Optimizing Hydrokinetic Turbine Blade Angle of Attack

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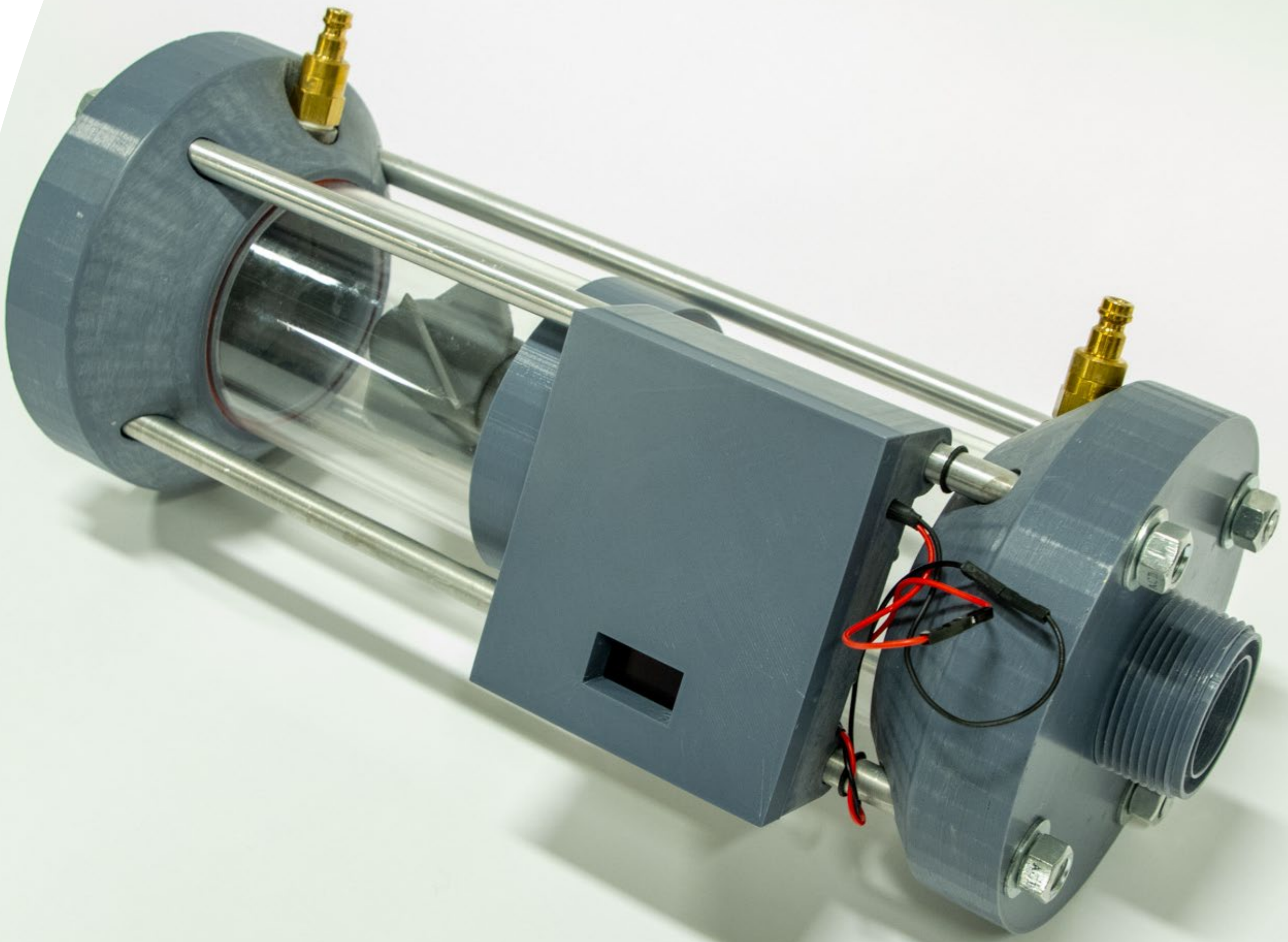
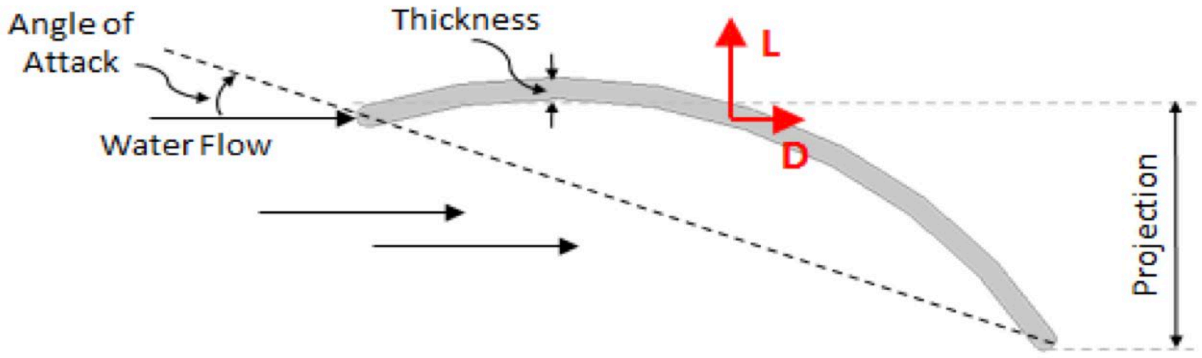
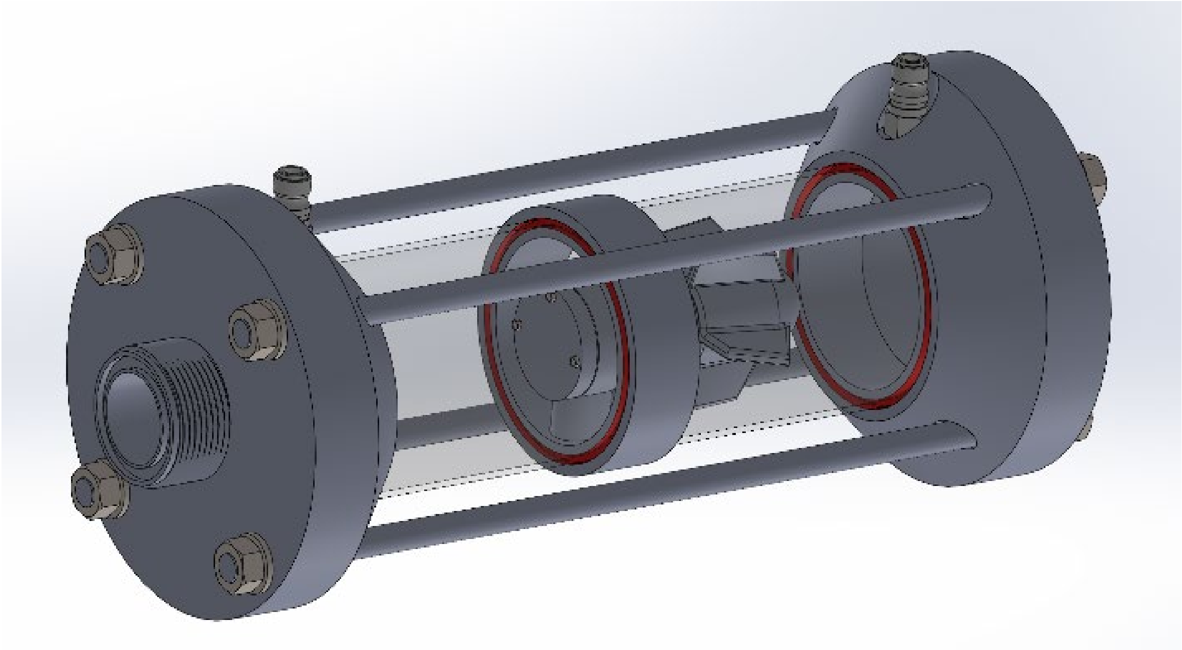


