Comparison of mass boom and box beam wing structure engineering essay

In mass boom wing structure there are flanges with one or two spares to bear the bending and the tortional load is carried by spar webs. The outer wing is only works against the buckling due to shear forces with help of the ribs and span wise stiffeners. Mass boom structure is mostly use on slow aircraft with thick wings and low wing loadings.

Failure of spar boom is catastrophic, due to the absence of fail-safe characteristics; the mass boom wing structure is no longer used in new transport aircraft designs. Due to the high stress in the spar boom the deflections under bending loads are large. The skin plays no part in, the absorbing the bending moment so that is not used very efficiently. If two-spar configuration is used, the spar height is less than the airfoil thickness. The forces in the spar booms due to bending are thus increased and more material will be required. Many ribs are required to stabilize the spar booms. The skin will be buckle when loaded if no stringers are used; this will adversely affected the aerodynamic cleanness.

Box beam structure

In box beam construction there are thin skins or webs and stringer jointed in box shape. This wing designed to carry shear, bending and torsional loads.

Box beam structures incorporate skin panels, which are stressed only to take shear forces, but also the end load due to bending. From the point of view of fail-safe design and stressed skin structure is much better than the mass boom type.

This method is more suitable for aircraft wings with medium to high load intensities and differs from the mass boom concept in that the upper and lower skins also contribute to the span wise bending resistance. Another difference is that the concept incorporates span wise stringers to support the highly-stressed skin panel area. The resultant use of a large number of end-load carrying members improves the overall structural damage tolerance.

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Cross sections of two spar box beam wing layouts

Advantages of box beam structure

The advantages of the box beam will be evident when considerable skin thickness is required to obtain sufficient tensional rigidity on wing design for high speed and thin, high aspect ratio wings. In lightly loaded wings, however the stress level in the upper skin will be kept fairly low to avoid buckling and the differences in weight will be small as compared with the mass boom type.

Disadvantages of box beam structure

Design difficulties and disadvantages include: Interactions between the ribs and stringers so that each rib either has to pass below the stringers or the load path must be broken. Many joints are present, leading to high structural weight, assembly times, complexity, Costs & stress concentration areas.

Material selection for the wing structure

Some important factors have been considered during the selection of a material for aeronautical application.

Materials properties must be considered for structural application as:

- Ultimate stress

- Yield stress

- Stiffness

- Temperature limits

- Corrosion resistance

- Fatigue resistance

- Fracture toughness

- Fragility at low temperatures

- Crack growth resistance

- Ductility

- Maintainability

- Reliability

- Fabricability

The main group of materials used in aircraft construction has been:

- wood

- steel

- aluminum alloys

- titanium alloys

- fiber reinforced composites

Aluminium alloy –

Aluminum alloys are the most widely used materials in aircraft structures. Al alloys are easily formed and machined. Its relatively inexpensive material. Al alloys experience a significant reduction in strength at higher temperatures, limiting their application in supersonic aircraft.

Rib is a structural part of the wing to maintain the aerodynamic shape, Act along with the skin to resist the distributed aerodynamic pressure loads, distribute concentrated loads into the structure & redistribute stress around any discontinuities Increase the column buckling strength of the stringers through end restraint. Increase the skin panel buckling strength. Group 7000 aluminium alloy used in Compression applications like this, where static strength is more important than fatigue or damage tolerance. It is also used in Upper wing surfaces and beams.

Wing Spars Transmit bending and tensional loads. Produce a closed-cell structure to provide resistance to torsion, shear and tension loads. These usually comprise thin aluminium alloy webs and flanges, sometimes with separate vertical stiffeners riveted to the webs. The flanges are extruded or machined and bolted or riveted onto the webs.

Skin is to form impermeable aerodynamic surface, Transmit aerodynamic forces to ribs & stringers, Resist shear torsion loads. Airacraft wing also uses aluminium alloy.

Bending moment reduction of the wing

The bending-moment is the force at each location on the spar that bends the wing upward during normal non-inverted flight, the force rotating the wing around the fuselage. The bending-moment is zero at the wing-tip and maximum at the root. But its value is not proportional across the span. In other words, it is not half as much at the wing mid-point as it is at the root. In fact, the mid-point bending-moment is only about a 1/4 of the root value.

A340-200 is a modern passenger transport design which has box beam structure wing with 197ft wing span and 610, 000 lb maximum takeoff weight.

Bending moment = (Total weight*Total wing span)/8

The maximum bending moment magnitude occurs at the wing root

Wing weight is linearly proportional to the wing root bending moment. Therefore if we reduce the weight of the aircraft by using light material it can reduce the maximum bending moment on the wing root. Also the wing span is proportional to bending moment, the bending moment can be reduced by reducing the wing span of the aircraft.

Wing with high aspect ratio with entire swept box structure wing moves towards the root and therefore forward of the aircraft. Then in order to maintain balance smaller wing lift and larger tail plane lift will be requied. The inboard shift in the lift will decrease the wing root bending moment.

When engines are mounted on the wings, their weight is obviously going to be borne by the wing structure, along with inertia loads as the aircraft manoeuvres. Thrust forces from the engines will also be carried by the wings. With pod-mounted engines the thrust force is bellow the wing and so this tends to twist the wing. This can be used to balance the effect of the aerodynamics of the wing which create a nose down pitching moment. Another advantage of wing mounted engines is that their weight is close to the area in which lift is produce. This reduces the total fuselage reducing the shear force and bending moment at the wing attachment to the fuselage. So putting the engines on the wings provides bending relief.

Outboard fuel tanks reduce the wing bending moment.

If the landing gear is not mounted under the wing it reduce the wing weight and it also reduce the bending moment of the wing.

Braced wings reduce the wing weight by 30% and it helps to reduce the bending moment of the wing.

Effect of wing thickness to wing weight

Wing thickness is primarily affect to the drag, weight, maximum lift and fuel volume. Increase wing thickness is decrease wing weight since both bending and tortional thickness increase with increasing the thickness.

Wing weight is strongly affected by thickness, particularly for cantilever wings. Thicker is lighter

Effect of Thickness Ratio on Wing Weight

GD method to estimate the wing weight of the commercial transport aircrafts

Ww = {0. 00428(S0. 48) (A) (MH) 0. 43 (WTO nult) 0. 84 (🚺¬) 0. 14}/ [{100 (t/c) m }0. 74 (Cos ƒ™1/2)1. 54]

Definition of terms and data of Boeing 747-400

Ww = Structural weight of the wing

S = Wing area in ft2 = 6027. 78 ft2

A = Wing aspect ratio = 7. 4

WTO = Take off weight in lbs = 875, 000 lb

nult = design ultimate load factor = 1. 5

🚺¬ = Wing taper ratio = 0. 37

(t/c) m = Maximum wing thickness ratio

ƒ™1/2 = Wing semi-chord sweep angle = 33. 50

MH = Maximum Mach number at sea level = 0. 885

This equation is valid only in the following parameter ranges

MH from 0. 4 to 0. 8

(t/c)m from 0. 08 to 0. 15 and A from 4 to 12

Ww = {0. 00428(60280. 48) (7. 4) (0. 885) 0. 43 (875000Ã- 1. 5) 0. 84 (0. 37) 0. 14}/ [{100 (t/c) m }0. 74 (Cos 33. 50)1. 54]

When (t/c)m is 0. 08, Ww = 36747. 3657

When (t/c)m is 0. 15 Ww = 23078. 37734

From the above calculations we can come to a conclusion that the thicker wing is lighter than the thinner wing.