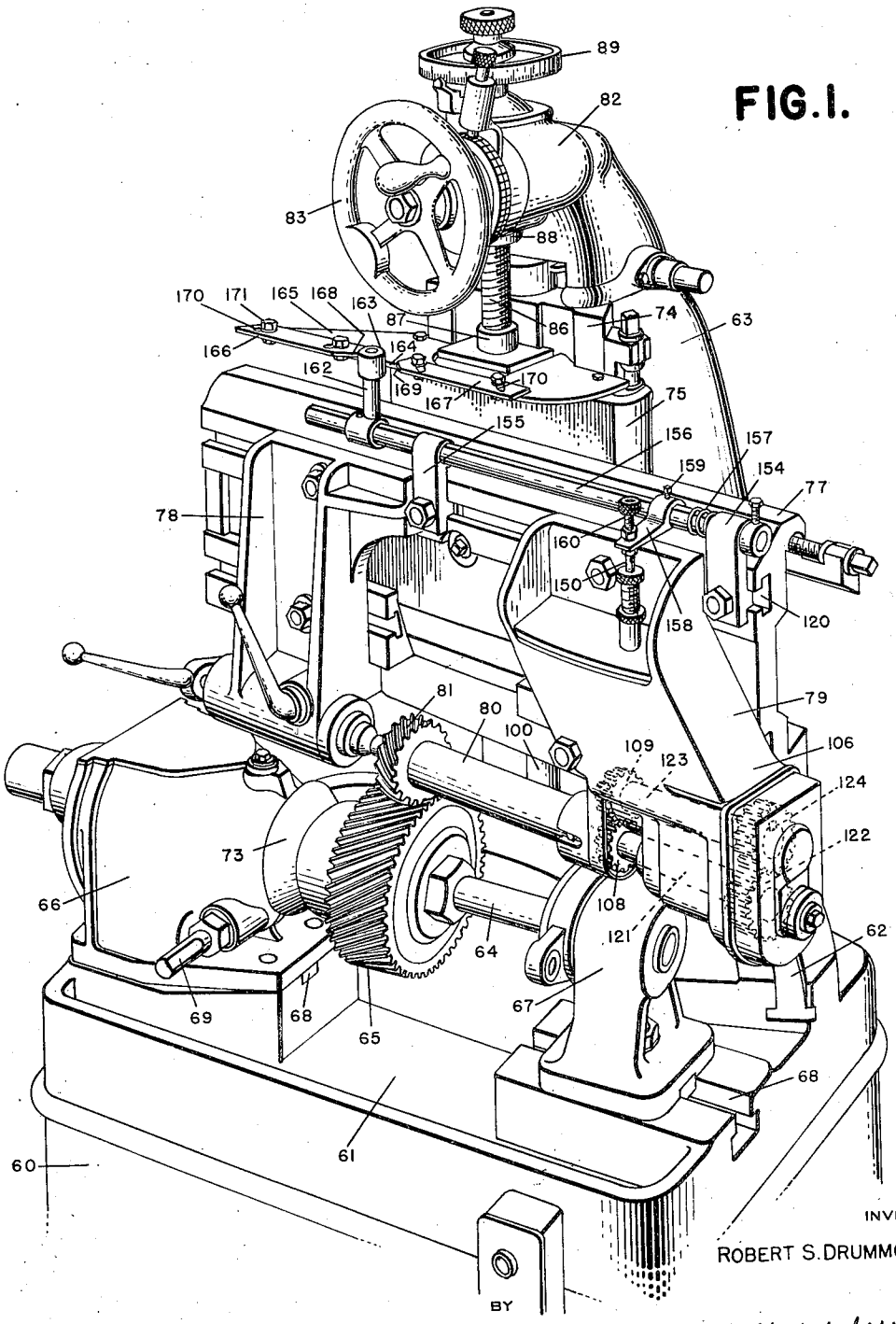
March 15, 1938. R. S. DRUMMOND 2,111,045

LAPPING MACHINE

Filed Aug. 7, 1935 4 Sheets-Sheet 1

FIG. 1.



