The PCS positive X-axis extends toward the annular cavity, is always perpendicular to the face surface, bisects the intercept line of the face surface plane with the partition's axial plane and bisects the intercept arc line of the wave surface and partition's axial plane; i.e. the X-axis bisects the perimeter sections of the cavity profile in the partition's axial plane. The partition's Y-axis is perpendicular the X-axis at the PCS origin with its positive part directed away from the pivot point; i.e. the Y-axis is always parallel to the face surface intercept with the partition's axial plane, through the PCS origin, and has its positive part directed away from the partition pivot.

Although more complex from the analytic perspective, this engine (or pump) design has the redeeming feature of permitting very large engine displacements with very small partition angular displacements.

With reference to figures 53a and 53b, a major engine design parameter is the partition's maximum angular displacement, ϵ, into the annular cavity. Epsilon is measured relative to the partition's completely retracted position; i.e. with the partition's circle segment perimeter (gap edge) tangent the face surface plane. Other program entries are: the distance of the partition pivot point from the face surface plane, e_c [A(6)], the Y_{max}[A(5)] dimension which is half the length of the partition's circle segment cord at the face surface when the partition is fully extended into the cavity; (i.e. at angle ϵ), and S_R[A(2)], the swing radius length at the partition's full cavity extension.
The swing radius is the perpendicular distance between the pivot point and the partition's X-axis and is always parallel to and distance e_c from the face surface; i.e. the swing radius extends from the partition pivot point to the X-axis and is perpendicular thereto. Major design parameters in the CIR engine shared with the preceding engine design is radius R, from the pivot points to the rotor axis and the face surface angle, [A(22)].

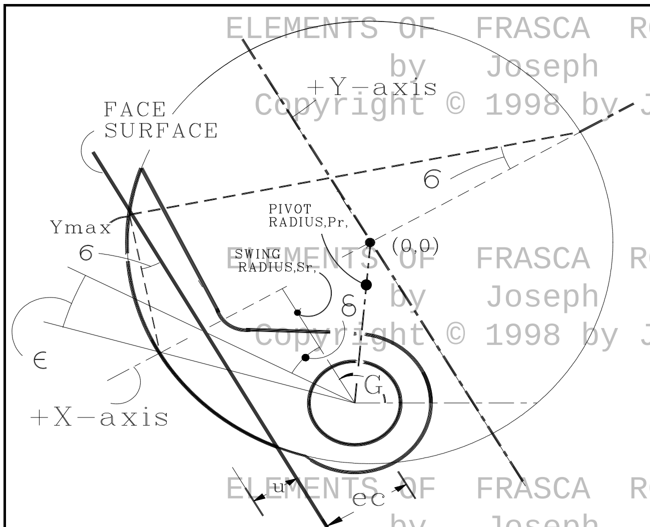

FIGURE 53a THE PARTITION COORDINATE SYSTEM.

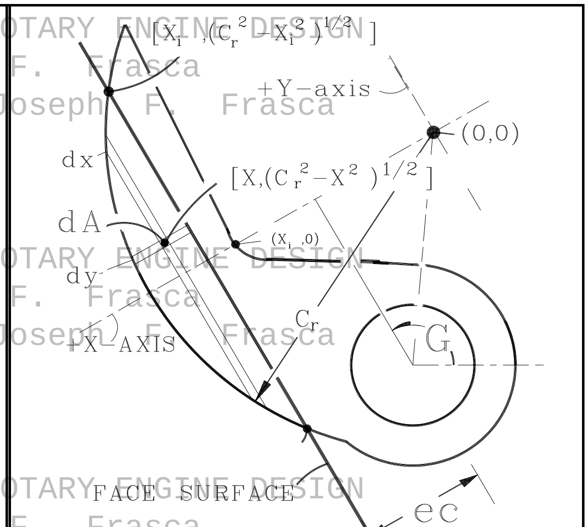

FIGURE 53b DIFFERENTIAL AREA, dA.

