MSU AEROSPACE STUDENT

Engineering Report Memo

Date: 03/30/2025

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To: Robert Wolz, ASE 4721 Lab Instructor

Subject: *Airfoil Memo*

References:

XFOIL (2013), Massachusetts Institute of Technology, Boston, Massachusetts, web.mit.edu/drela/Public/web/xfoil/

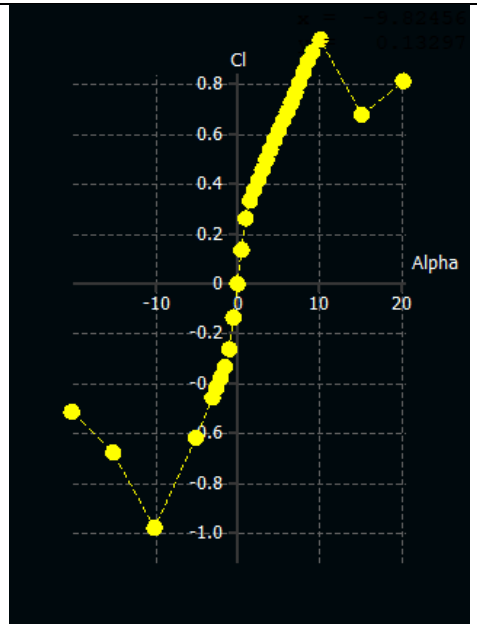
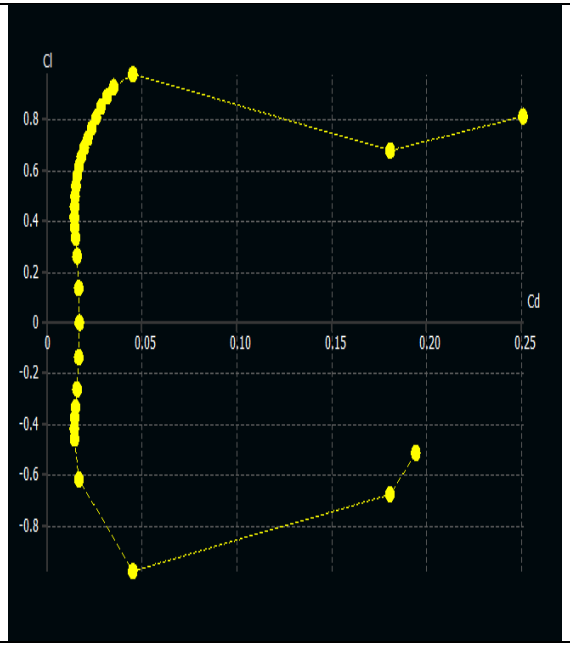
XFLR5 (2024), Massachusetts Institute of Technology, Boston, https://www.xflr5.tech/xflr5.htm

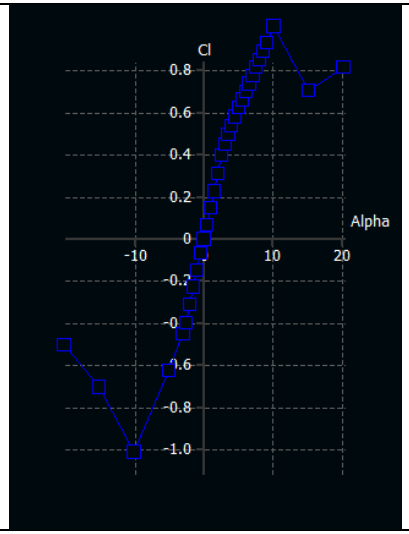
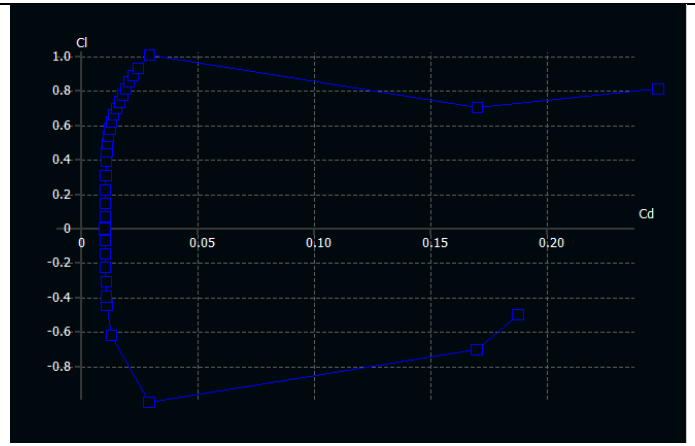
The MathWorks Inc. (2022). MATLAB version: 9.13.0 (R2022b), Natick, Massachusetts: The MathWorks Inc. https://www.mathworks.com

