Numerical Investigation of Aerodynamics of a Wing with Spanwise-Varying Flap Deflection.

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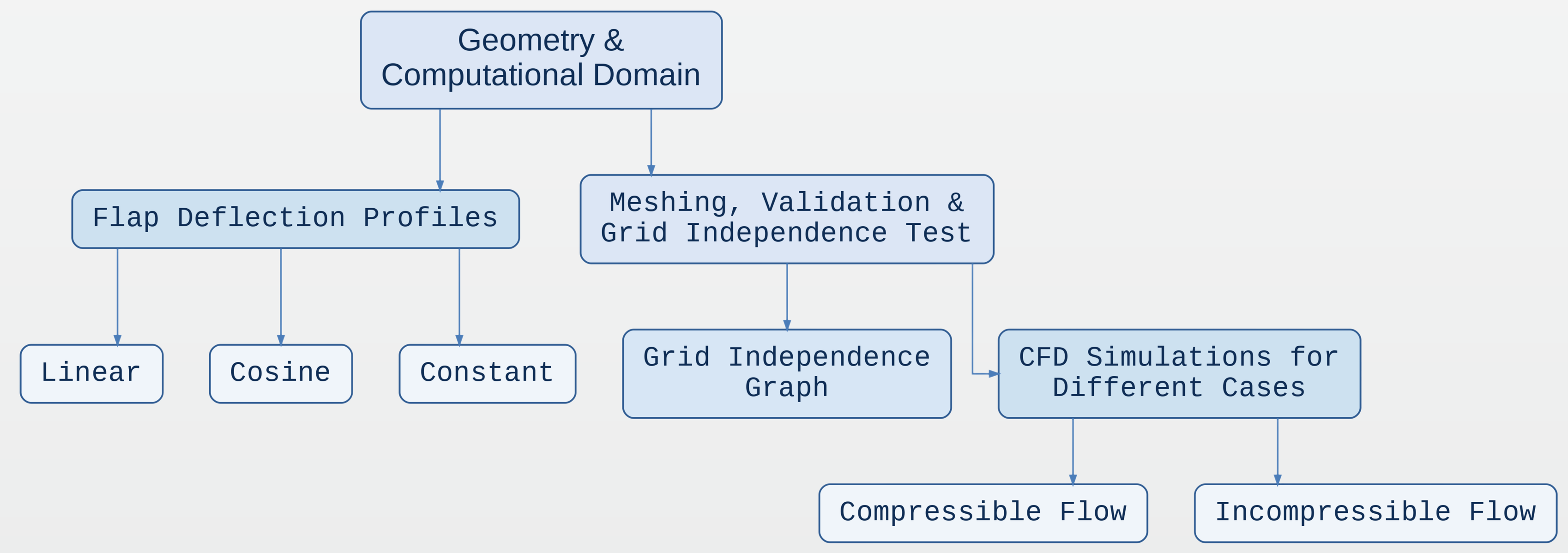
INTRODUCTION & OBJECTIVE

- This project analyzes aerodynamic effects of spanwise-varying flap deflection on wing using numerical approach.
- Aim is to study the influence of flap deflection on pressure distribution, lift, drag, Q-criterion, pressure recovery for compressible and incompressible.
- A comparative analysis was conducted among Linear, Cosine, and Constant flap deflection profiles, and their performance was systematically evaluated.
- Objective is to provide insights for designing adaptive and efficient high lift wing configurations

