Birefringent Sensors for Motors

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Introduction

- Strain Measurement
  - strain gage
    - provides point-by-point data
  - photoelasticity
    - provides point-by-point data or full-field data
    - non-destructive measurement
    - static and dynamic measurements
    - higher bandwidth

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Photoelasticity

- Birefringent materials have the ability to resolve an impinging light vector into two orthogonal circularly polarized components which propagate with different velocities through the material.
- Transparent photoelastic materials such as some polymeric plastics or glasses become birefringent when stress is applied.
- When linearly polarized light is transmitted through a birefringent plastic relative phase retardation will occur.
- The light exiting a birefringent plastic can be passed through a linear polarizer to convert the phase retardation into a two-dimensional intensity patterns.

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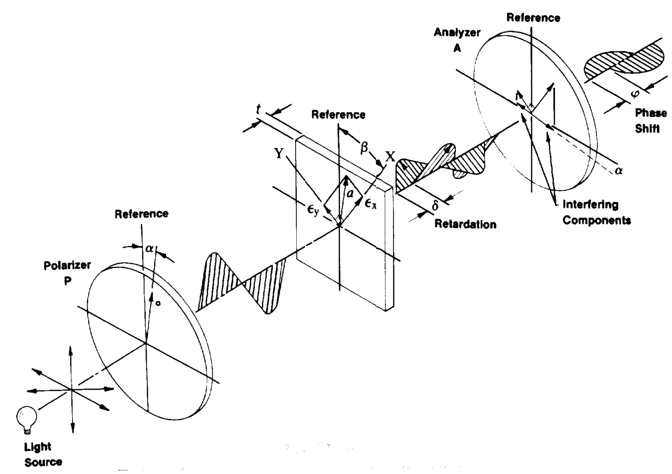
Optical Strain Analysis



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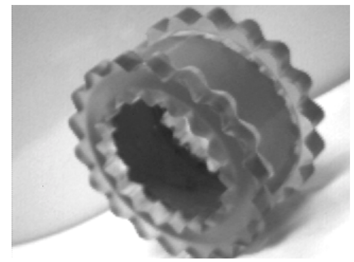
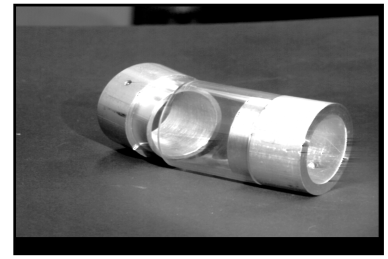
Photoelastic Strain Analysis

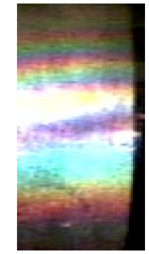
- primarily used to provide a qualitative analysis of the deformation or residual strain in a component
- typically needs human interpretation for proper analysis
- neural network image processing is proposed for analyzing the fringe patterns of a shaft coupler made from birefringent plastic.

Sensor Description

- polycarbonate plastic coupling with a high strain-optical coefficient
- coating of aluminum filled epoxy on the inner surface of the plastic coupling to reflect light back out







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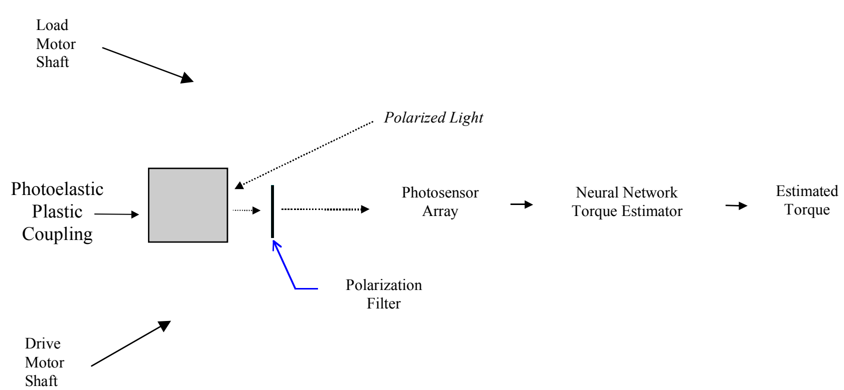
Conceptual Optical Torque Sensor



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Neural Network

- nonlinear processing elements operating in parallel and arranged roughly similar to biological neural networks.
- processing elements (nodes) are connected via weights (synapses) that are typically adapted during training phase.
- incoming signals (stimulus) are multiplied by the weights, and summed at the processing elements, or nodes.
- can learn a mapping between the given inputs and corresponding outputs through training samples.

