Advanced joined wing designs engineering essay

Joined wings also known as box or bi-diamond wings consist of two sets of wings joined together at the wing tips. This configuration replaces an aircraft's vertical and horizontal tail planes. The idea was first patented by Julian Wolkovitch in 1980s. The tandem wings can be a combination of sweepback wings coupled with forward swept wings. Student will be expected to conduct a critical overview of the future generation aircraft designs (Boeing, NASA, Lockheed-Martin) adapting the advance joined-wing concept. CFD Analysis of forward and backward swept joined wings will be conducted to obtain aerodynamics characteristics such as lift, drag, pitching moment and stalling behavior.

Introduction

Closed Wing Concept

A joined wing is a closed wing concept. It is a concept which is a non planar wing plan form. The concept of joined wing aircraft was to have the forward wings sweep back and unite with an extra pair of wings that make contact down and forward from the plane's tail, enwrapping the plane's fuselage in a diamond shape. This configuration is an entirely new aircraft configuration originally envisioned by NASA and ACA Industries during the early 1980's, of which Julian Wolkowitch played a great part. For this configuration the aircraft employs a conventional fuselage and incorporates two wings joined together as per mentioned earlier forming a diamond shape. The main objective is to negate the influence of the wingtip vortices, which commonly appears at the tip of the wings. A joined or box wing, for a stated lift, wingspan and vertical extent can achieve the minimum conceivable induced drag.

PROJECT REQUIREMENTS

The aim of this project is to design a bi-diamond which would meet the following requirements:-

Mission Requirements

Conduct a critical overview of the future generation aircraft designs (Boeing, NASA, Lockheed-Martin) adapting the advance joined-wing concept.

CFD Analysis of forward and backward swept joined wings to be conducted to obtain aerodynamics characteristics such as lift, drag, pitching moment and stalling behavior.

Product Assurance Requirements

Reliability of the proposed designs or chosen techniques.

Consider availability and technological readiness in order to be brought into use.

Maintainability, calibration and testing of components.

Performance Requirements

Stability

Effective functioning of the concept

Reliability

Safe and efficient design

Structural strength and stiffness

Physical Requirements

It must endure natural flight conditions

Cost Effective Solution

PROJECT TIME LINE

DIFFERENT WING CONFIGURATIONS:

mONOPLANES: Monoplanes are the conventional single wing aircrafts. The wing could be configured at different heights related to the fuselage.

BIPLANES – in these configuration two planes of approximately equal size, are put together one on top of another. It was the common type during the early aviation history until Monoplanes took over.

MULTIPLANES: Several planes stacked on top of another.

STAGGERED DESIGN: In this design either the forward or the back wing is slightly forward.

CANTILEVERED DESIGN: In this design the skin supports the structure and is self supporting.

BRACED DESIGN: In this design external structures are used for support.

CLOSED WING DESIGN: The wings in this design are joined together near the tips. Following are some configurations for closed wing design.

Joined, Box or Diamond Wings: Two wings joined together near their tips to form a diamond shape in both the plan view and the front view.

Annular Wing: Also known as Circular, Flat or Cylindrical wing are symmetrical in shape and have annular lifting surfaces.

Following are some configurations for the Joined wing design.

Background

Aircraft designers during the early times recognized the benefits of a biplane since it had more surfaces for lift. The only backdrop was the wires that structurally held the wings together, which created a lot of profile drag, which practically voided the added benefit of the extra lifting surfaces. Hence the research and development focused more towards the commonly seen single wing of today. It was structurally sound and did not have the incredible profile drag the biplanes had. However, the technological readiness of today, with the advent of new materials and structural ideas, the biplane concept is no longer troubled by the high profile drag. One of the upcoming configurations for the biplane is the joined wing. The joined wing not only creates a more structurally sound wing system, it also cuts down on the vortices shedding off the wingtips, thus helping reduce the induced drag. The joined wing also offers more area for control surfaces, making it very stable. With this increase in lift and stability and reduction in drag, the plane could theoretically have a longer range or be lighter in weight compared to its single counterpart.

Current Studies

Modern study of Joined wing model was promoted during the 1980’s by Julian Wolkovitch. She is a leading expert and advocate of the joined wing. Today, many companies and organizations are continuing his work to make the joined wing configuration a flying reality.

During periods of armed conflict or international emergencies, a military’s capability to airlift troops, equipment, and other cargo quickly and efficiently is of prime importance. However, recent developments have caused the military to re-evaluate nearly every aspect of its mission, strength and readiness. For instance, there are no longer pressing reasons to maintain a sustained military presence in foreign countries. Similarly, foreign countries are becoming increasingly hostile towards the idea of allowing a foreign military presence on their soil. Operationally, this means that the countries cannot count on logistics support, such as refuelling, during airlift operations. In addition, the military’s responsibilities are expanding to include domestic and international humanitarian relief efforts.

In order to meet the future needs of the military Lockheed Martin is one of the companies which is looking into incorporate the blended wing-bodies (BWBs) and joined-wing configurations, as well as a conventional high-wing design on the next generation tankers. The hope is that the joined wing tanker, designated the New Strategic Aircraft, will be able to carry more fuel and have a two-boom system, thereby allowing the Air Force to refuel more planes with fewer tankers. The revolutionary box wing concept is the current focus of the advanced concept development work at Lockheed Martin Aeronautics Company under the AMA program. A twin boom aircraft can provide the USAF with the same number of refueling booms, but at half the number of aircraft. The box wing tanker is also equipped with two drogue refueling systems for inter-service and international operations. A radioscaled model has flown eleven successful flights, validating Lockheed Martin’s choice of the joined wing configuration.

