

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Aerospaziale

Relazione per la prova finale
«Studio di profili alari invertiti in
effetto suolo»

Tutor universitario: Prof. Francesco Picano

Laureando: *Niccolò Agnoletto*

Padova, 12/07/2022



1966 Chaparral 2E



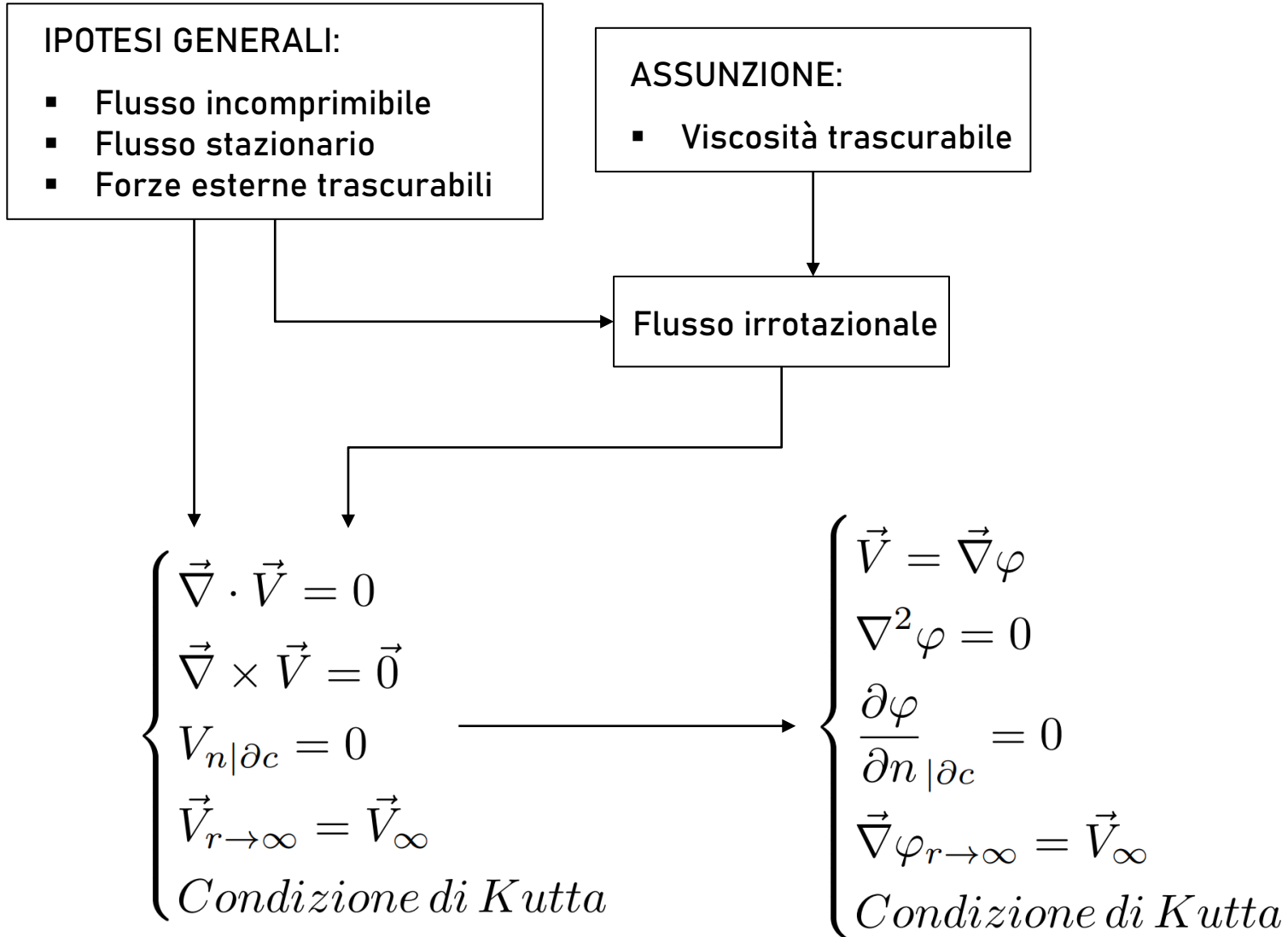
Volkswagen I.D. R



MG 15.20 EVO - RaceUP



Ferrari F1-75



Potenziale della velocità:

