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Aircraft forces due to interference between a jet efflux and a slotted flap

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AIRCRAFT FORCES DUE TO INTERFERENCE BETWEEN A JET EFFLUX AND A SLOTTED FLAP

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AIRCRAFT FORCES DUE TO INTERFERENCE BETWEEN A JET EFFLUX AND A SLOTTED FLAP

1. NOTATION AND UNITS

SI British

A	wing aspect ratio, $(\text{wing span})^2/S_{ref}$
B	coefficient used in evaluating θ_{jc} in Equation (3.9)
C_{Da}	aircraft drag coefficient resulting from aerodynamic forces, excluding contribution from jet/flap interference effects
C_{Db}	drag coefficient resulting from aerodynamic forces arising from jet/flap interference effects
C_{La}	aircraft lift coefficient resulting from aerodynamic forces, excluding contribution from jet/flap interference effects
C_{Lb}	lift coefficient resulting from aerodynamic forces arising from jet/flap interference effects
$C_{L\alpha}$	incidence-dependent component of C_{Lb}
$C_{L\theta}$	flap-dependent component of C_{Lb}
C_m	total aircraft pitching moment coefficient (see Sketch 1.3)
C_{ma}	pitching moment coefficient resulting from aerodynamic forces, excluding jet/flap interference effects
C_{mb}	pitching moment coefficient resulting from aerodynamic forces arising from jet/flap interference effects
C_{me}	propulsion contribution to pitching moment coefficient, excluding jet/flap interference effects
C_{mp}	propulsion contribution to pitching moment coefficient including jet/flap interference
C_{TG}	gross thrust coefficient, $(\text{total engine gross thrust})/(\text{free-stream kinetic pressure} \times S_{ref})$
C_{TN}	net thrust coefficient
C_{XD}	momentum force coefficient associated with the air that passes through the engines, calculated at free-stream velocity
C_{XT}	coefficient of resultant force parallel to free-stream (see Sketch 1.3a)

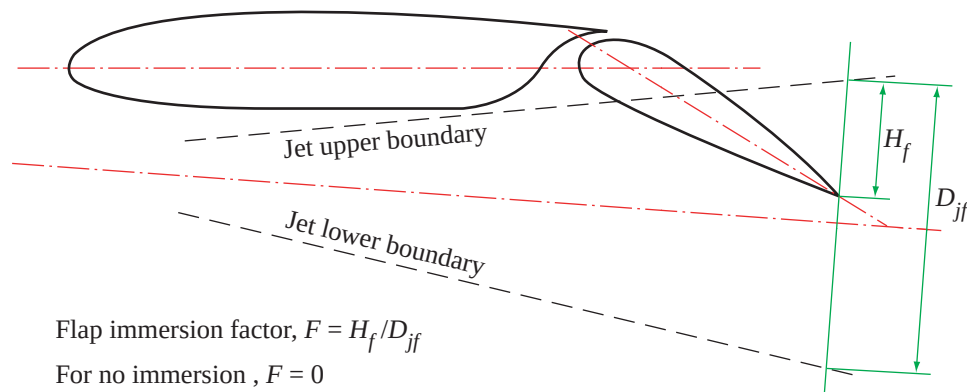
C_{ZT}	coefficient of resultant force normal to free-stream (see Sketch 1.3a)		
C_μ	two-dimensional trailing-edge jet momentum coefficient, derived from Equation (4.1)		
c	local wing chord		
$\bar{c}$	wing aerodynamic mean chord		
c'	extended wing chord (see Sketch 1.6)	m	ft
c''	projected chord of extended wing (see Sketch 1.6)	m	ft
c_f	flap chord (see Sketch 1.6)	m	ft
$c_{f\text{aux}}$	chord of flap final, or auxiliary, element (see Sketch 1.6b)	m	ft
D_j	jet diameter at start of jet diffusion (see Sketch 1.2)	m	ft
D_{jf}	jet diameter at flap trailing-edge (see Sketch 1.1)	m	ft
E	coefficient used in evaluating θ_{jc} in Equation (3.9)		
F	flap immersion factor (see Sketch 1.1)		
F_1, F_2	coefficients used in evaluating K_4 in Equation (4.19)		
G, G_1	coefficients used in evaluating $C_{L\alpha}$ in Equation (4.13)		
H_f	distance of flap trailing-edge from jet upper boundary (see Sketch 1.1)	m	ft
h_e, h_i	moment arms associated with propulsion forces (see Sketch 1.5a)	m	ft
h_f	moment arm associated with jet/flap interference forces (see Sketch 1.5)	m	ft
K	part-span vortex drag factor		
K_1	coefficient used in evaluating $C_{L\alpha}$ in Equation (4.13)		
K_2	ratio of extended wing chord to local wing chord, c'/c		
$K_3, K_{3\text{aux}}$	coefficients used in evaluating $C_{L\theta}$ in Equation (4.17)		
K_4	coefficient used in evaluating K		
l_c	distance of centre-of-pressure measured from wing leading-edge (see Sketch 1.5a)	m	ft

