CHAPTER A21
LOADS AND STRESSES ON RIBS AND FRAMES

A21.1 Introduction. For aerodynamic reasons the wing contour in the chord direction must be maintained without appreciable distortion. Unless the wing skin is quite thick, spanwise stringers must be attached to the skin in order to increase the bending efficiency of the wing. Therefore to hold the skin-stringer wing surface to contour shape and also to limit the length of stringers to an efficient column compressive strength, internal support or brace units are required. These structural units are referred to as wing ribs. The ribs also have another major purpose, namely, to act as a transfer or distribution unit. All the loads applied to the wing are reacted at the wing supporting points, thus these applied loads must be transferred into the wing cellular structure composed of skin, stringers, spars, etc., and then reacted at the wing support points. The applied loads may be only the distributed surface airloads which require relatively light internal ribs to provide this carry through or transfer requirement, to rather rugged or heavy ribs which must absorb and transmit large concentrated applied loads such as those from landing gear reactions, power plant reactions and fuselage reactions. In between these two extremes of applied load magnitudes are such loads as reactions at supporting points for ailerons, flaps, leading edge high lift units and the many internal dead weight loads such as fuel and military armament and other installations. Thus ribs can vary from a very light structure which serves primarily as a former to a heavy structure which must receive and transfer loads involving thousands of pounds.

Since the airplane control surfaces (vertical and horizontal stabilizer, etc.) are nothing more than small size wings, internal ribs are likewise needed in these structures.

The skin-stringer construction which forms the shell of the fuselage likewise needs internal forming units to hold the fuselage cross-section to contour shape, to limit the column length of the stringers and to act as transfer agents of internal and externally applied loads. Since a fuselage must usually have clear internal space to house the payload such as passengers in a commercial transport, these internal fuselage units which are usually referred to as frames are of the open or ring type. Fuselage frames vary in size and strength from very light former type to rugged heavy types which must transfer large concentrated loads into the fuselage shell such as those from landing gear reactions, wing reactions, tail reactions, power plant reactions, etc. The dead weight of all the payload and fixed equipment inside the fuselage must be carried to frames by other structure such as the fuselage floor system and then transmitted to the fuselage shell structure. Since the dead weight must be multiplied by the design acceleration factors, these internal loads become quite large in magnitude.

Another important purpose or action of ribs and frames is to redistribute the shear at discontinuities and practical wings and fuselages contain many cut-outs and openings and thus discontinuities in the basic structural layout.

A21.2 Types of Wing Rib Construction.

Figs. A21.1 to 6 illustrate the common types of wing construction. Fig. 1 illustrates a sheet metal channel for a leading edge 3

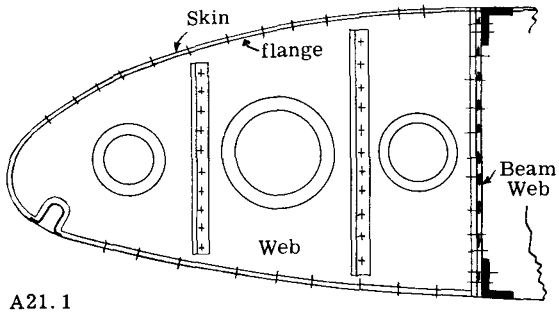


Fig. A21.1

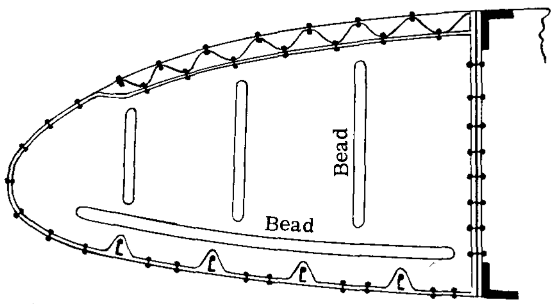


Fig. A21.2

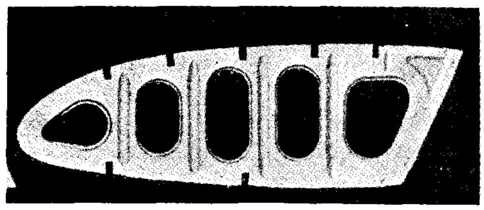


Fig. A21.3

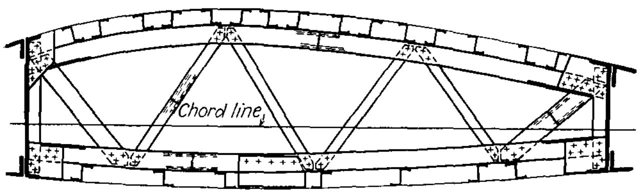
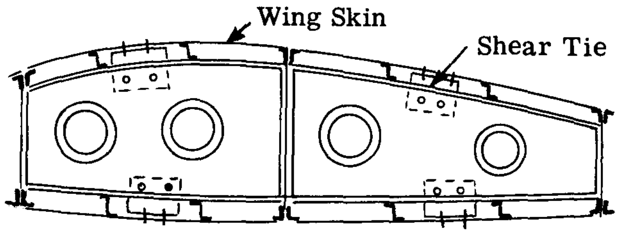


Fig. A21.4



Ribs in 3 Spar Wing.

Fig. A21.5

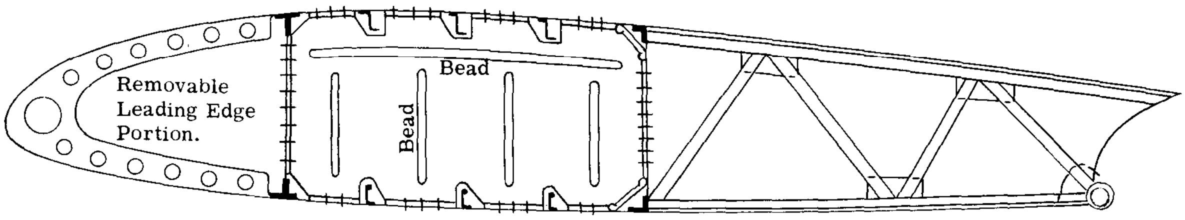


Fig. A21.6

stringer, single spar, single cell wing structure. The rib is riveted, or spot-welded, or glued to the skin along it boundary. Fig. 2 shows the same leading edge cell but with spanwise corrugations on the top skin and stringers on the bottom. On the top the rib flange rests below the corrugations, whereas the stringers on the bottom pass through cut-outs in the rib. Fig. 3 illustrates the general type of sheet metal rib that can be quickly made by use of large presses and rubber dies. Figs. 4 and 5 illustrate rib types for middle portion of wing section. The rib flanges may rest below stringers or be notched for allowing stringers to pass through. Ribs that are subjected to considerable torsional forces in the plane of the rib should have some shear ties to the skin. For ribs that rest below stringers this shear tie can be made by a few sheet metal angle clips as illustrated in Fig. 5. Fig. A21.7 shows an artist's drawing of the wing structure of the Beechcraft Bonanza commercial airplane. It should be noticed that various types and shapes of ribs and formers are required in airplane design. Photographs A21.1 to 3 illustrate typical rib construction in various type aircraft, both large and small. Since ribs compose an appreciable part of the wing structural weight, it is important that they be made as light as safety permits and also be efficient relative to cost of fabrication and assembly. Rib development and design involves considerable static testing to verify and assist the theoretical analysis and design.

A21.3 Distribution of Concentrated Loads to Thin Sheet Panels.

In Art. A21.1 it was brought out that ribs were used to transmit external loads into the wing cellular beam structure. Concentrated external loads must be distributed to the rib before the rib can transfer the load to the wing beam structure. In other words, a concentrated load applied directly to the edge of a thin sheet would cause sheet to buckle or cripple under the localized stress. Thus a structural element usually called a web stiffener or a web flange is fastened to the web and the concentrated load goes into the stiffener which in turn transfers the load to the web. To get the load into the stiffener usually requires an end fitting. In general the distributed air loads on the wing surface are usually of such magnitude that the loads can be distributed to rib web by direct bearing of flange normal to edge of rib web without causing local buckling, thus stiffeners are usually not needed to transfer air pressures to wing ribs.

EXAMPLE PROBLEM ILLUSTRATING TRANSFER OF CONCENTRATED LOAD TO SHEET PANEL.

Fig. A21.8 shows a cantilever beam composed of 2 flanges and a web. A concentrated load of 1000 lb. is applied at point (A) in the direction shown. Another concentrated load of 1000 lb. is applied at point (E) as shown.

To distribute the load of 1000 lb. at (A), a horizontal stiffener (AB) and a vertical stiffener (CAD) are added as shown. A fitting would be required at (A) which would be attached to both stiffeners. The horizontal component of the 1000 lb. load which equals 800 lb. is taken by the stiffener (AB) and the vertical component which equals 600 lb. is taken by the

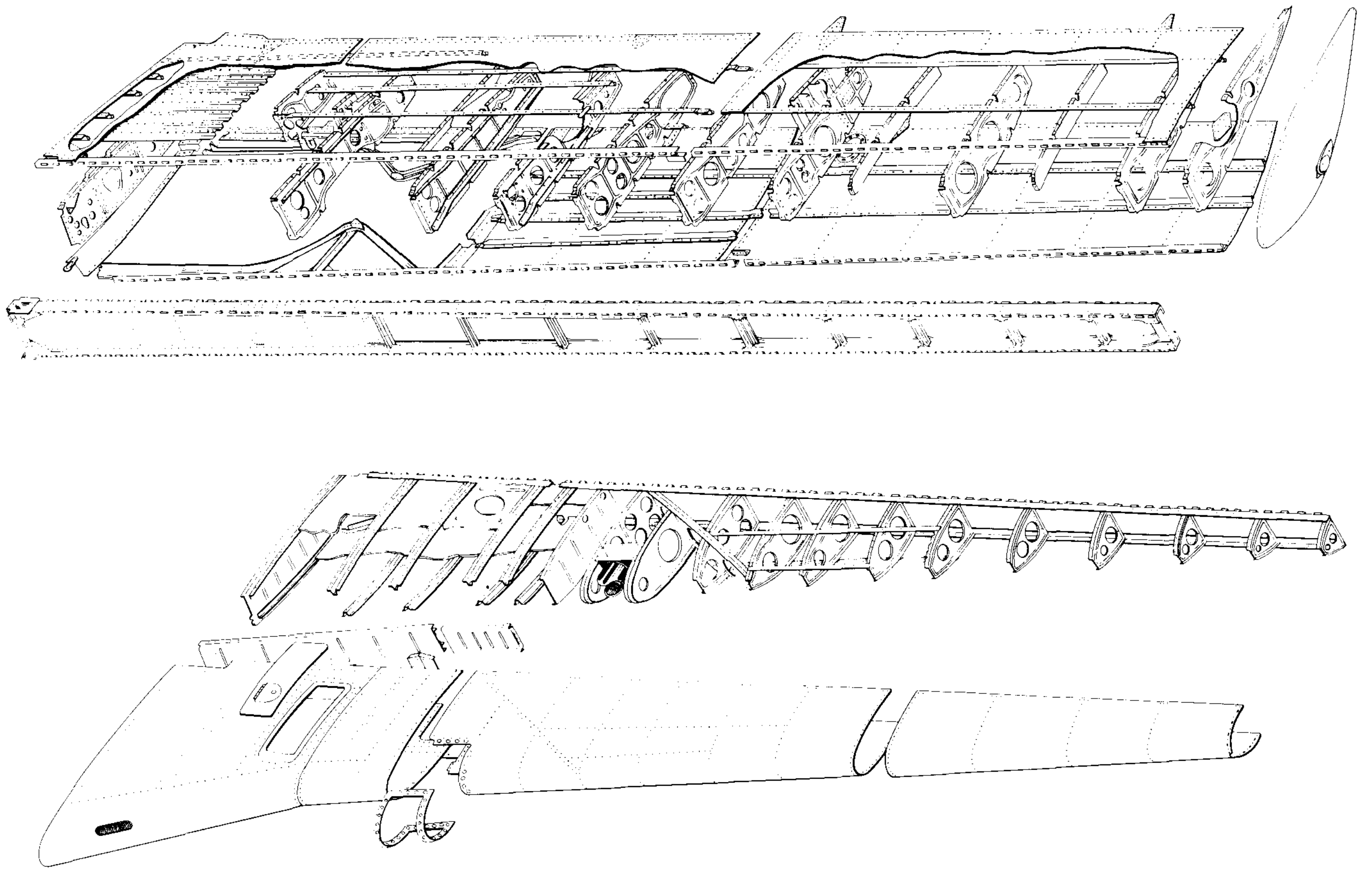


Fig. A21.7 General Structural Details of Wing for Beechcraft "Bonanza" Commercial Airplane.

vertical stiffener CD. The vertical load at E would be transferred to stiffener EF through fitting at E. The problem is to find the shear flows in the web panels, the stiffener loads and the beam flange loads.