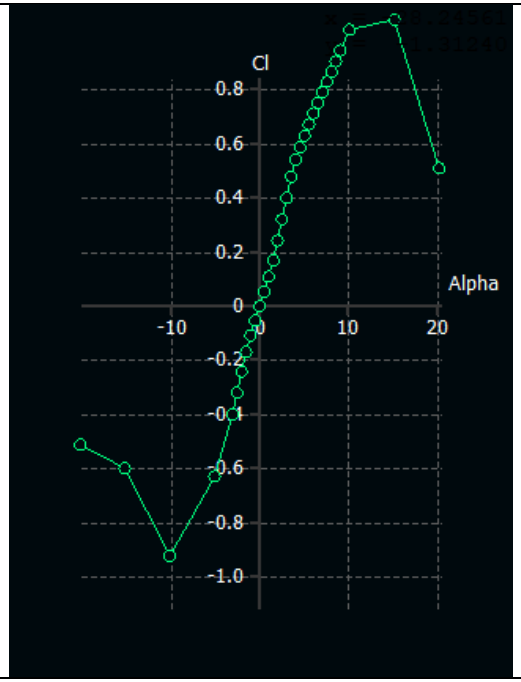
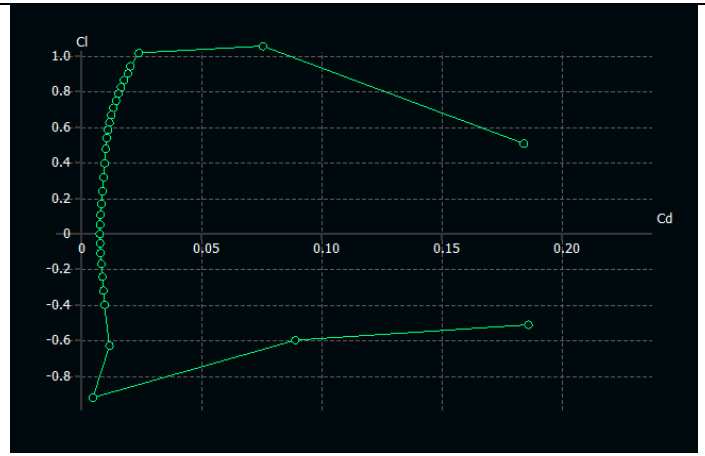
In this memo, a NACA 0012 and Wortman airfoil are analyzed computationally. A wind tunnel test is also conducted, and the values of wake pressure are recorded using the wake-rack system. Through the integration of the pressures obtained, the value of the coefficient of drag at different Reynold's numbers for different angles of attack is obtained with the help of MATLAB.

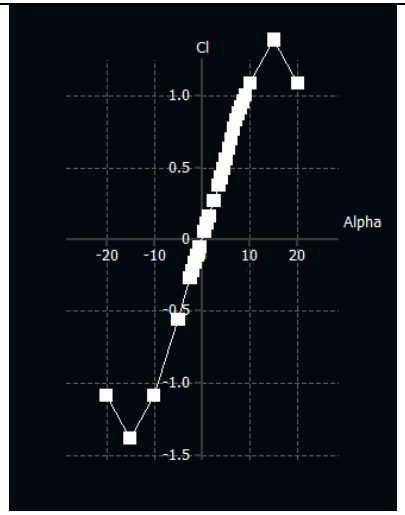
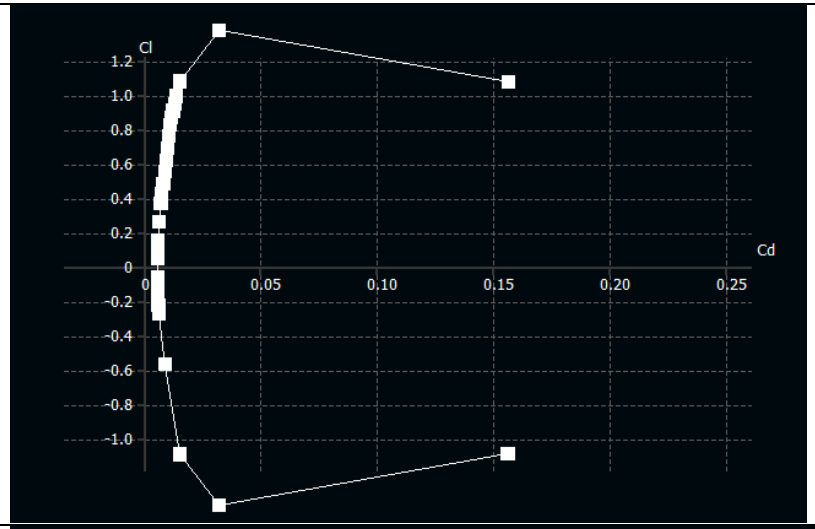
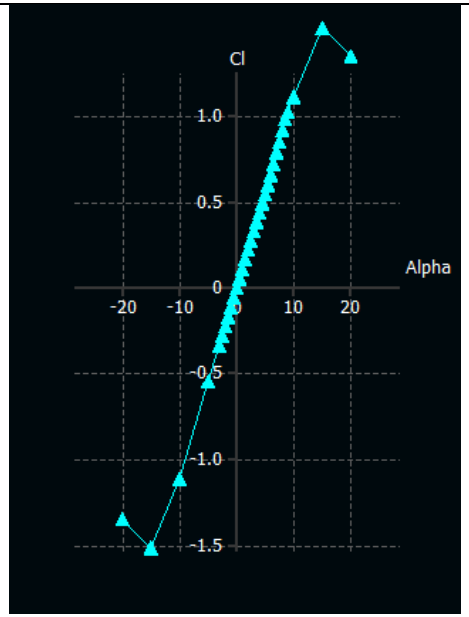
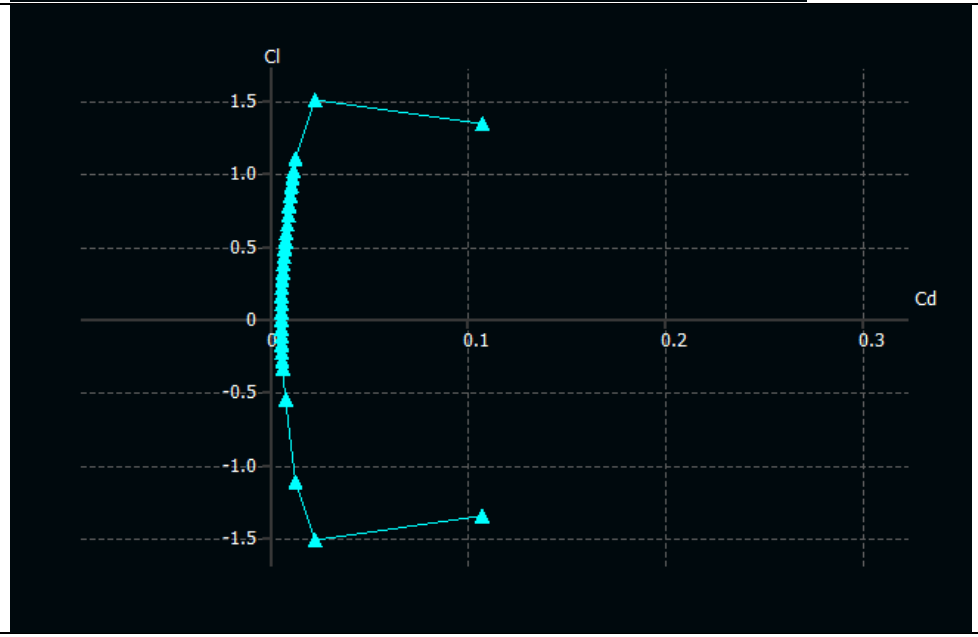
Discussion:

