ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 1

EO M431.01 – EXPLAIN FEATURES OF WING DESIGN

Total Time: 30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Obtain a model of a light fixed-wing aircraft with wing struts, fixed gear and control surface detail.

Prepare slides of the figures located at Attachment A.

Obtain a model of a wing.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize, and summarize features of wing design.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain features of wing design.

IMPORTANCE

It is important for cadets to be able to explain features of wing design as it directly relates to the production of lift by the wing. Being able to explain features of wing design provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.

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Use the model aircraft with articulated control surfaces and flaps throughout this lesson to illustrate features of wing design as they are discussed.

Teaching point 1 **Explain airfoils.**

Time: 10 min Method: Interactive Lecture

AIRFOILS

Chord. An imaginary straight line joining the leading and trailing edges of the wing. The mean aerodynamic chord (MAC) is the average chord of the wing.

The shape and design of the wing is directly influenced by the intended purpose of the aircraft. Aircraft designed to fly slowly typically have thick airfoils, while aircraft designed to fly fast have thin airfoils.



Show the slide of Figure A-1 to the cadets.

The very thin layer of air lying over the surface of the wing is called the boundary layer. At the front of the wing, the boundary layer flows smoothly over the surface and this area is called the laminar layer. As the air flows further along the wing, it slows down due to skin friction, the layer becomes thicker, and it becomes turbulent. The turbulent area is called the turbulent layer.

The transition point between the laminar and turbulent areas tends to move forward as airspeed and the angle of attack increase.

Conventional Airfoils

Conventional airfoils generally are the thickest at 25 percent of the chord and can be found in a variety of shapes and designs.



Show the slide of Figure A-2 to the cadets and describe the different airfoil shapes.

Laminar Flow Airfoils



Show the slide of Figure A-3 to the cadets and show the differences between conventional and laminar flow airfoil shapes.

Laminar flow airfoils have their thickest point at 50 percent of the chord, a leading edge that is more pointed and upper and lower surfaces that are nearly symmetrical. Originally developed to make aircraft fly faster, they can be found on many different aircraft types.

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The design of the laminar flow airfoil reduces drag by maintaining the laminar flow of air throughout a greater percentage of the chord. The pressure distribution is more even, but the transition point moves forward more rapidly near the point of stall.

PLANFORM



Show the slide of Figure A-4 to the cadets.

The shape of the wing as seen from directly above is called the planform. The three general wing shapes are:

- rectangular,
- elliptical (rounded), and
- delta (swept).

Aspect ratio. The relationship between the length of the wing and its width (chord). It is calculated by dividing the span by the average chord.

A wing with a high aspect ratio generates more lift with less induced drag than a wing with the same wing area and a low aspect ratio. High aspect ratio wings are commonly found on gliders.

Angle of Incidence



Show the slide of Figure A-5 to the cadets.

The angle of incidence is the angle at which the wing is permanently inclined to the longitudinal axis of the aircraft.

The angle of incidence affects the following items:

- flight visibility,
- takeoff and landing characteristics, and
- amount of drag in level flight.

Wash-Out and Wash-In

To reduce the tendency of the wing to stall suddenly, the wing can be designed so that the angle of incidence at the wing tip is different than the angle of incidence at the wing root.



Show the slide of Figure A-6 to the cadets.

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The twist in the wing causes the tip and root to stall at slightly different angles of attack and improves the stall characteristics. If the wing root stalls before the wing tip, the ailerons, located closer to the wing tip, can still be effective during the early part of the stall.

Decreasing the angle of incidence at the wing tip is called wash-out and increasing the angle is called wash-in.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What happens to the transition point as airspeed and angle of attack increase?

Q2. What is the aspect ratio of a wing?

Q3. What is it called when the angle of incidence at the wing tip is decreased?

ANTICIPATED ANSWERS:

A1. The transition point moves forward.

A2. The relationship between the length of the wing and its width (chord). It is computed by dividing the span by the average chord.

A3. Wash-out.

Teaching point 2 **Explain high-lift devices.**

Time: 10 min Method: Interactive Lecture

HIGH-LIFT DEVICES

The efficiency of a wing can be improved by either increasing the amount of lift generated, or by decreasing the amount of induced drag created. High-lift devices can be used individually or in various combinations to create a very efficient wing.

Although great gains in efficiency can be realized by adding these devices to a wing, there are penalties to pay, such as increased weight and increased mechanical complexity.

Wing Tip Design

Induced drag can be reduced by limiting the formation of wing tip vortices. This is done by preventing air from spilling over the wing tip by modifying the wing tips in one of the following ways:

- installing wing tip fuel tanks,
- using wing tip plates or winglets, and
- drooping the wing tips.



Show Figures A-7 and A-8 to the cadets.

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Wing Fences



Show the slide of Figure A-9 to the cadets. Wing fences can also be seen in Figure A-8.

Wing fences are vertical surfaces attached to the upper surface of the wing. They act as guides and control the direction of airflow over the wing, especially at high angles of attack. This improves low-speed handling and stall characteristics.

SLATS



Show the slide of Figure A-10 to the cadets.

Auxiliary airfoils that automatically move out in front of the leading edge at high angles of attack are known as slats. The resulting opening changes the airflow over the leading edge, smoothing out eddies that form on the top of the wing.

