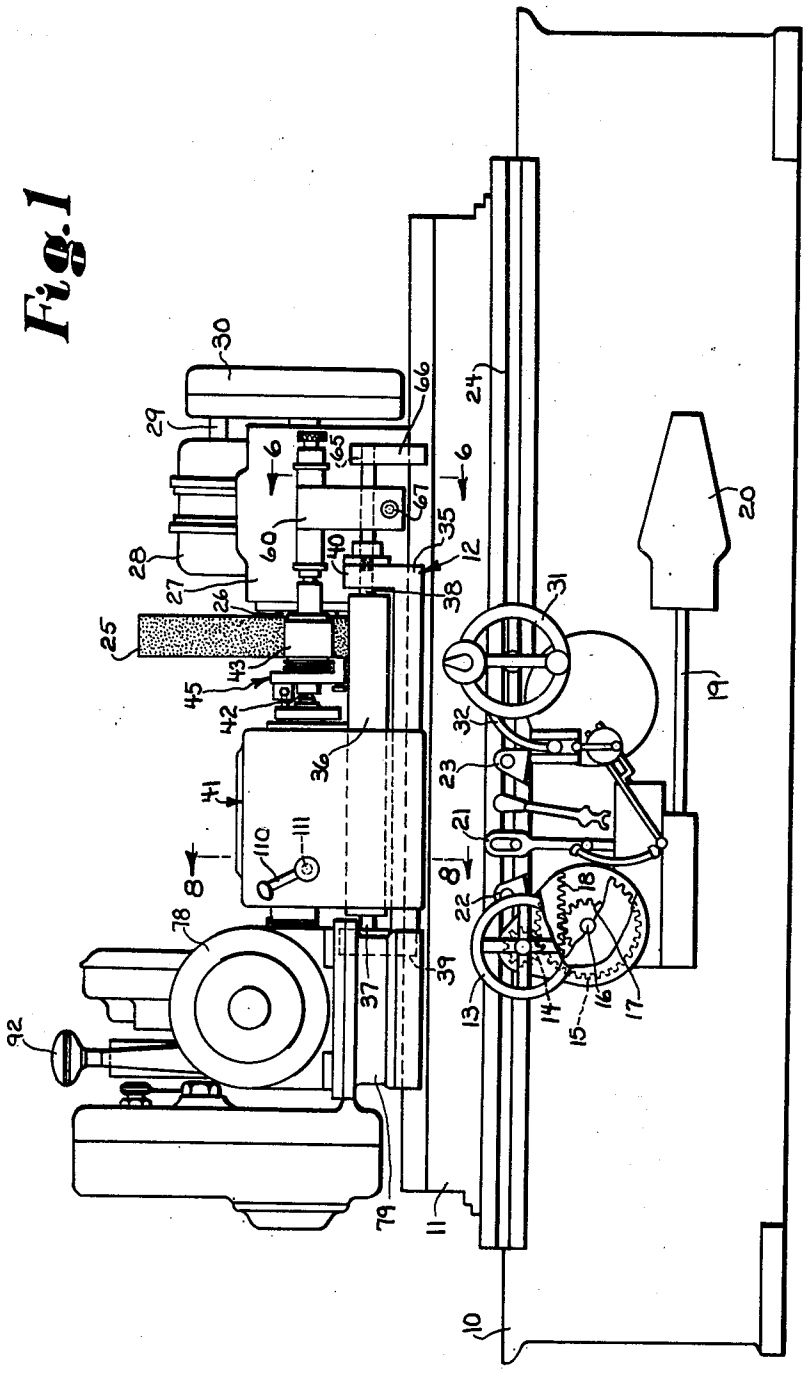
June 10, 1952 C. J. GREEN 2,599,987

PISTON GRINDING MACHINE

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Fig. 1



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Fig. 2

