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Wing Tip Vortex Reduction

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Background

Winglets are used vastly in commercial jets. The main purpose of a winglet is to minimize the vortex effect forming at the tip of the wing in result to the transition between higher pressure and lower pressure. The main purpose of this project is to research, design, and test a new wing tip device that will improve the wing's aerodynamic efficiency

Requirements

The device's primary requirement is to achieve a 13% increase in lift to drag ratio (aerodynamic efficiency) compared to the bare wing, while accounting for the additional weight of the structure. The device must also be structurally feasible such that wing loading doesn't result in an undesirable state of stress.

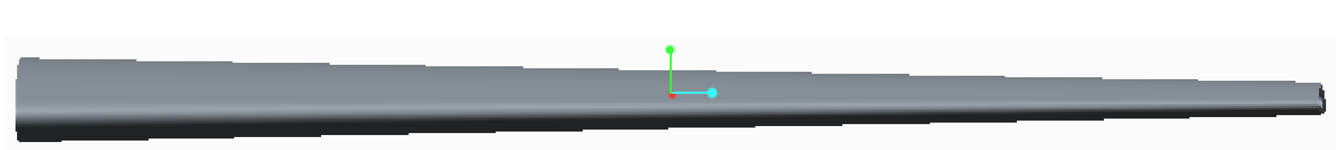
Performance

SPAN (M)	MAC (M)	TAPER RATIO	ROOT CHORD (M)	TIP CHORD (M)
8.153	2.389	0.375	3.251	1.219
AREA (M^2)	DENSITY (KG/M^3)	VELOCITY (M/S)	VISCOSITY (KG/M*S)	Re
19.146	1.225	80	1.846E-5	12683405

NACA 4415 BASE WING CHARACTERISTICS

WING MODEL	LIFT (N)	PRESSURE DRAG (N)	TOTAL DRAG (N)	L/D
BASE WING	102563	6622	6952	14.75
150˚ BLENDED	109499	6351	6713	16.31
180˚ BLENDED	109499	6325	6682	16.51
JTT 03	114255	6206	6611	17.28

