April 10, 1956 M. GOLDBERG 2,741,132

DOUBLE-CONTACT CAM MECHANISMS

Filed June 30, 1952 3 Sheets-Sheet 1

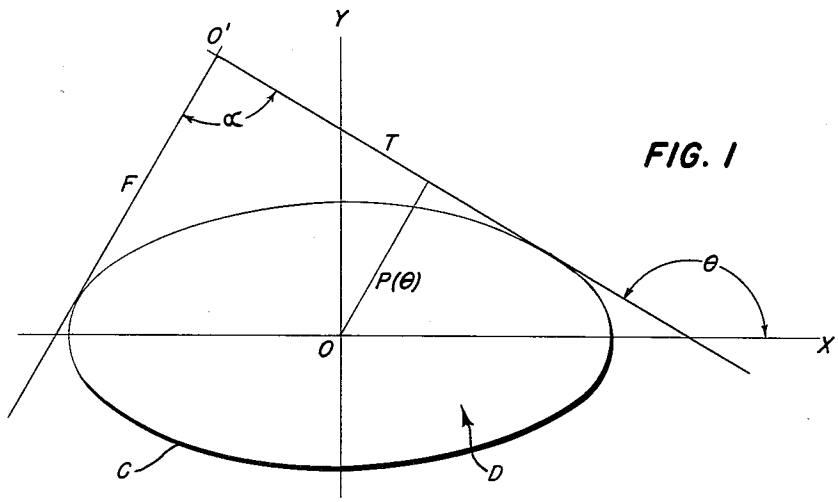


FIG. 1

