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Method of torque measurement based on volumetric strain

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Abstract

This thesis presents a method of torque measurement based on the volumetric strain principle. As opposed to the conventional methods of torque measurement where either the surface strain or angle of twist of a shaft is used, this method converts the applied torque into volumetric strain observed by the two sealed hollow chambers inside the sensing shaft. This volumetric strain is then read as a differential pressure signal using a high quality differential pressure transducer through an electronics readout design. With the designed ±5 V full scale, the resolution of the readout is 0.006 % at one standard deviation noise. The method is first presented and analyzed in terms of theoretical error sources. Then a prototype torque sensor is presented based on the proposed method and a Finite Element Method (FEM) analysis is conducted. With the proposed design parameters of the torque sensor, the FEM analysis showed that the range of the setup is ±300 N·m with a mechanical sensitivity of 2.131 Pa/N·m. The commonly available low range differential pressure sensors have a very high resolution, which is when combined with the mechanical sensitivity observed from the FEM analysis, enables a very high deformation-to-sensing factor. However, a search for the calibration setups for low range differential pressures indicated that there are no suitable calibration setups for the low range differential pressure transducers. This motivated the work of designing a high performance calibration setup for low range differential pressure sensors. The range of this setup is ±320 Pa with an achievable resolution of 0.001 %of the full scale. Using this setup the designed readout electronics along with the differential pressure sensor was characterized. Next, the prototype torque sensor was manufactured and the presented method of torque measurement using the volumetric strain is experimentally verified in two steps. The experiments are first conducted using a commercial torque wrench with the aim to compare the output of the sensor to that of the simulation results. Based on the experiments, the verified mechanical sensitivity of the setup is 2.31 Pa/N·m, which is well within the expected simulation-to-experimental offset margin. Next, the prototype sensor is placed in line with the high quality commercial torque sensor and output from both the prototype and commercial torque sensors is compared. Based on these experiments, it is concluded that the method of torque sensing utilizing volumetric strain of sealed chambers inside the shaft is fully applicable and can be used for torque measurements. This type of torque sensor can be used for in-line torque measurements in industrial applications. Moreover, the sensor can provide a high resolution in comparison to conventional torque sensors. Furthermore, the design of the sensor renders it less vulnerable to the harsh industrial common-mode errors such as pressure, axial loading and temperature changes. Future work is also proposed in order to optimize the design in terms of mechanical and environmental factors.

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