G. Airfoils: Lift Distribution & Pitching Moments

Content Area: **Science**
Course(s):
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-ETS1-2	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-ETS1-3	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-ETS1-4	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-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.
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.

Enduring Understandings

Students will come to understand:

1. Distributed forces do not necessarily have to be uniform and non-uniform distributed forces tend to cause torques.
2. The combination of the non-uniform force distribution on the bottom surface of an airfoil and the non-uniform force distribution on the top surface of an airfoil lead to aerodynamic pitching moments.
3. Pitching moments must be counteracted by opposing moments if an aircraft is to remain in a steady flight condition, and there are many different aircraft configurations that satisfy this condition.

Essential Questions

The following questions will guide student inquiry:

- What factors affect the pitching moment generated when fluids in motion interact with objects in the flow?
- How does the shape of a body in motion relative to a fluid affect the pitching moment acting on that body?
- What are the advantages and disadvantages of different aircraft configurations designed to counter the pitching moment coefficient?

Knowledge and Skills

Unit Content:

The forces generated by the upper and lower surfaces of an airfoil vary from the leading to trailing edge of the airfoil. This differing distribution of force on the upper and lower surfaces of an airfoil lead to net torques or moments to act about the airfoil's aerodynamic center, tending to pitch the airfoil nose-down. Just as with other aerodynamic forces (lift and drag), this pitching moment can be expressed in terms of a pitching moment coefficient and explored as a function of angle of attack. This unit explores the nature of the pitching moment coefficient and its implications on aircraft design. Stated simply, all airfoils tend to pitch nose-down as a result of developing lift. This nose-down pitching moment must be balanced by an equal nose-up pitching moment generated by another aerodynamic surface. In most aircraft, this counterbalancing moment is provided by the aircraft's horizontal tail. As with lift and drag, the affect of airfoil camber and thickness on pitching moment coefficient will be explored.

- Airfoil Pressure Distribution & Nonuniform distributed forces
- Definition of Center of Pressure and Aerodynamic Center (2 days)
- Review of Torques and Moments (2 days)
- Pitching Moment Coefficient and Aerodynamic Pitching Moment Equation
- How Airfoil Geometry Affects Pitching Moment (the role of thickness and camber) (2 days)

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

An airfoil's unavoidable pitching moment necessitates a counterbalancing torque if an aircraft is going to fly in steady flight. Engineers have experimented with various means of producing this counterbalancing moment. Canards and flying wings represet unusual alternative aircraft configurations that produce the counterbalancing moment.

- Practical Significance: Flying Wings, Canards, and aircraft configurations (1 day)
- Application of integral calculus to find the center of pressure of a nonuniform distributed force given the force distribution as a function of length (such as lift as a function of chord length)

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

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