CONTINENTAL AIRCRAFT ENGINE CO

DETROIT MICHIGAN

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6- SHEETS

CONTINENTAL O-1430-1 ENGINE

STRESS ANALYSIS OF CONNECTING RODS

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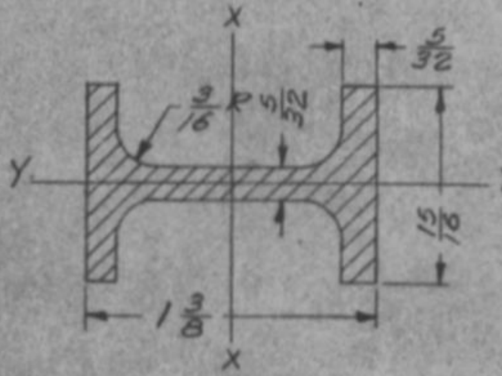
CONTINENTAL 0-1430-1 ENGINE

Oct. 1933

References: A.S.I.C. No. 421
"Design of 1000 hp. flat engine etc."
by Continental Aircraft Engine Co.
"Indicator as a means of improving Aircraft Engine Performance, Prescott Journal S.A.E. Sept.32 Jan.33



Section of column

Area, A	0.489 sq.in.
Ixx	0.1257 in⁴
Iyy	.0125 in⁴
Rod length center to centerLL	7.75 in.
Crank radius R	2.5 in.
Piston assy. wt.(Dwg. 4212)	5.325 lb.
Reciprocating wt. Wi	6.415 lb.
Piston area (5.5 bore)	23.76 sq.in.

Gas load on column, F-= 830 x 23.76 = 19750 lb. where 830 is max. gas pressure estimated from indicator cards of various test cylinders under supercharged conditions. Neglecting obliquity of connecting rod at time of max. gas pressure, and bending of column, the compression stress in column section is
S_c = F/A = 19750/.489 = 40400 psi.

According to the Rankine formula, the compression stress in column is $S_c = F/A + .000526L^2 F/Ixx$ = 45,400 psi.
or $F/A + .000131L_1^2 F/Iyy$ = 42,600 psi.
where L_1 = 4.25 in. (blade rod).

Considering engine speeds of rating, 25% and 50% overspeeds, i.e 3000, 3750 and 4500 RPM. for inertia loads.
$Fi = .0000284\ Wi\ RN^2 fa = .0006021N^2$ where fa for L/R = 3.1 is 1.322
@3000 RPM. Fi = 5420 lbs.
@3750 RPM. Fi = 8470 lbs.
@4500 RPM. Fi = 12200 lbs.

Tension stress in rod column due to inertia only, as occurs at exhaust top center is
S_t @3000 RPM. = 11,100 psi.
@3750 RPM. = 17,300 psi.
@4500 RPM. = 25,000 psi.

Compression stress at combustion dead center with no change of gas load

S_c @3000 RPM. 45400 - 11,100 = 34,300 psi.
@3750 RPM. 45400 - 17,300 = 28,100 psi.
@4500 RPM. 45400 - 25,000 = 20,400 psi.

Whipping stress due to shortness of column is small as shown by following computation at 4500 RPM. It occurs 90 degrees out of phase from maximum gas or inertia stresses. The whipping force is $F_w = 4.02 \times 10^{-6}\ ALN^2R \sin\theta$

θ = Crank angle and is maxinum at 90°

$F_w = 4.02 \times 10^{-6} \times .489 \times 7.75 \times 4500^2 \times 2.5 \times 1 = 770$ lb.

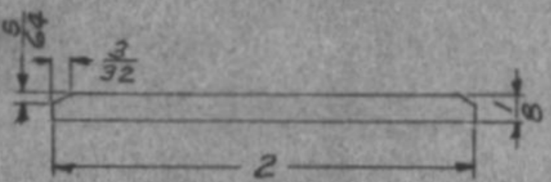
Bending stress from whip is $.1283\ LF_w/Z$

$S_w = .1283 \times 7.75 \times 770 \times (.6875/.1257) = 4180$ psi. @4500 RPM.

Comparative compressive stresses connecting rod column (Gas load/area).

	Cyclone 1820F	V-1570	Wasp R-1340	Hyper 0-1430
Horsepower	670	630	650	1000
RPM.	1900	2400	2200	3000
Bore, in.	6.125	5.125	5.75	5.5
Max. gas pressure psi.	750	595	790	830
Column stress psi.	47,000	34,000	53,700	40,400

Stress in small end of connecting rods



Area = .243
I = .000322 neglecting chamfer
S = F/2A
D = 1.656

Forces are due to inertia from piston assembly including piston pin

$$F = .0000284 \times 5.325 \times 2.5N^2 = .000378N^2$$

@3000 RPM, F = 3400 lbs. S = 7000 psi.
@3750 RPM, F = 5300 lbs. S = 10,900 psi.
@4500 RPM, F = 7650 lbs. S = 15,800 psi.

