May 26, 1942. K. L. HERRMANN 2,284,319

CAM FORMING FIXTURE

Filed Nov. 12, 1940 2 Sheets-Sheet 1

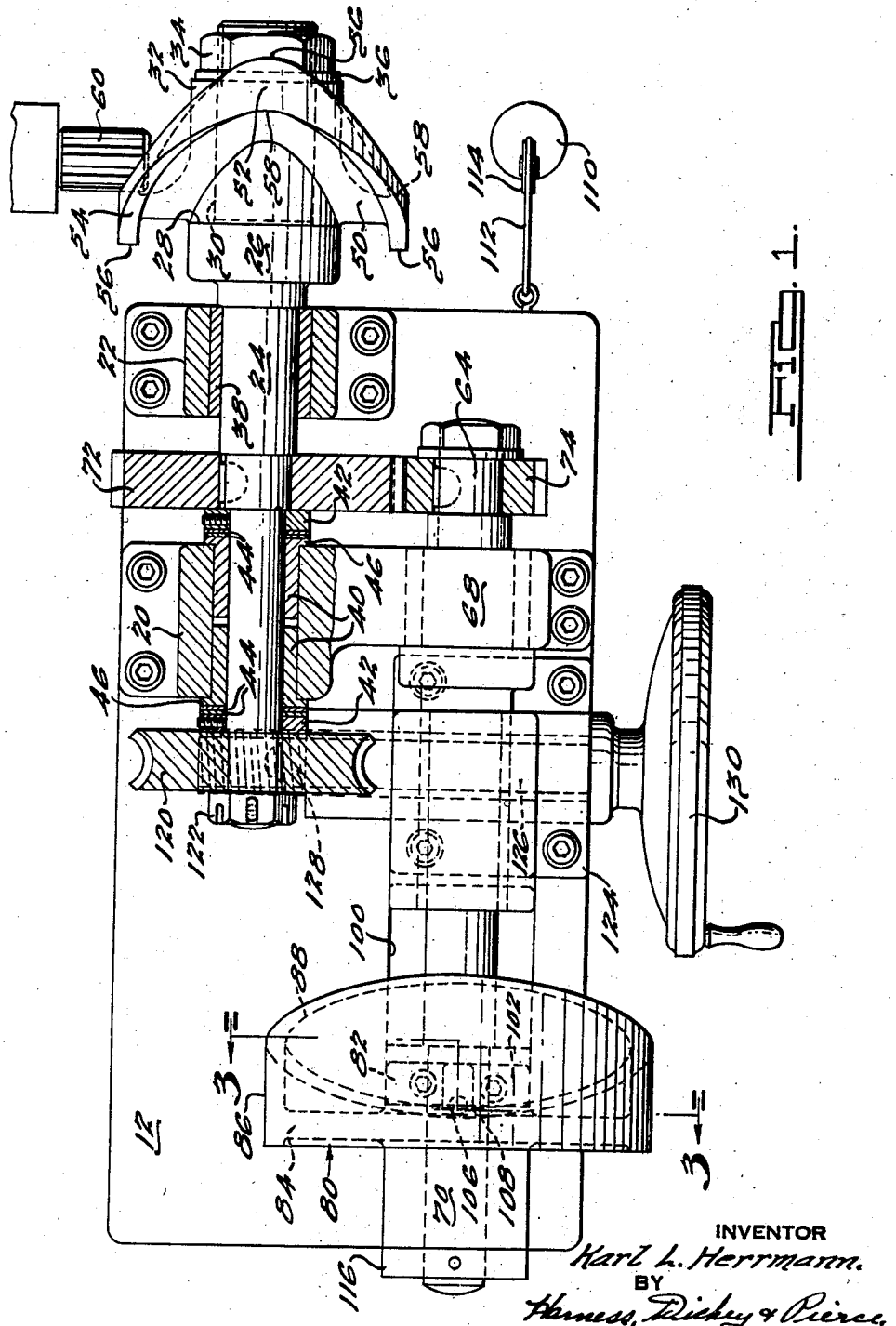


FIG. 1.

