THEORY OF SOARING FLIGHT

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PART 6

Horizontal Dynamic Soaring Maneuvers

Thus far we have studied the influences which are exerted essentially by the vertical component of the wind pulsations. Now it remains to investigate those which are essentially exerted by the horizontal gustiness. They are the ones that give rise to truly dynamic soaring. The lack of any evidence of any definite rhythm or periodicity which was sought by many experimenters hampers the application of the theory of dynamic soaring by horizontal maneuvers, to the understanding of bird flight and to flight testing even more than was the case with the vertical component. For the purpose of the study of the theory it will therefore suffice to consider mathematically simple idealized gust patterns of which many imagine the real gusts of the winds to be compounded.

The simplest picture of longitudinal gustiness consists of a regular fluctuation of the wind speed between a maximum and a minimum. Let us assume the acceleration was constant during each phase either $+a$ or $-a$, and that an air mass large compared to the aircraft and its progress is being so shaken back and forth by pressures which act far away and transmit themselves with sonic velocity, much faster than the aircraft flies. If the craft faces the direction in which the wind speed increases (head-on gust) it would experience a pull or thrust by virtue of its own inertia. The ensuing lull would obviously create an apparent drag. However, if the pilot executes a 180° turn just before the lull begins, the craft would be subject to another thrust gain. In reality he cannot turn instantaneously nor without penalty of energy expenditure. Yet assume for the moment he could. He could then soar indefinitely provided $a/g = D/L = \tan\varepsilon$ where ε is the best glide ratio in calm air. The gust frequency does not enter the calculation of lift and drag but it determines the wind velocity amplitude required to soar in this manner, viz.

$$W_{\max} - W_{\min} = \tfrac{1}{2}aT = \tfrac{1}{2}Tg \tan\varepsilon$$

where T is the full cycle period. For instance for $\tan\varepsilon = \frac{1}{16}$ the wind extreme difference would have to be exactly one ft/sec for every second taken by the gust cycle. This would take rather strenuous maneuvering for a manned aircraft. Birds perhaps can take advantage of similar conditions, obviously the smaller are favored. In reality the conditions are of course never as favorable as under the above idealized assumptions.

It may be interesting to consider a few less drastic idealizations. A sinusoidal gust in which both the acceleration and the velocity of the wind would be sine functions of time would be more likely to occur than the sharp reversal. The gain that can be derived from any given span between maximum and minimum gust velocity is independent of the "character" of the gust. But with a variable acceleration, it is no longer possible to attain both lift and drag balance without loss or gain of altitudes. The resulting waves of the flight path absorb extra power which we saw in an earlier chapter to amount to a fraction of the static power required indicated by 3/2 times the square of the flight speed fluctuation amplitude if the wave is of a phugoid character. Hence it amounts to only a few per cent.

Aside from this, the dynamic maneuver entails a (more serious) power penalty in that extra lift has to be created to balance the centrifugal force arising in the turns. Also part of the time the course will not be parallel to the gust.

One may wonder what the best maneuver, that would furnish the greatest net gain or require the least sinusoidal gust velocity amplitude to soar, should look like. Mere circling furnishes an instantaneous thrust acceleration $a = a_0 \sin^2 \Theta$ where Θ is the course angle as measured from the direction of the presumably linear harmonic gust. The gross gain per cycle is then only half as great as that of the impossible sudden course reversal in the hypothetical abruptly reversing gust, without allowing for loss due to banking and roller coasting. Allowing for banking the velocity span required to permit soaring becomes

$$W_{\max} - W_{\min} = Tg \tan\varepsilon \sqrt{1 + (2\pi v/tg)^2}$$

where v is the average flight speed. This makes it several times as tough for fast craft than for slow ones. For man to soar this way would seem to be very difficult. That a few occasional deliberate turning maneuvers may yield a noticeable lift is, however, possible.