AEM 617 Student Lecture: Hinge Moments

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What are Hinge Moments?

Moments induced by forces on hinged geometry, measured about the hinge axis.

Hinged Geometry on a Typical Aircraft

- Control surfaces (aileron, elevator, rudder)
- Lift devices (flap, slat, spoiler)
- Landing gear
- Gear and bay doors
- Engine components (nozzle, inlet, cowl flaps)
- Others (cargo ramp, Concorde nose)

What are Hinge Moments?

My primary interest is control surface hinge moments.

Control Surface Hinge Moment Significance

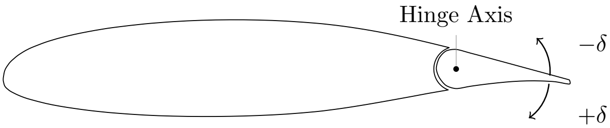
- Pilot stick forces
- Aircraft flying quality (Cooper-Harper scale)
- Structural and mechanical requirements

What are Hinge Moments?

Forces Acting on a Control Surface

- Aerodynamic
  - Pressure
  - Viscous stress
- Weight
- Inertia*

What are Hinge Moments?

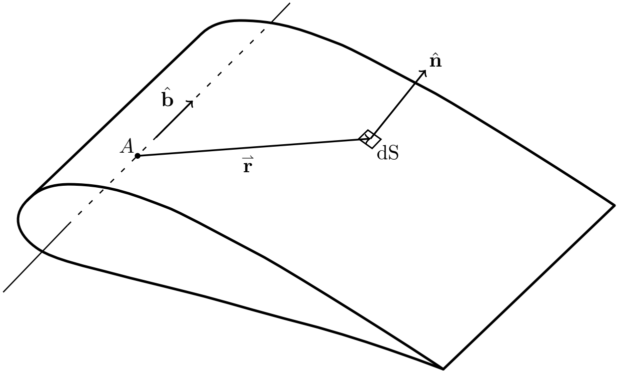


GA(W)-1 Airfoil with a 20% aileron

δ: deflection angle

$$\vec{\mathbf{M}}_A = -\iint_S \vec{\mathbf{r}} \times P\hat{\mathbf{n}}\mathrm{d}S + \iint_S \vec{\mathbf{r}} \times (\tilde{\tau} \cdot \hat{\mathbf{n}})\,\mathrm{d}S$$

$$H = \vec{\mathbf{M}}_A \cdot \hat{\mathbf{b}}$$



Hinge Moment Coefficient

$$C_h = \frac{H}{q_\infty S_f \bar{c}_f}$$

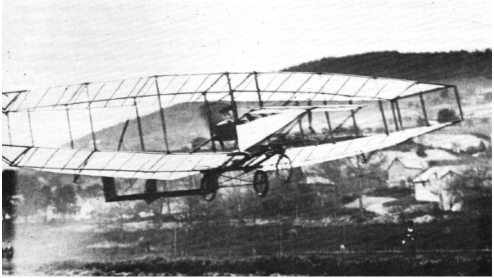
$$q_\infty = \frac{1}{2}\rho_\infty V_\infty^2$$

S_f: Planform area of the surface aft of the hinge line.
$\bar{c}_f$: Mean chord of the surface aft of the hinge line, measured normal to the hinge axis.

Note

Positive C_h is a trailing edge down moment.

The AEA White Wing



Courtesy: aviation-history.com

- Designed by F. W. Baldwin and Glenn Curtiss in 1908
- First aircraft to use ailerons for control
- Curtiss made a controlled flight over 1000 ft

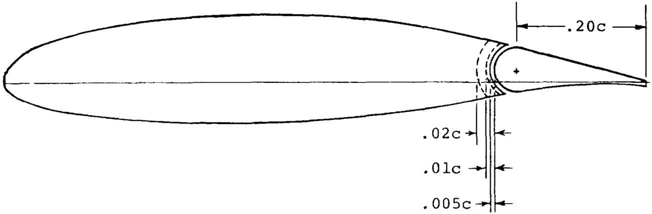
The Farman III

- Designed by Henry Farman in 1909
- Single-acting ailerons
- First use of ailerons hinged directly to the wing structure