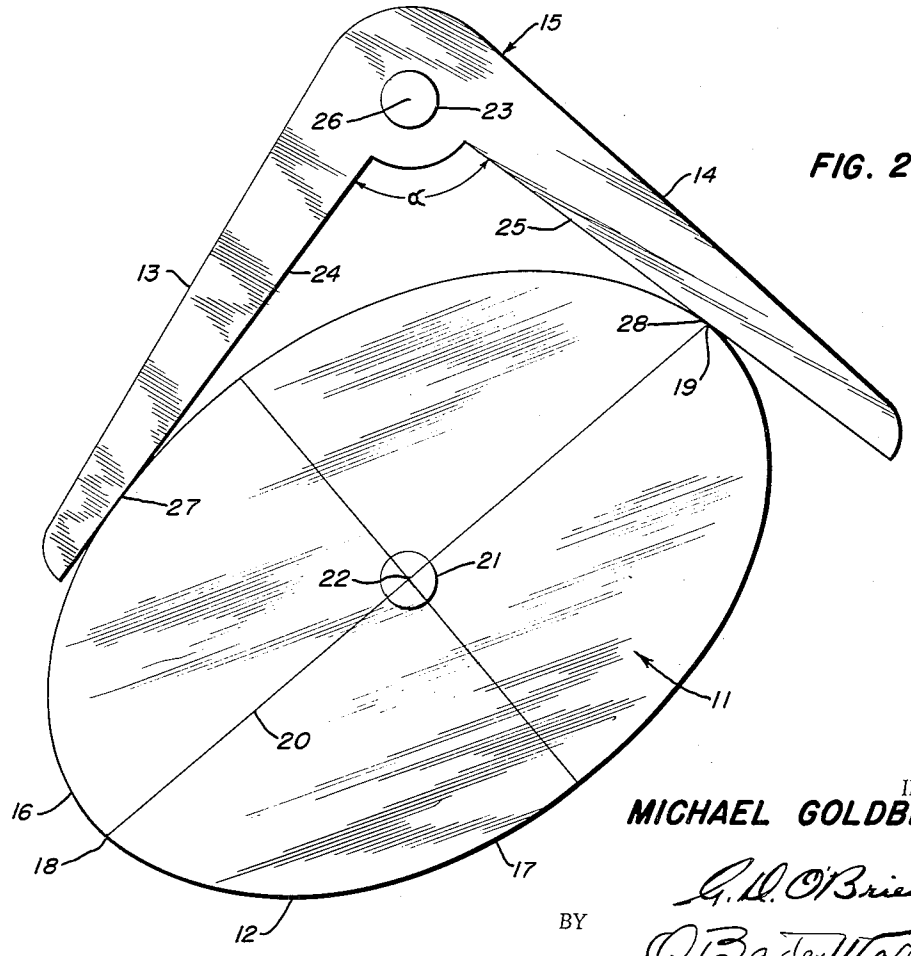


FIG. 2

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FIG. 3

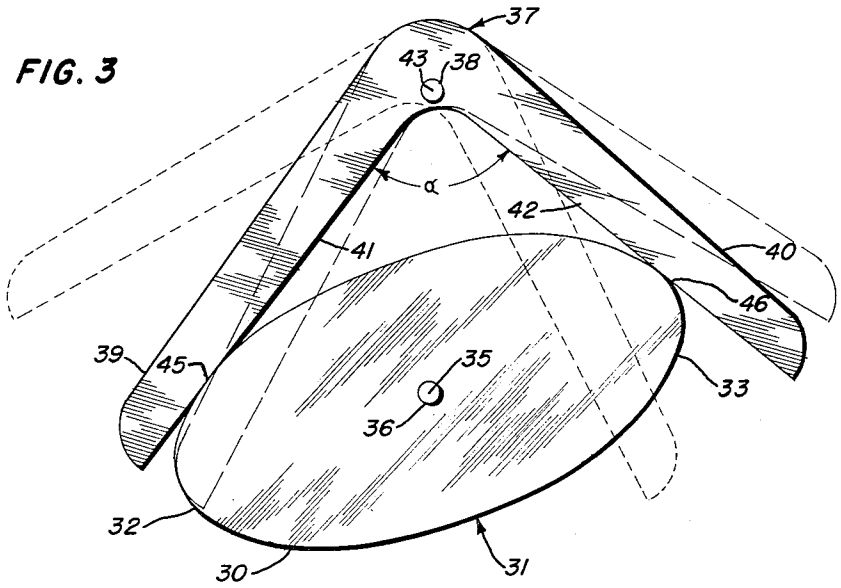
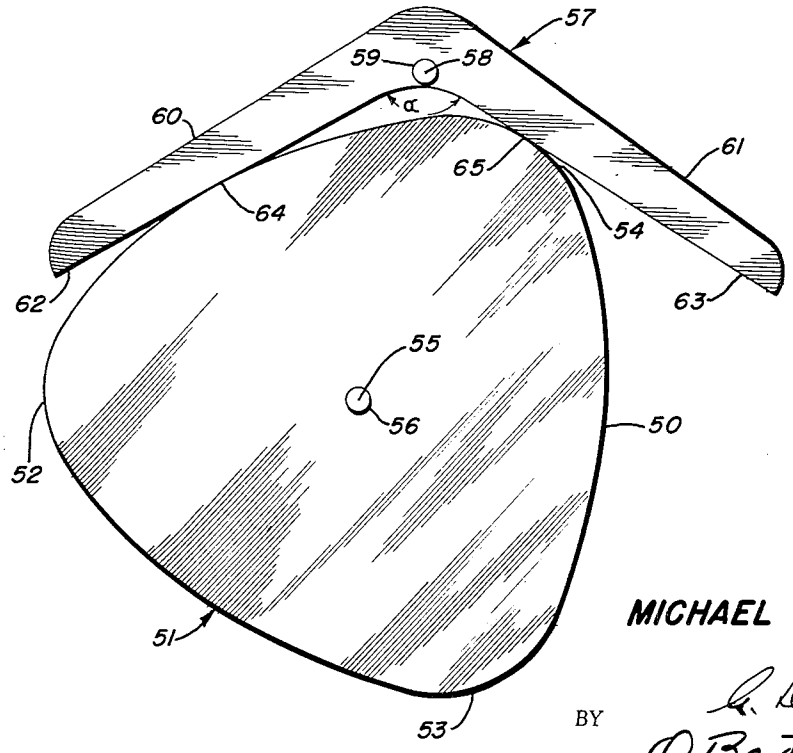