l_e	moment arm associated with propulsion forces (see Sketch 1.5a)	m	ft
l_f	moment arm associated with jet/flap interference forces (see Sketch 1.5)	m	ft
l_0	distance between wing leading-edge and aircraft centre-of-gravity (see Sketch 1.5a)	m	ft
N	number of engines per wing		
S_{ref}	aircraft reference area	m ²	ft ²
S_j	wing area influenced by jets (see Equation (4.2))	m ²	ft ²
t	local wing maximum thickness	m	ft
Y	coefficient used in evaluating λ_1 in Equation (3.8)		
α	aircraft incidence	degree	degree
α_l	inclination of local chord relative to aircraft reference plane (see Sketch 1.3a)	degree	degree
δ_f	flap angle (see Sketch 1.3)	degree	degree
δ_{faux}	flap angle for final, or auxiliary, element of flap (see Sketch 1.3c)	degree	degree
ΔC_{XT}	change in C_{XT} due to jet/flap interference		
ΔC_{ZT}	change in C_{ZT} due to jet/flap interference		
η_i	distance from aircraft centre-line to inboard limit of jet(s), non-dimensionalised with respect to wing semi-span (see Sketch 1.7)		
η_o	distance from aircraft centre-line to outboard limit of jet(s), non-dimensionalised with respect to wing semi-span (see Sketch 1.7)		
η_j	propulsive efficiency factor		
θ_d	angle through which jet is deflected due to jet/flap interference	degree	degree
θ_e	inclination of powerplant thrust line relative to aircraft reference plane, $\theta_{ew} + \alpha_l$	degree	degree
θ_{ew}	inclination of powerplant thrust line relative to local wing chord (see Sketch 1.3b)	degree	degree
θ_f	inclination of flap trailing-edge upper-surface relative to local wing chord (see Sketch 1.3)	degree	degree

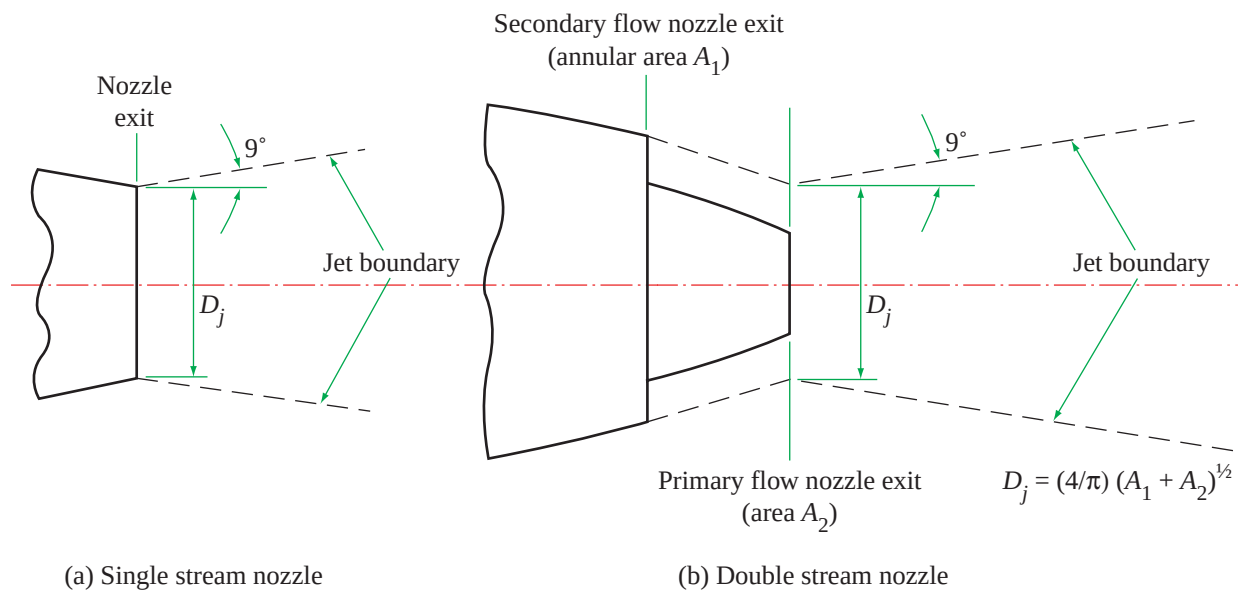
θ_j	inclination of deflected jet relative to aircraft reference plane, $\theta_{jw} + \alpha_l$	degree	degree
θ_{jc}	theoretical deflection angle for that part of jet which impinges on flap, used in evaluating η_j in Equation (3.7)	degree	degree
θ_{jw}	inclination of deflected jet relative to local wing chord (see Sketch 1.3b)	degree	degree
θ_m	theoretical maximum jet deflection angle, $\theta_f - \theta_{ew}$	degree	degree
λ_1	fraction of jet area impinging on flap		
λ_2	fraction of λ_1 lost through scrubbing or by lateral spread of jet		
λ_m	jet momentum ratio, see Equation (3.1)		
Φ	part-span factor on lift coefficient		
<i>Subscripts</i>			
2D	denotes value for aerofoil		
3D	denotes value for wing		