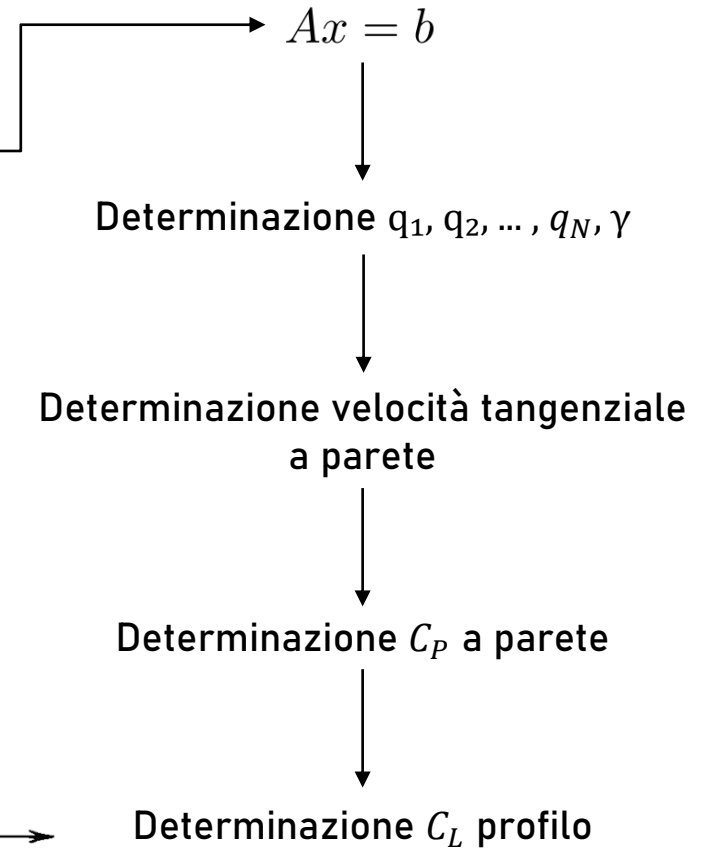
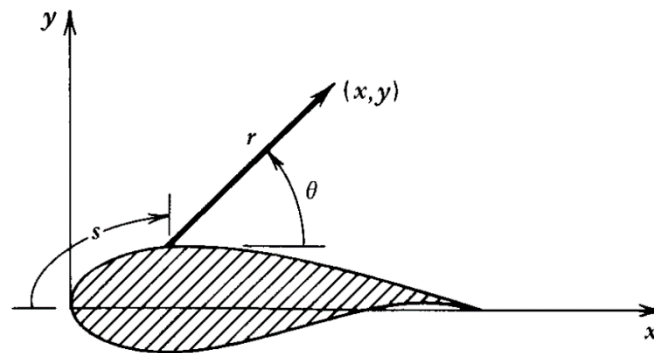
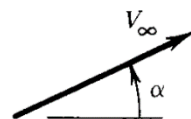
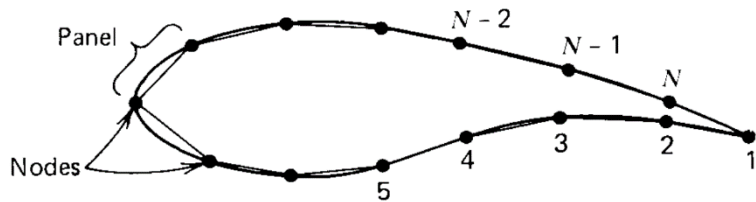
$$\varphi = V_{\infty} (x \cos \alpha + y \sin \alpha) + \sum_{j=1}^N q_j \int_{panel\ j} \frac{\ln r}{2\pi} ds - \gamma \sum_{j=1}^N \int_{panel\ j} \frac{\theta}{2\pi} ds$$

Condizione di impermeabilità (per ogni pannello):

$$-u_i \sin(\theta_i) + v_i \cos(\theta_i) = 0$$

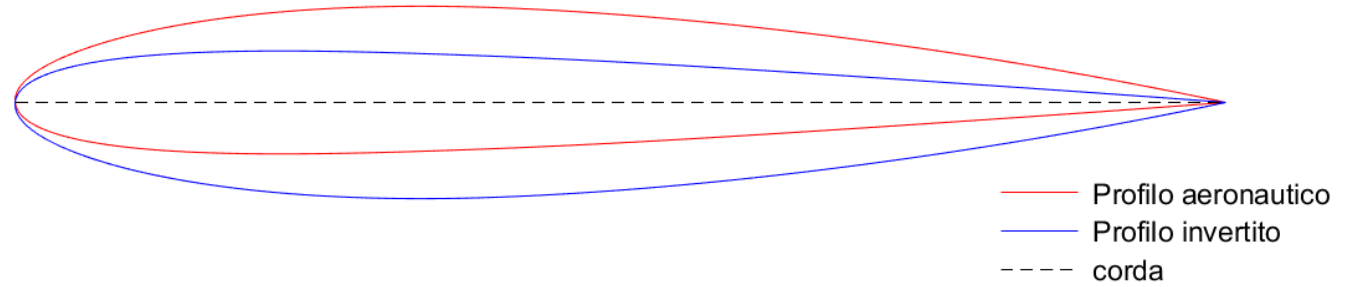
Condizione di Kutta:

$$u_1 \cos(\theta_1) + v_1 \sin(\theta_1) = -u_N \cos(\theta_N) - v_N \sin(\theta_N)$$



Differenze
fondamentali:

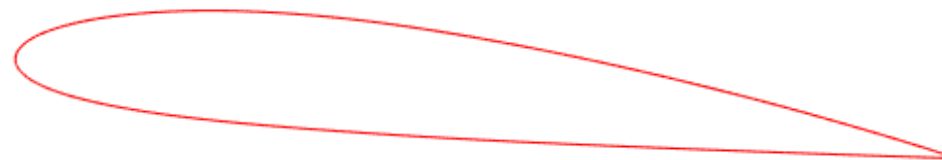
- Il profilo è invertito
- Il profilo è in effetto suolo