NACA 4415 WING MODEL PROPERTIES AT α = 12˚

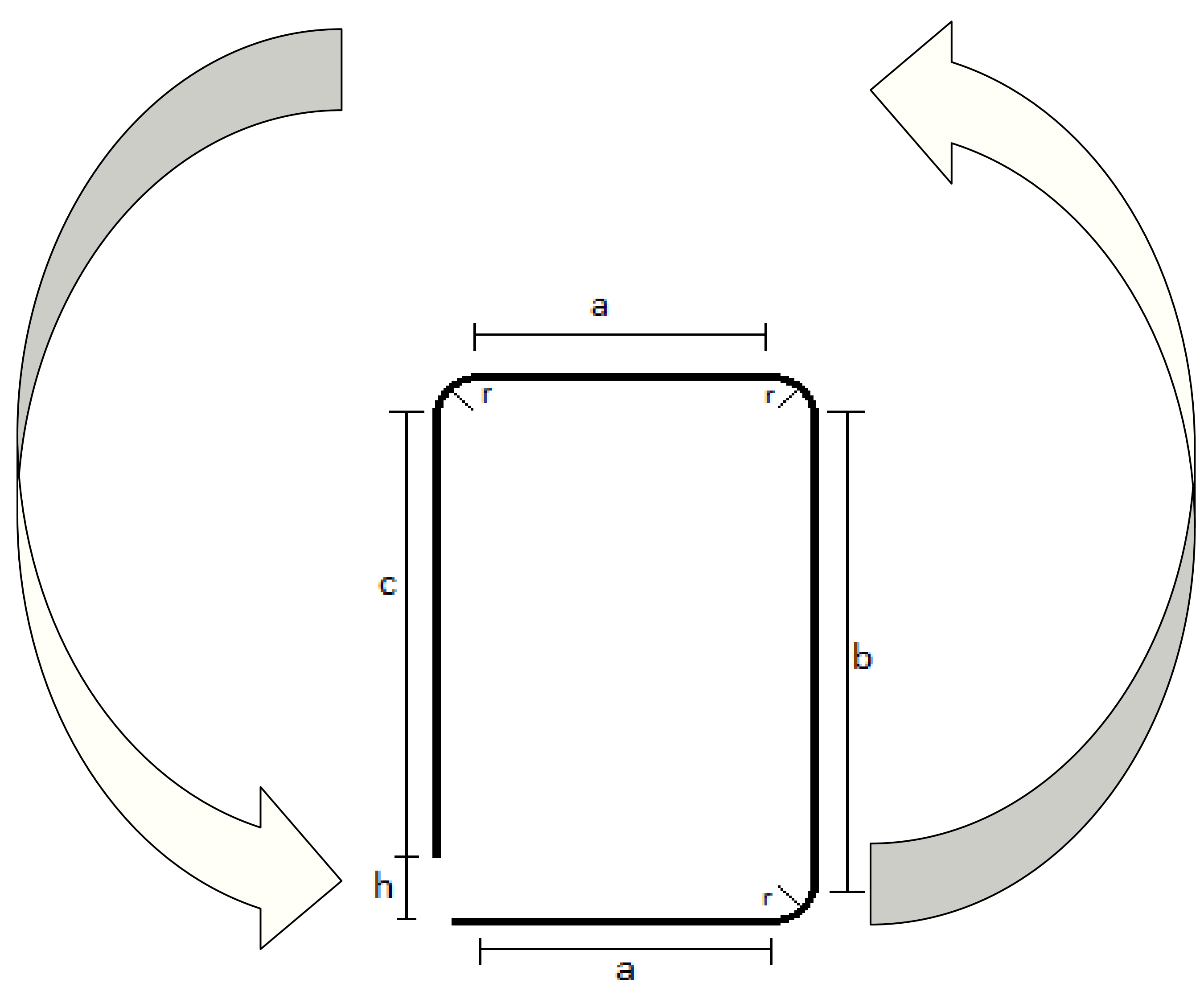


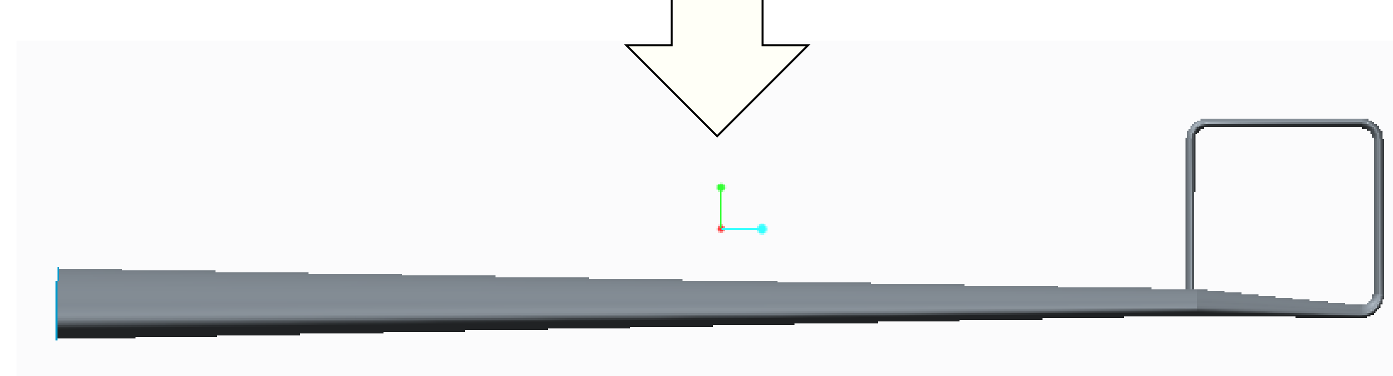
NACA 4415 BASE WING

Optimization

The optimization process is based on a multi-variable form of Newton's method. The device is first defined in terms of its respective geometric parameters. It is assumed that the device's lift to drag ratio is a function of said values. These parameters are then used to create dimensionless ratios, decreasing the effective number of variables. Using an initial guess for the design, one of these ratios is varied over a range of values while holding the others fixed. This is performed for each variable in order to evaluate the gradient of the lift to drag function. The maximum values are then applied to the initial guess in order to produce a new design. The entire process is then repeated. When incorporating the results from the final iteration with the wingtip design, the L/D ratio conveyed a 17 % increase.