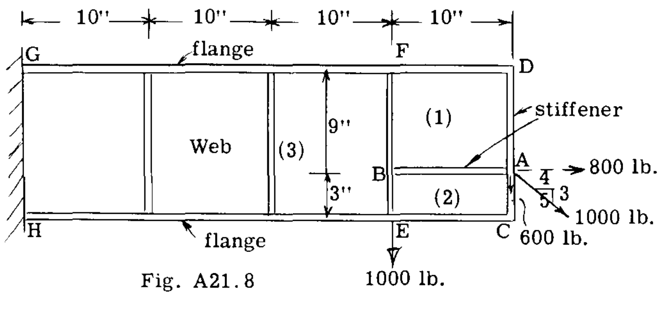


Fig. A21.8

SOLUTION: It will be assumed that the beam flanges develop the entire resistance to beam bending moments, thus shear flow is constant on a web panel.

The shear flows on web panels (1) and (2) will be computed treating each component of the 1000 lb. load as acting separately and the results added to give the final shear flow.

Figs. A21.9 and A21.10 show free bodies of that portion including web panels (1) and (2) and stiffeners CAD and AB and the external load at (A). In Fig. A21.9 the shear flows q_1 and q_2

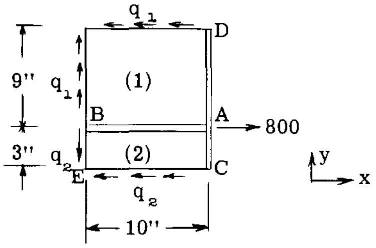


Fig. A21.9

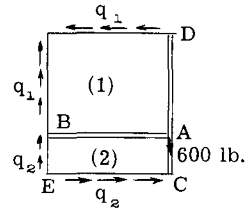


Fig. A21.10

on the top and bottom edges respectively have been assumed with the sense as shown. Taking moments about point E,

$\Sigma M_E = 800 \times 3 - 12 \times 10q_1 = 0$, whence $q_1 =$ 20 lb./in.

$\Sigma F_X = 800 - 20 \times 10 - 10q_2 = 0$, whence $q_2 =$ 60 lb./in.

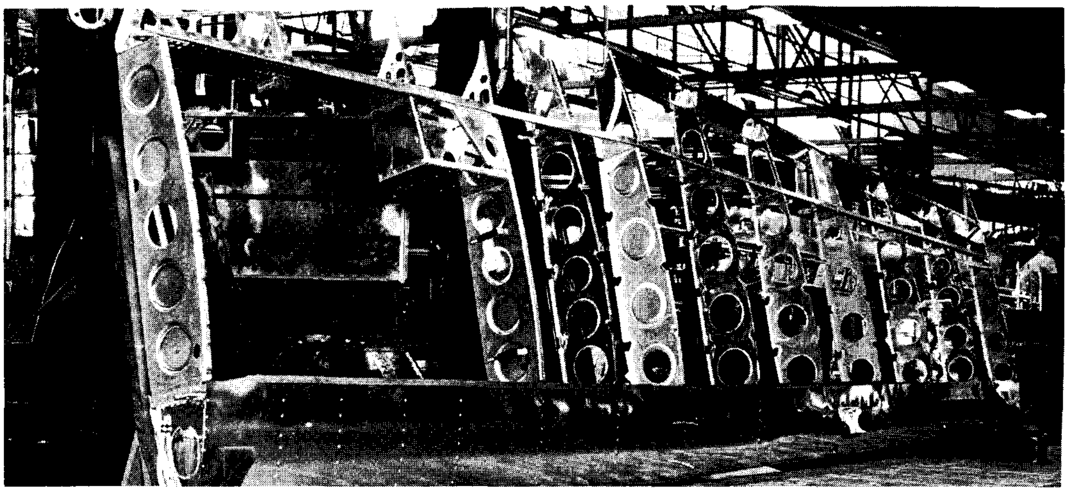


PHOTO. A21.1 Type of Wing Ribs Used in Cessna 180 Model Airplane, a 4 Place Commercial Airplane.

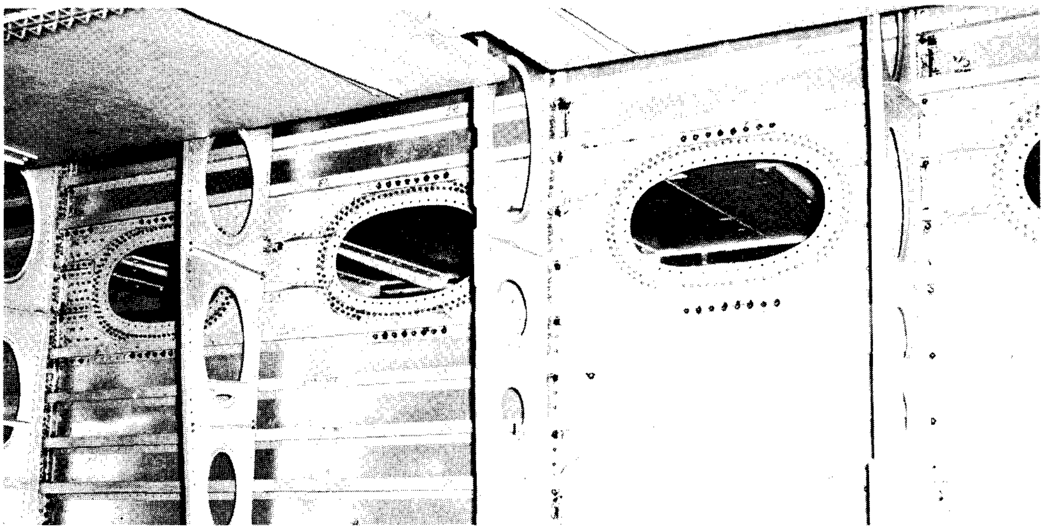


PHOTO. A21.2 Rib Type Used in Outer Panel-Fuel Tank Section- of Douglas DC-8 Commercial Jet Airliner.

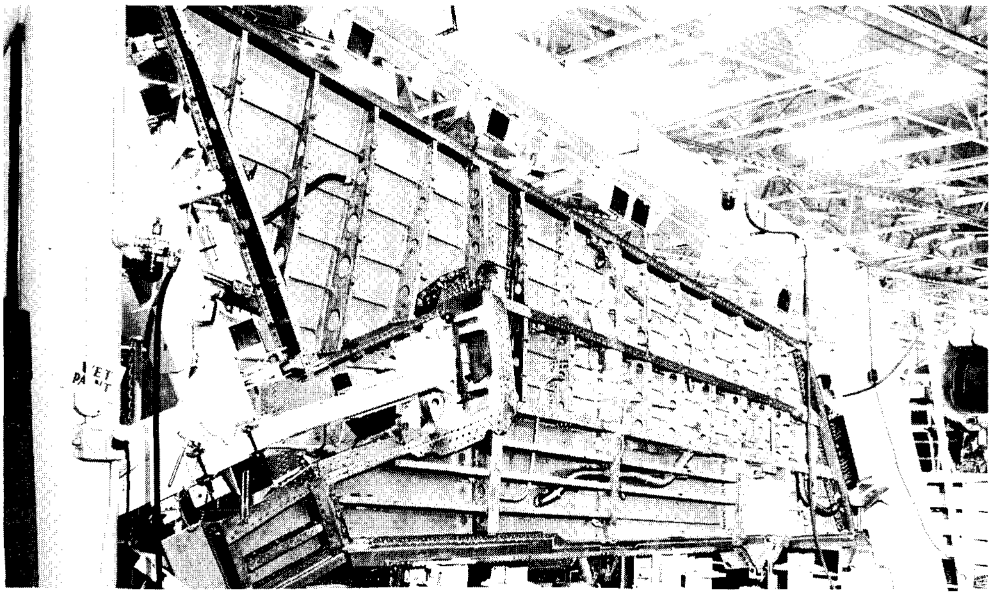


PHOTO. A21.3 Rib Construction and Arrangement in High Speed, Swept Wing, Fighter Type of Aircraft. North American Aviation - Navy Fury - Jet Airplane.

Referring to Fig. A21.10,

$\Sigma M_E = 600 \times 10 - 12 \times 10 q_1 = 0$, whence $q_1 =$ 50 lb. in.

$\Sigma F_X = -50 \times 10 + 10 q_2 = 0$, whence $q_2 =$ 50 lb./in.

Combining the two shear flows for the two loads,

$q_1 = 20 + 50 = 70$ lb./in.

$q_2 = 60 - 50 = 10$ lb./in.

Fig. A21.11 shows the results. Fig. A21.12 shows stiffener AB as a free body, and Fig. A21.13 the axial load diagram on stiffener AB, which comes directly from Fig. A21.11 by starting at one end and adding the shear flows.

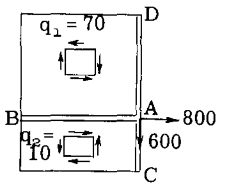


Fig. A21.11

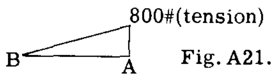


Fig. A21.13

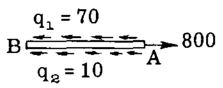


Fig. A21.12

Fig. A21.14 shows a free body of the vertical stiffener CAD, and Fig. A21.15 the axial load diagram for the stiffener.

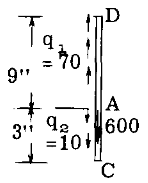


Fig. A21.14

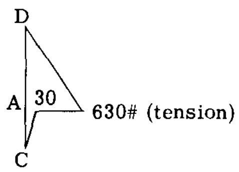


Fig. A21.15

The shear flows q_1 and q_2 could of course be determined using both components of forces at (A) acting simultaneously. For example, consider free body in Fig. A21.15a.

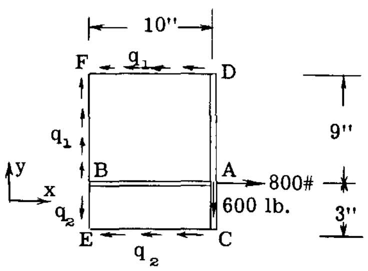


Fig. A21.15a

$\Sigma F_X = 800 - 10 q_1 - 10 q_2 = 0$ - - - - - (1)

$\Sigma F_y = -600 + 9 q_1 - 3 q_2 = 0$ - - - - - - (2)

Solving equations (1) and (2) gives,

$q_1 = 70$ lb./in., $q_2 = 10$ lb./in., which checks first solution.

The shear flow q_3 in web panel (3) is obtained by considering stiffener EBF as a free body, see Fig. A21.16.

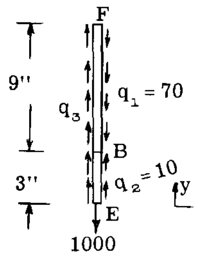


Fig. A21.16

$\Sigma F_y = 12 q_3 + 10 \times 3 - 9 \times 70 - 1000 = 0$

whence, $q_3 = 133.33$ lb./in.

The shear flow q_3 could also be found by treating entire beam to right of section through panel (3). For this free body,

$\Sigma F_y = -600 - 1000 + 12 q_3 = 0$

whence, $q_3 = 133.33$

Fig. A21.17 shows diagram of axial load in stiffener EF as determined from Fig. A21.16 by starting at one end and adding up the forces to any section.