SLOTS



Show the slide of Figure A-11 to the cadets. Slots can also be seen in Figure A-10.

Slots affect the airflow in the same way as slats, except that they are passageways built into the wing. Slots can either be full- or partial-span.



Slats are moving devices. Slots are built into the wing and do not move.

FLAPS

The most common high-lift device found on a wing is the flap. Located at the trailing edge, their primary purpose is to increase lift by changing the camber of the wing. Some styles of flaps also increase the effective wing area. The increased lift causes a lower stall speed and allows the aircraft to approach at a slower airspeed.



Show the slide of Figure A-12 to the cadets.

With a small amount of flap deflection, the amount of extra lift produced is greater than the amount of extra drag. As the amount of deflection increases, the amount of extra drag catches up to and passes the amount of extra lift being generated. The extra drag produced can be used to improve landing capabilities by slowing

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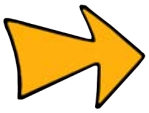
the aircraft down and creating a steeper approach angle (useful in approaching a runway with obstacles near the threshold).



Show the slide of Figure A-13 to the cadets.

Generally, the amount of drag produced by flaps reduces acceleration to the point where flaps should not be deployed during takeoff (as is the case with plain and split flaps). Slotted, Zap, and Fowler flaps produce more lift than drag at small amounts of deflection (5–15 degrees) and are usually recommended for takeoff.



In some aircraft, landing with full flaps and a crosswind is not recommended as the flaps may disrupt the airflow over the tail surfaces and make it difficult to control the aircraft during the ground roll.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. How can induced drag be reduced by wing tip design?

Q2. What is the main difference between slats and slots?

Q3. What do flaps increase?

ANTICIPATED ANSWERS:

A1. Induced drag can be reduced by:

- installing wing tip fuel tanks,
- using wing tip plates or winglets, and
- drooping the wing tips.

A2. Slats are moving devices. Slots are built into the wing and do not move.

A3. Flaps increase lift and drag. They may also increase the effective wing area.

Teaching point 3 **Explain spoilers and speed brakes.**

Time: 5 min Method: Interactive Lecture



Show the slide of Figure A-14 to the cadets.

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SPOILERS

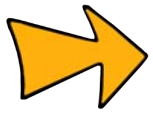
Spoilers are devices on a wing that are used to decrease the lift and increase the drag being produced. They work by being extended up from the top surface of the wing and disrupting the airflow. Spoilers are found on almost all types of gliders and are used to increase the rate of descent during the landing approach.

Spoilers can also be used to supplement aileron control or replace ailerons completely. A deployed spoiler has the same effect as an up-going aileron, causing the aircraft to bank to that side.

SPEED BRAKES

Speed (dive) brakes are devices that are extended into the airflow, creating drag, with minimal effect on the lift being produced. Speed brakes allow aircraft to slow down without reducing thrust, and to control approach angles.

Speed brakes may be plates that extend out of a wing or hinged doors that open out from the fuselage.



Most gliders have speed brakes that extend out of the bottom of the wing.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS:

Q1. Where are spoilers located?

Q2. What control surface can spoilers supplement or replace?

Q3. What do speed brakes create?

ANTICIPATED ANSWERS:

A1. On the top surface of a wing.

A2. Ailerons.

A3. Drag.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What is the chord?

Q2. How can adding devices negatively affect a wing?

Q3. What do spoilers increase during the landing approach of most gliders?

ANTICIPATED ANSWERS:

A1. An imaginary straight line joining the leading and trailing edges of the wing.

A2. They create increased weight and mechanical complexity.

A3. The rate of descent.

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CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CRR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

Understanding wing design, the features that improve the efficiency of the wing and devices that produce drag to control the approach angle provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

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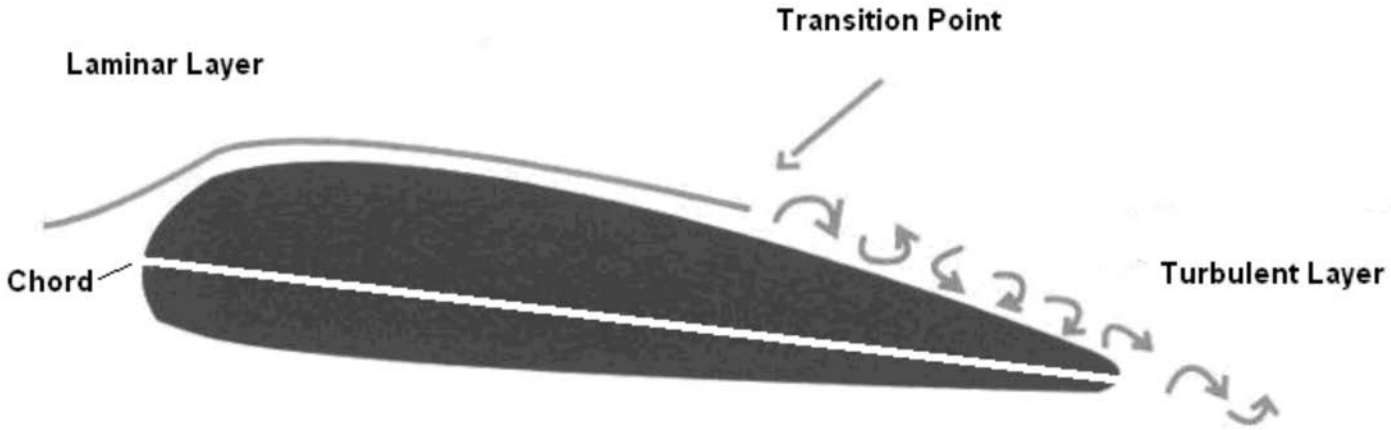

