THEORY OF SOARING FLIGHT

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SYNOPSIS

If in observed feats of soaring flight of birds no sign of energy expenditure or consumption is visible, one must conclude that possibly the bird draws energy from the air in which it flies.

Even where there are no vertical wind components the mere existence of different horizontal wind velocities can be utilized by a body.

It is not possible to define the energy available in any dynamic situation because the amount of air "affected" and the power required in calm air depend on the flight "maneuver."

The problem arises what thrust power is actually available at any instant. Any disparity between the power required and that applied will primarily affect the flight velocity and the flight path. In the glider no engine power is available and gravity is the sole source of motive power.

It is of interest to determine the power requirements of maneuvers departing from straight level flight. Horizontal turns in a glider require increased speed because the aerodynamically generated lift must suffice to make up not only for gravity but also for centrifugal force.

At any given instant in the flight path of a complicated maneuver properly executed there is an equilibrium between gravity, inertia forces, and air forces.

PART 3

Soaring Effects

THE QUESTION may now be posed: Under what conditions can the power necessary for sustained flight be gleaned or wrested from suitably available sources within the atmosphere in addition to the extra power which may be the penalty for executing whatever maneuvers are required to get it. We propose to subdivide the soaring effects into three major classes or types which in combination together appear to compose the aggregate of the soaring phenomena.

Static Soaring Flight

A simple and obvious consideration of the relativity of motion of aircraft, air and earth proves that the presence of a vertical wind component is equivalent to a potential energy gain. When the upward wind component exceeds the minimum sinking speed of the craft in still air then sustained flight or even climb is possible without the expenditure of motive power. To soar in the least vertical wind the craft has to be designed for minimum sinking speed which is attained at the angle of attack of maximum $\frac{C_L^3}{C_D^2}$

However, when practicting static soaring flight above the windward slope of a mountain it may not always be possible to maintain the angle of attack of least sinking speed. For instance, if the windspeed is higher than the forward flight speed of the aircraft the latter would drift back and find itself forced down against the slope. To soar above flat slopes it is necessary to favor higher speeds. Only where these conditions do not apply may high-lift devices have merits.

The maximum value of $\frac{C_L^3}{C_D^2}$ which is associated with the minimum sinking speed can be expressed in terms of the aspect ratio AR and parasite drag coefficient C_o viz: $\left(\frac{C_L^3}{C_D^2}\right)_{max.} = \frac{(3\pi AR)^{3/2}}{16\sqrt{C_o}} = \frac{1.81\sqrt{AR^3}}{\sqrt{C_o}}$

This follows directly from the theory of induced drag increasing at the rate of the square of the lift coefficient, provided, of course, that the aspect ratio is not so high that it becomes impossible to attain the theoretically best lift coefficient without paying a severe penalty in the form of an increased parasite drag or without stalling first.

Soaring birds fly at speeds between 20 and 80 ft./sec. With glide ratios of the order of 1:8 to 1:25 their sinking speeds probably range from 1 to 7 ft./sec. This, then, is the order of magnitude of the rising wind component velocity which enables them to soar statically without effort.

Contemporary airplanes have glide ratios of about 1:10 and sinking speeds somewhere between 10 and 25 ft./sec. power off. The sailplanes which were recently developed to compete at the soaring contests attain performances much more comparable to the soaring birds. Wing loadings have been tried as low as 2 lbs./sq. ft. and flying speeds down to 20 mph; gliding ratios as high as 1:20 and sinking speeds as low as 2 ft./sec. have become a reality. It is certain that many of the spectacular soaring flights and records were accomplished essentially, if not wholly, by static soaring in rising currents of air. This fact is an incentive to explore and investigate where and when rising currents are produced in the atmosphere and what vertical velocity components occur in them.

The simplest and most obvious cause for the generation of a rising current is the vertical deflection of the wind by the presence of an extensive obstacle in its path such as a mountain range or an elevated coast. It is intriguing to inquire how high and how far to the windward and leeward the influence of such an obstacle extends.