Incompressible Aerodynamics Wind Tunnel Lab Report

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Abstract

The objective of the report and the main experiment is to calculate lift and drag on a 2_d NACA 0012 aerofoil, lift can be calculated on a lot of programs but the problem is in drag and this is because we doesn't have analytical equations for drag except the induced drag so, that's why we use experiments in calculating drag.
Lift is calculated by measuring pressure distribution along upper and lower surfaces of aerofoil and integrating along the area to get normal and axial forces and, drag is calculated by measuring the velocity distribution of the aerofoil wake and use conservation of momentum but still we have some factors which affect our measurements like: the Reynolds number, differences in freestream turbulence model and tunnel blockage and other more but some of them can corrected

1. Introduction

We want to calculate lift and drag on a 2-d NACA 0012 aerofoil with a chord of 0.152m for a different angle of attack, to analyze the performance and the aerofoil characteristics.
Objectives of the experiment is calculating lift and drag experimentally by using the wind tunnels which is a device or tool used to study the effects of air on objects and how by calculating pressure distributions using static tubes and trancdusers and manometers we can get the lift and drag coefficients

2. Methodology

- We used the following equipment in this experiment are:
  1- the wind tunnel which is the main device
  2- the aerofoil we want to analyze it
  3- Manometer
  4- Pitot static tube
  5- Wake strake




- the experiment procedure is:

1- First, we must make sure that our aerofoil section is mounted across the entire width of the test section to get rid of 3-D effect, and the wing incidence angle set to zero as a start. and ensure that the wake rake is locked in an upright position.
2- Now we can switch the wind tunnel ON and set the free stream velocity to 20 m/s and measure static pressure on the wing surfaces by using the 23 taps on the wing; 12 taps on upper surface and 11 on lower surface those taps are located on mid span to be as far as possible from the wall as still calculations there is not accurate
3- Set the airfoil to zero incidence and a rake that is consisted of 13 pitot propes is mounted then traverse the wake rake until we found the rake position
4- Repeat that procedure for different angle of attack: 3,6,9,12,15.

- Now this is the steps for calculating the aerodynamics coefficients from the wind tunnel data:

1- Measure the pressure coefficient at each point

$$C_p = \frac{p_S - p_\infty}{\frac{1}{2}\rho V_\infty^2} = \frac{p_S - p_\infty}{p_T - p_\infty}$$

2- calculate the normal force coefficient by integrating the pressure around the aerofoil

$$C_n = \frac{1}{\mathrm{c}}\oint_{Lower} C_p dx - \frac{1}{\mathrm{c}}\oint_{Upper} C_p dx$$

Then, we know that from the Cn only we can get the CL since Ca and alpha is small so it can be ignored

$$C_l = C_n cos\alpha$$

Based on the thin aerofoil theory, the theoretical value of the lift coefficient for 2D symmetric aerofoils is given by:

$$c_l = 2\pi\alpha$$

3- then, we can calculate the pitching moment by multiplying the normal force by its distance from a reference location

$$C_m = \frac{1}{\mathrm{c}^2}\oint_{Lower} C_p(x - x_{ref})dx - \frac{1}{\mathrm{c}^2}\oint_{Upper} C_p(x - x_{ref})dx$$

4- The drag coefficient can be obtained by:

$$c_d = \frac{D}{\frac{1}{2}\rho V_\infty^2 c} = \frac{2}{c}\int_{wake} \frac{u(y)}{V_\infty}\left(1 - \frac{u(y)}{V_\infty}\right) dy$$