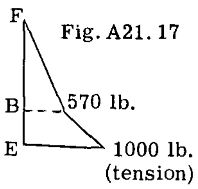


Fig. A21.17

After the web shear flows have been determined the axial loads in the beam flanges follow as the algebraic sum of the shear flows. Fig. A21.18 shows the shear flows along each beam flange as previously found. The upper and lower beam flange loads are indicated by the diagrams adjacent to each flange.

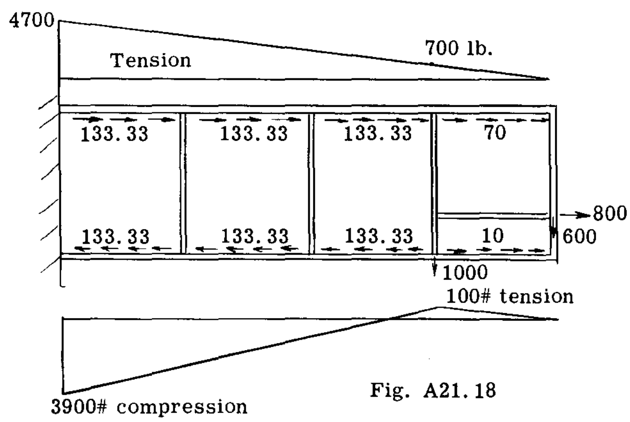


Fig. A21.18

In this example problem the applied external load at point (A) was acting in the plane of the beam web, thus two stiffeners were sufficient to take care of its two components. Often loads are applied which have three rectangular components. In this case, the structure should be arranged so that line of action of applied force acts at intersection of two webs as illustrated in Fig. A21.19 where a load P is applied at point (0) and its components P_z, P_y

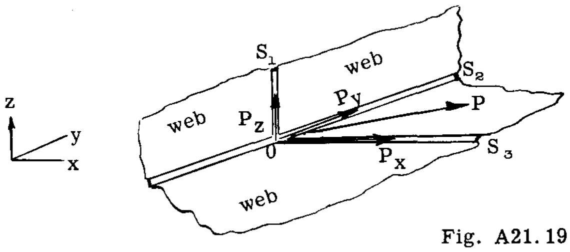


Fig. A21.19

and P_x are distributed to the web panels by using three stiffeners S_1, S_2 and S_3 intersecting at (0).

In cases where a load must be applied normal to the web panel, the stiffener must be designed strong enough or transfer the load in bending to adjacent webs.

In this chapter, the webs are assumed to resist pure shear along their boundaries. In most practical thin web structures, the webs will buckle under the compressive stresses due to shear stresses and thus produce tensile field stresses in addition to the shear stresses. The subject of tension field beams is discussed in detail in Volume II. In general the additional stresses due to tension field action can be superimposed on those found for the non-buckling case as explained in this chapter.

STRESSES IN WING RIBS

A21.4 Rib for Single Cell 2 Flange Beam.

Fig. A21.20 illustrates a rib in a 2-flange single cell leading edge type of beam. Assume that the air-load on the trailing edge portion (not shown in the figure) produces a couple reaction P and a shear reaction R as shown. These loads are distributed to the cell walls by the rib which is fastened continuously to the cell walls. Let q = shear flow per inch on rib perimeter which is necessary to hold rib in equilibrium under the given loads P and R.

Taking moments about some point such as (1) of all forces in the plane of the rib:

$$\Sigma M_1 = -Ph + 2Aq = 0$$

hence

$$q = Ph/2A. \quad (A = \text{enclosed area of cell})$$

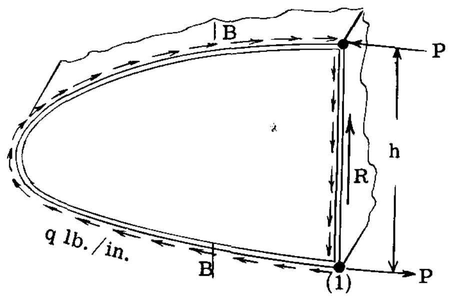


Fig. A21.20

With q known the shear and bending moment at various sections along the rib can be determined. For example, consider the section at B-B in Fig. A21.20. Fig. A21.21 shows a free body of the portion forward of this section.

The bending moment at section B-B equals:

$M_B = 2qA_1$ where A_1 is the area of the shaded portion.

Let F_x equal the horizontal component of the flange load at this section.

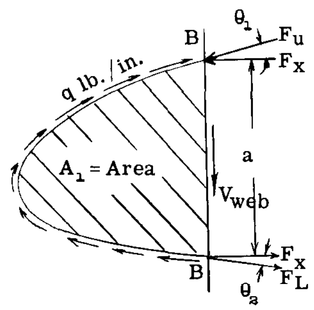


Fig. A21.21

$$F_x = M_B/a = 2qA_1/a$$

The true upper flange load $F_u = F_x/\cos\theta_1$ and the lower flange load equals $F_L = F_x/\cos\theta_2$.

The vertical shear on the rib web at B-B equals the vertical component of the shear flow q minus the vertical components of the flange loads. Hence

$$V_{web} = q\,a - F_x \tan\theta_1 - F_x \tan\theta_2$$
$$= q\,a - \frac{2\,q\,A_1}{a}(\tan\theta_1 + \tan\theta_2)$$

Illustrative Problem

The rib in the leading edge portion of the wing as illustrated in Fig. A21.22 will be analyzed.

A distributed external load as shown will be assumed.

Solution:

The total air load aft of beam = 8 x 40/2 = 160 lb. The arm to its c.g. location from the beam equals 40/3 = 13.33". Hence the reactions at the beam flange points due to the loads on the trailing edge portion equals:

P = 160 x 13.33/10 = 213.2 lb. (See Fig. A21.23)

Shear reaction V_r = 160 lb.

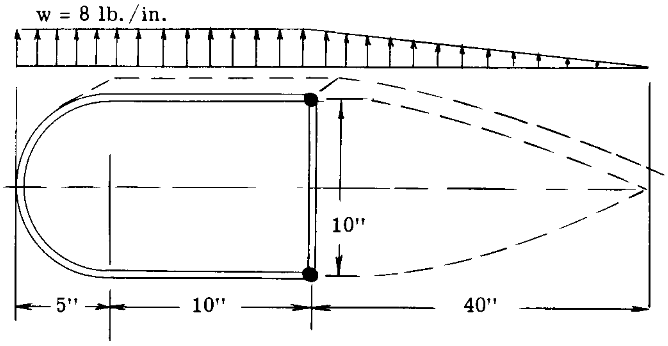


Fig. A21.22

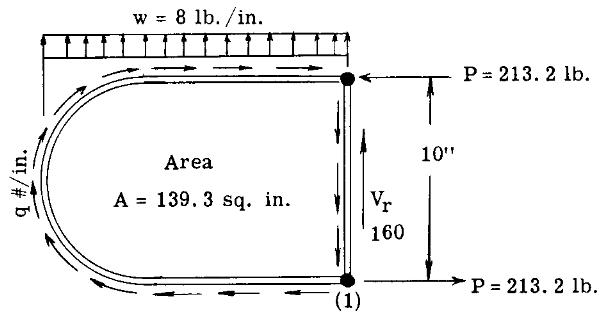


Fig. A21.23

Let q be the constant flow reaction of the cell skin on the rib perimeter which is necessary to hold the rib in equilibrium under the applied air loads.

Take moments about some point such as the lower flange (1).

$$\Sigma M = -213.2 \times 10 + 8 \times 15 \times 7.5 + 2 \times 139.3\, q = 0$$

whence, q = 1232/278.6 = 4.42 lb./in.

With the applied forces on the rib known, the shears and bending moments at various sections as desired can be calculated. For example, consider a section B-B, 2.5" from the leading edge. Fig. A21.24.

Bending moment at section B-B =

$$8 \times 2.5 \times 1.25 + 4.42 \times 2 \times 15.4 = 161 \text{ in.lb.}$$

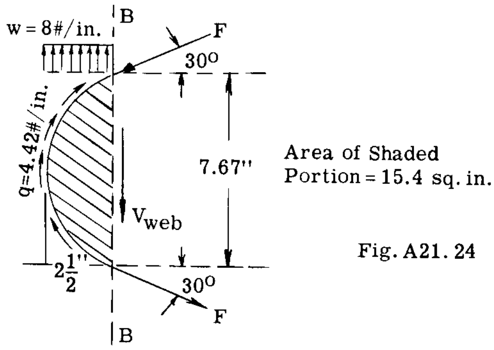


Fig. A21.24

A21.5 Stresses in Rib for 3 Stringer Single Cell Beam.

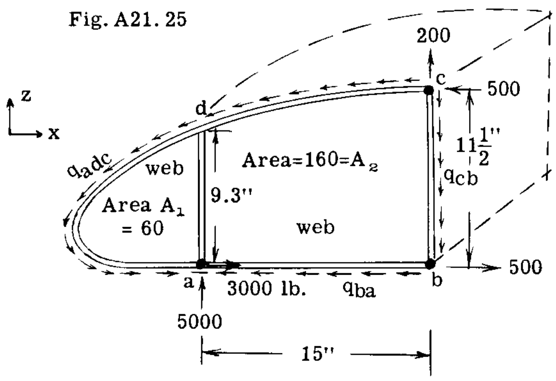
Fig. A21.25 shows a rib that fits into a single cell beam with 3 stringers labeled (a), (b) and (c). An external load is applied at point (a) whose components are 5000 and 3000 lbs. as shown. Additional reactions from a trailing edge rib are shown at points (b) and (c). A vertical stiffener ad is necessary to distribute the load of 5000 lb. at (a). The following values will be determined: -

(1) Rib web shear loads on each side of stiffener ad.

(2) Rib flange load at section ad.

(3) Rib flange and web load at section just to left of line bc.

Fig. A21.25



SOLUTION. It will be assumed that the 3 stringers develop the entire wing beam bending resistance, thus the wing shear flow is constant between the stringers. The wing rib is riveted to the wing skin and thus the edge forces on the rib boundary will be assumed to be the same as the shear flow distribution. In other words, the three shear flows q_{adc}, q_{ba} and q_{cb} hold the external loads in equilibrium. The sense of these 3 unknown shear flows will be assumed as shown in Fig. A21.25.

To find q_{adc}, take moments about point (b)

$$\Sigma M_b = -2(A_1 + A_2)\ q_{adc} + 5000 \times 15 - 500 \times 11.5 = 0$$

$$= -2(60 + 160)\ q_{adc} + 75000 - 5750 = 0$$

whence, q_{adc} = 157.3 lb./in. with sense as assumed.

To find q_{cb} take $\Sigma F_z = 0$

$$\Sigma F_z = 5000 + 200 - 157.3 \times 11.5 - 11.5\ q_{cb} = 0$$

whence, q_{cb} = 295 lb./in.

To find q_{ba} take $\Sigma F_x = 0$

$$\Sigma F_x = -500 + 3000 + 500 - 157.3 \times 15 - 15\ q_{ba} = 0$$

whence, q_{ba} = 42.7 lb./in.

With these supporting skin forces on the rib boundary, the rib is now in equilibrium and thus the web shears and flange loads can be determined. Consider as a free body that portion of the rib just to the left of the stiffener ad centerline as shown in Fig. A21.26.

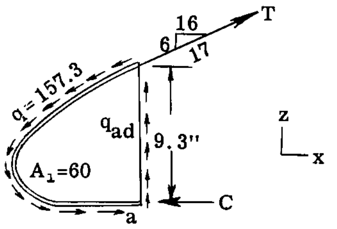


Fig. A21.26

To find flange load T take moments about point (a),

$$\Sigma M_a = (16/17)T \times 9.3 - 157.3 \times 60 \times 2 = 0$$

whence, T = 2158 lb.

To find flange load C take $\Sigma F_x = 0$

ΣF_x = 2158 (16/17) - C = 0, whence C = 2034 lb.

To find web shear q_{ad} take $\Sigma F_z = 0$

$$\Sigma F_z = 2158\ (6/17) - 157.3 \times 9.3 + 9.3\ q_{ad} = 0$$

whence, q_{ad} = 74.6 lb./in.