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March 15, 1938. R. S. DRUMMOND 2,111,045

LAPPING MACHINE

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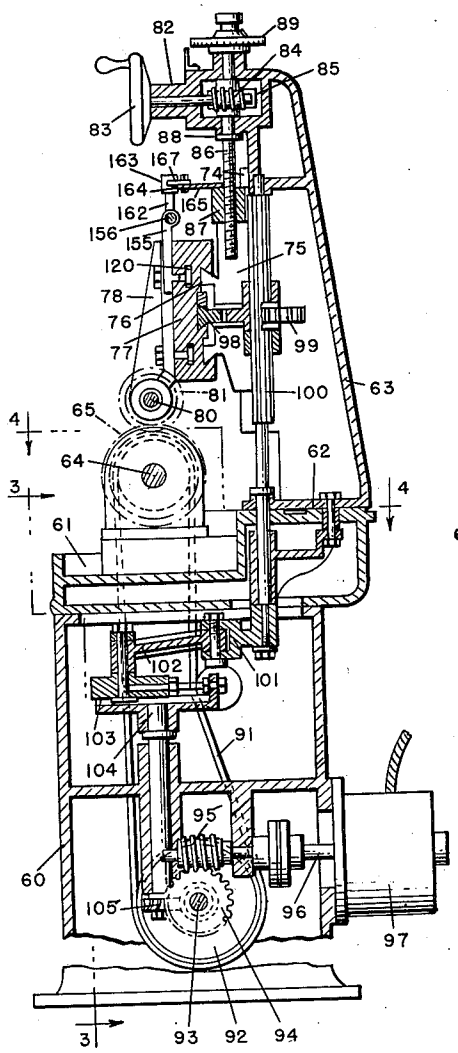


FIG. 2.

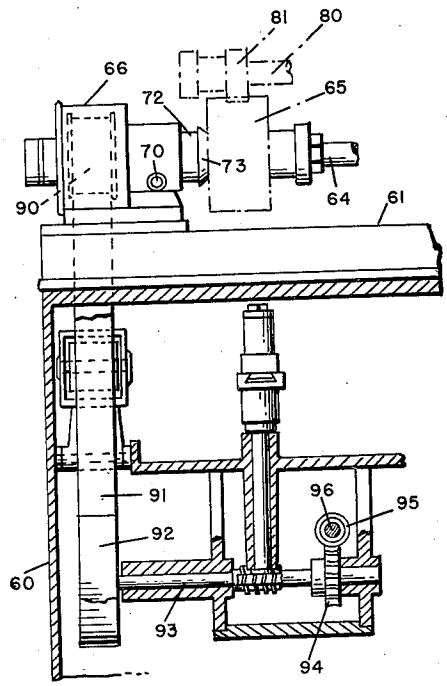


FIG. 3.

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LAPPING MACHINE

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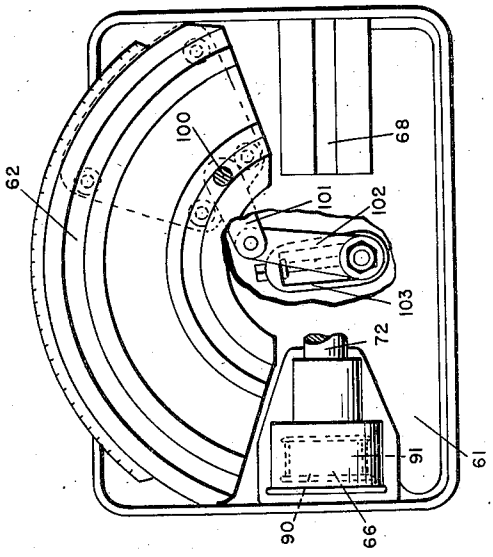


FIG. 4.

