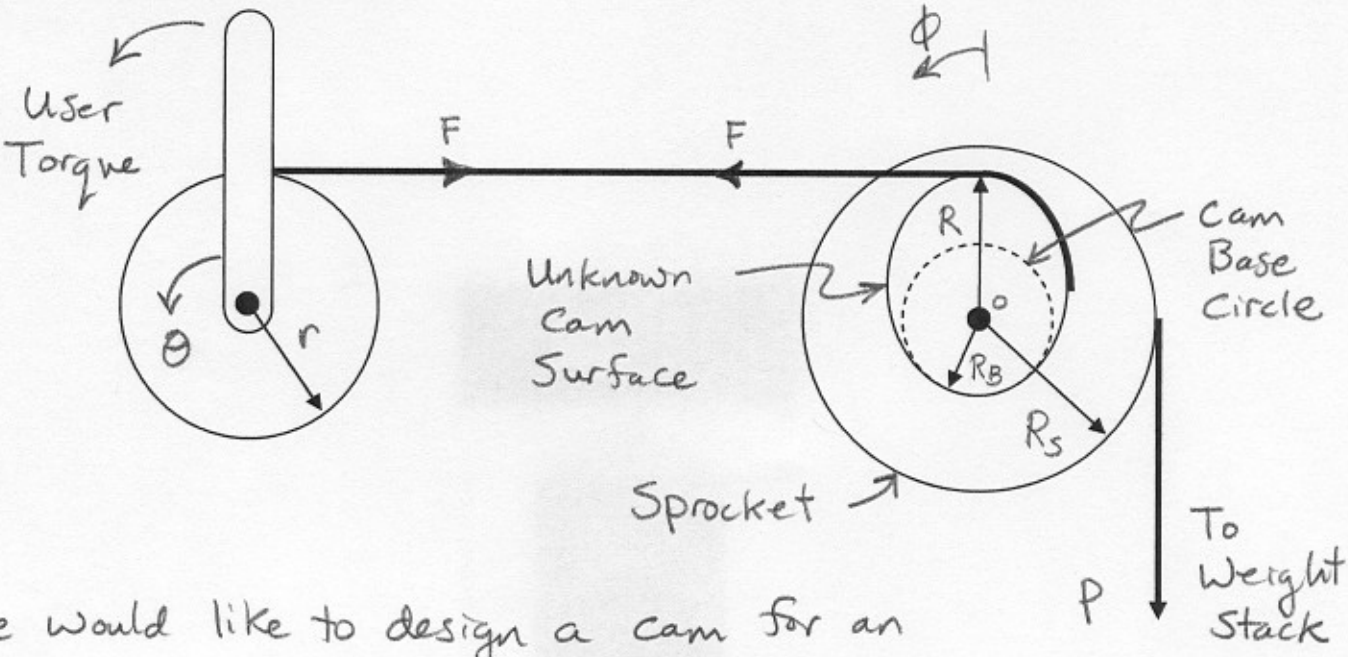
Negative Cam Design



- We would like to design a cam for an exercise machine using a negative cam design

$$\circlearrowleft + \sum M_o = RF - PR_s = 0 \rightarrow RF = PR_s = \text{Constant}$$

$$\text{Cam Radius} = R = \frac{PR_s}{F} = \frac{\text{Constant}}{\text{User Force}}$$

So if the strength increases for a given angle, R must decrease since PR_s is constant. Design the cam by inversion