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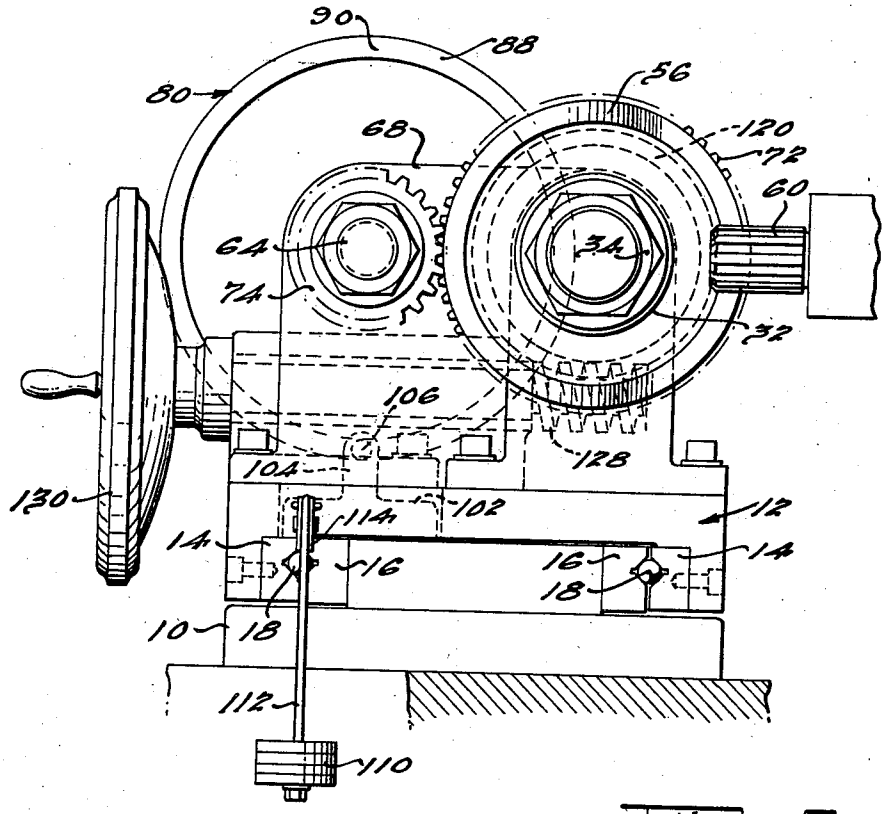


FIG. 2.

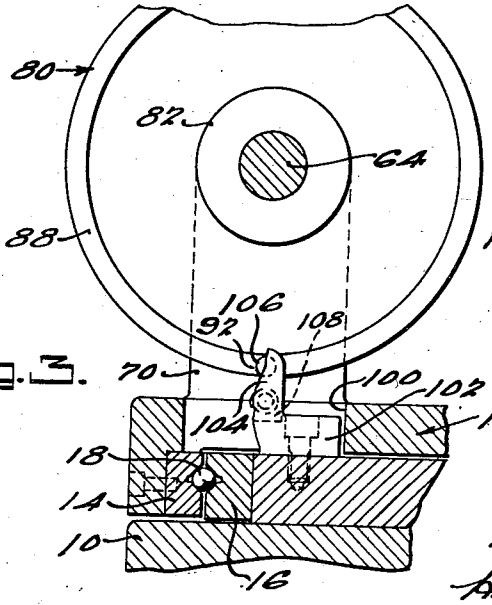


FIG. 3.

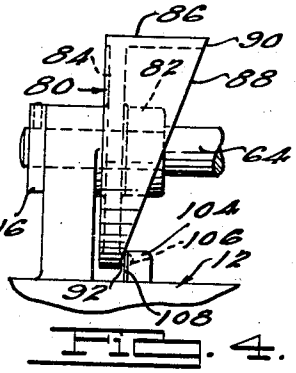


FIG. 4.

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CAM FORMING FIXTURE

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Application November 12, 1940, Serial No. 365,200

3 Claims. (Cl. 90—13.7)

This invention relates to means for forming cylindrical or axial type cams and has for its principal object the provision of a device by means of which a cylindrical or axial type cam having a plurality of axial high points throughout its angular extent may be accurately and uniformly produced.