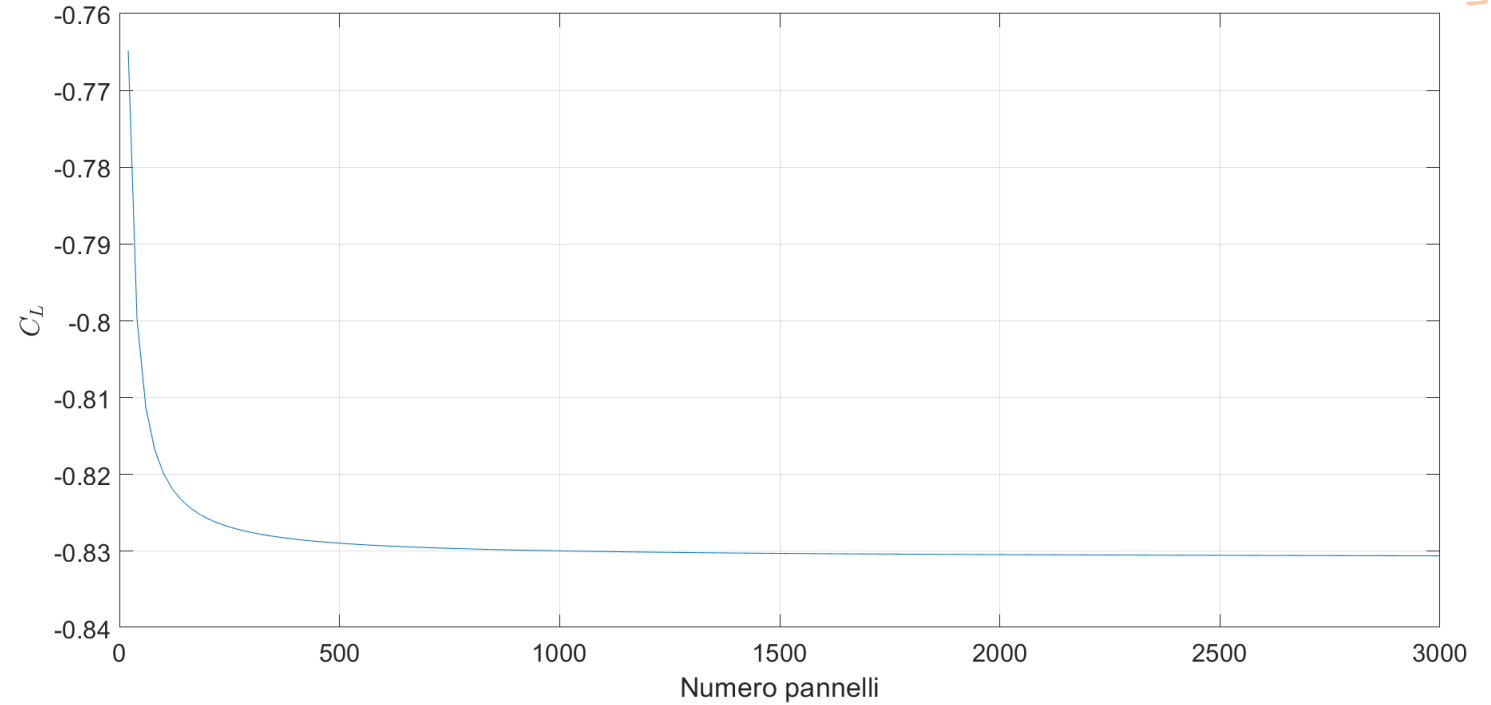
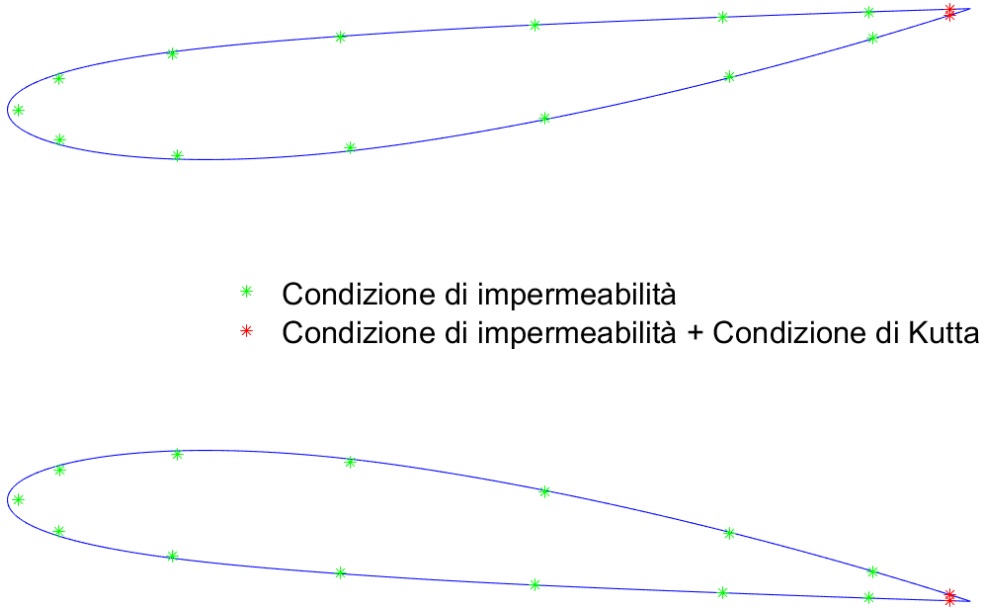
Inversione profilo NACA 2412



— Profilo reale
— Profilo fittizio
— Suolo



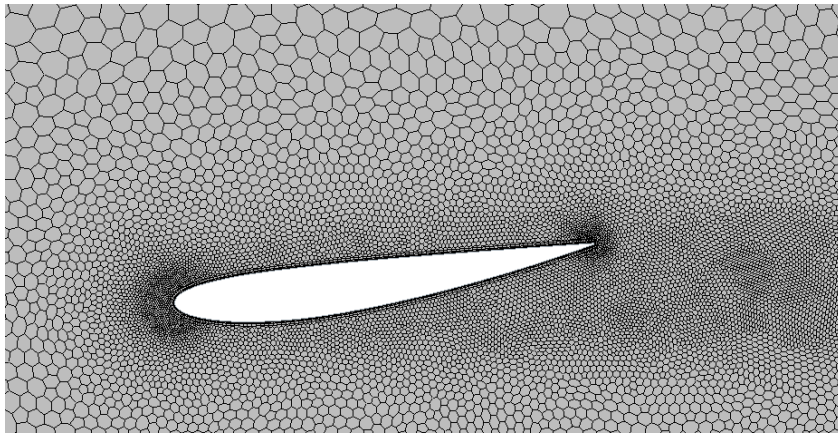
Introduzione profilo simmetrico rispetto al suolo



