SUBPART C - STRUCTURE

GENERAL

CS 23.301 Loads

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

(b) Unless otherwise provided, the air, ground and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the aeroplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

(c) If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

(d) Simplified structural design criteria may be used if they result in design loads not less than those prescribed in CS 23.331 to 23.521. For aeroplanes described in appendix A, paragraph A23.1, the design criteria of Appendix A of CS-23 are an approved equivalent of CS 23.321 to 23.459. If Appendix A is used, the entire Appendix must be substituted for the corresponding paragraphs of this CS-23.

CS 23.302 Canard or tandem wing configurations

The forward structure of a canard or tandem wing configuration must –

(a) Meet all requirements of subpart C and subpart D of CS-23 applicable to a wing; and

(b) Meet all requirements applicable to the function performed by these surfaces.

CS 23.303 Factor of safety

Unless otherwise provided, a factor of safety of 1·5 must be used.

CS 23.305 Strength and deformation

(a) The structure must be able to support limit loads without detrimental, permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation.

(b) The structure must be able to support ultimate loads without failure for at least three seconds, except local failures or structural instabilities between limit and ultimate load are acceptable only if the structure can sustain the required ultimate load for at least three seconds. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the three second limit does not apply.

CS 23.307 Proof of structure (See AMC 23.307)

(a) Compliance with the strength and deformation requirements of CS 23.305 must be shown for each critical load condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, substantiating load tests must be made. Dynamic tests, including structural flight tests, are acceptable if the design load conditions have been simulated.

(b) Certain parts of the structure must be tested as specified in Subpart D of CS-23.

FLIGHT LOADS

CS 23.321 General (See AMC 23.321 (c))

(a) Flight load factors represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the aeroplane) to the weight of the aeroplane. A positive flight load factor is one in which the aerodynamic force acts upward, with respect to the aeroplane.

(b) Compliance with the flight load requirements of this subpart must be shown –

(1) At each critical altitude within the range in which the aeroplane may be expected to operate;

(2) At each weight from the design minimum weight to the design maximum weight; and

(3) For each required altitude and weight, for any practicable distribution of disposable load within the operating limitations specified in CS 23.1583 to 23.1589.

(c) When significant the effects of compressibility must be taken into account.

CS 23.331 Symmetrical flight conditions

(a) The appropriate balancing horizontal tail load must be accounted for in a rational or conservative manner when determining the wing loads and linear inertia loads corresponding to any of the symmetrical flight conditions specified in CS 23.331 to 23.341.

(b) The incremental horizontal tail loads due to manoeuvring and gusts must be reacted by the angular inertia of the aeroplane in a rational or conservative manner.

(c) Mutual influence of the aerodynamic surfaces must be taken into account when determining flight loads.

CS 23.333 Flight envelope

(a) *General.* Compliance with the strength requirements of this subpart must be shown at any combination of airspeed and load factor on and within the boundaries of a flight envelope (similar to the one in sub-paragraph (d)) that represents the envelope of the flight loading conditions specified by the manoeuvring and gust criteria of sub-paragraphs (b) and (c) respectively.

(b) *Manoeuvring envelope.* Except where limited by maximum (static) lift coefficients, the aeroplane is assumed to be subjected to symmetrical manoeuvres resulting in the following limit load factors:

(1) The positive manoeuvring load factor specified in CS 23.337 at speeds up to V_D;

(2) The negative manoeuvring load factor specified in CS 23.337 at V_C; and

(3) Factors varying linearly with speed from the specified value at V_C to 0·0 at V_D for the normal and commuter category, and -1·0 at V_D for the aerobatic and utility categories.

(c) *Gust envelope*

(1) The aeroplane is assumed to be subjected to symmetrical vertical gusts in level flight. The resulting limit load factors must correspond to the conditions determined as follows:

(i) Positive (up) and negative (down) gusts of 50 fps at V_C must be considered at altitudes between sea level and 6096 m (20 000 ft). The gust velocity may be reduced linearly from 50 fps at 6096 m (20 000 ft) to 25 fps at 15240 m (50 000 ft); and

(ii) Positive and negative gusts of 25 fps at V_D must be considered at altitudes between sea level and 6096 m (20 000 ft). The gust velocity may be reduced linearly from 25 fps at 6096 m (20 000 ft) to 12·5 fps at 15240 m (50 000 ft).

(iii) In addition, for commuter category aeroplanes, positive (up) and negative (down) rough air gusts of 66 fps at V_B must be considered at altitudes between sea level and 6096 m (20 000 ft). The gust velocity may be reduced linearly from 66 fps at 6096 m (20 000 ft) to 38 fps at 15240 m (50 000 ft).

