jets or the performance of the electric engine.

Test Bench vs. In-Car Measurement

The environment of a test bench allows more flexibility when it comes to measurement systems. Cable routings may be more chaotic and it is possible to test single components of a powertrain separately. Telemetry systems can be relatively spacious since it is possible to mount them on shaft extensions for several reasons.

When it comes to the testing of encapsulated modules or testing of integrated components especially during vehicle driving operation, to validate the entire system, shaft extensions and complicated wire routings become an issue. The challenge is to integrate a telemetry system into a prototype without significant changes of the engine size. Fig. 2 shows an excerpt of measurements of a hybrid car with an integrated SAW telemetry system, recorded during driving performance tests in Sweden in winter 2019 [3]. Hybrid powertrains have even less available space when the engine is integrated into the gearbox.

Findings

SAW temperature measurement systems are an enlargement of existing telemetry solutions. It addresses the demand to perform sophisticated measurement tasks in the field of automotive electric engine development.

The system can be used in the most confined of spaces and can be fully integrated in any electric motor housing without significant adoptions. The components can flexibly be adapted to any dimension of the engine under test. The operation temperature covers a wide range of -40°C to +275°C and only a one-point calibration is needed for accurate and precise measurements. The robust system setup delivers constantly reliable measured values, even at the highest speeds or under the influence of lubricants. Another unique feature is the stability in electromagnetic fields which makes it ideal for use in electric engines.

The system provides reliable and dynamical data and allows temperature measurements in places, that have not been accessible with conventional telemetry systems so far.

References

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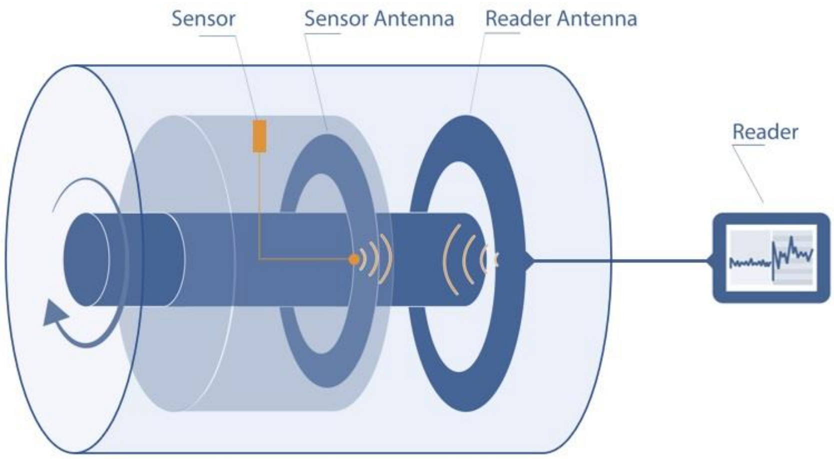

Fig. 1. System configuration SAW telemetry

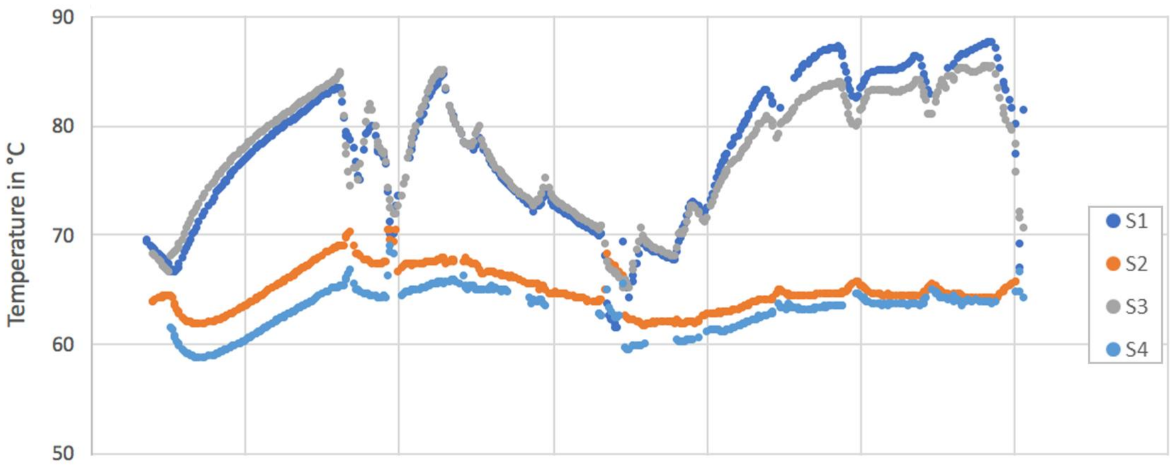

Fig. 2. Temperature plot over time (arb. unit) of a 4 channel SAW telemetry measurement with Sensors S1 to S4 during vehicle prototype tests in Sweden