EFFECTS OF A WINGTIP-MOUNTED PROPELLER
ON WING LIFT, INDUCED DRAG, AND
SHED VORTEX PATTERN

by

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CHAPTER I

INTRODUCTION

The use of a wing, having a finite span, to produce lift results in three penalties which would not exist if the lifting surface had an infinite span. These three penalties are:

1. Decrease in lift near the wing tips (and, therefore, a lower $C_L$ of the wing at any angle of attack and a lower $C_{L_{\text{max}}}$).

2. Increase in wing drag by the amount of the induced drag.

3. Creation of downwash behind the wing (e.g., at the tail surfaces) which is not constant, but is a function of the wing lift coefficient.

This fact has long been recognized. At the turn of the century, Lanchester postulated the type of flow that a real finite span wing would experience. His sketches predicted the formation and shedding of vortices which wrap up into large-scale vortices trailing downstream from each wing tip. Figure 1 is a reproduction of his sketches published in Aerodynamics (27).
Figure 1. Lanchester's Sketches of Vortex Motion in the Periptyery
Prandtl first discussed the problem of the three-dimensional flow over a wing of finite span in 1911 and published his treatment of the problem in 1918. The Prandtl wing theory is the basis for most of the work which has been done to date on the finite-span lifting wing.

Not only have the problems been long recognized, but the history of the attempts to improve the effectiveness of a finite lifting wing predates the Wright brothers' first powered flight. Pope (37) reports that Lanchester secured a patent in 1897 covering the use of end-plates on wings.

The principal objectives of various schemes to alter the flow around finite-span wings are:

a) The increase of wing lift (i.e., increase \( C_{L_{\text{max}}} \) and \( C_{L_{\alpha}} \)).

b) The decrease of wing drag (by reduction of induced drag).

The maximum lift coefficient of the wing is always less than the maximum coefficient of lift of the wing sections in two-dimensional flow. The reason for this difference is that the loss of lift near the wing tips causes the maximum lift coefficient of sections near the tips to be less than if the flow were two-dimensional. Also, the stall of the wing effectively begins when some portion of the wing stalls; that is, there is separation
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35. Munk, M. M. Note on Vortices and on Their Relation to the Lift of Airfoils. NACA Technical Note 184, Washington, 1924.