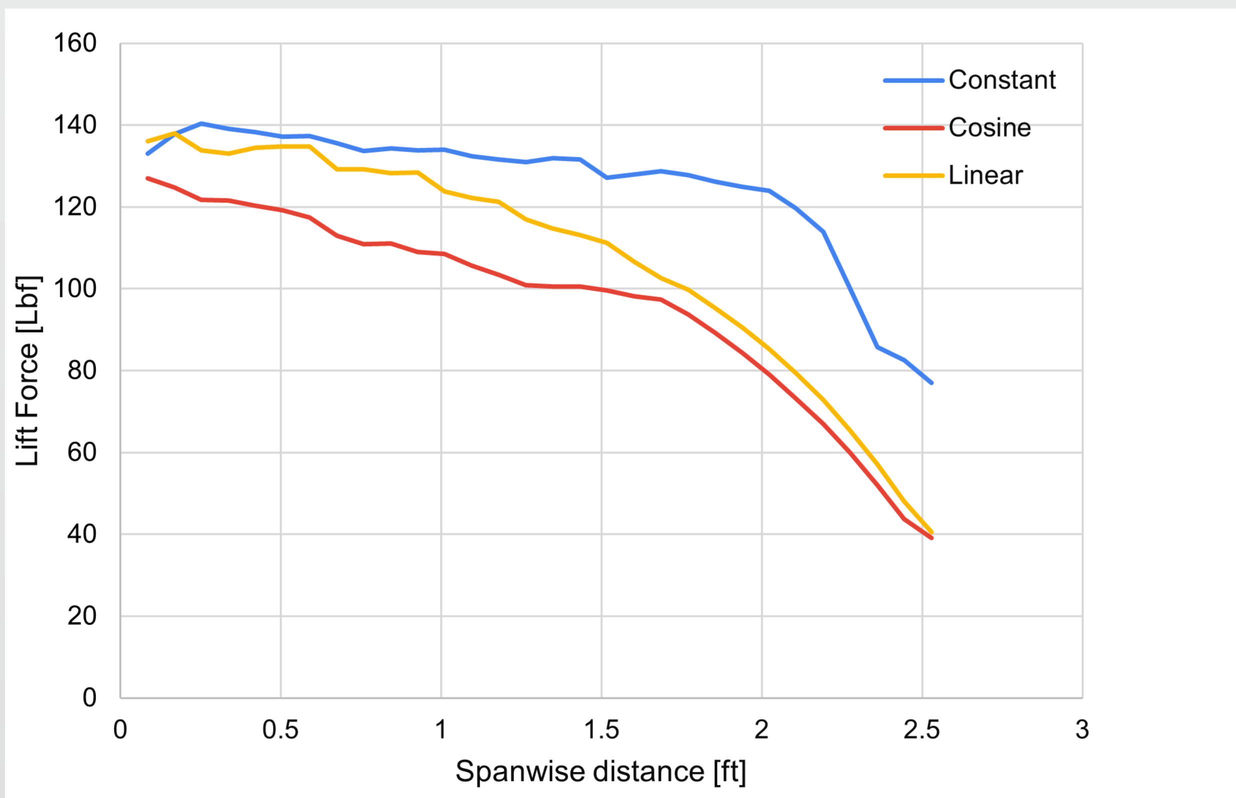
METHODOLOGY



RESULTS & DISCUSSION

Flap Deflection Condition	Compressible Flow			Incompressible Flow		
	Cl (Coefficient of Lift)	Cd (Coefficient of Drag)	PUI (Cp)	Cl (Coefficient of Lift)	Cd (Coefficient of Drag)	PUI (Cp)
Linear	0.58	0.06	0.47	0.33	0.027	0.29
Constant	0.68	0.08	0.46	0.52	0.04	0.13
Cosine	0.40	0.042	0.505	0.32	0.025	0.350

Table 1: Comparison of Flow properties



Graph 1: Spanwise Lift Distribution [compressible]

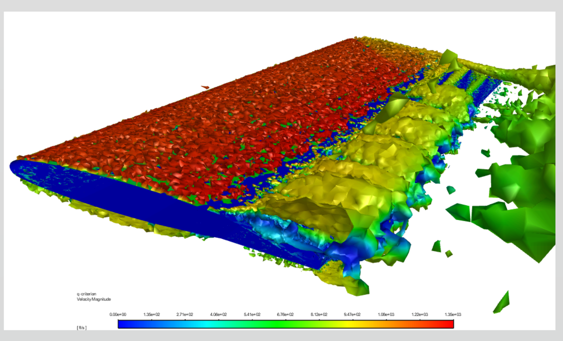


Figure 1: Linear (Compressible Flow)

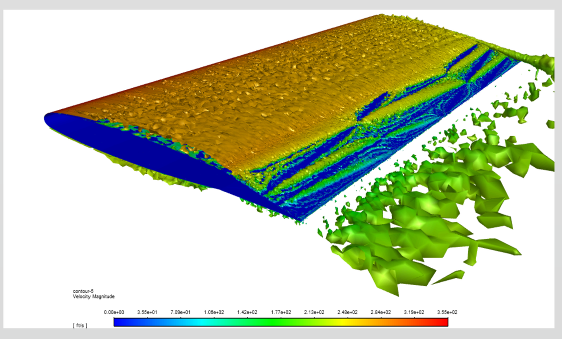


Figure 2: Linear (Incompressible Flow)