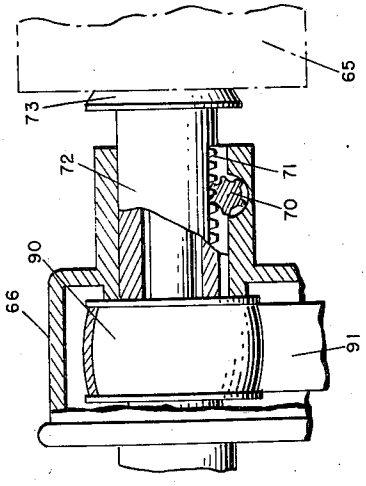
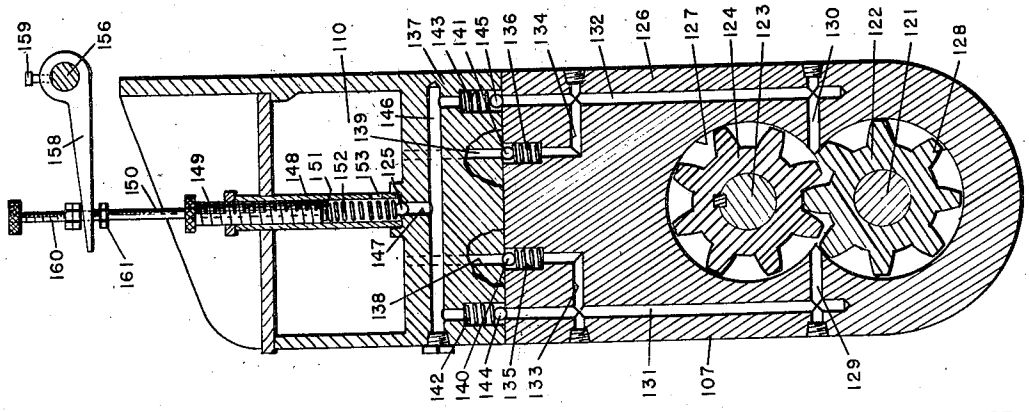


FIG. 5.

FIG. 6.



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LAPPING MACHINE

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FIG. 7.

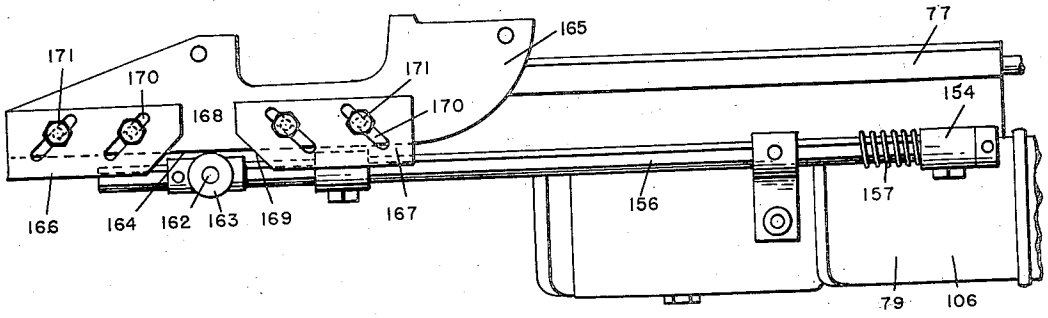
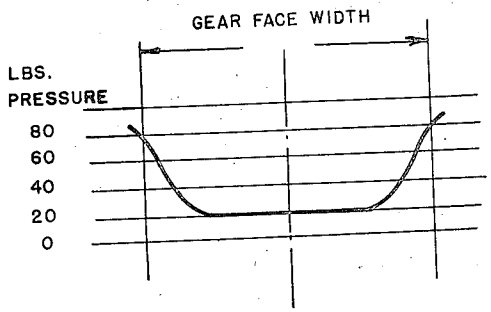


FIG. 10.