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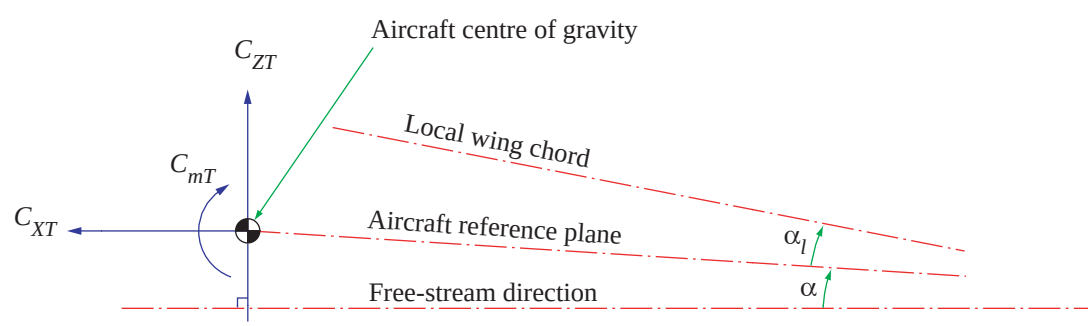
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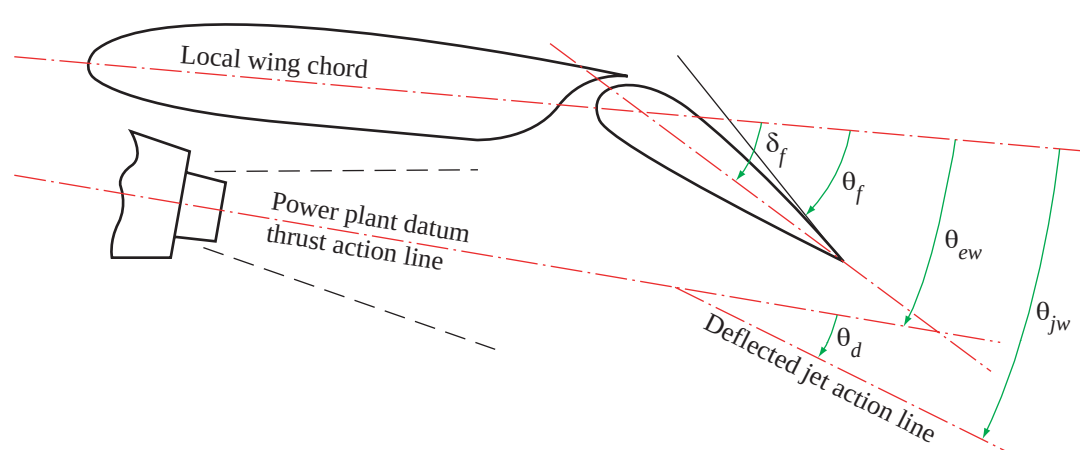
Sketch 1.1 Definition of flap immersion factor