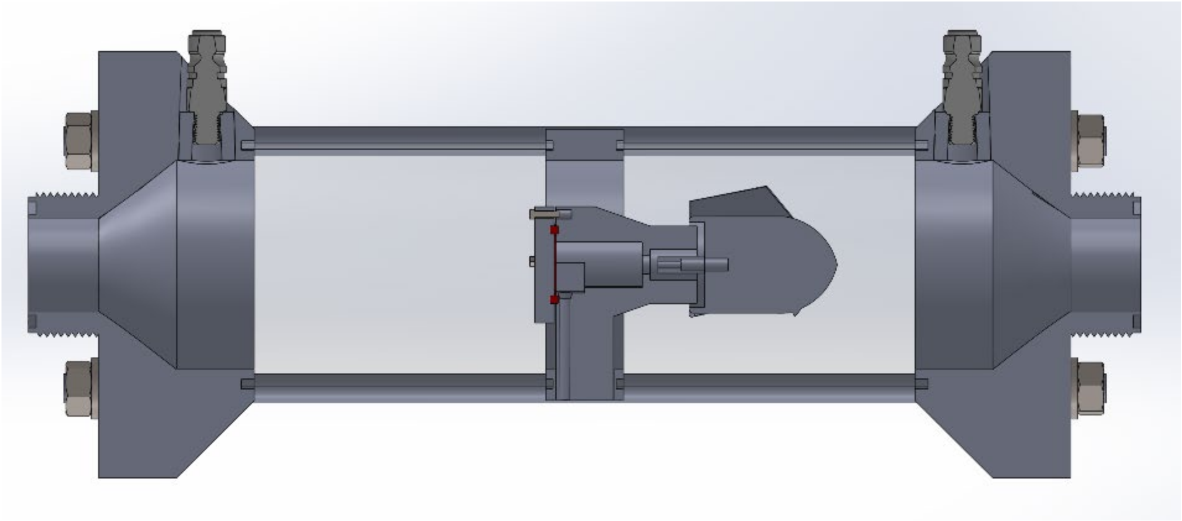
Description of Project

- Hydrokinetic Turbine Blade Angle of Attack
- Prototyping
- Electronics/Software
- Testing
- CDF Analysis
- Validation