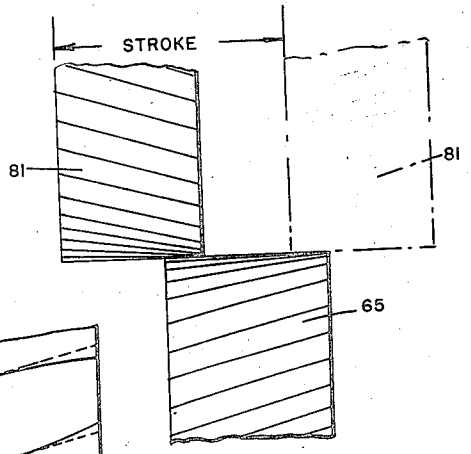


FIG. 8.

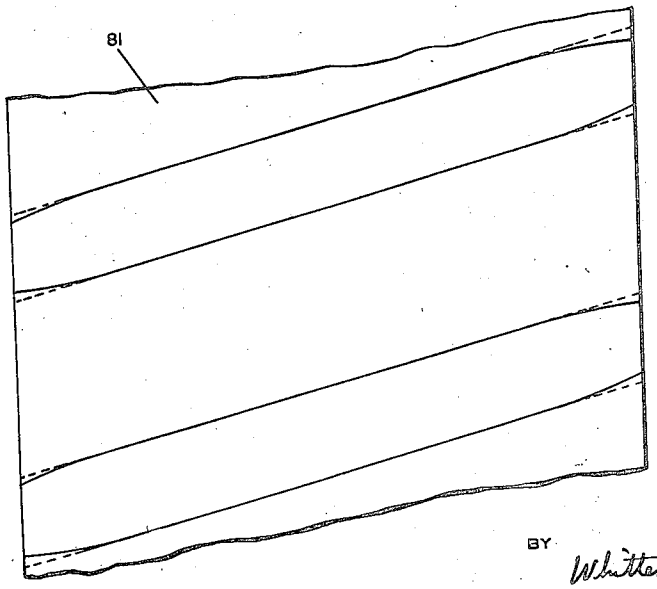


FIG. 9.

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Patented Mar. 15, 1938

2,111,045

UNITED STATES PATENT OFFICE

2,111,045

LAPPING MACHINE

Robert S. Drummond, Detroit, Mich.

Application August 7, 1935, Serial No. 35,114

8 Claims. (Cl. 51—26)

The invention relates to the art of finishing gears and is an improvement in the invention disclosed in my prior Patent No. 1,989,651 patented January 29, 1935.

The principal object of the invention is to obtain a crowning effect during the finishing of the gears whereby the ends of the teeth are slightly rounded. When gears finished in this manner are run together, there is avoided the harsh edge bearing which in the case of ordinary gears may be very slightly out of line in the mounting of the case.

My invention may be applied to machines adapted for lapping, burnishing or cutting of gears and is particularly adapted for improving the finishing of gears by the method shown in my prior patent above mentioned. My invention may be embodied in an attachment which can be added to the machine shown in my prior patent, or it may be made as an integral part of a machine for finishing gears.

My invention is especially adapted for use in lapping gears by means of a rotary lapping tool in the form of a gear, the axis of the tool being crossed with respect to the axis of the gear being finished, preferably at an angle of less than 30°. The invention is also effective when the rotary finishing tool is of a form to produce burnishing or of a form to produce cutting or shaving of the gear teeth.

In the drawings

Figure 1 is a perspective view of a gear finishing machine embodying my invention with certain portions of the oil pump in the power tail stock diagrammatically shown in dotted lines;

Figure 2 is a vertical section through the machine;

Figure 3 is a sectional view illustrating a portion of the drive mechanism taken substantially on the line 3—3 of Figure 2;

Figure 4 is a horizontal sectional view taken on the line 4—4 of Figure 2;

Figure 5 is a detail view of a portion of Figure 1 with parts broken away;

Figure 6 is a diagrammatic sectional view through the power tail stock showing the oil pump and valves;

Figure 7 is a top plan view of the mechanism for varying the oil pressure in order to obtain the crowning effect;

Figure 8 is a diagrammatic view showing the relationship between the gear and the finishing tool during the finishing operation;

Figure 9 is an enlarged diagrammatic view of the gear teeth of a helical gear after the crowning effect has been produced, the rounding of the teeth being somewhat exaggerated;

Figure 10 is a diagram illustrating the change in oil pressure during the reciprocation of the gear with respect to the finishing tool.

