AN INBOARD-WING ARRANGEMENT FOR HIGH-CAPACITY AIRLIFT AND SEALIFT VEHICLES

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Summary

The purpose of this paper is to consider the application of an inboard-wing design arrangement to high-capacity airlift and sealift logistic support vehicles. The inboard-wing arrangement consists of a relatively low aspect- ratio rectangular wing that has large bodies attached to each wing tip. All of the required wing area is located between the two bodies and there are no outboard cantilevered wing panels as are found on conventional aircraft. When compared to a conventional aircraft design the use of an inboard-wing design would permit an increase in capacity within more reasonable geometric constraints. In addition, such a design would provide the increased lift required without creating a potentially dangerous trailing vortex wake.

The concept could be applied to an airship by utilizing twin hulls connected with an inboard-wing. The hulls would contain helium to provide buoyant lift. The connecting wing would provide additional kinetic lift in forward flight. The additional lift would permit greater combinations of payload and altitude than would be possible with a conventional airship with buoyant lift alone.

The concept could also be applied to a sealift vehicle by connecting twin hulls with an inboard wing. The under surface of the wing could provide a boundary for an air cushion that would permit operation as a wing-in-ground (WIG) vehicle with a speed advantage over surface craft. In addition, the wing would provide some lift that would enhance the payload capability.

Introduction

It is conceivable that trouble spots that might affect the free world could occur in many different localities. If it were necessary to contain or disrupt such spots with the presence of stabilizing forces from distant countries, the logistic support required could cause some concern. Among the concerns are: the type of material to be transported; the quantity to be transported; the speed required; the distance required and the basing constraints. The inboard wing concept to be considered herein as a logistic support aircraft was originally conceived as a means of developing a high-capacity commercial transport airplane. When compared to a conventional single-body design, the use of two bodies doubles the capacity for the same overall length. Connecting the bodies with a low aspect ratio rectangular wing can provide sufficient wing surface area within an overall span less than that of a high aspect ratio cantilever wing design. Some experimental results have been obtained in low-speed wind tunnels for an inboard-wing airplane design. The implication of those results as related to aircraft will be discussed herein. In addition the application of the design concept to an airship and to a sealift vehicle will be considered.

Discussion

The Basic Concept.- Conventional transport airplanes generally have a center fuselage with cantilevered outboard wing panels attached to each side of the fuselage. Typically these wings have a high aspect ratio (the ratio of span to chord) since such wings tend to minimize lift loss at the wing tip. The lift loss at the tip of a lifting wing is a result of the positive pressure from the under side of the wing rotating around the wing tip and destroying some of the negative pressure on the upper surface. Greater lift efficiency.might be expected for the high aspect ratio wing since less of the wing area is affected by the lift loss at the wing tip. Increasing the capacity of commercial transports has generally been accomplished by increasing the physical size of conventional designs. However, with wing spans that are already quite large, further increases in the physical size of such airframes may lead to problems in manufacturing, in ground handling, and in aerodynamic behavior. As the size and weight increase, the aerodynamic lift required must increase. Cantilevered wing panels tend to bend and to twist under aerodynamic load. As a result, it is necessary to provide sufficient structural strength at the wing root attachment to accommodate the aerodynamic load. The additional structure required at the root juncture generally adds weight to the airplane. In addition, at the tip of a cantilevered wing panel the flow that rotates from the lower surface to the upper surface forms a vortex. As the size and weight of the airplane increase, the lift required to sustain flight increases. As a result, the tip vortex strength increases and may create a dangerous hazard to aircraft trailing in the path of the vortex. The concept of the inboard wing originated as a means of alleviating some of the structural and weight concerns and to reduce or eliminate the tip vortex hazard. The concept consists of a relatively low aspect-ratio rectangular wing with large bodies attached at each wing tip. With such an arrangement the wing would be mounted as an end-supported beam that would be less likely to bend or to twist under aerodynamic load and thus should be lighter per square foot than a cantilevered wing panel. The large bodies attached to the wing tips should act as fences to prevent tip flow and thus reduce or eliminate the tip vortex. In addition, the large twin bodies would serve to increase the passenger and cargo capacity.

High-Capacity Airplane. - Wind tunnel tests of an inboard-wing conceptual model indicated that the addition of bodies to the tips of a low aspect ratio wing did prevent the flow of air around the wing tip and there was no spanwise flow on the wing. With all of the airflow over the wing being in the streamwise direction, the lifting efficiency of the wing was increased. The lift provided per degree of angle of attack was increased about 20 percent when the bodies were attached to the wing tips. The lift provided by the wing is a function of the wing efficiency and the angle of attack, the wing area and the dynamic pressure of the airstream. The wing efficiency may be determined from tunnel tests and is dependent on the airfoil shape and the type of airflow over the airfoil. The wing area is a function of the chosen geometric arrangement. The dynamic pressure is a function of the airspeed and the altitude - increasing with increasing airspeed and decreasing with increasing altitude. The lift of an airplane is determined from the relation Lift = C_LSq where C_L is the lift coefficient (wing efficiency), S is the wing area and q is the dynamic pressure.