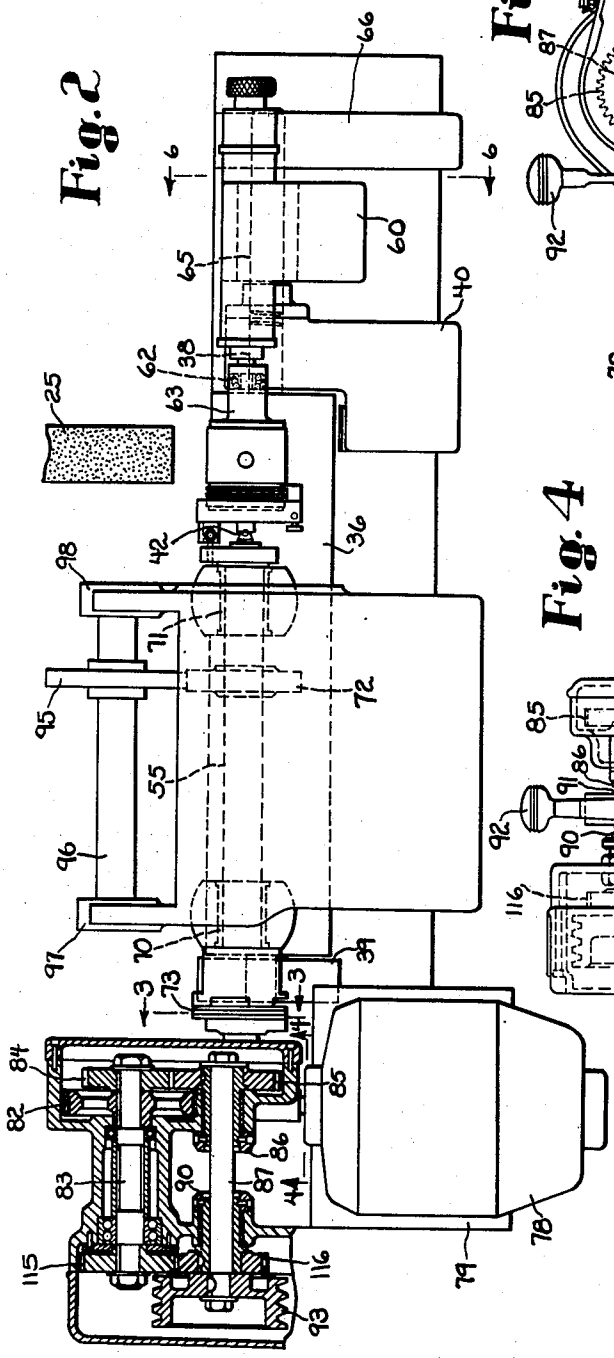


Fig. 3

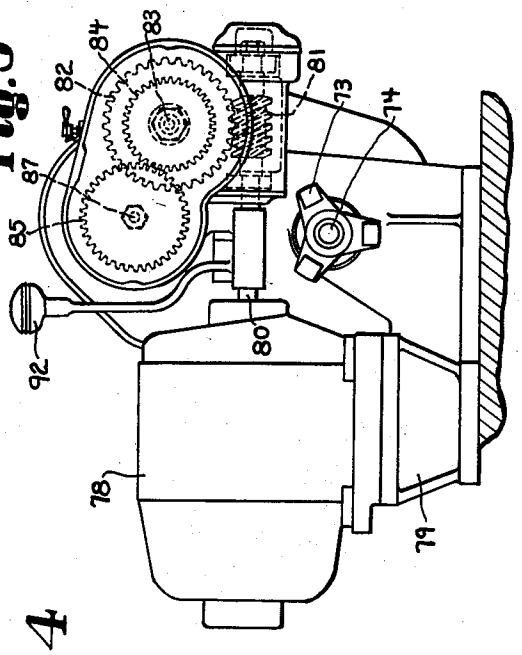
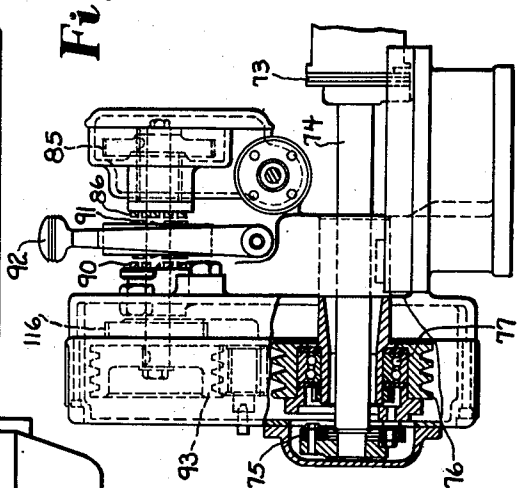


Fig. 4



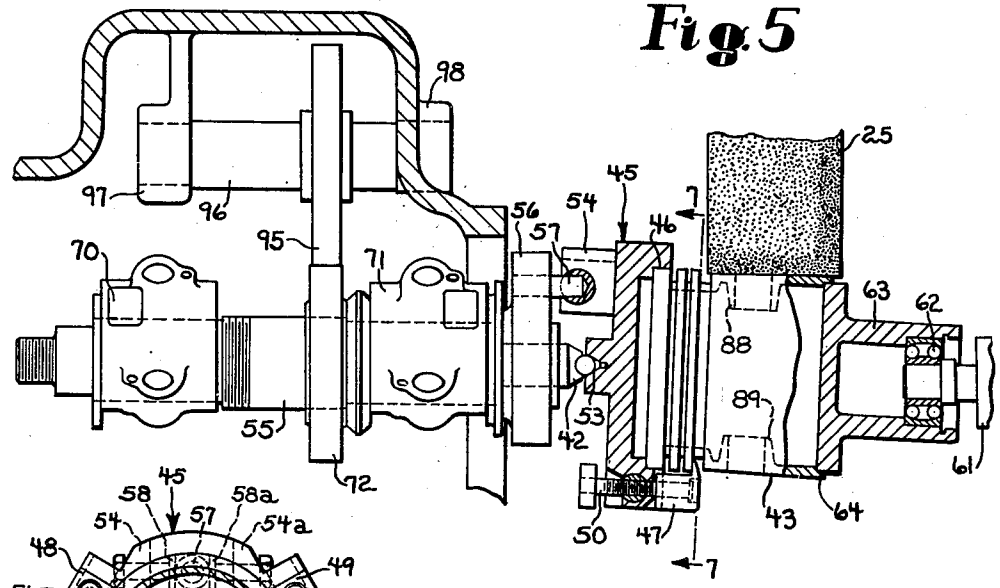
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PISTON GRINDING MACHINE