The drawings illustrate a machine which in general construction is substantially the same as that disclosed in Figures 6 to 11 of Patent No. 1,989,651 but modified therefrom to obtain the crowning effect in accordance with the present invention. It is also substantially the same as one of the machines shown in my co-pending application, Serial No. 3,663, filed January 26, 1935. The machine is provided with a hollow base 60 which at a convenient height is provided with a table 61. At the rear of the table are segmental ways 62 on which is mounted a vertical column 63. At the front of the table 61 provision is made for carrying the arbor 64 on which the finishing tool 65 is mounted. This consists of a head stock 66 and tail stock 67, the latter being adjustable in the ways 68 on the table 61. These are so located that the horizontal axis of the arbor 64 intersects the vertical axis about which the column 63 is angularly adjustable on the ways 62. For adjusting the finishing tool axially there is provided the square shank 69 which carries at its opposite end the pinion 70 (see Figure 5). The pinion 70 meshes with the rack 71 on the sleeve 72 which in turn has a collar 73 abutting the finishing tool 65. Thus upon rotation of the square shank 69 with a suitable handle, the finishing tool 65 may be axially adjusted in the bearings on the head stock 66 and tail stock 67.

The column 63 is provided with vertical ways 74 for mounting the crosshead 75. The crosshead is in turn provided with horizontal ways 76 on which is horizontally adjustable a carriage 77. This carriage has depending therefrom arms 78 and 79 in which are mounted bearings for the arbor 80 for the gear 81 to be finished. For vertically adjusting the arbor 80, the following mechanism is used. The column 63 is provided at the top thereof with a frame 82 in which a handwheel 83 is journaled. The handwheel carries a worm 84 engaging a worm wheel 85 which in turn is mounted on the adjustment screw 86. This screw threadedly engages a nut 87 on the crosshead 75 while it is provided with a suitable thrust collar 88 to prevent axial movement thereof. The screw also carries at its upper end the index wheel 89 for indicating the vertical adjustment of the crosshead.

The arbor 64 is driven by suitable means such

as the pulley 90 which is connected by a belt 91 to a pulley 92 on a shaft 93 arranged in the bottom of the hollow base 60. The shaft 93 has a gear 94 engaging worm 95 on a shaft 96 driven by an electric motor 97. The speed of rotation of the arbor 64 for the finishing tool may be suitably regulated by providing the proper ratio of the gears in the driving mechanism. Provision is also made for automatically reciprocating the carriage 77, this comprising a rack 98 on the carriage 77 engaging a gear wheel 99 splined upon a vertical shaft 100 which is oscillated by a rock arm 101 connected to a link 102 engaging an adjustable throw crank 103 on a shaft 104. The shaft 104 is driven through the medium of a reduction worm gearing 105 from the shaft 93. Thus the rotation of the shaft 93 rotates the gear finishing tool 65 and at the same time reciprocates the gear to be finished in the direction of the axis of the latter. The amplitude of movement is determined by the throw of the adjustable crank 103 which may be set according to the width of the gear which is being finished. The rate of axial feed of the gear may be determined by the proper gear ratio.

