

Development of a Code for Aeroelastic Optimization of Wings with Stress Constraints Aggregation

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Presentazione del Progetto



➤ Obiettivi

- Open Source
- Basso Costo
- Computazionale
- Versatilità

➤ Software



openMDAO

v 1.7.3

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* N A S T R A N
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PANAIR

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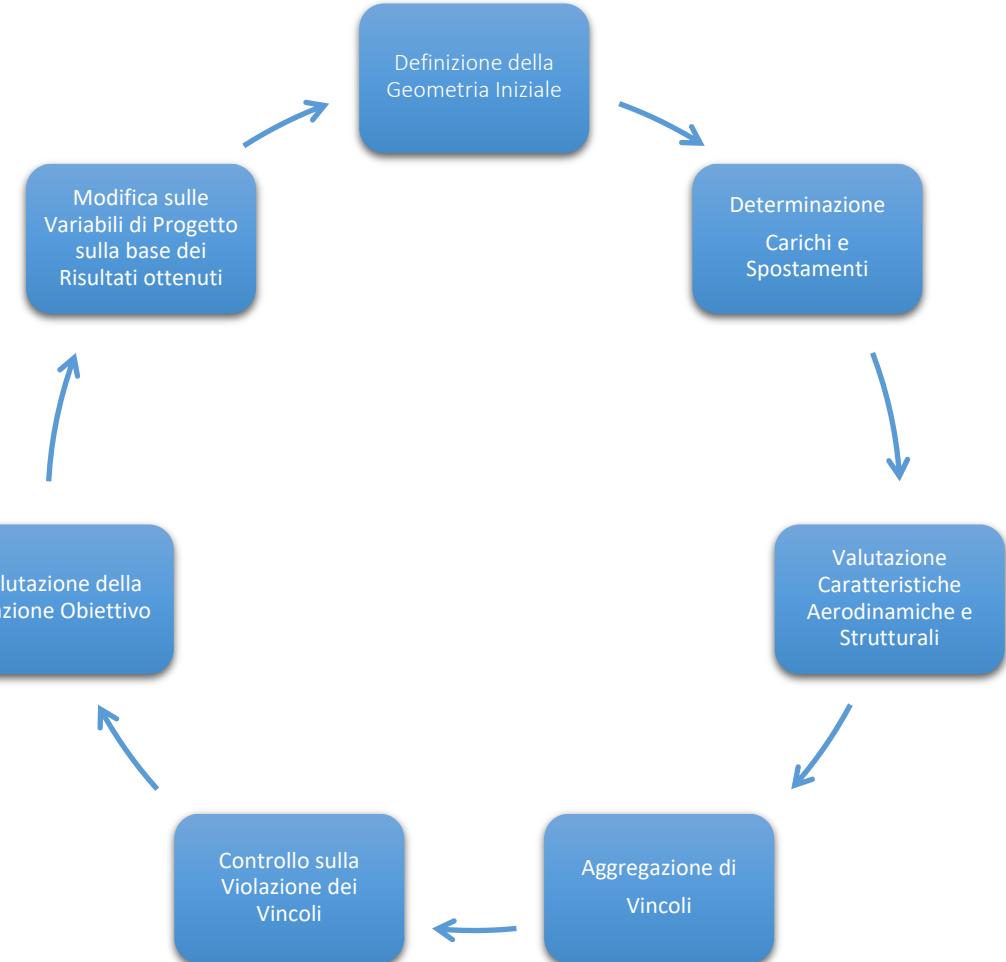
➤ Software



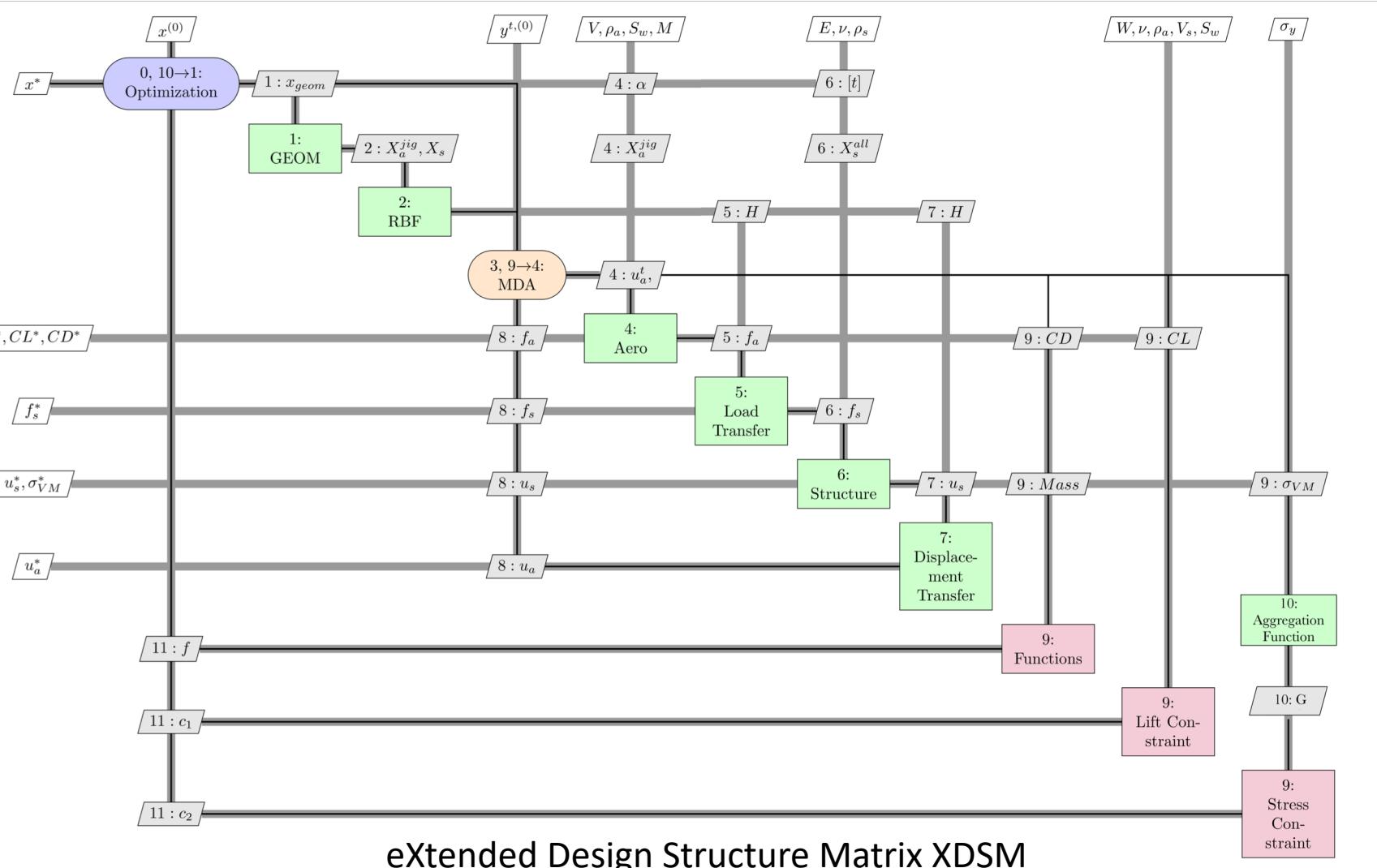
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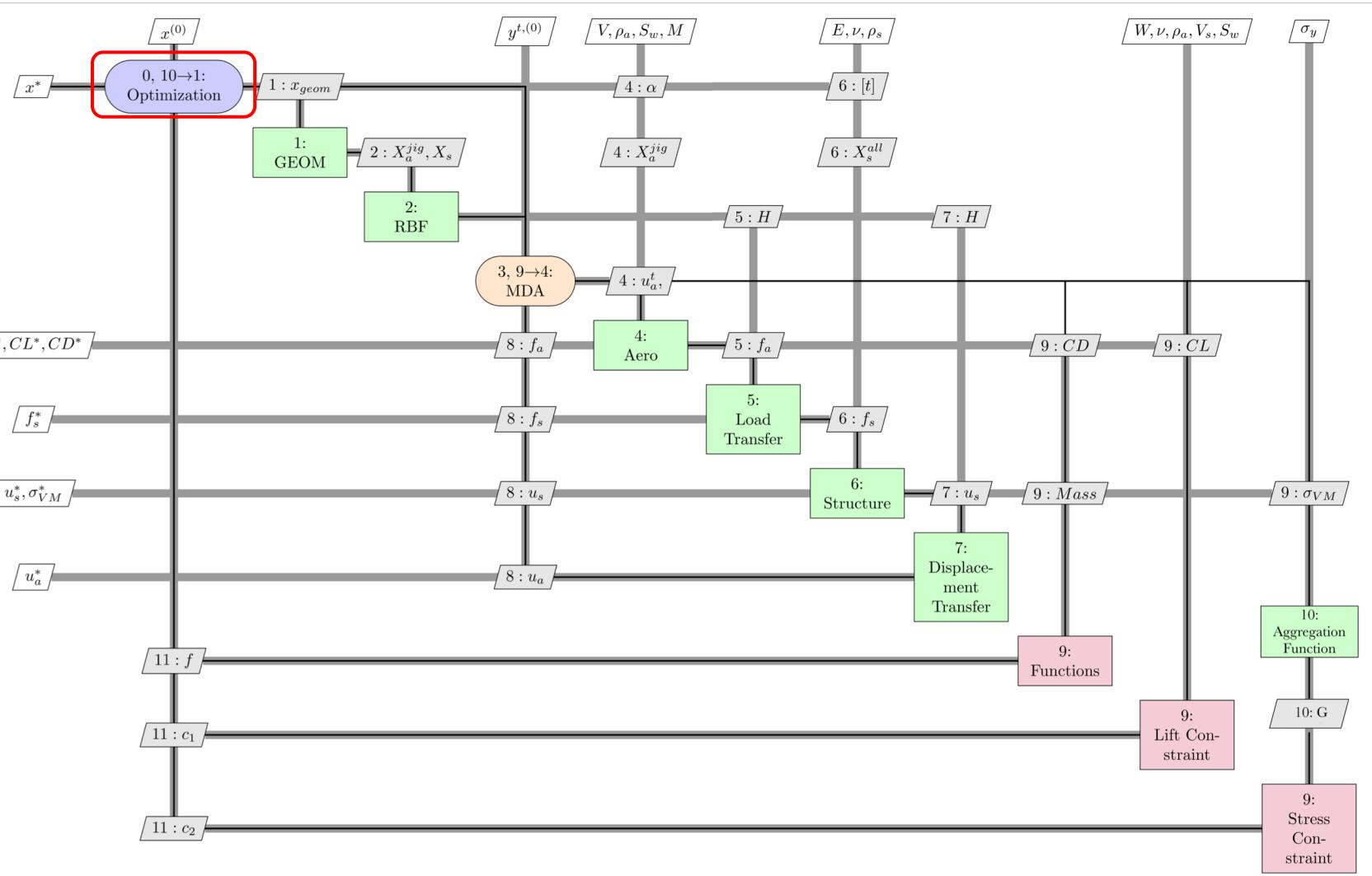
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Ciclo di Ottimizzazione

