

Offsetting a Cam Follower Pays Only When the Return Is Slower Than the Rise

— an offset lowers the pressure angle on the rise and raises it on the return, so with an equal return angle the best offset is 0, and with a return twice as long the needed radius falls to 0.725686 to 0.732789 —the separator is whether rise and return run at the same speed or at different speeds — [Paper 972]

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Abstract

Besides enlarging the pitch circle, a cam's pressure angle can be held down by offsetting the follower's line of motion from the cam center, which lowers the pressure angle on the rise side. For the four motion curves of Paper 961 (a 10 mm rise over 60 degrees), this paper adds return angles of 60, 90 and 120 degrees and a follower offset, and searches for the offset that makes smallest the pitch circle holding the largest pressure angle to 30 degrees on both rise and return. No new theorem or law is claimed. First, with zero offset the values of Paper 961 return: with zero offset and a 60 degree return, the needed pitch circle was 21.4575 mm for simple harmonic and 28.3851 mm for the cycloid, within 10^{-3} mm of Paper 961 (Section 2). Second, if the return has the same angle as the rise, offsetting gains nothing: with a 60 degree return, the best offset was 0.0000 mm for all four curves, and the needed radius stayed at its zero-offset value (Section 2). Third, the slower the return, the larger the best offset and the smaller the needed radius: for simple harmonic, a 90 degree return gave a best offset of 2.4335 mm and needed radius 17.4135 mm, and a 120 degree return gave 3.6194 mm and **15.6138** mm (Section 3). Fourth, the proportion of reduction is nearly the same for every curve: the needed radius relative to zero offset was 0.811534 to 0.815958 for a 90 degree return and **0.725686** to **0.732789** for 120 degrees (Section 3). Fifth, the separator is whether rise and return run at the same speed or at different speeds: the offset is subtracted in the numerator of the rise pressure angle and added in that of the return. At the same speed, lowering one raised the other by the same amount; with a slower return, its spare margin could be passed to the rise (Section 4). **Keywords:** cam, pressure angle, follower offset, return stroke, pitch circle, motion curve.

Scope of this paper (scope note): No new theorem or law is claimed: that offsetting a follower's line of motion from the cam center lowers the pressure angle on the rise and raises it on the return, and the pressure angle formula for an offset translating follower, are known in cam design. These are set values: the 10 mm rise, 60 degree rise angle and four motion curves are those of Paper 961, and the return angles of 60, 90 and 120 degrees, the allowed pressure angle of 30 degrees and the offset search range of 0 to 15 mm are set here. They correspond to no machine's cam. Only a translating roller follower is treated: flat-faced followers, swinging-arm followers, dwell segments and reversing the direction of rotation are not included. Profile strength is not treated: contact stress, materials, undercutting (Paper 967) and bearing friction from the side thrust are not treated. Relation to earlier papers: Paper 961, in its scope note, treated only a radial roller follower, leaving out followers offset from the center, flat-faced followers and swinging-arm followers; this paper sits in the seat of followers offset from the center (no earlier occupant). Paper 961 showed that even among cam curves with the same peak velocity, the pitch circle holding the pressure angle changes with where the angle peaks. Here a return and a follower offset are added to the same curves, and how the offset changes the needed radius is counted. Paper 967 showed that the roller size avoiding undercutting is ordered by deceleration. Here only the pressure angle is examined. What is added: reproducing Paper 961 at zero offset, finding best offsets and needed radii for three return angles, showing that the best offset is zero for an equal return angle, showing that the proportion of reduction is nearly independent of the curve, and placing the separator on "same speed, or different speeds".

1. Notation and the Question

Setting: a rise of $h = 10$ mm takes place over $\beta = 60$ degrees, and the return follows the same curve backward over an angle β_r . With the follower's line of motion offset by e from the cam center, the starting height for pitch circle radius R_p is $y_0 = \sqrt{R_p^2 - e^2}$, and the pressure angle is

$$\tan \phi = \frac{\pm(h/\beta) v(u) - e}{y_0 + h s(u)}$$

(+ and β on the rise, $-$ and β_r on the return). With u divided into 4000 steps, the largest pressure angles on rise and return were found, and R_p holding the larger of them to 30 degrees was found by bisection. The offset e was refined by golden-section search over 0 to 15 mm to make the needed R_p smallest.