(2) The following assumptions must be made:

(i) The shape of the gust is –

$$U = \frac{U_{de}}{2}\left(1 - \cos\frac{2\pi s}{25\overline{C}}\right)$$

where –

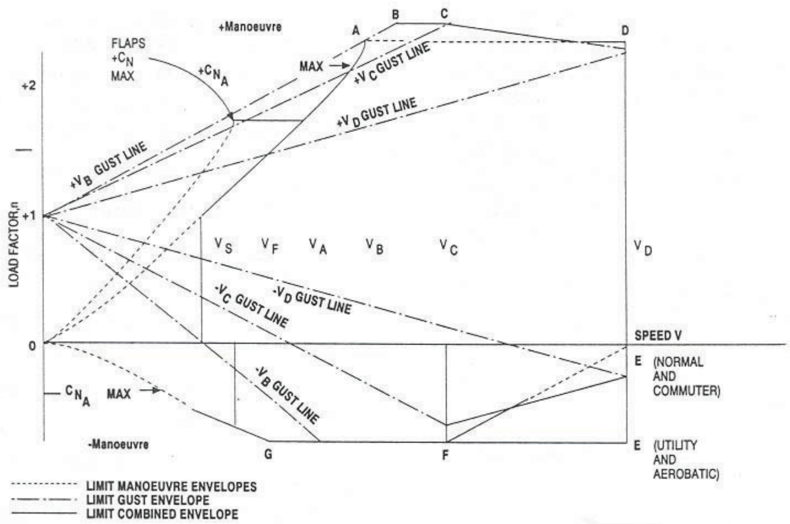
s = Distance penetrated into gust (ft.);

$\overline{C}$ = Mean geometric chord of wing (ft.); and

U_{de} = Derived gust velocity referred to in sub-paragraph (1) linearly with speed between V_C and V_D.

(ii) Gust load factors vary linearly with speed between V_C and V_D.

(d) *Flight envelope*



Note: Point G need not be investigated when the supplementary condition specified in CS 23.369 is investigated.

CS 23.335 Design airspeeds

Except as provided in sub-paragraph (a) (4) , the selected design airspeeds are equivalent airspeeds (EAS).

(a) *Design cruising speed, V_C.* For V_C the following apply:

(1) V_C (in knots) may not be less than –

(i) 33 $\sqrt{W/S}$ (for normal, utility and commuter category aeroplanes); and

(ii) 36 $\sqrt{W/S}$ (for aerobatic category aeroplanes).

where W/S = wing loading at design maximum take-off weight lb/ft^2.

(2) For values of W/S more than 20, the multiplying factors may be decreased linearly with W/S to a value of 28·6 where $W/S = 100$.

(3) V_C need not be more than 0·9 V_H at sea level.

(4) At altitudes where an M_D is established, a cruising speed M_C limited by compressibility may be selected.

(b) *Design dive speed, V_D.* For V_D the following apply:

(1) V_D/M_D may not be less than 1·25 V_C/M_C; and

(2) With $V_{C\,min}$, the required minimum design cruising speed, V_D may not be less than –

(i) 1·40 $V_{C\,min}$ for normal and commuter category aeroplanes;

(ii) 1·50 $V_{C\,min}$ for utility category aeroplanes; and

(iii) 1·55 $V_{C\,min}$ for aerobatic category aeroplanes.

(3) For values of W/S more than 20, the multiplying factors in sub-paragraph (2) may be decreased linearly with W/S to a value of 1·35 where $W/S = 100$.

(4) Compliance with sub-paragraphs (1) and (2) need not be shown if V_D/M_D is selected so that the minimum speed margin between V_C/M_C and V_D/M_D is the greater of the following:

(i) The speed increase resulting when, from the initial condition of stabilised flight at V_C/M_C, the aeroplane is assumed to be upset, flown for 20 seconds along a flight path 7·5° below the initial path and then pulled up with a load factor of 1·5 (0·5 g. acceleration increment). At least 75% maximum continuous power for reciprocating engines and maximum cruising power for turbines, or, if less, the power required for V_C/M_C for both kinds of engines, must be assumed until the pull-up is initiated, at which point power reduction and pilot-controlled drag devices may be used; and

(ii) Mach 0·05 for normal, utility, and aerobatic category aeroplanes (at altitudes where M_D is established).

(iii) Mach 0·07 for commuter category aeroplanes (at altitudes where M_D is established) unless a rational analysis, including the effects of automatic systems, is used to determine a lower margin. If a rational analysis is used, the minimum speed margin must be enough to provide for atmospheric variations (such as horizontal gusts, and the penetration of jet streams or cold fronts), instrument errors, airframe production variations, and must not be less than Mach 0·05.

(c) *Design manoeuvring speed V_A.* For V_A, the following applies:

(1) V_A may not be less than $V_S\sqrt{n}$ where –

(i) V_S is a computed stalling speed with flaps retracted at the design weight, normally based on the maximum aeroplane normal force coefficients, C_{NA}; and

(ii) n is the limit manoeuvring load factor used in design.

(2) The value of V_A need not exceed the value of V_C used in design.

(d) *Design speed for maximum gust intensity, V_B.* For V_B, the following applies:

(1) V_B may not be less than the speed determined by the intersection of the line representing the maximum positive lift $C_{N\,MAX}$ and the line representing the rough air gust velocity on the gust V-n diagram, or $V_{S1}\sqrt{n_g}$, whichever is less, where –

(i) n_g the positive aeroplane gust load factor due to gust, at speed V_C (in accordance with CS 23.341), and at the particular weight under consideration; and

(ii) V_{S1} is the stalling speed with the flaps retracted at the particular weight under consideration.

