FCET SMOKE FLOW VIZ RESEARCH

Github Link

Presentation Link

Project Abstract

Automation of a Wind Tunnel Smoke Flow Visualization (SFV) Rig

When analyzing the properties and features of flow around aerodynamic devices, there are quantitative techniques such as particle image velocimetry (PIV) and hot-wire anemometry, while the SFV method provides a simpler set-up and qualitative look at the flow field. The SFV technique consists of a nichrome wire that is coated in propylene glycol and is heated to create lines of smoke through the wind tunnel. It allows for the visual identification of key features such as boundary layers, laminar or turbulent flow and vortex shedding. Currently, each instrument in the setup is controlled manually and is only effective for flow speeds under 5 m/s, therefore limiting the precision of equipment usage for unsteady conditions and the range of possible cases to study. This project aims to increase the efficiency, precision, and versatility of the SFV setup by automating the components using a microcontroller, as well as implementing capacitors to rapidly discharge high levels of current for usage above 5 m/s. The desired circuit and code design will obtain inputs either from an encoder signal or a manual trigger and output precise, timed controls to the wire heating, the dispensing of propylene glycol, the camera, and the capacitors. Design solutions will be evaluated based on the metrics of usability, compatibility and responsiveness. Ultimately, this system maximized the usage of SFV and aided in the studies of laminar separation bubbles. Through iterative design and evaluation of metrics, the created design was able to produce informative images in a consistent manner while additions are being made to augment the usage of the instruments through the ability to read and save data.

Encoder Research

- "Encoders are sensing devices whose purpose is to provide feedback about the motion of objects to control systems. This feedback allows the control system to establish whether the object being monitored is being correctly moved or positioned and permits adjustments to be made or actions to be taken based on the movement and position of the object."
- Selection considerations
  - Environmental conditions, vibration
  - Resolution
  - Size
  - Design/compatibility

Types of Encoders

- Linear Encoders
- Rotary Encoders
- Angle Encoders
- Absolute Encoders
- Incremental Encoders
- https://www.thomasnet.com/articles/automation-electronics/types-of-encoders-a-thomasnet-buying-guide/#:~:text=Optical%20encoders%20are%20the%20most,lines%20and%20alternating%20translucent%20slots

Encoder Technologies

- Magnetic
- Optical
- Capacitive
- https://www.cuidevices.com/blog/capacitive-magnetic-and-optical-encoders-comparing-the-technologies

	Capacitive	Optical	Magnetic
Resistance to Dirt, Dust, Oil	High	Low	High
Accuracy	High	High	Low
Temperature Range	Wide	Medium	Narrow
Current Consumption	Low	High	Medium
Programmability	Yes	No	No
Package Size	Small	Medium	Medium
EMC Immunity	High	High	High
Magnetic Immunity	High	High	Low
Resolution Range	Wide	Wide	Narrow

Current Experimental Setup

- Encoder: AMT22 Series, 28 mm, 14 Bit, Single-Turn, Absolute, SPI Interface, Capacitive Modular Encoder, AMT Viewpoint software
- Microcontroller: Arduino Mega, Arduino Uno
- Active grid motor: STM 23S-3RN
- Camera: Photron Fastcam SA5
- Valve: 12V DC solenoid valve
- Wire: 30 AWG Nichrome wire

Code and Arduino Resources

- https://pythonforundergradengineers.com/python-arduino-potentiometer.html
- https://makersportal.com/blog/2018/2/25/python-datalogger-reading-the-serial-output-from-arduino-to-analyze-data-using-pyserial
- https://pythonforundergradengineers.com/python-arduino-LED.html

