An Investigation of Dynamic Soaring and its Applications to the Albatross and RC Sailplanes

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Abstract

Dynamic soaring is a technique used the sea bird the Albatross. This technique allows for the bird to stay in the air for extended periods of time with very little effort. Dynamic soaring utilizes the wind gradient on the surface of the ocean to maintain its airspeed. A similar technique is used by RC glider pilots to achieve high speeds by using the shear wind layer on the leeward side of mountain ridges.

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Nomenclature

T  = period
ω  = angular velocity
R  = radius
V  = groundspeed
h  = altitude
Ze = energy height
θ  = inclination angle
I. Introduction

Dynamic Soaring is a technique used by the sea bird Albatross to travel long distances over the ocean by extracting energy from the shear wind gradient. This technique is advantageous because it does not require thermals to maintain altitude and velocity. The Albatross utilizes a flight pattern to maintain its airspeed with minimal effort and can, in fact, lock its wings and only make small adjustments for control. This allows the albatross to stay airborne for days or even months at a time. The concept of dynamic soaring, copied from the Albatross, has recently been adopted by RC sailplane pilots. These pilots fly the sailplanes in a circular pattern on the leeward side of mountain ridges, passing from high winds coming off the top of the ridge to still air on the backside of the ridge to achieve speeds upwards of 450 mph.

II. Background

Most of the research done on dynamic soaring up to this point has been done on the flight patterns of the Albatross rather than optimization of dynamic soaring of sailplanes. However the concept still applies. The main difference is the flight pattern. The Albatross's flight pattern is optimized for traversing long distances while the flight pattern for the sailplanes is optimized for achieving high speeds. The flight path of the Albatross can be seen in Fig. 1.

The main concept behind dynamic soaring is to extract energy by flying into and out of the high wind shear layer and can be broken down into four steps. As the Albatross moves through the boundary layer and flies in the opposite direction of the wind, the groundspeed remains constant but the airspeed increases by the speed of the high-speed wind. This point of the maneuver is position 1 of Fig. 1. An efficient 180 degree turn will maintain airspeed. Since the Albatross is maintaining
airspeed but is now moving with the wind, the groundspeed will increase. This is position 2. When the Albatross reduces altitude and moves back through the boundary layer into the more still air, position 3, it will again gain airspeed since it is again moving through a favorable gradient even though it is moving in the opposite direction. At the same time, ground speed is maintained. Another efficient 180 degree turn returns the Albatross to the original height and direction but at a higher speed, shown as position 4. The beauty of this maneuver is that, because of the wind gradient, the Albatross is increasing airspeed throughout the maneuver, even while climbing.

The dynamic soaring technique used by RC glider pilots is very similar. The first major difference is the nature of the boundary layer. The pilots will fly the sailplanes on the leeward side of a windy ridge so the boundary layer is more of a shear layer as can be seen in Fig 2. The second difference is that the pilot are attempting to achieve high speed and not travel long distances so the second turn is into the circle to close off the loop. Other than the two minor differences the dynamics of the maneuver still behave the same way.

III. Methodology Results

In order to better understand the application of dynamic soaring to RC sailplanes, a study of flights was done by analyzing videos on YouTube. Three separate videos of sailplanes performing the dynamic soaring maneuver were broken down and analyzed. The velocity would have been the most difficult value to get out of the video. Fortunately, the pilot was accompanied by someone with a radar gun who would call out the ground speed for each pass of the glider.

Another important piece of information that could be gathered from the video was the period of the maneuver. The location of the aircraft was not always obvious when watching the video so the period was found by the noise that the glider made, which was quite loud, rather than a visual check of when the glider made a pass. The flight path was assumed to be circular so that the angular velocity could be found using the equation
\[
\omega = \frac{2\pi}{T}
\]

With both the angular velocity and the ground speed known, the radius of the maneuver could then be found using the equation
\[
R = \frac{V}{\omega}
\]

The inclination of the maneuver then needed to be found in order to find the change in height from the peak of the maneuver to the lowest point. To find the inclination, the video was paused at two points along the flight path where the glider was visible. A snapshot was then taken for each point and then overlaid on top of each other. This resulted in Fig. 2, 3, and 4.
Figure 2: Inclination angle from video 1

Figure 3: Inclination angle from video 2

Figure 4: Inclination angle from video 3
Even though, to be completely accurate, the video would have to be taken perfectly perpendicular to the flight path, it was assumed that this was fairly close to the actual inclination of the maneuver. Also, as mentioned earlier, for the majority of the videos it was very difficult to locate the sailplane. Therefore, the inclination angle could not be found for each cycle so it was assumed that the angle was the same for each cycle. With this, the change in height can be found by

$$\Delta h = 2R \sin \theta$$

With both velocity and the change in height known, the change in energy height, defined as

$$Ze = h + \frac{V^2}{2g}$$

could be plotted against constant energy height contours in units of feet for all three videos of the dynamic soaring maneuver, as can be seen in Fig. 5, 6, and 7. It can be seen that energy is being added to the system at all points during the maneuver. The increase in altitude increases the potential energy of the glider while maintaining the kinetic energy. Once the glider passed through the shear layer, the groundspeed is increased which also increases the kinetic energy of the glider. This cycle is repeated to achieve high speeds.

Figure 5: The energy height of the flight path of video 1 plotted on constant energy height contours
Figure 6: The energy height of the flight path of video 2 plotted on constant energy height contours

Figure 7: The energy height of the flight path of video 3 plotted on constant energy height contours
IV. Conclusion

The method of dynamic soaring has been adopted by the sea bird, the Albatross, to stay in the air for extended periods of time. It is very efficient and requires little effort to perform the maneuver. The maneuver has only recently been adopted by RC sailplane hobbyist to achieve very high speeds. To better understand the maneuver, it would be advantageous to get more accurate data than analyzing YouTube videos. A small GPS transceiver to measure groundspeed and altitude could be placed inside a glider along with a pitot tube to measure airspeed. This would allow for more detailed analysis.
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