If the input rotation is $\theta \rightarrow s = r\theta = R\phi$

$$\therefore \quad \phi = \frac{r\theta}{R}$$

We can determine R as we did on p. 6-5

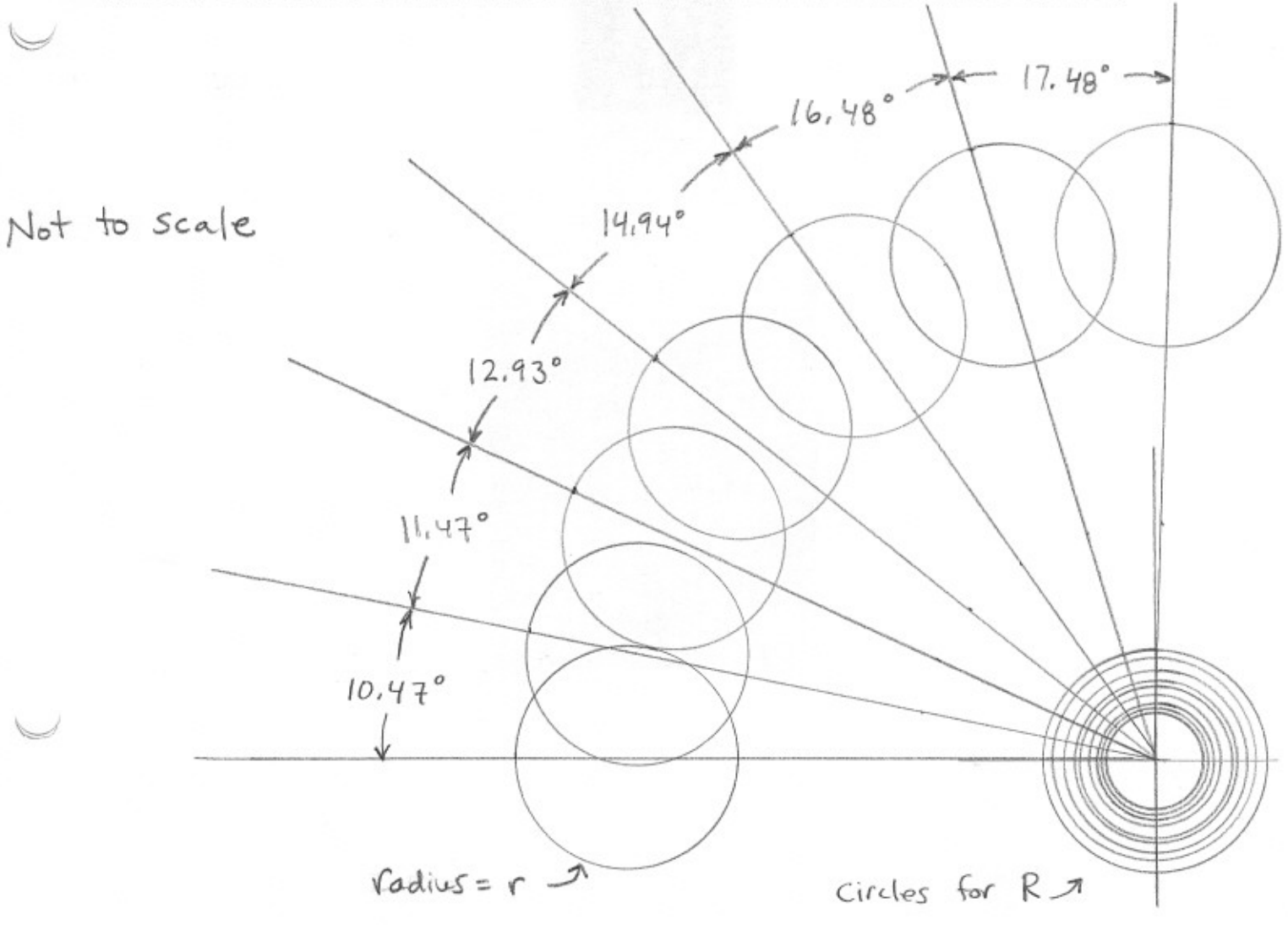
$$R = R_b \left(\frac{\text{maximum strength}}{\text{strength}} \right)$$

We can determine by averaging R and using the equation

$$\phi = \frac{r\theta}{\frac{1}{2}(R_i + R_{i+1})}$$

Choosing Rb = 1.5" and r = 3"

Angle	Normalized Strength	R=Rb(max.strength/strength) (inches)	Phi (deg.)
0	.5	1.5(1/.5) = 3"	0.5*3"(10 deg.)/(3+2.73) = 10.47
10	.55	1.5(1/.55) = 2.73"	0.5*3"(10 deg.)/(2.73+2.5) = 11.47
20	.6	2.5	12.93
30	.7	2.14	14.94
40	.8	1.88	16.48
50	.85	1.765	17.48
60	.9	1.67	18.48
70	.95	1.58	19.48
80	1	1.5	19.48
90	.95	1.58	18.48
100	.9	1.67	16.94
110	.8	1.88	14.94
120	.7	2.14	12.93
130	.6	2.5	10.9
140	.5	3	10
		Total Rotation	**225.4 deg.**



CAM Manufacturing and Practical Considerations

- Cams are usually made from medium to high carbon steels and sometimes plastics
- To make a cam a milling machine or grinder is needed
- Usually continuous numerical control (CNC) machines are required to generate the precision needed. Common increments are $\frac{1}{10}$, $\frac{1}{4}$, $\frac{1}{2}$ and 1 degree. Since the machine only has the x and y coordinates of the specified displacement, the machine has to interpolate the missing data.