Smoke Flow Literature Review

- Papers from:
  - https://drive.google.com/drive/folders/17lmvlWtnZ_uoro7y_4VE0kZJ-q3x1EDU?usp=sharing
- Paper 1
  - Camera: Canon 5D Mark II DSLR
  - Sens: ISO-100
  - Aperture: F6.3
  - Shutter speed: 1/200s
  - Flash: Canon 600EX-RT, 1/128 of max power output, flash duration of 100μs measured using an optical-to-electrical analog converter (Tektronix P6701B)
- Paper 2 (Used laser sheet)
  - Camera: FAST-CAM SA-3 which records images up to 60,000 fps, with an internal memory of 4 GB, only max FPS of 250 was used, lower frame rates were also used, so the authors believe that these images could have been obtained with a standard camera
  - Lens: Nikon 105-mm lens (model AF Micro Nikkor 105 mm)
  - Aperture: F/2.8
- Paper 3 (Used laser sheet)
  - Camera: commercial digital camera with a snapshot resolution of 4,000 × 6,000 pixels and a 50 Hz video recording resolution of 720 × 1280 pixels during the smoke flow visualization
  - Manual operation
- Paper 4
  - Camera: Nikon D70s DSLR
  - 4 FPS

- Flash: Nikon SB 800 Speedlight

➢ Paper 5
- Camera: Nikon D70s digital camera which acquired four consecutive images per second with an image resolution of six megapixels
- Flash: Nikon SB 800 Speedlight, i.e., a high-speed flash, which was triggered wirelessly by the camera

Camera Alternatives

➢ Imager SCMOS
- Datasheet in drive

➢ Stingray F125B
- Pin 7 gnd (black) and pin 4 trigger (red)
- Vimba software
- Manuals in drive
- https://www.alliedvision.com/en/products/software.html
- https://github.com/alliedvision/VimbaPython

➢ DSLR Camera
- https://www.youtube.com/watch?v=oQkVPrsatbQ&t=717s&ab_channel=VecVideosVecVideos
- https://www.youtube.com/watch?v=_ZOJilvAwBE&ab_channel=SunPixelVideo
- http://www.doc-diy.net/photo/remote_pinout/

➢ Photron Camera
- Manuals in drive
- https://www.youtube.com/watch?v=cLVt1M9vAzw&t=31s&ab_channel=PhotronMarketing
- https://photron.com/photron-support/
- PFV4 software
- Ethernet connection to pc
- Connect to "TRIG TTL IN" BNC cable

Smoke Flow Components Resources

➢ Valve
- http://bc-robotics.com/tutorials/controlling-a-solenoid-valve-with-arduino/

➢ Camera
- https://drive.google.com/drive/folders/1uzS8pdFq9TwNUtFZqKad7nzDRWsV8fpy?usp=sharing

➢ Wire, (powered using 120v to 5V relay to Arduino)
- https://lastminuteengineers.com/one-channel-relay-module-arduino-tutorial/

➢ Capacitors
- https://www.electronics-tutorials.ws/rc/rc_1.html

- https://www.electronics-tutorials.ws/rc/rc_2.html

➢ Encoder
- https://www.cuidevices.com/product/resource/sample-code/amt22

Experimental Setup Notes

1. Reynolds number range 60,000, 100,000, AOAs of 4deg and 8deg and 15deg for each (steady-state)
2. Repeat 1 with turbulence grids
3. Run unsteady cases for Re= 60,000 and alpha=15 and k=0.01, 0.05, 0.1, 0.4, 0.7, 1, 1.2, 1.5
4. For k=0.01 and 0.05 do the highest amplitude case and 10% amplitude
5. Look at reattachment and how they evolve downstream, unsteady vortex shedding and how it gets affected by free-stream turbulence
6. Clean tunnel, smallest grid, bigger grid if time permits
7. Improve beads uniformity, wire smoothness and tension
8. Optimize lighting

Smoke Flow Setup Specifics

➢ Propylene glycol: https://www.amazon.ca/dp/B076FCWZZ6/ref=cm_sw_r_oth_api_glt_i_AD2YF0B3D9KRYWSDD21R?_encoding=UTF8&psc=1
➢ Used 2kg of weights to straighten nichrome wire
➢ Used Allen key to wrap wire at the bottom as it does not deform
➢ Connect circuit to camera's "TRIG TTL IN" BNC cable
➢ PFV settings
- Live mode after recording
- Configuration>Trigger>Direct Trigger
- I/O> TRIG TTL IN> TRIG POS
- Choose frame rate, do calibration, focus on the frame, then you are ready for recording

➢ Frequently wipe funnel and under it as well as wire to prevent leaks
➢ Use Windex and microfiber cloth to clean test section glass
➢ Zeroing encoder position: Re-upload encUno arduino program twice, once with line 82 uncommented and once with line 82 commented before starting active grid
➢ Encoder mounting: https://www.youtube.com/watch?v=NNBdfpqhKBI&ab_channel=CUIDevices