To find the shear in the web just to right of stiffener ad, consider the free body formed by cutting through the rib on each side of the stiffener attachment line as shown in Fig. A21.27. The forces as found above are shown on this free body.

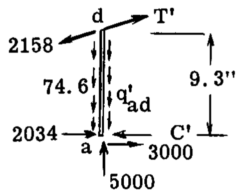


Fig. A21.27

To find web shear q'_{ad} take $\Sigma F_z = 0$

$$\Sigma F_z = 5000 - 9.3 \times 74.6 - 9.3\ q'_{ad} = 0$$

whence, q'_{ad} = 463 lb./in.

To find flange load C' take $\Sigma F_x = 0$, considering joint (a) as a free body,

ΣF_x = 2034 + 3000 - C' = 0, whence, C' = 5034 lb.

At joint (d) T' obviously equals 2158 lb. The stiffener ad carries a compressive load of 5000 lb. at its (a) end and decreases uniformly by the amount equal to the two shear flows or 463 + 74.6 = 537.6 lb./in.

The results obtained by considering Fig. A21.27 could also be obtained by treating the entire rib portion to the left of a section just to right of stiffener ad, as shown in Fig. A21.28.

To find rib flange load T' take moments about point (a).

$$\Sigma M_a = (16/17)\ T' \times 9.3 - 157.3 \times 60 \times 2 = 0$$

whence, T' = 2158 lb.

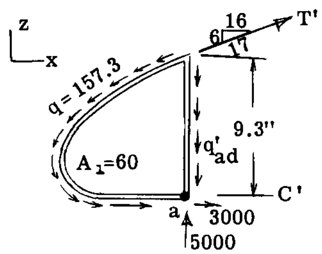


Fig. A21.28

To find flange load C' take $\Sigma F_x = 0$

$$\Sigma F_x = -C' + 3000 + 2158(16/17) = 0$$

whence, C' = 5034 lb.

To find q'_{ad} take $\Sigma F_z = 0$

$$\Sigma F_z = 2158(6/17) - 157.3 \times 9.3 + 5000 - 9.3\ q'_{ad} = 0$$

whence, q'_{ad} = 463 lb./in.

The above values are the same as previously obtained.

The rib flange loads and web shear will be calculated for a section just to left of line cb. Fig. A21.29 shows the free body for the rib to left of this section.

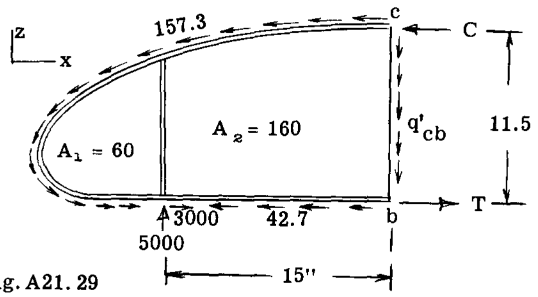


Fig. A21.29

To find flange load C take moments about point (b).

$$\Sigma M_b = -157.3 \times 2\ (160 + 60) + 5000 \times 15 - 11.5\ C = 0$$

whence, C = 500 lb.

To find flange load T take $\Sigma F_x = 0$

$$\Sigma F_x = 3000 - 157.3 \times 15 - 15 \times 42.7 - 500 + T = 0$$

whence, T = 500 lb.

To find q'_{cb} take $\Sigma F_z = 0$

$$\Sigma F_z = 5000 - 157.3 \times 11.5 - 11.5\ q'_{cb} = 0$$

whence, q'_{cb} = 278 lb./in.

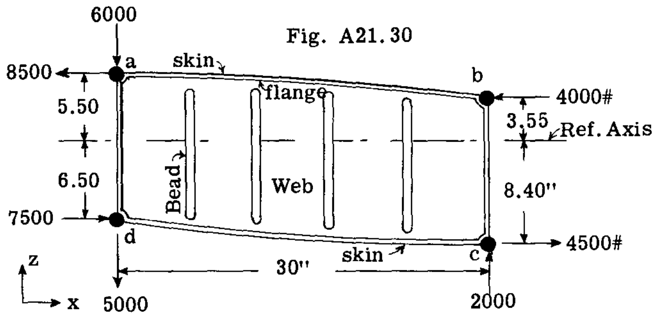
The above results could have been obtained with less numerical work by considering the forces to right of section cb in Fig. A21.29.

A21.6 Stress Analysis of Rib for Single Cell Multiple Stringer Wing.

When there are more than three spanwise stringers in a wing, there are four or more panels in the cell walls, thus the reactions of the cell walls upon the rib boundary cannot be found by statics as was possible in the 3 stringer case of the previous example problem.

Fig. A21.30 illustrates a wing section consisting of four spanwise flange members. The concentrated loads acting at the four corners of the box might be representative of reactions from the engine mount or nacelle structure and the reactions from a rib which supports the wing flap. These loads must be distributed into the walls of the wing box beam which necessitates a rib. Before the rib can be designed, the bending and shear forces on the rib must be determined. The calculations which follow illustrate a method of procedure.

Fig. A21.30



SOLUTION:

The total shear load on the wing in the Z direction equals V_Z = -6000 - 5000 + 2000 = -9000 lb. and V_X = -8500 + 7500 - 4000 + 4500 = -500 lb.

The boundary forces on the rib will be equal to the shear flow force system on the cell walls due to the given external force system.

From Chapter A14, page A14.8, equation (14), the expression for shear flow is,

$$q_y = -(K_3 V_X - K_1 V_Z)\ \Sigma xA - (K_2 V_Z - K_1 V_X)\ \Sigma zA \quad (1)$$

The constants K depend on the section properties of the wing cross-section. Table A21.1 gives the calculation of the moment of inertia and product of inertia about centroidal Z and X axes. In this example the 4 stringers a, b, c and d have been considered as the entire effective material in resisting wing bending stresses.

TABLE A21.1

1	2	3	4	5	6	7	8	9	10	11
Flange No.	Area A	Z'	X'	AZ'	AZ'^2	AX'	AX'^2	AX' z'	$Z = Z' - \bar{Z}$	$X = X' - \bar{X}$
a	2.00	5.50	0	11.00	60.5	0	0	0	6.36	-11.8
b	1.25	3.55	30	4.43	15.72	37.50	1125	132.9	4.41	18.2
c	1.15	-8.40	30	- 9.66	82.20	34.50	1035	-289.8	-7.54	18.2
d	1.70	-6.50	0	-11.04	71.90	0	0	0	-5.64	-11.8
Σ	6.10			- 5.27	230.3	72.00	2160	-156.9		

$$\bar{z} = \Sigma AZ'/\Sigma A = -5.27/6.10 = -.865"$$

$$\bar{x} = \Sigma AX'/\Sigma A = 72.0/6.10 = 11.8"$$

Centroidal x and z moments of inertia:

$$I_X = 230.3 - 6.10 \times .865^2 = 225.8$$

$$I_Z = 2160 - 6.10 \times 11.8^2 = 1310$$

$$I_{XZ} = -156.9 - 610 \times -.865 \times 11.8 = -94.7$$

With the wing section properties known, the constants K can be calculated.

$$K_1 = I_{XZ}/(I_X I_Z - I_{XZ}^2)$$
$$= -94.7/(225.8 \times 1310 - 94.7^2) =$$
$$-94.7/286700 = -.00033$$

$$K_2 = I_Z/286700 = 1310/286700 = .00456$$

$$K_3 = I_X/286700 = 225.8/286700 = .000786$$

Substituting in equation (1),

$$q_y = -\left[.000786\ (-500) - (-.00033)(-9000)\right] \Sigma xA - \left[.00456\ (-9000) - (-.00033)(-500)\right] \Sigma zA$$

whence,

$$q_y = 3.363\ \Sigma xA + 41.205\ \Sigma zA \quad - - - - - \quad (2)$$

Since the shear flow at any point on the cell walls is unknown, it will be assumed zero on web ad, or imagine the web is cut as shown in Fig. A21.31. The static shear flows can now be found.

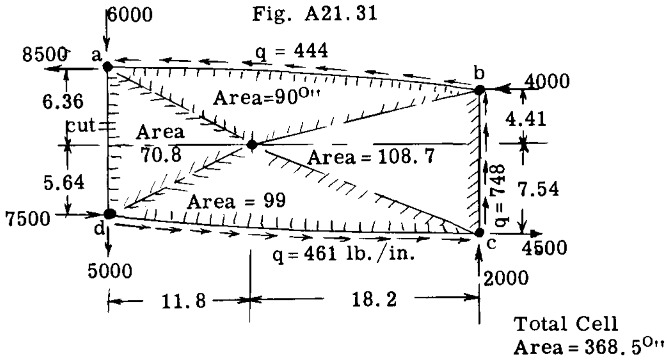
$$q_{ab} = 3.363\ (-11.8)(2.0) + 41.205 \times 6.36 \times 2 = 444 \text{ lb./in.}$$

$$q_{bc} = 444 + 3.363 \times 18.2 \times 1.25 + 41.205 \times 4.41 \times 1.25 = 748 \text{ lb./in.}$$

$$q_{cd} = 748 + 3.363 \times 18.2 \times 1.15 + 41.205\ (-7.54)(1.15) = 461 \text{ lb./in.}$$

These shear flows are plotted on Fig. A21.31. Refer to Chapter A14 regarding sense of shear flows.

Fig. A21.31



The moments of the forces in the plane of the rib will now be calculated:

Taking moments about the c.g. of the beam cross section (See Fig. A21.31):

$$\Sigma M_{c.g.} = -11000 \times 11.8 - 8500 \times 6.36 - 7500 \times 5.65 - 4000 \times 4.41 - 4500 \times 7.54 - 2000 \times 18.2 - 444 \times 2 \times 90 - 748 \times 2 \times 108.7 - 461 \times 2 \times 99 = -648400 \text{ in.lb.}$$

For equilibrium $\Sigma M_{c.g.}$ must equal zero, therefore a constant flow shear q_1 acting around the rib perimeter is necessary which will produce a moment of 648400 in.lb.

$$q_1 = \frac{M}{2A} = \frac{648400}{2 \times 368.5} = 880 \text{ lb./in.}$$

(Note: 368.5 = total area of cell)

Adding this shear flow to that of Fig. A21.31, the resulting force system of Fig. A21.32 is obtained. The reactions of the beam cell walls on the rib have now been determined and the bending moments and shears on the rib can now be calculated.

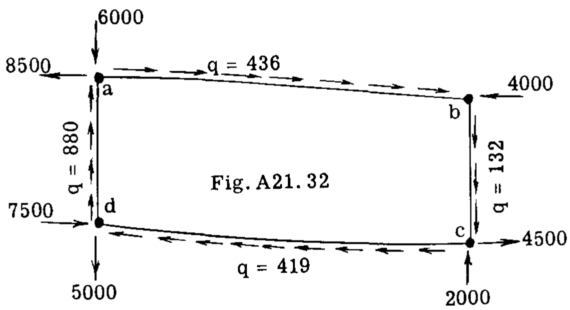
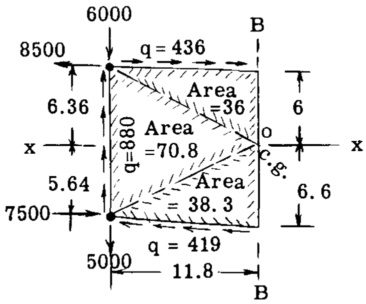


Fig. A21.32

To illustrate, consider the rib section B-B which passes through the c.g. of the beam section. Fig. A21.33 shows a free body of the bulkhead portion to the left of section B-B.



