PRELIMINARY REPORT ON VORTEX GENERATED LIFT

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Introduction

Although vorticity has its place of honor in aerodynamic theory, aircraft designers have traditionally regarded the vortex as an adversary. Thus, with the exception of vortex generators used to delay turbulent separation, virtually no effort has been made to put the vortex to work as a primary means of generating lift. Yet, while the most efficiently slotted and flapped aircraft wing cannot develop a lift coefficient much higher than 3, most birds in landing configuration are capable of landing at zero forward speed without flapping their wings. They do this by generating relatively large spanwise vortices through increasing the angle of attack and by manipulating their wing tip primary feathers.

Our science of aerodynamics owes much to the early studies of bird flight. But while we have overtaken the birds in high speed flight technology, we are unable to land a fixed wing aircraft -- power off -- without maintaining considerable forward speed. It is, therefore, proposed that the capability which most birds possess,to land almost vertically and without power,be re-examined and the phenomena exhibited at bird landing be used to improve the low speed performance of fixed wing aircraft.

The Bird Landing

Assuming a "power off" condition, the bird lands at angles of attack of up to 60°. Analyzing this in the light of our traditional aerodynamic principles, we might conclude that the bird invites a disaster each time it lands. But since most birds have an excellent safety record in spite of such "dangerous" landing techniques, let's examine the bird's wing geometry and look for clues to its obviously high lift capability. The most configuration change occurs at the wing tip where the primary feathers form an ascending cascade in a pronounced reflex in the general profile.

The "wrong" way arrangement of the wing tip primary feathers make sense and become the right arrangement only if we accept a totally reversed flow. Indeed, ample photographic evidence -- ruffled feathers -- exists of such reversed flow being generated on top of a landing bird's wing.

A high angle of attack is bound to produce a leading edge flow separation in the form of a vortex. Fed by the reversed flow this leading edge vortex increases until it reaches the geometric limits of the wing chord, anchored firmly in the lee of the wing and nesting in the reflexed curvature of the trailing edge.

If we accept this vortex information, we can find a ready verification of a lift coefficient in theorder of 12 and perhaps more in the Magnus Effect of the rotating mass of air.

The Vortex

The vortex phenomenon is well described in literature, but let's summarize its description as a mass of fluid rotating around a core with the speed of rotation $V = f(1/r)$ and pressure $p = f(r)$. The vortex core where no fluid movement exists is about 20-25% r. The primary flow is circumferential, the secondary flow is radial and, in the case of a thre-dimensional vortex, there is also an axial flow.

There are two basic conditions to be met in order for a vortex to exist:

1. Low pressure core
2. Rotational movement

One cannot exist without the other and once one condition is produced by some means, the other condition appears automatically.

This permits us to generate a vortex by a linear lowering of pressure or by inducing a rotary movement in a mass of fluid. The first method of generating vortices is exemplified in nature in dust devils, tornadoes and vortices in pipes. The second -- in placing obstacles of suitable geometry in a potential flow. It is this second method that the birds seem to favor.

Generating Vortices

1. Decreasing pressure in an axial flow causes the surrounding fluid to rotate around the core.
2. Inducing a rotating movement in a fluid causes a pressure drop in the center core and an axial flow.

The vortices generated with the first method are stable and three-dimensional (dust devils, tornadoes, flow in pipes, outlets, etc.). They are stable because no additional mass is introduced, only energy to compensate for the friction losses.

Vortices generated with the second method require the continuous introducing of mass, which causes a growing of the vortex until it is greater than the obstacle and is swept awry by the current.

Stabilizing Vortices

The way to keep it stable is to bleed it off at the same rate as it is fed. This can be done by limiting the radius of the vortices by placing a sharp edge against shaving the flow (shaving it off), or by suction at a given point. Those methods are effective for the two and three-dimensional vortices. In the use of three-dimensional vortices the bleeding off usually occurs at the free end of the vortex.

Controlling the Circumferential Speed of the Vortices

The speed being inversely proportional to the radius of the vortex, by decreasing the radius we will increase the speed. This can be done by changing the curvature of the wall which is adjoining the vortex.