FIG. 4



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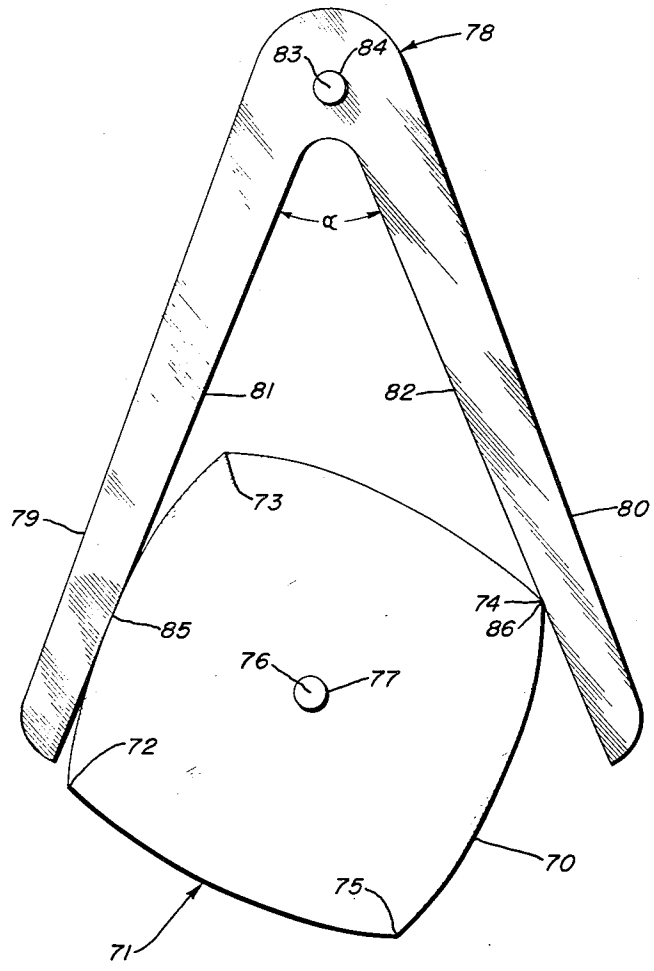
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FIG. 5



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DOUBLE-CONTACT CAM MECHANISMS

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6 Claims. (Cl. 74—54)

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to devices for changing rotation into angular oscillation and more particularly to multilobed cams having two-legged followers making double contact with the cams.

The familiar Scotch yoke mechanism converts uniform rotation into sinusoidal oscillation along a straight line and has a follower making double contact with an eccentrically mounted circular cam. This principle is utilized to convert rotation into angular oscillation in the patent to H. J. Rober, No. 911,073, patented February 2, 1909.

Heretofore, the use of a convex multilobed cam with a two-legged angular follower, each leg of which makes and maintains contact with the cam at all times has not been known. The multilobed cams of this invention coact with a follower having angularly disposed legs, the inner surfaces of which are substantially flat, and which surfaces are always maintained in contact with the contour of the cam. By virtue of this double contact the follower is positively oscillated by said cam.

In the prior art, contact between multilobed cams and a single contact follower has been maintained by use of springs or the like. Rollers have been utilized on the follower to replace sharp point contact with the surface of the cam. The cams and followers of this invention have the advantage over the prior art in that the cam positively drives the follower at all times, and there is, therefore, no possibility of vibration such as may result when the contact between the cam and the follower is maintained by a spring. Further, since the contours of the cams of this invention, during the course of a complete revolution, directly contact a large portion of the substantially flat planar faces of the two legs of the follower, the wearing of the surfaces of the followers is greatly reduced as compared with the wear which results from the concentration of loads on the relatively small pintle of a roller.

It is, therefore, an object of this invention to provide a device for converting rotation into angular oscillation.

It is a further object of this invention to provide a multilobed cam and a two-legged follower which follower makes double contact at all times with the contour of the cam.

It is an additional object of this invention to provide a family of convex multilobed cams making double contact at all times with the angularly disposed legs of a family of cam followers.

It is a further object of this invention to provide a double contact substantially plane-faced follower driven by a convex multilobed cam so that the follower oscillates angularly about its axis of oscillation, or its pivot.

Still another object of this invention is to provide a cam and double contact follower of rigid construction, so constructed and arranged that any desired integral

number of angular oscillations may be imparted to the follower for each revolution of the cam.

Other objects of this invention will be apparent from a consideration of the following specification when considered in connection with the annexed drawings in which:

Fig. 1 shows diagrammatically one form of a cam and double contact follower;

Fig. 2 shows an elevation of a cam of a more general form and its follower;

Fig. 3 shows an elevation of a two-lobed cam of a simpler form and its follower;

Fig. 4 shows an elevation of a three-lobed cam and its follower and

Fig. 5 shows an elevation of a four-lobed cam and its follower.

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in Fig. 1 a diagrammatic illustration of a multilobed cam and double contact follower which forms the subject of this invention.