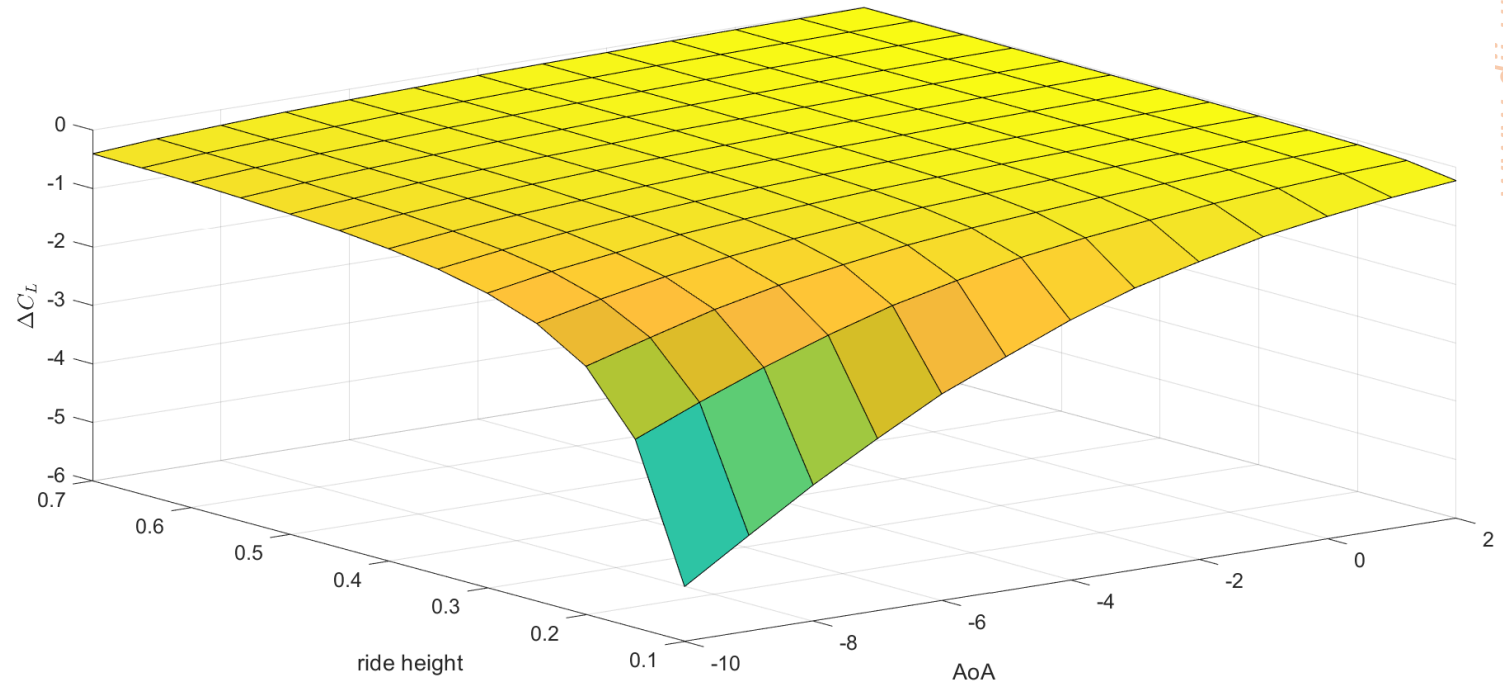
Studio di convergenza del C_L per il NACA 2412

Non considerazione:

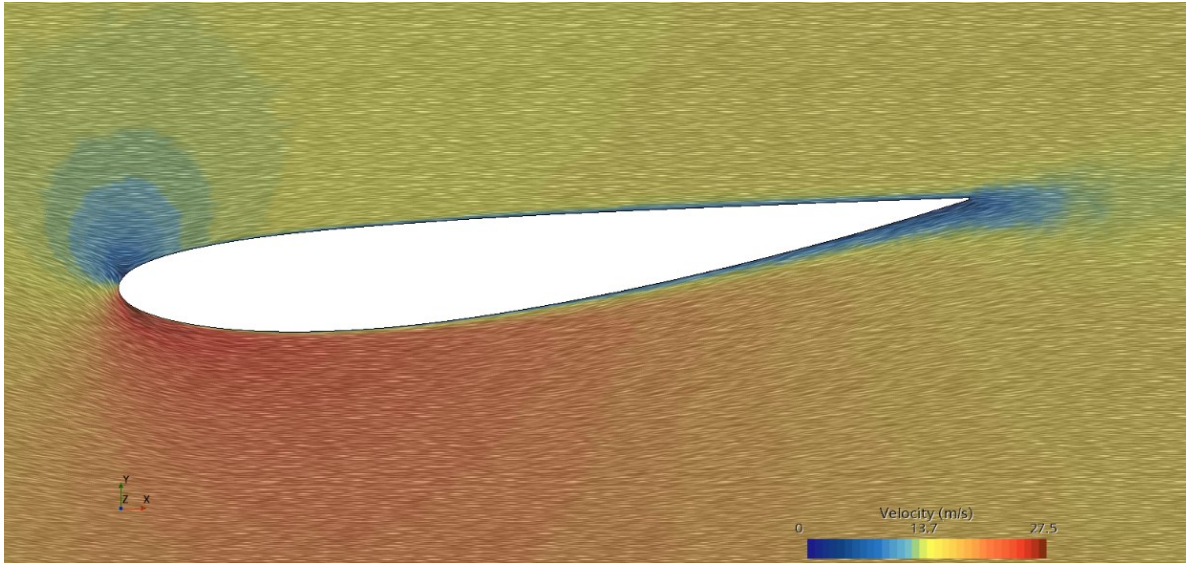
- Dello strato limite del profilo
- Dello strato limite del suolo
- Degli sforzi viscosi agenti sul profilo