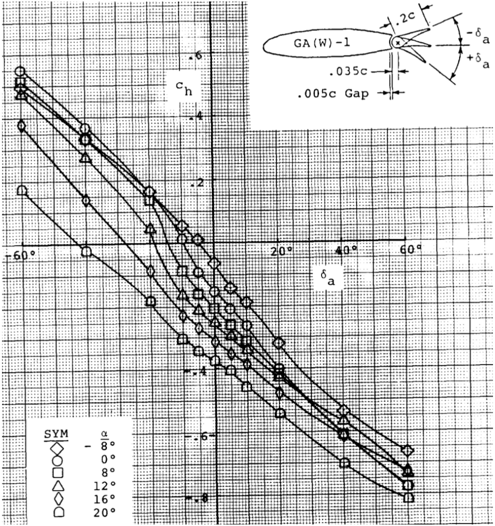
Courtesy: wikipedia.org

Case Study: GA(W)-1 Airfoil with 20% Aileron

- 17% thick
- Large leading edge radius to increase stall angle of attack
- Blunt trailing edge with nearly parallel upper and lower surfaces
- Nearly uniform pressure distribution when $C_l = 0.4$
- Used on Piper Tomahawk, Beech 77 Skipper, Fairchild T-46



Courtesy: NASA CR-2833



Courtesy: NASA CR-2833

Notes:

- Fairly linear
- $C_{h_{\delta_a}} < 0$
- $C_{h_\alpha} < 0$
- Stick-free position is where $C_h = 0$

Effect of Control Surface Sizing (Clark Y)

Variation with chord

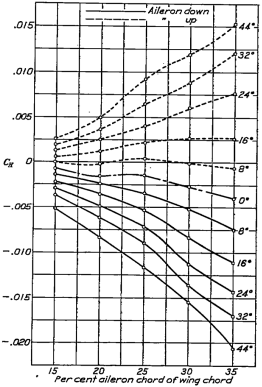


FIGURE 9.—Clark Y wing section. C_H for varying aileron chord—20-inch span (67 per cent of wing semispan). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

Variation with span

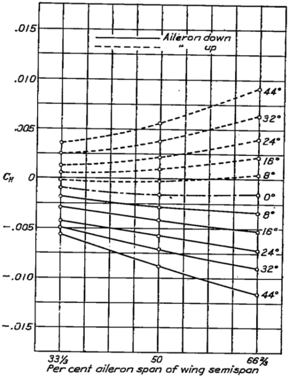


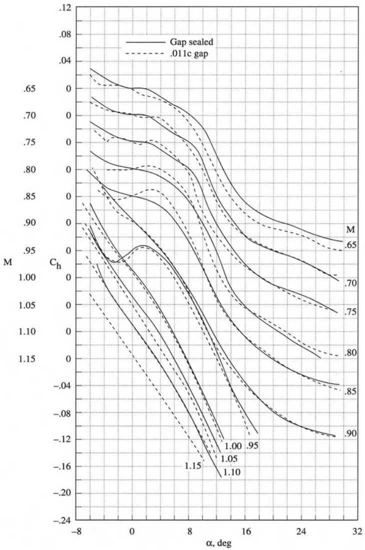
FIGURE 10.—Clark Y wing section. C_H for varying span—2.5-inch chord (25 per cent of wing chord). Pitch angle 0°. Roll angle 0°. Yaw angle 0°

Note: C_H in this reference is defined using wing measurements.

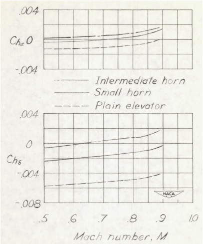
Images Courtesy: B. H. Monish, NACA Report No. 370

Effect of Speed

- Hinge moments increase as mach number increases
- Transonic region is especially troubling.



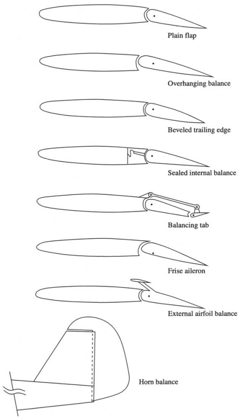
W. Hewitt Phillips, *Journey in Aerospace Research*



Courtesy: Johnson and Thompson, NACA RM-L50B13

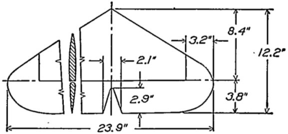
Counteracting Hinge Moments

- Hinge moments grew as aircraft became larger and faster
- Engineers started designing features into control surfaces to balance hinge moments
- Care must be taken to not over balance the moments...

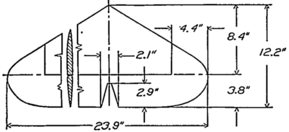


Courtesy: W. Hewitt Phillips, *Journey in Aerospace Research*

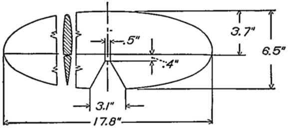
Minor differences can have major consequences.