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Fig. 5



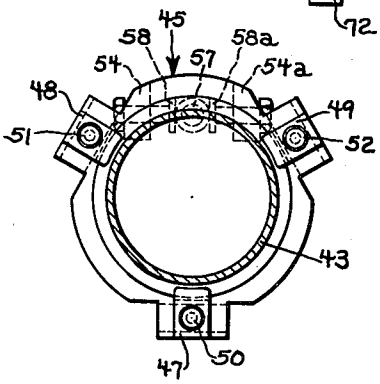


Fig. 7

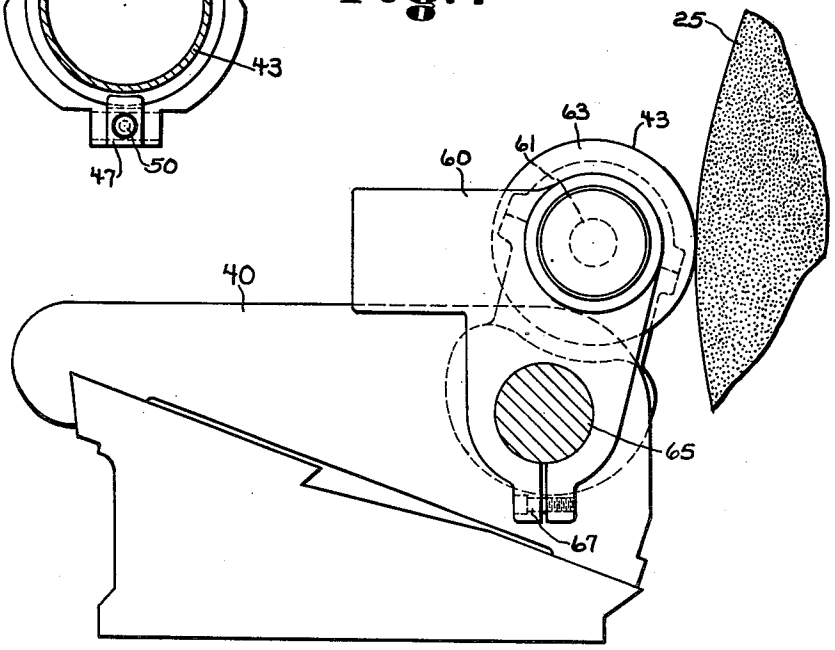


Fig. 6

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PISTON GRINDING MACHINE

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Fig. 9

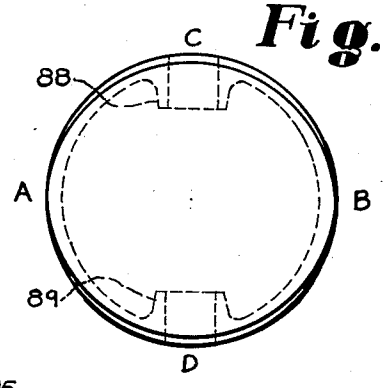
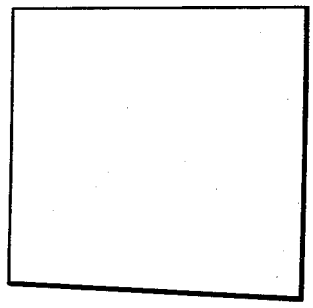


Fig. 10



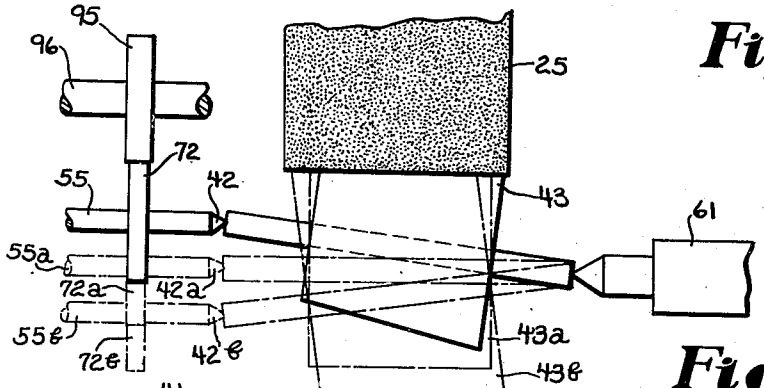


Fig. 11

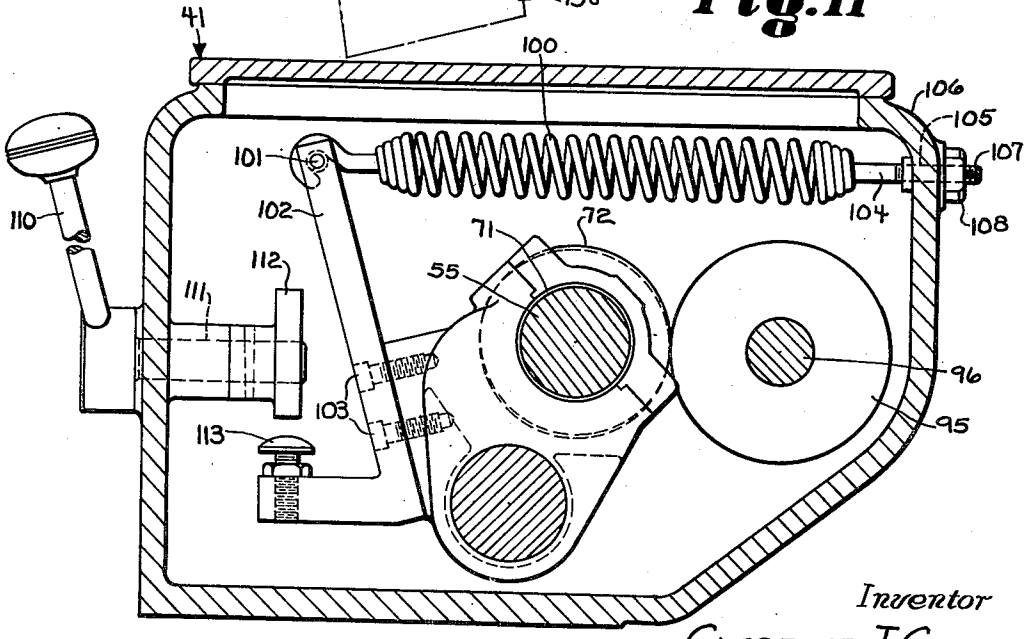


Fig. 8

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Patented June 10, 1952

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UNITED STATES PATENT OFFICE

2,599,987

PISTON GRINDING MACHINE

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Application March 31, 1949, Serial No. 84,659

8 Claims. (Cl. 51—101)

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The invention relates to grinding machines and more particularly to a grinding machine for grinding irregular shapes such as elliptical or oval surfaces on pistons and the like.