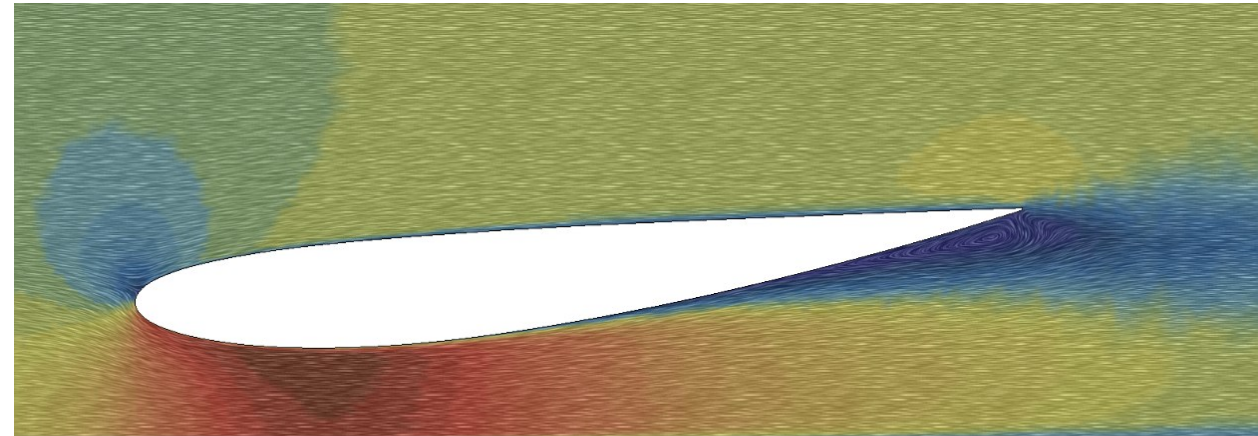
*Mesh poligonale utilizzata nelle simulazioni
CFD*



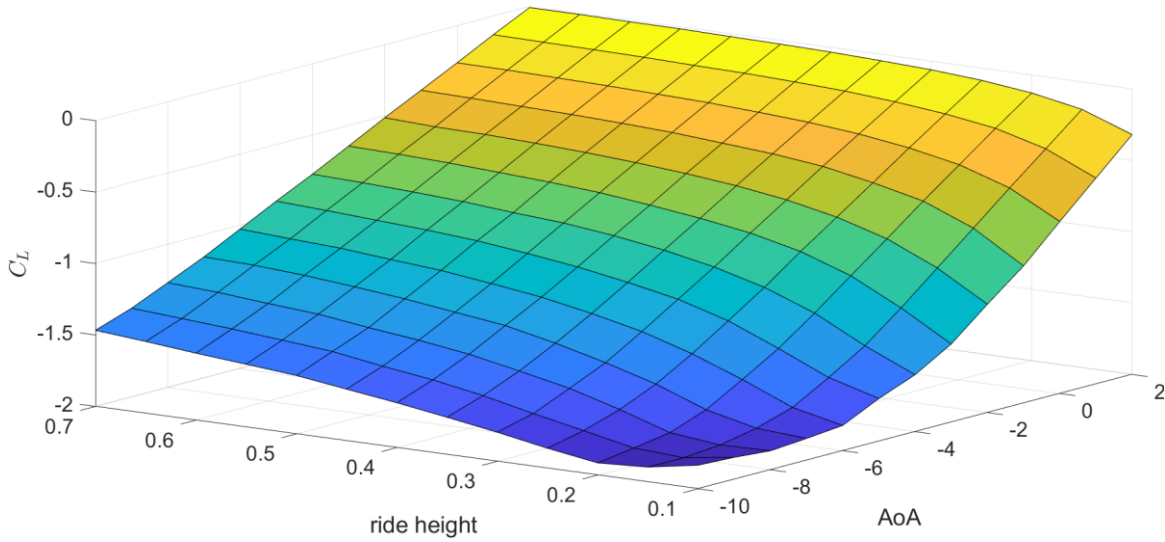
*Differenza tra il C_L previsto dalla CFD e dallo script in funzione
dell'angolo d'attacco e della ride height per il NACA 2412*



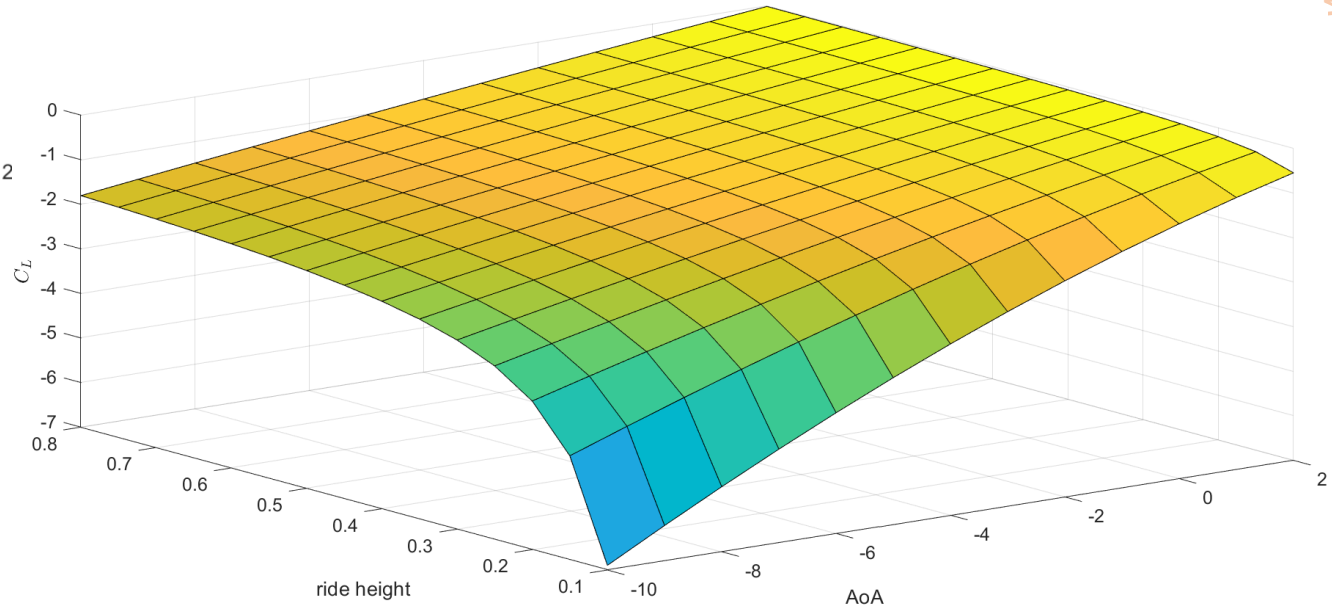
*NACA 2412, AoA = -6° , ride height = $0.5c$, velocità = 15 m/s,
 $Re = 4.9 \times 10^5$*



