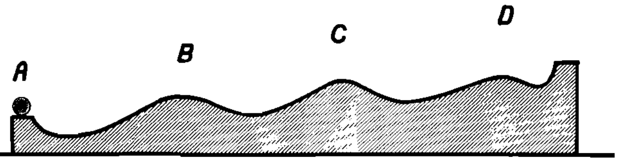

Fig. 13. Brazin's dynamic soaring analogy.

The third source of energy for soaring is that which Lord Rayleigh described as flight through air which possess velocity fluctuations. Based on this thesis, S. P. Langley (ref. 13) made a study of the energy available in the wind. However, the actual mechanism of dynamic soaring was not clearly disclosed until Klemperer (ref. 14) published his paper. When finally reduced to its simplest form, dynamic soaring is merely the rectification of the turbulence in the air mass in such a way that potential energy is gained. Klemperer's contribution points a clear path toward the duplication of this process by man. So far, only certain birds are known to utilize dynamic soaring, in particular, the albatross.

The strict condition to be fulfilled which Klemperer points out is that the sailplane or bird must be immobile against pitching under the influence of gusts. Under this condition, an upwardly direct gust results in increasing the angle of attack, thereby lifting the bird or sailplane. A gust having a horizontal component of velocity will result in an increased effective airspeed, thereby increasing the lift. In practice, this process might be accomplished on a sailplane by using modern gyroscopes and servo controls.

A simple model of an analogy for dynamic soaring is shown in figure 13. By oscillating the model along its axis with a higher acceleration in the forward direction than in the reverse, the marble is made to climb to the last stage of the model. Interestingly, Bazin (ref. 15) and Lanchester (ref. 16) invented this analogy independently.

Idrac (ref. 17) in his carefully documented study of the soaring flight of birds described a second type of dynamic soaring practiced by the albatross. This bird flies an elliptic path, one vortex of which is in a high velocity flow and the other near the water's surface in the relative low velocity wind. In other words, this bird rectifies the energy in the boundary layer of the earth.

The last phase of soaring has yet to be accomplished by man, although many have tried it. The Russians have recently (1956) flown a sailplane with elastically supported flapping wings capable of being tuned to the turbulence. No significant gains were reported, nor was any demonstration made to indicate such gains. Perhaps we need to study the dynamic soaring of birds in more detail before we can hope to succeed.

The last and least understood phase of bird flight is that of flapping. Aerodynamic theories for unsteady lifting of wings have been developed, but still there is much to be learned from the complex flapping motion of flexible wings, having slots which can open or close in various phases of the flapping motion.

In so far as the actual motions of flapping flight are concerned by far the best description is contained in the documentary work of Marey (ref. 18), who used a time lapse photographic technique to define the flapping motion of the wings of birds. His three-dimensional models showing the flapping sequence are works of art. However, his studies, while of historic interest, contribute little to an exact understanding of the physical mechanism of bird propulsion by flapping.

Of the more recent works in the field of flapping flight, there is the work of Kuchemann and Weber. In a chapter of their book entitled, "Aerodynamic Propulsion in Nature," the authors make a clear comparison of the oscillating wing and the propeller.

At the very low speeds of landing and take-off of birds, the propulsive efficiency of a propeller would be rather low. However, if the entire wing span is used to accelerate a large mass of the air over it, thereby achieving a change in momentum with a relatively small velocity increment applied to the large mass, the efficiency remains quite high. In fact, if the flapping wing as a propulsor could be designed for airplanes which are to take off and land in short distances, it would provide a very important contribution in its high propulsive efficiency at low speeds.

The actual power required for flapping flight and the propulsive efficiency of the bird have not yet been measured. This is a challenging problem, but one fraught with experimental difficulties. However, with modern miniaturized instruments and telemetering, it should be possible to gain some insight into this problem.

From the zoological side, there has been a very thorough study made of the musculature of buzzards by Fisher (ref. 20). However, the question of determining which muscle plays a part in delivering power to the wing has not been satisfactorily answered. If it were, we could be able to determine the power output which these muscles can provide for flapping flight.

From the standpoint of the biophysics of bird flight, we probably can sum up our status by saying we know very little. A few measurements have been made which were quite revealing when the bird was compared to man's creation, the airplane. However, there are still many facets which challenge both the experimentalist and the theorist in this field of natural flight. It is the author's hope that some of these challenges will be accepted by biologists, physicists, engineers, and mathematicians.

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