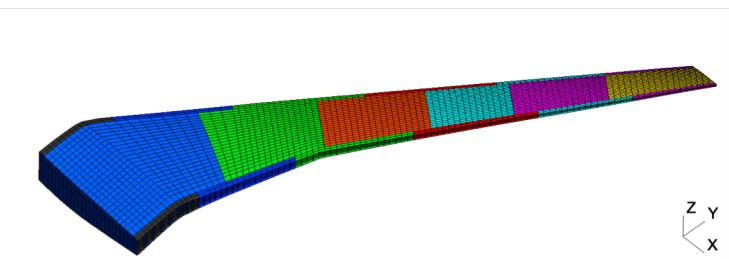


Ciclo di Ottimizzazione

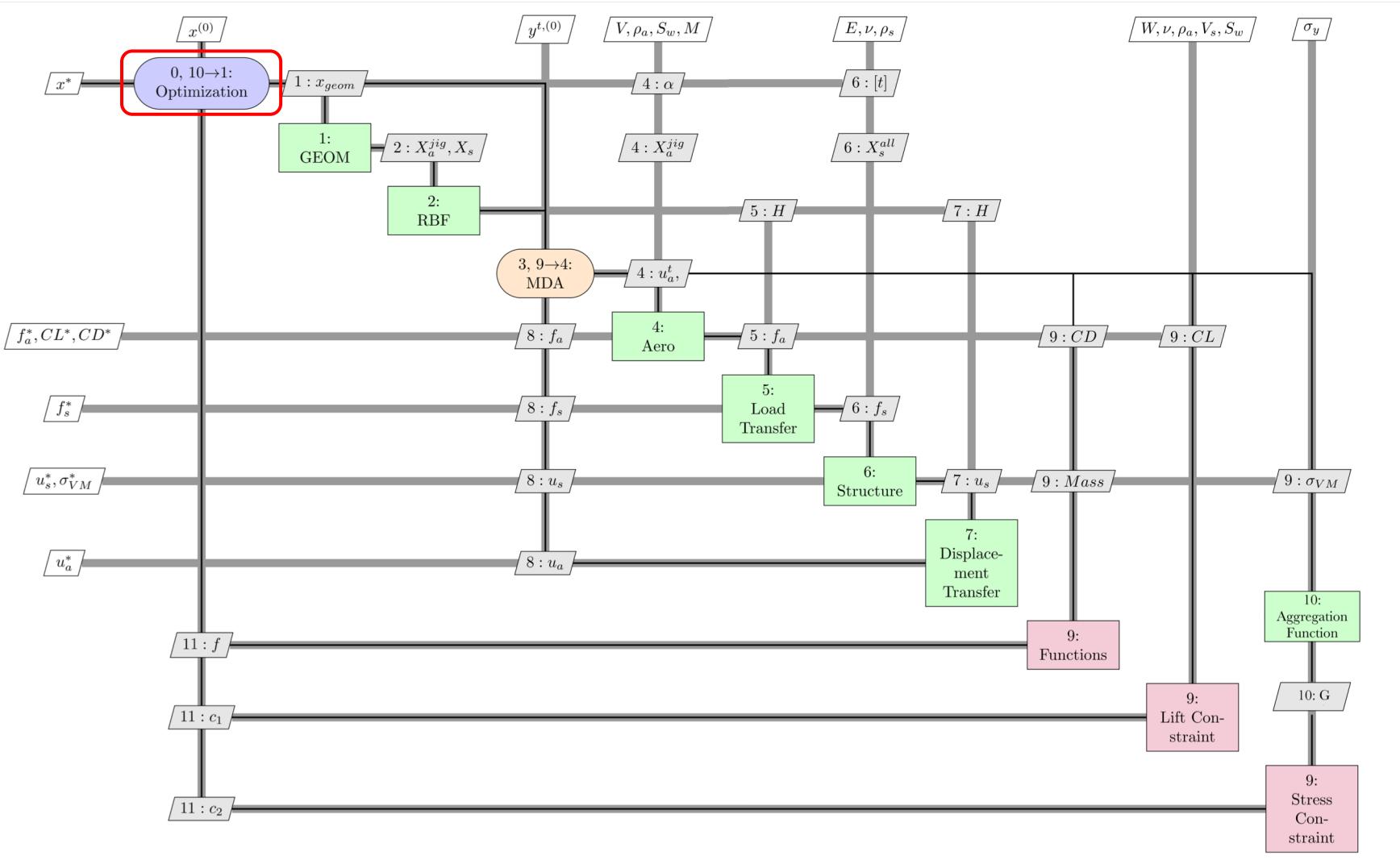


➤ Ciclo di Ottimizzazione

- ❖ Driver
 - COBYLA (gradient free)
 - SLSQP (gradient based)
- ❖ Variabili di Progetto
 - Angolo di attacco α
 - Angolo di freccia Λ
 - Allungamento alare b
 - Spessore pannelli $\{t\}$