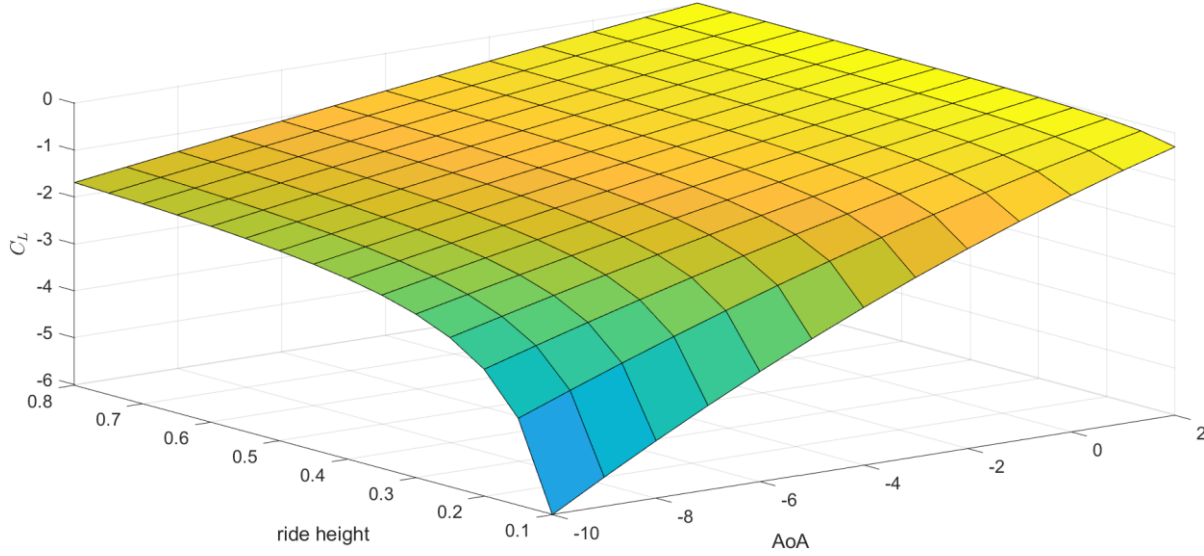
*NACA 2412, AoA = -6° , ride height = $0.1c$, velocità = 15 m/s,
 $Re = 4.9 \times 10^5$*



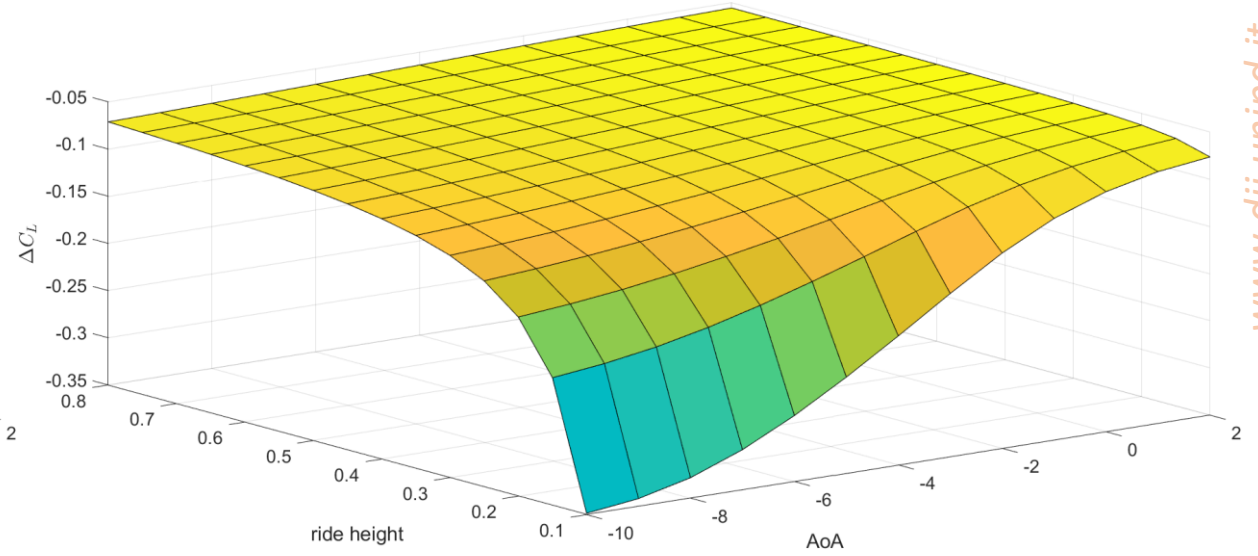
C_L previsto dalla CFD in funzione dell'angolo d'attacco e della ride height per il NACA 2412