Objects of the invention include the provision of means for accurately producing a cylindrical or axial type of cam having a plurality of high points throughout its angular area by mounting the cam to be formed in a fixture arranged for reciprocatory movement in the direction of the cam axis and effecting reciprocation of the fixture by means of a master cylindrical or axial cam having a single high point in its angular extent, the cam to be formed and the master cam being geared together for simultaneous operation by gears having a ratio equal to the number of axial high points on the cam to be formed over the single high point of the master cam; the provision of means for forming a cylindrical or axial cam having a plurality of high points in its angular extent by means of a master cam of such simple configuration as to permit its accurate production by an exceedingly simple machine operation; the provision of a cam forming fixture as above described in which the operative face of the master cam lies in a single plane; and the provision of means for forming a cylindrical or axial type of cam having a plurality of axial high points in its angular extent and including curved cam surfaces connecting said high points arranged to effect uniformly accelerating and decelerating movements of a connected part during uniform rotation of the cam, by a generating operation capable of forming the cam tracks in an extremely accurate manner.

The above being among the objects of the present invention the same consists in certain novel features of construction and combinations of parts to be hereinafter described with reference to the accompanying drawings, and then claimed, having the above and other objects in view.

In the accompanying drawings which illustrate a suitable embodiment of the present invention and in which like numerals refer to like parts throughout the several different views,

Fig. 1 is a partially broken, partially sectioned plan view of my improved fixture showing the same supporting a piece of work in operative relation with respect to a cutting tool;

Fig. 2 is an end elevational view of the fixture shown in Fig. 1, taken looking from the righthand end of the fixture as viewed in Fig. 1;

Fig. 3 is a fragmentary, partially broken vertical sectional view taken on the line 3—3 of Fig. 1; and,

Fig. 4 is a reduced side elevational view of the master cam.

The present invention is adaptable for use in the forming of any cylindrical or axial type cam having a plurality of axial high points in its angular extent and the cam surface of which is designed to uniformly accelerate and decelerate a connected part, but it has been particularly designed for the purpose of accurately forming the operative faces of the cam which forms the connecting means between the pistons and the power shaft of the barrel type engine shown and described in my application for Letters Patent of the United States for improvements in Internal combustion engine, filed May 14, 1937, and serially numbered 142,653. For that reason reference will principally be made hereinafter to the cam shown and described in my said prior patent application for the purpose of illustration only, the application of the present invention to similar cams for other uses or variations of such cam thus being made apparent to those skilled in the art without further explanation.

In my prior application above identified an internal combustion engine of a type commonly known as a barrel type engine is shown which includes a straight power shaft each end of which is centrally received by a cylinder block. Each cylinder block provides a plurality of cylinders circularly arranged about the axis of the power shaft with their axes parallel to the axis of the power shaft. Each cylinder of each cylinder block is axially aligned with a cylinder of the other block and reciprocably received in each opposed pair of cylinders is a double ended piston. The central portion of each of the pistons is relieved or cut away for reception of the rim of a cylindrical or axial type cam fixed to the power shaft, and rollers are supported by each double ended piston on opposite sides of the rim of the cam and bear against such rim so that reciprocatory movement of the piston acting against the cam faces causes rotation of the cam and consequently the power shaft. In the particular construction shown in my copending application above referred to the cam is provided with two axial high points on each axial face thereof so that each piston is caused to reciprocate twice in both directions through the full extent of its movement during each rotation of the cam. In other words, each piston completes

four strokes of operation during each rotation of the cam and power shaft.

As will be appreciated it is desirable in a construction of the type described that the curvature of the cam be such that the pistons are uniformly accelerated and decelerated during their reciprocatory movement and this requires that the curvature of the relative path of movement of the roller axes with respect to the cam faces follow a true sine curve. Where these cams are employed in an engine such as shown and described in my prior application above identified it is extremely important that the cam faces be extremely accurately formed for otherwise improper relative movement between the cam and the pistons is bound to occur, fostering early destruction of the wearing surfaces between these parts, as well as other undesirable conditions which will be readily appreciated by those skilled in the art.

Such cams may be formed or generated by apparatus already suggested, such for instance as illustrated in United States Letters Patent No. 1,351,365, if a sufficiently accurate master cam comprising a duplicate of the desired cam is first provided. However, it has been my experience that it is substantially impossible to provide a sufficiently accurate master cam duplicating the desired cam with existing apparatus. The present invention provides a means whereby the desired cam may be accurately and quickly formed by the use of a master cam which is not a duplicate of the desired cam but which may be constructed in an extremely accurate manner by existing apparatus of the simplest type. Inasmuch as the accuracy of the final product is primarily dependent upon the accuracy of the master cam, the present invention thus provides a means by which the desired cam may be produced in an extremely accurate manner and yet by relatively simple apparatus.

