Problem 1

(a) Describe three different principles of torque sensing. Discuss relative advantages and disadvantages of the three approaches.

(b) A torque sensor is needed for measuring the drive torque that is transmitted to a link of a robot (i.e., joint torque). What characteristics and specifications of the sensor and the requirement of the system should be considered in selecting a suitable torque sensor for this application?

Solution

Problem 1

(a) Use Strain Gages

Strain gages are mounted on an existing member that transmits the measured torque. The strains are measured using a bridge circuit and conditioned using a bridge amplifier. The amplifier output is calibrated for the required torque.

Measure Reaction on Housing/Support Structure

Strain gages (or load cells) are mounted at the anchoring locations of the housing of the torque transmitting system. The forces that are needed to maintain the housing stationary are measured. The torque is calculated using the applicable equations, or calibrated using known torque measurements.

Measure Motor Current

If the torque is generated by an electric motor, the armature current (or field current in the case of permanent-magnet rotor) determines the torque generated by the motor. This magnetic torque has to be compensated for such factors as rotor inertia in order to determine the transmitted torque.

Approach	Advantages	Disadvantages
Strain-Gage Torque Sensor	• Common approach with standard instrumentation. • High signal output (with a bridge amplifier, which is common). • Reasonably linear and accurate.	• May have to include a new member or modification to mount strain gages (loading, reduction of stiffness and bandwidth. • Needs a commutating device as the member rotates. • Calibration is difficult for complex structures.
Reaction Torque Sensor	• Sensing location is stationary (commutation not required). • No mechanical loading by the sensor.	• Structural modifications may be necessary for mounting the gages. • Includes torque due to rotor inertia and should be

	• Bearing friction and magnetic torque of motor do not enter into the result.	compensated for. • Sensitivity may be poor.
Motor-Current Torque Sensor	• Not very intrusive on the system. • Current measurement is simple and does not require expensive sensors. • System stiffness and bandwidth are not affected/degraded.	• Measures magnetic torque which has to be compensated for such effects as inertia and damping. • Current readings can be noisy and nonlinear (particularly if both field current and armature current are variable).

(b) Sensor Characteristics

- Principle of operation should be compatible with the required measurement (for example, current sensing approach is not possible with a hydraulic manipulator).
- Nature of the sensor output (e.g., Is the output available in a linear form? Is compensation needed?).
- Effect on the original system (e.g., Will the sensor introduce mechanical/electrical loading? Will a strain sensing member be needed? Will the necessary members and modifications introduce loading and reduce stiffness, bandwidth, etc.?).
- Cost and availability.
- Is commutation needed in acquiring the sensor signal?
- Form of the signal output (DC, AC, modulated, etc.).
- Impedance characteristics of the sensor.
- Signal conditioning requirements.

Sensor Specifications

- Accuracy.
- Speed of response/bandwidth.
- Dynamic range and resolution.
- Output signal level.
- Linearity.
- Impedance

System Characteristics and Requirements

- Minimal intrusion (modification).
- Availability of mounting locations.

- Is the required performance of the system achievable with available sensors?
- Time constraints on having the final system operational.
- The purpose of the torque sensing (system monitoring, diagnosis, control, etc.).
- Nature of the control system that uses torque sensing.
- Available budget.
- Would one sensor be adequate for measuring the required torque?\