Lesson:

Pitch Trim

Objectives:

- Knowledge
    - An understanding of the aerodynamics related to longitudinal (pitch) stability
- Skill
    - Use of the pitch trim system to control the glider's airspeed

Materials / Equipment

Publications

- Flight Training Manual for Gliders (Holtz)
  Lesson 4.4 – Using the Trim Control

Documents

Simulation Files

Flight Plan

- Airspeed_Control.fpl

Replay

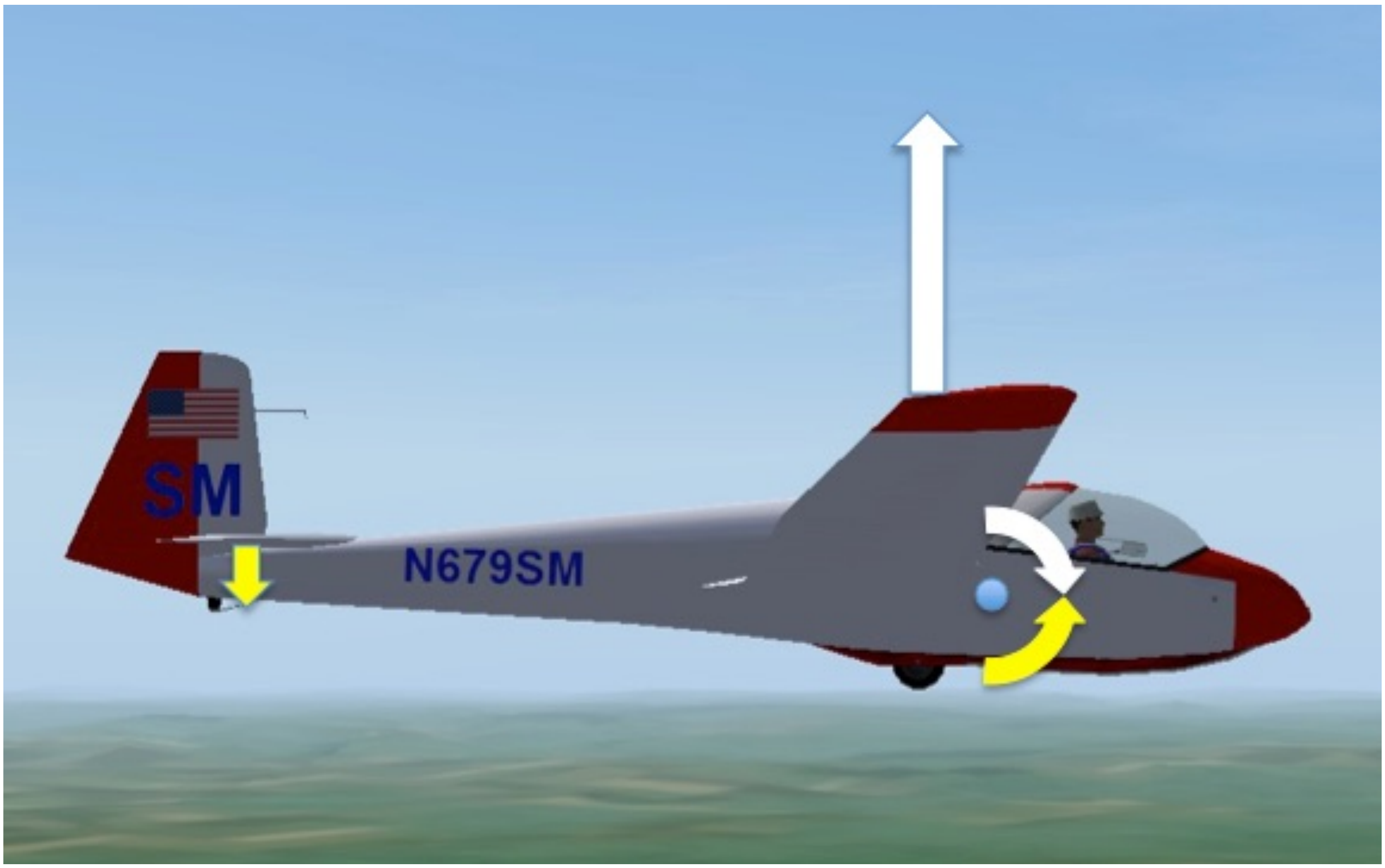
- Longitudinal_Stability.rpy
- Pitch_Trim.rpy

Presentation

Aerodynamics – Longitudinal (Pitch) Stability
An aircraft is longitudinally stable when a change in angle of attack causes the pitching moment on the aircraft to change so as to restore the angle of attack.