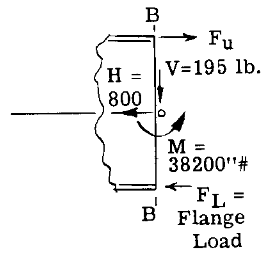


Fig. A21.33 Fig. A21.34

Moments at section B-B will be referred to the point (O):

$$\Sigma M_O = -11000 \times 11.8 - 8500 \times 6.36 - 7500 \times 5.64 + 436 \times 2 \times 36 + 880 \times 2 \times 70.8 + 419 \times 2 \times 38.3 =$$
$$-38200 \text{ in.lb.}$$

The resultant external shear force along the section B-B equals the summation of the z components of all the forces.

$$V = \Sigma F_z = -11000 + 12 \times 880 - 436 \times 0.36 + 419 \times 0.96 = -195 \text{ lb.}$$

The resultant load normal to the section B-B equals the summation of the force components in the x direction.

$$H = \Sigma F_x = -8500 + 7500 + (436 - 419)\ 11.8 = -800 \text{ lb.}$$

Fig. A21.34 shows these resultant forces referred to point (O) of the cross-section. If we assume that the rib flanges develop the entire resistance to normal stresses, we can find flange loads by simple statics.

To find upper flange load F_u take moments about lower flange point.

$$\Sigma M = 12.6\ F_u - 38200 - 800 \times 6.6 = 0$$

whence, $F_u = 3443$ lb. tension

To find F_L use $\Sigma F_x = 0$

$\Sigma F_x = 3443 - 800 - F_L = 0$, whence $F_L =$ 2643 lb. compression.

The shear flow on web equals V/12.6 = 195/12.6 = 15.5 lb./in. This result neglects effect of flanges not being normal to section B-B, which inclination is negligible in this case.

If the entire cross-section of rib is effective in bending, then the web thickness and flange sizes of the rib would be needed to obtain the section moment of inertia which is necessary in the beam equation for bending stresses. The forces at (O) would then be referred to neutral axis of section before bending and shear stresses on the rib section could be calculated.

To obtain a complete picture of the web and flange forces, several sections along the rib span should be analyzed as illustrated for section B-B.

A21.7 Rib Loads Due to Discontinuities in Wing Skin Covering.

As referred to before, ribs in addition to transmitting external loads to wing cell structure are also a means of re-distributing the shear forces at a discontinuity, the most common discontinuity being a cut-out in one or more of the webs or walls of the wing beam cross section. The usual procedure in finding the boundary forces on a rib located adjacent to a cut-out is to find the applied shear flows in the wing on two sections, one on each side of the rib. Then the algebraic sum of these two shear flows will give the rib boundary forces. With the boundary forces known the rib web and flange stresses can be found as previously illustrated. The procedure can best be illustrated by example problems.

A21.8 Example Problem. Wing with Cut-Out Subjected to Torsion.

Fig. A21.35 shows a rectangular single cell wing beam with four stringers or flanges located at the four corners. The upper surface skin is discontinued in the center bay (2). The wing is subjected to a torsional moment of

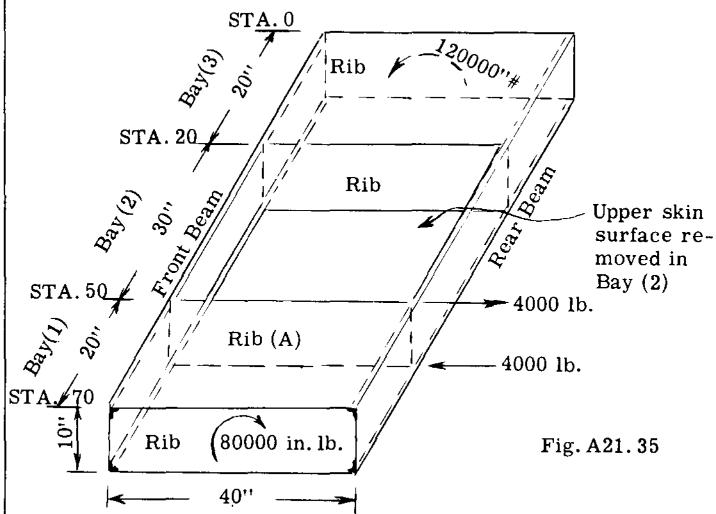


Fig. A21.35

80000 in.lb. at Station (70) and a couple force at Station (50) as shown in Fig. A21.35. The problem will be to determine the applied forces on rib (A).

SOLUTION:

The applied shear flow on the cell walls will be found for two cross-sections of the wing, one on each side of rib (A).

In bay (1) the torsional moment M is 80000 in.lb. The applied shear flow on a cross-section of the wing in bay (1) thus equals,

$$q = \frac{M}{2A} = \frac{80000}{2 \times 10 \times 40} = 100 \text{ lb./in.}$$

This shear flow system is shown on Fig. A21.36 which is a free body of rib (A). In bay (2), since the top skin is removed, the torsional moment must be taken by the front and rear vertical webs, since any shear flow in the bottom skin could not be balanced.

The torsional moment in bay (2) is,

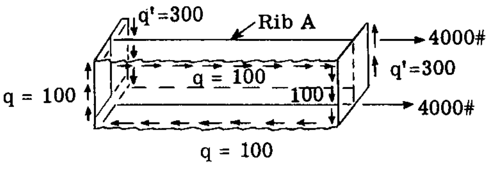
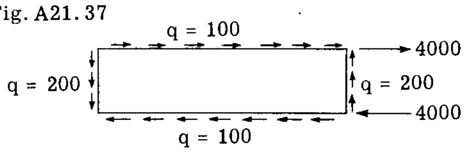


Fig. A21.36

M = 80000 + 4000 x 10 = 120000 in.lb.

The total shear load on each vertical web thus equals 120000/40 = 3000 lb., which gives a shear flow q' = 3000/10 = 300 lb./in. on each web. This applied shear is shown on the free body of rib (A) in Fig. A21.36. On the left end of the rib a shear flow of 100 is acting

Fig. A21.37



up and on the other side a shear flow of 300 is acting down, thus the rib web must take the difference or 200 acting down. On the right end of the rib the load on the rib web is 200 lb./in. up. The loads on the top and bottom flanges of the rib is obviously 100 lb./in. Fig. A21.37 shows the loads applied to the rib boundary when the torsion in bay (1) and the external couple force is transferred to the cross-section of bay (2).

<u>ADDITIONAL EFFECTS DUE TO DIFFERENTIAL BENDING OF BEAMS IN BAY (2).</u>

The torsion in bay (1) and the external couple force are thrown off as couple force on the front and rear beams of middle bay (2), with the total shear load on each beam being 3000 lb. as previously calculated. These beam shear loads must be transmitted to bay (3) and thus cause bending of the beams in bay (2). Since each beam is attached to relative rigid box structures at each end, namely bays (1) and (3), the beams tend to bend with no rotation of their ends. If we neglect the deflections of these end box structures, we can assume that the beams bend with no rotation of their ends or each beam is fixed ended. Fig. A21.38a illustrates the deflection of the front beam in bay (2) under the assumption of no end rotation. The beam elastic curve has a point of inflection at the span midpoint. Figs. 38b, c show the beams bending moment and shear diagrams.

The end moments are M = VL/2 = 3000 x 30/2 = 45000 in.lb. Assuming the beam flanges develop the entire bending resistance the beam

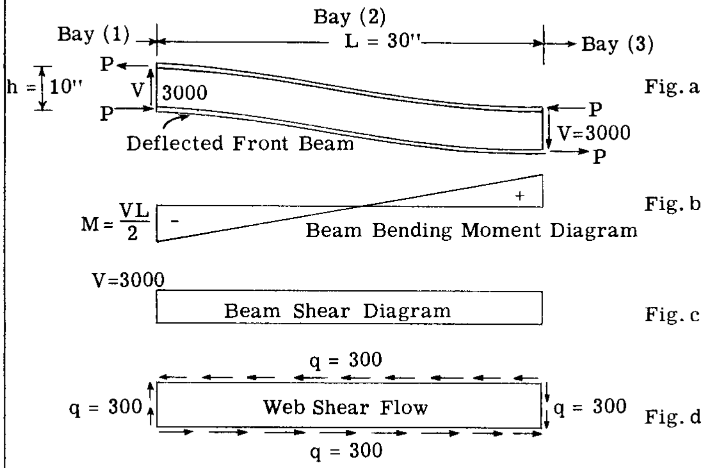


Fig. A21.38

flange loads at the beam ends are P = 45000/10 = 4500 lb. (See Fig. a).

The deflection of the rear beam would be the reverse of Fig. a, and thus all forces would also be reversed.

Fig. A21.39 shows bay (1) of the wing as a free body acted upon by the flange loads due to bending of the beams in bay (2). These internal flange forces from bay (2) must be held in equilibrium by the internal stresses in the adjacent wing structure of bay (1).

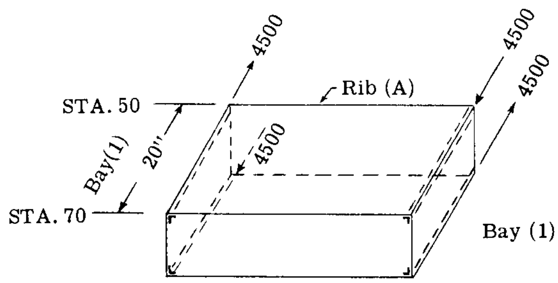


Fig. A21.39

According to the well known principle of mechanics formulated by Saint Vennat, the stresses resulting from such an internal force system will be negligible at a distance from the forces. This distance in case of a cut-out is usually assumed as approximately equal to the width of the cut-out, or in general to the width of the adjacent wing bay. Thus in Fig. A21.39 the flange loads of 4500 lbs. each are assumed to be dissipated at a uniform rate for a distance of 20 inches. Thus the shear flow created by each stringer load which equals the change in axial load per inch in the stringer in bay (1) equals 4500/20 = 225 lb.

Fig. A21.40 shows a segment 1 inch wide cut from wing bay (1) with the ΔP load in each flange member. To find the shear flow on the cross-section the front web is first assumed cut, and thus the static shear flow $q_s = \Sigma\Delta P$ from cut face where q_s is zero. Fig. A21.40 shows this static shear flow.

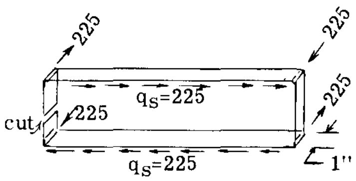


Fig. A21.40

For equilibrium of the cross-section, the moment of the forces in the plane of the cross-section must equal zero. Taking moments about lower left hand corner of the q_s force system,

$M = 225 \times 40 \times 10 = 90000$ in.lb. For equilibrium a moment of -90000 is necessary. Therefore a constant shear flow system q must be added to develop a moment of -90000. Thus $q = M/2A = (-90000/2 \times 10 \times 40) = -112.5$ lb./in. Adding this shear flow to that for q_s in Fig. A21.40 gives the final values in Fig. A21.41. This shear flow system represents the stress

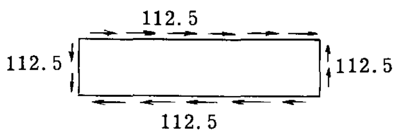


Fig. A21.41

system caused on cross-section of bay (1) due to the differential bending of the beams in bay (2). This shear flow system must therefore be resisted by rib (A) as it must terminate at end of bay (1). Therefore the shear flows in Fig. A21.41 are applied boundary loads to rib (A) and these must be added to the rib loads in Fig. A21.37 to give the final rib loads of Fig. A21.42. With the final rib loads

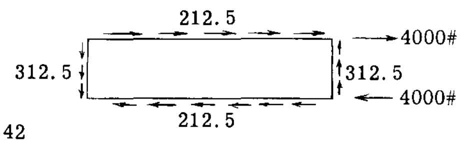


Fig. A21.42

known, the rib flange and web stresses can be found as previously explained.

A21.9 Example Problem. Wing with Cut-Out Subjected to Bending and Torsional Loads.

Fig. A21.43 shows a portion of a 4 stringer single cell cantilever beam composed of 3 bays formed by the four ribs. The loads on the structure consist of loads applied to end of bay (1) as shown. The areas of corner stringers a, b, c and d are shown in ( ) adjacent to each stringer.

