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How do wings work?

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Abstract

The popular explanation of lift is common, quick, sounds logical and gives the correct answer, yet also introduces misconceptions, uses a nonsensical physical argument and misleadingly invokes Bernoulli's equation. A simple analysis of pressure gradients and the curvature of streamlines is presented here to give a more correct explanation of lift.

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The science behind aeronautics continues to fascinate and many students are attracted to engineering as a result of an early interest in aircraft. The most commonly asked question is how a wing can produce lift. Unfortunately the most widely used explanation of lift is wrong in a number of key points. Not only is this confusing for students, but in the worst case it can lead to a fundamental misunderstanding of some of the most important aerodynamic principles. In this article I will demonstrate why the popular explanation for lift is wrong and then propose an alternative explanation.

The popular explanation

Figure 1 shows a typical aerofoil—the cross-sectional shape of a wing—immersed in a flow where the streamlines have been visualized with smoke particles. At the front is the stagnation point (S), which is the location where the oncoming flow divides into that moving above and that moving below the wing. The argument revolves around the observation that the distance from this point S to the trailing edge (T) is greater along the upper surface than along the lower surface. If it is assumed that two neighbouring fluid particles which 'split' at S should meet again at T then this requires that the average velocity on the upper surface is greater than that on the lower surface.

Now Bernoulli's equation is quoted, which states that larger velocities imply lower pressures

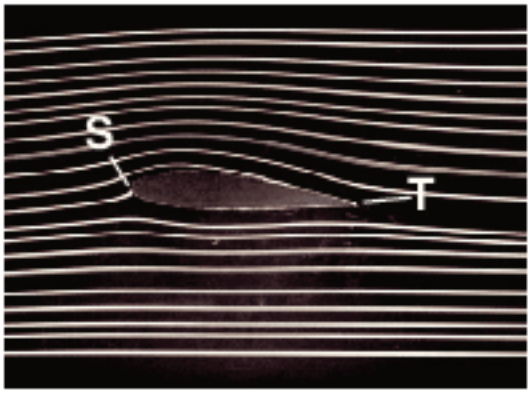

Figure 1. Streamlines around an aerofoil section visualized with smoke.

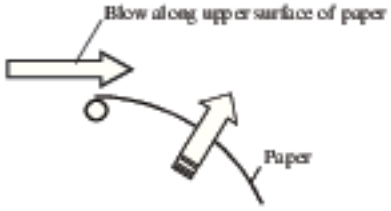

Figure 2. Paper lifts when air is blown along its upper surface.

and thus a net upwards pressure force is generated. Bernoulli's equation is often demonstrated by blowing over a piece of paper held between both hands as demonstrated in figure 2. As air is blown along the upper surface of the sheet of paper it rises

0031-9120/03/060497+07$30.00