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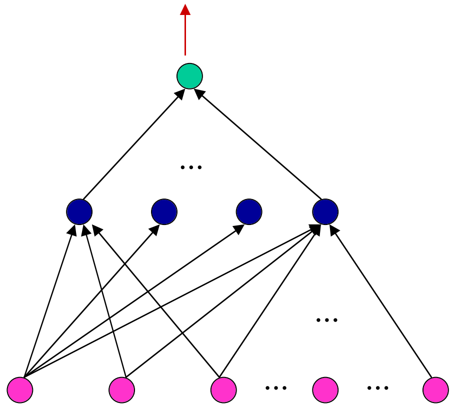
Neural Network



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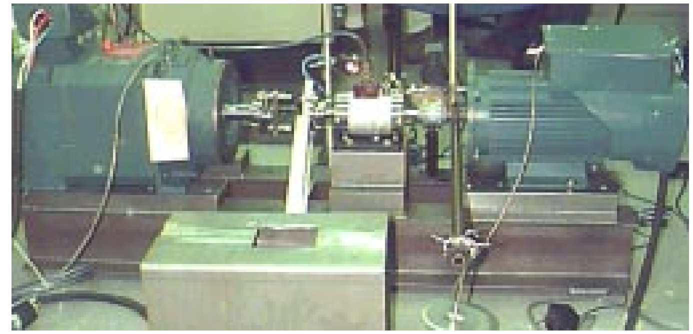
Experimental Setup (Static Test)



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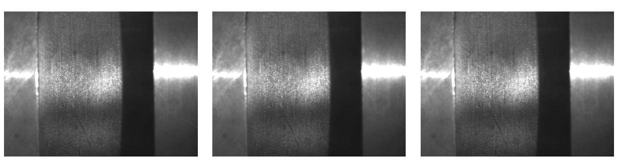
Typical Optical Torque Sensor Images



(a) 20 pound-inches (b) 40 pound-inches (c) 60 pound-inches

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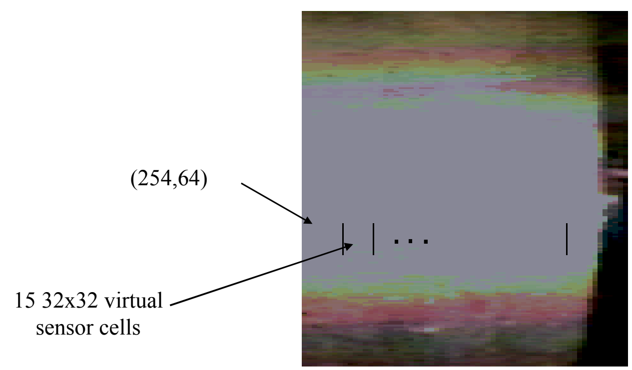
Image Pre-Processing



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Experimental Setup (Dynamic Test)

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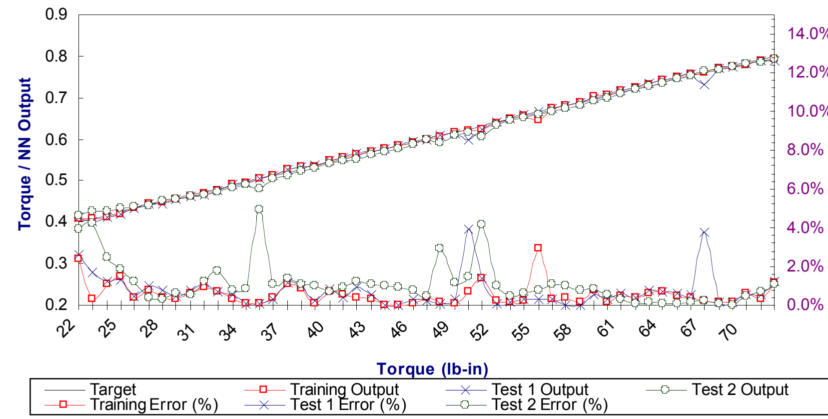
Static Test Result