Ciclo di Ottimizzazione



➤ Ciclo di Ottimizzazione

❖ Vincoli

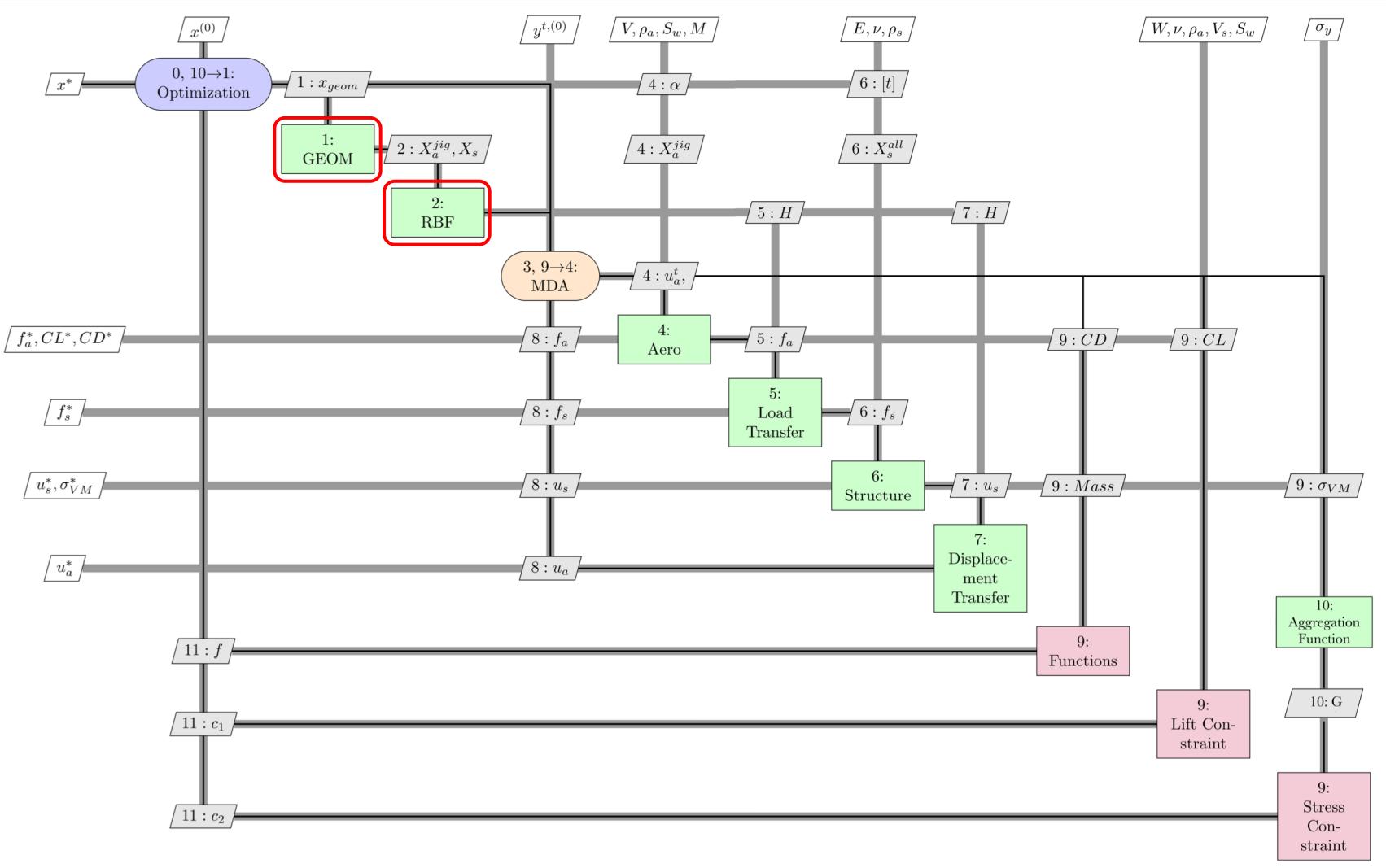
- Portanza $C_L - \frac{2W}{\rho_a V_\infty^2 S_w} > 0$
- Tensioni $\sigma_i - \sigma_{yield} > 0$
 $\forall i = 1, \dots, N_e$

❖ Oggetto dell' ottimizzazione

- Massa m
- Resistenza indotta C_{D_i}
- Funzione generica

$$f = \alpha m + \beta C_{D_i}$$

Ciclo di Ottimizzazione



➤ Generazione della geometria

- Occ Airconics
 - Parametri geometrici
 (b, c, Λ)
 - Gmsh

❖ OUTPUT

- Mesh strutturale X_s
 - Mesh aerodinamica X_a

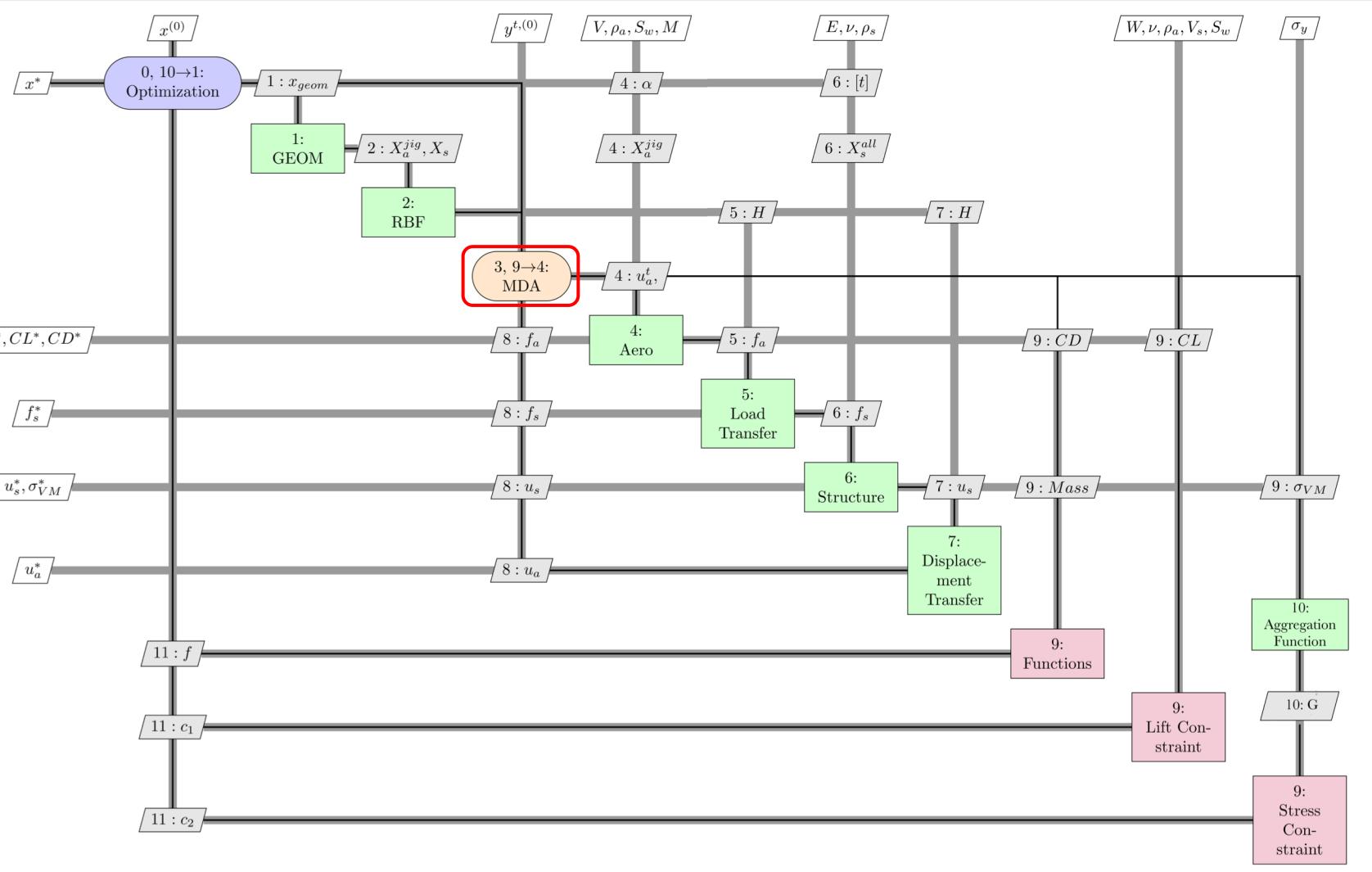
➤ Funzioni di interpolazione

- Radial Basis Function

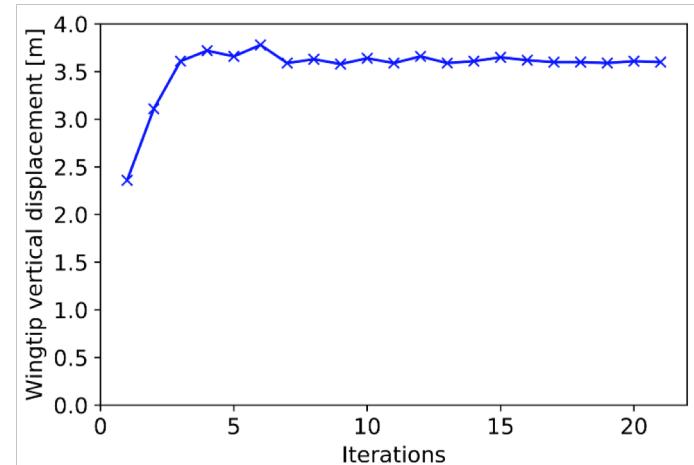
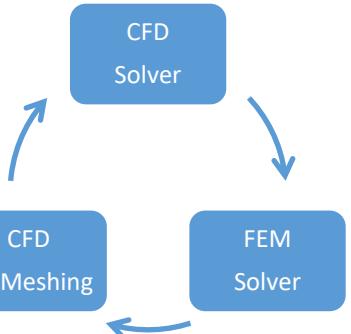
❖ OUTPUT