Future/In progress work

➢ Capacitors implementation for trials over 5m/s
- https://www.electronics-tutorials.ws/rc/rc_1.html
- https://www.electronics-tutorials.ws/rc/rc_2.html
- https://www.youtube.com/watch?v=GrvvkYTW_0k&ab_channel=AddOhms

- https://www.youtube.com/watch?v=3PkpOeHTnfo&ab_channel=Indrek
- Report/Documentation
  - Setup/code guide
  - Summary of summer work
  - More github documentation
  - Add pdfs to github
    - FCET SFV Abstract
    - FCET SFV Documentation
    - FCET SFV Presentation
    - FCET SFV Summary
- Low priority
  - Snubber/Diode because of 5v relay resetting circuit
  - Really fast input - port manipulation
    - https://forum.arduino.cc/t/reading-really-fast-digital-input/204463/7
    - https://www.instructables.com/Arduino-and-Port-Manipulation/
- https://gfm.aps.org/ (Deadline: Sept. 17)
- Read encoder values after 1s of starting readline so the beginning of graph is not glitched

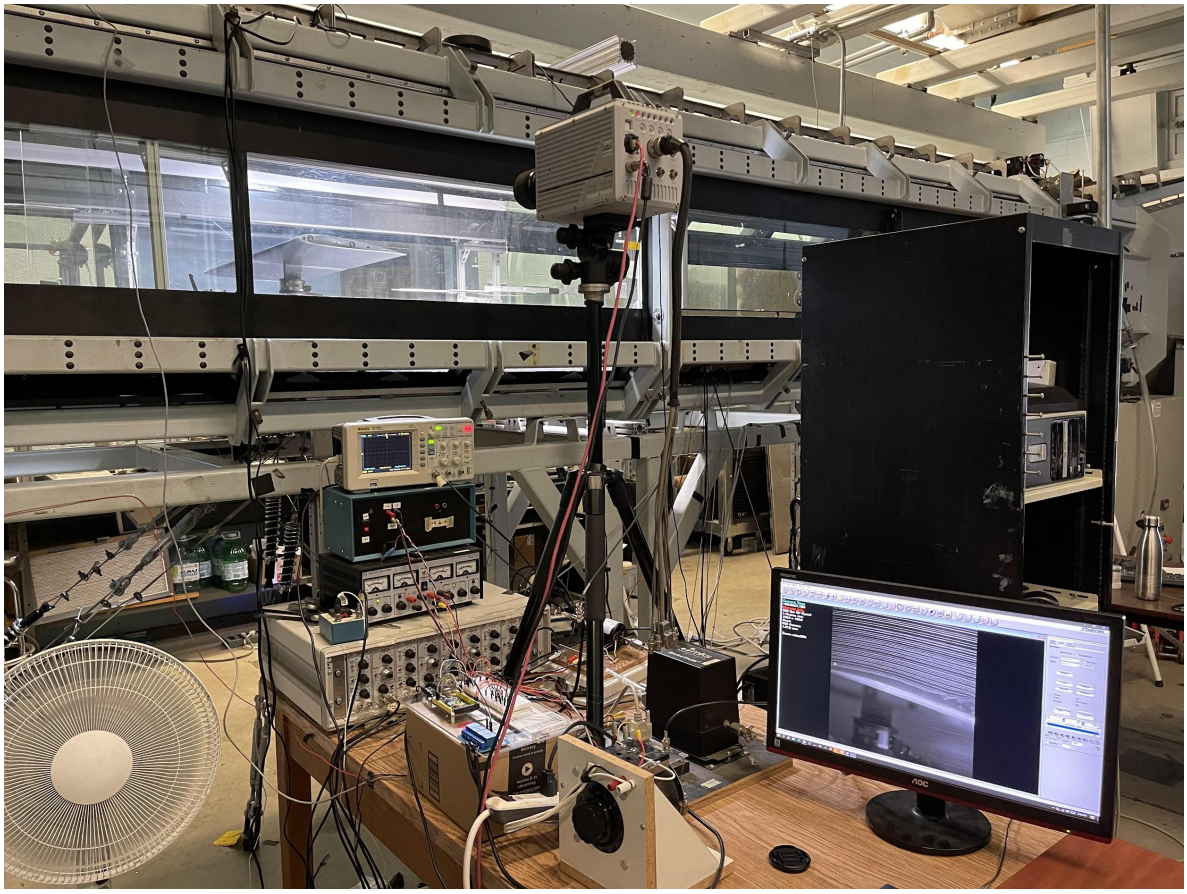
Progress Log

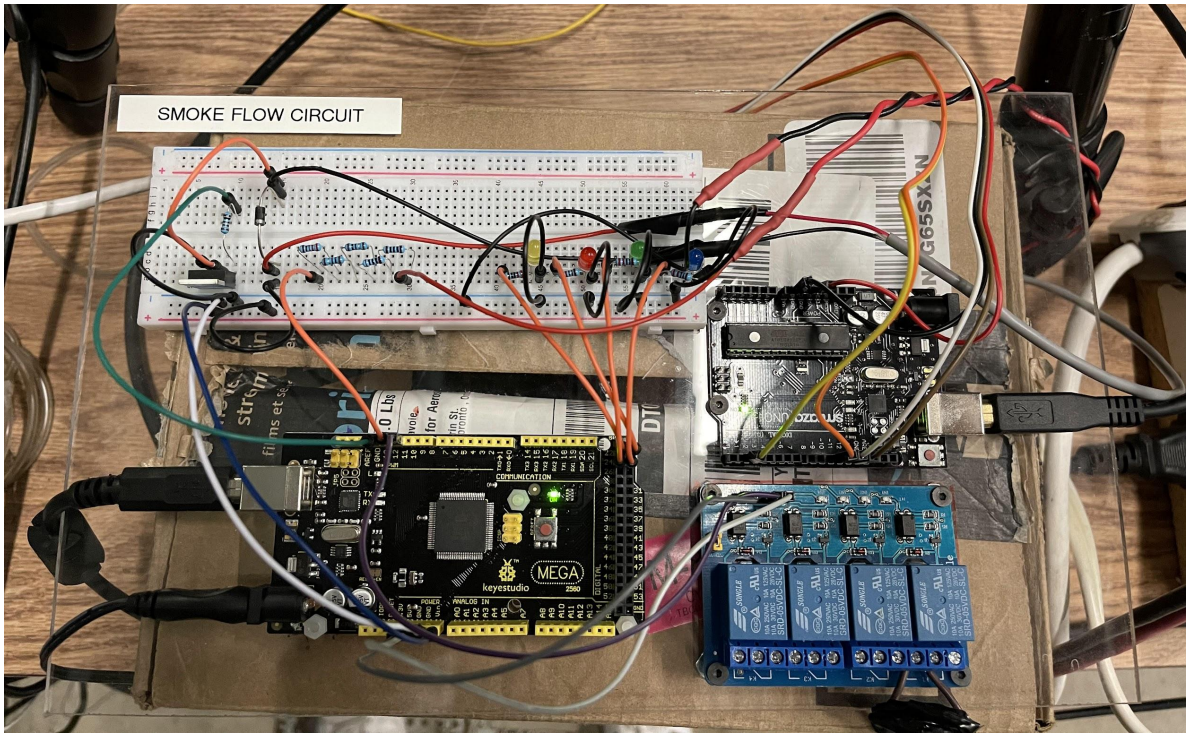
Week	Work done	Notes
1	Administrative Stuff	-Review papers from Prof. Lavoie
2	Researched Papers, learned Arduino, python implementation	
3	Researched encoders, connected encoder to read position	-Check min delay required for encoder code -Look into what coupling to use to address the issue
4	Implemented code into python and lit LED if encoder value is within a range as a proof of concept for the input and output which will later be camera/valve/wire	-Remember to change the COM port -Remember to be in conda env
5	Researched cameras, experimental setups, camera to Arduino connection, connected solenoid valve to circuit + code using transistor, diode and resistor, added Stingray F125B camera to the circuit, learned its software	-Draw a circuit for the valve and camera -Find what camera to use -Slightly over 12V power supply -NE555 timing chip? -Potentiometer to adjust time interval? -Blink without delay for camera delay -Put stuff into methods -Look into really fast input
6	Read through stingray camera's manuals and python API, changed the camera to Imager SCMOS and learned its control, started setting up an experimental setup	-Research python API -Research how to control, trigger methods
7	Had a meeting with Phil, set up experimental smoke flow viz setup with wire, valve, Photron camera connected to my pc, rheostat and Arduino, changed Arduino Uno to mega, created manual mode python code and improved active grid mode, improved and organized general code on Arduino	-Replace wire, optimize voltage, look into controlling rheostat -Had short circuit and therefore had to replace some parts, fixed cable management and insulating wires to prevent the issue
8	Took some smoke flow viz case photos, replaced valve, created code that does smoke flow setup in a sequence automatically, installed	-See serial issue in code, fix pfv4 software issues -Fix coding issues in comments

