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Topic : "Design of Online Torque Transducer with Wireless Data Transmission"

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Abstract

In a mechanical system, the acting mechanical power is the most important quantity of rotating shaft of machines. There are many methods to measure it such as by measuring the torque on the rotating shaft and measuring the rotational speed. There are many standardised instrument (eg. Tachometer) for the online measurement of the rotational speed whereas online torque measurement is complicated. Reliable and repeatable measurement is a crucial matter in every kind of system in which the operation is based on torque value. Conventional method of torque measurement includes setup utilizing dynamometer, belt and pulley system and torque estimation methods by measuring various parameters like power, current, speed, pressure, etc. However these methods have number of demerits like bulky, complex to set up, error, require careful calibration, limited to static torque (belt and pulley system) etc.

In order to overcome the demerits of indirect torque measurement and other conventional methods of torque measurement, ERDA has designed a system for online torque measurement called as torque transducer. This torque transducer to be fixed onto the machine shaft which can measure the torque and transmits the torque value / data to a PC located in the vicinity.

The paper provides detailed overview of various components of torque transducer and their principle of operation. Simulation results are also presented for various input torque values.

Keywords: strain gauge, wireless torque transducer, Wheatstone bridge

1. Introduction

Torque measurement is of fundamental importance in all rotating bodies and applies to the rotation of shafts in many things like pumps, rotational cutting equipment, gearbox shafts, vehicle axle, electric motor, engine, transmission, crankshaft, rotor, a bicycle crank. Measuring torque helps in reducing downtime, improving product quality, and maximising the energy efficiency of the test equipment. Based on these torque readings, process engineers can speed up or slow down the process, shut down the equipment to avoid any failure or diagnose any potential breakdown in the equipment. Torque measurement is also a necessary part of measuring the power transmitted by rotating shafts [1].

Conventional methods of torque measurement includes dynamometer, belt-pulley systems. Dynamometer is a direct method of torque measurement providing high accuracy and repeatability. There are various types of dynamometer viz., mechanical dynamometer, hydraulic dynamometer and electromagnetic dynamometer. Each type uses its specific principle to convert absorbed torque into a measurable form (force, pressure, flow rate, current etc). It can handle wide range of torque values and can be used for both static and dynamic torque measurement.

Belt-pulley system is relatively inexpensive and easy to set up system. The system involves a pair of pulleys connected by a belt wherein one pulley is attached to the shaft with unknown torque and the other pulley is driven by a separate motor with known speed. By measuring the speed difference and the known speed of the motor, the speed of the unknown torque shaft can be calculated. This method calculates torque indirectly. This system can be easily assembled and disassembled making them portable. It has no direct contact with the rotating shaft, hence no wear and tear problem.

These methods are simple to use, easy to setup. However, each of these methods have some demerits. Dynamometer method has demerit of high cost for high precision models, more complexity and non-portability owing to bulkiness of the system portable. Belt-pulley system method has greater inaccuracy due to indirect measurement method and belt spillage and pulley misalignment, limited measuring range.

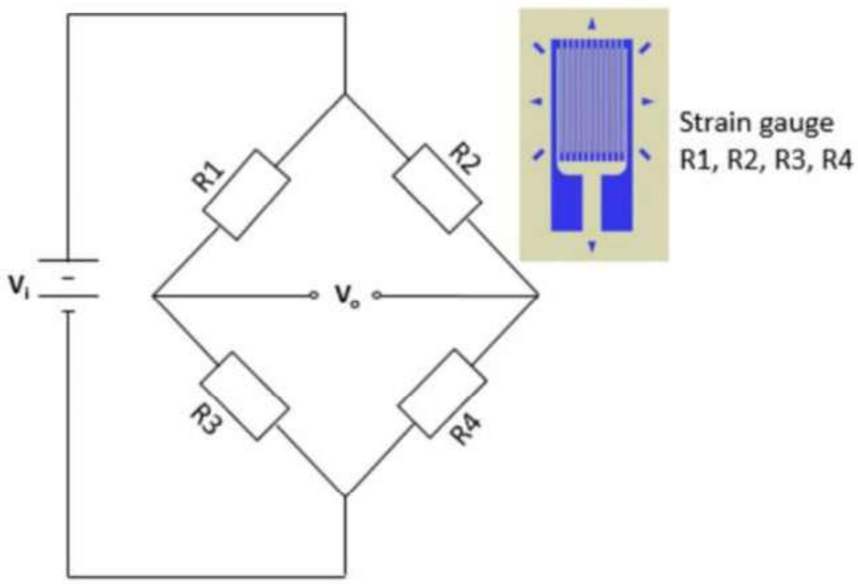
2. Proposed System

The proposed torque transducer system consists of following subsystems: 1) strain gauge 2) power management circuit 3) signal conditioning circuit 4) transceiver circuit 5) display unit.