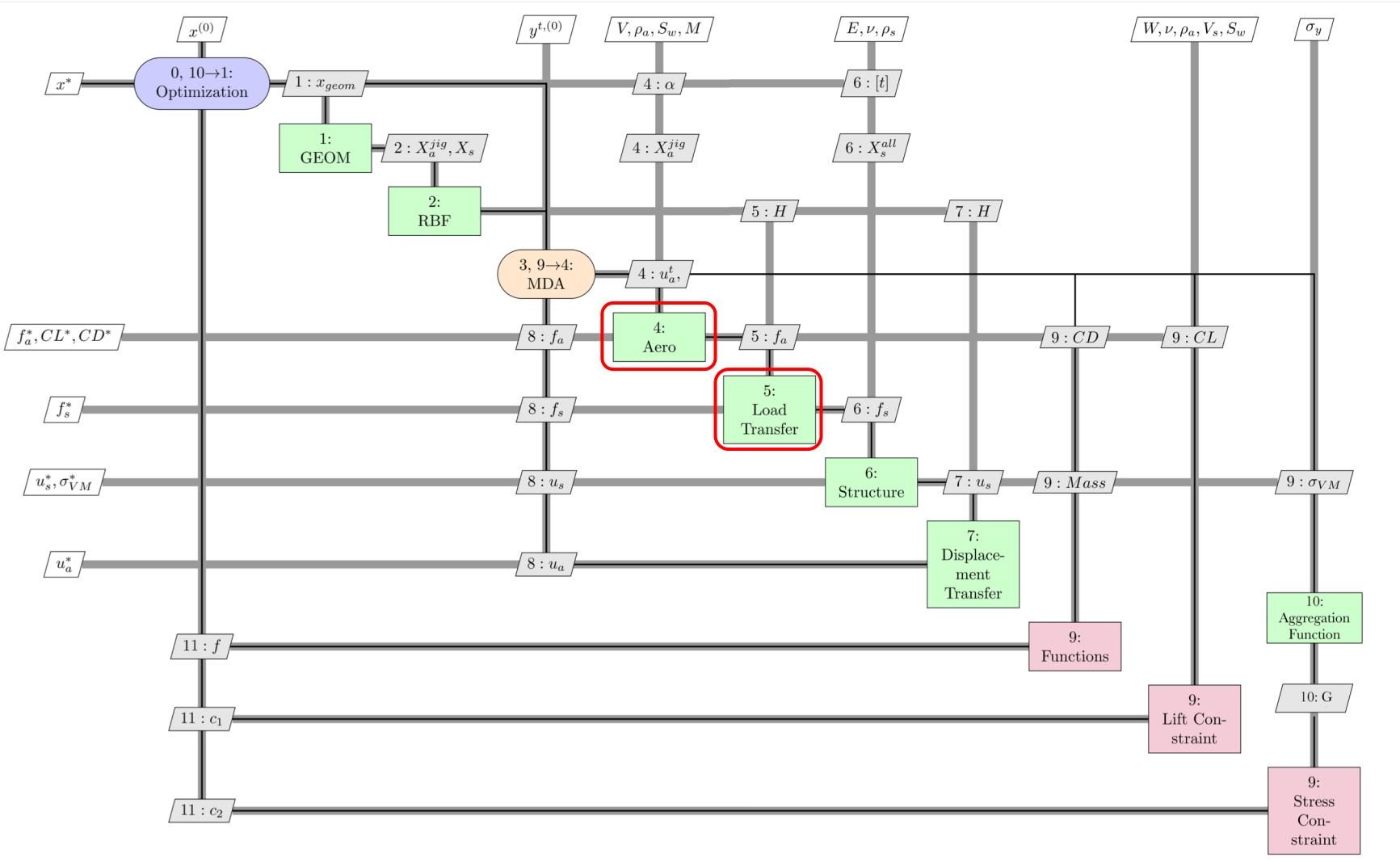
- Matrice di interpolazione H

Ciclo di Ottimizzazione



➤ Determinazione dei carichi aerodinamici considerando l' accoppiamento aeroelastico





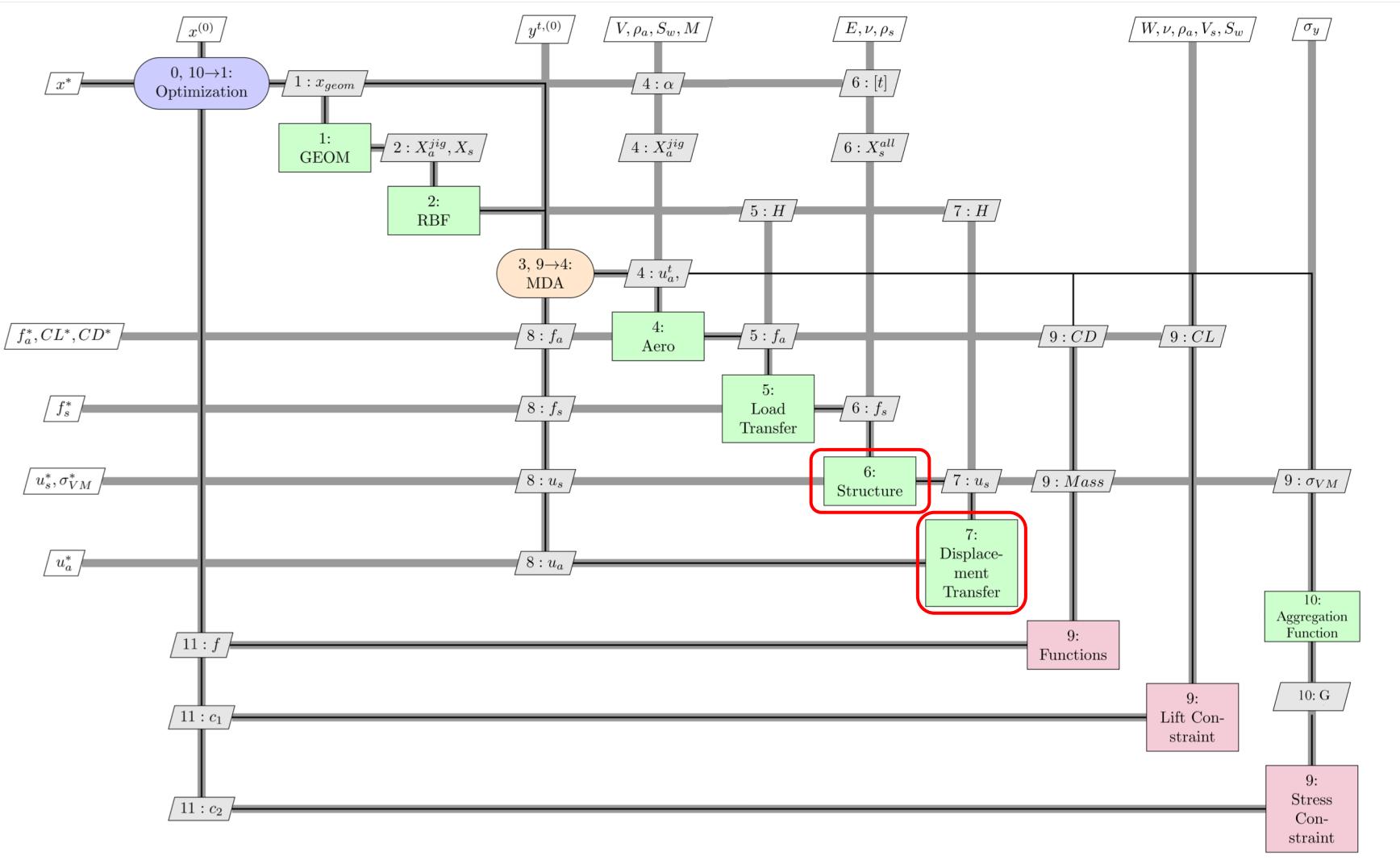
➤ Analisi Aerodinamica

- Determinazione dei coefficienti di pressione C_p nei control point
- Integrazione numerica del C_p lungo i pannelli
- Distribuzione delle forze tra i vertici dei pannelli aerodinamici

➤ Trasferimento dei Carichi

$$f_s = H^T f_a$$

Ciclo di Ottimizzazione



➤ Analisi Strutturale

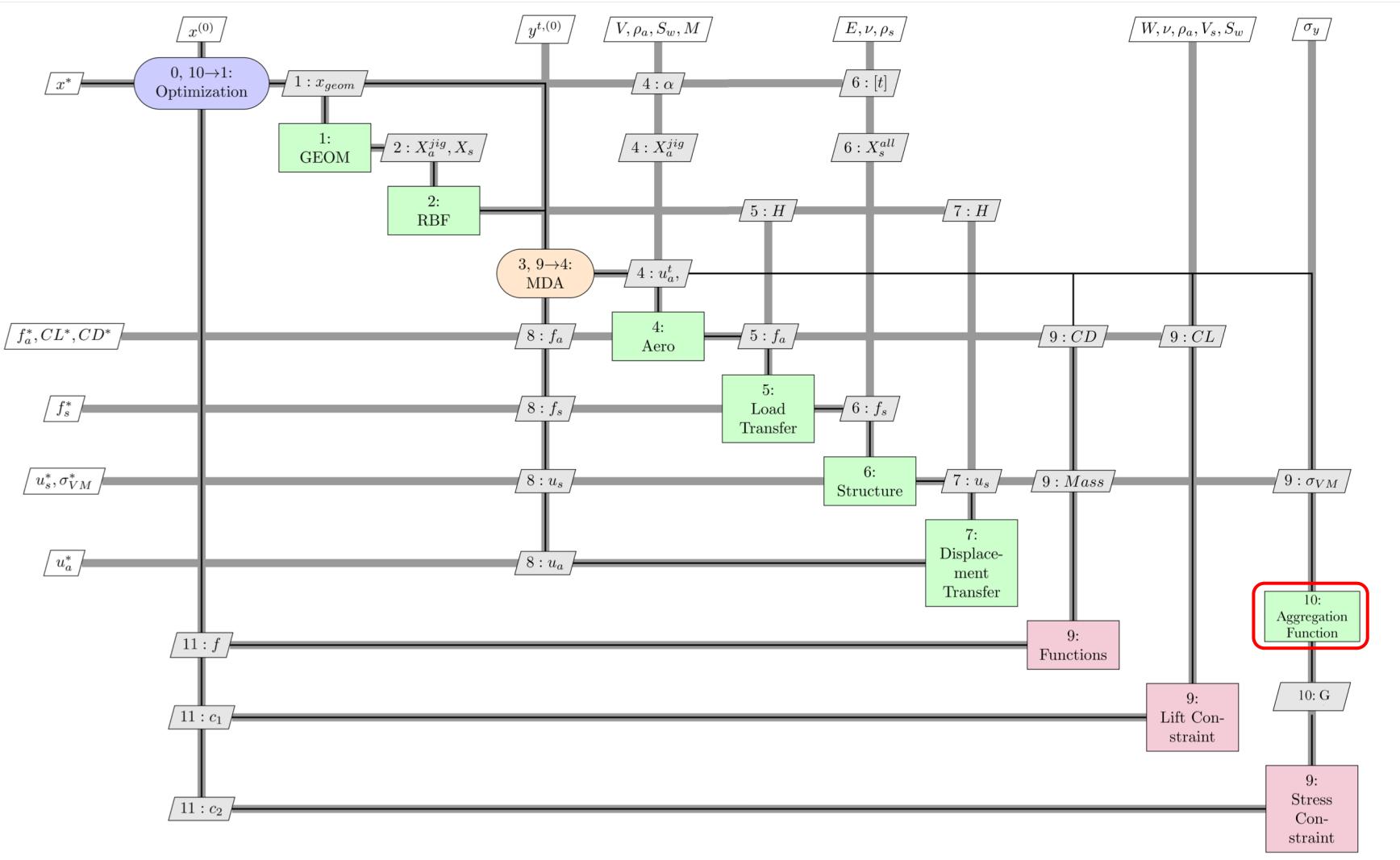
- Creazione dei file di input tramite l' uso di elementi shell lineari
 - Determinazione degli spostamenti nodali e delle tensioni risolvendo l' equazione