To avoid pinching, the deflection is proportional to following.

@3000 RPM. $FD^2/EI = \dfrac{3400 \times (1.656)^2}{30 \times 10^6 \times .000322} = .965$

compared with corresponding figure of 1.235 for Wasp(R-1340) engine at 2200 RPM.

<u>Compression stress</u> at combustion dead center with no change of gas load

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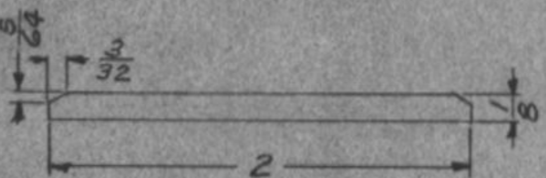

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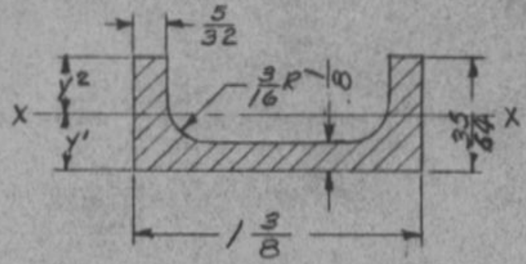
Stress in fork (as sect. B-B, fig. 24, A.S.I.C. 421)

F_r = 19,750 lb. Y_1 = .1725
B = .73° Y_2 = .374
A = .318 Ix = .0078
C = .875 x = .156



Fork free from end wise constraint, stress from gas load is

$$S_c = \frac{19,750}{2}\left[\frac{.956}{.318} + \frac{.374}{.0078}(.875 - .156 - .1725 \times .956)\right]$$

$$= .9875\ (3.00 + 26.6) = 292,000 \text{ psi.}$$

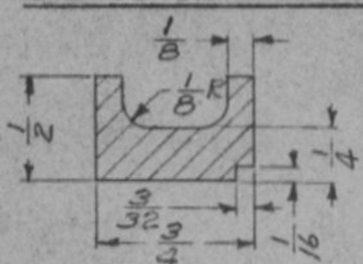
Since the ends of this fork are constrained from endwise deflection, the greater portion of the bending stresses are eliminated.
Without bending, the fork stress is

$$S_c = \frac{19,750}{2} \times \frac{.956}{.318} = 29,600 \text{ psi.}$$

The bearing shell ends must provide against an endwise force due to gas load of F = (F_r/2) tan 17 = .9875 x .305 = 3010 lbs.
shear stress = endwise force/shear area
S_s = 3010/.994 = 3030 psi.
the bearing shell end pressure is endwise force/bearing area
p_b = 3010/1.118 = 2700 psi.

Loads from inertia act in the oppsite direction to the gas load considerably decreasing the above stresses. At exhaust dead center the inertia loads only are acting. These loads are always less than gas loads as can be seen from inspecting following section on bearing cap which has same inertia loads. The same areas of constraint are given by central land of bearing shell.

Stress in bearing cap of fork rod.



Area = .245 Y_1 = .190
C = 3.875 Y_2 = .310
Ix = .00411 Z = .0135
(Notch & fillets neglected for Ix, Y_1, Y_2, & Z)

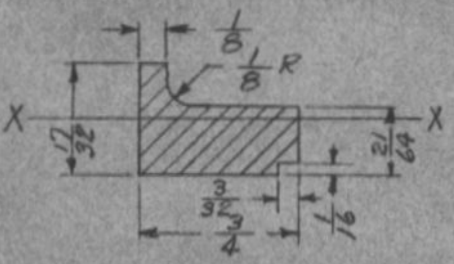
Centrifugal wt. @crankpin minus cap and 1/2 shell
W = 4.974 - 2.324 = 2.65 lb.
F_c = .0000284 x 2.65 x $2.5N^2$ = $.000188N^2$

@3000 F_c = 1690 F_i = 5420 F = 7110 lb.
@3750 F_c = 2650 F_i = 8470 F = 11,120 lb.
@4500 F_c = 3810 F_i = 12,200 F = 16,010 lb.

$$\text{Stress} = F\left(\frac{.023 \times 3.875}{.0135} + \frac{0.5}{2 \times .246}\right) = 7.72F$$

S @3000 = 54,800 psi.
@3750 = 85,600 psi.
@4500 = 123,000 psi.

Stress in strap between fork and bolt of fork rod.



