Laboratory Report

Arjun Nair[1], Alessandro Pegoraro[2], Alessandro Piana[3], Francesco Poggi[4], Kovindaraj Venkatesh[5]

[1]arjun.nair@mail.polimi.it & 302312
[2]alessandro1.pegoraro@mail.polimi.it & 303712
[3]alessandro5.piana@mail.polimi.it & 299828
[4]francesco.poggi@mail.polimi.it & 308670
[5]kovindaraj.venkatesh@mail.polimi.it & 298879

24 December 2025

1. Hess-Smith Method

1.1. *Task 1 - Validation with XFOIL*

To validate the numerical implementation, the number of panels used to discretize the NACA 0008 airfoil was increased to 301. This choice was made to minimize discrepancies arising from geometric discretization and to ensure that any observed differences were not attributable to the different levels of numerical accuracy between the present MATLAB® code and XFOIL.

The pressure coefficient C_p, lift coefficient C_l, and moment coefficient C_m obtained from the MATLAB® implementation were then compared with the corresponding results computed using XFOIL over a range of angles of attack. The results are shown in table 1.

1.2. *Task 2 - Comparison with another airfoil*

In this section, the aerodynamic performance of the NACA 0008 airfoil is compared with that of the *AG26 Bubble Dancer* airfoil.

The comparison is performed at a Reynolds number of $Re = 5 \cdot 10^5$ in order to assess the differences in the aerodynamic behavior of the two airfoils under identical flow conditions. Furthermore, to investigate the effect of turbulence intensity on the boundary-layer development, the evolution of the transition and separation locations is analyzed by comparing the pressure coefficient C_p distributions at $Re = 4 \cdot 10^5$ and $Re = 3 \cdot 10^5$.

The angle of attack selected for this analysis is $\alpha = 3°$. All aerodynamic data are obtained using XFOIL.

The results highlight substantial differences in the C_p distributions of the two airfoils, which lead to markedly different aerodynamic coefficients as well as distinct transition and separation points along the chord.

From the results in the table and from the graphs we can easily see how the transition starts earlier for higher Reynolds numbers.

2. Weissinger Method

2.1. *Task 3 - Validation with XFLR5*

To validate the MATLAB® code, XFLR5 was used and the results were compared. The outcome was a very satisfying similarity between the data, with small relative errors

α - AoA	$-5°$	$-3°$	$-1°$	$2°$	$4°$
C_l - Hess Smith	-0.5952	-0.3574	-0.1192	0.2383	0.4764
C_l - Xfoil	-0.5848	-0.3511	-0.1171	0.2341	0.4680
Relative error	1.778%	1.794%	1.793%	1.794%	1.794%

TABLE 1. Validation of Hess Smith code with Xfoil

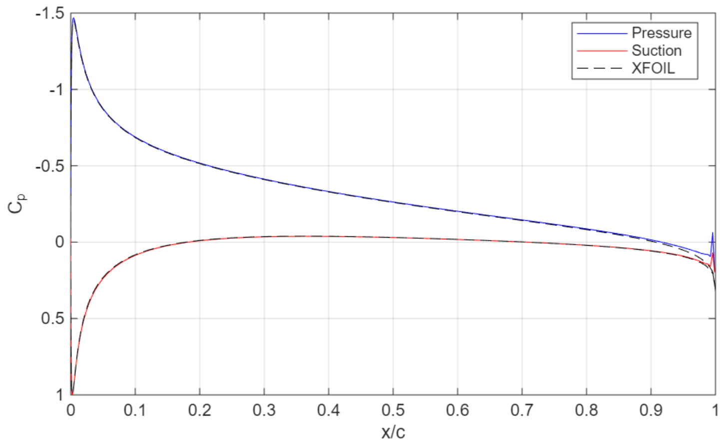

FIGURE 1. C_p distribution comparison between methods

Airfoil	Re	C_l	C_m	$x_{tr}[x/c]$	$x_{sep}[x/c]$
NACA0008	$5 \cdot 10^5$	0.3686	-0.0061	0.3521	0.9318
	$4 \cdot 10^5$	0.3688	-0.0057	0.4085	0.9316
	$3 \cdot 10^5$	0.3702	-0.0056	0.4864	0.9312
AG26 Bubble Dancer	$5 \cdot 10^5$	0.6366	-0.0626	0.4887	0.9574
	$4 \cdot 10^5$	0.6363	-0.0625	0.5255	0.9571
	$3 \cdot 10^5$	0.6366	-0.0624	0.5714	0.9564

TABLE 2. Profile coefficients and transition/separation points at different Re, $\alpha = 3°$

on the C_{L_α} and a sufficiently low error on the C_{Di_α}. The method's accuracy become lower as the angle of attack rises. The results are shown in figure 2.

2.2. *Task 4 - Cessna 172 Skyhawk / Vimana Comparison*

The comparison done in this section is between the *Cessna 172 Skyhawk* and the *Vimana*; they both are small aircraft and fly at low speeds. The results are compared in the table 3. From the table it's possible to easily see how the 2 aircraft are similar, the *Vimana* has a major downforce caused by the tail, that influences the total lift and also increases the tail induced drag.

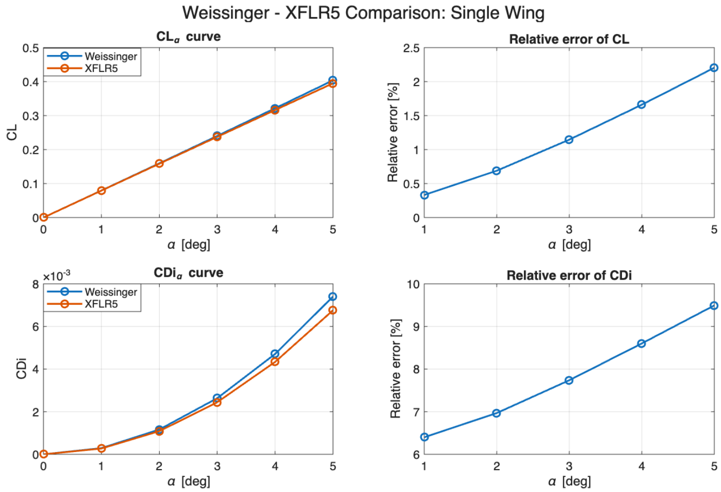

FIGURE 2. C_{L_α} and C_{Di_α} comparison between MATLAB® and XFLR5

Aircraft	L_{wing} [N]	L_{tail} [N]	L_{tot} [N]	C_L	$D_{i_{wing}}$ [N]	$D_{i_{tail}}$ [N]	$D_{i_{tot}}$ [N]	C_{D_i}
Cessna 172	20215.944	−421.516	19794.428	0.516	468.858	9.105	477.963	0.012
Vimana	13620.224	−919.875	12700.348	0.607	389.618	38.422	428.040	0.020

TABLE 3. Aircraft data comparison