We determine the circle segment radius C_r with reference to figure 53a. From similar triangles:

$$\delta = ATN\,(ec/S_R), \qquad u = S_R\,[TAN\,(\delta + \epsilon) - TAN\,\delta\,], \qquad u/Y_{max} = Y_{max}/(2C_r - u).$$

And finally the partition's circle segment radius, C_r, is:

53) $$C_r = (Y_{max}^2 + u^2)/(2u).$$

The constant distance pivot radius, P_r, between the partition's pivot point and the PCS origin is,

53$_a$) $$P_r = [S_r^2 + z^2]^{1/2}.$$

Where $z = C_r - S_r TAN(\delta + \epsilon)$. With the partition fully retracted, the angle, P_a, is defined between S_r and P_r as:

53$_{a1}$) $$P_a = ATN\,\left((C_r - e_c) / (P_r^2 - (C_r - e_c)^2)^{1/2}\right).$$

The instant perpendicular distance between the face surface plane and the PCS origin is X_i. At full partition retraction,

53$_{a2}$) $$X_i = X_{max} = ec + P_r\,SIN\,P_a.$$

At maximum partition extension into the annular cavity,

53$_{a3}$) $$X_i = X_{min} = ec + P_r\,SIN\,(P_a + \epsilon).$$

Using rectilinear coordinates in figure 53b, the general equation for the partition area in the annular cavity is:

53$_b$) $$_{PART}\text{Area} = \int_{X_i}^{C_r} \int_{-[C_r^2 - X_i^2]^{1/2}}^{[C_r^2 - X_i^2]^{1/2}} dy\,dX = \int_{X_i}^{C_r} 2\,[C_r^2 - X_i^2]^{1/2}\,dX.$$

Using $X = C_r COS\,\Omega$ and $dX = -C_r SIN\,\Omega\, d\Omega$,

53$_{b1}$) $$_{PART}\text{Area} = \int_{ACS(X_i/C_r)}^{0} -2C_r^2\, SIN^2\Omega\, d\Omega = {}^{*}C_r^2\left[-\Omega + 1/2\, SIN\, 2\Omega\right]_{ACS(X_i/C_r)}^{0} = C_r^2\, ACS(X_i/C_r) - X_i\,[C_r^2 - X_i^2]^{1/2}.$$

The partition area equation is then:

53$_{b2}$) $$_{PART}\text{Area} = C_r^2 ACS(X_i/C_r) - X_i\,[C_r^2 - X_i^2]^{1/2} \equiv C_r^2 ATN([C_r^2 - X_i^2]^{1/2}/X_i) - X_i\,[C_r^2 - X_i^2]^{1/2}.$$

At maximum partition extension into the cavity $X_i = X_{min}$; therefore, the maximum partition cavity area is:

53$_{b3}$) $$_{PART}\text{Area}_{max} = C_r^2 ACS(X_{min}/C_r) - X_{min}\,[C_r^2 - X_{min}^2]^{1/2}.$$

Using the program entry for the desired VVC volume ratio, AR, and the value of $_{PART}A_{max}$, the program increases the value of X_i in 53b1 by iteration from its initial minimum value X_{min} until the ratio $_{PART}A_{MAX}/_{PART}A >= AR$; i.e. the program incrementally decreases the partition angular displacement into the cavity until the desired AR is achieved. The constant X_m is defined as the value of X_i when the desired ratio is attained; i.e. $X_m = X_i$ when $_{PART}A_{MAX}/_{PART}A >= AR$. We now find the partition's angular displacement α to achieve this minimum area.

Although the relative orientations of the various elements, S_r, P_r, circle center etc, remain at all times the same, in the present design, S_r becomes shorter and the PCS origin rotates slightly clockwise while the bisecting points of both the cavity arc and cord move slightly.

At minimum partition cavity area, using $U_m = (X_m - e_c)$ and $V_m = (C_r - X_m + e_c)$, and with reference to 53a and 53b,

53$_c$) $$_mS_r = [P_r^2 - (X_m - ec)^2]^{1/2} = [P_r^2 - U_m^2]^{1/2},$$

53$_{c1}$) $$\Gamma_m = ATN([C_r - X_m + e_c]/S_r),$$

With $\delta_m = ATN(e_c/S_r)$, the actual partition angular displacement, α_2, between minimum and maximum areas is:

53$_{c2}$) $$\alpha_2 = \epsilon - (\Gamma_m - \delta_m).$$

The minimum extension into the cavity is :

