Feb. 18, 1936. H. ALFARO 2,030,907

CAM GENERATING MACHINE

Filed Aug. 4, 1934 2 Sheets-Sheet 1

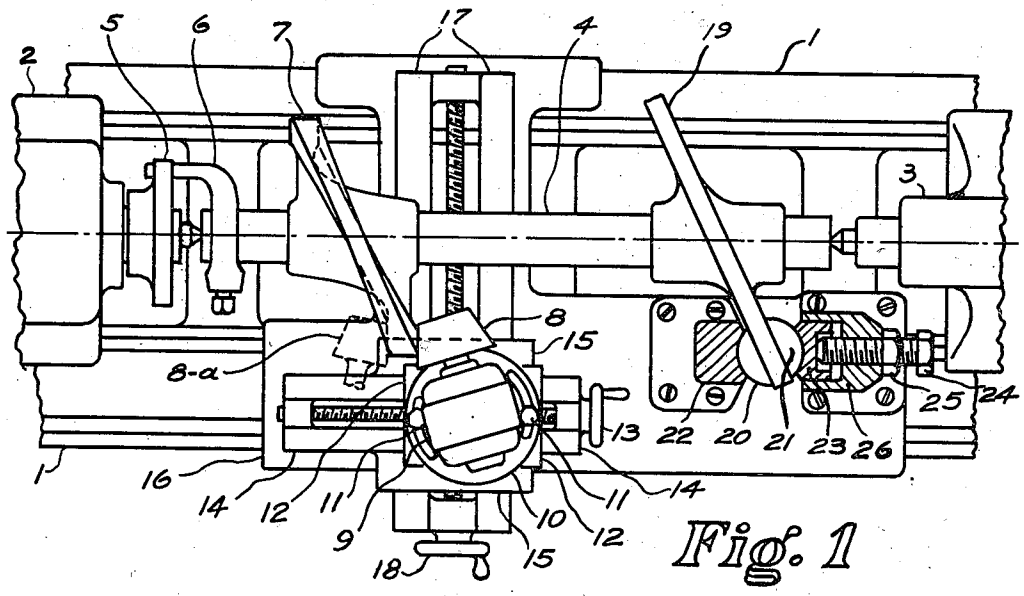


Fig. 1

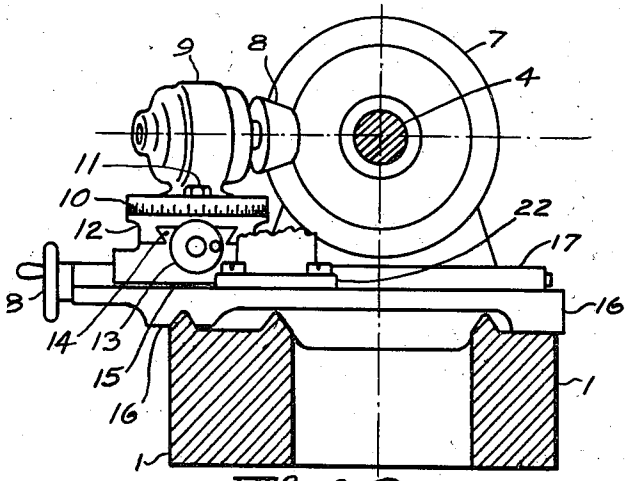


Fig. 2

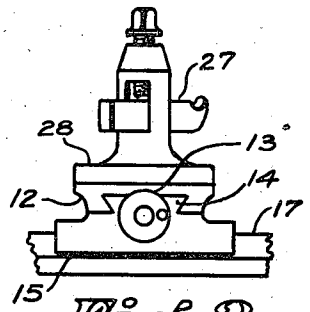


Fig. 3

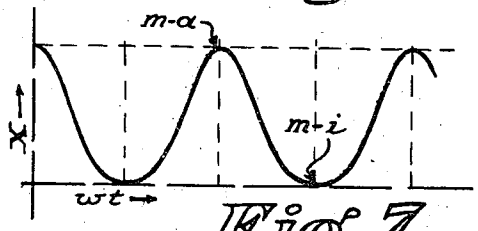


Fig. 7

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CAM GENERATING MACHINE

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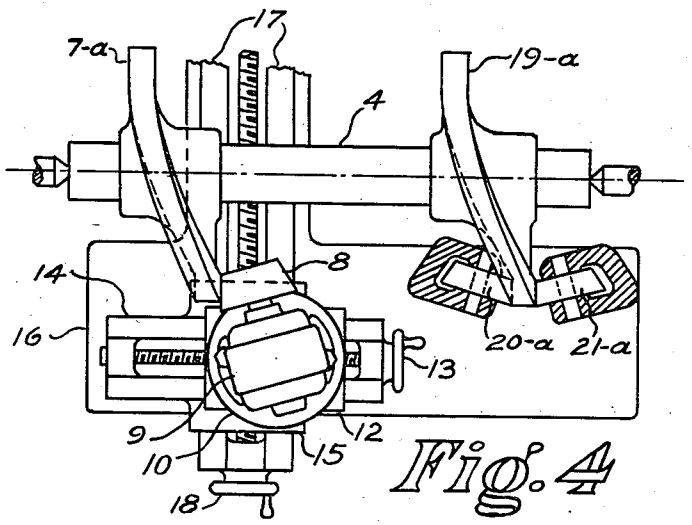


Fig. 4

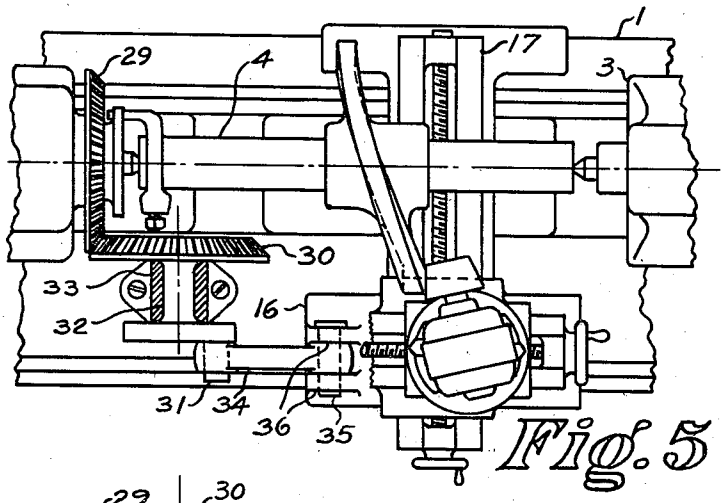


Fig. 5

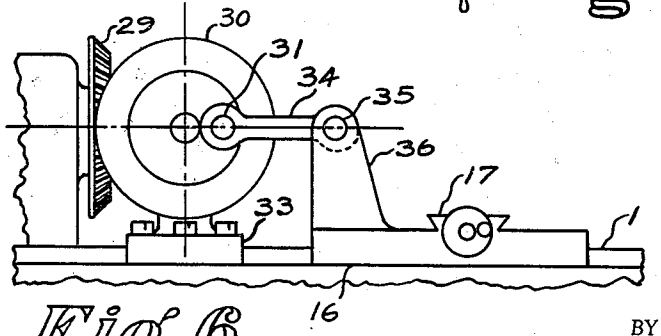


Fig. 6

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UNITED STATES PATENT OFFICE

2,030,907

CAM GENERATING MACHINE

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Application August 4, 1934, Serial No. 738,503

17 Claims. (Cl. 51—101)

This invention relates to cam generating machines and more particularly to a machine for generating wabbler cams for internal combustion engines of the barrel type, such as disclosed in my applications Serial No. 674,198 filed June 3, 1933 and Serial No. 710,428 filed February 9, 1934, in which the cylinders are grouped about a central shaft and the motion of the pistons in the cylinders is controlled by cams on the central shaft which receive the end thrust of the pistons, preferably through rollers carried by the pistons and traveling upon the faces of the cams.

