H. Real Wings: 3D Flow, Separation, & Vorticies

Content Area: **Science**
Course(s): **CAD Architect**
Time Period: **Marking Period 1**
Length: **1**
Status: **Published**

Assessment

"Do Now" Activities

"Exit Ticket" Activities

Practice Problem Worksheets

Quizzes

Standards

SCI.9-12.HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
SCI.9-12.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
SCI.9-12.HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
SCI.9-12.HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
SCI.9-12.HS-PS1-3	Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
SCI.9-12.HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Enduring Understandings

Students will come to understand:

1. The same intermolecular attractive forces that hold the molecules of a fluid together also are responsible for the viscous nature of a fluid.
2. The Reynolds Number is a dimensionless coefficient that characterizes the nature of a boundary layer, and this boundary layer and the pressure gradient predict the point of low separation.
3. Wings can be created with various planforms, or shapes when viewed from above, that affect the operation of the wing.

4. The finite span of a real wing is responsible for the formation of wingtip vorticies and spanwise flows; airfoil characteristics assume infinite span wings and thus are an approximation of reality.

Essential Questions

The following questions will guide student inquiry:

- How does the viscous nature of real fluids, such as air, impact the actual operation of aircraft wings?
- How do the three-dimensional characteristics of aerodynamic surfaces affect design decisions for a given set of design parameters?

Knowledge and Skills

Unit Content:

The development of aerodynamic theory to this point in the course has assumed inviscid flow, or flow through a fluid where the fluid's viscosity is negligible. However, even air has a certain amount of viscosity and this viscosity creates a boundary layer around all surfaces in the fluid flow. The behavior of this boundary layer affects the previously discussed aerodynamic coefficients and motivates many of the aerodynamic flow control devices seen in practical experience. Additionally, to this point, all airfoils have been treated as two-dimensionl cross sections. However, wings are three dimensional planar surfaces. The effect of spanwise flow and wing planform (the shape of the wing when viewed from above) also contribute to the aerodynamic character of an aircraft and are the subject of this unit. This unit should also make clear that wing planform is affect by three geometric factors, namely: (1) aspect ratio, (2) taper, and (3) sweepback. All wing planforms are some combination of these three variables. The next unit will explore how aspect ratio affects the three-dimensional flow characteristics of a wing. The unit that follows the next will explore how taper and sweepback respectively affect the three-dimensional flow around a wing.

- Definition of Viscous Flow and Friction Effects
- Surface Boundary Layers and Laminar vs. Turbulent Flow (1 day)
- Dimensionless Coefficient for Viscous Flow: Reynolds Number (Re) (1 day)
- Pressure Gradient, Reynolds Number, and Flow Separation (2 days)
- Geometry of wing planforms (definition of area, span, average chord, aspect ratio, taper ratio, sweep angle, and mean aerodynamic chord) (1 day)
- Development of Lift by a finite wing, tip vorticies, and Spanwise flow (2 days)

Science, Technology, Engineering, Mathematics, and/or Aerospace Skill(s):

Many everyday devices are designed to control the boundary layer, and thus affect the lift, or more commonly the drag, acting on the body.

- Practical Examples: Dimples on Golf Balls, Fur on Tennis Balls, Vortex Generators on Tractor Trailer Trailers and aircraft wings, etc.

- Scale Effect and Wind Tunnel Testing (1 day)

Resources

Textbook(s):

Hurt, H. H. (1965). *Aerodynamics for Naval aviators*. Washington, DC: Federal Aviation Administration.

Cessna Aircraft Company. (1977). *Pilots operating handbook: Cessna 172*. Wichita, KS: Cessna Aircraft Company.

Federal Aviation Administration. (2013). *The pilots handbook of aeronautical knowledge*. Washington, DC: Author.

Lab Equipment:

Pasco Low Speed Wind Tunnel

Balsa tools to create airfoil sections

Foam cutter and foam cutting tools to create airfoil sections

Balsa gliders

Video Camera/digital camera

Computer Software:

Microsoft Excel

Foilsim

NASA Site