

A Flat-Faced Follower Has Zero Pressure Angle, Yet the Base Circle for a Convex Profile Is Set by Deceleration

— the lower bound on the base circle rises in the order parabola, simple harmonic, 3-4-5 polynomial, cycloid, and all four exceed the pitch circle a roller needs for a 30 degree pressure angle —the separator is whether the follower's shape asks the cam for slope or for bending — [Paper 977]

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Abstract

With a roller follower, the pitch circle holding the pressure angle is set by peak velocity (Paper 961), and the roller size avoiding undercutting by deceleration (Paper 967). A flat-faced follower always touches the profile with its face, so its pressure angle is zero, but unless the profile is convex the face bridges across it. For the four motion curves of Paper 961 (a 10 mm rise over 60 degrees), this paper finds the lower bound on the base circle radius that keeps a flat-faced translating follower's profile convex and how far the contact point slides across the face, and compares them with the pitch circle a roller follower needs. No new theorem or law is claimed. First, the lower bound on the base circle rises in the order of deceleration: the lower bound was 31.4756 mm for the parabola, 35.0000 mm for simple harmonic, 43.3369 mm for the 3-4-5 polynomial and **48.2270** mm for the cycloid (Section 2). Second, the bound is set in the decelerating part of the rise: the setting position was $u = 0.5000$, where the parabola starts to decelerate, $u = 1.0000$ at the end of the rise for simple harmonic, $u = 0.7840$ for the 3-4-5 polynomial and $u = 0.7455$ for the cycloid. The bounds for simple harmonic and the parabola matched closed forms within 10^{-9} (Section 2). Third, all four exceed the pitch circle a roller needs for a 30 degree pressure angle: relative to the roller's needed pitch circle (Paper 961) the ratios were 1.120939 for the parabola, 1.631131 for simple harmonic, 1.643741 for the 3-4-5 polynomial and **1.699024** for the cycloid (Section 3). Fourth, the face width is set by peak velocity: the largest sideways travel of the contact point on the face was 19.0986 mm for parabola and cycloid, 17.9049 mm for the 3-4-5 polynomial and 15.0000 mm for simple harmonic, agreeing within 10^{-9} with rise over cam angle times the peak velocity factor (Section 3). Fifth, the separator is whether the follower's shape asks the cam for slope or for bending: a roller asks the cam for slope (pressure angle), and the needed pitch circle was smallest for simple harmonic. A flat face asks for bending (convexity), and the needed base circle was smallest for the parabola, with simple harmonic second (Section 4). **Keywords:** cam, flat-faced follower, base circle, profile curvature, pressure angle, motion curve.

Scope of this paper (scope note): No new theorem or law is claimed: that a flat-faced follower has zero pressure angle, that the convexity condition is written as the base circle radius plus the lift and its second derivative, and that face width is set by the largest travel of the contact point, are all known in cam design. The setting is that of Paper 961: the 10 mm rise, 60 degrees of cam angle, four motion curves and the pitch circles a roller needs for a 30 degree pressure angle are those of Paper 961, corresponding to no machine's cam. Only a translating flat-faced follower is treated: the face is perpendicular to the follower's motion; offset faces, swinging-arm followers and the return segment are not included. Profile strength is not treated: contact stress, materials, face friction and wear, and the detailed curvature at junctions with dwells are not treated. Relation to earlier papers: Paper 972, in its scope note, treated only a translating roller follower, leaving out flat-faced followers, swinging-arm followers, dwell segments and reversing rotation; this paper sits in the seat of flat-faced followers (no earlier occupant). Paper 961, in its scope note, also left out flat-faced followers; this paper sits in that seat as well. 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 it is counted what takes over in setting cam size for a follower whose pressure angle is zero. Paper 967 showed that the roller size avoiding undercutting is ordered by deceleration. Here it is counted that for a flat-faced follower, too, the convexity condition sets the base circle in the order of deceleration. What is added: finding the lower bound on the base circle and its setting position for four curves, checking simple harmonic and the parabola against closed forms, comparing with the roller's needed pitch circle, finding the face width, and placing the separator on "slope, or bending".

1. Notation and the Question

Setting: as in Paper 961, a rise of $h = 10$ mm takes place over a cam angle of $\beta = 60$ degrees ($\pi/3$ radians), with lift $s(u)$ at dimensionless angle u , velocity factor $v = ds/du$ and acceleration factor $a = d^2s/du^2$. For a translating flat-faced follower, the profile's radius of curvature at the contact point and the sideways travel of the contact point on the face are

$$\rho = R_b + h s + \frac{h}{\beta^2} a, \quad e = \frac{h}{\beta} v$$

(R_b the base circle radius). A convex profile needs $\rho > 0$, so the lower bound on the base circle radius is the maximum of $-hs - (h/\beta^2)a$, searched with u divided into 4000 steps.