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Figure A-1 Laminar and Turbulent Layers

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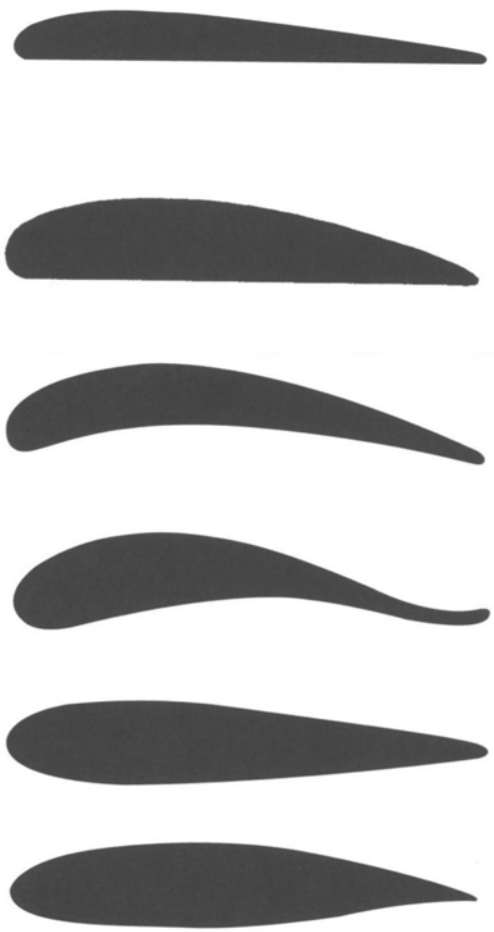

• Low camber • Low drag • High speed • Thin wing section	• Race planes • Fighters • Interceptors
• Deep camber • High lift • Low speed • Thick wing section	• Transports • Freighters • Bombers
• Deep camber • High lift • Low speed • Thin wing section	• Transports • Freighters • Bombers
• Low lift • High drag • Reflex trailing edge wing section	• Very little movement of centre of pressure • Good stability
• Symmetrical wing section (cambered top and bottom)	• Very little movement of centre of pressure • Good stability
• GA(W)-1 airfoil • Thicker for better structure and lower weight • Good stall characteristics	• Camber is maintained farther rearward which increases lifting capability over more of the airfoil and decreases drag

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Figure A-2 Airfoil Sections

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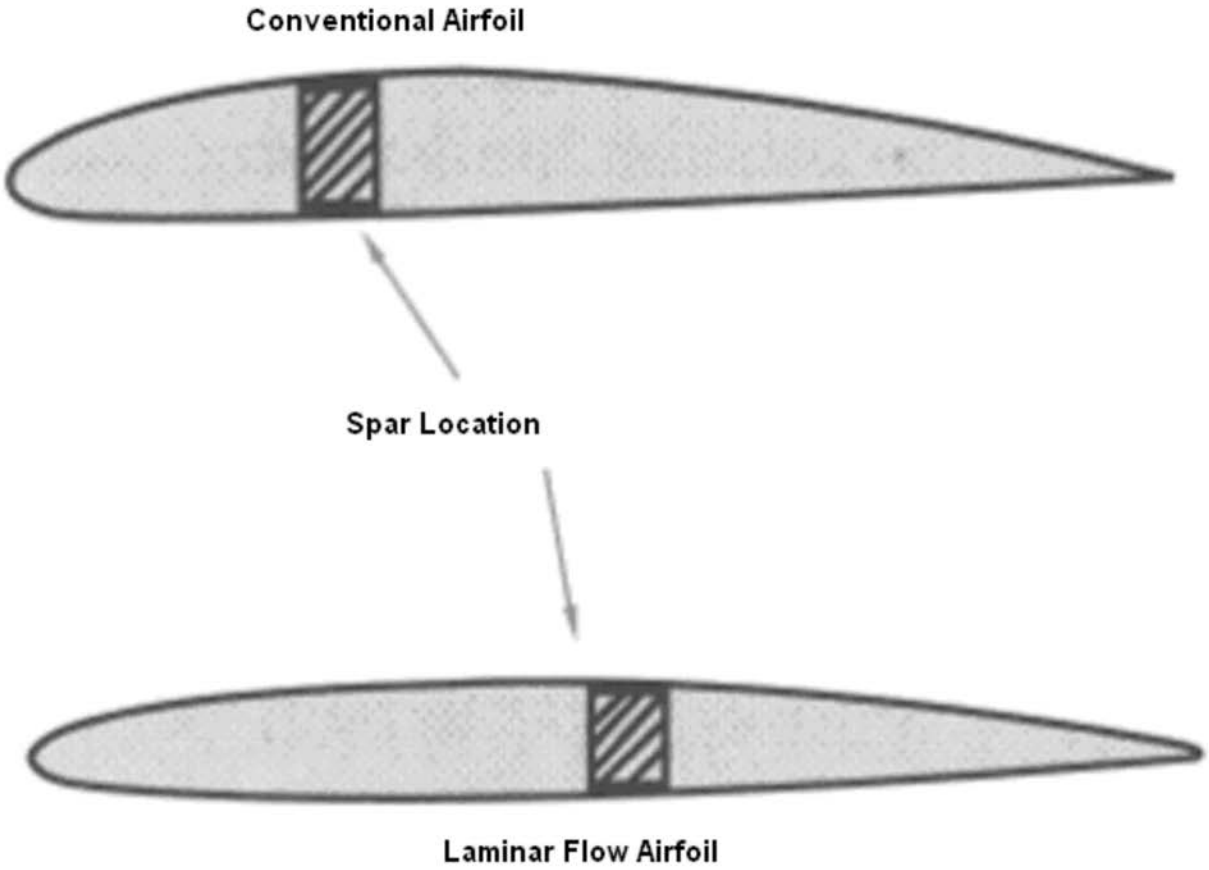