It can be shown mathematically that the only angles α (expressed in radians) which can be used for double contact cam followers of this invention are defined by the equation

$$\alpha=\pi(1-a/b) \tag{1}$$

where a/b is a proper fraction in its lowest terms and where a is odd. The contours of the surfaces of the multilobed cams of this invention may have a wide variety of shapes, the most general of which may be described by an equation of the form

$$\arccos p(\theta) + \arccos p(\theta+\pi/b)=\pi a/b \tag{2}$$

where, referring to Fig. 1, O is the origin for Cartesian coordinates X and Y, tangents T and F are a diagrammatic illustration of a two-legged follower, C is a diagrammatic illustration of the contour of a multilobed cam D, and $p(\theta)$ is the distance from the origin O to line T which is tangent to the contour C of the cam D and intersects the X axis at an angle equal to θ. The distance from the center of rotation or origin O of the cam D to the center of oscillation O' of the follower F is taken as unity. The distance $p(\theta)$ from the origin O to the line T may vary in an arbitrary way in the interval from $\theta=0$ to $\theta=\pi/b$. Equation 2 then defines the distance $p(\theta)$ from the origin to the line T in the interval from $\theta=\pi/b$ to $\theta=2\pi/b$ and similarly for all other intervals around the circumference of the cam. For a practical contour it is necessary to preserve the continuity of $p(\theta)$, and to insure convexity it is necessary that the curvature of the surface, which is equal to $p(\theta)+p''(\theta)$, where '' indicates the second derivative, be greater than zero at every point on the contour. To avoid sharp points the first derivative of $p(\theta)$ must also be continuous. With respect to the contours of the cams of this invention, it is not necessary that the second derivative be continuous for all values of θ.

Referring now to Fig. 2, there is illustrated a cam **11** whose contour **12** satisfies Equation 2. In this instance $a=1$ and $b=2$. The angle α, determined by legs **13** and **14** of follower **15** is then determined by Equation 1

$$\alpha=\pi(1-\tfrac{1}{2})=\pi/2=90°$$

Segments **16** and **17** of contour **12** are determined by the points of intersection **18** and **19** between contour **12** and a coordinate axis **20** through axis of rotation **22** of cam **11**. The curve which describes the contour of segment **16** is any arbitrary convex curve which satisfies Equation 2. Segment **17** is then made identical to segment **16**. In other words contour **12** of cam **11** is made

up of a whole number of identical portions, or segments, which repeat periodically.

One of the simplest families of cams of this type is described by the equation

$$p(\theta)=\cos(\pi a/2b+\phi\cos b\theta) \tag{3}$$

where ϕ is a constant angle arbitrarily taken small enough to insure the convexity of the curve. In this case the value of ϕ must satisfy the equation

$$\cot\left(\frac{\pi a}{2b}-\phi\right)-\phi b^2>0 \tag{4}$$

For example, contour **30** of cam **31** of Fig. 3 is obtained when $a=1$, $b=2$, and $\phi=18°$. The range of values that ϕ may take in this case is from $\phi>0$ to $\phi<90°$. The angle α is then determined by the equation

$$\alpha=\pi(1-\tfrac{1}{2})=90°$$

Three-lobed contour **50** of cam **51**, Fig. 4, is obtained when $a=1$, $b=3$, and $\phi=10°$. The range of values that ϕ may take in this case is from $\phi>0$ to $\phi<30°$. The angle α determined by the legs of the follower is found from the equation

$$\alpha=\pi(1-\tfrac{1}{3})=120°$$

Four-lobed contour **70** of cam **71** shown in Fig. 5 is obtained when $b=4$, $a=3$ and $\phi=1°\ 30'$. The range of values that ϕ may take in this case is from $\phi>0$ to $\phi<1°\ 36'$. The angle α determined by the two legs of the follower is found from the equation

$$\alpha=\pi(1-\tfrac{3}{4})=45°$$

Referring to the cam **11** of Fig. 2, the most general case, the contour **12** is a periodic curve, that is, it is made up of a whole number of identical portions. Similarly contours **30**, **50**, and **70** of cam **31**, **51** and **71** of Figs. 3, 4 and 5 are periodic curves. In addition the contours of cams **31**, **51** and **71** have two or more axes of symmetry. It should be noted in the simpler cases, that there are as many lobes as there are axes of symmetry. The cam **11** of Fig. 2, however, has no axis of symmetry. Thus it can be seen that contours of the cams of this invention are periodic curves. Contours of the more general case, such as will satisfy Equation 2, need not be symmetric about any axis, while contours of the more simple case, which satisfy Equation 3, are symmetric about a number of axes equal to the number of lobes formed by the contour of the cam.