Question: how much smaller does offsetting the follower make the pitch circle that holds the pressure angle on both rise and return?

2. Equal Return Angle

Computation 2.1: with zero offset and a 60 degree return, the needed pitch circle was 21.4575 mm for simple harmonic and 28.3851 mm for the cycloid, within 10^{-3} mm of Paper 961. Searching the best offset with a 60 degree

return gave 0.0000 mm for all four curves, with needed radii unchanged at 28.0797 mm (parabola), 21.4575 mm (simple harmonic), 28.3851 mm (cycloid) and 26.3648 mm (3-4-5 polynomial), a ratio of 1.000000.

Observation 2.2

if the return has the same angle as the rise, offsetting gains nothing.Returning along the same curve over the same angle makes the return pressure angle a mirror of the rise: an offset that lowers one raises the other by the same amount, so the best offset was zero.

3. Slower Returns

Computation 3.1: best offsets and needed pitch circles for 90 and 120 degree returns.

curve, return	zero offset (mm)	best offset (mm)	needed radius (mm)	ratio to zero offset
parabola, 90	28.0797	3.1831	22.7898	0.811611
simple harmonic, 90	21.4575	2.4335	17.4135	0.811534
cycloid, 90	28.3851	3.1395	23.1610	0.815958
3-4-5 polynomial, 90	26.3648	2.9341	21.4840	0.814875
parabola, 120	28.0797	4.7746	20.3771	0.725686
simple harmonic, 120	21.4575	3.6194	15.6138	0.727660
cycloid, 120	28.3851	4.6881	20.8003	0.732789
3-4-5 polynomial, 120	26.3648	4.3772	19.2865	0.731525

For all four curves, offsetting made the needed radius more than 10 percent smaller with a 120 degree return.

Observation 3.2

the slower the return, the more offsetting gains.Going from a 90 to a 120 degree return, the best offset grew and the radius ratio fell for all four curves: the ratio was 0.811534 to 0.815958 at 90 degrees and 0.725686 to 0.732789 at 120 degrees, nearly the same for every curve.

4. The Separator

Observation 4.1

the separator is whether rise and return run at the same speed or at different speeds. The offset e is subtracted in the numerator of the rise pressure angle and added in that of the return: at the same speed, spare margin on one side is shortfall on the other, and the best offset was zero. With a slower return, the return pressure angle has spare margin, and offsetting passes it to the rise, turning 21.4575 mm into 15.6138 mm for simple harmonic.

Observation 4.2

what is not said. Flat-faced or swinging-arm followers, dwell segments, direction of rotation, contact stress, undercutting and which offset to use are not treated. What is shown is that for the four curves of Paper 961, the gain from offsetting appears only with a slower return, in a proportion nearly independent of the curve.

5. Roll Call and Closing

1. pressure angle of an offset follower (Section 1): **subtracted on the rise, added on the return.**
2. zero offset reproduces Paper 961 (Computation 2.1): **21.4575 and 28.3851 mm.**
3. best offset 0 for a 60 degree return (Computation 2.1): **offsetting gains nothing.**
4. **15.6138 mm for simple harmonic with a 120 degree return** (Computation 3.1): **a slow return gains.**
5. ratios **0.725686 to 0.732789** (Computation 3.1): **nearly the same for every curve.**
6. same speed, or different speeds (Observation 4.1): **the separator; the scope note of Paper 961.**

Closing: Offsetting a cam follower pays only when the return is slower than the rise. For the four curves of Paper 961, the best offset was zero with a return equal to the 60 degree rise, but with a 120 degree return it became 3.6194 to 4.7746 mm and the needed radius fell to 0.725686 to 0.732789 of zero offset: for simple harmonic, 21.4575 mm became 15.6138 mm. The separator is whether rise and return run at the same speed or at different speeds. Placed among the earlier papers: to the pressure angle Paper 961 counted with a follower through the center, the offset and return Paper 961 did not include were added. To be honest: neither contact strength nor undercutting was examined. Where the gain from offsetting appears and how large it is, and no further.

References

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