One object of the invention is to provide a simple and thoroughly practical grinding machine for grinding an oval or elliptical shape on an automotive piston. Another object of the invention is to provide a piston grinding machine with a master cam and follower roller which are arranged to produce a tapered oval or elliptical shape on a work piece. Another object of the invention is to provide a cam type machine for generating a predetermined tapered contour on the periphery of a piston. A further object of the invention is to provide a piston grinding machine having a pivotally mounted rock bar which is oscillated during a grinding operation by means of a master cam and follower roller to support one end of a work piece to be ground while the other end is rotatably supported on a fixed axis to facilitate generating an irregular shape which tapers from one end to the other. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts, as will be exemplified in the structure to be hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which is shown one of various possible embodiments of the mechanical features of this invention:

Fig. 1 is a front elevation of a grinding machine embodying the invention;

Fig. 2 is a fragmentary plan view of the machine, on an enlarged scale, showing the work supporting and driving mechanism;

Fig. 3 is a sectional view taken approximately on the line 3—3 of Fig. 2, showing the work driving mechanism;

Fig. 4 is a sectional view taken approximately on the line 4—4 of Fig. 2, showing a portion of the work driving mechanism;

Fig. 5 is a fragmentary horizontal sectional view, on an enlarged scale, showing the work supporting arrangement together with the master cam and follower roller;

Fig. 6 is a fragmetary cross sectional view, on an enlarged scale, taken approximately on the line 6—6 of Fig. 2, showing the pivotal support for the footstock;

Fig. 7 is a cross sectional view, taken approximately on the line 7—7 of Fig. 5, showing a portion of the work supporting and driving device in end elevation;

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Fig. 8 is a diagrammatic showing of the essential parts of the machine;

Fig. 9 is an elevation, on an enlarged scale, of the ground portion of the work piece;

Fig. 10 is a left hand end elevation of Fig. 9 showing the shape of the ground work piece; and

Fig. 11 is a diagrammatic view showing the arrangement of the parts set up for grinding tapered ovals on pistons being ground, tapering in either direction.

A grinding machine has been illustrated in the drawings comprising a base 10 which supports a longitudinally movable work table 11 on the usual flat and V-ways (not shown). The table 11 serves as a support for a cam grinding unit 12 which will be hereinafter described. The table 11 may be reciprocated longitudinally relative to the base 10 to facilitate positioning the work piece being ground for a grinding operation by means of a manually operable traverse mechanism comprising a traverse wheel 13. The traverse wheel 13 is connected to rotate a gear 14 which meshes with a gear 15 mounted on a rotatable shaft 16. The shaft 16 also supports a gear 17 which meshes with a rack bar 18 depending from the underside of the work table 11. It will be readily apparent from the foregoing disclosure that a manual rotation of the traverse wheel 13 will be imparted through the rack and gear mechanism above described to produce a longitudinal traversing movement of the table 11. The direction of rotation of the traverse wheel 13 serves to determine the direction of movement of the table 11. This mechanism is substantially the same as that disclosed in the prior United States patent to C. H. Norton, No. 762,838, dated June 14, 1904, to which reference may be had for details of disclosure not contained herein.

The table 11, if desired, may be reciprocated longitudinally by a power operated mechanism such as that shown in the prior patent above referred to. This mechanism may comprise a rotatable power driven shaft 19 which is driven by means of a multiple speed drive contained within a casing 20. The rotatable shaft 19 is connected through a reversing clutch (not shown) which is actuated by means of a reversing lever 21. The reversing lever 21 is actuated by a pair of adjustable table dogs 22 and 23 which are adjustably supported in a T-slot 24 formed in the front edge of the table 11.

A rotatable grinding wheel 25 is mounted on one end of a rotatable wheel spindle 26. The

wheel spindle 26 is journalled in spindle bearings (not shown) supported within a transversely movable wheel slide 27. The wheel slide 27 is arranged to be adjusted transversely on the usual flat and V-ways (not shown) formed on the base 10. The grinding wheel 25 may be driven by any suitable means, such as for example, a motor 28 mounted on the upper surface of the wheel slide 27. The motor is provided with an armature shaft 29 which is connected by a multiple V-belt drive (not shown) contained within a belt guard 30.

A manually operable feed wheel 31 is mounted on the front of the machine base 10 and is operatively connected to rotate a feed screw (not shown) to cause the grinding wheel 25 and the wheel slide 27 to move transversely toward or from the work table 11, depending upon the direction of rotation of the feed wheel 31. In the construction illustrated in the drawings, the feed wheel 31 may be actuated either manually or automatically as desired. A mechanically actuated feed pawl 32, such as that shown in the prior patent above referred to, is reciprocated automatically to advance the grinding wheel 25 at the ends of the reciprocatory stroke of the table 11.

A cam grinding unit 12 comprises a frame 35 which is clamped to the upper surface of the work table 11. The frame 35 serves as a support for a rock bar 36. The rock bar 36 is provided at its opposite ends with a pair of spaced axially aligned trunnions 37 and 38 which are supported by a pair of spaced bearing brackets 39 and 40 respectively. The bearing brackets 39 and 40 are fixedly mounted on the frame 35. A headstock unit 41 to be hereinafter described is provided with a work supporting center 42 which is arranged to engage and support one end of a piston 43 to be ground.

