SECS Senior Design
Available Projects – Fall 2023

Development of a Multi-Image Sensor (MIS) Pipeline Inspection Camera

Sponsor: Telespector Corp, Dave Piccirilli (davepic@telespector.com)

Telespector is a Michigan-based manufacturer of waste and storm water pipeline inspection and joint sealing repair systems.

Project Overview

Currently, most pipeline inspection cameras are electromechanical devices which require small electric motors, gears, bearings and waterproof seals to pan and rotate the head of a single-image video camera. The moving parts of the camera head are often damaged due to accidental mishandling which leads to expensive repairs and downtime. If the seals fail, wastewater can enter the camera body causing extensive damage to the electronics.

With the advances in small CMOS video image sensors, video stitching technology and small high-intensity LED lighting, we believe that a multi-image sensor camera that mimics the operation and viewing range of a mechanical pan and tilt camera is a viable option. This camera would have no moving parts, gears, and dynamic seals, eliminating the vast majority of pipeline camera failures and associated downtime.

Project Scope

- Ascertain the feasibility of developing a 360-degree, multi-sensor camera that meets the requirements of this project, utilizing as much off-the-shelf technology as possible.
- Create a working prototype that fits the size constraints and requirements of a modern pipeline inspection camera.

MIS Camera Requirements

- Operate the stitching or viewing function with a joystick to mimic current pan and tilt camera operation.
- Object measurement capability through the forward-looking image sensor.
- Pipe diameter and roundness (ovality) measurement through the forward-looking image sensor.
- Camera designed for easy maintenance.
- All image sensors must have high definition (1080P minimum) specifications.
- All image sensors must have digital zoom capability.
- Video and signal transmission through 150-ft of cable (HD over coax).
- Minimize the number of conductors in the transmission cable by utilizing current multiplexing technologies.

- Operation voltage 12-36 VDC.
- Electrical protection for over/under voltage, short-circuit, reverse polarity and power-on-coax.

We have relationships with companies that may provide hardware for some of the above-mentioned requirements and other companies through internet research e.g., gopro.com, video-stitch.com.

NOTE: Confidentiality and assignment agreements are required before students can begin work on this project.

Small-Scale Prototype of Drop Weight Impact Testing System

Sponsor**:** Marco Gerini-Romagnoli, Ph.D. (geriniromagnoli@oakland.edu)

Project goals and objectives

The project involves the development of a small-scale prototype of a drop weight impact testing system. The full-scale machine will be used primarily to test the impact strength of crash-resistant adhesive joints, in a lap shear configuration.

Design Specifications

The target specifications for the full-scale model are:

- Energy range: 1 – 450 J
- Max impact velocity: 4.5 m/s
- Max drop height: 1 – 1.5 m
- Max drop mass: 25 kg
- Mass increments: 5 kg
- Max specimen length: 100 mm (between grips)
- Total machine height: 2.5 m

Deliverables

The scale model should consist of:

- Drop tower frame.
- Drop weight hoisting and retention system. The drop height should be adjustable.
- System to detect impact force and specimen deformation, with acquisition system (e.g., Arduino).
  The system may be based on accelerometer(s), optical encoder(s), or similar solutions. If an accelerometer or load cell is used, the impact load/acceleration detector should be attached to the anvil, not to the striker.
- Simplified grips for flat dogbone specimens (0.3 – 1.5 mm thick) loaded in tension.

The scale model should be able to accept specimens with the following properties:

- Shape/Size: rectangular 10 x 1.5 mm cross section, 30 mm length
- Stiffness: 15 kN/mm maximum

The samples will be provided by FAJRI. Moreover, the scale model should be designed with the following design constraints in mind:

- Suggested scale (height): 1:5
- The scale model must demonstrate stability in operation.
- A transparent protective enclosure must be in place before the operator is allowed to hoist the drop weight and start the test. The enclosure may be replaced with a safety system of equal (or superior) effectiveness if needed.
- NVH considerations: can the noise associated with impact testing be minimized?

Additional deliverables:

The design of functional grips may be too complex for the small-scale prototype, and it is not required. It is acceptable to have two screws holding the sample on the machine at both ends. However:

- The prototype should be designed to be possibly retrofitted with a penetration testing fixture and striker. The design of these components is not required, but a schematic of the conversion/retrofit operation is welcome.
- Detailed cost estimate for the full-scale apparatus.