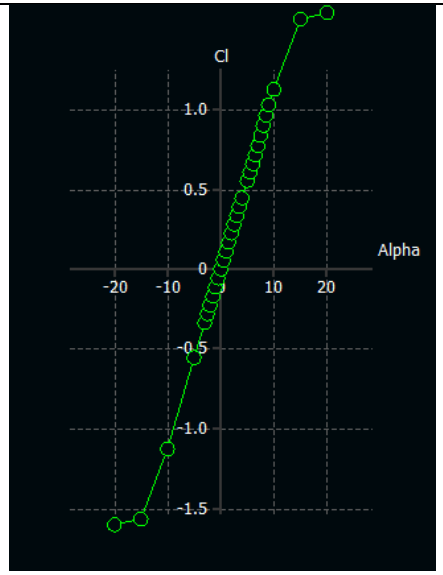
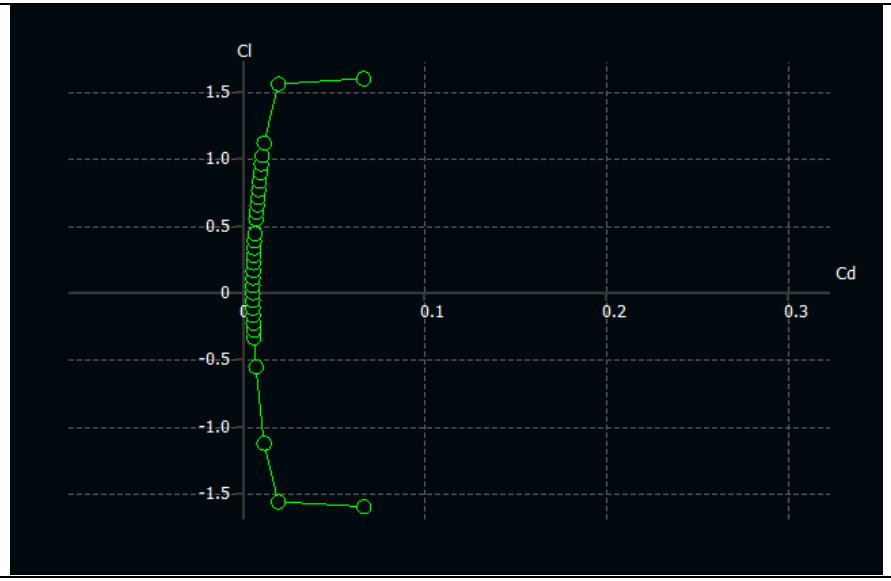
Part 1: NACA 0012 airfoil