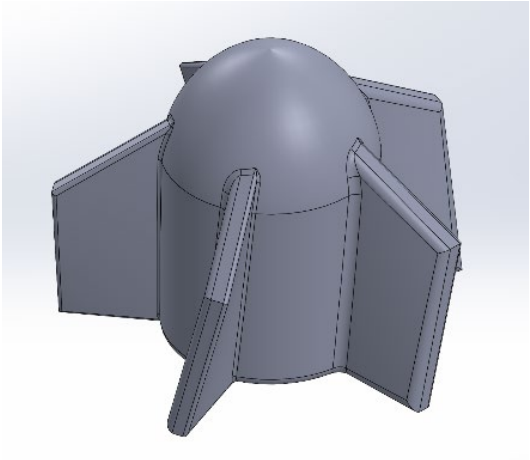


SolidWorks Model

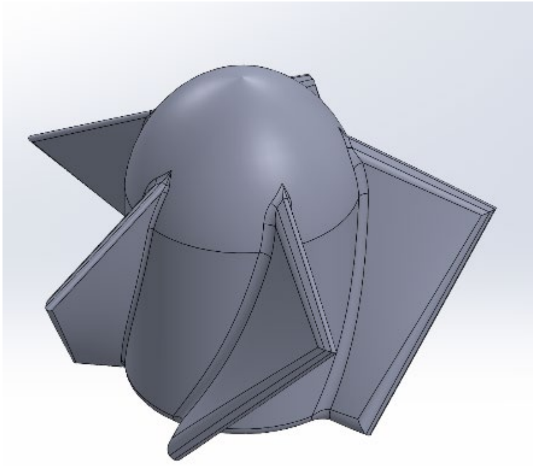




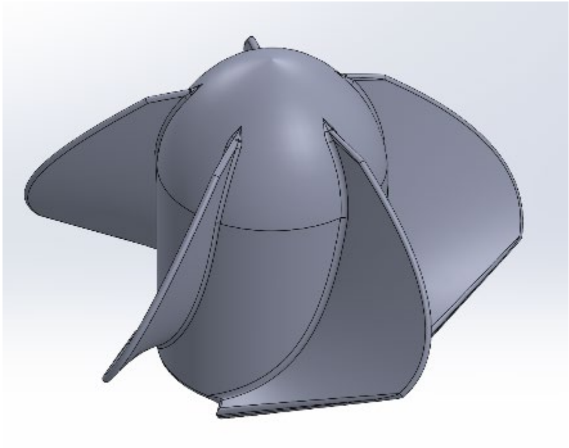
SolidWorks Model



15 Degree Angle of Attack



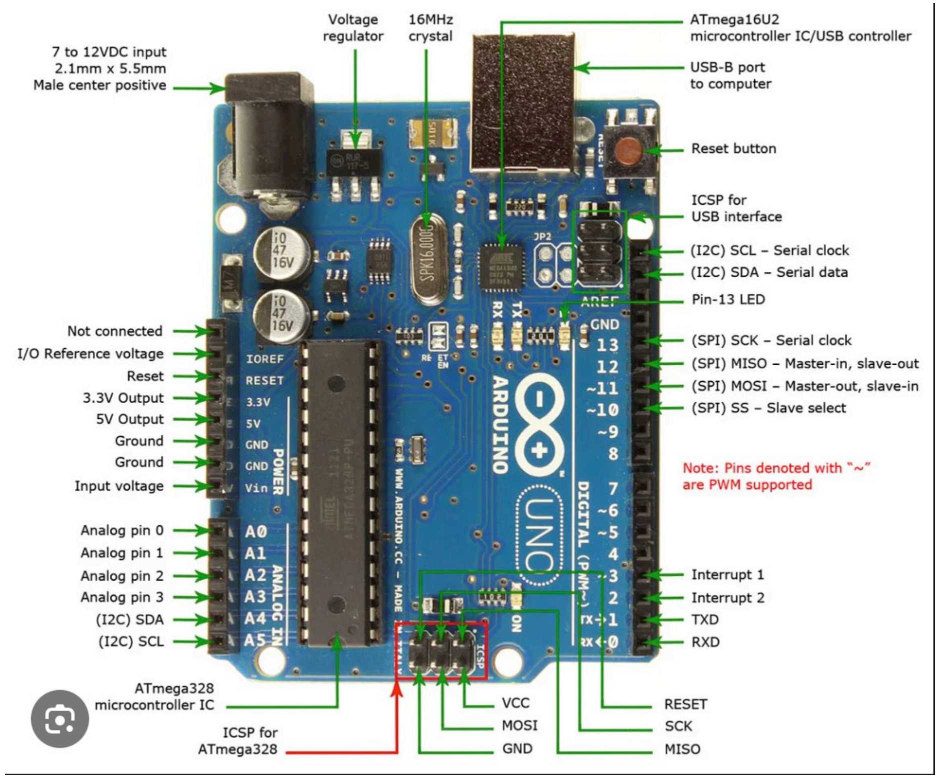
45 Degree Angle of Attack



67.5 Degree Angle of Attack

Electronics

- Primary electronics is an Arduino Uno R3 handling measurement via analog input pins as well as data output both visually and digitally.
- 0.96-inch OLED I2C Display for direct data output.



Software

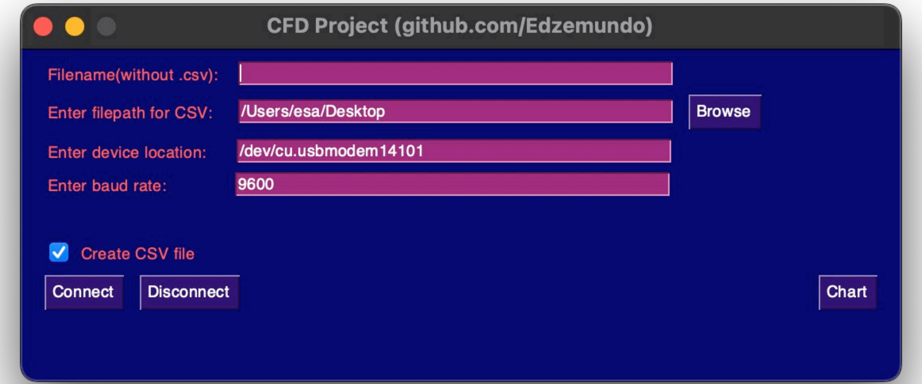
- Voltage acquisition and display to the mini-OLED programmed directly in Arduino for minimum latency. The Arduino also transmits the voltage data on a serial connection.
- Data chart visualization and data file (CSV) creation is handled through Python. Data is read through the serial connection where a graph is plotted live through the matplot library, and the data is saved as a CSV file.
- Chart creation from the CSV also handled through Python.

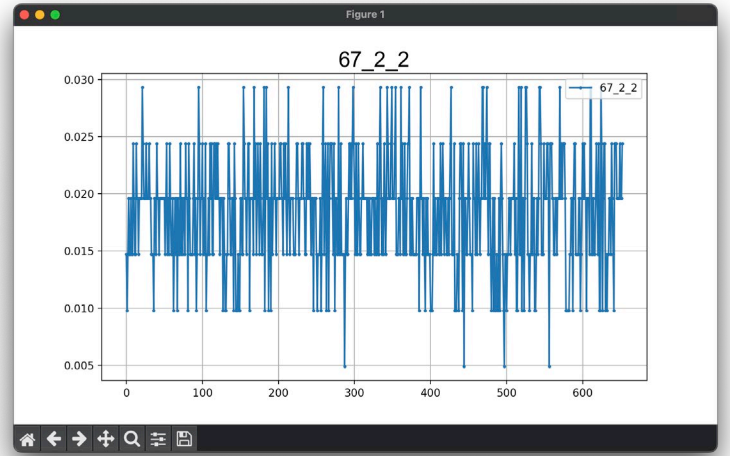
```
void setup() {
  Serial.begin(9600);

  if(!display.begin(SSD1306_SWITCHCAPVCC, SCREEN_ADDRESS)) {
    Serial.println(F("SSD1306 allocation failed"));
    for(;;); // Don't proceed, loop forever
  }
}

void loop() {
  int analogValue = analogRead(analogPin);  // Read the analog value from the sensor
  float voltage = analogValue * (5.0 / 1023.0);  // Convert the analog value to voltage
  Serial.println(voltage, 4);  // Print the voltage to the Serial Monitor
  printVoltage(voltage);
  delay(sampleDelay);  // Wait for the specified sample delay
}

void printVoltage(float number){
  display.clearDisplay();
  display.setTextSize(2);              // Normal 1:1 pixel scale
  display.setTextColor(SSD1306_WHITE);        // Draw white text
  display.setCursor(0,0);              // Start at top-left corner
  display.println("Voltage: ");
  display.println(number,4);
```

