"Lift, an answer to Hal"

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To: SAMTalk <SAMTalk@topica.com> 18/12/03

From the February/March 2004 issue of SAM 600 of Australia Newsletter, Peter Bennett, editor

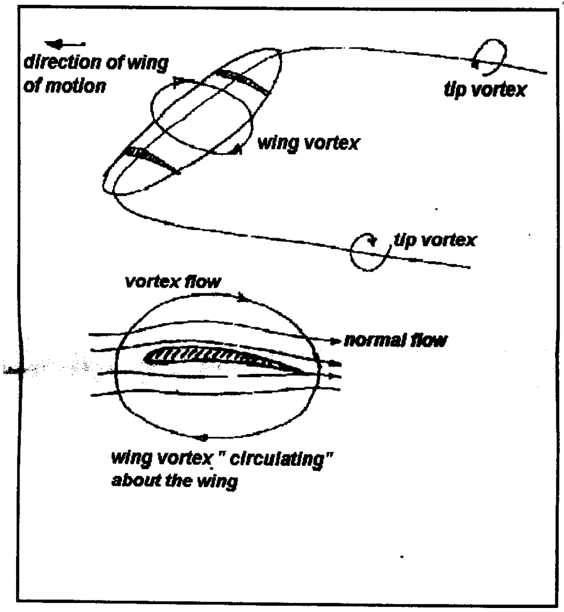
Dear Hal, Thanks for the theory on lift that you ask me to consider. It brings forth the question of how can we explain in simple terms the generation of lift by a wing profile. I have thought about this problem many times, always coming to the conclusion that the production of lift is quite hard, almost impossible, to bring to simple terms, because it involves some concepts that are not everyday themes of discussion. The consequences of lift are easier to understand.

Because of this inherent complexity, many incomplete explanations have been presented. A typical one consists of considering two air molecules that separate at the the leading edge of a wing. When they arrive at the same time at the trailing edge the one that traversed the longer distance, which is supposed to be over the upper profile must have a greater velocity than that over the lower profile. A higher velocity means that its kinetic energy is larger at the point of arrival than that of the lower molecule. But as they started with the same energy at the leading edge, this can only mean that the pressure on the upper molecule is smaller, (total energy = kinetic energy plus pressure).

Thus there is a difference in the pressures on top and bottom of the airfoil, this difference in pressure times the area of the wing is the lift. This is what is normally taught in high school but it ain't true, as there is of course no reason why the two molecules should arrive at the trailing edge at the same time.

I mention this as I am sure many of us have tried to frame this mysterious lift generation in some simpler way, precisely so we can discuss it in groups such as this one. The explanation of lift is the work, independent and almost simultaneous of three persons, two who were engineers, one a mathematician, Lanchester in England, Kutta in Germany and Joukowsky in Russia, all about 1900.

This explanation introduces the necessary complication of the existence of vortices about the wing, vortices that are really quite familiar to us in the form of wing-tip vortices, but that we seldom associate with the production of lift. We all have seen the photos of a plane shedding a long vortex trail from its wing tips (it was shown in this list some time ago), but we have to think that these wing tip vortices are not isolated on each tip. They are connected by another vortex strand over the wing, forming what is called a horseshoe vortex. The vortex formed over the wing rotates in such a way that its velocity over the top adds to the normal airflow, the vortex velocity at the bottom of the profile goes against the airflow. See sketch attached. One can imagine this associated vortex flow 'circulating' over the wing. In fact "circulation" is absolutely necessary to the generation of lift. Once we accept this, the argument of conservation of energy tells us that the pressure on top must be less than the pressure at bottom and that lift is generated.



The difficult part in this explanation is to think of a mechanism for the start of the vortex when the wing begins to move, and this has to do with the nature of the flow about the trailing edge. The mechanism was eventually found by Kutta and Joukowsky , and many early , experimental confirmations of these ideas were at hand, even before 1910. This theory has stood the test of time, in fact it has to be one of the most brilliant developments in engineering and science of the past century. What gives me particular pleasure is the fact that Lanchester was just an amateur mathematician, in fact a builder of motor cars by trade, he could have been any one of us, yet his fertile mind was able to bring forth the importance of a phenomenon that would have appeared totally unrelated to the lift: the existence of the tip vortices.

As for the consequences, they fit what Eut and Hank Baer have said. The lift force on the wing must be countered exactly by the momentum of the airflow in the opposite direction following Newton's equation applied to the system of air and wing. This is what Eut has stressed. Hank spoke of the importance of negative pressures, and he is quite right, as most of lift derives from that, as the curve in the sail suggests and the condensation pattern of the photo shows.
Sergio