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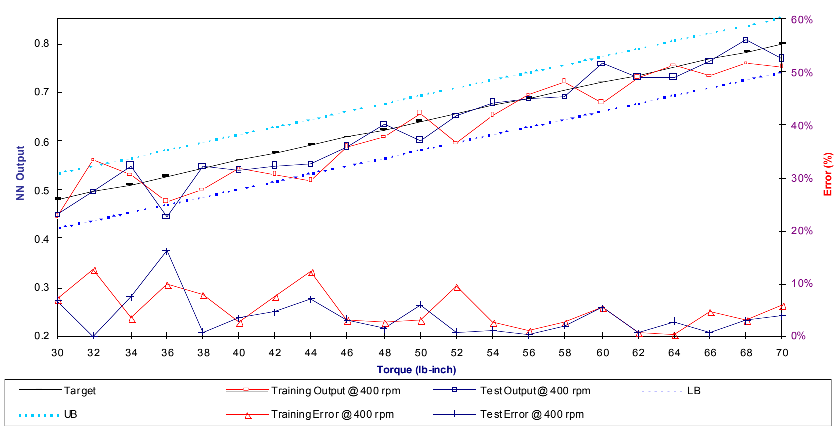
Dynamic Test Result (Low Speed)



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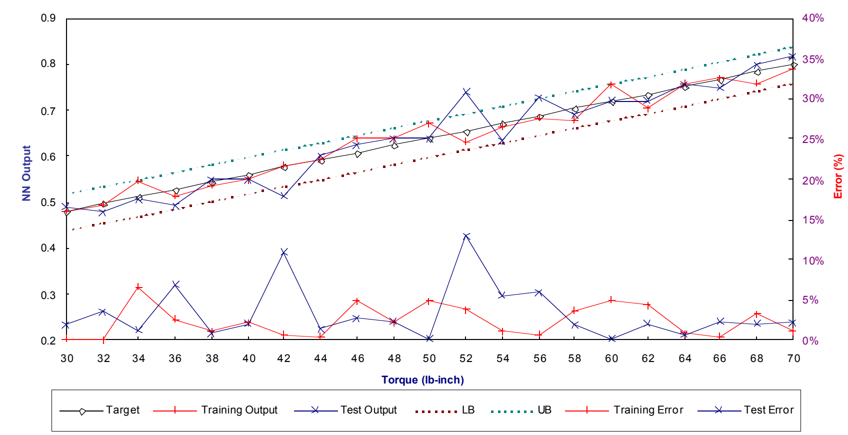
Dynamic Test Result @ 900 RPM



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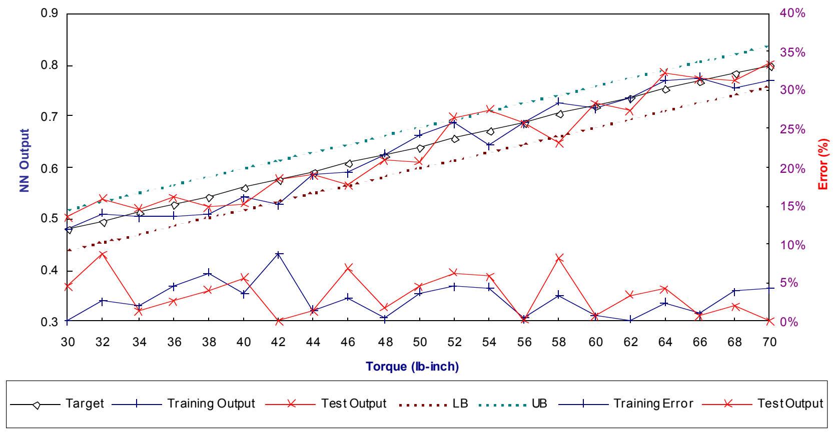
Dynamic Test Result @ 1500 RPM



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Conclusions

- accurately measure static and dynamic shaft torque values
- static test results showed less than 1% error.
- dynamic test results showed 3.3% error at 900 rpm and 3.5% error at 1500 rpm
  - for these dynamic tests, the torque fluctuation from the test apparatus was reflected to the results.
- use non-contacting optical sensing to produce a motor torque sensor
- replace CCD camera by a linear array of photodetectors with a considerable reduction in system complexity

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