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Layton, D.M.

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QUASI-HYBRID AIRSHIPS

D. M. Layton*
Naval Postgraduate School
Monterey, California

ABSTRACT

The dynamic lift required for operating even a conventionally shaped nonrigid airship with a weight in excess of the static buoyancy may be obtained by operating in a quasi-hybrid mode wherein the deflected longitudinal control surfaces are used to obtain dynamic lift at near-zero angles of attack of the airship envelope. This results in a significant reduction in the drag of the airship and, as a result, a decrease in the power required to fly at a given airspeed.

NOMENCLATURE

C_D	Drag coefficient of entire airship
C'_L	Lift coefficient of Fins/elevators
V	Airship volume
V^{23}	Characteristic area
α	Angle of attack of envelope (Deg)
δ	Deflection angle of elevator (Deg)

INTRODUCTION

Any vehicle operating in a medium may develop a lifting force from one or more of the three primary sources, as shown in Figure 1.

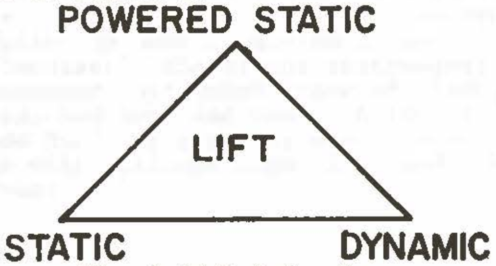

Fig. 1 Lift Triangle

A vehicle operating in the atmosphere which displaces a volume of air whose weight is in excess of that of the vehicle is developing Static lift. This is, of course, the case of the buoyant balloon.

If the vehicle develops an aerodynamic force by moving through the air, it is obtaining Dynamic lift, as is represented by the conventional, fixed-wing airplane. A vehicle that is supported by a reaction with the air from an internally generated power source is said to be developing Powered Static lift. This is the case of the vertically launched rocket, and is also the type of lift developed by the helicopter.

It is not at all unusual for an airborne vehicle to use a combination of the three primary lift sources. This vehicle is called a 'hybrid'.The most common hybrid aircraft is probably the helicopter, inasmuch as there have been few helicopters built in the past ten years that did not have at least a test vehicle equipped with some sort of aero-dynamic wing to provide a Dynamic lift augmentation to the basic Powered Static lift.

Even airships have made various uses of the hybrid principles. Some of the rigid airships had rotatable propellor systems that could be tilted so as to offer a vertical thrust component (Powered Static lift) to assist the Static lift. Rotation of the ducted fans on the AD-500 provided this service, and such a schema is the essence of the Helio-Stat design.

Dynamic lift augmentation for an airship is usually thought of as coming from massive wings added to a somewhat typical airship planform, as in the Megalifter concept, or from the shape of the envelope itself, as with the Aeron design and the Helium Horse. It is quite possible, however, to have a more subtle form of Dynamic lift augmentation, even with a conventionally shaped pressure airship.

The United States Navy's pressure airships of the 1940's-1960's were traditionally launched with a negative buoyancy. This meant that these airships took-off and flew at least the first portion of the mission in a heavier-than-air state. In fact, due to the poor handling qualities of a 'light' airship, provisions were added in the late 1950's that would permit the recovery of sea water ballast in order to maintain the heavieness of the airship.

It was the belief of most of the airship pilots of that period that the Dynamic lift was obtained solely from the aerodynamic shape of the airship envelope. It was recognized that, in order to obtain sufficient Dynamic lift, one must fly above a minimum velocity and the airship must be pitched up so as to provide a positive angle of attack. This pitch-up was relatively easy to accomplish due to the unique trim possibilities of the ballonet system. By pumping air into the aft ballonet and valving air from the forward ballonet

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*Professor, Department of Aeronautics
Associate Fellow, AIAA

(in order to maintain a constant over-pressure of the lifting gas), the center of buoyancy moved forward and the airship became 'tail heavy'. This permitted the airship to fly at a positive pitch angle, and therefore a positive angle of attack, with very little longitudinal control surface deflection, and Dynamic lift was obtained.

DYNAMIC LIFT

There were several indications that not all of this Dynamic lift was obtained from the airship envelope. It was possible during a 'heavy' take-off, once sufficient airspeed was developed to provide longitudinal control authority, to perform a maneuver in which Dynamic lift was generated at near-zero angles of attack. Once the airship was moving and stabilized on the take-off run, a sudden increase in engine power would cause a nose-up moment, as shown in Figure 2, due to the low position of the propellors in respect to the center of buoyancy.

If, at the same time that the throttles were advanced, full down elevator control was applied, the dynamic lift on the elevators would produce a tail-up moment, as shown also in Figure 2, and the airship would rise off the surface.