In the finishing of gears according to the present invention, the pressure between the teeth of the finishing tool and the gear to be finished is developed by retarding the rotation of the gear, and for this purpose I provide a suitable mechanism which may be referred to generally as a power tail stock 106. This is mounted on horizontal ways 120 on the column 63 to permit horizontal adjustment. Within the power tail stock is a gear pump 107 which is driven from the shaft 80 through the medium of intermeshing gear wheels 108 and 109. The gear 108 is mounted on a shaft 121 which has at its opposite end loosely mounted thereon the driven oil pump gear 122. The gear 109 is keyed to a parallel shaft 123 to which is keyed the driving oil pump gear 124. The oil or other fluid propelled by the pump is supplied by a reservoir 110 and is discharged against the resistance of a spring-closed valve 125. Figure 6 shows diagrammatically the path of flow of the fluid from the reservoir to the gear pump and back to the reservoir again, and for convenience the various connections are shown in substantially the same plane, although it is to be understood that in the actual construction of the machine the conduits and the relief valves may be located in whatever relationship is found most suitable from a manufacturing standpoint. As shown in the drawings, the pump gears 124 and 122 are within a block 126 having intersecting cylindrical bores 127 and 128 forming the pump casing. Conduits 129 and 130 lead from opposite sides of the casing and communicate respectively with vertical passageways 131 and 132 leading to the top of the block 126. There are also the branch passageways 133 and 134 communicating with the enlarged bores 135 and 136 at the top of the block. The upper block 137 has vertical passageways 138 leading between the bore 135 and the reservoir 110 and there is a corresponding vertical passageway 139 leading from the bore 136 to the reservoir. Spring-closed relief valves 140 and 141 are arranged in the bores 135 and 136 to seat against the lower face of the upper block 137. There are similar enlarged bores 142 and 143 in alignment with passageways 131 and 132 and having therein the spring-closed relief valves 144 and 145 seating against the upper face of the lock block 126. The bores 142 and 143 communicate with a horizontal passageway 146 which in turn communicates with a vertical passageway 147 in which the relief valve 125 is located. A tubular conduit 148 extends through the reservoir and projects above the same. Within the tubular conduit is an adjustable sleeve 149 carrying within the same a push rod 150. A head 151 at the lower end of the rod 150 bears against a coil spring 152 which in turn bears against the ball valve 125. The spring tension of the valve may therefore be adjusted by vertical movement of the push rod 150 and an initial tension may be obtained by the adjusting sleeve 149 which at its lower end abuts the head 151.

With the construction of oil pump described, the resistance to rotation will be obtained when the pump is rotated in either direction. Thus assuming that gear 124 is rotating clockwise in the figure, the oil from the reservoir 110 will flow downwardly through passage 139 through relief valve 141, passage 134, passage 132, passage 130 to the gear casing. It will then travel back to the reservoir through passageways 129 and 131, relief valve 142, passage 146, passage 147 to the relief valve 125 and thence outwardly through the port 153 in the tubular conduit 148. Similarly, if the pump gear 124 is rotating in a counter-clockwise direction, the oil will flow downwardly through passage 138, relief valve 140, passages 133, 131, and 129 to the gear pump casing and will flow back to the reservoir through passages 130, 132, relief valve 145, passages 146 and 147 to the ball valve 125 and thence outwardly through port 153. It will be obvious therefore that in either direction of rotation the resistance to rotation of the gear to be finished will be dependent upon the spring tension on the relief ball valve 125.

In accordance with my invention, I make provision to vary the spring tension on the relief valve 125 in accordance with the position of reciprocation of the gear being finished. For this purpose I provide on the carriage 77 a pair of brackets 154 and 155 in which is journaled a rock shaft 156. An arm 158 adjustably secured to the rock shaft by a screw 159 extends over the upper end of the push rod 150 and is provided with an adjusting screw 160 projecting through the same and contacting with the upper head 161 of the push rod. A torsional spring 157 having its ends anchored in the rock shaft and bracket 154 respectively actuates the rock shaft to remove the lever 158 upward away from the push rod. A second rocker arm 162 on the rock shaft 156 has a roller 163 thereon adapted to contact with the edge 164 of a plate 165 which in turn is mounted on the crosshead 75 of the machine. Two cam plates 166 and 167 are secured to the plate 165 on opposite sides of the roller 163 and have cam faces 168 and 169 respectively positioned to contact with said roller during the reciprocation thereof, the cam plates having angling slots 170 for receiving the locating screws 171 in order to permit adjustment of the cam plates. This permits of varying the pressure as desired at each end of the stroke and permits the proper adjustment to be made for different gears requiring a different length of stroke.