The fundamental requirement for static longitudinal stability is the aft surface must have greater authority (leverage) in restoring a pitch attitude than the forward surface has in exacerbating it.

The following diagram shows the wing placed on the glider such that the center of lift (white arrow) is behind the center of gravity (blue dot). In this configuration, lift generated by the wing creates a nose-down pitching moment. The horizontal tail of the glider is designed to create an equal but opposite nose-up pitching moment.



Wing and Tail moments in equilibrium (trim)

When the wing and tail-generated moments are in equilibrium, the glider is said to be in “trim”, and will naturally tend to maintain its pitch attitude (angle of attack) and therefore its airspeed. For example:

If the airflow around the glider suddenly resulted in an increased angle of attack (e.g. when entering a thermal updraft), the wing would immediately generate more lift and a corresponding increase in nose-down pitching moment. The same change in angle of attack, however, would cause the tail of the glider to generate an increased down force; thus counteracting the pitching moment created by the wing.

The horizontal tail on most gliders is composed of a horizontal stabilizer (fixed portion) and an elevator (movable). The elevator enables the pilot to vary the down-force generated by the tail, and thereby affect pitch changes.

The angle at which the horizontal stabilizer is mounted to the glider is designed to optimize the aerodynamic efficiency (minimize the drag) at the glider's normal cruising speed (angle of attack). That would likely be the best glide speed. This is certainly the case for the ASK-13 in Condor. The image on the previous page shows the ASK-13 trimmed for the best glide speed (angle of attack) of 42 knots. Notice the elevator is in trail, streamlined to produce minimum drag.

The down-force produced by the tail is a function of its angle of attack and the glider's airspeed. At speeds less than 42 knots, the horizontal tail does not produce enough down-force to counteract the wing moment unless the elevator is deflected up into the airstream, as shown at the right.

ASK-13 @ 32 knots

ASK-13 @ 60 knots

Likewise, at speeds greater than 42 knots, the tail produces too much down-force unless the elevator is deflected into the airstream below the horizontal stabilizer.

Pitch Trim Systems

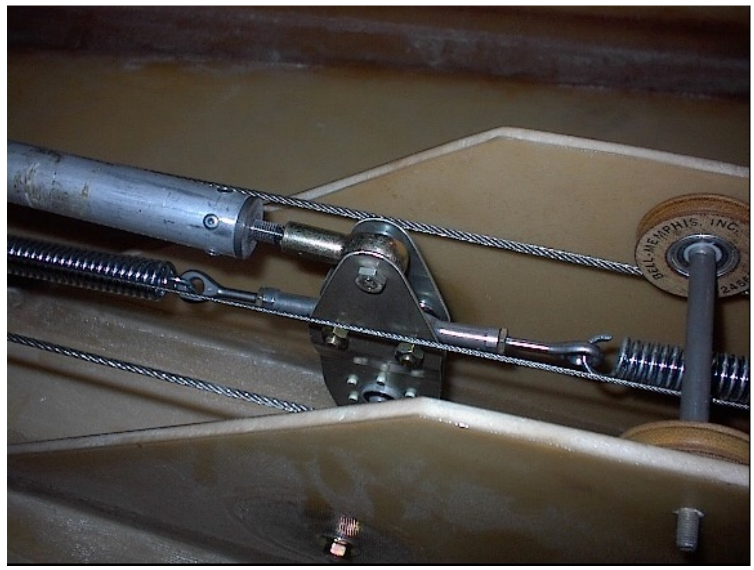
In the previous lesson on Airspeed Control, when holding speeds other than 42 knots, you needed to apply either forward or backpressure on the stick to hold the desired pitch attitude. That pressure was the result of deflecting the elevator into the airstream. What you were feeling in the stick was the airstream essentially trying to push the elevator back into trail. If you had to hold these pressures for any length of time, your arm muscles would become quite tired.

Fortunately, most gliders are equipped with a system designed to hold the elevator at the required angle of deflection. These pitch trim systems typically employ either mechanical leverage or aerodynamic forces.