2.1 Strain Gauge

The strain gauge is a type of sensor that converts the mechanical effect into an electrical signal. The strain gauge gets affected by the change in temperature which generates error. To overcome such error, the strain gauges are arranged in a Wheatstone bridge configuration which utilizes four number of strain gauges. This configuration is shown in figure 1.

Fig.1 Wheatstone Bridge configuration of Strain Gauges



This Wheatstone bridge configuration setup of strain gauges is mounted on the shaft of the motor whose torque is to be measured.

2.2 Power management circuit

The wheatstone configuration of strain gauge needs a DC power source for its operation. A rechargeable type lithium ion chemistry based compact coin cell can be used for the purpose. The battery charging circuit includes radio frequency (RF) power harvester along with buck-boost converter. The RF power harvester topology employs the RF receiver that converts RF into DC form. A buck-boost converter connected at the output of the RF receiver will process the DC output voltage at suitable level needed for charging the coin cell. The power management circuit ensures charging of the coin cell during shaft rotation.

2.3 Signal conditioning circuit

The small magnitude voltage (of the order of mV) obtained at the output terminals of the strain gauge is given to high precision instrumentation amplifier thus ensuring the amplification of the input data by a gain of suitable value. The analog signal obtained at the output of instrumentation amplifier is given to a microcontroller which converts the amplified output data into torque value by suitable calibration.

2.4 Transceiver Circuit

The transceiver signal conditioned data wirelessly to a monitoring station. It facilitates real-time data transmission, enabling timely interventions and monitoring.

2.5 Display Unit

Display unit comprises a computer located in the nearby vicinity.

3. Working of Torque Transducer System

When torque is applied to the shaft, the shaft gets twisted in the direction of rotation, thereby producing shear strain. This causes elongation in one gauge pair along opposite direction and compression in other gauge pair along opposite direction. These changes in the strain gauges lead to an increase in the circuit resistance due to tensile strain produced by one pair of gauges and a decrease in the circuit resistance due to the compression strain produced by the other pair. This leads to an unbalanced bridge and hence the change in resistance will develop an output voltage across the output terminals of the wheatstone bridge. Strain gauges work on the principle of the conductor's resistance which gives the value of Gauge Factor by the formula:

$$GF = \frac{\Delta R}{R * \varepsilon} \tag{1}$$

Where, ΔR = change in resistance, R = resistance of the unreformed gauge and ε = strain

Strain of a single strain gauge for balanced wheatstone bridge circuit is given by

$$\varepsilon = \frac{\varepsilon_i}{4} \tag{2}$$

Hence, it is evident that to achieve maximum bridge sensitivity, the two gauges are mounted in the direction of maximum tensile strain and remaining two gauges along the direction of maximum compressive strain.

The voltage received at the output of the Wheatstone bridge is of the order of mV which is amplified using a high precision instrumentation amplifier. The amplified output is fed to the microcontroller for ADC conversion. The transceiver circuit aids in displaying the obtained torque data on the monitoring station.

4. Simulation and Result Discussion

A simulation is carried out in MATLAB Simulink environment for conversion of known torque value into the strain and then application of obtained strain to strain gauges connected in Wheatstone bridge configuration (figure 2). The simulation results are displayed in figure 3. The application of obtained strain to strain gauges results in Wheatstone bridge output (of the order of mV) which can be amplified using high precision instrumentation amplifier. The amplified output plot pattern is found to follow the input torque pattern. This shows the linear relationship between the torque, strain and the amplifier output indicating that the amplified output can be converted to the torque post application of suitable scaling factor.

The working of the torque transducer shows that this system transmits the torque data to a monitoring station wirelessly.