$$\frac{L}{D} = f(a, b, c, h, r, chord\ length)$$



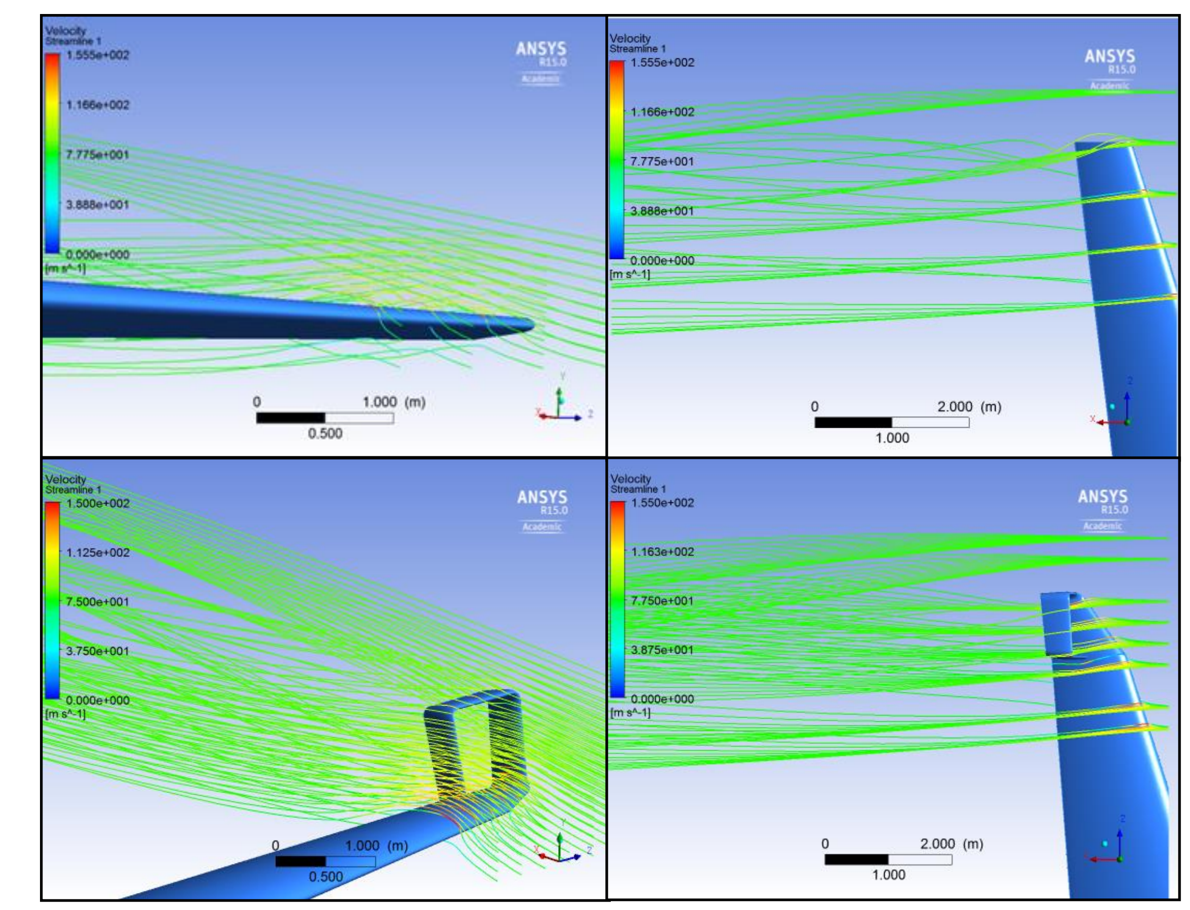


NACA 4415 JTT 03 Wing Tip Device

ANSYS FLUENT

α◦	LIFT (N)	PRESSURE	VISCOUS	DRAG (N)	L/D
0	30379	958	313	1271	23.9
6	74198	2794	335	3129	23.71
9	94921	4309	365	4674	20.31
12	114255	6206	405	6611	17.28