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Figure A-3 Conventional and Laminar Flow Airfoils

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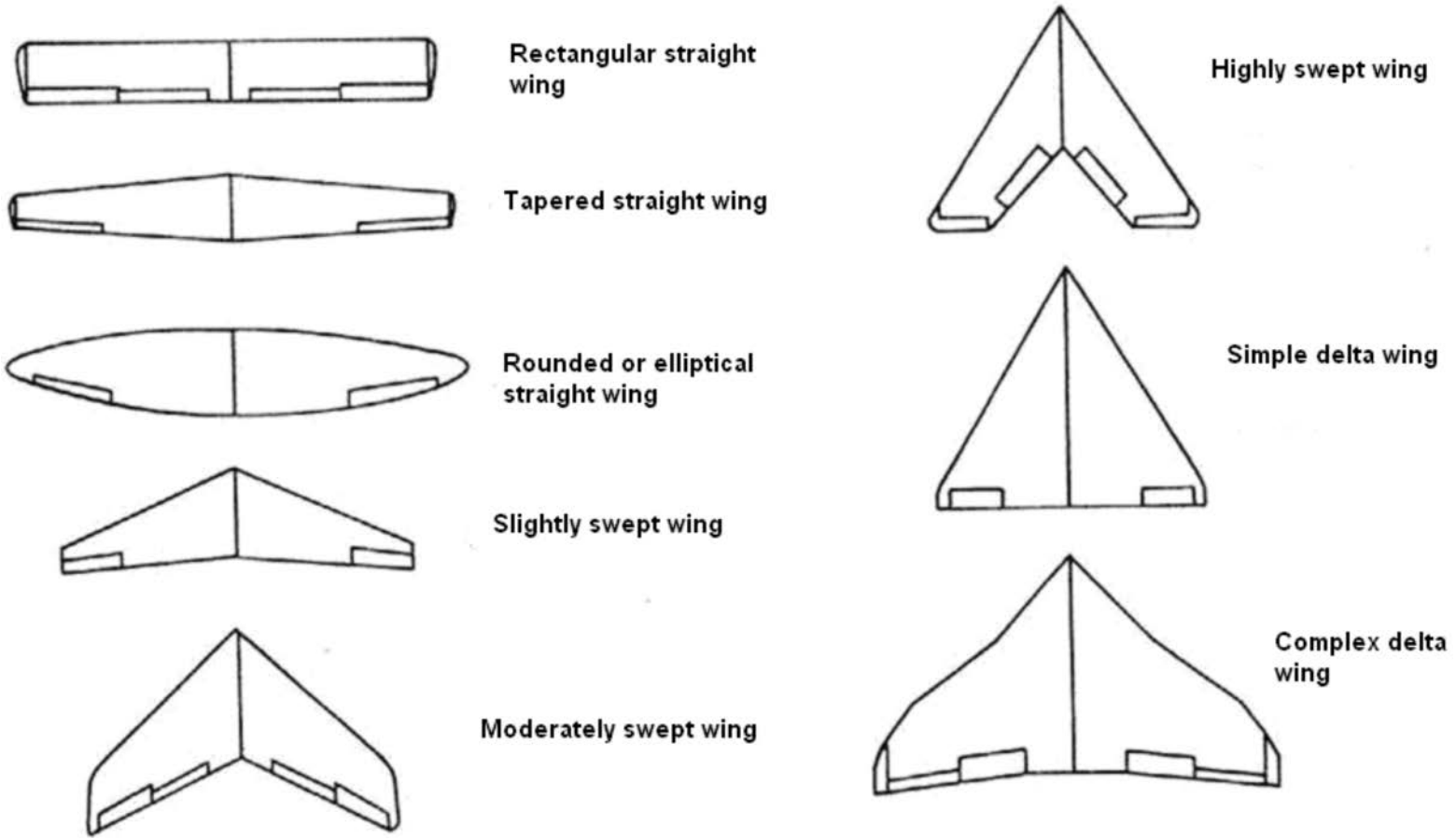

Note. From "SP-367 Introduction to the Aerodynamics of Flight", NASA. Retrieved October 22, 2008, from http://history.nasa.gov/SP-367/f13b.htm