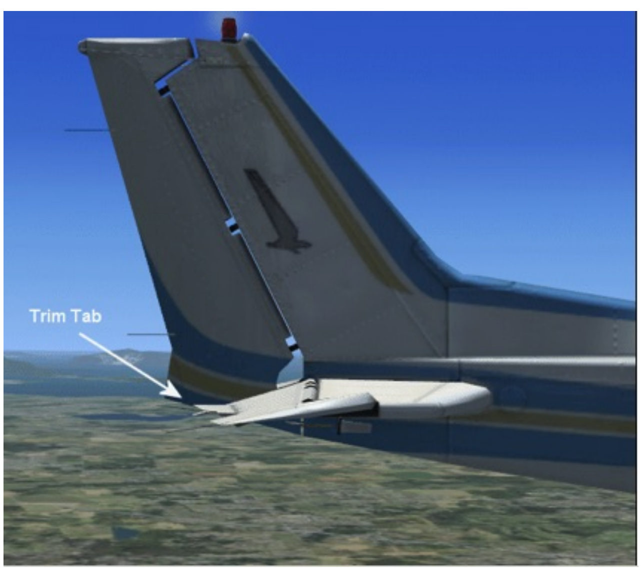
The image at the right shows a mechanical system of springs linked into the elevator control system. The cockpit trim control is used to adjust the spring tension as needed to hold the elevator in place.

The images below each show a trim tab; basically an elevator on the elevator. A trim tab aerodynamically holds the elevator in place.

The trim control in the cockpit is used to deflect the trim tab, in this case up, which in turn holds the elevator down so the pilot doesn't have to.



Mechanical Trim System



Airplane Trim Tab

Grob-103 Trim Tab

Introduction

We often refer to trimming the glider for a specific airspeed, but we are actually trimming (balancing) the glider to fly at a specific angle of attack. For example, if the glider was trimmed and flying wings level at a specific speed, and was then rolled into a turn without applying any backpressure on the stick, the glider's airspeed would increase, but the angle of attack would remain the same.

Demonstration I – Longitudinal (Pitch) Stability

The purpose of this demonstration is to help you visualize how the longitudinal stability, designed and built into a glider, tends to restore any disruption in the trimmed angle of attack.

Set-up

- Load Replay == Longitudinal_Stability.rpy
- Reset Replay to the Beginning (<<)
- Press PAUSE (P) key to start/stop each Replay time segment

09:00:35 - 09:00:38

As the demonstration begins, the ASK-13's wing and tail moments are balanced (trimmed) to hold a pitch attitude (angle of attack) that results in an airspeed of 42 knots with no control input from the pilot.

09:00:39 – 09:00:41

The pilot moves the stick back, increasing the wing's angle of attack. As a result, the glider begins to slow down; eventually reaching a minimum of 35 knots.

09:00:42 – 09:00:47

It looks as though the pilot moves the stick forward. In fact, she is simply releasing all pressure on the stick; allowing the glider to seek its own pitch attitude.

> At speeds below 42 knots in the ASK-13, the horizontal tail does not produce enough down force to balance the wing moment unless additional down force is provided by deflecting the elevator up into the airstream. With the stick pressure released, the airstream pushes the elevator down into trail, the horizontal tail is over-powered by the wing moment, and the glider responds by pitching down; initially rather dramatically. The aircraft's momentum takes the pitch attitude past (below) the 42-knot position, and the decrease in angle of attack causes the airspeed to increase beyond the 42-knot target; eventually to a speed of 48 knots, but not before the glider starts pitching up again.

09:00:48 – 09:00:54

At speeds above 42 knots, the horizontal tail produces more down force than is required to balance the wing moment. The tail now over-powers the wing moment, the glider pitches up, the aircraft's momentum takes it past (above) the 42-knot attitude, but the speed only decreases to 36 knots as the wing begins once again to over-power the tail.

09:00:55 – End of Replay

The aircraft continues to pitch up and down, but the oscillations gradually damp out (decline in amplitude). With each cycle, the minimum airspeed (maximum angle of attack) increases and the maximum airspeed (minimum angle of attack) decreases, both trending toward the trimmed airspeed of 42 knots.

After about a dozen oscillations, the glider's longitudinal stability has reestablished the original 42-knot pitch attitude (angle of attack, airspeed).