Sketch 1.2 Illustration of method used to define jet boundary

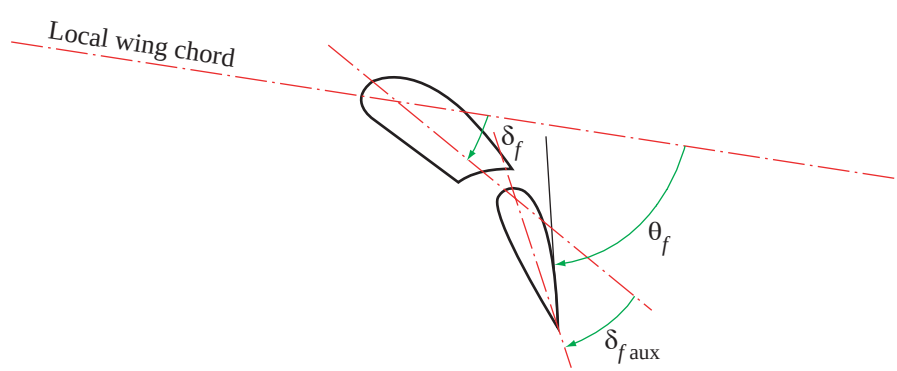


(a) Definition of incidence, wing twist and forces



(b) Definition of angles for single-element flap

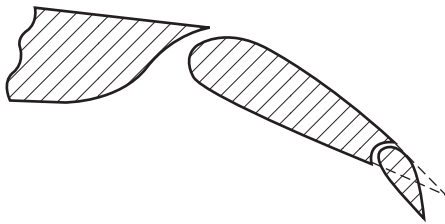
Note: All angles are drawn in the positive direction



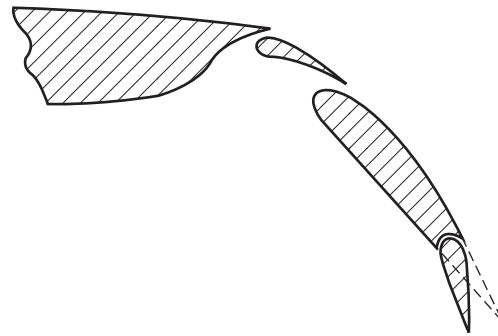
(b) Definition of angles for double-element flap

Sketch 1.3 Definition of angles and forces

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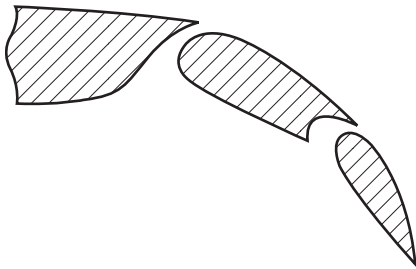