$$K u_s = f_s$$

➤ Trasferimento degli spostamenti

$$X_a = X_a^0 + u_a = X_a^0 + H u_s$$

Ciclo di Ottimizzazione



➤ Aggregazione dei vincoli sulle tensioni

- Riduzione dei vincoli
- Derivabilità della funzione

$$\mathbf{f} = (f_1, f_2, \dots, f_N)$$

$$\lim_{p \rightarrow \infty} \mathbf{G}(\mathbf{f}, p) = \max(f_1, f_2, \dots, f_N)$$

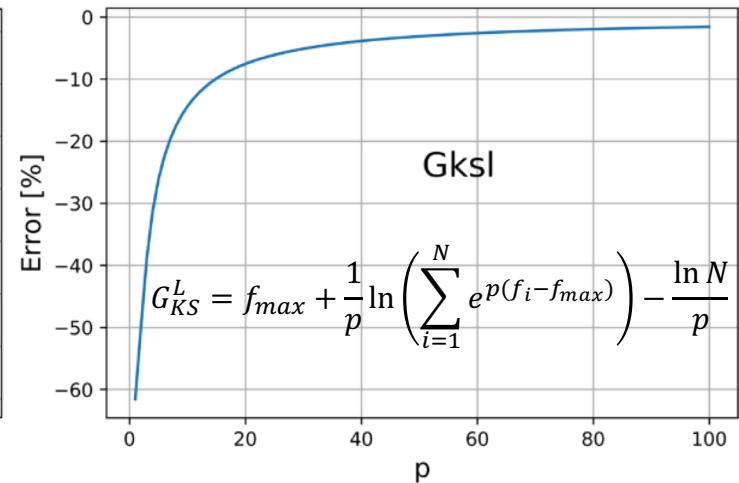
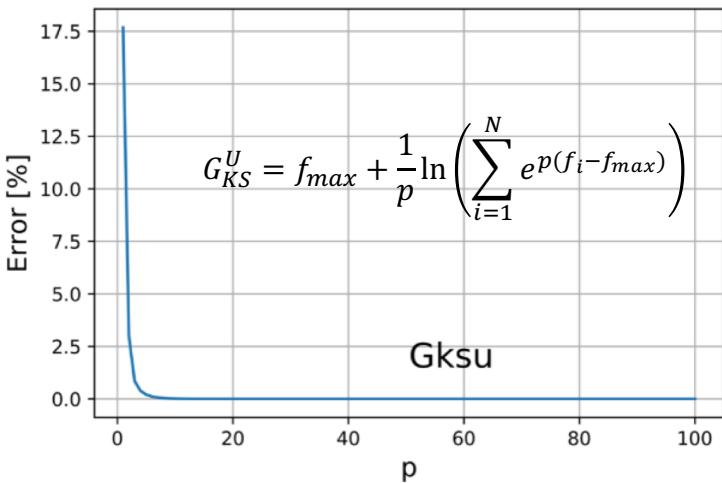
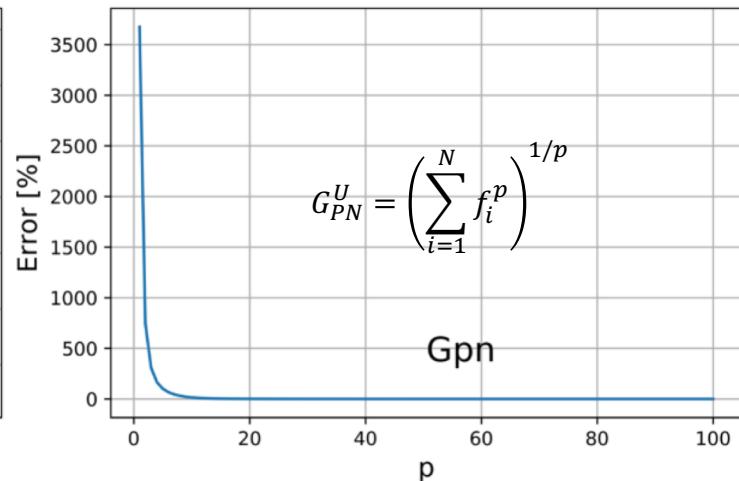
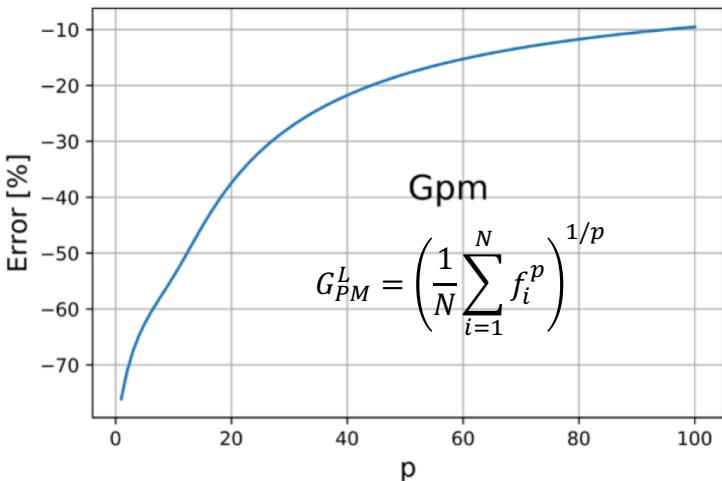
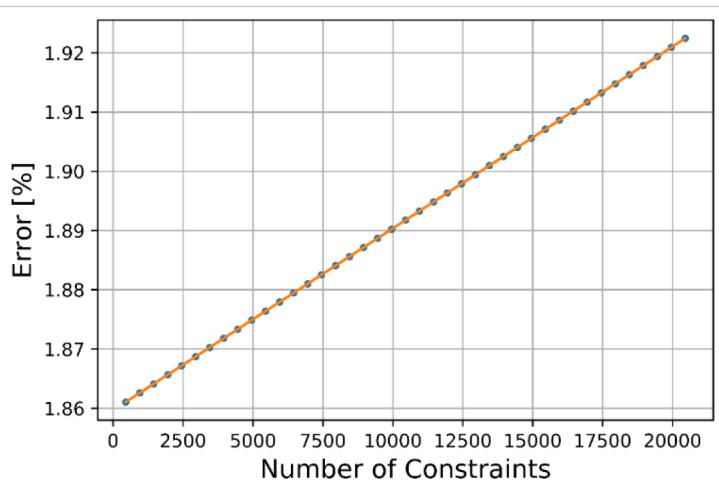
Effetto del Draw-Down Factor p