Referring now to the accompanying drawings and particularly Fig. 2 it will be noted that the device or fixture illustrative of the present invention includes a base member **10** having a flat bottom face which adapts it to be mounted upon the table of a milling machine, boring mill, or grinder in conjunction with which the forming of the cam may be accomplished. The base **10** reciprocably supports thereon for movement in a plane parallel to the bottom face thereof a slide indicated generally at **12** and while the slide **12** may be supported in any suitable or conventional manner for reciprocatory movement upon the base **10** the particular means shown by way of illustration and as being preferable comprises linear race members **14** and **16** secured to the slide **12** and base **10**, respectively, with interposed ball bearing elements **18**.

As best illustrated in Fig. 1 the slide **12** has suitably fixed to its upper surface a pair of axially spaced bearing blocks **20** and **22** which rotatably support between them a work shaft or arbor indicated generally at **24** arranged with its axis parallel to the direction of reciprocatory movement of the slide **12** on the base **10**. The outer end of the arbor **24** is enlarged as at **26** to provide a shoulder **28** and is provided with a concentric projection or pilot **30** of smaller diameter projecting outwardly therebeyond and which is adapted to accurately receive the hub **32** of the workpiece cam thereon, the cam being securely fixed upon the arbor **24** by clamping one end of the hub **32** against the shoulder **28** by means of a nut **34** threaded upon the outer end of the arbor **24** and an interposed washer **36**.

The bearing block **22** is provided with a bearing bushing **38** for rotatably supporting the arbor **24** therein and the bearing block **20** is provided with a pair of bearing bushings **40** for the same purpose. Although any suitable means may be provided for maintaining the arbor **24** against relative axial movement in the bearing blocks **20** and **22**, the particular method shown by way of illustration consists of a pair of collars **42** suitably fixed to the work shaft or arbor **24** on either side of the bearing block **20**, together with washers **44** interposed between the collars **42** and the outwardly flanged outer ends **46** of the bearing bushings **40** which overlie and abut the corresponding end faces of the bearing block **20**.

Referring now to Fig. 1 and particularly to the work piece cam shown mounted on the work arbor **24** it will be noted that the hub **32** thereof is provided with a radially outwardly extending but axially curved web portion **50** formed integrally therewith terminating in a generally cylindrical rim portion **52** the opposite axial faces of which form cam faces **54**, the cam faces **54** being circular when viewed axially of the cam and being of a material dimension measured radially of the cam. Although, as previously mentioned, the number of axial high points on the cam is immaterial from the standpoint of the present invention, the particular cam shown being that employed in the engine shown and described in my prior application previously identified it including the axial high points **56** on each axial face which high points are, of course, disposed diametrically opposite from one another and between each high point **56** there is a corresponding low point **58**. It will also be appreciated that the high point **56** on each side or end of the cam will have a corresponding low point **58** on the opposite side or end of the cam. It is also to be understood that the desired curvature of the cam face is such as to impart uniform accelerating and decelerating movements in a direction parallel to the cam to any element connected to the cam for relative movement with respect thereto during uniform rotation of the cam.

The desired contour or curvature of the cam faces **54** is, in accordance with the present invention, obtained by operating upon the corresponding faces of the rough or partially machined workpiece by means of a suitable metal removing tool which may, for instance, be a milling cutter such as illustrated at **60** in Fig. 1 particularly for the rough machining operation and which, for instance, may be a grinding wheel for the finishing operation. Whether the tool employed in a milling cutter such as **60**, or a grinding wheel, its axis will be arranged in a plane perpendicular to the axis of the work arbor **24** and consequently the workpiece or cam preferably will be arranged in a radial direction with respect to the axis of the arbor and workpiece or cam. The milling cutter **60** or other tool will be held in bodily fixed relation but will, of course, be suitably rotated during the machining operation and the cam will be axially reciprocated and simultaneously rotated in order to feed the marginal edges of its peripheral portion or rim past the tool to generate the desired curvature of such marginal edges.