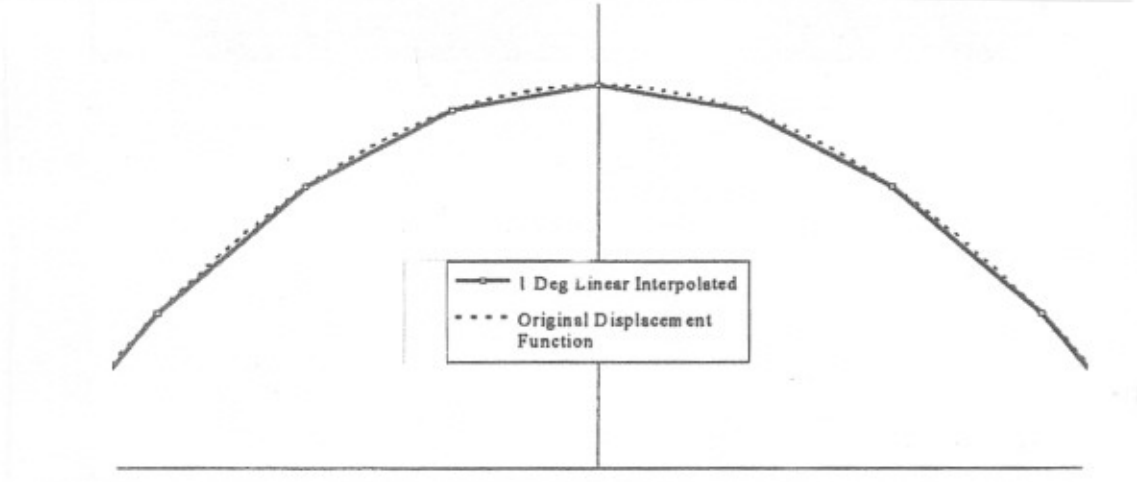
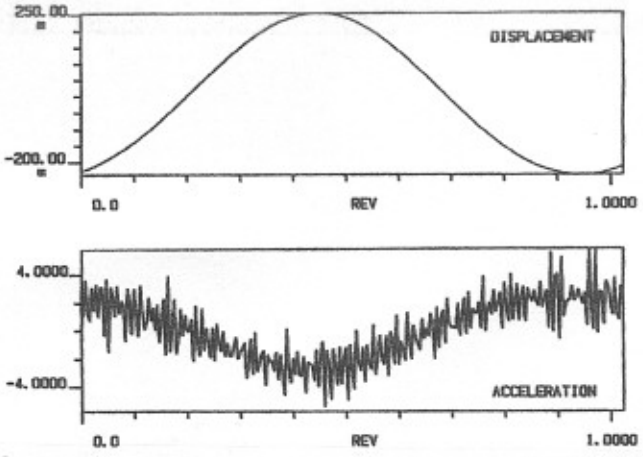


FIGURE 8-55
Cam contour as designed and as made with 1° linear interpolation CNC[8]

- Manufacturing errors can occur due to the cutting process feed rate, tool sharpness, milling speed, chatter, milling tool deflection, etc.

- Consider a cam that has a roller follower. The following cam was milled on a high quality CNC milling machine using 1 degree linear interpolation



* These cams were about 8 in (200 mm) in diameter. If the cam diameter is larger, then smaller angular increments of digitization will be needed as the distance along the pitch curve between data points for any angular increment increases linearly with prime circle diameter.

FIGURE 8-56
Displacement and acceleration of eccentric cam made with 1° linear interpolation CNC

The actual displacement is true to the theoretical, but the acceleration has a significant amount of vibratory noise. Compare with the same shaped cam that has the same geometry except it was turned and ground.

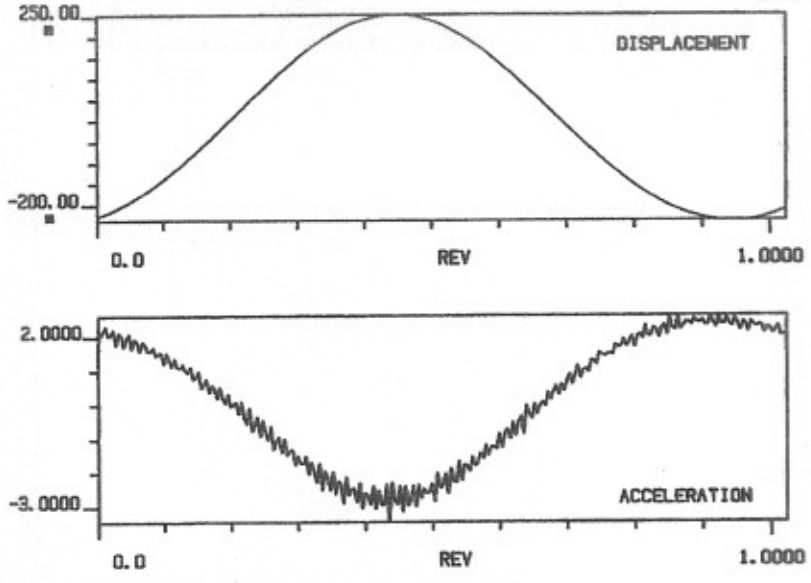


FIGURE 8-11
Displacement and acceleration as measured on the follower of an eccentric cam

- A ground cam is superior to a milled cam but is more costly to make
- Cam lubrication is also very important to reduce wear + heat