The piston 43 to be ground is supported at its left hand end by means of a work holder 45 having a recess 46 adapted to receive the left hand end of the piston 43 (Fig. 5). The work holder 45 is provided with pivotally mounted clamping jaws 47, 48 and 49 which are actuated by adjusting screws 50, 51 and 52 respectively. As illustrated in Figs. 5 and 7, the clamping jaws 47, 48 and 49 are arranged to engage one of the grooves formed in the periphery of the piston 43 being ground to hold the piston rigidly in position on the work holder 45. A center hole 53 is provided on the work holder 45 which is arranged to be supported by the center 42. The work holder 45 is provided with a pair of spaced driving lugs 54 and 54a (Figs. 5 and 7). The headstock center 42 is mounted on the right hand end of a rotatable master cam spindle 55. The master cam spindle 55 also supports a driving plate 56 having a driving pin 57 fixedly mounted thereon. The driving pin 57 is arranged to project between the lugs 54 and 54a. The lugs 54 and 54a are provided with opposed aligned adjusting screws 58 and 58a which are arranged to engage opposite sides of the driving pin 57. By adjusting the screws 58 and 58a, the timing or positioning of the piston being ground may be adjusted relative to the master cam to be hereinafter described.

In the grinding of automotive pistons such as some of the aluminum alloy and other alloy pistons, it is desirable to grind a relief on the sides of the piston adjacent to the thickened boss portions 88 and 89 (Figs. 5 and 9) due to the fact that when the piston becomes heated during use this portion of the piston expands greater than the lower and cylindrical portions thereof. The portions of the piston at right angles to the plane of the bosses 88 and 89 is a relatively thin cylindrical portion and therefore does not need the same amount of relief. It is therefore desirable in grinding certain pistons that the elements of the peripheral surface thereof on axis A—B be substantially parallel whereas the elements on the axis C—D be tapered from the right hand end of the piston 43 (Fig. 5) toward the left hand end thereof. In other words the right hand end of the piston 43 (Fig. 5) may be substantially cylindrical and this surface then tapers on the axis C—D toward the left (Fig. 5) to produce a desired relief on the axis C—D passing through the hub portions 88 and 89 (Figs. 5 and 9), so as to compensate for greater expansion at this point due to heating of the piston in normal use.

In order to accomplish the desired result, a footstock 60 is provided having a footstock spindle 61 which supports a self-aligning anti-friction bearing 62. The bearing 62 serves as a support for a work holder 63 (Fig. 5) which is arranged to engage a recess 64 formed within the right hand end of the piston 43. In order to facilitate grinding the above described complex shape on the piston 43, the footstock 60 is preferably mounted independent of the rock bar 36. As illustrated in the drawings, a rock shaft 65 is fixedly mounted at its left hand end in the bracket 40. The right hand end of the rock shaft 65 is supported by a bracket 66 which is mounted on the table 11. The footstock 60 is supported on the rock shaft 65 and is arranged to be clamped in adjusted position thereon by means of clamping screws 67 (Fig. 6).

The master cam spindle 55 is supported in spaced aligned bearings 70 and 71 which are in turn supported by the rock bar 36. The master cam spindle 55 supports a master cam 72 which is shaped to generate a predetermined contour on the work piece as will be hereinafter described.

A suitable driving mechanism is provided for the master cam spindle 55 comprising a universal joint 73 (Figs. 2 and 4) which connects the master cam spindle 55 with a rotatable shaft 74. A universal joint 75 serves to drivingly connect the shaft 74 with a multiple V-groove pulley 76 which is supported by anti-friction bearings 77. An electric motor 78 is supported by a bracket 79 on the table 11. The motor 78 is provided with an armature shaft 80 which is connected to rotate a worm 81 (Fig. 3). The worm 81 meshes with a worm gear 82 which is keyed on a rotatable shaft 83. A gear 84 is also keyed on the shaft 83 and meshes with a gear 85 which is keyed on a rotatable clutch member 86. The clutch member 86 is rotatably supported on a shaft 87.

It is desirable to provide for a multiple speed of the piston 43 being ground. This is preferably accomplished by providing a second gear train comprising a gear 88 keyed on the left hand end of the shaft 83. The gear 115 meshes with a gear 116 which is keyed on a rotatable clutch member 90. The clutch member 90 is also rotatably supported on the shaft 87. A slidably mounted clutch member 91 is provided which is keyed on the shaft 87 and is arranged so that it may be shifted longitudinally relative thereto by means of a manually operable lever 92 into engagement with either the clutch member 86

or the clutch member 90 depending upon the speed of rotation desired. The shaft 87 is provided with a multiple V-groove pulley 93 which is connected by multiple V-belts with the multiple V-groove pulley 76 so that rotated power of the motor 78 will be transmitted through the gear mechanism above described to rotate the shaft 74 and the master cam spindle 55 to rotate the piston 43 being ground.

A master cam follower roller 95 is mounted on a rotatable shaft 96 which is carried by a pair of spaced brackets 97 and 98 formed integral with the headstock unit 41.

A suitable mechanism is provided for yieldingly maintaining the master cam 72 in operative engagement with the follower roller 95 during a grinding operation. This mechanism may comprise a tension spring 100 which is connected at one end by a stud 101 with a bracket 102 (Fig. 8). The bracket 102 is fixedly mounted by means of screws 103 on the rock bar 36. The other end of the spring 100 is provided with a stud 104 which passes through a hole or aperture 105 in the casing 106 of the headstock unit 41. The right hand end of the stud 104 is provided with a threaded portion 107 which is engaged by a nut 108. It will be readily apparent from the foregoing disclosure that by adjustment of the nut 108, the tension of the spring 90 may be varied as desired to maintain the master cam 72 in operative engagement with the master cam roller 95 with the desired pressure during a grinding operation.