Reynold's number	CL vs aplha	Cl vs Cd	L/D max
1e5			38

2e5	 Cl 0.8 0.6 0.4 0.2 0 -10 10 20 Alpha -0.8 -1.0	 Cl 1.0 0.8 0.6 0.4 0.2 0 0 0.05 0.10 0.15 0.20 Cd -0.2 -0.4 -0.6 -0.8	47

3e5	 Cl 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 -1.0 -10 0 10 20 Alpha	 Cl 1.0 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 0 0,05 0,10 0,15 0,20 Cd	53

1e6	 Cl 1.0 0.5 0 -0.5 -1.0 -1.5 -20 -10 10 20 Alpha	 Cl 1.2 1.0 0.8 0.6 0.4 0.2 0 -0.2 -0.4 -0.6 -0.8 -1.0 0 0.05 0.10 0.15 0.20 0.25 Cd	75
2e6	 Cl 1.0 0.5 0 -0.5 -1.0 -1.5 -20 -10 10 20 Alpha	 Cl 1.5 1.0 0.5 0 -0.5 -1.0 -1.5 0 0.1 0.2 0.3 Cd	92

3e6			100

<u>Figure 1:</u> Table presenting the graphs c_L vs α; c_L vs c_D at the different Reynold's numbers

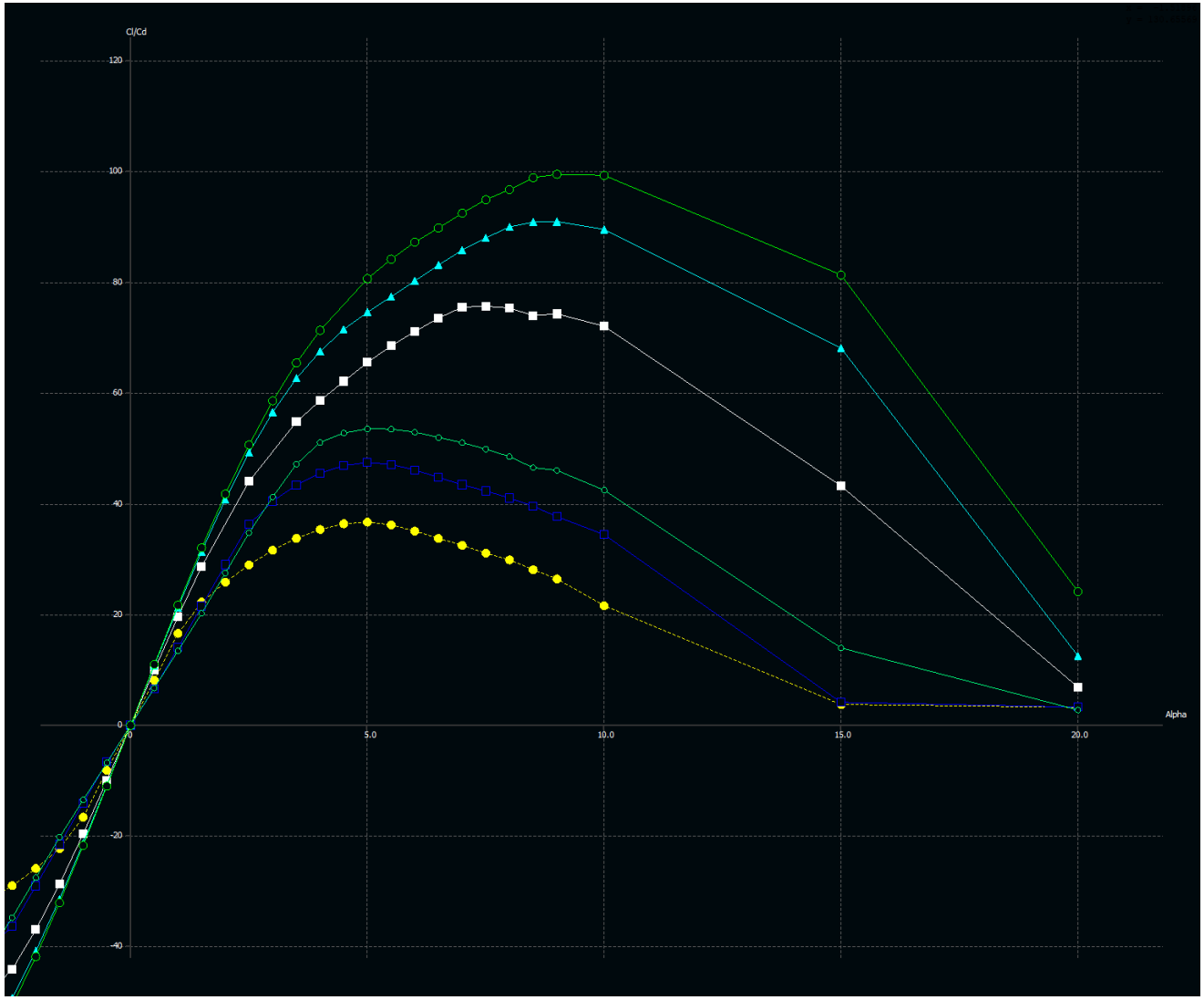


Figure 2: Graph representing cl/cd vs α

Assuming that $Re = \frac{\rho V c}{\mu}$, V = $\frac{Re* \mu}{\rho * c}$ and $\rho = 1.225 \frac{kg}{m3}$, $\mu = 0.00001825$, and c = 3.5 in = 0.1016 m, we have:

