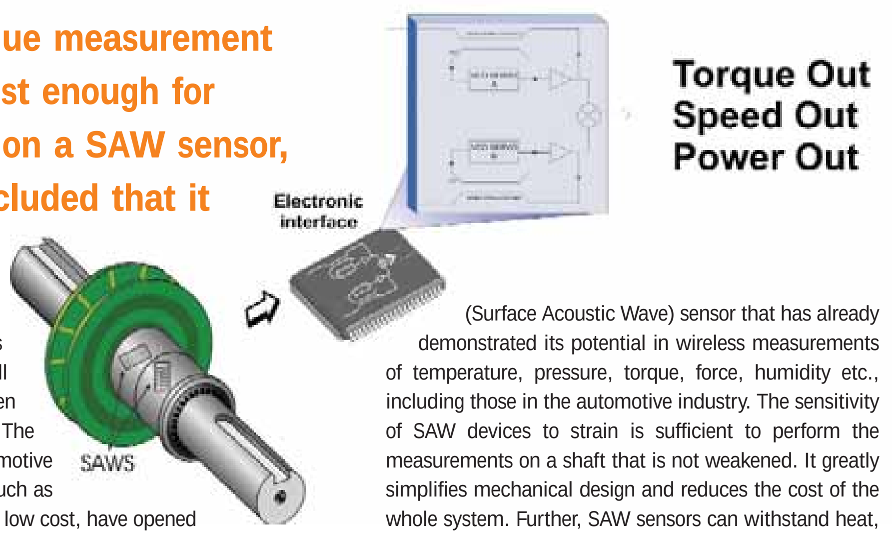
Robust sensors can improve the dynamics of servo drive systems

Much has been heard of non-contact torque measurement in recent years, but is the technique robust enough for mainstream use? Now independent trails on a SAW sensor, as made by Sensor Technology, have concluded that it stands to redefine servo systems design



With servo drive systems continually improving in performance capability, improved control of the electromechanical system dynamics is becoming an increasingly common industrial requirement. However, impulse transient demands from such systems can excite mechanical torsional resonances in the associated drive-train, ultimately leading to controller instability and premature failure.

Practical mechanical drive systems can be complex, incorporating several interconnecting shafts and elastic couplings, the dominant fundamental resonant frequency of which is typically less than 300Hz, which often overlaps with the closed-loop dynamic bandwidth imposed by the control scheme. The higher resonant modes often remain relatively unexcited, allowing a large proportion of typical industrial drive systems to be accurately modelled using a two-inertia approximation.

Until recently, difficulties in acquiring reliable, low-noise, low-cost, shaft torque transducers that are non-invasive to the mechanical drive system, have precluded the use of direct torque feedback in all but a minority of specialised closed-loop servo-drive systems. Often, commonly employed torque transducers such as strain gauge, optical and inductive devices, are too mechanically compliant when incorporated in a drive system, thereby degrading stability margins and reducing closed-loop bandwidth. Moreover, the additional cost associated with their integration is prohibitive.

Torque sensors play an important role in automatic controllers for a great variety of complex mechanical systems, from mixers to machine tools. Currently, one of the major consumers of torque sensors is the automotive industry. Sensors are needed to measure torque on drive-shafts and crankshafts of engines in order to optimise transmission and engine operation and improve vehicle stability. Torque sensors are also required for electrical power assisted steering systems (EPAS) that will be installed even in small cars. The benefits of automotive developments, such as high volume and low cost, have opened up the motor control market for SAW-based sensing systems, in-particular for motor torque feedback where significant system performance enhancements can be realised by the feedback of dynamic shaft torque information.

Eliminating the weak link

Most conventional torque sensors employ a weak link (for example a torsion bar) to translate torque into a relatively large mechanical movement that can be measured by a potentiometer, capacitive sensor, inductive, sensor, magnetic sensor or optical angular position sensor. Alternatively, a strain produced by the torque on the surface of the torsion bar can be measured using either piezoresistive or piezoelectric strain gauges. In any case, because of the big difference between nominal measured torque and the specified overload capability, a mechanical stop that complicates a mechanical design is usually required. Also, many of the above mentioned sensors need a clock-spring wire connecting the shaft and the stationary interrogation unit. This also adds to the complexity and cost of the sensor.

A search for a wireless device sensitive enough to omit the weak link and thus not requiring the mechanical stop has led to two most promising cost-effective candidates for high-volume applications. The first one is a magneto-elastic sensor the long-term stability of which still needs to be proven. The second one is a SAW (Surface Acoustic Wave) sensor that has already demonstrated its potential in wireless measurements of temperature, pressure, torque, force, humidity etc., including those in the automotive industry. The sensitivity of SAW devices to strain is sufficient to perform the measurements on a shaft that is not weakened. It greatly simplifies mechanical design and reduces the cost of the whole system. Further, SAW sensors can withstand heat, dirt and mechanical vibration that represent problems for other types of sensor. The fact that SAW sensors work at radio frequencies makes it easier to arrange a non-contact coupling between the rotating shaft and the stationary interrogation unit. A careful design of the latter allows reduction of the influence of electromagnetic interference to an acceptable level.

A typical SAW torque transducer contains two SAW devices mounted on a shaft of known stiffness. Each device consists of an array of thin metal electrodes deposited at fractional wavelengths apart on a polished piezoelectric substrate. An RF signal applied to the electrodes excites a surface acoustic wave over the device that resonates at a frequency determined by the distance between the inter-digital metal electrodes. Torsion applied to the transducer creates two components of strain, subjecting one SAW device to tension and the other to compression. The strain varies the resonant frequency of the SAW devices, the outputs of which are connected to an RF coupler. After mixing and signal processing, the sum and difference frequencies provide shaft torque, temperature and axial stress compensation. Since the SAW sensors operate at radio frequencies, typically in the 200MHz and 433Mhz ranges, a simple non-contact coupling between the rotational devices and stationary processing unit is readily achieved and, by careful design, the influence of electromagnetic interference can be reduced to acceptable levels.

Integration of the SAW sensor inside a servo-motor is viable, leading to a compact unit suitable for industrial servo-control applications.

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