(i) Single-slotted

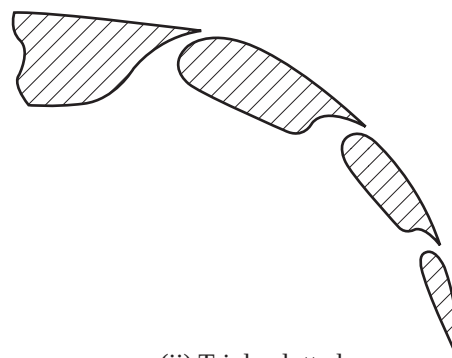


(ii) Double-slotted

(a) Type A flaps: single main element



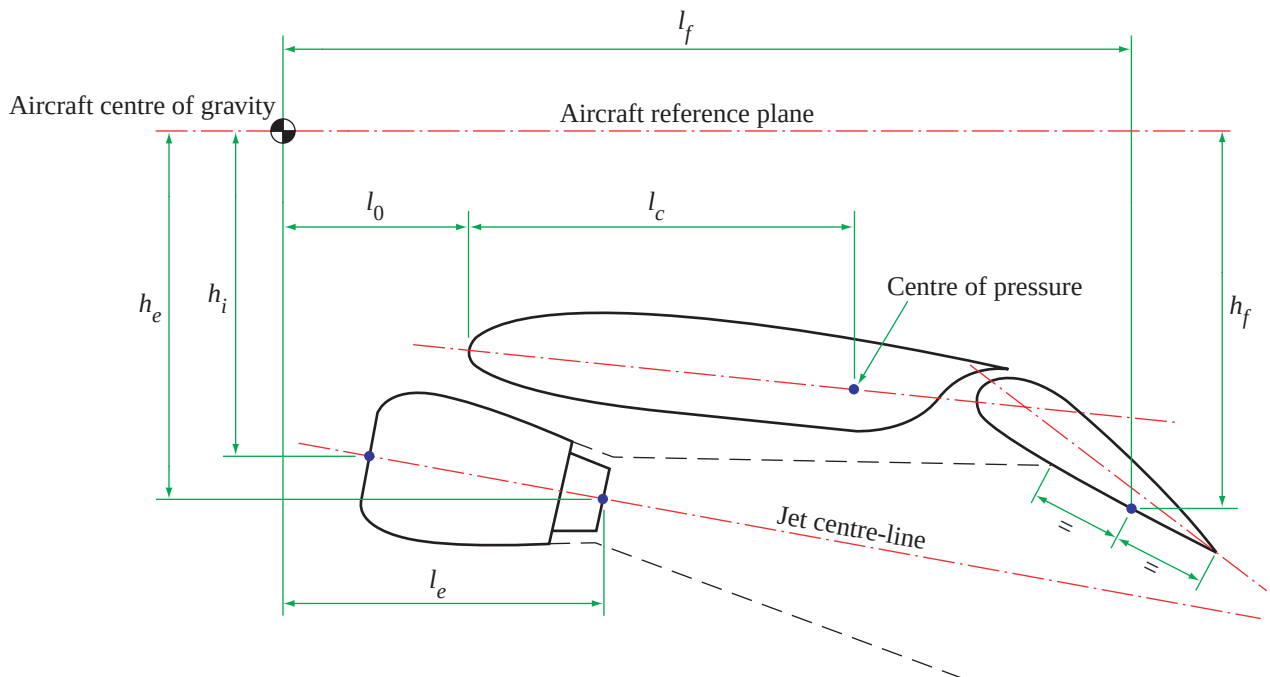
(i) Double-slotted



(ii) Triple-slotted

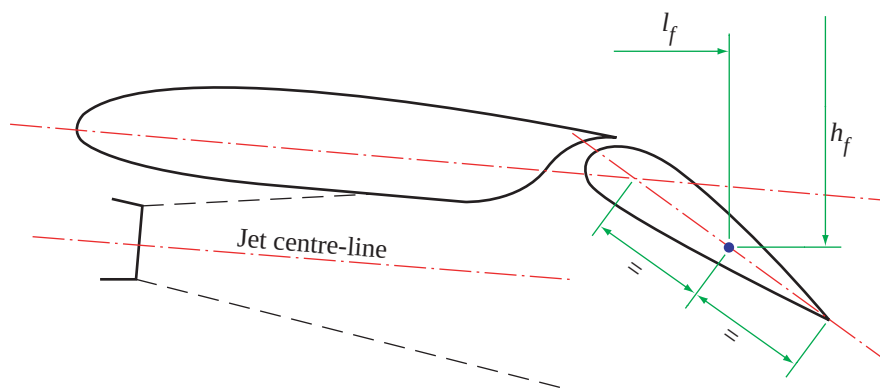
(b) Type B: multi- element

Sketch 1.4 Illustration of flap types



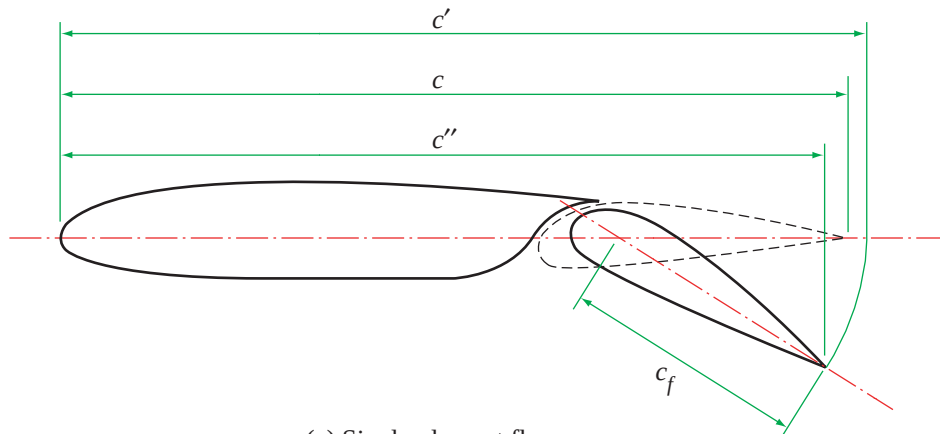
(a) General case