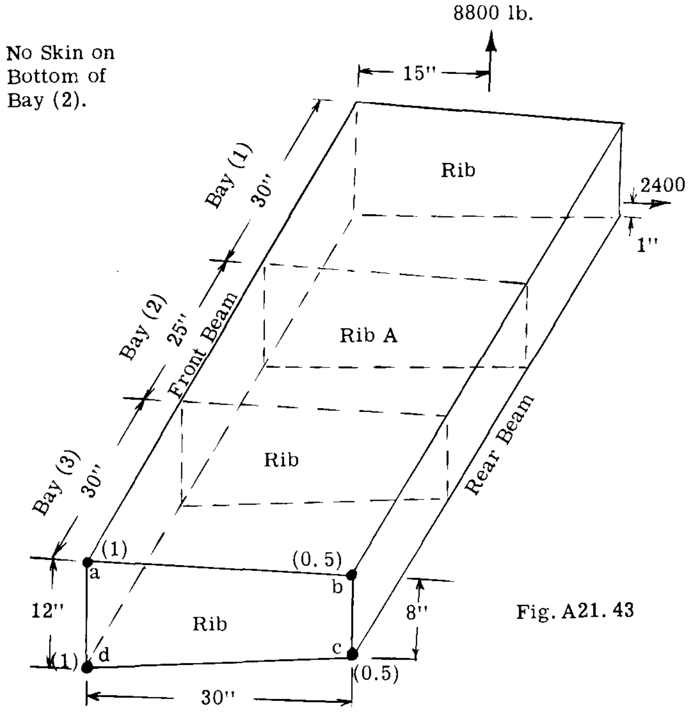


Fig. A21.43

The middle bay (2) has no skin on the bottom surface, or in other words, the middle bay has a channel cross-section, which fact often happens in practical wing design as for example a space or well for a retractable landing gear. The problem will be to find the shear flow in bays (1) and (2) and the boundary loads on rib (A) between bays (1) and (2).

Solution No. 1

This method of solution will make use of the shear center location for bay (2) in order to obtain the true torsional moment on bay (2). With this torsional moment known, the procedure is similar to the previous example involving wing torsion only.

We will first calculate the shear flow in wing bay (1). Fig. A21.44 shows the cross-section.

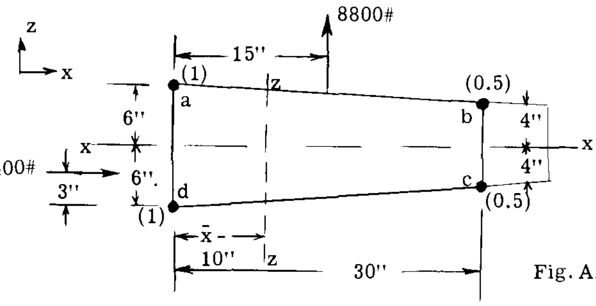


Fig. A21.44

The section moments of inertia are needed in calculating shear flows.

$$I_x = (1 \times 6^2 \times 2) + (0.5 \times 4^2 \times 2) = 88 \text{ in.}^4$$

$$\bar{X} = \Sigma Ax/\Sigma A = (1 \times 30)/3 = 10 \text{ in.}$$

$$I_z = (2 \times 10^2) + (1 \times 20^2) = 600 \text{ in.}^4$$

$$V_z = 8800 \text{ lb.}, \quad V_x = 2400 \text{ lb.}$$

$$q_y = -\frac{V_z}{I_x}\Sigma zA - \frac{V_x}{I_z}\Sigma xA, \text{ substituting}$$

$$q_y = -100\,\Sigma zA - 4\,\Sigma xA \text{ - - - - - - - - - - - (a)}$$

Since the shear flow is unknown at any point on cell, we will assume front web (ad) as cut or carrying zero shear.

$$q_{dc} = -100\,(-6)(1) - 4\,(-10)(1) = 640 \text{ lb./in}$$

$$q_{cb} = 640 - 100\,(-4)(0.5) - 4\,(20)\,0.5 = 800$$

$$q_{ba} = 800 - 100\,(4)(0.5) - 4\,(20)\,0.5 = 560$$

Fig. A21.45 shows these static shear flows.

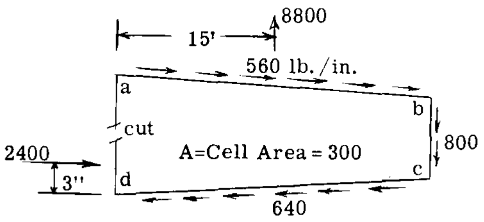


Fig. A21.45

To this shear flow, a constant shear flow must be added to make $\Sigma M = 0$. Take moments about point (d).

$$\Sigma M_d = -8800 \times 15 + 2400 \times 3 + 560 \times 30 \times 12 + 800 \times 8 \times 30 = 268800 \text{ in. lb., or } -266800$$

is required for equilibrium, hence the required constant shear flow $q = -M/2A = -268800/2 \times 300 = -448$. Adding this shear flow to that of Fig. A21.45, we obtain the shear flow of Fig. A21.46.

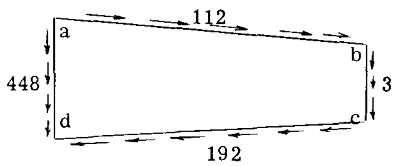


Fig. A21.46

This shear flow system would be the shear flow system for all 3 bays if the bottom skin in bay (2) was not removed. Removing the bottom skin in bay (2) will modify these shear flows of Fig. A21.46.

Therefore we consider bay (2) in its true condition with bottom skin removed. Fig. A21.47 shows the cross-section of bay (2).

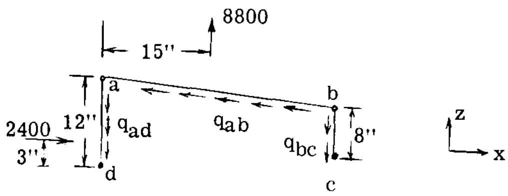


Fig. A21.47

The three shear flows can be determined by statics.

$$\Sigma F_x = 2400 - 30\,q_{ab} = 0, \text{ whence } q_{ab} = 80$$

$$\Sigma M_d = 2400 \times 3 - 8800 \times 15 - 80 \times 30 \times 12 + q_{bc}\,(8 \times 30) = 0, \text{ whence } q_{bc} = 640$$

$$\Sigma F_z = 8800 - 8 \times 640 + 2 \times 80 - 12\,q_{ad} = 0$$

$$\text{whence } q_{ad} = 320$$

Fig. A21.48 shows the results. This shear flow system is the final or true shear on bay (2).

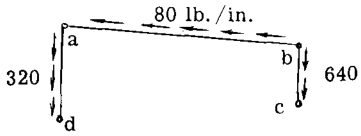


Fig. A21.48

Since we have a channel or open wing cross-section in bay (2), any torsional moment on this bay must be transmitted by differential bending of the front and rear beams. To obtain the torsional moment on bay (2), the shear center location must be known.

Horizontal location of shear center: - Assume the section bends about centroidal X axis without twist under a V_z load of 8800 lb.

$$q = -\frac{V_z}{I_x}\Sigma zA, \text{ or } q = -100\,\Sigma zA$$

$$q_{cb} = -100\,(-4)(0.5) = 200$$

$$q_{ba} = 200 - 100\,(4)(0.5) = 0$$

$$q_{ad} = 0 - 100\,(6)(1) = -600$$

Fig. A21.49 shows the shear flow results for bending about x-x without twist. The line of action of the resultant of this shear flow force system locates the horizontal position of the shear center.

$$\bar{X} = (200 \times 8 \times 30)/8800 = 5.45 \text{ in.}$$

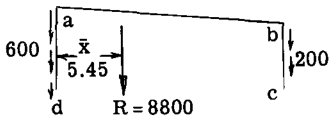


Fig. A21.49

Vertical position of shear center: -

Assume section bends about centroidal z axis without twist under a load of V_X = 2400 lb.

$$q = -\frac{V_X}{I_Z}\,\Sigma xA = -\,4\,\Sigma xA$$

$$q_{cb} = -4 \times 20 \times 0.5 = -\,40 \text{ lb./in.}$$

$$q_{ba} = -40 - 4 \times 20 \times 0.5 = -\,80$$

$$q_{ad} = -80 - 4\,(-10)\,1 = -40$$

Fig. A21.50 shows the shear flow results.

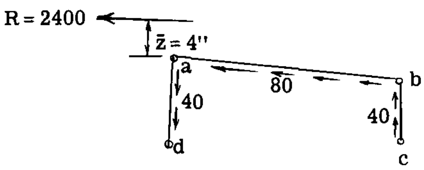


Fig. A21.50

The vertical distance $\bar{Z}$ from point (a) to the line of action of the resultant which locates the vertical location of shear center is,

$$\bar{Z} = \Sigma M_a/2400 = (40 \times 8 \times 30)/2400 = 4 \text{ in.}$$

Fig. A21.51 shows the shear center location and the external loads. The moment about the shear center which equals the torsion on the wing bay (2) equals,

$$M_{s.c.} = -\,8800 \times 9.55 - 2400 \times 13 = -115240 \text{ in.lb.}$$

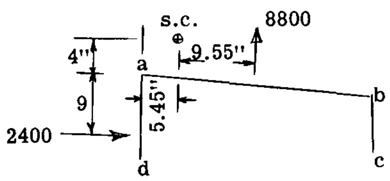


Fig. A21.51

This torsional moment must be resisted by front and rear beams. Hence shear load on each beam = 115240/30 = 3841·lb.

As in the previous example problem involving torsion, the beams in bay (2) will be assumed to bend without rotation of their ends, or in other words the bending moment at mid-point of bay is zero. The flange loads at points a, b, c and d on bay (1) from the differential bending of beams in bay (2), thus equal the beam shear times half the span of bay (2) divided by the beam depth.

For front beam P = 3841 x 12.5/12 = 4000 lb.

For rear beam P = 3841 x 12.5/8 = 6000 lb.

Fig. A21.52 shows these flange loads applied to bay (1). These loads are dissipated

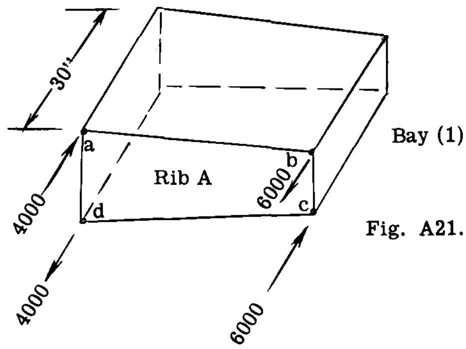


Fig. A21.52

uniformly in bay (1) over a distance of 30 inches, or the shear flow per inch produced by these flange loads equals ΔP = P/30, whence

$$\Delta P_a = \Delta P_d = 4000/30 = 133.3 \text{ and } \Delta P_b = \Delta P_c = 6000/30 = 200 \text{ lb.}$$

Fig. A21.53 shows an element of bay (1) one inch wide with these ΔP loads. The shear flow q assuming the front web cut equals ΣΔP. The resulting static shear flows which equals ΣΔP is shown in Fig. A21.53.

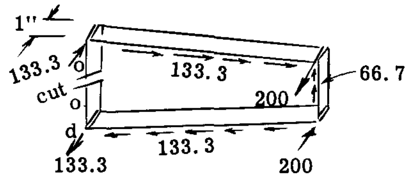


Fig. A21.53

The moment of this shear flow system about point (d) = 133.33 x 30 x 12 - 66.7 x 8 x 30 = 31980. For ΣM = 0, we need a constant shear flow q = - 31980/2 x 300 = -53.3 lb./in. Adding this constant shear flow to that of Fig. A21.53 gives the shear flow system of Fig. A21.54. These results represent the effect on bay (1)

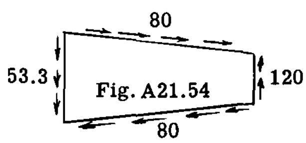


Fig. A21.54

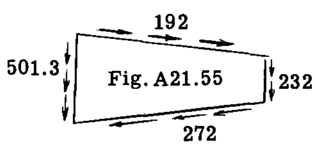


Fig. A21.55

of removing the bottom skin in bay (2). Adding the shear flows of Fig. A21.54 to those of Fig. A21.46, we obtain the final shear flows in bay (1) as shown in Fig. A21.55.