Figure 2: Simulation for torque transducer

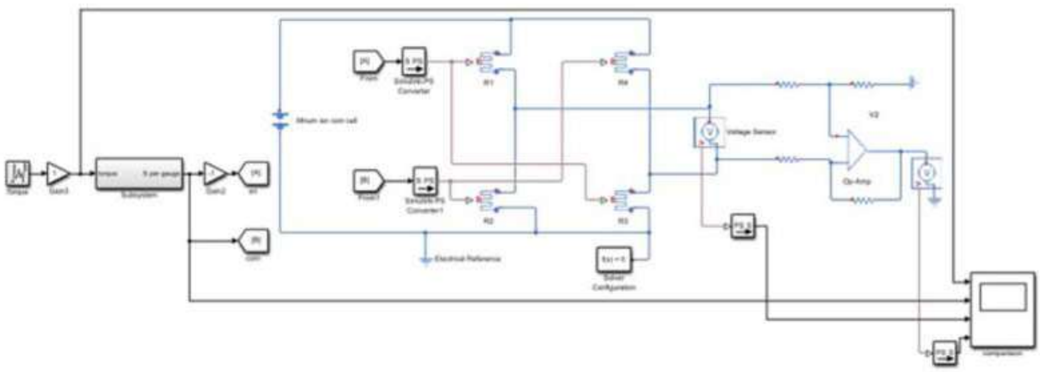
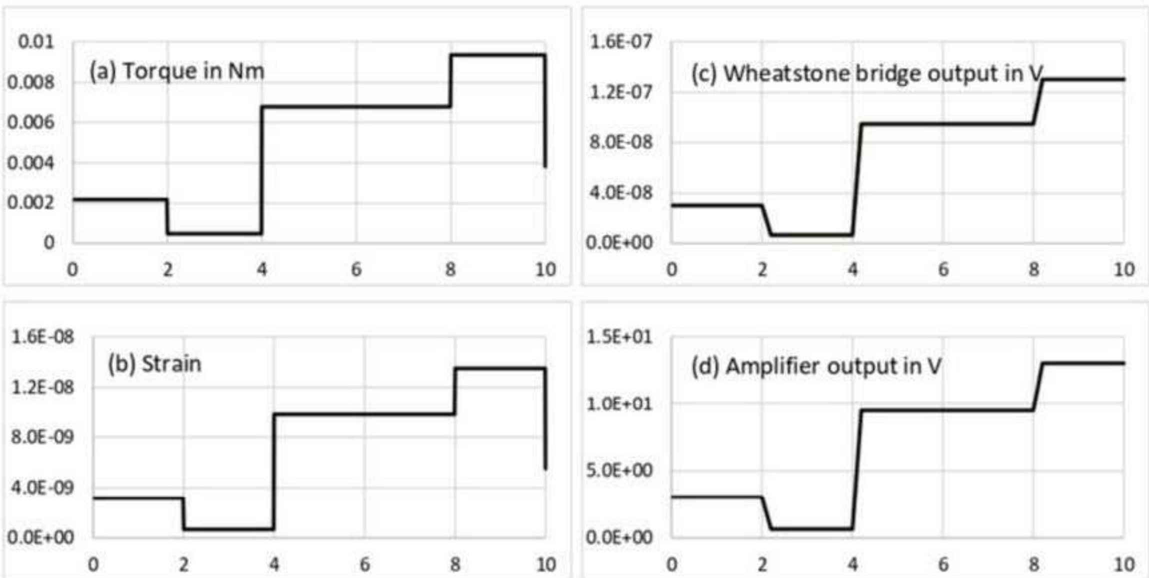


Figure 3: Simulation results



5. Conclusion

Concept of torque measurement using strain gauge is presented in the paper. Simulation carried out for the system along with its results are presented to support the theory / principle of operation. The proposed method of torque measurement is better as compared to the conventional methods due to various features of proposed system such as non-contact, compactness, light weight, retrofit type.

References

[1] D. Petreus C. Farca S P. Dobra, D. Moga, "Torque measurement system design," IEEE , 2008.

[2] M. Hilal Muftah and S. Mohamed Haris, "A strain gauge based system for measuring dynamic loading on a rotating shaft," International journal of mechanics, Issue 1, Volume 5, 2011.

[3] Rainer Schicker, R. S, "Measuring Torque Correctly", January 2022, from HBM an HBK company: https://www.hbm.com/en/0116/tips-and-tricks-torque-reference-book

[4] Krimmel, D. W. "Evolution and Future of torque measurement technology". Retrieved January 2022,

[5] S.M, V. "Data Measuring System For Torque Measurement On Running Shaft Based on non contact torsional Dynamometer"., Journal Of Engineering Science, 2019.