Note: All moment arms are drawn as positive values

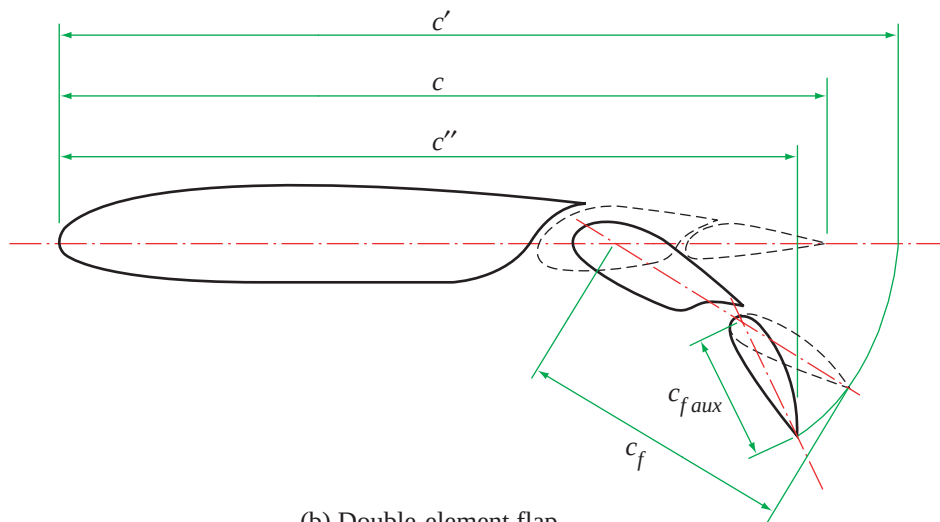


(b) Case of high flap immersion

Sketch 1.5 Moment arm definition

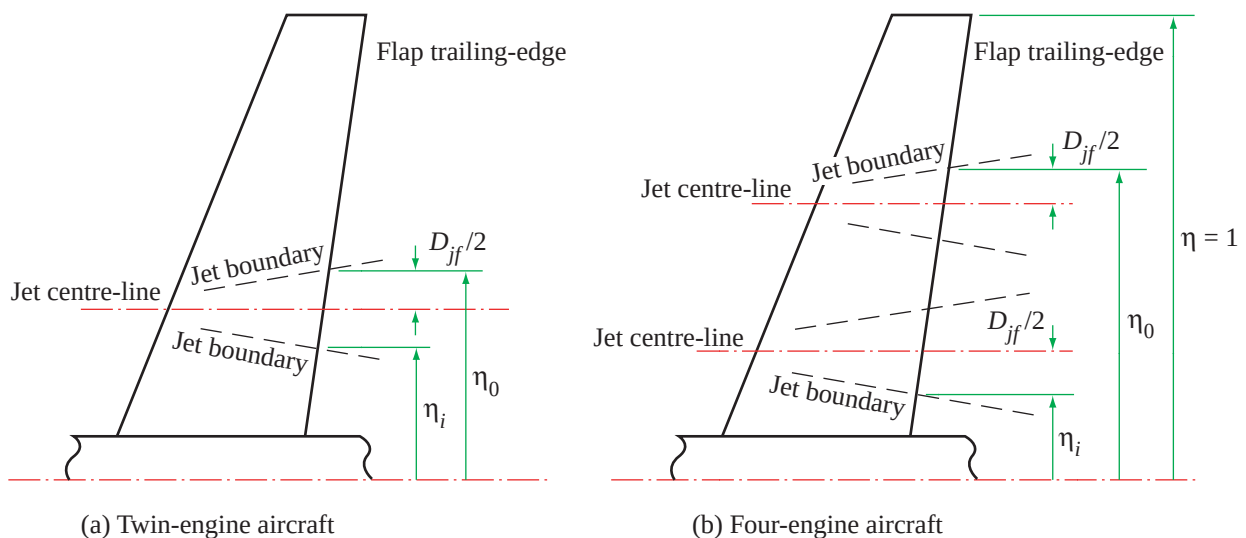


(a) Single-element flap



(b) Double-element flap

Sketch 1.6 Definition of wing and flap chords



(a) Twin-engine aircraft

(b) Four-engine aircraft

Sketch 1.7 Jet spanwise extent for use in evaluating part-span factors