The velocity ratio calculated by using the following formula

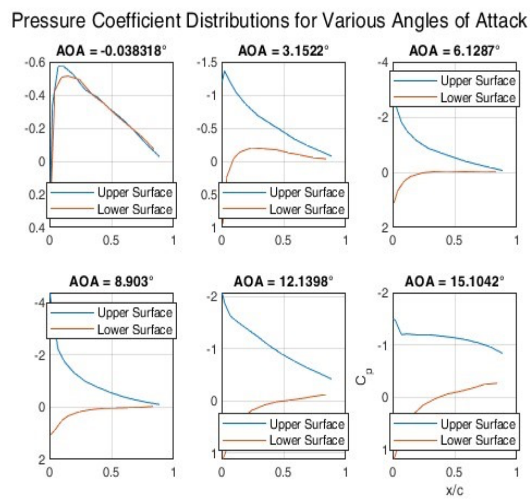
$$\frac{u(y)}{V_\infty} = \sqrt{\frac{p_{Tw}(y) - p_{sw}(y)}{p_T - p_\infty}}$$

All pressures used are:

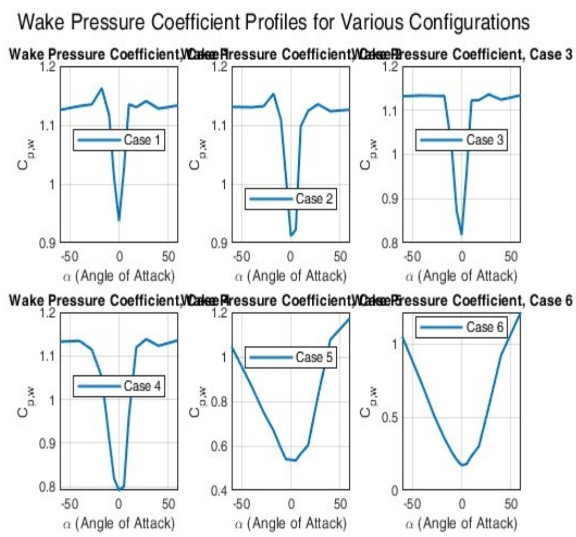
p_T = freestream total pressure
p_∞ = freestream static pressure
p_{Tw} = total pressure at a station in the wake
p_{sw} = static pressure at a station in the wake

3. Results and Discussion

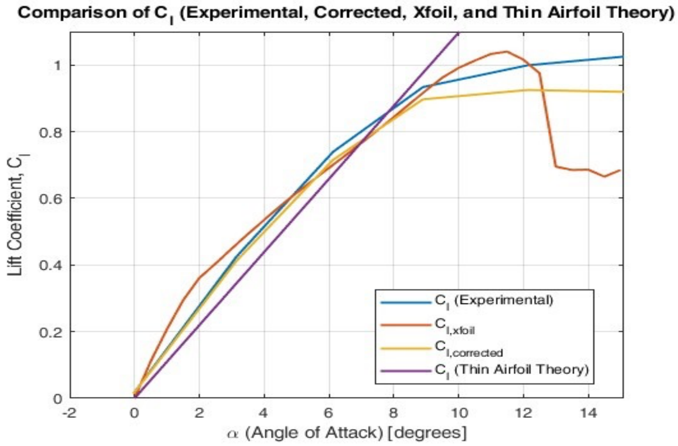
a- We can see here the effect of the AOA on the pressure distribution of the airfoil vertical axis is inverted so the pressure up is put above pressure down we can see here the peak point the point which has the maximum negative pressure which also can tell us where the flow will start to change from laminar to turbulent, on zero AOA we can see that upper pressure and lower pressures cancels each other due to using symmetric airfoil



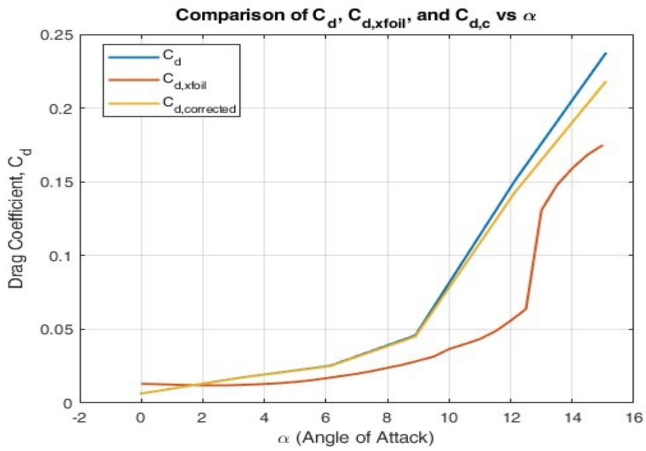
Cpw is the distribution of the pressure coefficient in the wake region behind the wing, which is due to separation, it appeared it is a symmetric graph which is due the symmetric airfoil used