Referring again to Fig. 2, in which there is shown one form of the invention, cam **11** is mounted on a pivot **21** so as to rotate about its axis of rotation **22** which is also the axis of pivot **21**. Pivot **21** comprises means for mounting cam **11** and for imparting rotation to cam **11** from a power source which is not illustrated. A follower **15** mounted on a pivot **23** has angularly extending legs **13** and **14**, whose interior faces **24** and **25** are substantially flat planes disposed at an angle, α, of 90°, as explained above, and with the planes determining said faces intersecting at axis of oscillation **26** of follower **15** which is also the axis of pivot **23**. Pivot **23** comprises means for applying the oscillation of follower **15** to a load which is not illustrated. The distance between axis of rotation **22** and axis of oscillation **26** is fixed so that the faces **24** and **25** of the legs **13** and **14** always contact the contour **12** of cam **11**. In the position illustrated the faces **24** and **25** contact contour **12** at points **27** and **28**. In the embodiment illustrated the spacial relationship between axis of rotation **22** and axis of oscillation **26** is also fixed so that rotation of cam **11** will cause follower **15** to oscillate. Rotation of cam **11** through 180° about axis of rotation **22** will cause follower **15** to execute one complete angular oscillation about axis **26**. An additional rotation of cam **11** through 180° will cause follower **15** to execute a second complete angular oscillation. As cam **11** rotates, the points of contact, which are always maintained between

the faces **24** and **25** of follower **15** and contour **12** of cam **11**, will move along faces **24** and **25**, whereby, the wearing of these faces due to friction and pressure is not concentrated, thus contributing to a longer trouble-free period of operation of the device.

In Fig. 3 there is shown another form of the invention. The elliptical cam **31** has two lobes, **32** and **33** respectively, two axes of symmetry, and an axis of rotation **35** which is also the axis of pivot **36**. Pivot **36** comprises means for mounting said cam **31** and for imparting rotation to the cam **31** from a power source which is not illustrated. Follower **37** mounted on a pivot **38** has an angularly extending legs **39** and **40**, the interior faces **41** and **42** thereof, being substantially flat planes disposed at an angle of 90°, as explained above, and with the planes determining said faces intersecting at the axis of oscillation **43** which is also the axis of pivot **38**. Pivot **38** comprises means for applying the oscillation of follower **37** to a load which is not illustrated. The distance between axis of rotation **35** and axis of oscillation **43** is fixed so that the faces **41** and **42** of legs **39** and **40** always contact the contour **30** of the cam **31**. In the position illustrated, the faces **41** and **42** contact contour **30** at points **45** and **46**, respectively. The spacial relationship between axis of rotation **35** and axis of oscillation **43** is also fixed so that rotation of cam **31** will cause follower **37** to oscillate. Rotation of cam **31** through 180° about its axis of rotation **35** will cause follower **37** to move angularly to the two extreme positions shown in the dotted lines and return to the position shown in the solid lines. An additional 180° of rotation of cam **11** will result in an additional complete angular oscillation of follower **37** about its axis of oscillation **43**.

In Fig. 4 there is illustrated a three-lobed cam **51**. The cam **51** has three lobes **52**, **53** and **54** and is mounted for rotation about an axis of rotation **55** which is also the axis of pivot **56**. Pivot **56** comprises means for mounting cam **51** and for imparting rotation to said cam from a power source which is not illustrated. A follower **57** is mounted for oscillation about an axis of oscillation **58** which is also the axis of pivot **59** with which the follower **57** oscillates. Pivot **59** comprises means for applying the oscillations of the follower to a load which is not shown. Angularly disposed legs **60** and **61** of follower **57** have substantially flat planar interior faces **62** and **63**. The distance between axis of rotation **55** and axis of oscillation **58** is fixed so that the faces **62** and **63** of legs **60** and **61** will always contact the contour **50** of cam **51**. In the position illustrated, faces **62** and **63** contact contour **50** at points **64** and **65**. The interior faces of the follower subtend an angle of 120°, as explained above, the apex of the angle coinciding with the axis of oscillation **58**. The spacial relationship between axis of rotation **55** and axis of oscillation **58** is fixed so that rotation of cam **51** will cause follower **57** to oscillate. Rotation of cam **51** through 120° will result in one complete oscillation of follower **57**; hence rotation through 360° will result in three complete oscillations of the follower about its center of oscillation.