In the operation of the machine as described, the driving motor 97 is energized, thereby rotating the gear finishing tool 65 which in turn causes the gear 81 to be rotated due to the intermeshing action of the teeth. A reciprocating feed movement is imparted in the direction of the axis of the gear by means of the automatic mechanism including the pinion 99 and rack 98

which cause reciprocation of the carriage 77 and the gear 81. This movement is of sufficient amplitude to spread the finishing action over the entire face width of the gear. The finishing tool is provided with a tooth thickness that is less than the interdental spaces in the gear prior to lapping which enables the original setting of the machine with the gear and finishing tool in full mesh, that is, with their axes spaced apart the exact distance for normal operation. The driving motor 97 is first operated in one direction to cause a finishing action on the tooth faces on one side thereof, and then by reversing the motor the opposite faces of the teeth are correspondingly subjected to a finishing action. The reversal of rotation may be accomplished manually, or if desired suitable timing mechanism can be used for automatically reversing the machine after a predetermined amount of finishing action in one direction.

During the axial reciprocation of the gear 81, the roller 163 is also reciprocated and bears against the edge 164 until near the end of the stroke when it rides up on one or the other of the cam faces 168 and 169. This causes a rocking movement of the rock shaft 156 against the action of the torsional spring 157 and the arm 158 presses downwardly on the push rod 150, thereby increasing the spring tension on the ball valve 125. Therefore the oil pressure is built-up to a higher degree which causes an increased retardation of the power tail stock and an increased pressure between the ends of the teeth of the gear being finished and the teeth of the finishing tool. This is diagrammatically illustrated in Figure 10 which is a pressure chart showing the change in oil pressure over the face width of the gear. Thus if the relief valve is set to normally operate under 20 pounds pressure when the roller is contacting with the edge 164, the pressure will rapidly build-up when lapping the ends of the gear to 80 pounds due to the effect of the cam faces 168 and 169 on the position of the roller. It is to be understood that the pressure chart is illustrative only, and the pressures may be varied as desired in order to give the amount of crowning effect which is found desirable for any particular gear finishing operation.

Figure 8 diagrammatically illustrates the correct setting for crowning gears in accordance with my invention. In this case the lap 65 is only slightly wider than the gear 81. The reciprocating stroke is sufficient so that at each end of the stroke only the ends of the gear teeth are in contact with the lap and it is at the ends of the stroke where the pressure is built-up to obtain the increased lapping effect. As an illustration, if the gear has a face width of $1\frac{1}{8}$ inches, the lap may have a face width of $1\frac{1}{4}$ inches and the stroke may be $1\frac{3}{4}$ inches. This, however, may be suitably varied and still obtain a beneficial effect. It should be remembered that the gear and lap are arranged with crossed axes so that the contact between the teeth of the gear and lap varies from the center position toward the positions at the ends of the stroke. The angle of contact is different at the ends of the stroke than at the center of the crossed axes. Another factor in the production of a crowning effect in my machine is the mechanism for producing the oscillating stroke. As previously described, the machine has a link 102 operated from a crank 103 and this causes a natural dwell at the two ends of the stroke which becomes relatively larger with respect to the lapping in the middle of the gear. This in itself will cause excessive lapping at the ends of the stroke and tends to chamfer or round the ends of the teeth.

Figure 9 is a diagrammatic view of the teeth of a helical gear which have been crowned in accordance with my invention. The chordal thickness in the middle of the gear is for example 125 thousandths of an inch, while the chordal thickness at the ends is 124 thousandths of an inch. This is merely an illustration however, and by means of my invention the ends of the teeth may be tapered off in any desired amount even to as much as 2 thousandths of an inch if desired. A gear finished in this manner is recognized as desirable due to the fact that in use it eliminates a very undesirable whine sound caused by mis-alignment of the shafts or edge bearing between the gears.