BOUNDARY LOADS ON RIB (A)

The boundary loads on rib (A) will equal the difference between the shear flows in bays (1) and (2). Fig. A21.56 shows a free body of rib (A) with the shears flows obtained from Figs. A21.55 and A21.48.

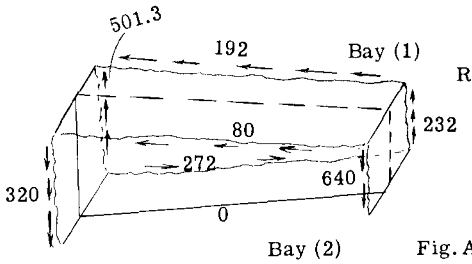


Fig. A21.56

The resulting applied boundary forces to the rib equal the algebraic sum of the shear flows on each side of the rib which gives the values in Fig. A21.57.

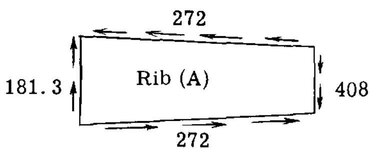


Fig. A21.57

With the rib boundary loads known, the stresses in the rib can be found as previously illustrated in this chapter.

Solution No. 2

This method of solution first finds the shear flow in all bays assuming bottom skin is not removed in center bay (2). This gives a shear flow in the bottom skin. However, the skin in bay (2) is actually removed so a corrective set of shear flows on bay (2) along the boundary lines of the bottom skin must be applied to eliminate the shear flows found in the bottom skin. The problem then consists of finding the influence of these corrective shear flows upon the shear flows as found for bays (1) and (2) when bottom skin in bay (2) was not removed.

The first step is to find the shear flows in all bays assuming bottom skin in bay (2) is not removed. The calculations would be exactly like those in solution (1) and the shear flow in all bays would be those in Fig. A21.46. The bottom skin in Fig. A21.46 has a shear flow of 192 with sense as shown. Since this skin is missing we reverse this shear flow and find the resisting shear flows on the other three sides of the bay cross-section. Fig. A21.58 shows the section, with the 3 unknown shear flows q_{ab}, q_{bc} and q_{ad}.

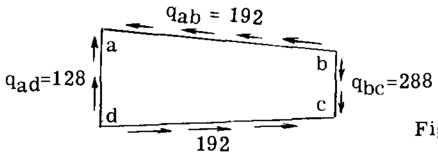


Fig. A21.58

To find q_{ab} use $\Sigma F_x = 0$, $192 \times 30 - 30\, q_{ab} = 0$ whence, $q_{ab} = 192$

$$\Sigma M_d = -30 \times 192 \times 12 + 8\, q_{bc} \times 30 = 0$$

whence, $q_{bc} = 288$

$$\Sigma F_z = 4 \times 192 - 8 \times 288 + 12\, q_{ad} = 0$$

whence, $q_{ad} = 128$

Adding the shear flows of Fig. A21.58 to those of Fig. A21.46 gives the final shear flows in bay (2) as shown in Fig. A21.59. These results check the results in Fig. A21.48 obtained in solution method (1).

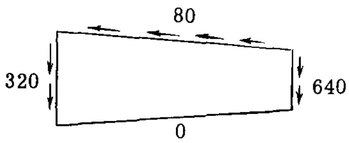


Fig. A21.59

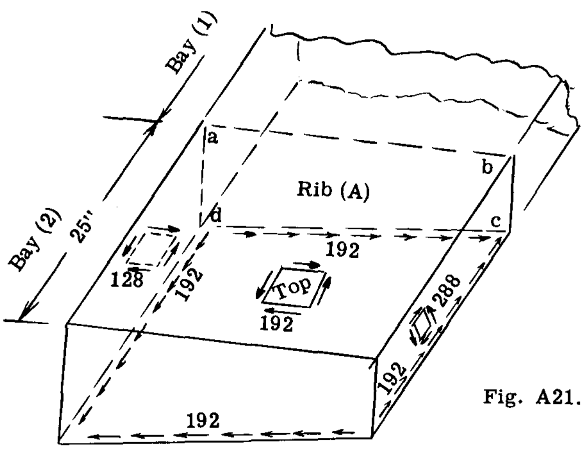


Fig. A21.60

Fig. A21.60 shows the corrective shear flows of Fig. A21.58 applied to bay (2). On the bottom skin the corrective shear flow is shown on the boundary of the cut-out. These shear flows cause differential bending of the front and rear beams in bay (2). If we make the assumption that the beam end suffer no rotation, the bending moment is zero at midpoint of the bay and thus the flange loads at points a, b, c and d of bay (1) equal the algebraic sum of the shear flows on each side of a flange times half the span of bay (2) or 12.5 inches. Thus from Fig. A21.60,

$$P_a = (192 + 128)12.5 = 4000 \text{ lb. compression}$$

$$P_b = (288 + 192)12.5 = 6000 \text{ lb. tension}$$

$$P_c = (288 + 192)12.5 = 6000 \text{ compression}$$

$$P_d = (128 + 192)12.5 = 4000 \text{ tension}$$

Referring to Fig. A21.52, we find that the P values above are the same as the P values obtained by solution (1). Thus the remainder of solution (2) would be identical to that in solution (1), and therefore the calculations will not be repeated here.

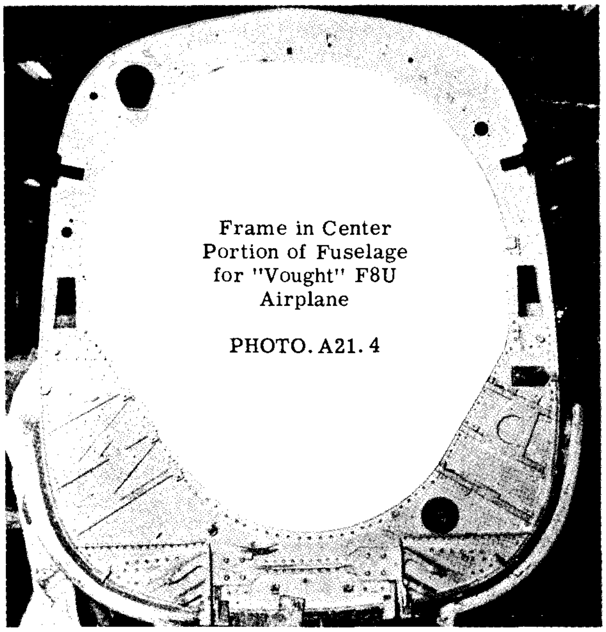
A21.10 Fuselage Frames

Frames in a fuselage serve the same purpose as ribs in wing structures. Ribs are usually of beam or truss construction and can be stress analyzed fairly accurately by statics. Fuselage frames however, are of the closed ring type of structure and are therefore statically indeterminate relative to internal stresses. Once the applied loads on a frame are known the internal stresses can be found by the application of the elastic theory as covered in Chapters A8, A9, A10 and A11. The loads on fuselage frames due to discontinuities in the fuselage structure, such as those due to windows and doors, can be approximately determined by the procedures previously presented for wing ribs.

The photographs on page 32 of Chapter A15 show some of the frame construction of the Douglas DC-8 airliner. Other pictures of fuselage construction are given in Chapter A20. Photographs A21.4 and 5 illustrate typical frame construction and arrangement.

A21.11 Supporting Boundary Forces on Fuselage Frames.

When external concentrated loads are applied to a fuselage frame through a suitable fitting or connection, the frame is held in equilibrium by reacting fuselage skin forces which are usually transferred to the frame boundary by rivets which fasten fuselage skin to frame. Since the fuselage shell is usually stress analyzed by the beam theory, it is therefore consistent to determine the distribution of the supporting skin forces by the same theory.



Frame in Center Portion of Fuselage for "Vought" F8U Airplane

PHOTO. A21.4

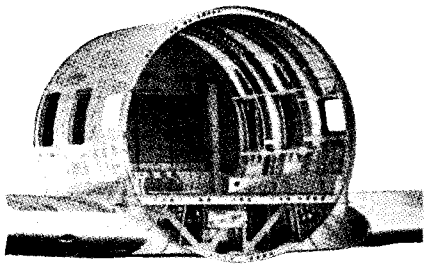


PHOTO. A21.5
Fuselage-Wing Portion of "Martin" 404 Transport

A21.12 Calculation of Frame Boundary Supporting Forces.

Example Problem 1

Fig. A21.61 illustrates a cross-section of a circular fuselage. Two concentrated loads of 2000 lb. each are applied to the fuselage frame at the points indicated. The problem is to determine the reacting shear flow forces in the fuselage skin which will balance the two externally applied loads. This fuselage section might be considered as the aft portion of a medium size fuselage and the loads are due to air loads on the horizontal tail surfaces. To make the numerical calculations short the fuselage stringer arrangement has been assumed symmetrical.

Solution:

In this solution the fuselage skin resisting forces will be assumed to vary according to the general beam theory. The general flexural shear flow equation for bending about the Y axis is,

$$q = -\frac{V_Z}{I_y}\Sigma zA \quad , \quad \text{where } V_Z = 4000 \text{ lb.}$$

The moment of inertia I_y of the fuselage cross-section is required. In this simplified illustration, the area of each stringer plus its effective skin will be taken as .15 sq.in. The student should of course realize after studying Chapters A19 and A20 that the true effective area should be used on the compressive side and that the skin on the tension side of the fuselage is entirely effective. These facts would tend to make the effective cross-section unsymmetrical about the Y axis. Since the only purpose of this illustrative solution is to show how the frame loads are balanced, the section being assumed as symmetrical which will greatly decrease the amount of calculations required.

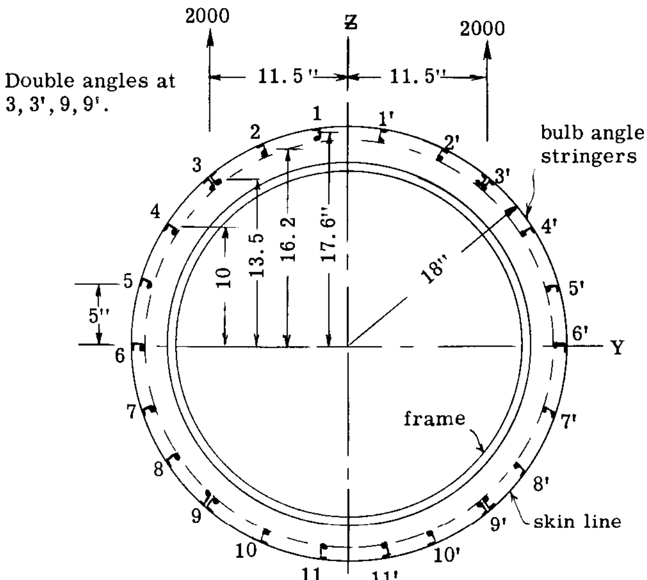


Fig. A21.61

Moment of inertia of fuselage section about Y axis which is the neutral axis under our simplified assumptions.

$$I_y = .15\ (17.6^2 + 16.2^2 + 13.5^2 + 13.5^2 + 10^2 + 5^2)4 = 637 \text{ in.}^4$$

Due to symmetry of effective section and external loading, the shear flow in the fuselage skin on the z axis or between stringers 1 and 1 and 11 or 11 will be zero. Thus starting with stringer (1) the shear flow in the skin resisting the external loads of 4000 lb. can be written around the circumference of the section.

$$q = -\frac{V_Z}{I_y}\Sigma zA = -\frac{4000}{637}\Sigma zA = -6.275\ \Sigma zA$$

$$q_{1-2} = -6.275 \times .15 \times 17.6 = -16.57 \text{ lb./in.}$$

$$q_{2-3} = -16.57 - 6.275 \times .15 \times 16.2 = -31.82$$

$$q_{3-4} = -31.82 - 6.275 \times .30 \times 13.5 = -57.22$$

$$q_{4-5} = -57.22 - 6.275 \times .15 \times 10 = -66.62$$

$$q_{5-6} = -66.62 - 6.275 \times .15 \times 5 = -71.32$$

Due to symmetry of effective cross-section, the shear flow is symmetrical about the Y axis.