This invention has for its object to provide a simple and inexpensive machine for manufacturing cams of the character referred to in which a generating cutter having a line of contact with the work corresponding to that of the piston thrust roller is caused to have a linear reciprocating motion related to the rotational movements of the work support in exactly the same way as the motions of an individual engine piston is related to the rotational movements of the engine shaft.

With the above and other objects in view, the invention may be said to comprise the machine as illustrated in the accompanying drawings, hereinafter described and particularly set forth in the appended claims, together with such variations and modifications thereof as will be apparent to those skilled in the art to which the invention appertains.

Reference should be had to the accompanying drawings forming a part of this specification, in which

Figure 1 is a fragmentary plan view of a machine embodying the invention;

Fig. 2 is a transverse vertical section showing the tool carriage in elevation;

Fig. 3 is a fragmentary elevation showing a tool and holder which may be substituted for the rotary cutting element shown in Figs. 1 and 2;

Fig. 4 is a fragmentary plan view showing a modified means for imparting linear reciprocation to the tool carriage;

Fig. 5 is a fragmentary plan view showing still another carriage actuating device;

Fig. 6 is a fragmentary side elevation of the tool carriage and actuating means shown in Fig. 5; and

Fig. 7 is a diagram showing the motion of the tool carriage.

In the machine of the present invention the wabbler cam blank is mounted upon a suitable support which rotates about a fixed axis and the work support is rotated while the cam faces are being generated by cutting or grinding elements mounted on a carriage to which a harmonic reciprocating motion corresponding to the motion which the cam is to impose on engine pistons is imparted.

Figs. 1 and 2 show a machine adapted to so correlate the rotational and linear movements of the work and tool carriage. In these figures the main frame or bed of the machine is indicated by the reference numeral 1. This bed as here shown is similar to that of a lathe and, as a matter of fact, a lathe with some alterations could be used. A head stock 2 provided with the usual power driven spindle is mounted at one end of bed 1, and a tail stock 3 is mounted at the other end. A mandrel 4 is mounted between the "centers" of head stock 2 and tail stock 3 and is attached to the head stock spindle for rotation therewith by means of a chuck 5 and a dog 6. A cam blank 7 is fixed to the mandrel 4 for rotation therewith and is engaged by a generating cutting element 8, which may be a milling cutter or a grinding wheel. The generating cutting element 8 is driven by suitable means. As herein shown, the cutting element 8 is fixed to the shaft of an electric motor 9. The base 10 of motor 9 is preferably circular and angularly adjustable about a vertical axis to permit the shaft of the cutting element to be set at any desirable angle with respect to the mandrel 4.

Clamping bolts 11 passing through circular slots in the base 10 secure the base 10 to a carriage slide 12 in the desired position of angular adjustment. The slide 12 can be moved lengthwise relative to the mandrel 4 on guides 14 by means of a lead screw operated by a handle 13. The guides 14 are an integral part of a cross slide 15 on a carriage 16. The cross slide 15 can be moved on guides 17 on the carriage 16 by means of a lead screw operated by a handle 18.

The carriage 16 is free to move lengthwise on longitudinal guides of the bed 1. The motions of carriage 16 parallel to the mandrel 4 on the bed 1 are controlled by a swash plate 19 fixed on the mandrel 4 in appropriate position with respect to the cam blank 7. Two spherical segments 20 and 21 are supported by concavities in members 22 and 23 and engage opposite faces of the swash plate 19. The member 22 is bolted directly to the carriage 16 and is fixed with respect to the carriage. The member 23 may be adjusted longitudinally of the carriage by means of a bolt 24 and a lock nut 25, being slidably supported by a member 26, which is bolted to the body of the carriage 16.