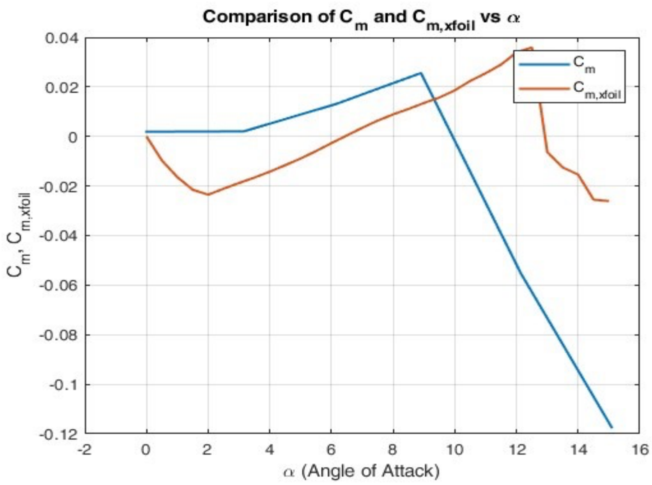


b- Due to symmetric airfoil at zero AOA CL is zero, there is different in slopes between experiment and thin airfoil theory due to errors while measuring in wind tunnel like differences in freestream turbulence model , tunnel blockage, boundary layer and roughness but not a huge error.



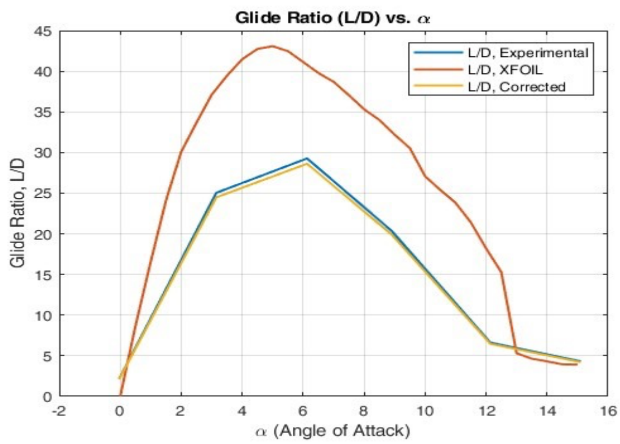
c- Corrected and uncorrected at low AOA are almost identical as still the effect of errors is not huge like tunnel blockage as AOA increases the separation drag increases and the curve increases





d- we can see obviously at low AOA the pitching moment is almost zero which means a neutral flight so airplane can fly upside down in this case

e- it refers to how efficient the plane glide or decent, for gliding we need maximum lift with lowest drag



f- tunnel blockage is attributed to solid blockage and wake blockage

solid blockage: due to lateral constraints to the flow pattern around the airfoil.

wake blockage: due to lateral constraints to the flow pattern around the wake.

if the overall blockage error is less than 5%, it can be neglected

4. Conclusions

At the end of procedures and steps that we briefly explained we will have lift, drag and pitching moment and we can get any other parameters from these.
Here are some suggestions we may add on next experiment:

1- We can use more advanced tools and techniques to measure the data
Like: a better pressure sensor, more efficient wake strake
2- Increases number of tubes which will give us a better accuracy

Author Contribution

1- Documentation:
Loay Mohamed & Mustafa taha
2- MATLAB code:
3- Loay Mohamed & Mustafa taha

References

- Lap handout
- Lecture note
- Anderson J D, Fundamentals of Aerodynamics, 6 th edition, McGraw-Hill.