Re number	V (m/s)
1.00E+05	1.47E+01
2.00E+05	2.93E+01
3.00E+05	4.40E+01
1.00E+06	1.47E+02
2.00E+06	2.93E+02
3.00E+06	4.40E+02

Figure 3: Table representing the values of V at different Reynold's number of an airfoil with 3.5 in chord length

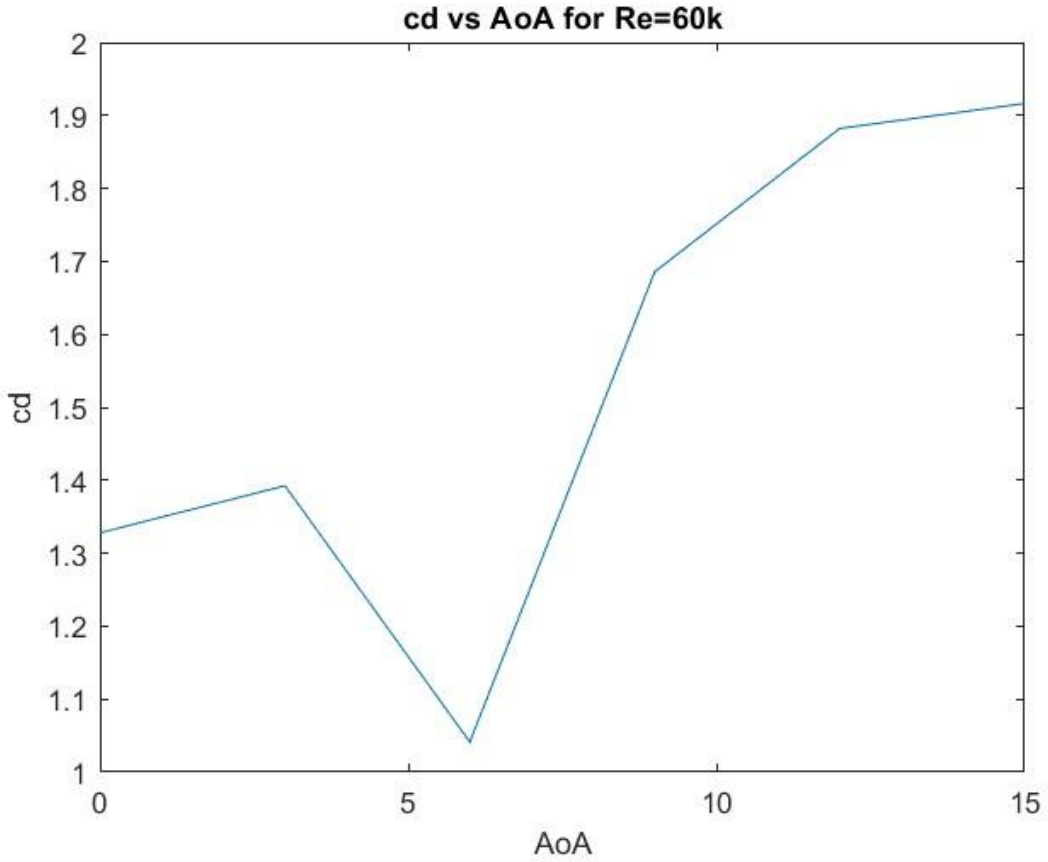