Demonstration II – Longitudinal (Pitch) Stability

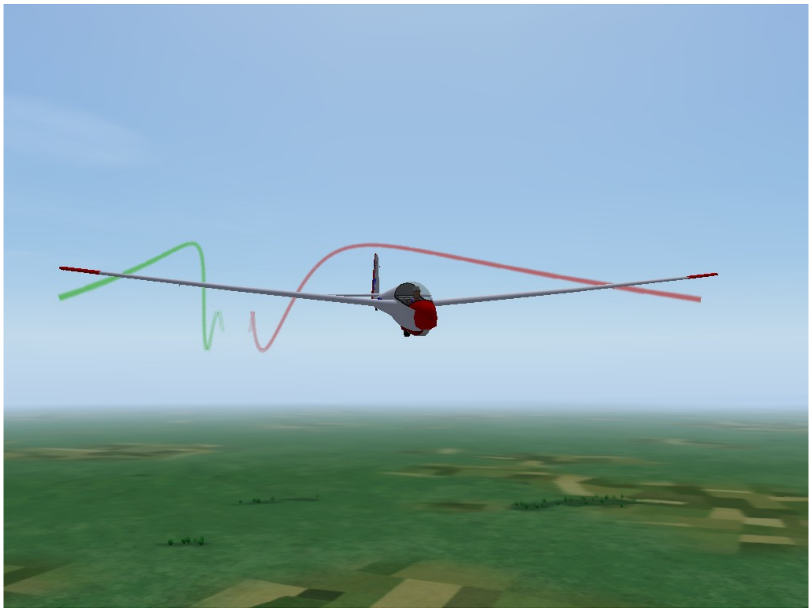
To get another perspective on longitudinal stability, watch the demonstration again from outside the glider.

Set-up

- Reset Replay to the Beginning (<<)
- Set Replay camera OFF (F9)
- Select External glider view (F2)
- Adjust View to match the image below

Description

As the demonstration begins, the glider is trimmed and stable at 42 knots. The pilot pitches the glider to a higher angle of attack and then completely releases the stick. At that point, longitudinal stability takes over.



Through a series of amplitude-diminishing oscillations, the glider gradually returns to a stable 42-knot pitch attitude, with no pitch control inputs from the pilot.

With each oscillation, notice how the minimum and maximum airspeed values, 35 knots and 48 knots respectively, both trend toward the trimmed airspeed of 42 knots.

- Press PAUSE (P) key to begin the demonstration

Demonstration – Using Pitch Trim

The purpose of this demonstration is to help you visualize how the pitch trim system is used to remove stick forces that result from changes in airspeed (angle of attack).

Set-up

- Load Replay == Pitch_Trim.rpy
- Reset Replay to the Beginning (<<)
- Press PAUSE (P) key to start/top each Replay time segment

09:01:50 - 09:01:56

As the demonstration begins, the ASK-13's wing and tail moments are balanced (trimmed) to hold a pitch attitude (angle of attack) that results in an airspeed of 42 knots with no control input from the pilot.

09:01:57 - 09:02:24

The pilot moves the stick forward to establish the pitch attitude (angle of attack) known to produce an airspeed of 50 knots.

09:02:25 – 09:02:29

Having stabilized at the target speed, rather than physically holding the required forward pressure, the pilot uses the trim control system to hold the elevator in place. She does so by moving the trim control lever forward until she no longer feels any pushback from the stick. Even though her relatively large arm muscles no longer feel any stick pressure, the wing and tail moments may not yet be perfectly balanced.

09:02:30 – 09:02:59

To insure the aircraft is properly trimmed, the pilot begins a series of fine-tuning adjustments. She completely lets go of the stick and watches to see whether the glider's pitch attitude changes. If the glider departs from the desired pitch attitude, the pilot uses the stick to reestablish the desired pitch attitude, and then adjusts the pitch trim control as appropriate; farther forward if the glider pitches up; slightly more aft if the glider pitches down.

09:03:00 – 09:03:14

After several fine-tuning iterations of "release-the-stick / reset-the-pitch / adjust-the-trim", the glider flies hands off at a trimmed (balanced) pitch attitude (angle of attack) airspeed of 50 knots.

09:03:15 – 09:03:39

The pilot pitches the glider to the 42-knot attitude. With the glider trimmed to fly at 50 knots, slowing to 42 knots requires the pilot apply and hold an increasing amount of backpressure on the stick.

09:03:40 – 09:04:04

The airspeed stabilizes at 42 knots and the pilot moves the pitch trim lever aft to relieve the backpressure on the stick. She then begins fine-tuning the trim setting, incrementally releasing the stick, reestablishing the pitch attitude, and readjusting the trim control.

09:04:05 – 09:04:21

The glider flies hands off at 42 knots.

09:04:22 – 09:04:49
The pilot maneuvers the glider to the 35-knot pitch attitude. With the glider trimmed to fly at 42 knots, slowing to 35 knots requires the pilot again apply, and gradually increase, backpressure on the stick.