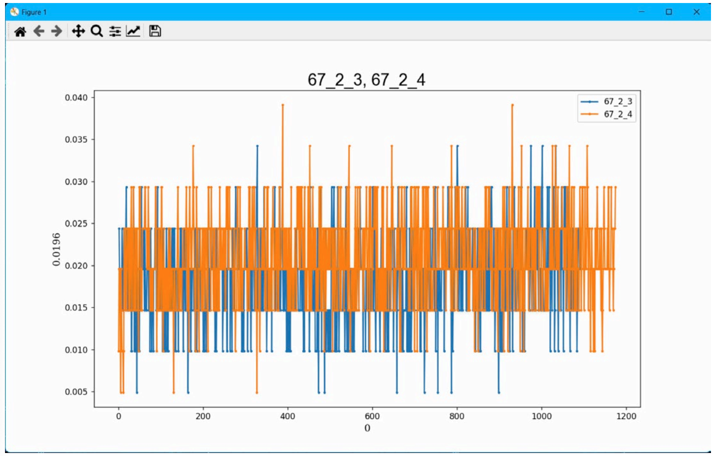
```
tabnine: test | explain | document | ask
def connect(serialPort, baudRate):
    # Initialize serial connection
    global ser
    ser = serial.Serial(serialPort, baudRate)
    if not ser.isOpen():
        try:
            ser.open()
            window["statustext"].update("Connected")
            window["connect"].update(disabled=True)
            window["disconnect"].update(disabled=False)
            window["chart"].update(disabled=False)

        except serial.SerialException:
            sg.Popup("Error connecting to Arduino. Please check your serial port settings.")
        except FileNotFoundError:
            sg.Popup("Error connecting to Arduino. Please check your serial port settings.")
    else:
        window["statustext"].update("Connected")
        window["connect"].update(disabled=True)
        window["disconnect"].update(disabled=False)
        window["chart"].update(disabled=False)
```

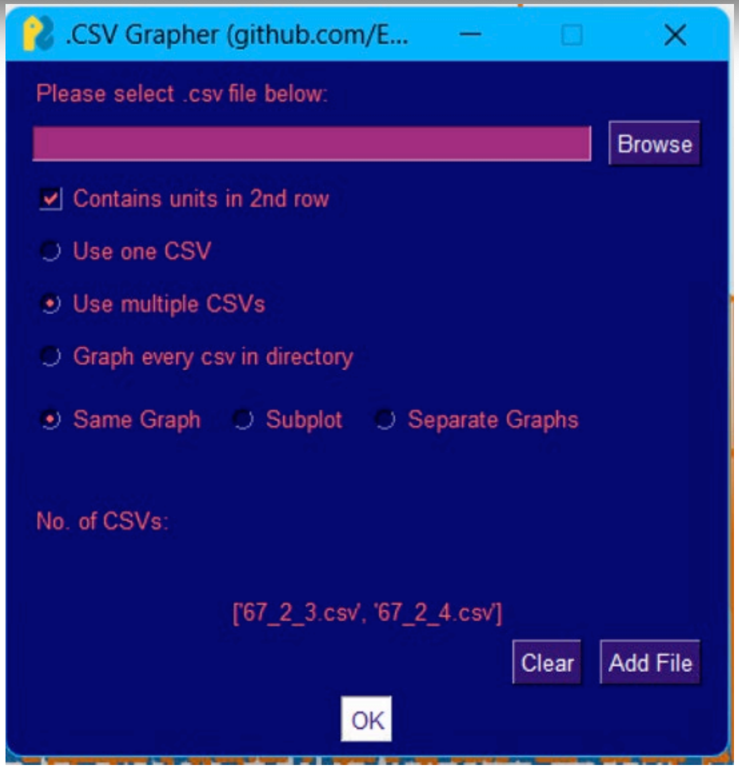
```
tabnine: test | explain | document | ask
def createCSV(filename):
    global file
    with open(filename, 'w') as file:
        file.write("Time,Voltage\n")
        for i, y in zip(xs, ys):
            file.write(f"{i},{y}\n")
```