It is desirable to provide a suitable mechanism for separating the master cam 72 from the follower roller 95 to facilitate removing the ground piston 43 from the machine and replacing it with a new piston to be ground. This mechanism may comprise a manually operable lever 110 (Figs. 1 and 8) which is mounted on the outer end of a rock shaft 111. A cam 112 is fixedly mounted on the inner end of the rock shaft 111 (Fig. 6). The cam 112 is arranged in the path of an adjustably mounted stud 113 carried by the bracket 102. When it is desired to separate the master cam 72 from the follower roller 95, the lever 110 may be rocked in a clockwise direction (Fig. 1) so that the cam 112 will move into engagement with the stud 113 after which continued movement of the lever 110 and the cam 112 serves to rock the rock bar 36 in a counterclockwise direction (Fig. 8) so as to separate the master cam 72 from the follower roller 95.

In order to generate the desired shape on the piston 43, it is desirable to support the piston in the work holder 45 so that when positioned in the machine as illustrated in Fig. 5, the transverse axis of the piston passing through the wrist pin bosses 88 and 89 will correspond with the short axis of the oval or ellipse formed on the master cam 72. This is preferably accomplished by providing a special fixture (not shown) by which the operator may locate the piston on the holder 45 in a definite position with relation to the lugs 54 and 54a and the driving screws 58 and 58a. After the piston has been thus located, the clamping jaws 47, 48 and 49 are swung into engagement with one of the grooves on the piston 43 and the screws 50, 51 and 52 are adjusted to clamp the piston 43 rigidly in position on the holder 45. The holder 45 together with the piston 43 are then positioned in the machine with the center hole 53 of the work holder engaging the headstock center 42 and the work holder 63 is moved into supporting engagement with the recess 64 formed in the open end of the piston 43.

The master cam 72 is then positioned so that one end of its long axis, that is the long axis of the oval or ellipse formed thereon, is in engagement with the master cam follower roller 95. With the parts in this position, the footstock 60 is rotarily adjusted on the shaft 65 (Figs. 2 and 6) so that the axis of the footstock spindle 61 is aligned with the axis of the master cam spindle 55. After this adjustment has been made, the clamping screws 67 are actuated to lock the footstock 60 in adjusted position. The driving screws 58 and 58a are then adjusted rotarily to adjust the position of the work holder 45 so that a transverse axis of the piston at right angles to the bosses 88 and 89 is positioned in a horizontal plane (Fig. 2). In this position the rock bar is in its extreme position rocked away from the grinding wheel and when the machine is started by the work driving motor 78, the rock bar will be rocked to oscillate the left hand end of the piston 43 during rotation thereof so as to generate a complex surface thereof in which an oval shape is produced which varies from a maximum relief at the left hand end to a minimum or zero relief at the right hand end of the piston 43. Due to the setup of the machine as above described, the axis of the piston being ground will be rocked from its left hand end during rotation thereof so that the oval or ellipse generated thereon will have the minor axis aligned with the axis of the wrist pin bosses 88 and 89. With this condition, a maximum relief will be produced on the piston 43 on diametrically opposite sides thereof at a point where the increased amount of metal in the piston due to the diametrically opposed bosses 88 and 89 causes a greater expansion when the ground piston is heated during use in an automotive engine or the like.

After the driving screws 58 and 58a have been initially adjusted for a grinding operation on a given size piston, it only becomes necessary to withdraw one of the screws 58 or 58a after a grinding operation has been completed to remove the ground work piece 43 and the shoulder 45 from the machine. The other screw 58 or 58a remaining in a fixed position so that when the next piston 43 and work holder 45 are mounted in the machine, it only becomes necessary to tighten one of the screws 58 or 58a to position the piston 43 to be ground in the desired location relative to the master cam 72.

It will be readily apparent from the foregoing disclosure that at diametrically opposite positions of the piston 43 being ground the axis of the footstock spindle 61 and the axis of the master cam spindle 55 will be aligned. As the master cam spindle 55 rotates, the master cam 72 will cause the rock bar to oscillate so that the work holder 45 and the left hand end of the piston 43 will be oscillated toward and from the periphery of the grinding wheel while the axis of the footstock spindle 61 maintains the axis of the work holder 63 in a relatively fixed position. This arrangement is diagrammatically illustrated in Fig. 11 which shows the master cam spindle 55 together with the piston 43 and the footstock spindle 61 as positioned in extreme positions, namely when the master cam 72 is positioned to engage the follower roller 95 on its long and short axes.

The tapered oval shape generated on the piston 43 may be varied by varying the longitudinal position of the piston 43 between the headstock center 42 and the aligning axis of the self-

aligning anti-friction bearing 62. This may be accomplished by providing longer or shorter work holders 63 on the footstock end. If a work holder 63 is provided which is short enough so that the right hand end of the piston 43 (Fig. 5) is in the plane of the aligning axis of the bearing 63, then a substantially cylindrical surface will be generated on the piston at the right hand end. In this case the relief will taper from a substantially true cylinder to an oval as governed by the master cam 72 and the position of the left hand end of the piston 43 relative to the headstock center 42. The work holder 45 may be similarly varied in length for positioning the left hand end of the piston 43 relative to the headstock center 42. It will be readily apparent from the foregoing disclosure that by providing longer or shorter work holders 63 and 45, the shape of the relief ground upon the periphery of the skirt of the piston 43 may be varied as desired. As shown in Figure 5 and diagrammatically in Fig. 11, the right hand end of the piston 43 is spaced from the axis of support on the footstock end so that a slight relief will be produced on the right hand end of the piston 43 which will increase toward the left due to the wabbling motion transmitted to the left hand end of the piston 43 by the master cam 72 which causes a rocking movement of the rock bar toward and from the grinding wheel 25 during rotation of the piston 43 being ground.