Figure A-4 Examples of Wing Planforms

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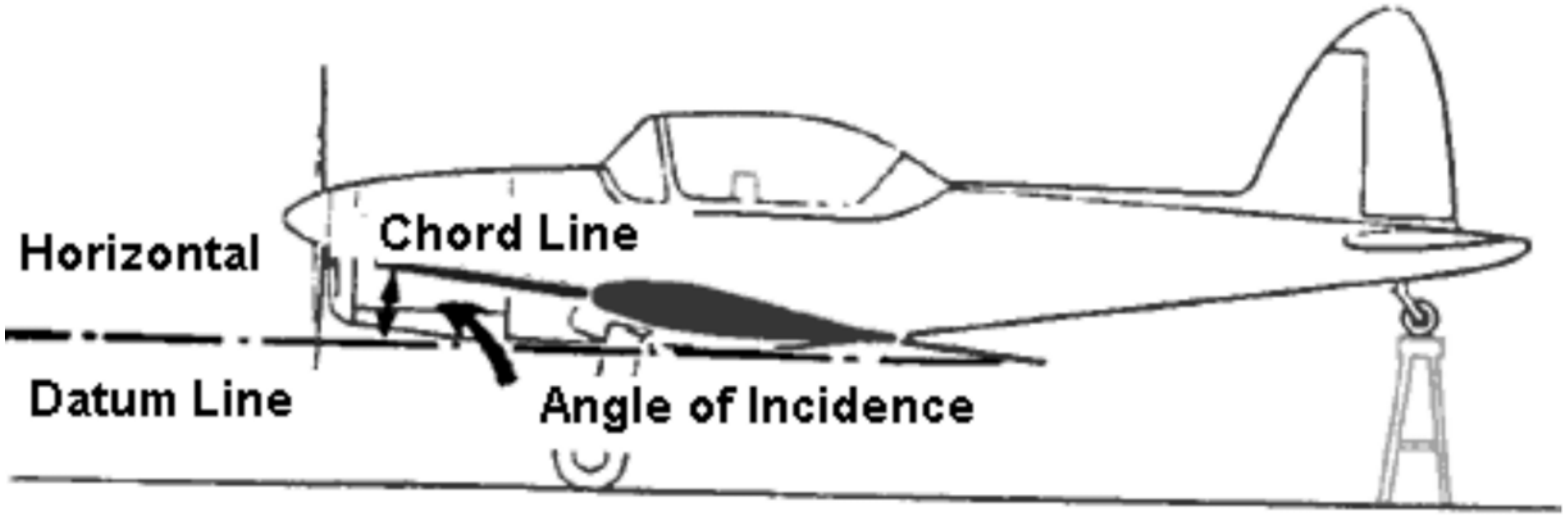

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Figure A-5 Angle of Incidence

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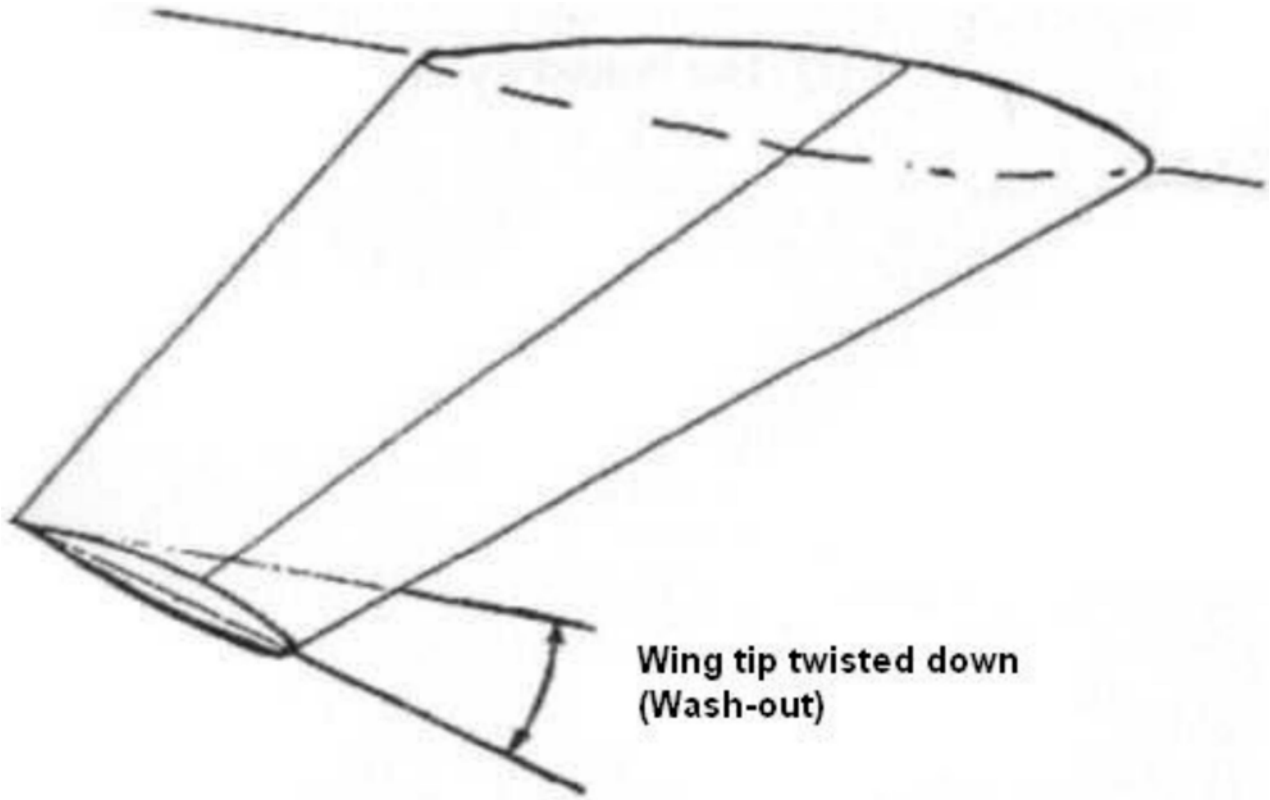