53$_{c3}$) $$\alpha_1 = (\Gamma_m - \delta_m), \text{ where } \alpha_1 + \alpha_2 = \epsilon.$$

Using the equation of partition angular extension, ϕ, into the annular cavity,

53$_{c4}$) $$\phi = \alpha_1 + (\alpha_2/2)[1 - COS\,u(\theta - ß)],$$

the major parameter X_i, the distance between the PCS origin and the face surface is:

53$_d$) $$X_i = P_r\, SIN(P_a - \phi) + e_c.$$

For clutter control $A(59) = P_a - \alpha_1$, and $\sigma = (\alpha_2/2)[1 - COS\,u(\theta - ß)]$.

53$_{d1}$) $$X_i = P_r\, SIN(A(59) - (\alpha/2)[1 - COS\,u(\theta - ß)]) + ec = P_r SIN(A(59) - \sigma) + e_c.$$

With the equation for X_i dependent on θ, we derive θ dependent equations for partition area, volume and arc length.

53$_{d3}$) $$\text{AREA}_{INST.} = C_r^2 ACS(X_i/C_r) - X_i[C_r^2 - X_i^2]^{1/2}.$$

Discussion will be limited to engines that have partitions with constant thickness, t. The annular cavity volume of said partitions at θ and the gap length, are given by:

53$_{d4}$) $$\text{PARVOL}_{INST.} = t\,[C_r^2 ACS(X_i/C_r) - X_i[C_r^2 - X_i^2]^{1/2}], \text{ and}$$

53$_{d5}$) $$\text{GAP LENGTH}_{INST.} = 2\, C_r ACS(X_i/C_r).$$

Although not covered in this discussion, this engine with tapered partitions would have its partition's thickness inversely proportional to the distance from the pivot point, as in the first engine designs discussed.

PARTITION ACCELERATION

The partition acceleration follows from 53d3 with:

$$\sigma = (\alpha_2/2)[1 - COS\,u(\theta - ß)],$$

$$d\sigma/dt = d\sigma/d\theta\; d\theta/dt = u\,(\alpha_2/2)[SIN\,u(\theta - ß)]\, d\theta/dt, \text{ and}$$

$$d^2\sigma/dt^2 = u^2\alpha_2/2\; COS\,u(\theta - ß)(d\theta/dt)^2 + u\alpha_2/2\; SIN\,u(\theta - ß)\; d^2\theta/dt^2,$$

which we approximated with:

$$d^2\sigma/dt^2 \approx (1.1)\, u^2\,(\alpha_2/2)\,[COS\,u(\theta - ß)]\,(d\theta/dt)^2.$$

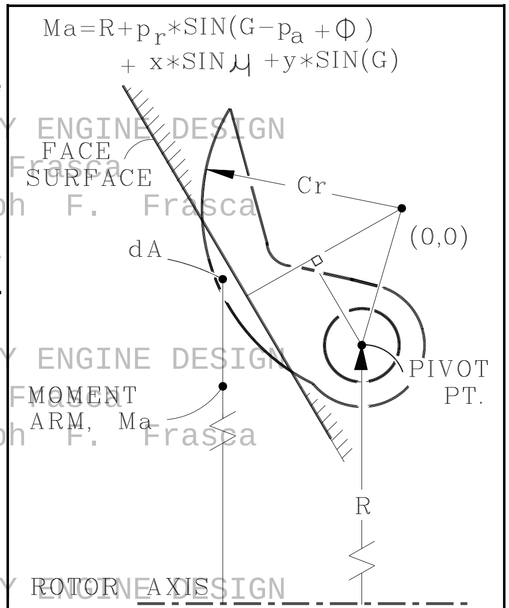

FIGURE 54 TORQUE ARM.

54 CIR ENGINE INSTANT TORQUE EQUATION.

With reference to figures 54, 54a, and 54b the pressure differential, dP, on a partition's area element, dA, located at point (x_m, y_n) in the PCS acts at moment arm distance, M_A, from the rotor axis to impart a moment to the rotor. The moment arm at (θ, x_m, y_n) is:

54) $$M_A = R + x_m SIN\,\mu + y_n SIN\,G + P_r SIN(G - A(59) + \sigma).$$