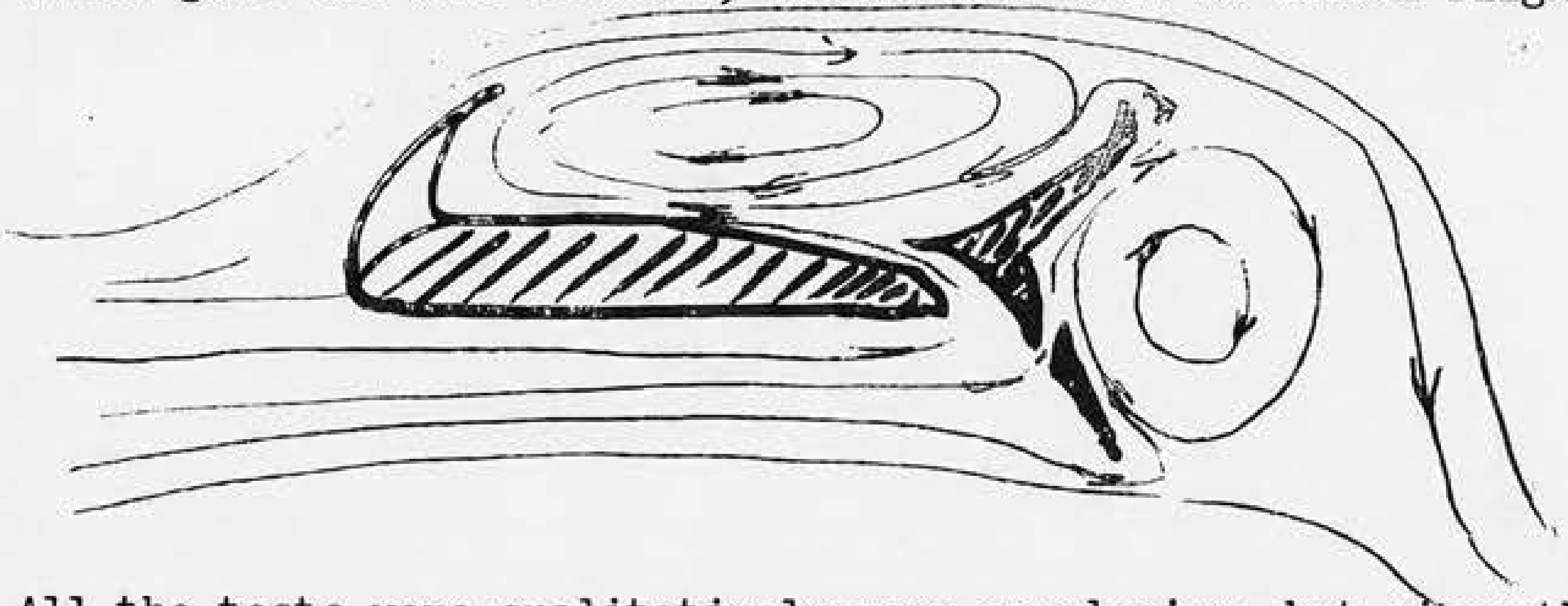
Another means of increasing the speed is introducing a greater mass into the vortex or expanding the existing mass by heating (this occurs in Nature in dust devils and tornadoes).

Flight Experiments

Being interested in flying wings since 1937, the author designed and built two successful wing gliders, the second a refinement of the first. While flying these gliders very unusual phenomena, which do not appear in standard aircraft, were observed. Among them was the capability to fly at angles higher than the conventional stalling angle (like the birds do). The behavior is as follows: my glider does not stall, but at 40 mph it mushes with a sink rate of 500 ft/min, but when lifted to a higher angle of attack it recovers flying capabilities, the sink rate decreases to 200 ft/min and remains constant with increasing angle of attack and decreasing speed, which indicates a steady increase of the lift coefficient.

This was investigated by tufting the wing and observing the flow in the summer of 1967. At angles above the stall the flow was shown to be reversed on the top of the wing from the trailing edge to about 30% of chord.

Experimentation was then started with models, trying to come as close as possible to the shape of a bird's wing in landing configuration. The final shape, which gave the best results, looked like this in actual flight:



All the tests were qualitatively very conclusive, but since this is a personal private project, no quantitative measurements were made due to lack of facilities and money.

The only measurements made with the glider were photographing the tufted wing and measuring the sinking speed and forward speed by triangulation. The variometer was of the very sensitive type (PZL) and the static pressure was connected to the pitot tube. The forward average speed was measured from the ground for a distance of about one mile.

Results: At 52 mph the glider had a minimum sinking speed of 200 ft/min.

At 40 mph the glider was mushing at a sink rate of 500 ft/min with the tufts on the trailing edge all curled up. At this point reverse flow was establishec the tufts pointed forward and the sink rate of 200 ft/min was re-established ar remained constant down to a forward speed of 27 mph.

The recalculated curves representing C_L/C_D L/D/V and W_{sink}/V_{speed} are shown. A we can see, the accuracy of speed measurements is irrelevant, we simply cut off the curves at any speed, but the tendency is obvious.

In witness of the flight characteristics demonstrated and the flow phenomena observed, there is no option but to conclude that a heretofore unused force is work. It is submitted that this is best explained by the presence of beneficia vortex flow activity.

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20.11.1969