It can be seen that, when shaft 4 is rotated,

the carriage 16 will have a simple harmonic motion in synchronism with the rotation of shaft 4. By adjustment of the bolt 24 sufficient freedom between the spherical segments 20 and 21 and the swash plate 19 may be provided to allow the plate 19 to slip freely between the segments when shaft 4 rotates. The rubbing surfaces of the segments and plate should be properly lubricated.

By means of the handle 13 the generating wheel 8 may be moved into engagement with the cam blank 7 and may be gradually advanced during the cutting or grinding operation. By means of the handle 18 the wheel 8 may be moved toward or away from the mandrel 4 to properly generate a track on the cam face for a roller of the size intended to coact with the cam.

To rough-cut the cam, I prefer to use first a simple cutting tool on the rough cam blank, such as that shown in Fig. 3 and indicated by the reference numeral 27. The tool 27 is supported by a tool post 28 which replaces the motor 9 and its support and which is mounted on the carriage slide 12 for angular adjustment in exactly the same way as the motor 9. Once the roughing is done, the tool post 28 is replaced by the motor 9 carrying a rough emery wheel. After grinding with the rough emery wheel the cam is hardened by heat treatment and is again placed in the machine for a final grinding and polishing, using the motor 9 and a very fine emery wheel at 8.

To generate the opposite face of the cam 7, the cam may be reversed in position on shaft 4 and the procedure repeated, but it is preferable to adjust the tool support longitudinally and angularly so as to bring the cutting element 8 into the position shown by dotted lines at 8—*a* in Fig. 1.

In the machine herein illustrated the generating cutting element is directly driven by an electric motor on the adjustable tool carrier. It will be apparent that, if desired, the tool may be driven through suitable gearing from a line shaft or other driving means mounted independently of the movable carriage.

In some cases it may be desirable to impart a back-and-forth motion to slide 15 during the cutting operation in order to generate a smoother rolling path on the cam face. This can be done by manually actuating the handle 18 alternately in opposite directions during operation of the machine, or automatic means may be provided for obtaining the same motion. In any case, the back-and-forth motion should be small and rather frequent as compared to the rotation of shaft 4. If desired, the members 22 and 23 supporting the spherical segments 20 and 21 could be mounted for adjustment transversely with respect to the mandrel 4 in order to vary the amplitude of the harmonic motion of the carriage.

The cutting element 8 is tapered and preferably conforms to the dimensions of the roller that is intended to operate in contact with the cam. The angle at which the axis of the cutting element 8 is set should also conform to that of the roller axis. Furthermore, the cutting or grinding element 8 is preferably longer axially than the corresponding roller in order to allow for wear and sharpening or trueing of its surface a number of times before it is actually necessary to replace it. It is desirable, for generating the cam face properly, that the portion of the cutting element in cutting engagement with the cam face should conform in diameter and angle to the roller that is to travel upon the cam face.

The mechanism above described provides a means to generate end cams for simple harmonic motion only, said cams being intended to coact with rollers that are tapered and tilted with respect to the cam axis. The amplitude of the said harmonic motion can be controlled by the angle of tilt of the swash plate 19 and/or by the distance from shaft 4, at which spherical segments 20 and 21 coact with swash plate 19.

This machine can be used to cut cams with compound harmonic motion of any kind by using a master cam of the desired shape instead of the swash plate 19. In this case I would prefer to use rollers engaging the master cam instead of the spherical segments 20 and 21. This is shown in Fig. 4, where 7—*a* and 19—*a* represent the cam to be cut and the master cam respectively and 20—*a* and 21—*a* the rollers coacting with the master cam. It can be easily seen that rollers 20—*a* and 21—*a* will follow the surface of the cam and will cause the carriage 16 to move accordingly on the guides of bed 1. Since the motor 9 and the generating cutting element 8 are rigidly mounted on the carriage 16, they will act on the rough piece from which the cam 7—*a* is to be shaped in the manner above described. Handles 13 and 18 can be adjusted until the desirable depth of cut is obtained.