The lift, or load-carrying capacity for an airplane with a given wing section and a given flight condition varies directly with the wing area. Quite large wing area's can be obtained with the inboard-wing arrangement since the low-aspect-ratio rectangular wing can maintain a large chord over the entire span of the wing. For the conceptual test model scaled to have two Boeing 747 bodies and a wing area of about 10,500 square feet, a lift of about 4,250.000 pounds was developed for cruising flight at a Mach number of 0.50 at 10,000 feet. The wing chord length for this conceptual airplane was about 90 feet and with a 12-percent thick airfoil section the maximum wing thickness was about 10.8 feet.. Thus a considerable amount of space is available in the wing for cargo, fuel or submerged engines. In addition, the use of two bodies doubles the passenger and cargo capacity of a basic 747 airplane. Thus a logistic support aircraft using such an arrangement would more than double the capacity of a basic 747 aircraft with no increase in length and a reduction in overall width.

Hybrid Airship. - A hybrid airship concept would be composed of a low aspect-ratio wing with large hulls attached to each wing tip. The hulls would contain the gas to provide for buoyant lift. The use of twin hulls rather than the conventional single hull would provide for increasing the volume of gas with no increase in overall length or for reducing the overall length for a given volume of gas. In forward flight the inboard-wing connecting the hulls would provide an increment of kinetic lift just as an airplane wing does in flight. The added increment of lift would permit very heavy loads to be carried to an operational altitude greater than that possible with buoyant lift alone. While an airship is likely to be slower than an airplane the kinetic lift for cruise with a wing area of 10,500 square feet would be about 150,000 pounds at a Mach number of only 0.10 and about 1,500,000 pounds for a Mach number of 0.30. Large wing chords should be possible with the hybrid airship so that a substantial amount of volume would be available within the wing. The load-carrying capability of the hybrid airship would be determined by the volume of gas for buoyant lift and by the wing area, flight speed and altitude for the kinetic lift. The use of two hulls provides for storage of a given quantity of gas in an overall length much less than that which would be required for a single hull airship. Connecting the hulls with a lifting wing provides for additional lift in forward flight. A primary advantage for the airship concept is that it provides access to locations that might be inaccessible for other means of transportation.

Wing-in-Ground Effect Sealift Vehicle. - A wing-in-ground (WIG) water-based vehicle would be composed of a low aspect-ratio wing with hulls attached to each wing tip.. The load-carrying capacity of such a vehicle would be determined by the size of the hulls plus the volume that again would be available from a thick wing. Such an arrangement would have a high-mounted wing with a trailing-edge flap that, when deflected, would effectively seal the gap between the trailing edge of the wing and the water surface. Jet engines would be mounted forward of the wing in such a way that the jet could be directed under the wing and between the hulls. With the flap deflected the pressure generated under the wing between the hulls would tend to lift the vehicle out of the water. Exploratory tests of such a concept have been conducted at NASA- Langley. These tests indicated that regulating the jet flow and the flap deflection could provide for vertical lift out of the water and for forward flight on an air cushion in the ground-effect mode or for free flight as an airplane. The load-carrying capability of conventional water-based ships is quite large but the speed of such ships is relatively low. However, the ability to lift the hulls out of the water and to operate in a ground-effect mode would provide a significant increase in speed over that for conventional surface ships.

Concluding Remarks

The concept of an airlift or a sealift vehicle utilizing an inboard-wing design has been considered. The concept is composed of a low aspect-ratio rectangular wing having large bodies attached to each wing tip. When compared to a conventional design having a single center body and outboard cantilevered wing panels, the inboard wing is intended to eliminate wing bending and twisting under aerodynamic load and the attendant structural and weight requirements. In addition, the concept should prevent the flow of air around the wingtip that results in a loss of lift near the wing tip. Flow around a wing tip also produces a vortex flow that could be hazardous to trailing aircraft. Preliminary wind-tunnel tests of the concept indicate that the lift effectiveness of the low aspect-ratio wing is improved with the addition of the tip-mounted bodies and that the tip vortex is eliminated. Thus it appears that through the use of a low aspect ratio wing with passenger/cargo fuselages attached to each wing tip, a suitable airlift aircraft could be achieved. Such a vehicle would have about twice the capacity of current airlift aircraft with no increase in overall length and a reduction in overall width.

When applied to a hybrid airship concept, the low aspect-ratio wing would have large hulls attached to each wing tip. The hulls would contain gas to provide buoyant lift. The inboard-wing would provide added kinetic lift in forward flight. The combination of buoyant lift and kinetic lift would provide greater load-carrying capability than a conventional airship in a vehicle with an overall length less than that of a conventional airship.

When applied to a sealift vehicle, the low aspect ratio-wing would have large hulls attached to each wing tip. The hulls would provide for floatation in water with very large loads. With properly located jet engines forward of the wing and with properly deflected wing trailing edge flaps, such a vehicle could operate on the water as a ship, above the water as a wing-in-ground effect vehicle, or in free air as an aircraft.

Each of the vehicle types considered is capable of carrying large and heavy loads. The aircraft has the advantage in speed but must have suitable bases for take-off and landing. The hybrid airship is slightly limited in speed but is able to operate in and out of areas otherwise inaccessible. The sealift vehicle requires water basing but is versatile in that it may operate as a surface ship, as a wing-in-ground effect vehicle, or in free flight as an aircraft.

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