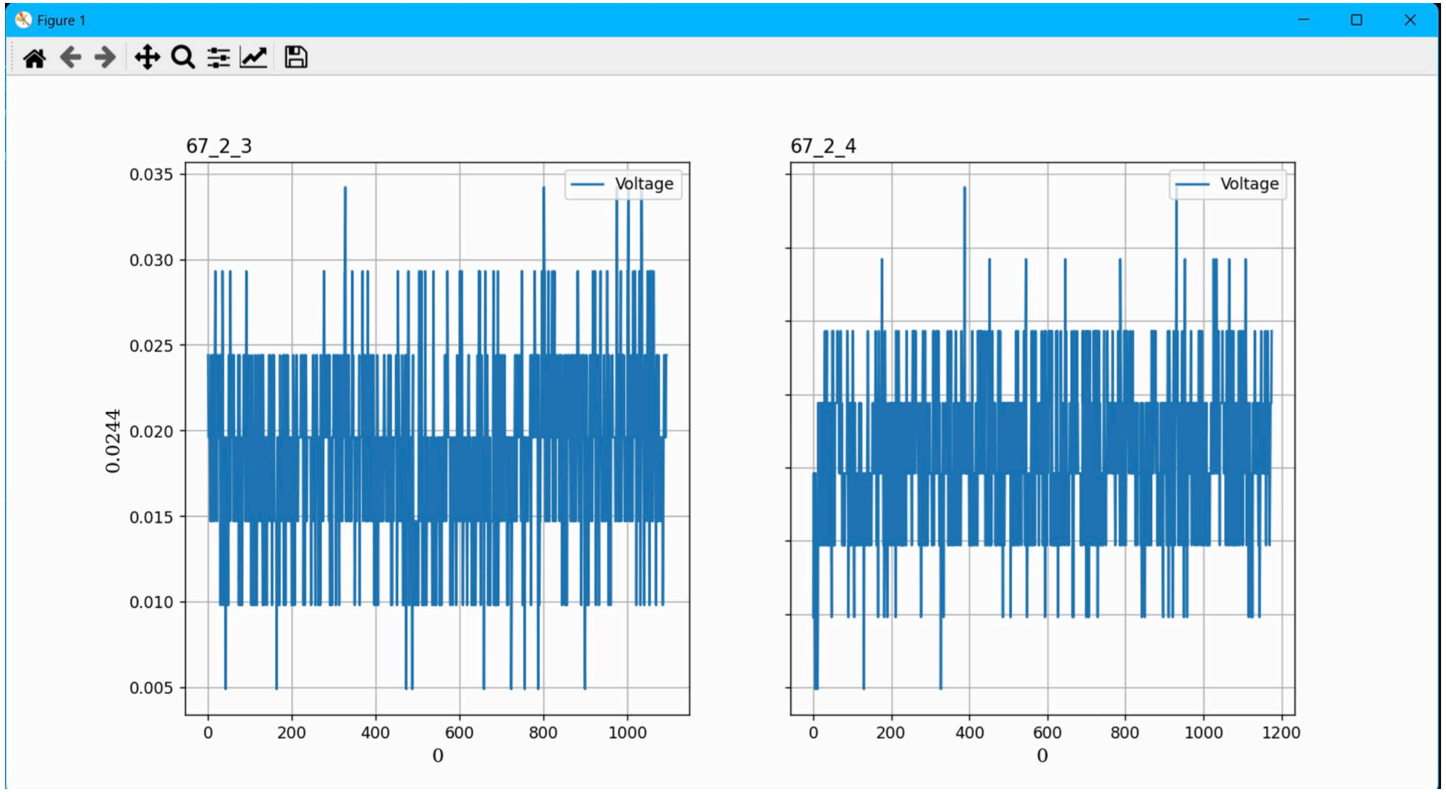
Output and Workflow



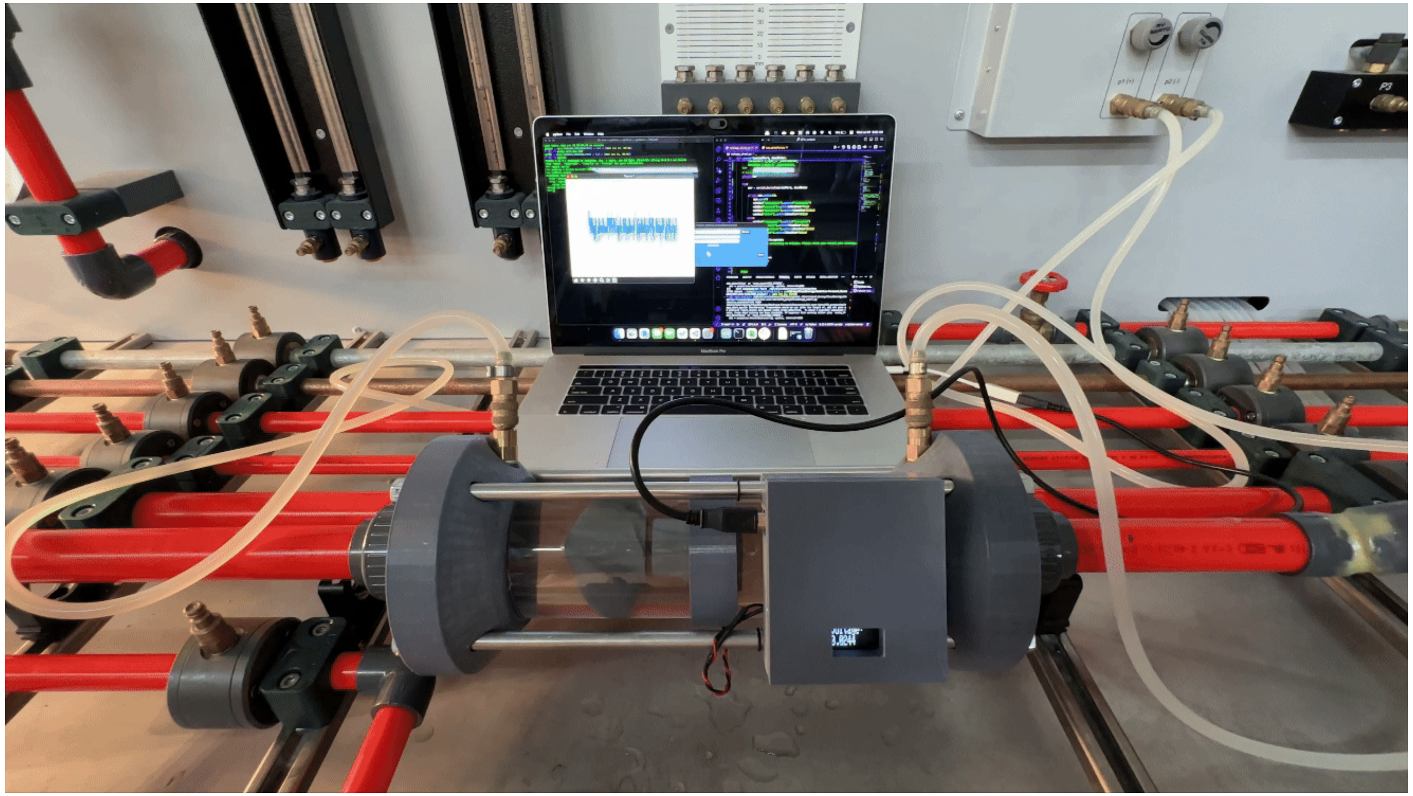








Testing



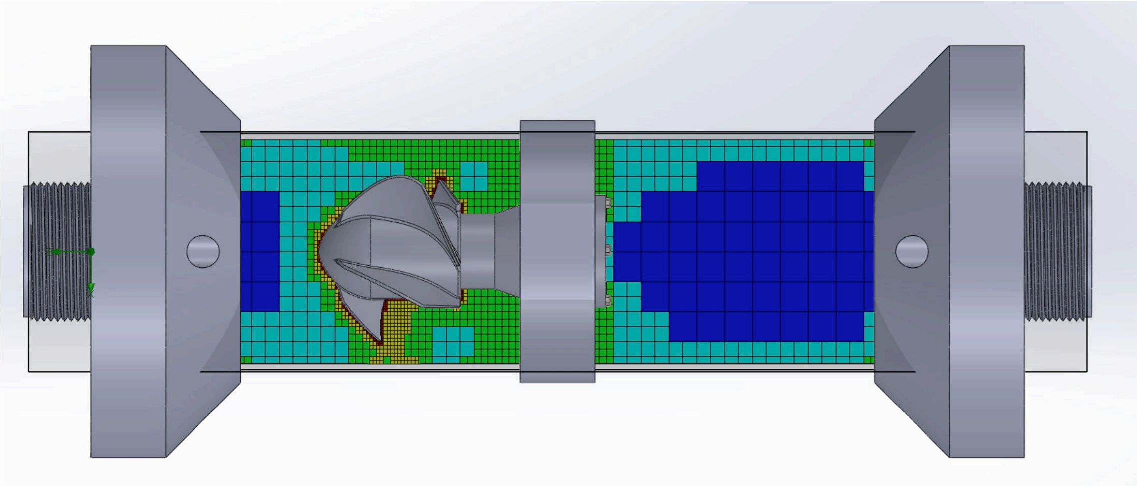
Experimental Data

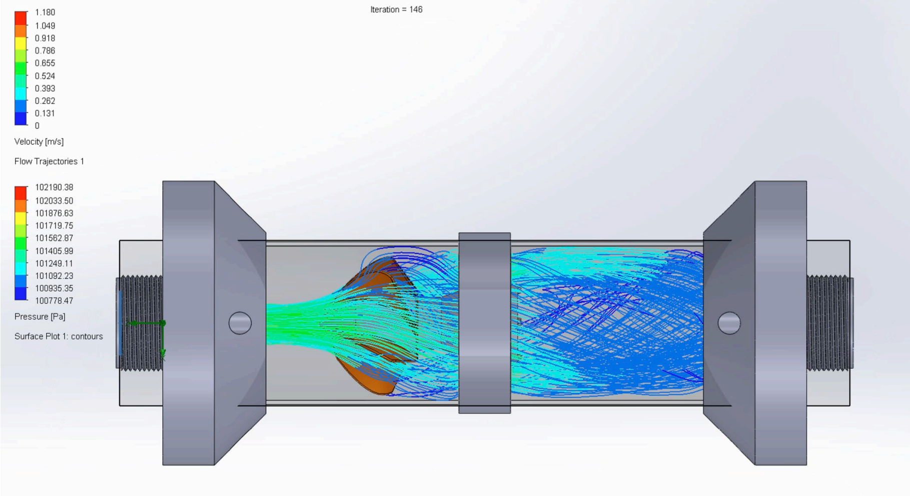
Angle of Attack 15 Degree					
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Average Voltage Output (mV)	Velocity (m/s)	Reynolds Number	Force (N)
2	50	9.3819	0.316736537	2.76E+04	0.226822990
2.1	110	13.3257	0.469796205	4.09E+04	0.499010577
2.2	130	15.2383	0.51072232	4.45E+04	0.589739773
2.3	150	16.0135	0.548603774	4.78E+04	0.680468969
2.4	165	17.6726	0.575380493	5.01E+04	0.748515866
2.5	170	17.8569	0.584033316	5.09E+04	0.771198165
2.6	185	18.1004	0.609254893	5.31E+04	0.839245061
2.7	200	18.2755	0.633473074	5.52E+04	0.907291958