Figure 4: Plot of cd vs angle of attack at Re = 60,000

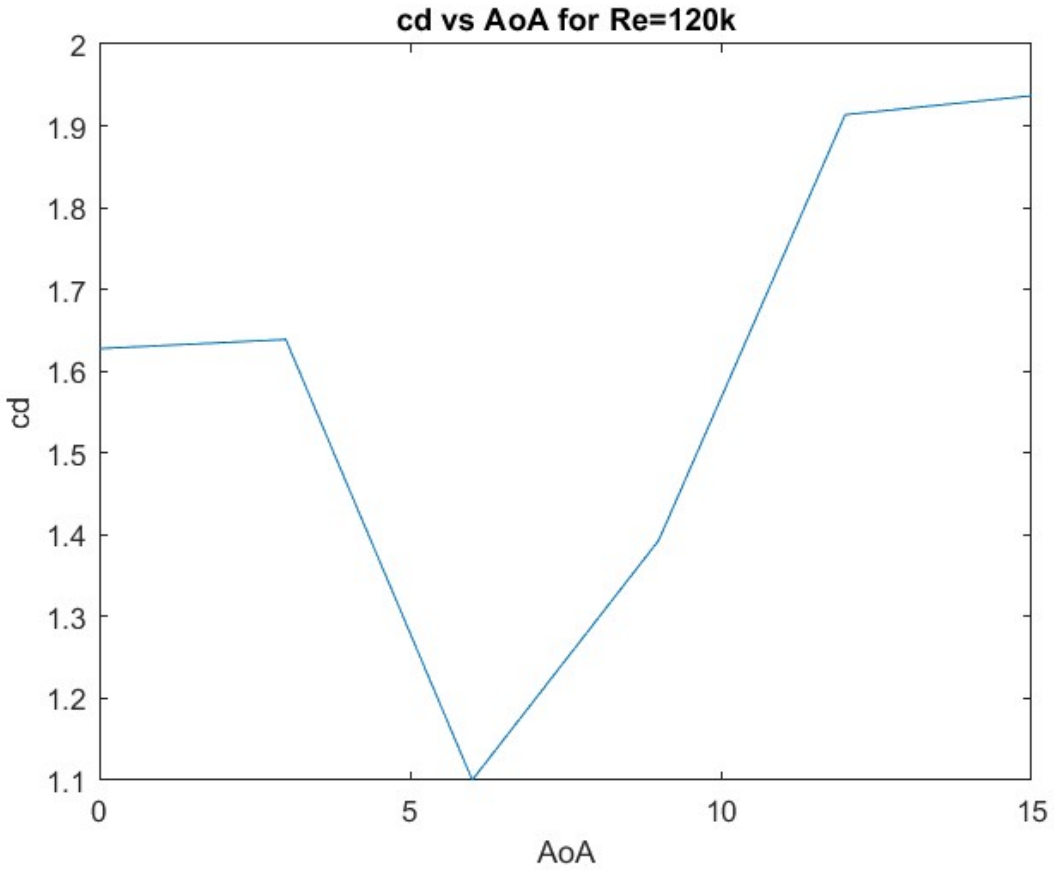


Figure 5: Plot of cd vs angle of attack at Re = 120,000

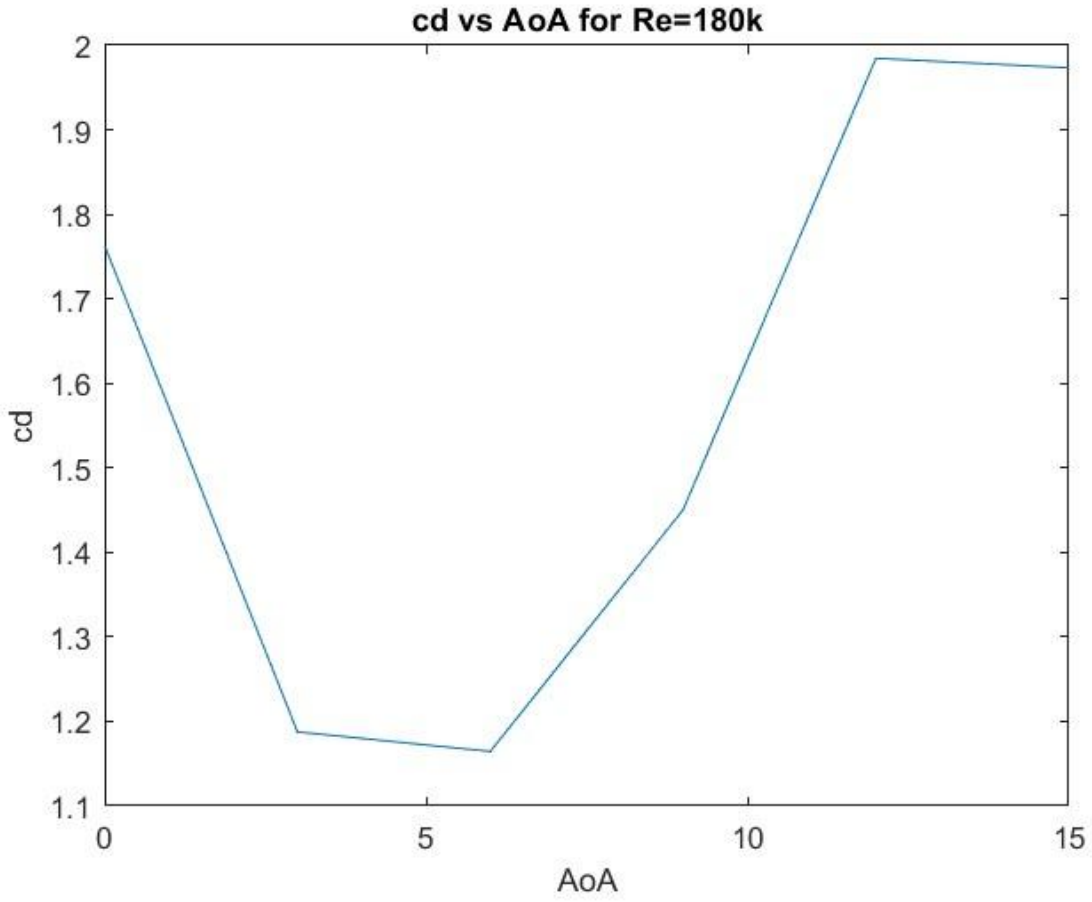


Figure 6: Plot of cd vs angle of attack at Re = 180,000