In order to cut cams designed to provide a slower piston speed when in the outer part of the stroke than when in the inner part of the stroke (as explained in my patent application Serial No. 674,428 filed June 3, 1933) a different type of mechanism to control the motions of the carriage may be provided. This would consist essentially in a rod and crank arrangement such as illustrated in Figs. 5 and 6.

A particularly desirable type of compound harmonic motion for this engine can be expressed by a formula of the form : $X=r\cos wt+r_1\cos w_12t$. Where X is the distance at which the moving point is located relatively to a datum center at any time t, r is the maximum distance which that moving point can reach ($=\frac{1}{2}$ total amplitude) ; $w=2\pi n$ where n is the number of complete oscillations per unit time.

This motion, if plotted against time, will resemble a sine curve in which the maxima or the minima of the curve (whichever correspond to the inner limit of stroke of the piston) will have a sharper appearance corresponding to a faster motion of the piston. This is shown in Figure 7, where x is plotted against wt. It can be seen that the maxima m—a are more pointed than the minima m—i.

Figs. 5 and 6 show the cam cutting machine arranged to cut cams designed to provide this type of motion. A bevel gear 29 fixed to the head stock spindle is in mesh with a bevel gear 30 of equal size. The gear 30 is connected to a crank 31 through a shaft 32 which rotates in a supporting bearing 33 and which is rigidly secured to the bed 1. A connecting rod 34 connects the crank 31 to a wrist pin 35, which is mounted in a standard integral with the body of the carriage 16.

It is apparent that the shafts 4 and 32 must turn at the same angular velocity and that for each position of shaft 4 in its rotation there is a definite position for the carriage 16. The connecting rod 34 can have any length desired. The shorter rod 34 is, the larger is the difference of piston speed between its inner and outer positions. This is equivalent to increasing the value of the second term of the above formula.

Furthermore, it is to be understood that the

particular forms of apparatus shown and described, and the particular procedure set forth, are presented for purposes of explanation and illustration and that various modifications of said apparatus and procedure can be made without departing from my invention as defined in the appended claims.

What I claim is:

1. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each revolution of the work support and for relating the linear movements of the carriage to the rotational movements of the work support, a shaft mounted on said carriage and disposed transversely with respect to the axis of the work support, the axis of the shaft being substantially coplanar with the axis of the work, a generating cutting element carried by said shaft and engageable with the work, means for adjusting said shaft in the plane of the axis of the work to various angles with respect to the axis of the work support, and means for driving said cutting element.

2. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each revolution of the work support and for relating the linear movements of the carriage to the rotational movements of the work support, a shaft mounted on said carriage with its axis substantially coplanar with the axis of the work and disposed at an angle of less than ninety degrees to the axis of the work support, a generating cutting element carried by said shaft and engageable with the work, and means for driving said cutting element.

3. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each revolution of the work support and for relating the linear movements of the carriage to the rotational movements of the work support, a shaft mounted on said carriage with its axis substantially coplanar with the axis of the work and disposed at an angle of less than ninety degrees to the axis of the work support, a generating cutting element carried by said shaft and engageable with the work, means for adjusting the cutting element relative to the work, and means for driving said cutting element.

4. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each rotation of the work support including means operatively connected to the work support for so varying the linear speed of the carriage as to provide a simple harmonic motion timed with reference to the rotation of the work, a revolving cutting tool mounted on the carriage with its axis disposed at an angle of less than ninety degrees to the axis of the work, and means for driving said tool.

5. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each rotation of the work support including means operatively connected to the work support for so varying the linear speed of the carriage as to provide a simple harmonic motion timed with reference to the rotation of the work, a revolving cutting tool mounted on the carriage with its axis disposed at an angle of less than ninety degrees to the axis of the work, means for adjusting said tool on said carriage, and means for driving the tool.

6. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each rotation of the work support including means operatively connected to the work support for so varying the linear speed of the carriage as to provide a compound harmonic motion timed with reference to the rotation of the work, a revolving cutting tool mounted on the carriage with its axis disposed at an angle of less than ninety degrees to the axis of the work, and means for driving said tool.

7. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each rotation of the work support including means operatively connected to the work support for so varying the linear speed of the carriage as to provide a compound harmonic motion timed with reference to the rotation of the work, a revolving cutting tool mounted on the carriage with its axis disposed at an angle of less than ninety degrees to the axis of the work, means for adjusting said tool on said carriage, and means for driving the tool.

8. A cam generating machine comprising a work support mounted for rotation about a fixed axis a carriage mounted for linear movement longitudinally of the axis of the work support, means for reciprocating the carriage during each rotation of the work support including means operatively connected to the work support for so varying the linear speed of the carriage as to provide a simple harmonic motion timed with reference to the rotation of the work, a revolving cutting tool mounted on the carriage with its axis disposed at an angle of less than ninety degrees to the axis of the work, means to set the revolving tool with its axis at various angles relative to the axis of rotation of the work, and means for driving the tool.

9. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool mounted on said carriage with its axis substantially coplanar with the axis of the mandrel and disposed at an angle to the mandrel, means interposed between the carriage and guiding element to impart movements to the carriage related to the rotation of the mandrel, and means for driving said tool.

10. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool mounted on said carriage with its axis substantially coplanar with the axis of the mandrel and disposed at an angle to the mandrel, means interposed between the carriage

and guiding element to impart movements to the carriage related to the rotation of the mandrel, means for adjusting said tool to different angles with respect to the mandrel, and means for driving said tool.

11. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool mounted on said carriage with its axis substantially coplanar with the axis of the mandrel and disposed at a fixed angle to the mandrel, means interposed between the carriage and guiding element to impart movements to the carriage related to the rotation of the mandrel, means for adjusting the tool bodily on said carriage, and means for driving said tool.

12. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool mounted on said carriage with its axis disposed at an angle to the mandrel, means interposed between the carriage and guiding element to impart movements to the carriage related to the rotation of the mandrel, means for adjusting said tool in the plane of the mandrel axis to different angles with respect to the mandrel, means for adjusting the revolving tool on said carriage longitudinally of the mandrel or transversely thereof without disturbing its angular adjustment, and means for driving said tool.

13. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool of frusto conical form mounted on said carriage with its axis disposed at an angle to the mandrel, means interposed between the carriage and guiding element to impart movements to the carriage related to the rotation of the mandrel, and means for driving said tool.

14. A cam generating machine, a rotatably supported work carrying mandrel, a guiding element carried by the mandrel, a carriage mounted for linear travel longitudinally of the mandrel, a revolving cutting tool of frusto conical form mounted on said carriage with its axis disposed at an angle to the mandrel, means interposed between the carriage and guiding element to impart movements to the carriage related to the rotation of the mandrel, means for adjusting said tool angularly with respect to the mandrel, means for shifting the tool bodily on the carriage without disturbing its angular adjustment, and means for driving the tool.

15. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work, a crank, a driving connection between said crank and work support, a connecting rod between the crank and carriage for reciprocating the carriage, a shaft on said carriage extending transversely with respect to the axis of the work support at an angle of less than ninety degrees, a cutting tool on said shaft, and means for driving said tool.

16. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work, a crank, a driving connection between said crank and work support, a connecting rod between the crank and carriage for reciprocating the carriage, a shaft on said carriage extending transversely with respect to the axis of the work support at an angle of less than ninety degrees, means for setting said shaft at different angles with respect to the axis of the work support, and means for driving said tool.

17. A cam generating machine comprising a work support mounted for rotation about a fixed axis, a carriage mounted for linear movement longitudinally of the axis of the work, means operated by the rotating work support for reciprocating said carriage, a shaft on said carriage extending transversely with respect to the axis of the work with its axis substantially coplanar with the axis of the work, means for adjusting said shaft angularly, means for adjusting the shaft bodily on the carriage toward or away from the axis of the work support, means for adjusting the shaft bodily on the carriage in a direction parallel with the axis of the work support, a cutting tool on said shaft, and means for driving the cutting tool.

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