Note. From "Wing Twist and Dihedral", 2001, Aerospaceweb.org. Retrieved October 22, 2008, from http://www.aerospaceweb.org/question/dynamics/q0055.shtml

Figure A-6 Wash-Out

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Note. From "Canada's Air Force, Image Gallery, Details", 2006, Department of National Defence, Copyright 2006 by Department of National Defence. Retrieved October 22, 2008, from http://www.airforceimagery.forces.gc.ca/netpub/server.np?find&catalog=casimages&template=detail2_e.np&field=itemid&op=matches&value=4461&site=casimages

Figure A-7 Wing Tip Tanks and Winglets

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Note. From "Cessna 170", 2008, Barnstormers.com. Retrieved October 22, 2008, from http:// www.barnstormers.com/listing_images.php?id=266438&ZOOM=%2Fclassified_files%2F266438-DSC04234.jpg

Figure A-8 Drooping the Wing Tips

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Note. From "STOL Kit", F. and H. (Aircraft). Retrieved October 22, 2008, from http://www.fandh-aircraft.co.uk/stol_kit.htm

Figure A-9 Wing Fences

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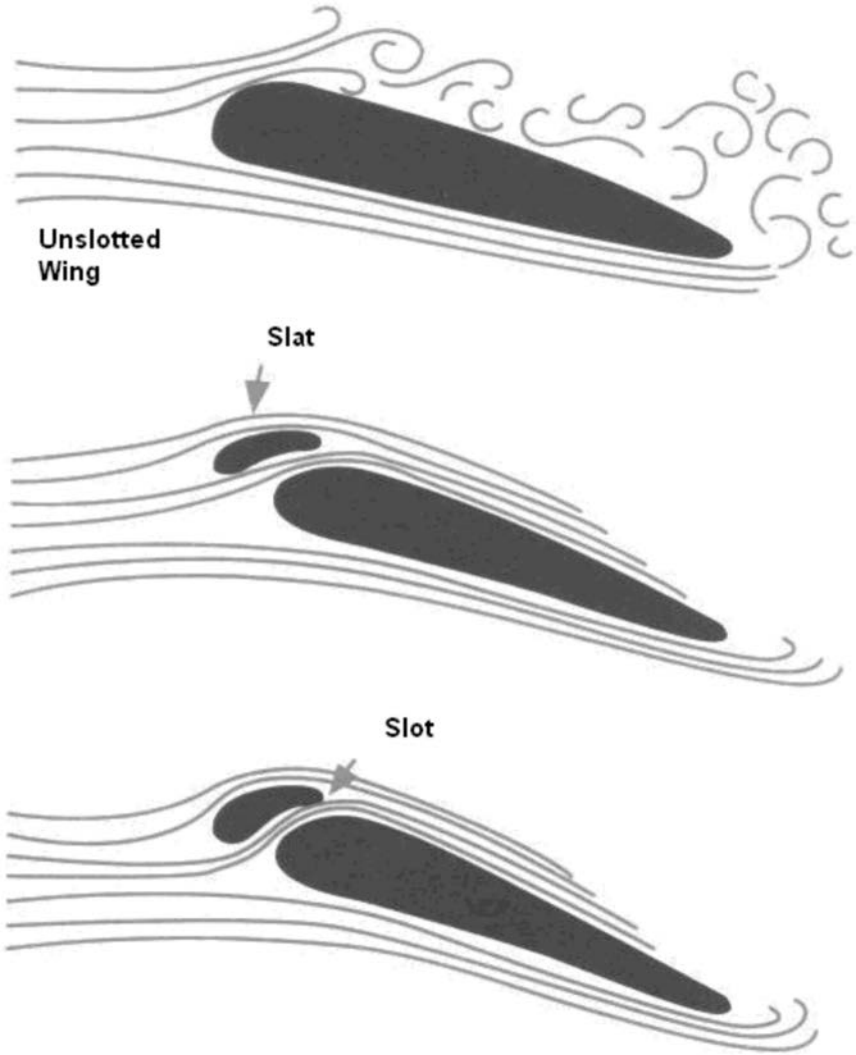

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Figure A-10 Slotted Wings

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Note. From "Stinson 108", 2005, Wikipedia. Retrieved October 22, 2008, from http://en.wikipedia.org/wiki/Image:Stinson108-3photo03.jpg