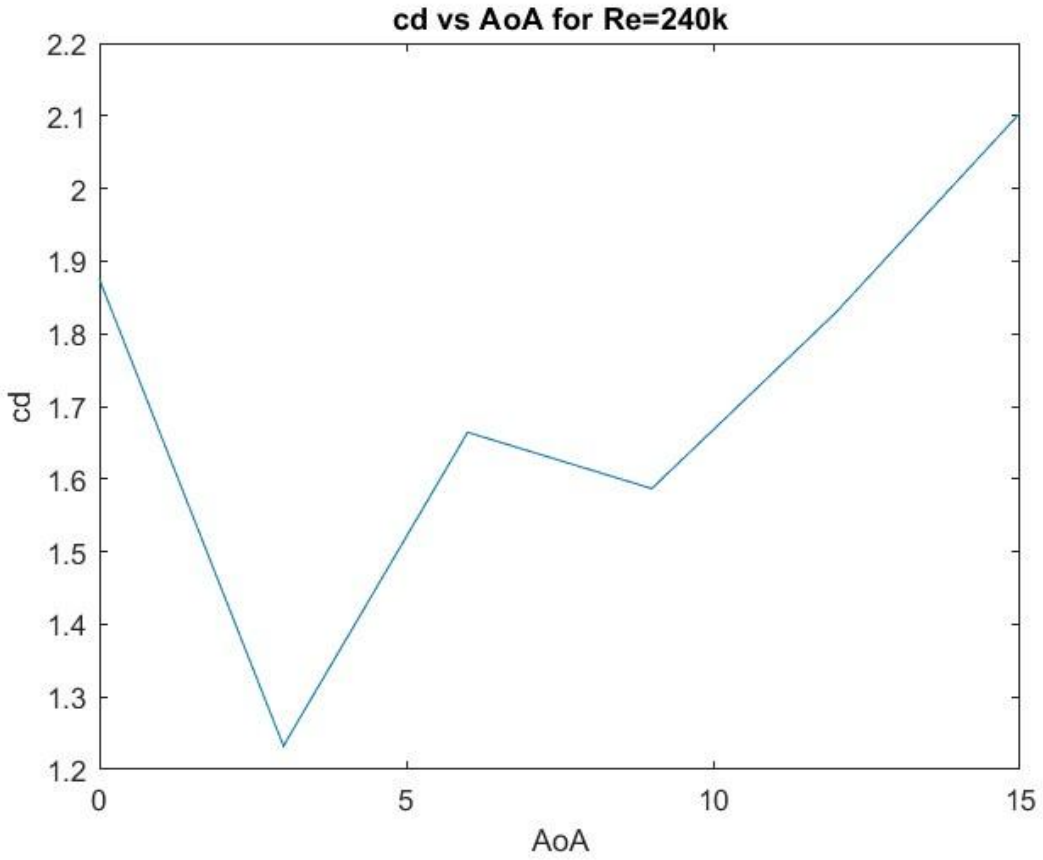


Figure 7: Plot of cd vs angle of attack at Re = 240,000

One observation that can be made is that the coefficient of drag increases as the Reynold's number increases, which makes sense because of the viscous forces that result.