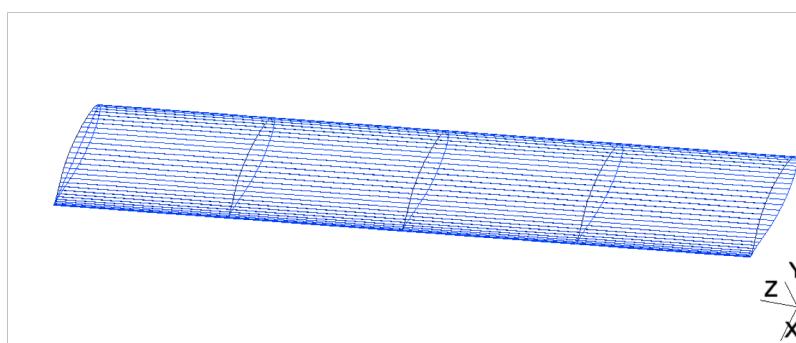
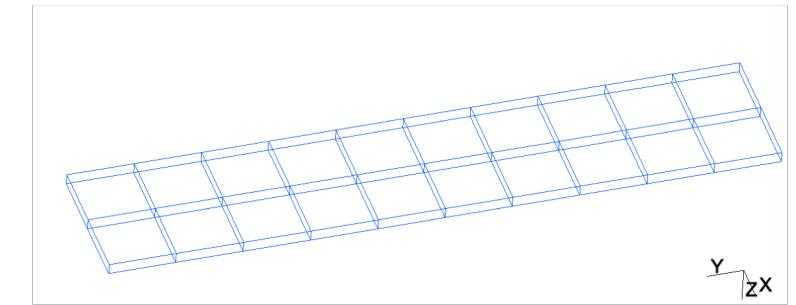
➤ Funzione di Kreisselmeier-Steinhauser

$$G_{KS}^U = \frac{1}{p} \ln \left(\sum_{i=1}^N e^{pf_i} \right)$$

$$G_{KS}^L = G_{KS}^U - \frac{1}{p} \ln(N) = \frac{1}{p} \ln \left(\frac{1}{N} \sum_{i=1}^N e^{pf_i} \right)$$

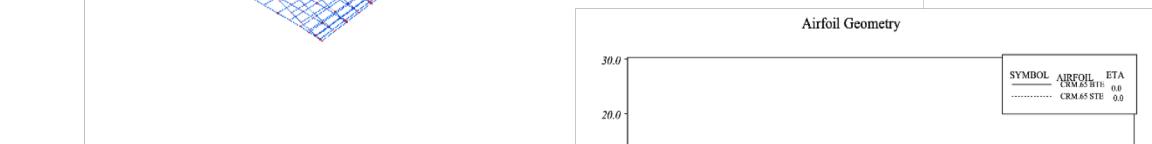
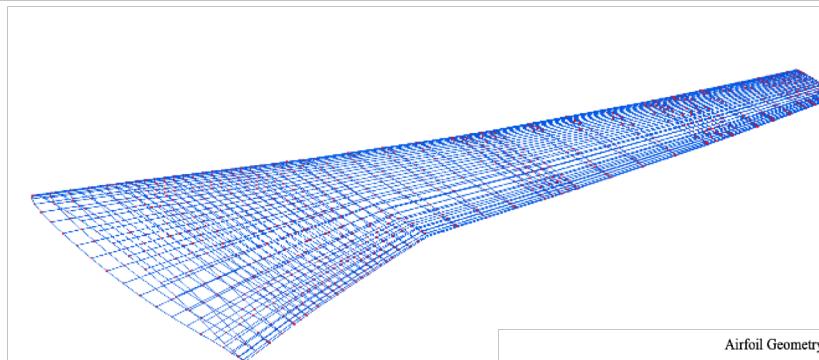
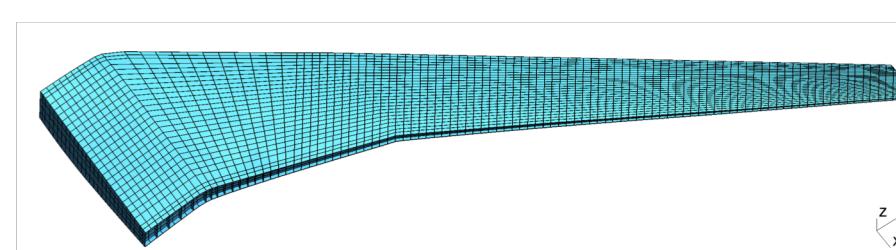


➤ Modello di Goland



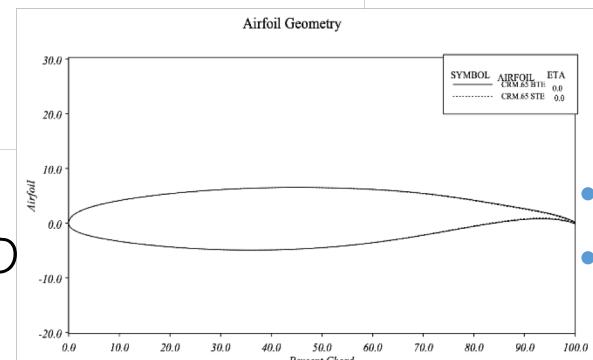
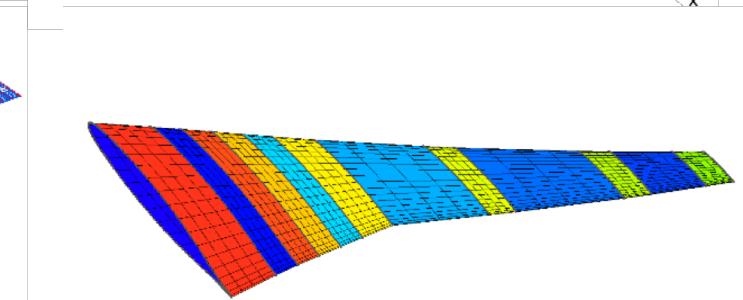
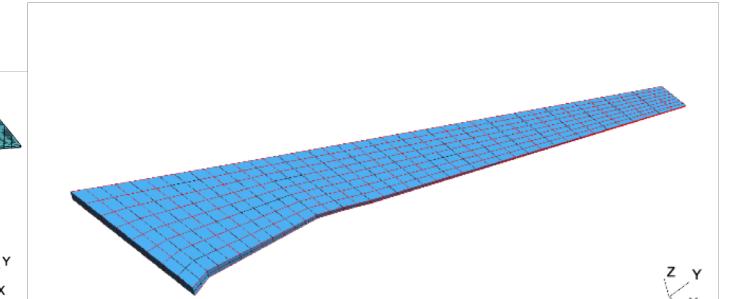
- \approx 50 Elementi
- 5 Sezioni mesh CFD

➤ NASA CRM Wing



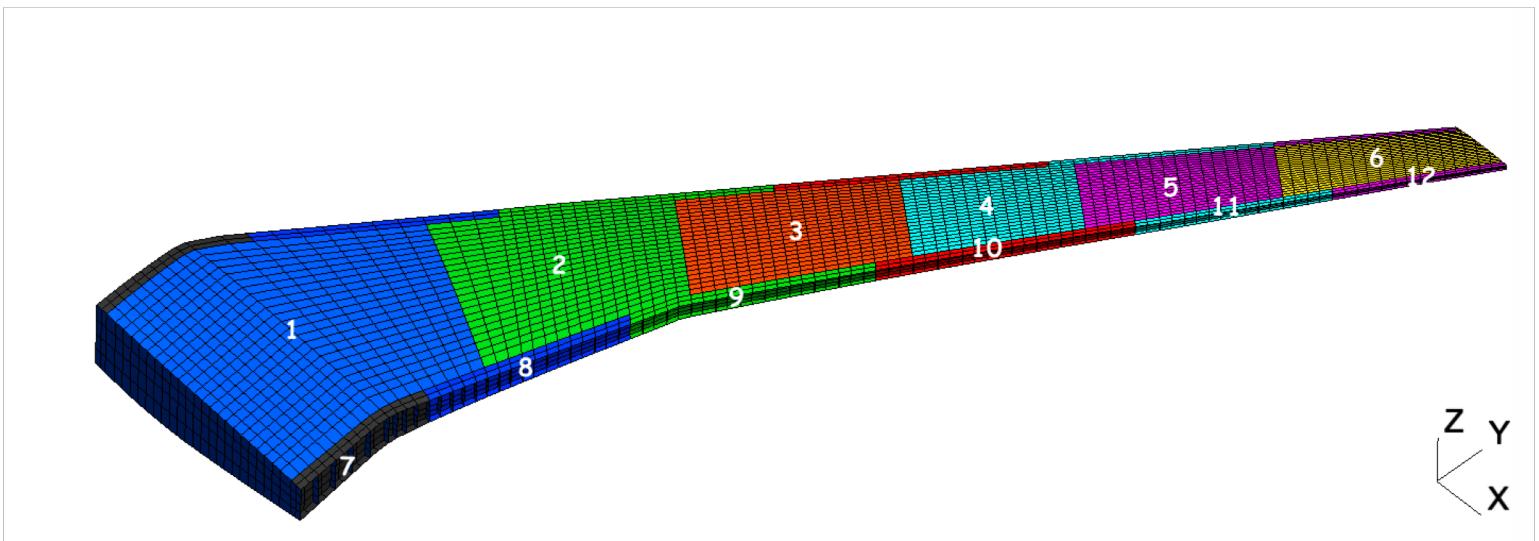
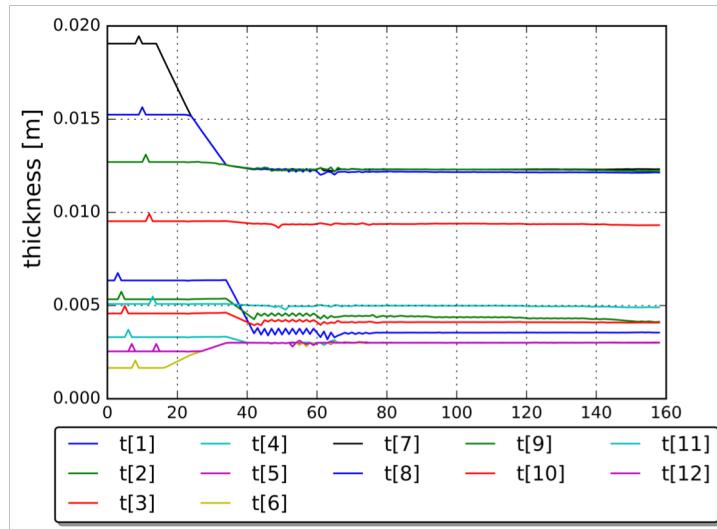
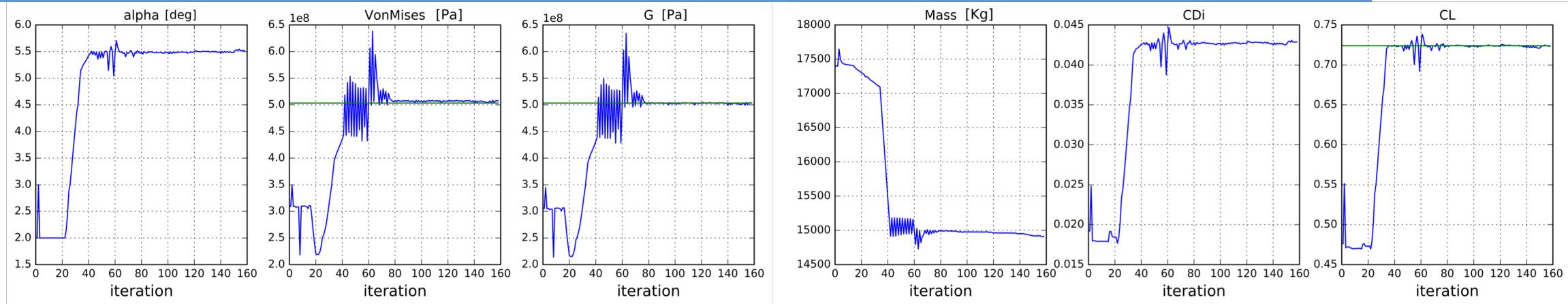
- \approx 25000 Elementi
- 50 Sezioni mesh CFD