Figure A-11 Leading Edge Slot

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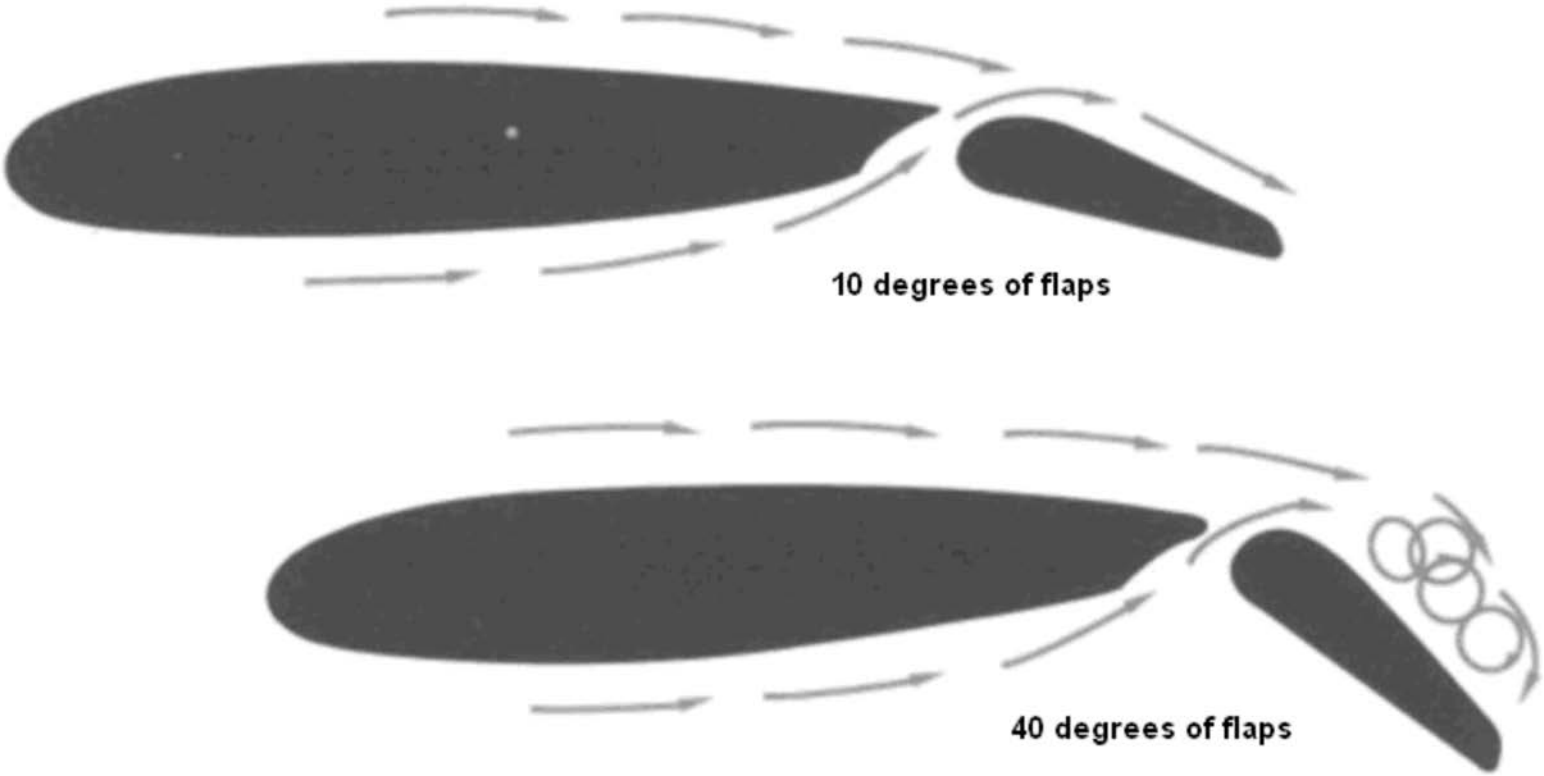