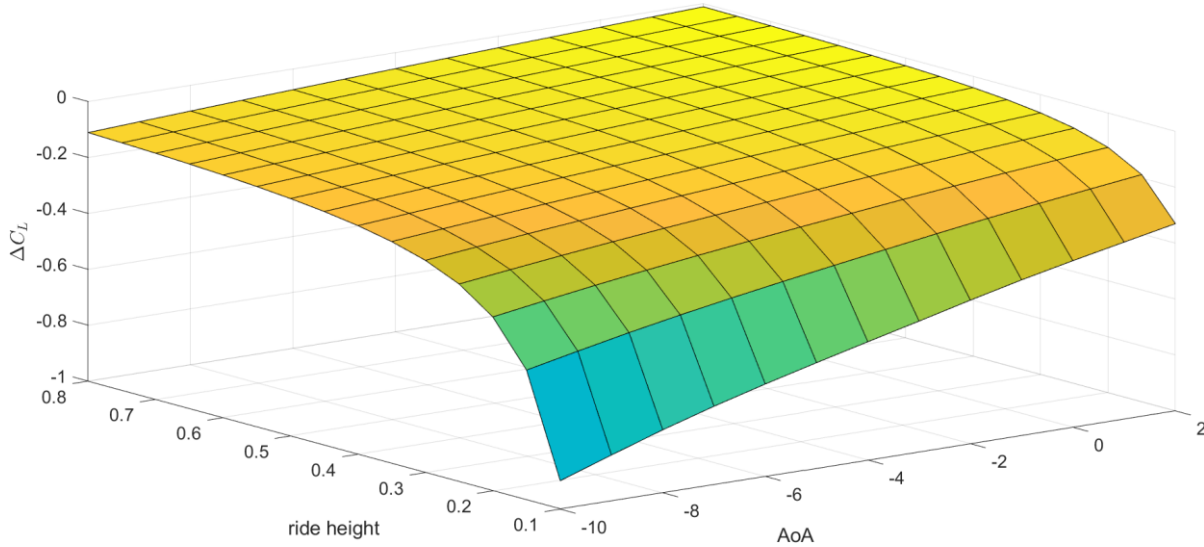
C_L previsto dallo script in funzione dell'angolo d'attacco e della ride height per il NACA 2412



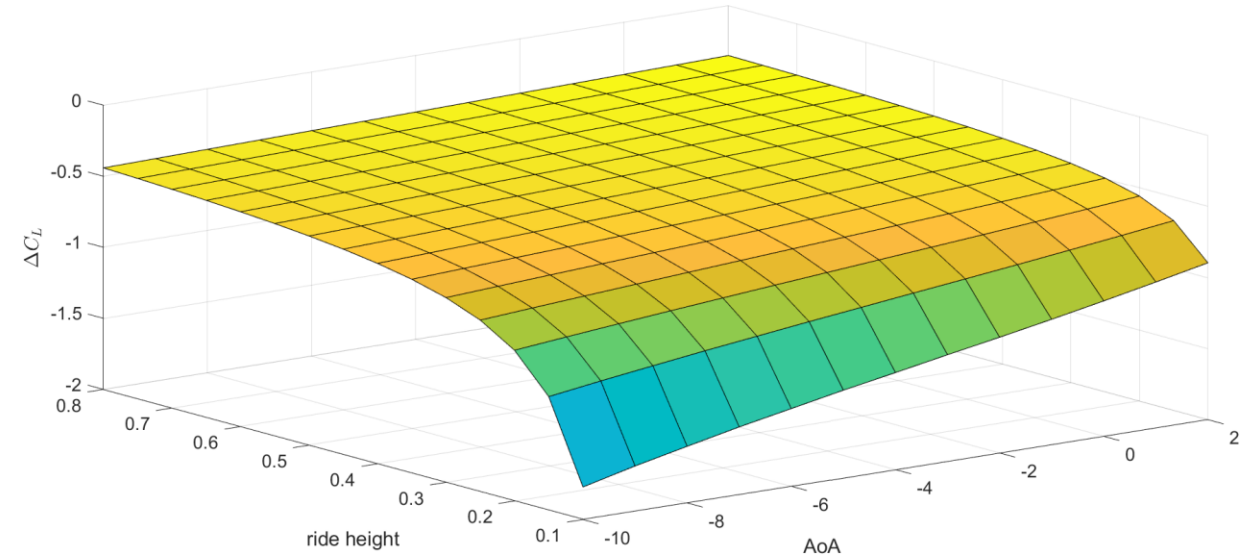
NACA 2208



NACA 2508 vs NACA 2208



NACA 2214 vs NACA 2208



NACA 5208 vs NACA 2208

$$C_L = f(\text{AoA}, \text{ride height}, \text{max. camber}, \text{pos. max. camber}, \text{max. thickness})$$

Negli intervalli:

- AoA : [-10° ; 2°]
- ride height : [0.1 c ; 1 c]
- max. camber : [2% c ; 5% c]
- pos. max. camber : [20% c ; 50% c]
- max. thickness : [6% c ; 15% c]

$$\frac{\partial C_L}{\partial(\text{AoA})} > 0$$

$$\frac{\partial C_L}{\partial(\text{ride height})} > 0$$

$$\frac{\partial C_L}{\partial(\text{max. camber})} < 0$$

$$\frac{\partial C_L}{\partial(\text{pos. max. camber})} < 0$$

$$\frac{\partial C_L}{\partial(\text{max. thickness})} < 0$$

$$\frac{\partial^2 C_L}{\partial(\text{AoA})^2} < 0$$

$$\frac{\partial^2 C_L}{\partial(\text{ride height})\partial(\text{AoA})} < 0$$

$$\frac{\partial^2 C_L}{\partial(\text{ride height})^2} < 0$$

$$\frac{\partial^2 C_L}{\partial(\text{max. camber})\partial(\text{AoA})} > 0$$

$$\frac{\partial^2 C_L}{\partial(\text{max. camber})\partial(\text{ride height})} > 0$$

$$\frac{\partial^2 C_L}{\partial(\text{max. thickness})\partial(\text{AoA})} > 0$$

