UNC Charlotte – Lee College of Engineering Senior Design Program

Company Information

Company Name	*United Protective Technologies, LLC*	**Date Submitted**	*11/12/2024*
Project Title	*Design of a Test Fixture to Characterize Stiction in Actuators (UPT_STICTION)*	**Planned Starting Semester**	*Spring 2025*

Senior Design Project Description

Personnel

Discipline	Number	Discipline	Number
Mechanical	3	Electrical	1
Computer	1	Systems	

Company and Project Overview:

United Protective Technologies (UPT) is an R&D-focused company with a commercial applications capability. UPT applies thin-film coatings to high-value components to provide wear resistance, reduce friction, prevent corrosion, and extend operating life. The commercial offerings have all been developed from R&D work done under the Small Business Innovative Research (SBIR) program. See https://www.upt-usa.com/

Project Requirements:

Thin-film Diamond-Like Carbon (DLC) coatings protect surfaces in contact and reduce the coefficient of sliding friction at critical interfaces. Recent work has been undertaken to deploy these coatings as replacements for hexavalent chrome coatings due to the cost savings in coating application and the reduced environmental impact of the DLC coating process compared to hexavalent chrome application.

While the running friction coefficient of DLC coatings, when applied to metallic surfaces, is well understood, the coefficient's transient behavior is not. This is due to the limitations of the standard tribological test equipment (See ASTM G99 and G144). Additionally, the friction behavior of DLC is not well understood when running against elastomeric seals often encountered in actuators.

The phenomenon known as “Stiction” (the transition between static and dynamic friction) [https://www.sciencedirect.com/science/article/pii/S0959152407001102] often requires that actuators be continuously dithered to maintain predictable control forces when system stability is affected. The actuator surface finish must be carefully balanced to maintain a tribological film with surface asperities while minimizing wear to seal surfaces from surface roughness. It is hypothesized that the oleophilic nature of DLC coatings will allow smoother surfaces to be used on dynamic sealing surfaces, extending seal life. It is also hypothesized that this phenomenon will allow a reduced difference and smoother transition between static friction and dynamic friction in actuator seals.

This project will build an experimental test device and perform experiments to test these hypotheses.

Expected Deliverables/Results:

- Literature search for stiction experimental work and results
- Design of a test fixture composed of a pressurized cylinder with an actuation rod, designed with standard dynamic sealing geometry [https://www.parker.com/content/dam/Parker-com/Literature/O-Ring-Division-Literature/ORD-5700.pdf] The test fixture should be designed such that the rod can all be easily disassembled so that desired coatings may be applied. Off-the-shelf (COTS) parts should be sourced for this purpose. The test fixture should be designed to move the rod at multiple speeds, and to record the forces required to do so. Data acquisition should be designed to capture the force at a sampling rate commensurate with anticipated surface roughness changes at the speed of piston travel, with a minimum of 4x oversampling of the data.
- An additional test fixture will be designed to compute the contact stress imposed on the rod by the device seal. This may be integrated into the main device or be a small, stand-alone device. Calculations to support this design will be required at the first design review.
- The test device(s) will be designed to be powered by 110V A/C delivered by a standard wall outlet.
- All electronics will be packaged and enclosed to prevent operator injury and system damage from the environment.
- The test device will be designed to be portable, on a rolling cart or other mobile platform.
- An experimental matrix showing planned experiments, with baseline data on no coatings, standard hydraulic rod coatings, and DLC-coated components. Multiple hydraulic fluids and seal elastomers should be included in the test matrix. Seal cross-section may be varied or fixed, depending on the results of the literature search and conversations with the Project Support Team.
- The Project Support Team will receive a final report showing experimental results, findings, and conclusions. Fixture drawings, electrical schematics, data files, control and function code, and all other project materials will be transferred to the Project Support Team. If the project produces publishable results, project participants must be willing to sign a publication release. In this case,

the students and the Faculty Mentor would be invited to appear as coauthors for any resulting publication.

Disposition of Deliverables at the End of the Project:

The test fixture is anticipated to be located on campus for the duration of the project and then delivered to UPT in the PORTAL Building on campus upon project completion, as directed by the Senior Design Committee. All electronic files, including data and written reports, will be delivered as agreed by the Faulty Mentor and the Project Support Team.

Suggested skills for team members:

- All
  - Interest in continued study of engineering at the graduate level
  - Experience as interns
- Electrical Engineer
  - Electrical circuit design
    - Low voltage control
    - Device power
    - Sensor data acquisition
  - Experience generating circuit schematic CAD drawings
  - Familiarity with Nyquist-Shannon sampling theory and frequency analysis of acquired data
  - Experience with Arduino or other microcontroller computer programming and implementation
- Mechanical Engineer
  - CAD Design
  - Completed Machine Design (Minimum of Mechanics of Materials)
  - Fabrication experience
  - Interest in engineering mechanics
- Computer Engineer
  - Experience with Arduino or other microcontroller computer programming and implementation
  - Experience with signal acquisition and file export
  - Experience with computer hardware construction and integration
  - Familiarity with Nyquist-Shannon sampling theory and frequency analysis of acquired data