The above mentioned controlled rotation and reciprocation is obtained in the following manner. A second or master cam shaft **64** is arranged in parallel but spaced relation with re-

spect to the work shaft or arbor 24 and is rotatably supported thereon between a pair of bearing blocks 68 and 70. The work shaft 24 is provided with a gear 72 fixed thereto between the bearing blocks 20 and 22 and the master cam shaft 64 is provided with a gear 74 fixed thereto in transverse alignment with the gear 72 and in meshing relationship with respect thereto. The ratio between the number of teeth on the gear 72 and the number of teeth on the gear 74 is equal to the ratio which the number of axial high points desired on the cam being formed bears to the number of high points on the master cam. In the case employed for the purpose of illustration, therefore, this ratio is 2 to 1.

Fixed to the master cam shaft 64 in abutting relation with respect to the forward face of the bearing block 70 is a master cam indicated generally at 80. It comprises a hub portion 82 fixed to the shaft 64, a radial web 84, and a cylindrical rim portion 86. The forward or righthand face or edge of the rim portion 86 as viewed in Fig. 1 may be straight or curved depending upon the type of motion desired to be imparted to the connected reciprocatory parts in actual use, but where a simple harmonic motion is desired for the connected reciprocatory parts, as is assumed in the particular apparatus shown, such face is wholly disposed in a single plane arranged at an angle with respect to a plane perpendicular to the axis of the shaft 64 so as to form a circular or axial cam surface 88. Inasmuch as the cam surface 88 lies in a single plane as described, it will be appreciated that the surface 88 may be accurately machined by any one of a number of conventional types of machine tools without the requirement of any unusual or expensive fixtures. For instance, in machine tools of the type where there is a relative reciprocatory movement between the work and the tool, such as in milling machines, grinders, planers, shapers, or boring mills, the cam needs only to be supported with its axis at the proper angle to the direction of relative reciprocation between the tool and the work to permit the tool to accurately machine the cam surface 88 in a true plane and at a proper angle with respect to the axis of the cam. In a machine tool where the work rotates relative to the cutting element, as for instance in a lathe, the cam to be machined needs only to be supported with its axis at the proper angle to the axis of rotation of the lathe chuck in order to enable the tool to accurately machine the cam surface 88 in a truly planular relation and at the proper angle with respect to its axis. It will be appreciated that by forming the cam 80 in the manner described such cam will have a single axial high point 90 and a single axial low point 92 and that any object such as a cam follower arranged for contact with the cam face 88 for movement in a direction parallel to the axis thereof will have imparted to it a uniformly accelerating and decelerating motion as the follower travels between the high point 90 and the low point 92 during uniform rotation of the cam. The angle of the cam face 88 is, of course, such with respect to the plane of the web 84 (assumed to be perpendicular to the axis of the shaft 64) that the distance, measured axially of the cam and of the shaft 64 between some specified point in the width of the cam face at the high point 90 thereof and an equivalent point on the low point 92 thereof, is equal to the axial distance desired between the high points 56 and the low points 58 of the cam to be formed by the fixture.

In order to employ the master cam 80 for effecting the desired reciprocatory movement of the work, the table 12 is provided with a slot-like opening 100 below the shaft 64 and extending to the right from the bearing block 70 as viewed in Fig. 1. A follower bracket 102 is fixed to the bore 10 within the opening 70 and is provided with an upwardly projecting portion 104 which projects upwardly into overlapping relationship with respect to the lower portion of the cam face 88. The lefthand end of the upwardly projecting portion 104 as viewed in Fig. 1 serves to support a suitable cam follower which, in the broader aspects of the present invention, may take any suitable form but which for the purpose of illustration is illustrated as a ball bearing 106 partially seated in a suitable recess in the lefthand end of the portion 104 and preferably secured against inadvertent displacement therefrom by means of a retainer plate 108 fixed to the corresponding end of the portion 104. The ball 106 is, of course, preferably arranged so as to contact the cam face 88 on a circle concentric with the axis of the cam of such diameter that the axial distance between the axial high and low points of the circle is equal to that between the axial high and low points of the desired cam to be formed.

Any suitable means may be provided for constantly urging the slide 12 to the right as viewed in Fig. 1 so as to maintain the cam face 88 constantly in contact with the ball 106, the particular means shown by way of illustration for accomplishing this result comprising a weight 110 connected to the slide 12 by means of a flexible cable 112 passing over a pulley 114. While the weight 110 will thus constantly urge the master cam 80 to the left as viewed in Fig. 1 into abutting relationship with respect to the forward face of the bearing block 70 and thus eliminate the necessity of any other means for preventing relative axial movement of the shaft 64 with respect to the slide 12, it is preferable to positively eliminate any possibility of such relative axial movement of the shaft 64 and while this may be accomplished in any suitable manner, a collar 116 fixed to the shaft 64 immediately to the left of the bearing block 70 and in abutting relationship with respect to the corresponding end face of the bearing block 70 is shown by way of illustration of a satisfactory means for accomplishing this result.