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Figure A-12 Flap Settings

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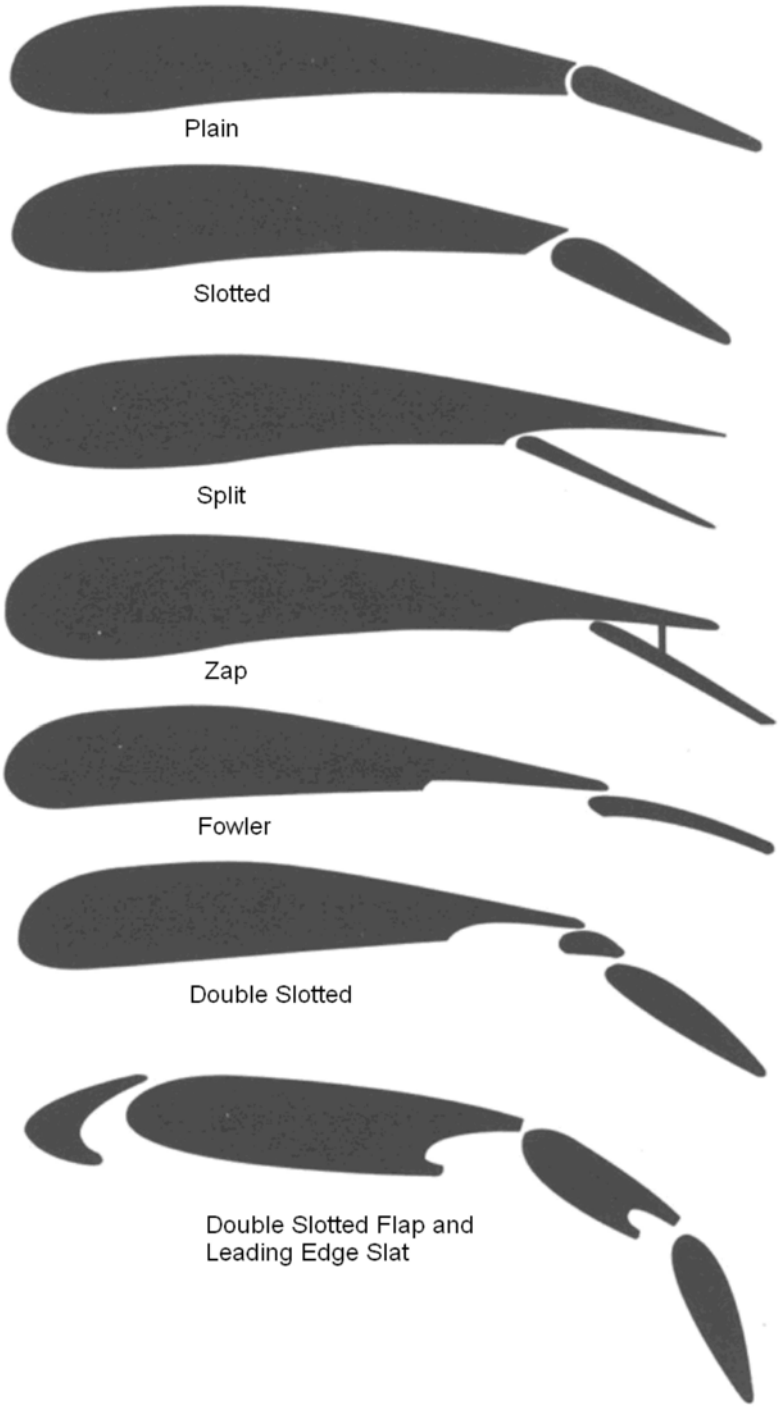

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Figure A-13 Flaps

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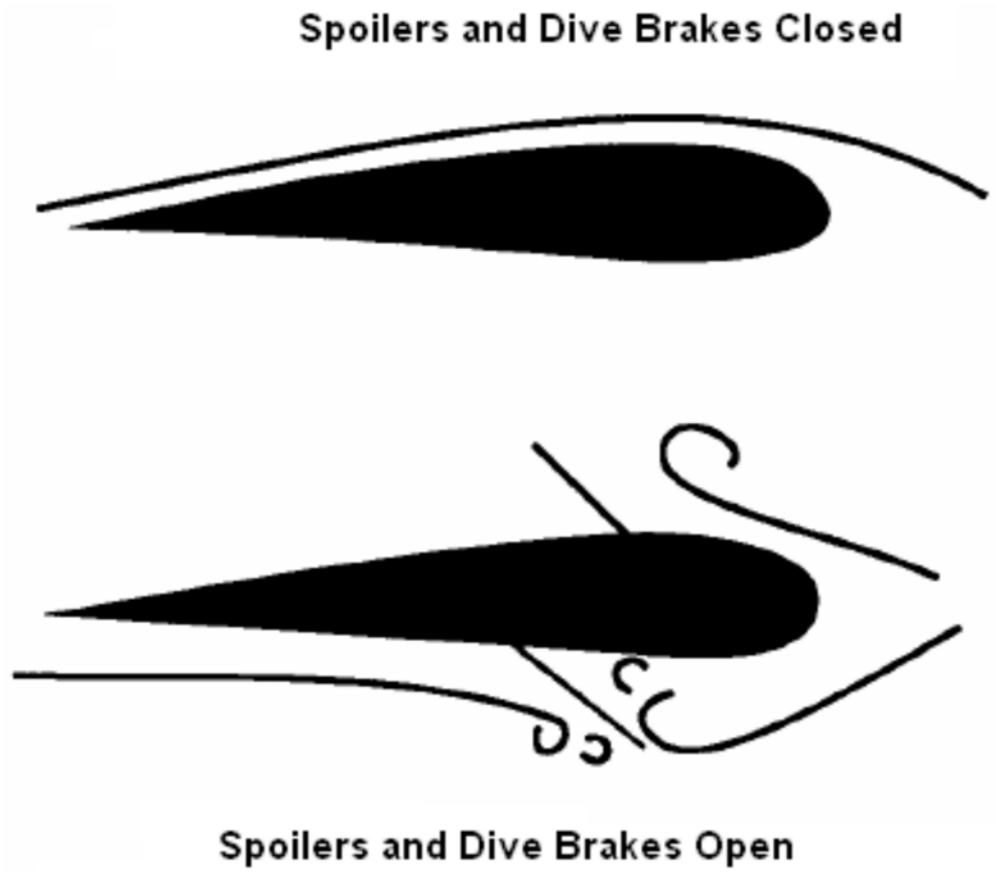

Note. From Air Cadet Gliding Program Manual (p. 6-3-2), 2008, Ottawa, ON: Department of National Defence.

Figure A-14 Spoilers and Dive Brakes

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