Similar, commercially available equipment

- Instron 9400: the Instron 9400 is the most popular drop weight impact test system. It uses compressed air to increase the striker's speed, shortening the stroke.
  Brochure: https://www.instron.com/-/media/literature-library/products/2020/02/9400-series-drop-tower-brochure.pdf
  Video: https://www.youtube.com/watch?v=K1eWMOZdB0o (tensile configuration at minute 0:41)
- University of Porto: MS Thesis, Development of a Drop Weight Machine for Adhesive Joints Testing: https://repositorio-aberto.up.pt/bitstream/10216/119362/2/321326.pdf

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Design and Implementation of a Microcontroller Based High-resolution Impedance Sensing System for Chemical Sensors

Sponsor: Hongwei Qu, Ph.D. (qu2@oakland.edu)

Goal

The project is to design and implement a sensing and visualization system for chemical sensors with current output. The system will feature a 20-bit high resolution, and capability of microcontroller-based data processing, storage visualization and communication.

System Description
The sensing system will consist of a transimpedance sensor interface circuit with potentiostat reference, and a 24-bit analog-to-digital converter (ADC). The acquired sensing data will be processed by a 32-bit microcontroller with peripherals for data visualization, storage, alarm setting and wireless (Bluetooth) communication with other devices. The total power consumption of the system will be limited to 200 mW.

Student Involvement
With supervision from the sponsoring faculty member, the participating students will design the front-end transimpedance amplifier (TIA), select and program the microcontroller, interface and peripherals using Python or C++ for data processing, storage and visualization. Then the students will implement and test the system on bread board level. A hand-held enclosure with visualization panel can be designed and 3-D printed for the system.

Drag Reduction System (DRS) on Rear Wing of FSAE Car

Sponsored by Members of FSAE Team: Bianca Vitale, Nicholas Spanos, Logan Rey, and Rafil Yousif

Team & Project Overview:
Formula SAE is an international organization that annually hosts student competitions, challenging collegiate teams to design and build formula-style race cars. These competitions provide a platform for teams to showcase their expertise and experience, both on and off the track. Off-track events focus on evaluating the teams' engineering practices, their understanding of the vehicle, and their business acumen. On track events push the vehicles to their limits and truly test the teams' engineering prowess. The on-track events consist of four key challenges: Skid pad, Accel, Autocross, and Endurance. The Skid pad event features a figure-eight track layout designed to measure the car's maximum lateral g-force capability. Accel assesses the vehicle's straight-line speed over a specified distance. Autocross evaluates the vehicle's agility and one-lap pace as it navigates a predefined course. Lastly, Endurance tests the vehicle's speed, fuel efficiency, and reliability over a 22-kilometer course.

Each event is assigned a unique point scale, and the cumulative score from all events determines our team's overall score and ranking in comparison to our competitors. The implementation of a drag reduction system (DRS) will allow our car to perform better and ultimately gain more points overall. DRS allows us to actuate aero elements on our aero package to decrease drag and thus increase our overall performance on straights. The lack of DRS hurt us at our last competition, and we lost out on a few tenths of a second per lap on our endurance run, which is one of the main driving forces behind our project.

The DRS for this project focuses primarily on the rear wing. This system will involve a button located on or near the steering wheel activating DRS. When activated, the top elements will rotate to the calculated attack angle (opens the wing). A light will also be implemented to alert the driver when DRS is activated. The driver can deactivate DRS by applying brake pressure or by pushing the button again. Once deactivated, the elements will rotate back to the previous position (closed wing) and the light will turn off.

Mechanical Design:
The elements on the rear wing of the Formula SAE 2023 vehicle will be designed in CAD and computational fluid dynamics (CFD) software. Two angles will be determined from CFD simulations: one resting angle and another angle when DRS is activated. The elements will be fabricated from carbon fiber and 3D printed molds. These molds will support the shape, strength of the elements, and mounting points for the servos. The wiring for the servos will be housed alongside the end plates of the rear wing. Drag force and element weight will be taken into account when determining the strength (ie torque) requirement of the servos.

Electrical Design:
The DRS will consist of a microcontroller embedded into the existing CAN system communicating with a peripheral motor, be it a servo or linear actuator, to move the rear wing element. The system will be operated manually by the driver and may incorporate an auto-closing feature, similar to the systems found on modern formula 1 cars.