➤ CRM Wing ridotto

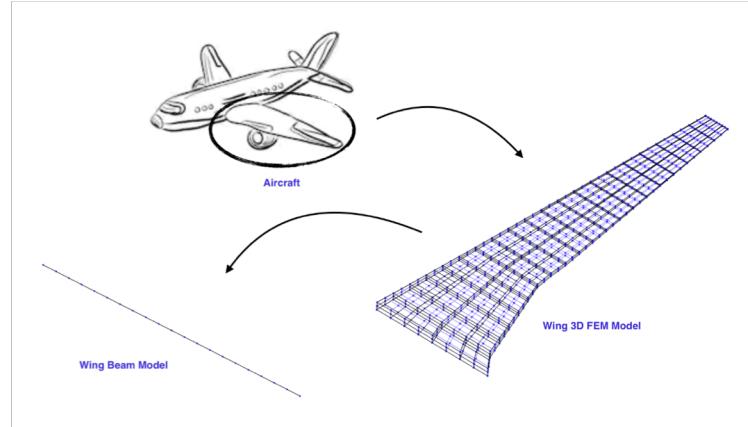


- \approx 1000 Elementi
- 20 Sezioni mesh CFD

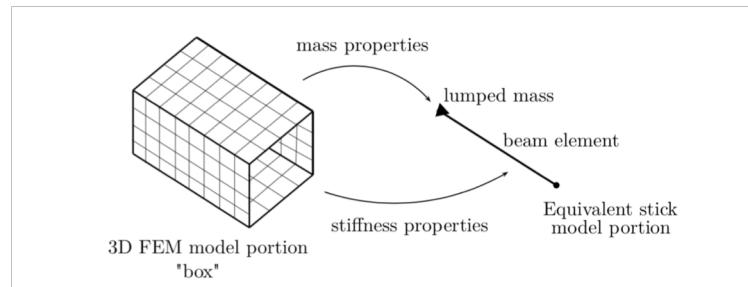
Risultati



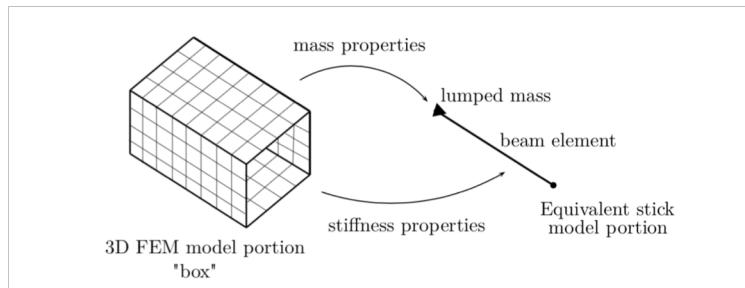
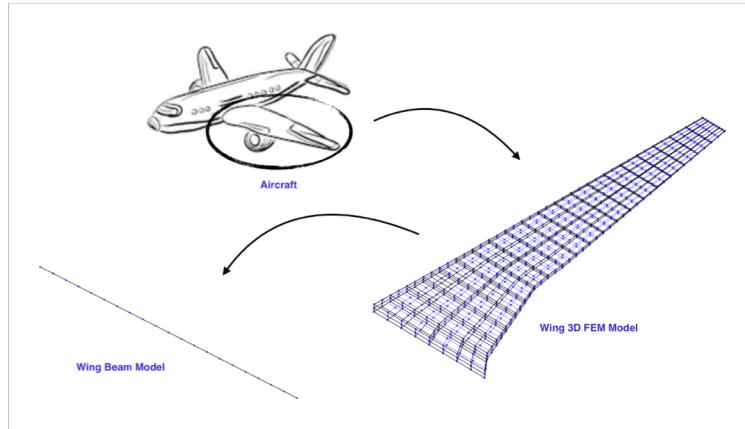
- Modello FEM equivalente costituito da un ridotto numero di soli elementi trave



- Estrazione proprietà di rigidezza
- Estrazione proprietà di massa
- Validazione del modello
 - ❖ Analisi statica
Confronto spostamenti e rotazioni
 - ❖ Analisi modale
Confronto forme modali e frequenze proprie



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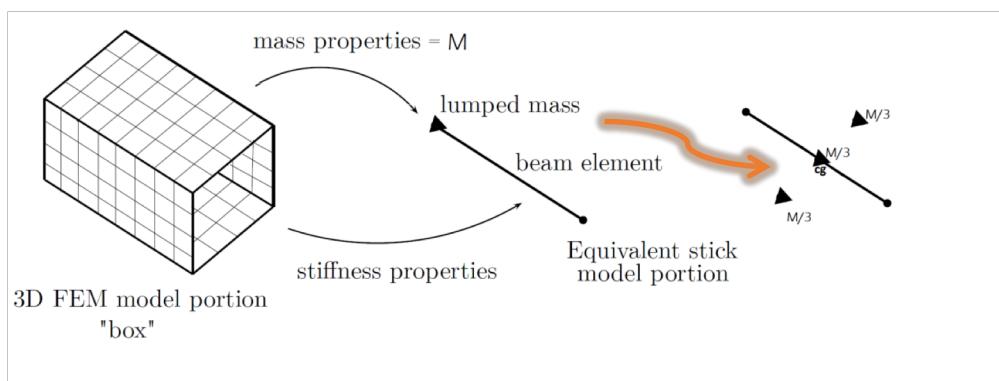
- Problemi Riscontrati
 - ❖ Non completa automatizzazione del processo
 - ❖ Errori non ammissibili per modi e frequenze torsionali