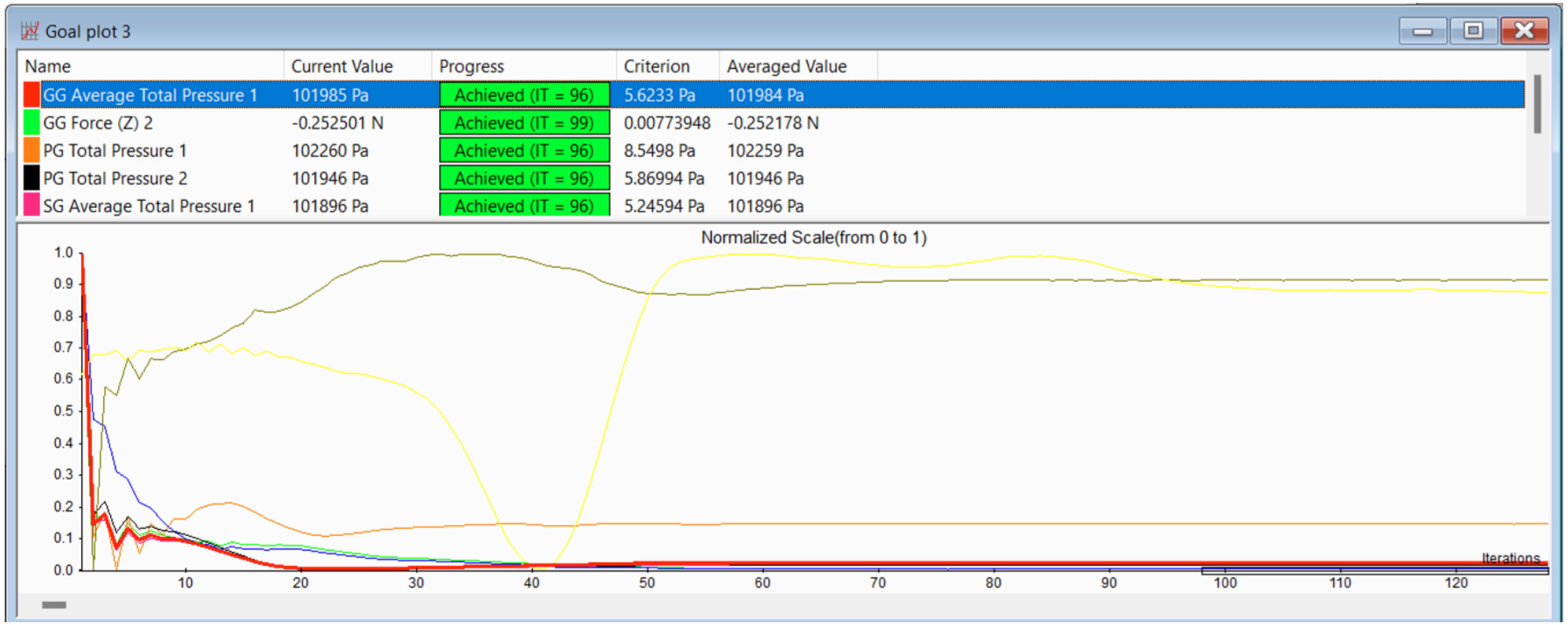
Angle of Attack 45 Degree					
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Average Voltage Output (mV)	Velocity (m/s)	Reynolds Number	Force (N)
2	10.0	10.9256	0.141648885	1.23E+04	0.045364598
2.1	50.0	11.1971	0.316736537	2.76E+04	0.226822990
2.2	100	11.3680	0.447933106	3.90E+04	0.453645979
2.3	150	11.6281	0.548603774	4.78E+04	0.680468969
2.4	185	13.8154	0.609254893	5.31E+04	0.839245061
2.5	220	15.6923	0.664392165	5.79E+04	0.998021154
2.6	250	17.8154	0.708244427	6.17E+04	1.134114948
2.7	290	20.5641	0.762802593	6.65E+04	1.315573340

Angle of Attack 67.5 Degree					
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Average Voltage Output (mV)	Velocity (m/s)	Reynolds Number	Force (N)
2	60.0	17.9636	0.346967492	3.02E+04	0.272187588
2.1	100	18.1276	0.447933106	3.90E+04	0.453645979
2.2	160	18.3752	0.566595542	4.94E+04	0.725833567
2.3	240	18.6263	0.693934984	6.05E+04	1.088750350
2.4	270	18.6263	0.736029199	6.41E+04	1.224844144
2.5	300	20.4435	0.775842898	6.76E+04	1.360937938
2.6	330	22.4524	0.813710896	7.09E+04	1.497031731
2.7	360	23.1203	0.849893313	7.41E+04	1.633125525

CFD Setup







Name	Current Value	Progress	Criterion	Averaged Value
GG Average Total Pressure 1	101985 Pa	Achieved (IT = 96)	5.6233 Pa	101984 Pa
GG Force (Z) 2	-0.252501 N	Achieved (IT = 99)	0.00773948	-0.252178 N
PG Total Pressure 1	102260 Pa	Achieved (IT = 96)	8.5498 Pa	102259 Pa
PG Total Pressure 2	101946 Pa	Achieved (IT = 96)	5.86994 Pa	101946 Pa
SG Average Total Pressure 1	101896 Pa	Achieved (IT = 96)	5.24594 Pa	101896 Pa

CFD Analysis

Angle of Attack 15 Degree CFD			
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Velocity (m/s)	Force (N)
2	116	0.4824	0.422759
2.1	127	0.5048	0.7835
2.2	139	0.5281	0.70661
2.3	152	0.5522	0.80032
2.4	165	0.5754	0.85887
2.5	175	0.5926	0.68812
2.6	194	0.6239	0.762988
2.7	201	0.6351	1.055756

Angle of Attack 67.5 Degree CFD			
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Velocity (m/s)	Force (N)
2	125	0.5008	0.26458885
2.1	134	0.5185	0.425788956
2.2	147	0.5431	0.679588425
2.3	160	0.5666	0.97845646
2.4	174	0.5909	1.058978854
2.5	188	0.6142	1.174489568
2.6	203	0.6382	1.255874565
2.7	218	0.6614	1.425548650

Angle of Attack 45 Degree CFD			
Input Water Flow Rate (m^3/h)	Delta Pressure (Pa)	Velocity (m/s)	Force (N)
2	19	0.1952	0.0528095
2.1	67	0.3666	0.248443
2.2	142	0.5338	0.52854659
2.3	155	0.5577	0.606312
2.4	169	0.5823	0.658608
2.5	243	0.6983	0.712137
2.6	263	0.7264	0.77155
2.7	330	0.8137	0.819163