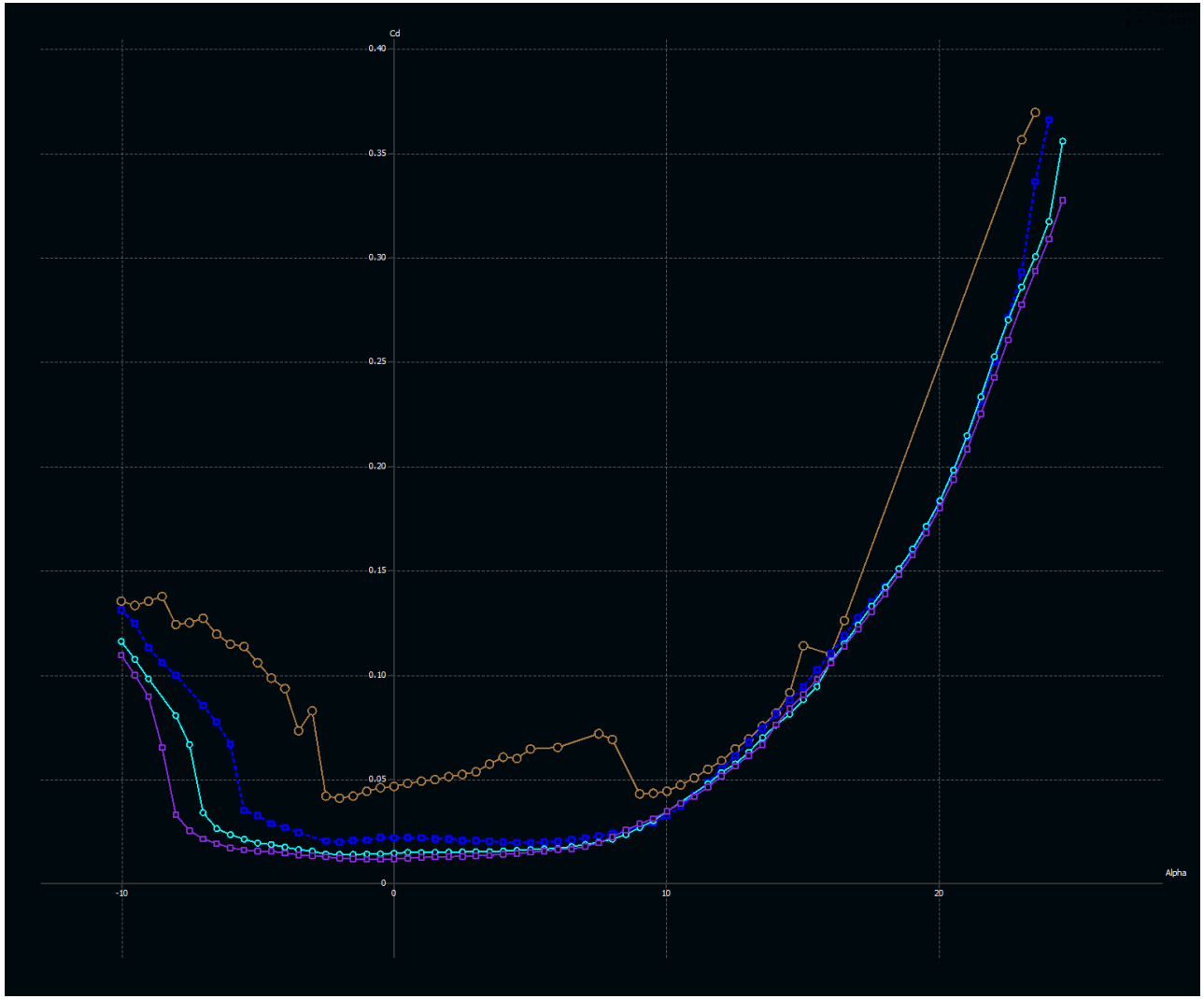


Figure 8: Graph representing cd vs α for the Wortman airfoil

The coefficient of drag is generally way lower computationally than what has been computed on MATLAB. This may be due to the position of the wake system on the airfoil. It is capturing the total pressure rather than the momentum deficit.

Conclusion/Recommendations:

Integrating wake rack is an easy method to measure drag of an airfoil. Using a series a Pitot tube to measure total pressure is an efficient alternative to measuring aerodynamic data, but one needs to take the wake rack position into account.

Operating the wind tunnel has been an interesting experience. Getting to manipulate the LabVIEW code that controls the air speed gives us an insight into how testing is conducted in industry and in research. Writing the MATLAB code to produce the graph has also been challenging, but it just shows how efficient MATLAB is in terms of data interpretation given the amount of data collected form the wind tunnel. This assignment has shaped my coding skills.

Appendix: MATLAB code

```
Re_list = [60, 120, 180, 240];
AoA = [0,3,6,9,12,15];
color = ["b", "g", "r", "c", "m", "y"];
fnumber = 1;
figure(fnumber);
cd_list = [];
for h = 1:numel(Re_list)
    for g = 1:numel(AoA)
        re = string(Re_list(h));
        a = string(AoA(g));
        f = readtable("WakePressure_Re"+re+"k_a"+a+"_xrake5c.dat");
        s = 32;
        data = [];
        wd_array = [];
        integral = [];
        Re = Re_list(h)*1000;
        nu = 0.00001825;
        rho = 1.225;
        q_inf_c = 0.5*Re*Re*nu*nu/rho/0.0889/0.0889;  %get dynamic viscosity
        for i = 1:size(f, 1)
            if mod(i,32) ~= 0 %if we are not at the 32nd row
                fdp = f{i, 4};
                tgp = f{i,3};
                sgp = f{s, 3};
                wd = fdp - (tgp - sgp);
                y_location_over_c = f{i, 1}/1000/0.0889;   %convert to meters then divide by chord length
                if wd/q_inf_c > 0
                    wd_array = [wd_array, wd/q_inf_c];
                    y_over_c = y_location_over_c;
                    data = [data, y_over_c];
                end
            else
                s = s+32;
```

```
            end

        end
        data = data.';
        wd_array = wd_array.';
        cm = [data wd_array];
        cm = sortrows(cm);
        disp(cm);
        D = trapz(cm(:,1), cm(:,2));   %integration
        disp(D/q_inf_c);
        cd_list = [cd_list, D];  %list of drag calculated
        plot(cm(:,2), cm(:,1));

        hold on;
        s = 32;
    end
    title("y/c vs wake_pressure/dynamic pressure for Re="+re+"k")
    xlabel("(p-pinf)/qinf")
    ylabel("y/c")
    legend('0deg', '3deg', '6deg', '9deg', '12deg', '15deg');
    hold off
if fnumber ~= 4
    fnumber = fnumber+1;
    figure(fnumber);
end
end

indices = 0;
fnumber = 5;

%plot cd vs angle of attack
for h = 1:numel(Re_list)
    figure(fnumber)
    indices = indices+6;
    cd = cd_list((indices-5):indices);
    plot(AoA, cd);
    xlabel("AoA");
```

```
    ylabel("cd");
    title("cd vs AoA for Re="+Re_list(h)+"k")
    fnumber = fnumber+1;
end
```