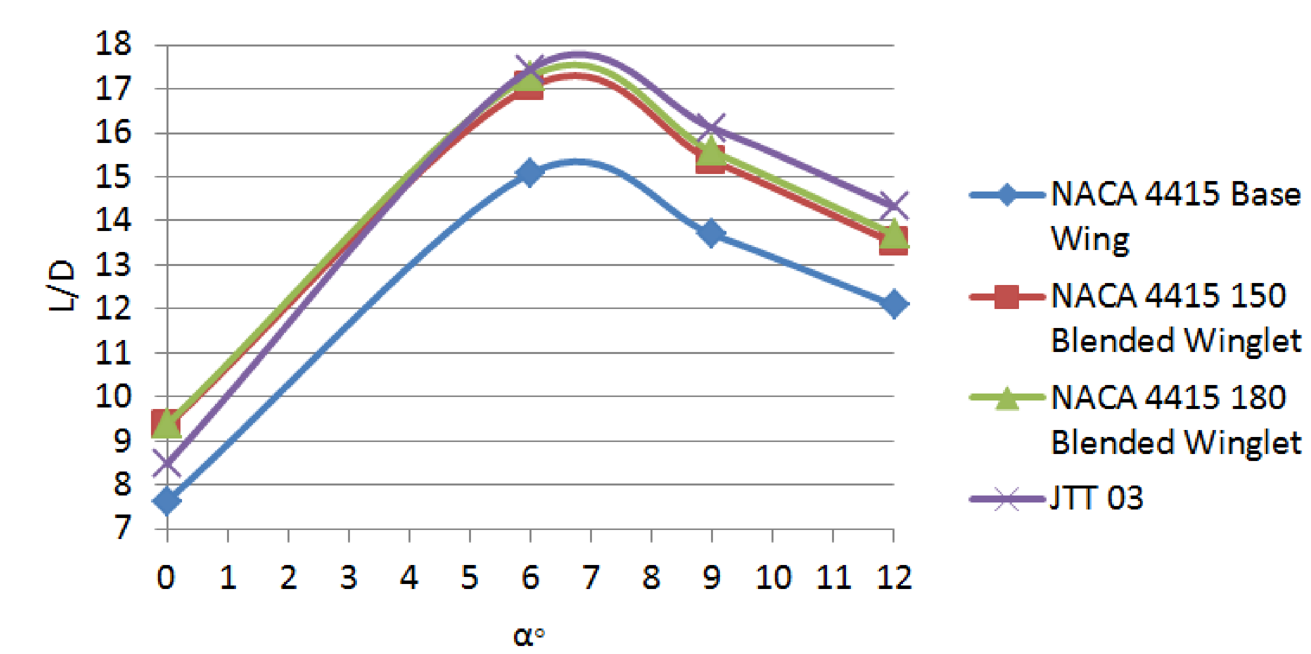
NACA 4415 JTT 03 Aerodynamic Characteristics



Velocity streamlines of flow over Base Wing (top) compared to JTT 03 (Bottom)

Economic Impact

Lift to Drag Ratio vs. Angle of Attack



The fuel consumption of the aircraft is inversely proportional to the L/D ratio. Improvement of the ratio will increase overall efficiency, thus saving fuel. This results in saving commercial airliners millions of dollars a year. Reduction of vortex formation also shortens waiting time between subsequent aircraft takeoffs, increasing the number of flights per day.