Tail surface 8, reference 1.

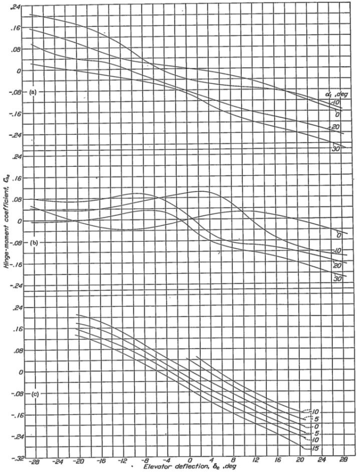


Tail surface 9, reference 1.



Tail surface 10, reference 2.

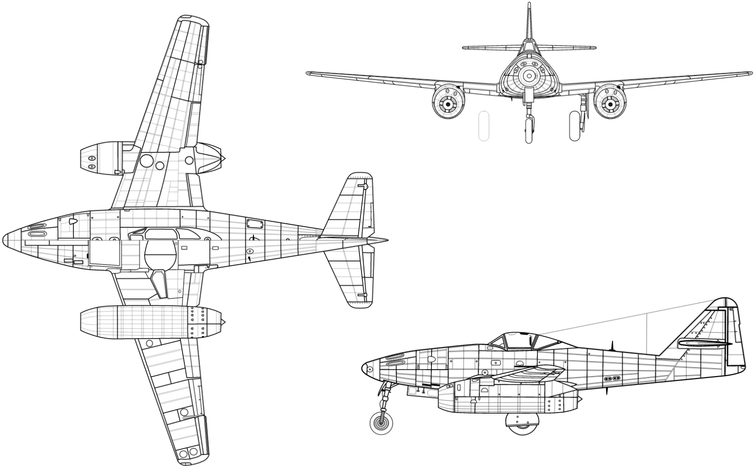
Images Courtesy: B. H. Monish, NACA Report No. 370



(a) FIGURE 37.—Tail surface 8. (b) FIGURE 38.—Tail surface 9. (c) FIGURE 39.—Tail surface 10.

Case Study: Me 262

Courtesy: wikipedia.org



Messerschmitt Me 262 *Schwalbe*

Courtesy: wikipedia.org

Case Study: Me 262

Video: tiny.cc/me262trim (17:47 - 19:12)

- Rudder trim
- Horizontal stabilizer incidence
- Leading edge slat
- Aileron

Case Study: Me 262

Runaway Trim

"I wanted to explore the effort necessary to recover from a runaway trim condition in a dive and at higher speeds. Even at 180 knots and with the nose only ten degrees below the horizon, the pull required to get back to level flight was quite high. I estimate the force to be in the 70- to 80-pound range."

Case Study: Me 262

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More Trim problems

- "At an indicated airspeed of 350 knots - equivalent to 395 knots true airspeed at my altitude - I needed both hands on the stick to keep the airplane from banking."
- Aileron trim could only be adjusted from the ground

Case Study: Me 262

Stick Force Reversal

"I tried to turn to the right. It took a lot of force to move the stick, with the airplane slowly rolling into a bank. Suddenly, the stick pressure disappeared completely and the Me 262 literally snapped into more than 60 degrees of bank. Moving the stick to the left to arrest the roll resulted in a similar force and pressure change in the opposite direction."

Case Study: Me 262

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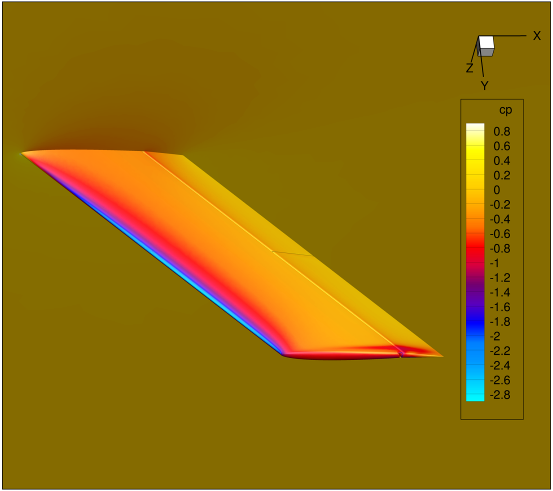
Causes

- Reverse flow over the upper surface of the up-deflected aileron
- Aileron was hung 10 mm lower than Messerschmitt's manufacturing specifications (Messershmitt allowed 1.5 mm)

Case Study: Me 262

Inkscape Demo

Thank you



My research.