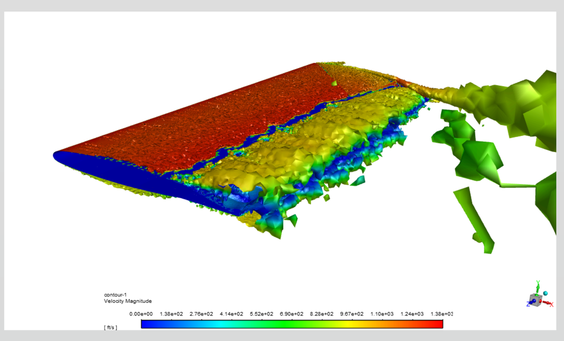


Figure 3: Constant (Compressible Flow)

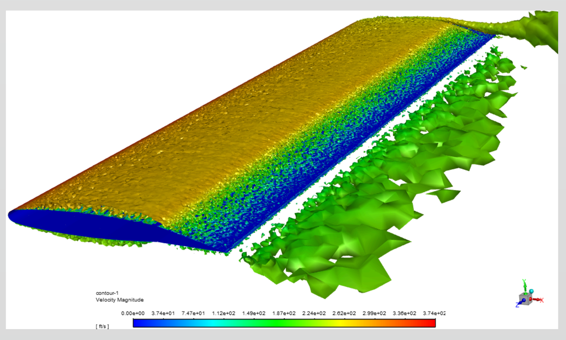


Figure 4: Constant (Incompressible Flow)

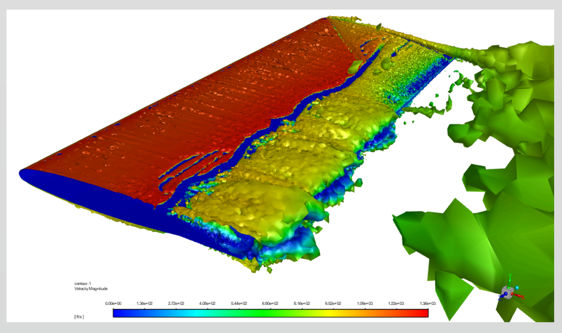


Figure 5: Cosine (Compressible Flow)

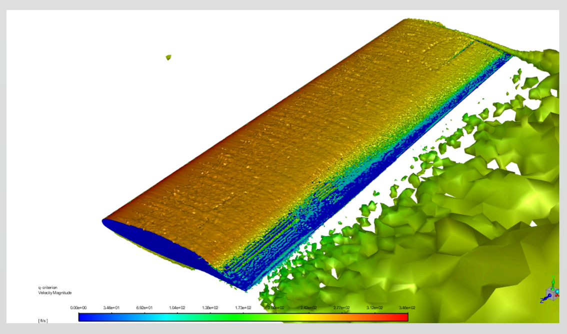


Figure 6: Cosine (Incompressible Flow)

- The effect of spanwise flap deflection on Cp and Q-criterion is analyzed across the wing.
- As flap deflection decreases from root to tip, the adverse pressure gradient between the upper and lower surfaces reduces, leading to diminished flow separation and weaker vortex formation.
- Q-criterion results indicate less vortex-dominated flow for both linear and cosine deflection profiles compared to a constant flap deflection case.

CONCLUSIONS

- Effective lift distribution was achieved for the wing with linear and cosine flap deflection compared to the wing with a constantly deflected flap.
- A constantly deflected flap provides greater lift, but with the trade-off of more drag and stronger wing tip vortices compared to a flap with varying deflection.
- Higher pressure recovery is achieved when flap deflection is varied along the span.
- With the cosine flap deflection profile, the deflection angle changes gradually near the root and tip. This weakens wing tip vortices and reduces drag.

FUTURE WORK

- Unsteady flow analysis can be performed to capture time-dependent flow changes due to different flap deflection profiles.
- The study can contribute to adaptive wing design, where flap deflection adjusts with flight conditions for improved aerodynamic efficiency.
- Further analysis can include different Mach numbers and angles of attack to evaluate aerodynamic performance across wider flight conditions.

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