09:04:50 – 09:05:04
As the airspeed stabilizes at 35 knots, the pilot first moves the trim control aft to remove the back-pressure on the stick, and then fine-tunes the trim setting.

09:05:05 – 09:05:12
The glider flies hands off at 35 knots.

09:05:13 – 09:05:49
The pilot initiates a speed change from 35 to 42 knots. With the glider trimmed to fly at 35 knots, accelerating to 42 knots requires the pilot apply and hold and increasing amount of forward-pressure on the stick.

09:05:50 – 09:06:00
As the airspeed stabilizes at 42 knots, the pilot moves the trim control forward to remove the forward pressure on the stick, and fine-tunes the trim.

09:06:01 – End of Replay
The glider flies hands off at 42 knots.

Exercise: Using the Pitch Trim Control System

Introduction
In this exercise, you will use the skills developed in the Airspeed Control lesson to make airspeed changes, either slowly or quickly, and then use the pitch trim control system to hold the target airspeed.

Set-up
- Select Free Flight
- Load Flight Plan / User == Airspeed_Control.fpl
- Start Flight
- Press "ESC"
- Select Ready for Flight

Description
As your Free Flight session begins, Condor defaults to a neutral trim setting corresponding to the glider's best glide speed. For the ASK-13, that speed is 42 knots. However, for some unknown reason, Condor's initial airspeed default always seems to be greater than 42 knots. Perhaps the Condor developers wanted to demonstrate the concept of longitudinal stability. In any case, as we now know, with the glider trimmed to fly at 42 knots, any airspeed greater than 42 knots will cause the tail moment (down-force) to over-power the wing moment. So, as the flight begins, the first thing you will experience is the glider pitching up on its own, followed by a series of pitch oscillations as it attempts to self-stabilize on its trimmed airspeed.

Rather than waiting for the glider to stabilize on its own, use small forward and aft movements of the stick to establish and hold a pitch attitude that produces an airspeed of 42 knots. Once stabilized, you should be able to release the stick entirely and have the glider hold 42 knots on its own.

Note: European designed gliders color-code the various controls to help in their proper identification. The pitch trim control in the ASK-13 is the green lever on the right side of the cockpit.

Unlike the other controls in the Condor cockpit, the pitch trim control lever does not appear to move when you apply your remote control (e.g. keyboard) inputs.

Condor does, however, temporarily display a percentage value in the lower right corner of the screen whenever you make a trim change.

The default value of zero represents a neutral trim position and results in a trimmed airspeed of 42 knots in the ASK-13. Negative values represent a nose down (forward) trim condition; the maximum of -100% resulting in a trimmed airspeed of about 56 knots. Positive values indicate nose up (aft) trim with +100% producing a trimmed airspeed of about 35 knots.

While these trim percentage indications may seem useful, real gliders have no such indication, other than perhaps the relative position of the pitch trim control lever. In real-world flight, you need to learn to trim the glider using the procedure described in steps 1-6 of this exercise.

To that end, I recommend you turn off the trim percentage indicator while learning to use the trim control system. Pressing the tilde (~) key, to the left of the numeric "1" on your keyboard, toggles Condor's screen messaging function on/off, including the trim percentage indication.

Exercise

Repeat the following exercise until you have mastered using the pitch control system.

1. Select a target airspeed and pitch the glider to establish that speed.

   As the airspeed indication approaches the target value, you will feel the stick forces increasing. If you are slowing down, the amount of backpressure needed to hold the target pitch attitude will increase until the airspeed reaches the target value; if you are speeding up, an increasing amount of forward pressure will be needed to hold the desired pitch attitude.

2. When the airspeed stabilizes on the target value, use the pitch trim control lever to remove the stick pressure. If you are holding aft stick pressure, move the pitch trim control aft; if holding forward stick pressure, move the pitch trim control forward.

   This can be a little tricky; as you apply pressure to the pitch system via the trim control system, you need to remove the pressure you are applying with your muscles via the stick.

3. Completely release the stick.

   If the glider pitches up or down, you need to do some fine-tuning.

4. Reestablish the desired pitch attitude.

5. If the glider pitched up when you released the stick in Step 3, you need to apply more nosed-down trim.

   If the glider pitched down when you released the stick in Step 3, you need to apply more nose-up trim.

6. Repeat steps 3-5 until the glider flies hands-off, wings level, at the desired pitch attitude (angle of attack / airspeed).

- Select "Ready for Flight" to begin the exercise.