Lockheed Martin’s high wing concept

Lockheed Martin’s Blended wing body concept

Lockheed Martin’s Diamond wing concept

Other companies are looking to validate the joined wing as well. NASA Langley (LaRC) has been working with the Boeing Military Airplane Company to verify Boeing’s joined wing design. So far, tests have been run in the LaRC 16-foot transonic tunnel at Mach 0. 32 to 0. 9. The Boeing configuration is proposed to replace the Navy’s E-2C Hawkeye. Aside from the experimental tests, many people are developing CFD programs to analyze the joined wing configuration.

Literature Review Overview

Julian Wolkovitch is the known to be the father of the Joined Wing concept. He claims the joined wing as “ arranged such that the wings form diamond shapes both in plan view and front view”. Here we have some figures which show us some type of joined wing as well as single wing.

Biplanes and joined wings can be described in terms of the stagger of the wings. Stagger is the longitudinal offset of the two wings relative to each other.

A positive stagger configuration is one where the top wing is closer to the nose. Differing staggers can be seen in figures below. The joined wing configurations, if designed correctly, have many benefits over the single wing. This chapter will discuss those benefits, as related by various researchers, in terms of aerodynamics, stability, design options, and in comparison to the single wing.

Wolkovitch’s concept was to have the front wings sweep back to join an additional pair of wings that reach down and forward from the plane’s tail, enclosing the plane’s fuselage in a diamond shape.

Advantages & Limitations:

Light Weight

The joined wing can offer great weight savings based on a number of factors. Just comparing a joined wing with a single wing that has the same airfoil, equal parasite and induced drag, and taper ratios, the joined wing is about 24% lighter than the single wing plane. This has a lot to do with the chord-wise tapering. Skin thickness helps to provide structural stability in the wings. Less skin thickness is required in the joined wing because of its bracing of the wings. This reduces the overall weight of the wing. Figure below shows the chord-wise tapering of the wing box and the skin thickness for the joined wing.

An added benefit besides the weight savings that the smaller skin thickness offers is that a larger wing box can be employed – one that extends from 5% to 75% of the chord. This adds to the amount of fuel that can be carried, thus extending the range. Figure below shows the optimum wing structures for the single wing and the joined wing – depicting the extended wing box, and the chord-wise tapering. As can been seen, the single wing has a more rectangular wing box that is positioned in the thickest part of the airfoil. The joined wing has a wing box that follows the contours of the airfoil and encompasses the entire airfoil. With this enlarged wing box in the joined wing, more fuel can be carried. It must be noted that this design point may not always be needed. For instance, in this study the wings are solid and are not used to carry fuel. Consequently, there would not be the added weight savings from the smaller skin thickness.

Other factors that tend to reduce the weight of the joined wing are reduction in sweep, large dihedrals, and joining the wings inboard of the tips.

Joined wings are not always necessarily lighter than single wings. Weight will be saved only if the geometric parameters of the joined wing are properly chosen and if the internal wing structure is optimized. In general, though, the standard joined wing and swept forward/swept rearward configurations tends to be lighter than the single wing with the same flight mission.

Stiffness

Since the two wings form a box-like structure, they tend to prevent each other from bending or twisting. This gives the joined wing a very high stiffness, both torsionally and flexurally.

Drag

The main concern of the early biplanes was the large amounts of profile drag the wings would experience due to the structural wires. As it turns out, in most design considerations the joined wing will have a lower overall drag than the single wing. This is mainly because it does not need the wiring that caused the high profile drag a biplane did for structural purposes. In addition, the joined wing produces a much lower induced drag — also contributing to the low total drag. Many other drag-reducing elements are discussed below.

Even though the consensus is that parasite drag is lower for joined wings, it is still open if the skin friction drag, commonly called the viscous drag, is lower than its single wing counterpart. Since the skin friction drag is part of the parasite drag, it follows that the pressure drag must be that much lower for the joined wing in order to make the parasite drag lower for the joined wing configuration. Some have stated that under the best of conditions the joined wing does indeed have a lower viscous drag.

Stability and Control

One of the obvious benefits of the joined wing is the availability of more control surfaces than the typical single wing. With the control surfaces on each wing, there are added maneuverability and control capabilities. Direct lift control and direct side force control can be achieved. Since the joined wing has effectively four places for control surfaces as compared with two for a single wing, the joined wing can offer more stabilizing features.

Because of the great stability of this configuration, there is no longer the need for the tail to be so far downstream in order to produce a long moment arm. Thus, the fuselage can be shortened, thereby reducing the weight a great deal.

High Lift

One of the major benefits reaped by the joined wing is its high trimmed CLmax . In general, for a statically stable joined wing configuration, when the front wing reaches its CLmax, the rear wing has generated much less lift than it is capable. While, this does give good recovery properties, with the rear wing not reaching its CLmax implies that the rear wing is oversized, unnecessarily adding weight.

The joined wing have less wing wetted area than the single wing and still achieve the same lift as the single wing plane. The less area can also go towards a large weight reduction or, since range is a function of lift coefficient, towards an extended range. Conversely, the span of the joined wing could be increased, maintaining the same weight, thereby reducing the induced drag, allowing for thin airfoils and a faster cruise. As stated before, one must keep in mind the mission of the plane in order to design the joined wing optimally for the desired features.

SUMMARY

There are many other benefits that can be realized with the joined wing.

The joined wing outdistances the single wing, especially at high altitude.

Unfortunately, the advantages of the joined wing decrease as its wing area is reduced. It is best to keep in mind that not all advantages can be gained at once. There is a lot of optimization and design that must be done.

Despite all of this research into the joined wing configuration, there is still much to learn and study.