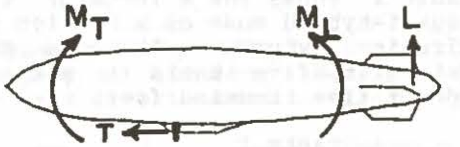

Fig. 2 Thrust/Fin Moments

The airship would 'lift off' even though it was heavy and the envelope was at near-zero angle of attack. Parenthetically it should be noted that as soon as the airshir lifted off, something needed to be done to the power/elevator combination or else the airship would pitch down with disastrous results.

LIFT DUE TO ANGLE OF ATTACK

Literature searches[1,2,3,4] show that as early as the 1920's, wind-tunnel and water-tunnel tests indicated that, for conventional airship shapes, less than twenty percent (20%) of the Dynamic lift was generated by the envelope and that the major portion of these dynamic forces were generated off the fins of the airship.

The following information is derived from 1954 flight test results of a Navy ZPG (then ZP2N-1) airship[5] and preliminary wind tunnel testing of a model at the Naval Postgraduate School. The Dynamic lift coefficient (C'_L) was calculated using the airship volume to the two-thirds power ($V^{2/3}$) as the characteristic area. The flight test angles of attack were obtained from an installed and calibrated vane. The flight test airship had 'X' planform control surfaces and the longitudinal control deflection was a sum and average of the controls.

Figure 3 shows the variation of the Dynamic lift coefficient with angle of attack for zero elevator deflection. The lift curve slope was approximately 0.011 per degree throughout the angle of attack range. It is to be noted that Dynamic lift was obtained even at zero angle of attack. This is due to the inclination of the fins with respect to the airship.

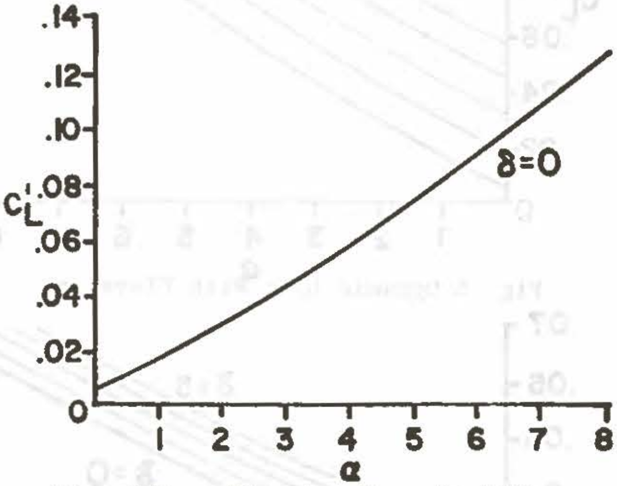

Fig. 3 Zero Elevator Dynamic Lift

The drag coefficient for the entire airship was also obtained and is shown in Figure 4.

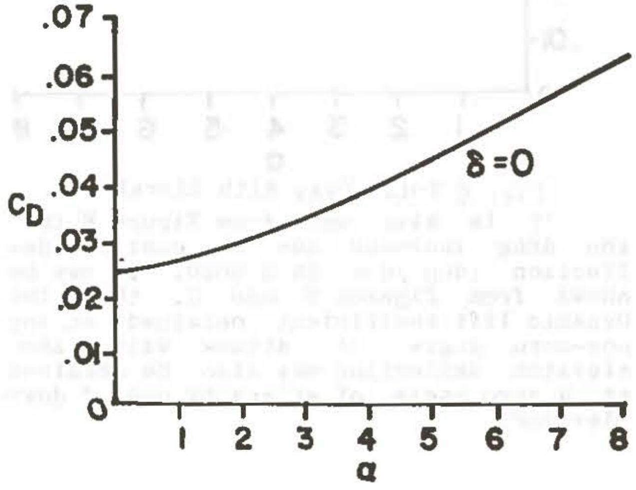

Fig. 4 Zero Elevator Total Drag

After about three degrees (3^o) angle of attack, the change of drag coefficient with angle of attack was approximately 0.006 per degree.

The data for Figures 3 and 4 were obtained at zero degrees of control surface deflection.

ELEVATOR EFFECTS

Additional test runs were conducted with various deflections of the longitudinal control surfaces, as shown in Figures 5 and 6. From Figure 5 it may be seen that the elevator control effectiveness ($dC'_L/d\delta$) was 0.012 per degree.