Question: for a flat-faced follower with zero pressure angle, what sets the size of the cam?

2. Lower Bound on the Base Circle

Computation 2.1: lower bounds on the base circle and setting positions for the four motion curves.

curve	lower bound (mm)	setting position u
parabola	31.4756	0.5000
simple harmonic	35.0000	1.0000
3-4-5 polynomial	43.3369	0.7840
cycloid	48.2270	0.7455

The bound for simple harmonic matched the closed form $h(\pi^2/2)/\beta^2 - h$ and that for the parabola matched $4h/\beta^2 - h/2$, both within 10^{-9} .

Observation 2.2

the lower bound on the base circle rises in the order of deceleration. From smallest, the bounds ran parabola, simple harmonic, 3-4-5 polynomial, cycloid, the same order as the peak deceleration factors of the four curves from smallest (4, 4.934802, 5.773502, 6.283185 in Papers 961 and 967): every setting position lay in the decelerating part, at the end of the rise for simple harmonic and at the start of deceleration for the parabola.

3. Against the Roller, and Face Width

Computation 3.1: ratio to the pitch circle a roller needs for a 30 degree pressure angle (Paper 961), and the largest sideways travel of the contact point.

curve	flat-face base circle bound	roller's needed pitch circle	ratio	largest contact travel
parabola	31.4756 mm	28.0797 mm	1.120939	19.0986 mm
simple harmonic	35.0000 mm	21.4575 mm	1.631131	15.0000 mm
3-4-5 polynomial	43.3369 mm	26.3648 mm	1.643741	17.9049 mm
cycloid	48.2270 mm	28.3851 mm	1.699024	19.0986 mm

The largest contact travel agreed within 10^{-9} with (h/β) times the peak velocity factor (2, $\pi/2$, 1.875, 2).

Observation 3.2

even with zero pressure angle, a flat-faced follower needs a larger cam. For all four curves, the base circle needed for a convex profile exceeded the pitch circle a roller needs for a 30 degree pressure angle, by ratios from 1.120939 for the parabola to 1.699024 for the cycloid: the sideways travel setting face width follows the velocity factor, smallest for simple harmonic at 15.0000 mm.

4. The Separator

Observation 4.1

the separator is whether the follower's shape asks the cam for slope or for bending. A roller follower limits the profile's slope (pressure angle), and the needed pitch circle ran simple harmonic, 3-4-5 polynomial, parabola, cycloid (Paper 961): a flat-faced follower limits the profile's bending (convexity), and the needed base circle ran parabola, simple harmonic, 3-4-5 polynomial, cycloid, with the parabola and simple harmonic trading places.

Observation 4.2

what is not said. Contact stress, materials, face friction and wear, offset faces or swinging-arm followers, the return segment, and which follower to use are not treated. What is shown is that, in the setting of Paper 961, the base circle of a flat-faced follower is set in the order of deceleration and exceeds a roller's needed pitch circle.

5. Roll Call and Closing

1. convexity condition and contact travel (Section 1): **bending and slope.**
2. bounds from 31.4756 to **48.2270** mm (Computation 2.1): **order of deceleration.**
3. simple harmonic 35.0000 and parabola 31.4756 by closed form (Computation 2.1): **check.**
4. ratios to the roller 1.120939 to **1.699024** (Computation 3.1): **all four larger.**
5. face width 15.0000 to 19.0986 mm (Computation 3.1): **set by the velocity factor.**
6. slope, or bending (Observation 4.1): **the separator; the scope notes of Papers 972 and 961.**

Closing: A flat-faced follower has zero pressure angle, yet the base circle for a convex profile is set by deceleration. For the four curves of Paper 961, the lower bound on the base circle was 31.4756 mm for the parabola, 35.0000 mm for simple harmonic, 43.3369 mm for the 3-4-5 polynomial and 48.2270 mm for the cycloid, 1.120939 to 1.699024 times the pitch circle a roller needs for a 30 degree pressure angle: the contact travel setting face width follows the velocity factor, smallest for simple harmonic at 15.0000 mm. The separator is whether the follower's shape asks the cam for slope or for bending. Placed among the earlier papers: the cam size that Papers 961 and 972 counted with a roller was counted for the flat-faced follower they did not include, and the deceleration order of Paper 967 appeared here as well. To be honest: neither contact strength nor face friction was examined. For a follower with zero pressure angle, what takes over in setting cam size, and no further.

References

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