As a check on the above work, the summation of the z components of the shear flow on each skin panel between the stringers should equal the external load of 4000 lb.

ΣF_Z of skin shear flow equals the vertical projected length of each panel times the shear flow q on that panel, or

$$\Sigma F_Z = [1.4 \times 16.57 + 2.7 \times 31.82 + 3.5 \times 57.22 + 5 \times 66.62 + 5 \times 71.32]\ 4 = 4000 \text{ lb.}$$

(check)

Fig. A21.62 shows the frame with its balanced load system. The internal stresses can now be found by the methods of Chapters A8 to A11.

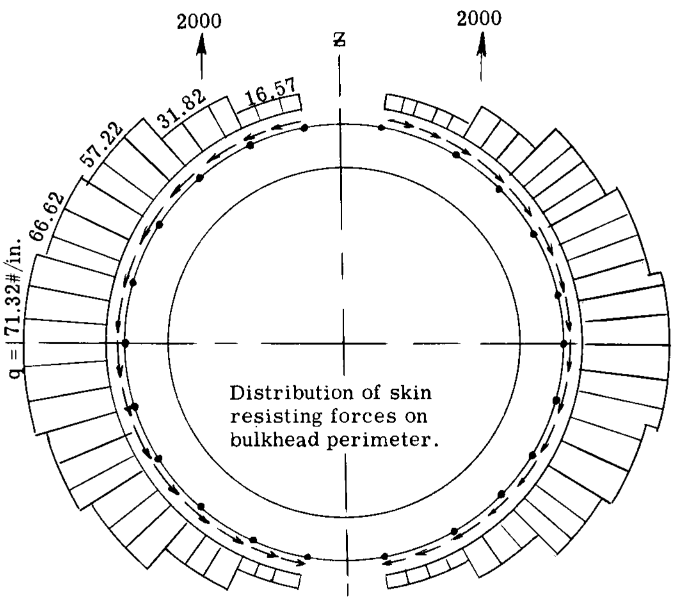


Fig. A21.62

Example Problem 2. Unsymmetrical Vertical Loading

In certain conditions in flying and landing, unsymmetrical concentrated loads are applied to the fuselage or hull structure. For example, Fig. A21.63 shows the same section and frame as was used in Problem 1. Due to an unsymmetrical load on the horizontal tail, the reactions from the tail on the fuselage are as illustrated in the figure. The total load in the z direction is still 4000 lb. but the loads are not symmetrical about the z axis. For analysis purposes, consider the loads as transferred to the c.g. of the section as indicated in Fig. A21.64. The moment of the two loads about the c.g. = 1500 x 11.5 - 2500 x 11.5 = -11500 in.lb. The shear load V_Z = 4000 produces the same shear flow pattern as Fig. A21.62. To balance the moment of -11500, a constant shear flow q_1 around the frame is necessary.

$$q = \frac{M}{2A} = \frac{11500}{2 \times \pi \times 18^2} = 5.65 \text{ lb./in.}$$

(A = area of fuselage cross-section)

Adding this constant force system to that of Fig. A21.62, gives the final boundary supporting forces on the frame as illustrated in Fig. A21.65. The elastic stress analysis of the frame can now proceed.

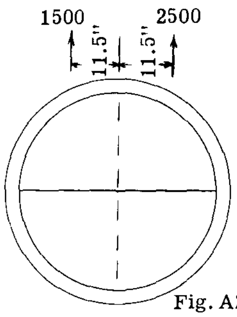


Fig. A21.63

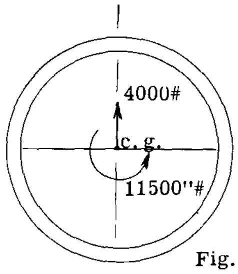


Fig. A21.64

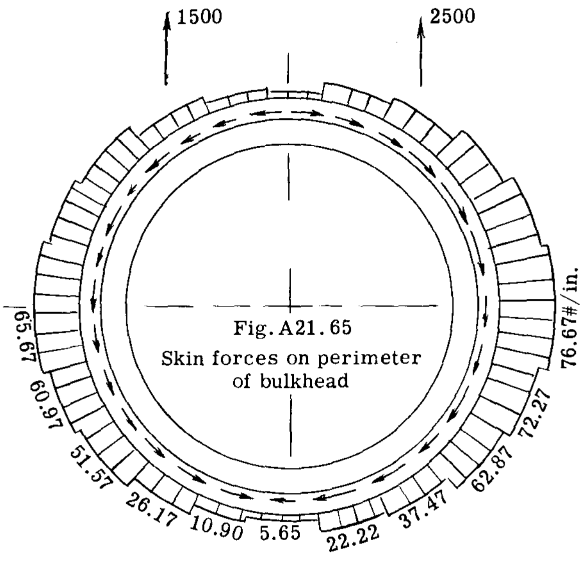


Fig. A21.65
Skin forces on perimeter of bulkhead

A21.13 Problems.

(1) Fig. A21.66 shows a cantilever beam loaded as shown. Find the shear flow in each of the 4 web panels. Draw axial load diagram for each of the vertical web stiffeners and also the horizontal stiffener be. Plot axial load diagram for beam flange members as obtained from web shear flows.

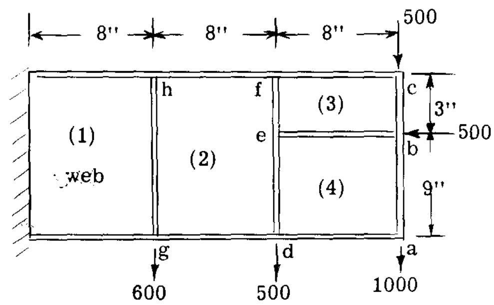


Fig. A21.66

(2)

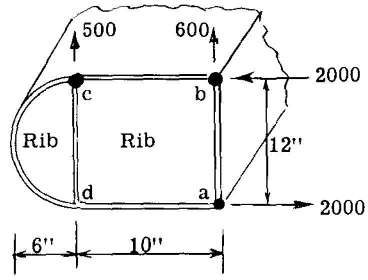


Fig. A21.67

Fig. A21.67 shows a wing rib inserted in a 3 flange single cell wing beam, which is subjected to the external loads as shown.

(1) Find rib flange loads at (c) and (d).

(2) Find rib web shear flow on each side of stiffener cd.

(3) Find rib flange and web loads at section 5" to left of line ab.

(3)

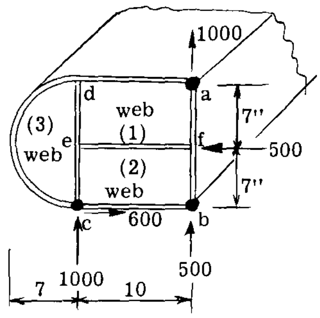


Fig. A21.68

Fig. A21.68 shows a 3 stringer single cell wing beam. A rib is inserted to distribute the concentrated loads as shown.

(1) Find shear flows in rib web panel (1) (2) and (3).

(2) Find rib flange loads at sections dc and ab.

(4)

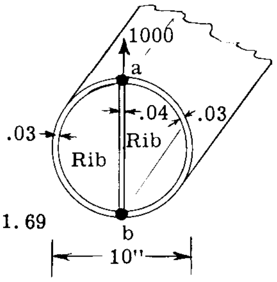


Fig. A21.69

Fig. A21.69 shows a 2 stringer, 2 cell wing beam. A rib is inserted to transfer 1000 lb. load to beam structure.

Find shear flow in rib web in each cell adjacent to line ab. Also rib flange loads adjacent to points (a) and (b).

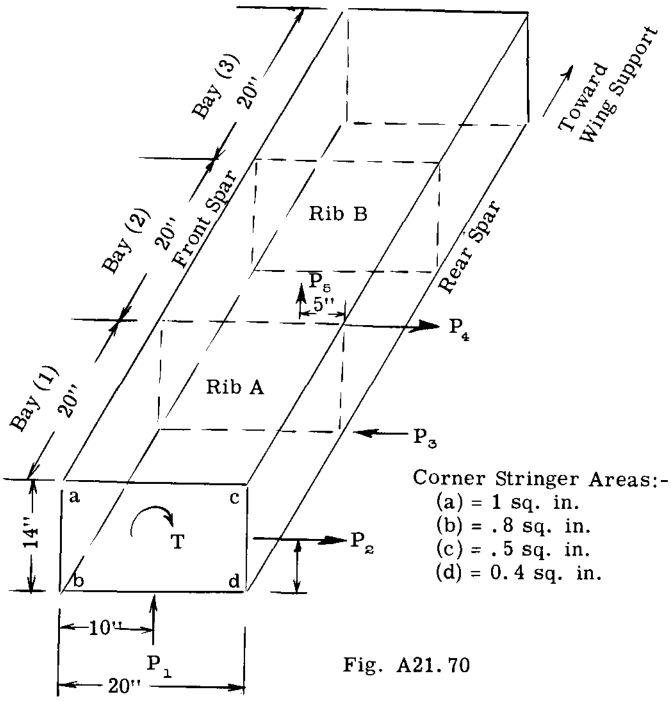


Fig. A21.70

(5) Fig. A21.70 shows 3 bays of a cantilever single cell, 4 stringer wing beam. The bottom skin in bay (2) is removed. Find the shear flows in all bays and boundary loads on ribs (A) and (B) when the external wing loads are as follows: T = 56000 in.lb., $P_1 = 0$, $P_2 = 0$, $P_3 = 2000$ lb., $P_4 = 2000$ lb., $P_5 = 0$.

(6) Same as problem (5) but upper skin in bay (2) is removed instead of the lower skin.

(7) Same as problem (5) but with the following external loads.

T = 56000 in.lb., $P_1 = 5000$ lb.,

$P_2 = 2000$ lb., $P_3 = P_4 = 0$ and $P_5 = 1000$ lb.

(8) Same as problem (7) but with top skin removed instead of lower skin.

(9) Same as (5) but with read spar web removed instead of bottom skin.

(10) Same as problem (7) but with rear spar web removed instead of bottom skin.

(11) In Fig. A21.71 the external bulkhead loads P_1 and P_2 equal 4000 lb. each and P_3 equals zero. The fuselage stringer material consists of four omega sections with an area of .25 sq. in. each. Determine the skin resisting forces on the bulkhead in balancing the above loads. Neglect any effective skin in this problem.

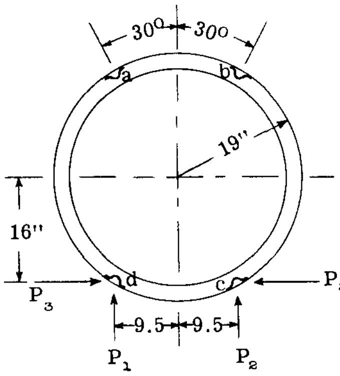


Fig. A21.71

(12) Same as problem (11) but make $P_1 = 4000$ and $P_2 = 6000$.

(13) Same as problem (12) but add $P_3 = 3000$ lb.

(14) In a water landing condition the hull frame of Fig. A21.72 is subjected to a normal bottom pressure of 200 lb. per in. The area of the bulb angle stringers is .11 sq. in. each and they are 7/8 in. deep. The area of the Z stringers is .18 sq. in. each and the depth 1.5 in. The area of the stringers a, b, c, d and e is .20 sq. in. each. Neglecting any effective skin determine the skin resisting forces on the frame in balancing the bottom water pressures.

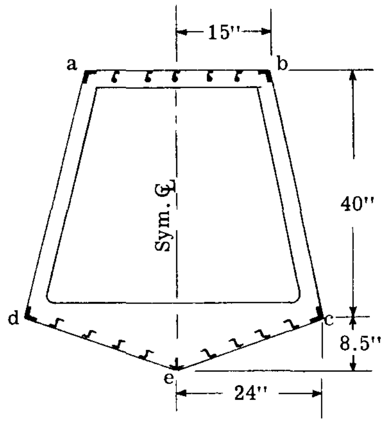


Fig. A21.72

(15) Same as problem (14) but consider that the water pressure is only acting on one side of the bottom of the frame.