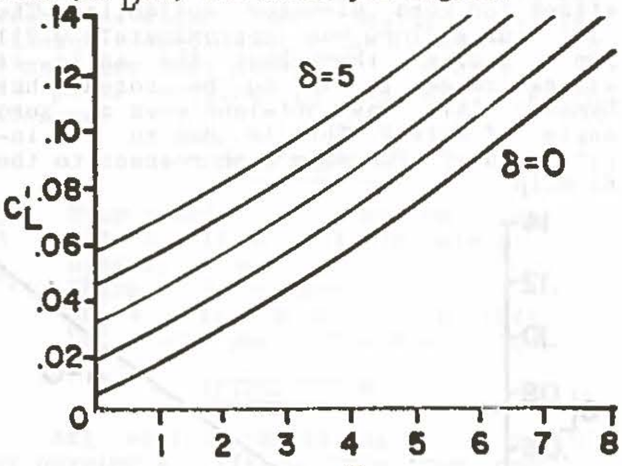

Fig. 5 Dynamic Lift With Elevator

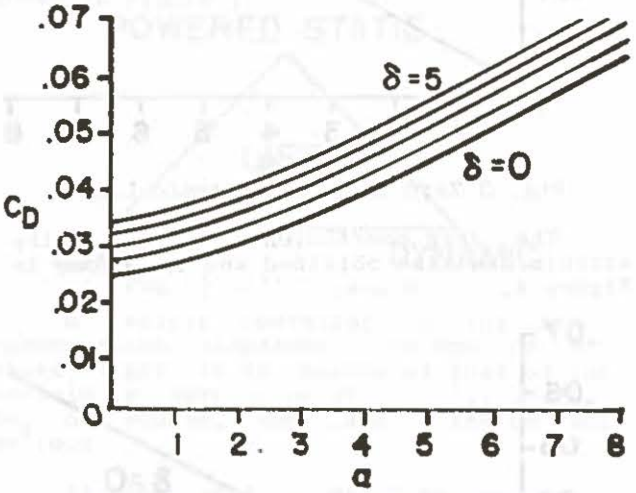

Fig. 6 Total Drag With Elevator

It is also seen from Figure 6 that the drag increase due to control deflection ($dC_D/d\delta$) is 0.0026. It may be shown from Figures 5 and 6, that the Dynamic lift coefficient obtained at any non-zero angle of attack with zero elevator deflection may also be obtained at a zero angle of attack by use of down elevator.

A drag polar for the Dynamic lift is shown in Figure 7 for both zero angle of attack (with elevator deflection) and zero elevator deflection (with angle of attack).

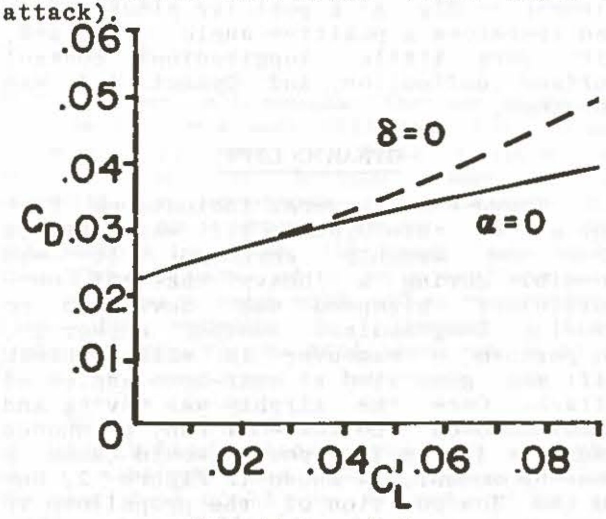

Fig. 7 Drag Polar

The divergence of these curves is a function of the Dynamic lift coefficient, and at a Dynamic lift coefficient of 0.08, the drag coefficient is twenty-four percent (24%) higher when angle of attack is used than when elevator deflection is used for Dynamic lift.

EFFECT ON POWER

Table I shows the effects of flying in a quasi-hybrid mode on a million cubic foot airship flying ten thousand pounds heavy at sixty-five knots at a standard altitude of five thousand feet.

TABLE I

VOLUME	1,000,000 ft^3
STATIC LIFT	60,000 lb
DYNAMIC LIFT	10,000 lb
ALTITUDE	5,000 ft
AIRSPEED	65 kts
POWER ($\alpha = 0$)	944 HP
POWER ($\delta = 0$)	1164 HP

CONCLUSIONS

The efficiency of a pressure airship may be improved by its operation in a hybrid mode. Not only does this permit a wider latitude in gross and net weights, but the handling qualities are improved when the airship is flown heavier than air.

Even a conventionally shaped pressure airship may be flown efficiently in a quasi-hybrid mode by using the Dynamic lift of the longatudinal control surfaces with less drag, and therefore less power required, rather than using the angle of attack of the airship for this lift. This method is most efficient at the higher values of Dynamic lift coefficient, i.e., heavier gross weights, and can result in savings of over twenty percent on the power required.

Although there are no indications that 'two are better than one', the use of the longitudinal control surfaces for lift supplement renews the idea of bow fins for airships. In the past, the bow fin concept has been advanced primarily for maneuvering enhancement, but the increased efficiency of using the fins for quasi-hybrid lift augmentation indicates that this idea should be re-considered. In fact, such tests are planned during the next year in a Naval Postgraduate School wind tunnel.

Use of down elevator to obtain the lifting force should be restricted to a value of control deflection that will permit sufficient control authority, should the need arise, and should be approached with caution at very low altitudes inasmuch as loss of airspeed and/or loss of control will result in a sudden tail-down moment, and the tail might strike the surface if sufficient clearance is not provided.

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