As shown in Figs. 5 and 11, the machine is set up with the axis of the footstock spindle 61 adjusted into alignment with the axis of the master cam spindle 55 when the high point of the master cam 72 is in engagement with the master cam roller 95 so that a tapered oval shape is generated on the piston tapering from the right hand end of the piston (Figs. 5 and 11) toward the left.

It may be desirable to grind the piston in the reverse manner, namely to mount the open end of the piston on the headstock center 42 in which case the taper on the piston will taper from the open end of the piston toward the right as shown diagrammatically in Fig. 11. In this condition of the parts, the footstock 60 is adjusted on its supporting shaft so that the axis of the footstock spindle is aligned with the axis of the master cam spindle 55 when the low point of the master cam 72 is in operative engagement with the master cam roller 72. In this application of the invention the master cam 72 would have to be generated to meet the reverse condition of operation.

In the first described method of operation the footstock spindle 61 is aligned with the axis of the master cam spindle 55 when the master cam spindle is positioned in broken line position 55*a* (Fig. 11) and the master cam 72*a* is positioned with the high point of the master cam 72 in operative engagement with the master cam roller 95. As the master cam spindle is rotated to rotate the master cam 72 and the piston 43 being ground, the footstock end of the spindle shown diagrammatically in Fig. 11 will rotate about the axis of the footstock spindle 61 while rotation of the master cam 72 will cause the rock bar 36 to rock the master cam spindle from position 55*a* (Fig. 11) to full line position 55 to generate a tapered oval shape on the piston 43 as illustrated in broken lines 43*a* (Fig. 11) in which the tapered oval tapers from the right hand end of the piston toward the left.

In the reverse setup above described the master cam spindle is positioned in position 55*a* with the low point of the master cam 72 in engagement with the follower roller 95. In this position of the parts, the footstock 60 is adjusted so that the axis of the footstock spindle 61 is aligned with the axis of the master cam spindle 55 in position 55*a*. When the master cam spindle 55*a* is rotated, the rotation thereof will be transmitted to rotate the piston 43 about the axis of the footstock spindle 61 while the master cam 72*a* will cause the rock bar 36 and the master cam spindle 55*a* to rock toward the position 55*b* (Fig. 11), that is it will rock the left hand end of the piston 43*a* away from the grinding wheel so that a tapered surface will be produced on the periphery of the piston as illustrated diagrammatically in broken lines 43*b* tapering from the left hand end thereof toward the right. If the latter arrangement of parts is utilized the work holder 45 may be eliminated and a special relatively large conical center be provided in place of the headstock center 42. This special driving center will engage the open end of the piston and be provided with a driving lug which projects within the hollow piston and drivingly engages one of the inwardly projecting wrist pin bosses 88 and 89.

The operation of this improved grinding machine will be readily apparent from the foregoing disclosure. Assuming all of the parts to have been previously adjusted and a master cam 72 of the desired contour is mounted on the master cam spindle 55, a work piece such as a piston 43 which has been previously located as above described on the work holder 45 is mounted in position in supporting engagement with the headstock center 42 and the work holder 63 carried by the footstock 60. As above described on the initial grinding operation the driving screws 58 and 58*a* are adjusted to locate the axis of the piston passing through the axis of the wrist pin bosses 88 and 89 in a predetermined relationship with the master cam 72. The grinding operation may then proceed and the grinding wheel may be advanced by actuation of the feed wheel 31 to grind the desired and predetermined shape on the periphery of the piston 43. After the piston has been ground to the predetermined size and contour, the machine may be stopped and one of the screws 58 or 58*a* loosened to facilitate removal of the work piece from the machine. It is of course necessary to move the footstock spindle 61 toward the right (Figs. 2 and 5) to withdraw the work holder 63 from the recess 64 after which the ground piston 43 and the work holder 45 may be removed from the machine. It will be readily apparent that by providing two or more work holders 45, one of the work holders may be loaded while a grinding operation on a piston 43 is proceeding so that the second assembly, namely a piston 43 and the second work holder 45 are ready to be inserted in the machine after the first ground work piece has been removed therefrom. It will be readily apparent from the foregoing disclosure that by providing a master cam 72 of the desired shape, any desired amount of relief may be ground on the piston axis passing through the axis of the wrist pin bosses 88 and 89.

It will thus be seen that there has been provided by this invention apparatus in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodi-

ment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a piston grinding machine having a transversely movable rotatable grinding wheel, a work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar, means including a master cam on said spindle and a follower roller to impart a rocking movement to said rock bar, means including a work supporting center on said spindle to support one end of a work piece to be ground, a pivotally mounted footstock on said table having a longitudinally adjustable spindle, a self-aligning workholder on said spindle to support the other end of the work piece, and means to adjust said footstock transversely so that its spindle axis is aligned with the axis of the master cam spindle when a high point of the master cam is in engagement with the follower roller so that the end of the work piece adjacent to the footstock rotates about a substantially fixed axis while the other end of the work piece rotates with the master cam spindle and is rocked toward and from the grinding wheel as controlled by the master cam to generate a variable relief on the work piece being ground.