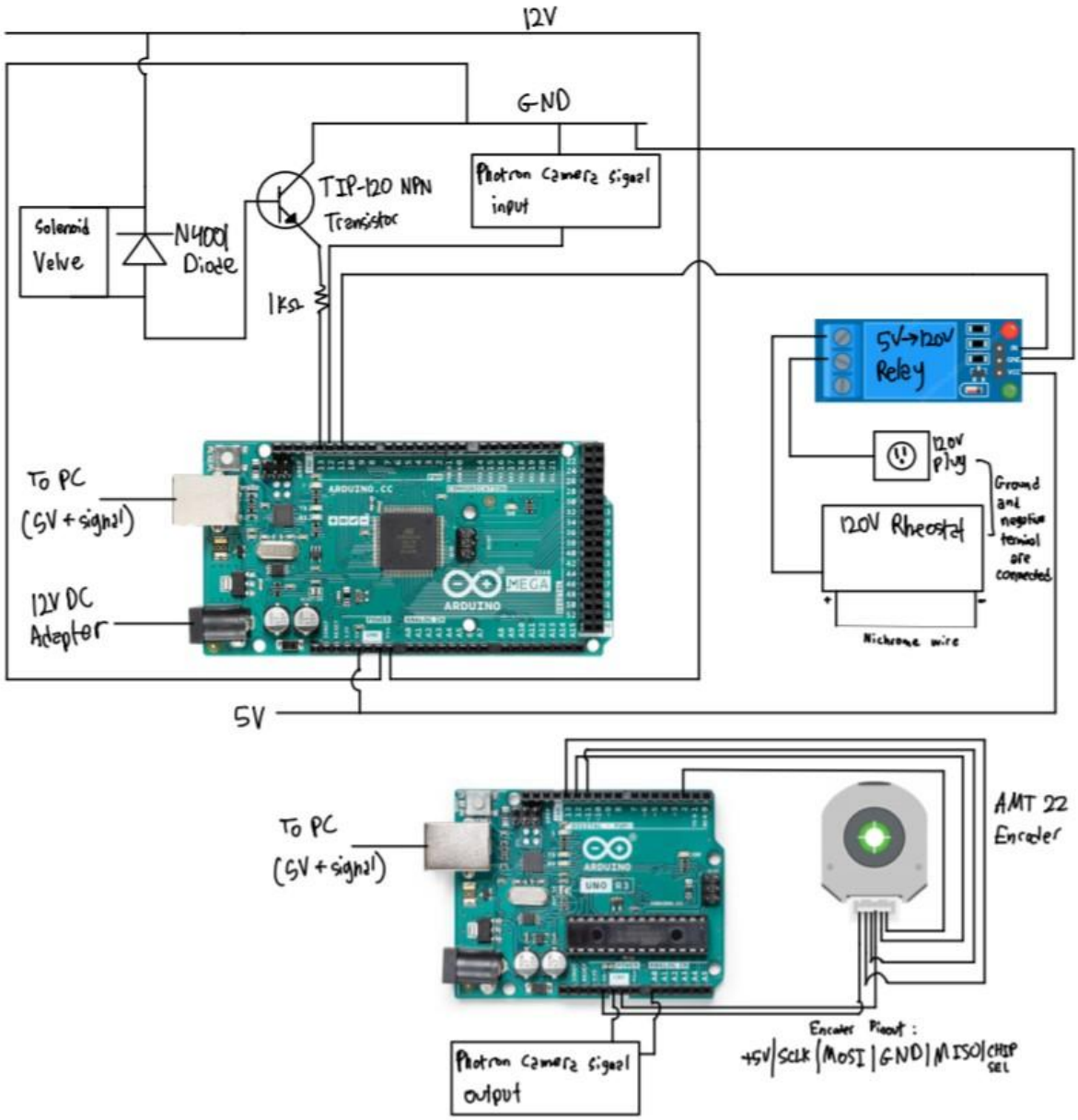
	5v relay for rheostat, researched capacitor usage, researched how to improve oil beads on the wire to improve streamlines quality	
9	Worked on improving setup, improved wire using weights to straighten it and thus bead uniformity resulting in visualization of the separation bubble, created GitHub, had a meeting with Phil, figured out camera frames issue - has something to do with changing to external trigger mode having too high current - reduced current to recommended range using resistors, removed encoder code from Arduino to prevent the serial lag issue, did Re60k, Re100k trials, improved code and made it more user-friendly, there is smooth experimental setup and automation now	To do: -Draw circuit diagrams✅ -Look into pfv4 software issue vs pfv3✅ -Mount 5v relay to board✅ -Fix pfv3 ext trigger not working✅ -Look into setup with smaller wind tunnel✅ -Camera signal emitting 80mA, should be below 30 - can fix by increasing resistance or decreasing voltage✅ -Why does the valve turn on and off when running the program at the start-> need a diode or snubber? -Add a second Arduino just for the encoder to run separately and not fill up serial, can run from the same python program maybe, but with different terminals running at the same time -Add code for a sequence that asks if bead formation is good, if not, dispense liquid again✅
10	Updated Github, set up code on lab pc so you can use code and pfv4 from the same device, used calibration target to measure distances and scale and enhance zoom focus, took more alpha=4,8 and Re=60k,100k cases	-Add parameter in code for Reynolds number, to change delays, use comments from lab pc code -Add option for if oil is already on the wire -Tighten the wire like a guitar string tightener? -Camera getting signal from wire signal -> need a snubber/diode?
11	N/A	N/A
12	Finished GitHub setup, readme, helped Daniel M. with PIV glass component, edited smoke flow pics with photoshop, worked on fixing encoder issue, added 2nd Arduino for the encoder, updated code and circuit for encoder usage, installed encoder on active grid motor	-Remove encoder code from Arduino Mega code, not necessary