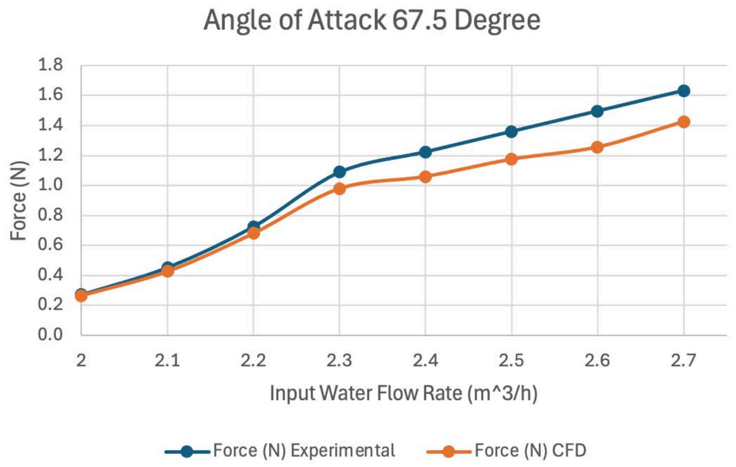
Validation

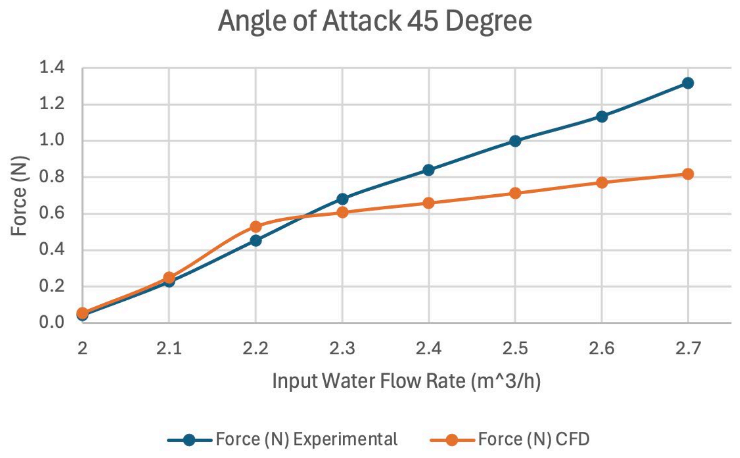
Validation 15 Degree						
Input Water Flow Rate (m^3/h)	Force (N) Experimental	Force (N) CFD	Percentage Error	Velocity (m/s) Experimental	Velocity (m/s) CFD	Velocity Percentage Error
2	0.226822990	0.422759	46.35%	0.316736537	0.4824	34.35%
2.1	0.499010577	0.7835	36.31%	0.469796205	0.5048	6.93%
2.2	0.589739773	0.70661	16.54%	0.51072232	0.5281	3.29%
2.3	0.680468969	0.80032	14.98%	0.548603774	0.5522	0.66%
2.4	0.748515866	0.85887	12.85%	0.575380493	0.5754	0.00%
2.5	0.771198165	0.68812	12.07%	0.584033316	0.5926	1.44%
2.6	0.839245061	0.762988	9.99%	0.609254893	0.6239	2.35%
2.7	0.907291958	1.055756	14.06%	0.633473074	0.6351	0.25%

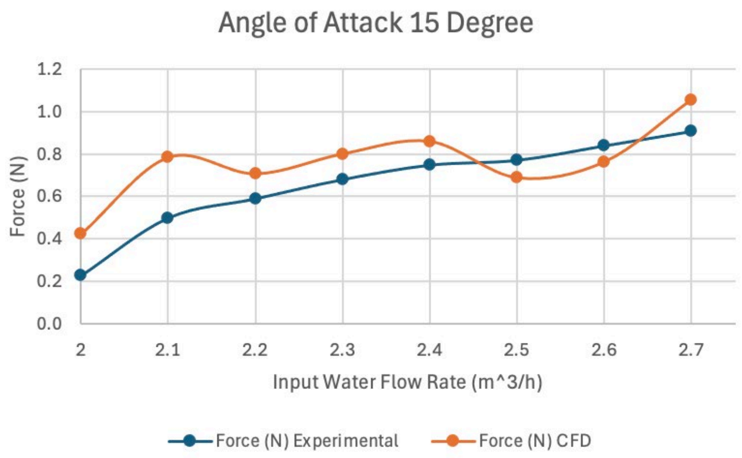
Validation 45 Degree						
Input Water Flow Rate (m^3/h)	Force (N) Experimental	Force (N) CFD	Force Percentage Error	Velocity (m/s) Experimental	Velocity (m/s) CFD	Velocity Percentage Error
2	0.045364598	0.0528095	14.10%	0.141648885	0.1952	27.45%
2.1	0.226822990	0.248443	8.70%	0.316736537	0.3666	13.61%
2.2	0.453645979	0.52854659	14.17%	0.447933106	0.5338	16.08%
2.3	0.680468969	0.606312	12.23%	0.548603774	0.5577	1.63%
2.4	0.839245061	0.658608	27.43%	0.609254893	0.5823	4.63%
2.5	0.998021154	0.712137	40.14%	0.664392165	0.6983	4.85%
2.6	1.134114948	0.77155	46.99%	0.708244427	0.7264	2.50%
2.7	1.315573340	0.819163	60.60%	0.762802593	0.8137	6.26%

Validation 67.5 Degree						
Input Water Flow Rate (m^3/h)	Force (N) Experimental	Force (N) CFD	Percentage Error	Velocity (m/s) Experimental	Velocity (m/s) CFD	Velocity Percentage Error
2	0.272187588	0.26458885	2.87%	0.346967492	0.5008	30.72%
2.1	0.453645979	0.425788956	6.54%	0.447933106	0.5185	13.61%
2.2	0.725833567	0.679588425	6.80%	0.566595542	0.5431	4.33%
2.3	1.088750350	0.97845646	11.27%	0.693934984	0.5666	22.47%
2.4	1.224844144	1.058978854	15.66%	0.736029199	0.5909	24.57%
2.5	1.360937938	1.174489568	15.87%	0.775842898	0.6142	26.32%
2.6	1.497031731	1.255874565	19.20%	0.813710896	0.6382	27.50%
2.7	1.633125525	1.42554865	14.56%	0.849893313	0.6614	28.51%

Conclusion


Angle of Attack 67.5 Degree
Force (N)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
Input Water Flow Rate (m^3/h)
Force (N) Experimental
Force (N) CFD


Angle of Attack 45 Degree
Force (N)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
Input Water Flow Rate (m^3/h)
Force (N) Experimental
Force (N) CFD


Angle of Attack 15 Degree
Force (N)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
Input Water Flow Rate (m^3/h)
Force (N) Experimental
Force (N) CFD

Questions