2. In a piston grinding machine having a rotatable grinding wheel, a work table, a rock bar pivotally supported on said table, a master cam spindle on said rock bar, means including a master cam on said spindle and a rotatable follower roller on said table to impart a controlled rocking movement to said rock bar when the spindle is rotated, means including a work supporting center on said spindle to support one end of a work piece to be ground, a pivotally mounted footstock, a pivotal support for the footstock on said table, a self-aligning workholder carried by the footstock for rotatably supporting the other end of the work piece, and means to adjust said footstock on its pivotal support so that its axis is aligned with the axis of the master cam spindle when the high point of the master cam is in engagement with the follower roller so that the end of the work piece adjacent to the footstock rotates about a substantially fixed axis while the other end of the work piece is rotated and wobbled as controlled by rotation of the master cam spindle and the master cam to generate a tapered contour on the work piece.

3. In a piston grinding machine having a transversely movable rotatable grinding wheel, a longitudinally movable work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar, means including an oval-shaped master cam on said spindle and a rotatable follower roller on said table, means including a workholder supported by said spindle to support one end of a piston to be ground, a pivotally mounted footstock having a spindle, the pivotal axis of the footstock being axially aligned with the pivotal axis of the rock bar, a self-aligning rotatable workholder on said footstock spindle to support the other end of the piston to be ground, means pivotally to adjust the footstock so that the axis of the spindle is aligned with the axis of the master cam spindle when a high point of the master cam is in engagement with the follower roller so that rotation of the master cam spindle will impart a rotary revolving movement to one end of the piston as controlled by the master cam while the other end of the piston is rotated by a substantially fixed axis to generate a tapered oval shape on the piston being ground.

4. In a piston grinding machine having a transversely movable rotatable grinding wheel, a work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar, means including a master cam on said spindle and a follower roller to impart a controlled rocking movement to said rock bar during rotation of said spindle, a workholder supported by said spindle to support one end of a work piece to be ground, a footstock pivotally mounted on said table, and means to adjust the footstock about its pivotal axis so that the footstock spindle may be positioned in axial alignment with the axis of the master cam spindle when a high point of the master cam is in engagement with the follower roller so that one end of the work piece to be ground rotates about a substantially fixed axis while the other end of the piston rotates and revolves with the master cam spindle as it is rocked by the master cam so as to generate a predetermined tapered shape on the work piece being ground.

5. In a piston grinding machine having a transversely movable rotatable grinding wheel, a longitudinally movable work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar which is arranged parallel to the axis of the rock bar, means including an oval-shaped master cam on said spindle and a follower roller on said table, means including a work supporting center on said spindle to support one end of a work piece to be ground, a pivotally mounted footstock on said table, the pivotal support for said footstock being axially aligned with the pivotal axis of the rock bar, a spindle on said footstock which is arranged parallel to the pivotal support of the axis of the rock bar and spaced therefrom by a distance equal to the spacing of the master cam spindle from said axis, and means to adjust the footstock about its axis so that the footstock spindle may be positioned in axial alignment with the axis of the master cam spindle when a high point of the master cam is in engagement with the follower roller so that one end of the piston being ground rotates about a substantially fixed axis of the footstock spindle while the other end of the piston rotates with the master cam spindle and is rocked toward and from the grinding wheel as controlled by the master cam to generate a tapered oval shape on the piston being ground.

6. In a piston grinding machine having a transversely movable rotatable grinding wheel, a work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar, means including a master cam on said spindle and a follower roller to impart a rocking movement to said rock bar, means including a work supporting center on said spindle to support one end of a work piece to be ground, a pivotally mounted footstock on said table having a footstock spindle to support the other end of the work piece, and means to adjust said footstock about its pivot so that the axis of the footstock spindle is aligned with the axis of the master cam spindle when a low point of the master cam is in engagement with the follower roller so that the end of the work piece adjacent to the footstock rotates about a substantially fixed axis while the other end of the work piece rotates with the master cam spindle and is rocked away from and toward the grinding wheel as controlled by the

master cam to generate a variable relief on the work piece being ground.

7. In a piston grinding machine having a transversely movable rotatable grinding wheel, a work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar, means including a master cam on said spindle and a follower roller to impart a controlled rocking movement to said rock bar during rotation of said spindle, a workholder supported by said spindle to support one end of a work piece to be ground, a footstock pivotally mounted on said table, and means to adjust the footstock about its pivotal axis so that the footstock spindle may be positioned in axial alignment with the axis of the master cam spindle when a low point of the master cam is in engagement with the follower roller so that one end of the work piece to be ground rotates about a substantially fixed axis while the other end of the piston rotates and revolves with the master cam spindle as it is rocked by the master cam so as to generate a predetermined tapered shape on the work piece being ground.

8. In a piston grinding machine having a transversely movable rotatable grinding wheel, a longitudinally movable work table, a rock bar pivotally supported on said table, a rotatable master cam spindle on said rock bar which is arranged parallel to the axis of the rock bar, means including an oval-shaped master cam on said spindle and a follower roller on said table, means including a work supporting center on said spindle to support one end of a work piece to be ground, a pivotally mounted footstock on said table, the pivotal support for said footstock being axially aligned with the pivotal axis of the rock bar, a spindle on said footstock which is arranged parallel to the pivotal support of the axis of the rock bar and spaced therefrom by a distance equal to the spacing of the master cam spindle from said axis, and means to adjust the footstock about its axis so that the footstock spindle may be positioned in axial alignment with the axis of the master cam spindle when a low point of the master cam is in engagement with the follower roller so that one end of the piston being ground rotates about a substantially fixed axis of the footstock spindle while the other end of the piston rotates with the master cam spindle and is rocked away from and toward the grinding wheel as controlled by the master cam to generate a tapered oval shape on the piston being ground.

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