To operate the DRS manually, a button will be incorporated into the steering wheel, granting the driver full authority over its positioning. To achieve this, an electrical harness will be created connecting the device powering the rear wing with the primary voltage source. This integration allows the devices powering the rear wing to be accessible in case modifications or improvements need to be made.

The CAN system will serve as the medium for transmitting and receiving data between the microcontroller and servos, including signals from the manual button. Once the manual operation is successfully implemented, an autonomous DRS will be explored that will function based on inputs such as brake pressure, throttle position, and wheel speed. The completion of the automated DRS will be reliant on the time remaining during the semester and the state of the manual operation. The same motors will be utilized for both modes of operation, with the manual operation acting as an override mode whenever necessary.

Expected Outcomes:
The goal of this project is to improve race times on the Formula SAE vehicle by reducing the amount of drag produced during vehicle operation. CFD simulations will be run on the top elements of the rear wing to determine the best angle of attack, allowing for the maximum increase of straight-line speed. DRS will be activated with a button, and a light will illuminate to indicate when the system is active. It will deactivate when the button is pushed again or when the driver applies pressure on the brakes. Automation of the DRS will be explored and implemented depending on the outcome of

the manual DRS, considering the manual operation serves as the foundation for this project.

Challenge Project: Table-to-Floor-to-Table Robot

Student design groups will design, build, test and compete with an autonomous robot that will

- Begin within a 24-in square of 1-in wide blue painter's tape located in the middle of a lab table
- Move to the floor and locate a 6-ft square of 1-in wide blue painter's tape near the table
- Trace around the 6-ft tape square (line following)
- Move back to within the tape square on the lab table.

The budget for each design group will be capped at $300.

All groups choosing this project will compete during the Expo on December 14, 2023. Each group will have a maximum of three attempts at the challenge. The winning group will have the minimum score, which will consist of the time to compete the challenge (in seconds) multiplied by the cost of the device.

Development of sensors controlling sheet metal inflow in stamping operations

Project Sponsors: Sergey Golovashchenko, PhD (golovash@oakland.edu), Hongwei Qu, PhD, (qu2@oakland.edu)

The proposed project is in the area of stamping of sheet metal panels for automotive applications where the general trend is to make cars and trucks lighter and use more advanced Ultra High Strength Steels and Aluminum Alloys. Implementation of new lighter and stronger materials brings many challenges in stamping processes including splitting and wrinkling of sheet metal during forming processes and deviation from the targeted shape of the part during elastic unloading. All these effects to a significant extent could be controlled by the drawbead system of a sheet metal forming die.

The project targets the development of technology and instrumentation for measuring forces controlling sheet metal inflow into the sheet metal forming die cavity. This effort is addressing the major need in automotive industry of minimizing variability in produced sheet metal components such as doors, hoods, decklids, fenders, etc. Typical deviation in dimensions of panels accepted by automotive industry is within 0.5 mm for outer skin panels, and 1mm for interior panels. Even though all parts coming from a stamping line seem to be the same, there are phenomena such as die wear, variability in properties of sheet metal, non-uniform lubricant distribution on the surface of the blank, and accumulation of dust type particles separating from stamped panels on the surface of the stamping die. The project targets the development of sensors which would be able to capture significant deviations from normal stamping conditions in production dies.

The general concept is to develop a sensor design suitable for measuring loads in drawbeads of a stamping die. The development will include the following steps:

1. designing a testing fixture based upon the existing drawbead simulator in OU Sheet Metal Forming lab. The CAD of the drawbead simulator and the opportunity to see it in operation will be provided to the team/designated team members assuming the restrictions on COVID will allow it;

2. selecting the sensor candidate from industrially produced range of sensors, designing the method to incorporate the selected sensor in the fragment of the experimental die, developing an electric circuit for amplifying the signal from the sensor and storing it in the computer;

3. developing the actual testing fixture to measure the loads in a fragment of a drawbead with actual dimensions used in production dies.

The resources to purchase the material for designed components and to purchase necessary off the shelf parts will be provided by OU Center of Advanced Manufacturing and Materials. The CAMM research group will be also helping in testing the designed fixture using the existing equipment.