13	Started work on adding python code to record, save and display live encoder data in CSV and graph form	
14	Continued work on encoder data, fixed encoder positioning on active grid axle to not be in the way of the axle coupling, added ability to read when the camera starts recording in order to find delays in recording to record a phase at the correct starting time, prepared final version of UnERD abstract	-Update readme, GitHub code, circuit graph, add media section, -Rewrite Arduino mega code -Fix filename feature, -Snubber/diode for 5v relay -Take updated circuit photos
15	Started taking unsteady cases with active grid, fixed recording issues and delays with code	
16	Worked on capacitors implementation, UnERD presentation, and documentation	

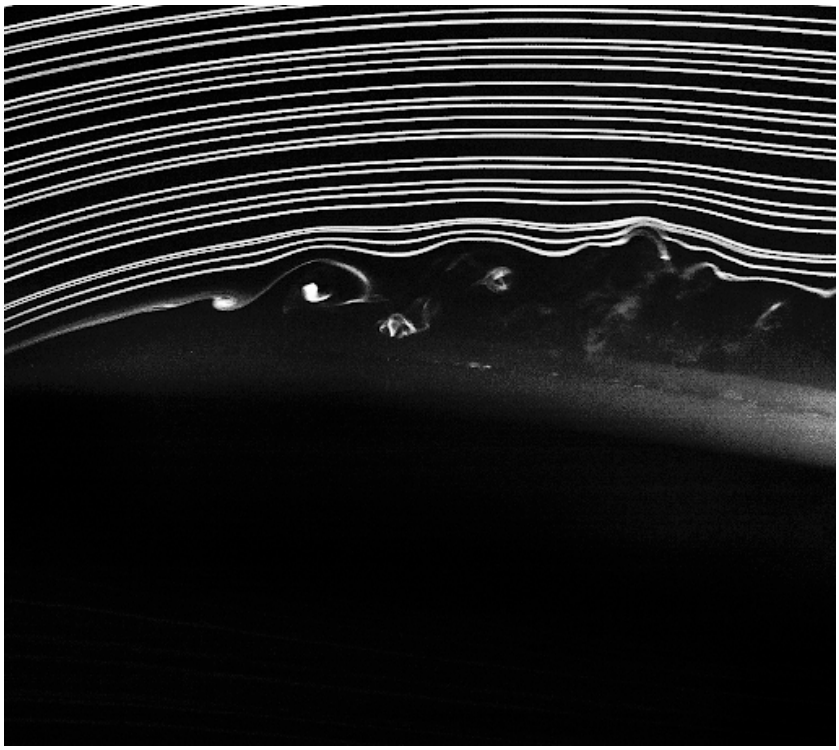
Experimental Setup Photos