In Fig. 5 there is disclosed a four-lobed cam **71**. The cam **71** has lobes **72**, **73**, **74** and **75** and is mounted for rotation about an axis of rotation **76** which is also the axis of pivot **77**. Pivot **77** comprises means for mounting cam **71** and for imparting rotation to the cam from a power source which is not illustrated. A follower **78** has angularly disposed legs **79** and **80**, the interior, substantially planar surfaces **81** and **82** of said legs, subtending an angle of 45° as explained above, and the apex of the angle coinciding with the axis of oscillation **83** of the follower **78**. The axis of oscillation **83** is also the axis of a pivot **84** which pivot comprises means for applying the oscillation of follower **78** to a load which is not illustrated. The distance between axis of rotation **76** and axis of oscillation **83** is fixed so that the inner surfaces **81** and **82** of the legs of the follower **78** always contact the sur-

faces of the contour **70** of cam **71**. In the position illustrated, faces **81** and **82** contact contour **70** at points **85** and **86**. The spacial relationship between axis of rotation **76** and axis of oscillation is fixed so that rotation of cam **71** will cause follower **78** to oscillate. The turning of cam **71** through 360° will, of course, cause the follower **78** to execute four complete oscillations.

In the explanation of the operation of the embodiments illustrated it has been assumed that the cam rotates to oscillate its associated follower. It is of course obvious that the cam may be held stationary and the axis of oscillation of the follower rotated around said cam to cause the follower to oscillate. Furthermore there may be limited movement of the axis of oscillation of the follower when the cam is rotated. It is only essential that the distance between the two axis be maintained constant or fixed.

Obviously, many modifications and variations are possible in the light of the above teachings. It is, therefore, understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination, a convex multilobed cam having an axis of rotation, the contour of said cam being a periodic curve, means mounting said cam for rotation about its axis of rotation, a two-legged follower having an axis of oscillation, the legs of said follower having substantially plane interior faces, the planes determining said faces intersecting at said axis of oscillation, and means mounting said follower for oscillation about its axis of oscillation, the contour of the cam, the angular relationship of said plane interior faces and the spacial relationship between the axis of rotation and the axis of oscillation being such that the substantially plane face of each leg of the follower contacts the contour of the cam throughout a complete revolution of said cam, whereby the follower oscillates about its axis of oscillation when the cam is rotated about its axis of rotation.

2. A device for changing rotation into oscillation comprising a cam having an axis of rotation; the contour of said cam being substantially described by an equation of the form

$$\arccos\ p(\theta)+\arccos\ p(\theta+\pi/b)=\pi a/b$$

the axis of rotation being the origin of a set of Cartesian coordinates for the equation, $p(\theta)$ being the distance from the origin to any line tangent to the contour of the cam, θ being the angle the line makes with one of said coordinates a/b being a proper fraction and a being odd; means mounting said cam for rotation about its axis of rotation,

a cam follower having an axis of oscillation and two legs, the inner surfaces of said legs defining substantially flat planes, said planes intersecting at said axis of oscillation and defining an angle α determined by an equation of the form

$$\alpha=\pi(1-a/b)$$

and means mounting said follower for oscillation about its axis of oscillation, the means for mounting said cam and said follower being located so that the inner surface of each leg of the follower contacts the contour of said cam.

3. A device for changing rotation into oscillation comprising a cam having an axis of rotation; the contour of said cam being substantially described by an equation of the form

$$p(\theta)=\cos(\pi a/2b+\phi\cos b\theta)$$

the axis of rotation being the origin of a set of Cartesian coordinates for the equation, $p(\theta)$ being the distance from the origin to any line tangent to the contour of the cam, θ being the angle the line makes with one of said coordinates a/b being a proper fraction, and a being odd, ϕ having a value which satisfies the equation

$$\cot\left(\frac{\pi a}{2b}-\phi\right)-\phi b^2>0$$

means mounting said cam for rotation about its axis of rotation, a cam follower having a fixed axis of oscillation and two legs, the inner surfaces of said legs defining substantially flat planes, said planes intersecting at the said axis of oscillation and defining an angle α determined by an equation of the form

$$\alpha=\pi(1-a/b)$$

and means mounting said follower for oscillation about its axis of oscillation, the inner surface of each leg of said follower contacting the contour of said cam.

4. The device as claimed in claim 3 in which $a=1$, $b=2$, and the value of ϕ is in the range of $\phi>0$ to $\phi<90°$.

5. The device as claimed in claim 3 in which $a=1$, $b=3$ and the value of ϕ is the range of $\phi>0$ to $\phi<30°$.

6. The device as claimed in claim 3 in which $a=3$, $b=4$ and the value of ϕ is in the range of $\phi>0$ to $\phi<7°36'$.

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