(2) V_B need not be greater than V_C.

CS 23.337 Limit manoeuvring load factors

(a) The positive limit manoeuvring load factor n may not be less than –

(1) $2{\cdot}1+\dfrac{24000}{W+10000}$ for normal and commuter category aeroplanes (where W = design maximum take-off weight lb), except that n need not be more than 3·8;

(2) 4·4 for utility category aeroplanes; or

(3) 6·0 for aerobatic category aeroplanes.

(b) The negative limit manoeuvring load factor may not be less than –

(1) 0·4 times the positive load factor for the normal, utility and commuter categories; or

(2) 0·5 times the positive load factor for the aerobatic category.

(c) Manoeuvring load factors lower than those specified in this paragraph may be used if the aeroplane has design features that make it impossible to exceed these values in flight.

CS 23.341 Gust load factors
(See AMC 23.341 (b))

(a) Each aeroplane must be designed to withstand loads on each lifting surface resulting from gusts specified in CS 23.333(c).

(b) The gust load for a canard or tandem wing configuration must be computed using a rational analysis, or may be computed in accordance with sub-paragraph (c) provided that the resulting net loads are shown to be conservative with respect to the gust criteria of CS 23.333(c).

(c) In the absence of a more rational analysis the gust load factors must be computed as follows:

$$n = 1 \pm \frac{kg\,\rho o\,Ude\,Va}{2(W/S)}$$

where –

$$kg = \frac{0.88\mu g}{5.3+\mu g} = \text{gust alleviation factor;}$$

$$\mu g = \frac{2(W/S)}{\rho\bar{C}ag} = \text{aeroplane mass ratio;}$$

U_{de} = Derived gust velocities referred to in CS 23.333 (c) (m/s);

$\underline{\rho o}$ = Density of air at sea-level (kg/m^3)

ρ = Density of air (kg/m^3) at the altitude considered;

W / S = Wing loading due to the applicable weight of the aeroplane in the particular load case (N/m^2);

$\overline{C}$ = Mean geometric chord (m);

g = Acceleration due to gravity (m/sec^2);

V = Aeroplane equivalent speed (m/s); and

a = Slope of the aeroplane normal force coefficient curve C_{NA} per radian if the gust loads are applied to the wings and horizontal tail surfaces simultaneously by a rational method. The wing lift curve slope C_L per radian may be used when the gust load is applied to the wings only and the horizontal tail gust loads are treated as a separate condition.

CS 23.343 Design fuel loads (See AMC 23.343 (b))

(a) The disposable load combinations must include each fuel load in the range from zero fuel to the selected maximum fuel load.

(b) If fuel is carried in the wings, the maximum allowable weight of the aeroplane without any fuel in the wing tank(s) must be established as "maximum zero wing fuel weight" if it is less than the maximum weight.

(c) For commuter category aeroplanes, a structural reserve fuel condition, not exceeding fuel necessary for 45 minutes of operation at maximum continuous power, may be selected. If a structural reserve fuel condition is selected, it must be used as the minimum fuel weight condition for showing compliance with the flight load requirements prescribed in this sub-part and:-

(1) The structure must be designed to withstand a condition of zero fuel in the wing at limit loads corresponding to:

(i) 90 percent of the manoeuvring load factors defined in CS 23.337, and

(ii) Gust velocities equal to 85 percent of the values prescribed in CS 23.333(c).

(2) The fatigue evaluation of the structure must account for any increase in operating stresses resulting from the design condition of sub-paragraph (c)(1).

(3) The flutter, deformation, and vibration requirements must also be met with zero fuel in the wings.

CS 23.345 High lift devices (See AMC 23.345 (d))

(a) If flaps or similar high lift devices are to be used for take-off, approach or landing, the aeroplane, with the flaps fully extended at V_F, is assumed to be subjected to symmetrical manoeuvres and gusts within the range determined by –

(1) Manoeuvring, to a positive limit load factor of 2·0; and

(2) Positive and negative gust of 7.62 m (25 ft) per second acting normal to the flight path in level flight.

(b) V_F must be assumed to be not less than 1·4 V_S or 1·8 V_{SF}, whichever is greater, where—

(1) V_S is the computed stalling speed with flaps retracted at the design weight; and

(2) V_{SF} is the computed stalling speed with flaps fully extended at the design weight.

However, if an automatic flap load limiting device is used, the aeroplane may be designed for the critical combinations of airspeed and flap position allowed by that device.

(c) In determining external loads on the aeroplane as a whole, thrust, slip-stream and pitching acceleration may be assumed to be zero.

(d) The flaps, their operating mechanism and their supporting structures, must be designed for the conditions prescribed in sub-paragraph (a) . In addition, with the flaps fully extended at speed V_F the following conditions, taken separately, must be accounted for:

(1) A head-on gust having a velocity of 7.6 m (25 ft) per second (EAS), combined with propeller slipstream corresponding to 75% of maximum continuous power; and

(2) The effects of propeller slipstream corresponding to maximum take-off power.