It will be appreciated from the foregoing description that the device thus far described includes a base with a table slidably supported thereon for reciprocatory movement, a pair of parallel shafts arranged with their axes parallel to the direction of reciprocation of the slide, one of the shafts adapted to have the workpiece cam fixed thereto and the other of the shafts having a cylindrical or axial type cam fixed thereto and of a specific type having a single high point and low point thereon, the shafts being connected together by gearing having a ratio equal to the number of high points desired on the workpiece to the single high point on the master cam, and a cam follower fixed to the base and against which the cam surface of the master cam is constantly urged. It will also be appreciated that upon rotation of either of the shafts, both of the shafts are caused to rotate as well as both the master cam and the workpiece cam and the workpiece cam caused to be rotated and recipro-

cated with the slide 12 in the proper manner relative to the tool operating upon it to accurately produce the required number of high points and low points thereon, as well as to produce the desired curvature between such high and low points. In this respect it may be noted without further comment that the gears 72 and 74 are preferably but not necessarily extremely accurately produced and fitted so as to assure a uniformly rotational movement of one through engagement with the other with substantially no backlash permitted between them. Such gears are readily available by modern production methods.

In view of the fact that the tool, illustrated as the tool 60 in the drawings, which is employed to machine the faces 54 of the work cam is rotated but held against bodily movement during a machining operation it will, of course, operate on the engaged active cam face of the workpiece cam to accurately form it to the desired shape and contour. The depth of cut of the tool 60 or its equivalent on the face of the workpiece cam may, of course, be easily and accurately controlled by adjusting the table of the milling machine or grinder on which the fixture is supported, longitudinally of its slide, to obtain the desired effect.

It is to be noted in connection with obtaining the desired curvature for the operative faces 56 of the workpiece cam, as will be readily appreciated by those skilled in the art, where it is desired to obtain such contour of the cam faces 56 that a simple harmonic motion will be imparted to the pistons or other connected parts by relative rotation of the cam, and where a roller is employed as a follower between the pistons or other element and the cam, the diameter of the tool 60 or other rotating type of cutting element such as a grinding wheel employed for finishing the surfaces 56 should be equal to the diameter of the follower roller. In other words where a follower roller, as differentiated from a shoe or the like, is employed for transmitting the force between the cam and a connected reciprocatory element such as a piston, it is the axis of the roller that must be considered and not its point of contact with the corresponding cam face 56. Thus, in such case the cam face 56 itself will not represent a true sine curve but the relative path of the axis of the roller as related to the cam face 56 will be a true sine curve where it is desired to impart a simple harmonic motion to the connected reciprocatory element. Obviously, by employing different types of generating means for the workpiece cam, that is, other than a rotating tool such as the tool 60, or by mounting the tool 60 or its equivalent for interrelated movement with the master cam, or by forming the face 88 of the master cam in a curved plane or otherwise instead of a straight plane as shown, variations may be obtained in the workpiece cam to obtain variations in the movement of the connected reciprocatory parts from a true harmonic motion, and this may be found desirable under some conditions. Ordinarily, however, where the cam is to be used in an engine of the type shown and described in my copending application above identified, a simple harmonic motion of the connected pistons will be desired and for that reason the cutter 60 or its equivalent will closely approach the diameter of the follower rollers which are to be employed, in order to obtain this result.

In any event one of the principal things to be noted in connection with this fixture is that by its use it is possible to use a master cam such as the cam 80 having a planular face which may be readily produced in a simple and extremely accurate manner and which is employed as the controlling means in the formation of the contour of the cam face or faces of an axial or cylindrical type cam having a plurality of axial high points throughout its angular extent. It, therefore, eliminates the necessity of the production of a master cam having a cam face substantially duplicating that desired in the finished work and requiring the laying out and the finishing of the cam surface of the master cam by highly skilled workmen, and which method in any event still leaves the question of accuracy always in doubt.