Area	= .266	X	= 1.093
C	= 1.937	Y_1	= .193
B	= 40°	Y_2	= .338
F	= Same as page 3	Ix	= .00485

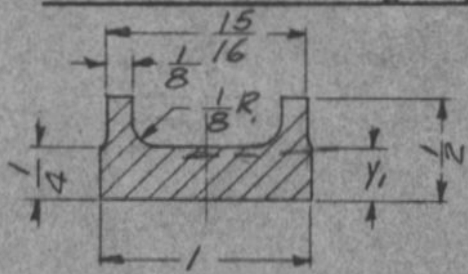
Assuming no constraint by bolts,

$$S = \frac{F}{4}\left[\frac{.643}{.266} + \frac{.338}{.00485}(1.937 - 1.093 - .193 \times .643)\right]$$
$$= \frac{F}{4}(2.42 + 50.00) = 13.1F = 93{,}000 \text{ psi. @3000 RPM.}$$

Since there is constraint, the [redacted] stress in this section is more nearly 2.42 F/4 or S @3000 = 4300 psi.

These straps probably will be prestressed by tightening of cap bolts or studs to values in excess of stress induced by the working loads.

Stress in bearing cap of blade rod.



A	= 0.314	C	= 4.187
Y_1	= .174	Ix	= .00472
Y_2	= .326	Z	= .0145

Centrifugal wt. minus cap wt. - 2.296 = 1.079 = 1.22 lb.

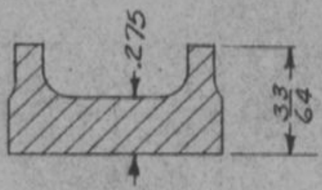
$$F_c = .0000284 \times 1.22 \times 2.5N^2 = .0000866N^2$$

@3000	F_c = 780	F_i = 5420	F = 6200 lb.
@3750	F_c = 1215	F_i = 8470	F = 9685 lb.
@4500	F_c = 1750	F_i = 12200	F = 13,950 lb.

$$S = F\left(\frac{.023 \times 4.187}{.0145} + \frac{0.5}{.314}\right) = 8.25F$$

S @3000 = 51,000 psi.
@3750 = 79,000 psi.
@4500 = 115,000 psi.

Stress in section between column and bolt of blade rod.



Section same as shown on page 4, except as shown.
Forces same as on page 4.

$B = 40^\circ$ $C = 2.093$ $X = 1.140$
$A = .337$ $Y_1 = .183$ $Y_2 = .3325$
$I_{xx} = .0053$

Assuming no constraint at bolt,

$$S = \frac{F}{2}\left[\frac{.643}{.337} + \frac{.3325}{.0053}(2.093 - 1.140 - .183 \times .643)\right]$$

$$= \frac{F}{2}\left[1.91 + 52.4\right] = 27.1F$$

S @3000 RPM. = 168,000 psi.

Since there is considerable constraint, the greater portion of the bending stresses do not occur, so that the stress in this section is more nearly 1.91 (F/2) or

S @3000 RPM. = 5920 psi.
@3750 RPM. = 9260 psi.
@4500 RPM. = 13,300 psi.

Connecting rod bolt stresses

The maximum force is due to inertia plus centrifugal forces of the same values acting on bearing caps.
Blade rod bolt 0.500 dia. 20 tpi. with neck 90% root dia. or .438 x.9 = .395, Area = .1225 sq. in. Fork rod bolt 0.375 dia. 24 tpi. with neck 90% root dia. or 324 x.9 = .292, Area = .067 sq.in.

Blade rod bolts, two.

@3000 RPM. F = 6200	S = 25,300 psi.
@3750 RPM. F = 9685	S = 39,500 psi.
@4500 RPM, F = 13,950	S = 57,000 psi.

Fork rod bolts, four.

@3000 RPM. F = 7110	S = 26,500 psi.
@3750 RPM. F = 11,120	S = 41,600 psi.
@4500 RPM. F = 16,010	S = 59,800 psi.

To limit the stress in the bolts to a value sufficient to prevent separation of cap from rod it will be necessary to screw these bolts until elongated by amounts shown below. Assume that 60,000 psi. stress will be sufficient, the elongation is

$$e = \frac{S}{E}(l_1 + l_2 A_1 / A_2)$$

The blade rod cap stud length may be taken as 2.00 of which $l_1 = 1.125 A_1 = .1225$ and $l_2 = .875$, $A_2 = .1964$

$$e = \frac{60,000}{29,000,000}\left(1.125 + \frac{.875 \times .1225}{.1964}\right) = .00207\ (1.125 + .545)$$

$= .00345$ or .0035 inch elongation of blade rod studs when set up.

The fork rod cap stud length may be taken as 2.125 of which $l_1 = 1.25$, $A_1 = .067$ and $l_2 = .875$, $A_2 = .1105$

$$e = \frac{60,000}{29,000,000}\left(1.25 + \frac{.875 \times .067}{.1105}\right) = .00207\ (1.25 + .53)$$

$= .0037$ or .0035 inch elongation of fork rod studs when set up.