➤ Modal Assurance Criteria MAC

$$MAC(\Phi_1, \Phi_2) = \frac{(\Phi_1^T \cdot \Phi_2)^2}{\|\Phi_1\|^2 \cdot \|\Phi_2\|^2}$$

$$0 \leq MAC \leq 1$$

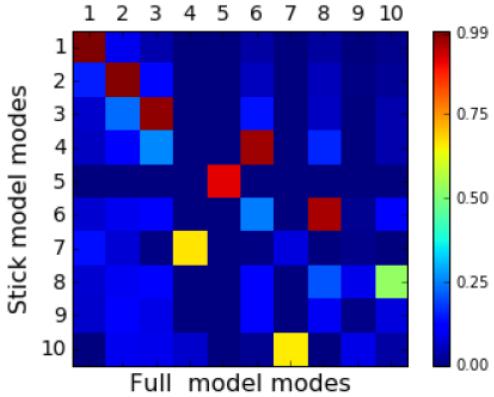
➤ Nuova Distribuzione della Massa



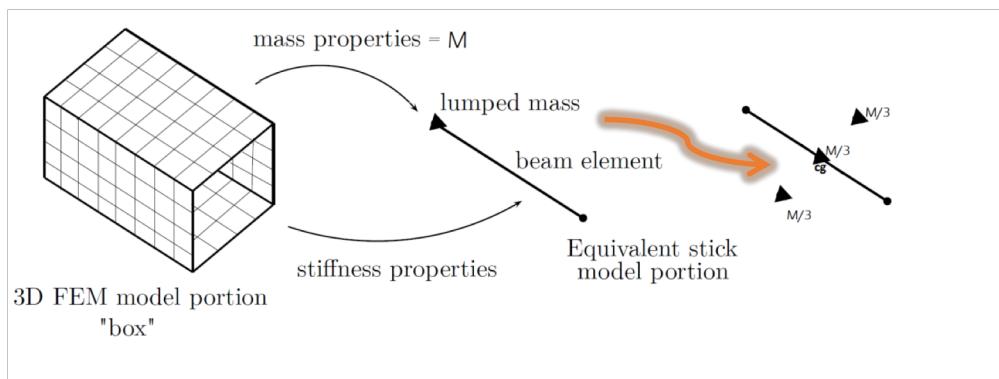
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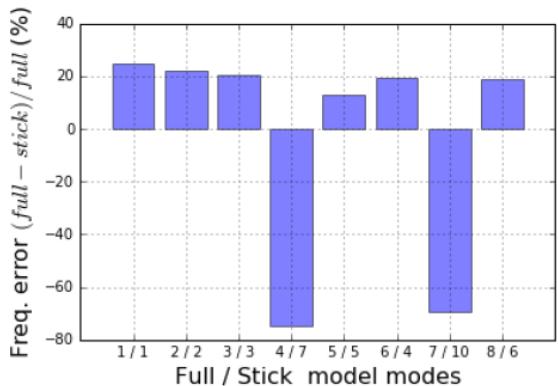
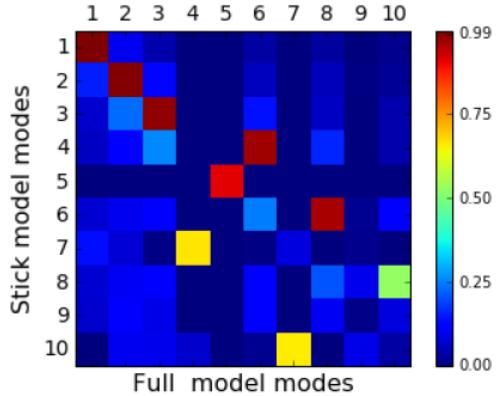
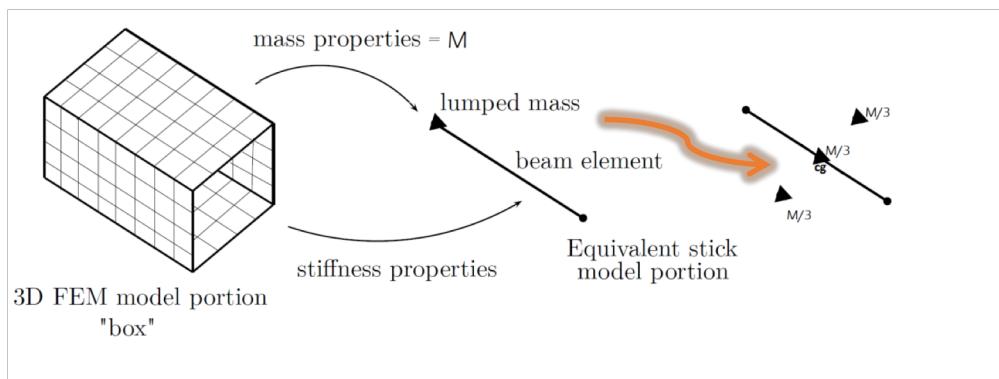


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➤ Nuova Distribuzione della Massa



Modifiche per l' implementazione del modello ridotto

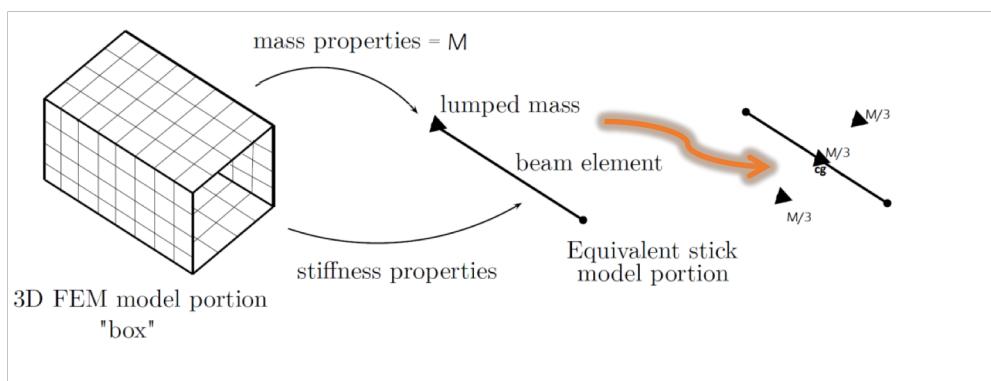


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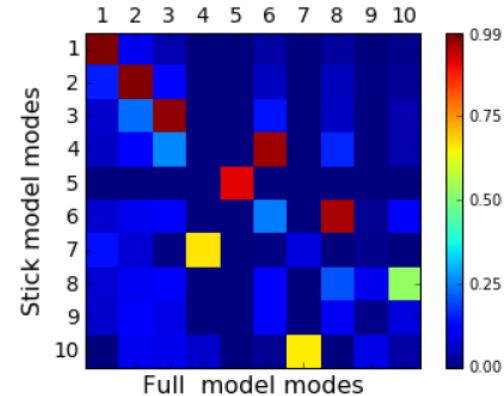
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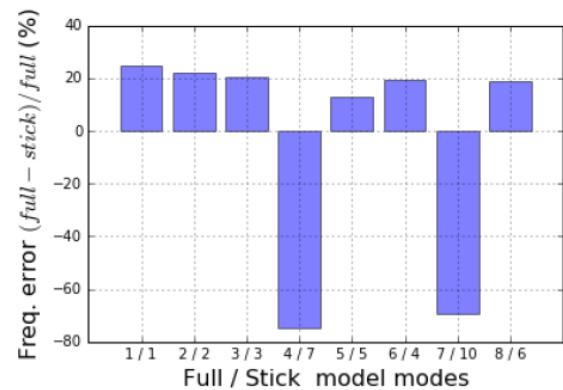
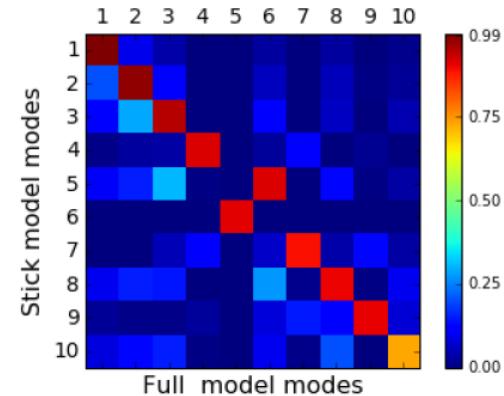
➤ Nuova Distribuzione della Massa



1 Lumped mass in the CG

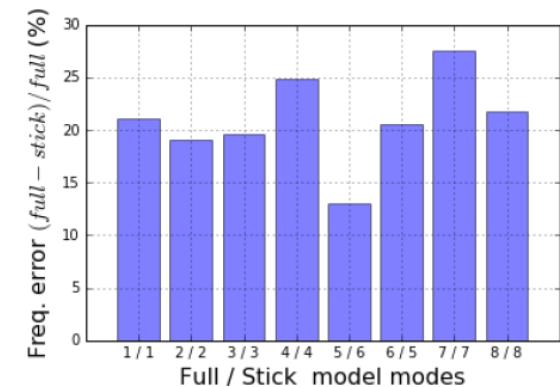


3 Lumped mass (LE,CG,TE)



[MODE 1:24.53%, MODE 2:21.88%, MODE 3:20.66%, MODE 4:**-74.55%**, MODE 5:13.13%, MODE 6: 19.57%, MODE 7: **-69.21%**, MODE 8: 18.59%]

[MODE 1:21.06%, MODE 2:19.00%, MODE 3:19.65%, MODE 4:**24.79%**, MODE 5:12.98%, MODE 6: 20.61%, MODE 7: **27.52%**, MODE 8: 21.78%]



❖ CONCLUSIONI

- Tutti i componenti del codice risultano validati
- Il costo computazionale risulta contenuto, rendendo il codice ideale per le fasi di progetto preliminare
- Il codice risulta molto versatile, sia in termini di scelta delle variabili di progetto che in termini di scelta del modello di ala

❖ LAVORI FUTURI

- Implementazione di un nuovo driver per l'ottimizzatore SOGOME
- Implementazione del componente strutturale dinamico
- Implementazione di uno strumento per analisi CFD High Fidelity

GRAZIE
PER
L' ATTENZIONE