It will further be appreciated that the fixture thus shown and described need not necessarily be employed to form the cams which are to be ultimately employed in an engine or other device requiring the same as it will be obvious that this fixture may be employed for accurately forming a master cam which may thereafter be employed as a master cam in a cam forming apparatus of the general type, for instance, illustrated in United States Patent No. 1,351,365 and which, in such case, will enable the desired final product to be accurately formed thereon.

Any suitable means may, of course, be provided for effecting rotation of the shafts 24 and 64 and it will be appreciated that inasmuch as the two shafts are connected together by the gears 72 and 74 one shaft only requires being driven and it may be driven by any suitable power means or may be rotated manually. For the purpose of illustration this last means is illustrated in the drawings and in accordance therewith the lefthand end of the work shaft 24 as illustrated in Fig. 1 has fixed thereto a worm wheel 120 by means of a nut 122. A transversely disposed bearing block 124 is fixed to the slide 12 in transverse alignment with the worm wheel 20 and rotatably supports therein a shaft 126 upon one end of which a worm 128 is formed and which lies in meshing relationship with respect to the worm wheel 120. On the opposite end of the shaft 126 a hand wheel 130 is fixed to the shaft so as to enable rotation of the shaft 126 and consequently the worm 128. Rotation of the latter as will be appreciated, will cause rotation of the worm wheel 20 at a relatively slower speed and consequently rotation of the work shaft 24 and the work cam, as well as the shaft 64 and master cam 80, thus causing the sequence of operations above described.

Formal changes may be made in the specific embodiment of the invention described without departing from the spirit or substance of the broad invention, the scope of which is commensurate with the appended claims.

What is claimed is:

1. Mechanism for forming a cylindrical cam having an axially disposed cam surface provided with a plurality of axial high points comprising, in combination, a reciprocably movable supporting member, a pair of shafts rotatably mounted on said member with their axes arranged in line with the direction of movement of said member and in spaced and parallel relation and maintained against relative axial movement in at least one direction thereon, means for supporting a workpiece on one of said shafts, a master cam fixed to the other of said shafts, said master cam being a cylindrical cam having an axially facing

cam surface providing one high point and one low point throughout its angular extent, speed reducing mechanism interconnecting said shafts having a ratio equivalent to the number of axial high points desired on one axial face of said workpiece to the single high point of the master cam, a relatively fixed cam follower arranged for engagement with the cam surface of said master cam, means constantly urging said master cam into engagement with said cam follower, means fixing said master cam against axial movement in at least one direction on its corresponding shaft, and means for effecting rotation of said shafts.

2. In a device of the type described, a base, a slide supported on said base for reciprocatory movement, a shaft rotatably mounted on said slide with its axis parallel to the direction of movement of said slide and fixed against axial movement with respect thereto, a second shaft rotatably mounted on said slide with its axis parallel to the axis of the first mentioned shaft, means for supporting a piece of work on the first mentioned shaft, a master cam fixed against relative rotation on the second mentioned shaft and held against movement axially of said shaft in at least one direction, said master cam being of the cylindrical type having an axially disposed cam face having a single high point and a single low point thereon, gearing interconnecting said shafts having a ratio equal to the ratio which the number of high points desired on the cam face of the work piece bears to the number of high points on the master cam, a cam follower fixed to said base and arranged to bear against the cam face of said master cam, means constantly urging said slide in the direction to maintain contact between said follower and the cam face of said master cam, and means for rotating at least one of said shafts.

3. Means for forming the cam face of a cylindrical cam having an axially facing cam surface provided with a plurality of axial high points in its circular extent comprising, in combination, a reciprocable slide, work supporting means comprising a shaft rotatably mounted on said slide with its axis parallel to the path of movement of said slide for reciprocatory movement with said slide toward and from a cutting means, a second shaft rotatably mounted on said slide in parallel relation to the first mentioned shaft for reciprocatory movement therewith, a cylindrical master cam fixed to said second shaft and having an axially disposed cam surface providing a follower track lying in a single plane disposed at an angle to a plane perpendicular to the axis of said master cam, a cam follower associated with said master cam surface and cooperating therewith to effect reciprocatory movement of said slide and shafts carried thereby upon rotation of said master cam, movement transmitting means interconnecting said shafts effective to turn said second mentioned shaft through as many complete revolutions per each revolution of said first mentioned shaft as there are axial high points on a single axial cam face of said work, and means for rotating said shafts.

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