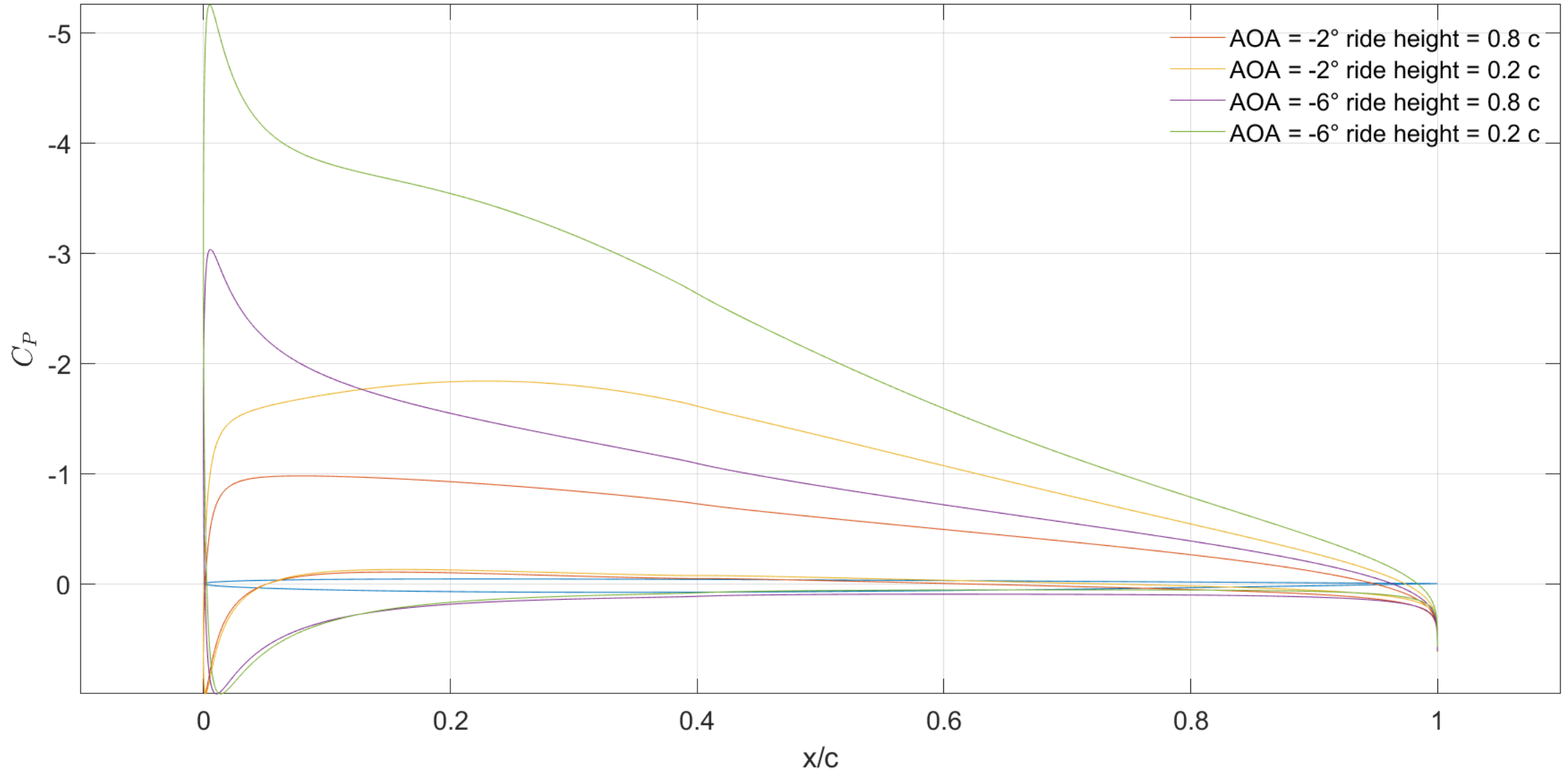
$$\frac{\partial^2 C_L}{\partial(\text{max. thickness})\partial(\text{ride height})} > 0$$

Negli intervalli:

- AoA : [-10° ; -2°]
- ride height : [0.25 c ; 1 c]
- max. camber : [2% c ; 5% c]
- pos. max. camber : [20% c ; 50% c]
- max. thickness : [6% c ; 15% c]

$$\frac{\partial^2 C_L}{\partial(\text{pos. max. thickness})\partial(\text{AoA})} > 0$$

$$\frac{\partial^2 C_L}{\partial(\text{pos. max. thickness})\partial(\text{ride height})} > 0$$



Andamento del coefficiente di pressione sull'estradosso e sull'intradosso del NACA 2412 per quattro combinazioni di AoA e ride height

- [1] Giorgio Graziani. “Aerodinamica”. In: (2010).
- [2] Joseph Katz. “Race Car Aerodynamics, Designing for Speed”. In: (1995).
- [3] Jack Moran. “An Introduction to Theoretical and Computational Aerodynamics”. In: (1984).
- [4] Dipak Sisodiya. “Investigation of Ground Effect on 2D Airfoils Using Panel Method”. In: (2017).