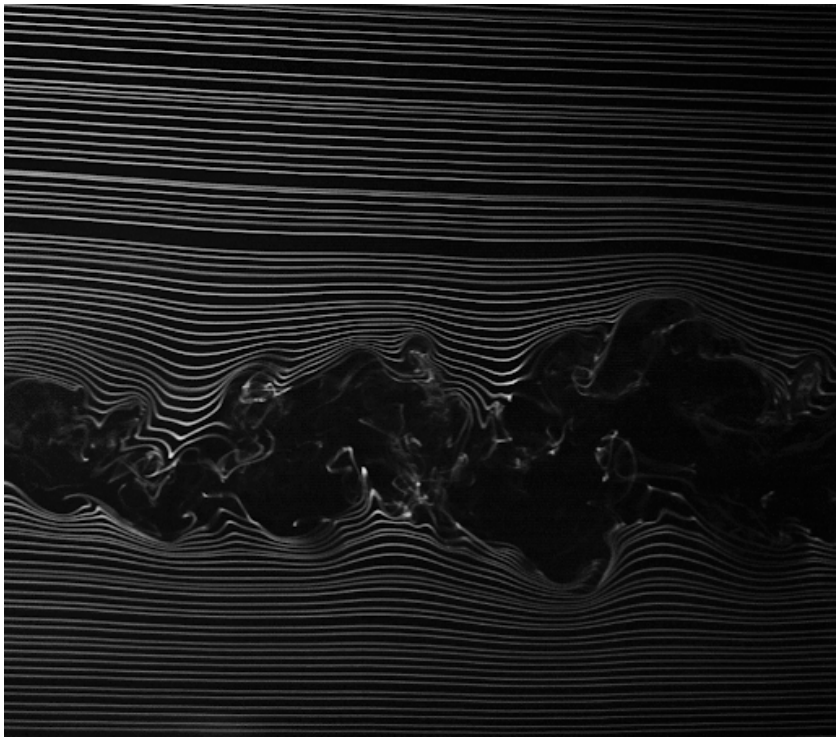



12V
GND
TIP-120 NPN Transistor
Photron Camera Signal input
Solenoid Velve
N4001 Diode
1kΩ
5V→120V Relay
120V Plug
120V Rheostat
Ground and negative terminal are connected
Nichrome wire
To PC (5V + signal)
12V DC Adapter
5V
To PC (5V + signal)
AMT 22 Encoder
Encoder Pinout :
+5V | SCLK | MOSI | GND | MISO | CHIP SEL
Photron Camera Signal output

Re 60k, Alpha 8°, Separation Bubble



Re 60k, Alpha 4°, Wake



More at:
https://docs.google.com/presentation/d/16J4Y5I4r7RJ0xJXcWhaKHc9rMGl_Y89D4mZZUveVm9U/edit?usp=sharing

Additional Resources

- https://www.cuidevices.com/resources/resource-library?resourcetypes=ALL&categories=rotary-encoders&page=2&tags=All&itemsPerPage=15
- https://www.cuidevices.com/product/motion/rotary-encoders/absolute/modular/amt22-series
- https://www.mcmaster.com/
- https://www.digikey.ca/