In the previous description of the operation of the machine, I have referred more particularly to lapping and as is well understood in the art the lapping effect is caused by introducing a lapping compound between the teeth of the lapping tool and the gear being finished. It is to be understood however that my invention also contemplates other finishing actions such as burnishing and cutting or shaving. The lapping action is obtained by making the rotary finishing tool of a relatively soft material such as cast iron, while burnishing is obtained with a finishing tool of harder material. Cutting or shaving is obtained by the use of a modified form of finishing tool as described in my co-pending application, Serial No. 3,662, filed January 26, 1935. Where the term rotary finishing tool is used in the specification and claims, it is meant to include within its meaning constructions useful for lapping, burnishing or cutting.

In finishing gears in accordance with my invention, the gear finishing tool and the gear to be finished have conjugate mating teeth and the angle between the axes is preferably maintained less than 25° to 30° and usually between 3° and 20°. If the gear to be finished is a straight spur gear, the finishing tool will be a helical gear having a helical angle within the above limits. On the other hand, if the gear to be finished is helical, the finishing tool may be in the form either of a straight spur gear or of a helical gear, but in each case the difference in helical angle should be such that when in proper mesh the angular difference between the axes is within the limits previously mentioned.

What I claim as my invention is:

1. A gear finishing machine comprising two arbors having their axes crossed at an angle less than 30°, one of said arbors being adapted to mount a gear member to be finished, a rotary finishing tool in the form of a gear member mounted on the other of said arbors to mesh with said gear to be finished, means for driving one of said arbors whereby the other of said arbors is driven by the intermeshing action of said gear members, means for resisting the rotation of said other arbor, means for feeding one of said members relative to the other in the direction of the axis of the gear to be finished and means automatically operated in timed relation to said feeding movement for varying the resistance to rotation of said other arbor during the feeding movement.

2. A gear finishing machine comprising two arbors having their axes crossed at an angle less

than 30°, one of said arbors being adapted to mount a gear member to be finished, a rotary finishing tool member mounted on the other of said arbors to mesh with said gear to be finished, means for driving one of said arbors whereby the other of said arbors is driven by the intermeshing action of said teeth, an oil pump driven by said other arbor, a relief valve for placing a predetermined resistance on said oil pump, means for feeding one of said members relative to the other in the direction of the axis of the gear to be finished and means for varying said relief valve during said feeding movement to vary the pressure between the teeth of said members.

3. A gear finishing machine comprising two arbors having their axes crossed at an angle less than 30°, one of said arbors being adapted to mount a gear member to be finished, a rotary finishing tool member mounted on the other of said arbors to mesh with said gear to be finished, means for driving one of said arbors whereby the other of said arbors is driven by the intermeshing action of said teeth, an oil pump driven by said other arbor, a relief valve for placing a predetermined resistance on said oil pump, means for feeding one of said members relative to the other in the direction of the axis of the gear to be finished, a rock shaft operatively connected to said relief valve to vary the pressure on said oil pump and cam means operatively associated with said rock shaft to rock the same during said feeding movement.

4. A gear finishing machine comprising an arbor having a rotary finishing tool thereon, means for rotating said arbor, a second arbor having an axis crossed at an angle less than 30° with axis of said first arbor and adapted to mount a gear to be finished in mesh with said rotary finishing tool, a gear pump driven by said second shaft, a relief valve for said gear pump, a movable rod for varying the pressure on said relief valve, a reciprocable carriage for mounting said second arbor, a rock shaft on said carriage, an arm on said rock shaft operatively associated with said rod, a rocker arm on said rock shaft and a stationary cam arranged in the path of said rocker arm to move the same during the reciprocation of said carriage.

5. A gear finishing machine comprising a frame, a pair of shafts in said frame, means for angularly adjusting one of said shafts on said frame to cause the axes of said shafts to be crossed, one of said shafts being adapted to mount a work gear member to be finished, a rotary finishing tool member mounted on the other of said shafts and having gear teeth adapted to mesh with said work gear when said axes are crossed, means for driving one of said members whereby the other of said members is driven by the intermeshing action of said gears, means for feeding one of said members relative to the other in a direction to spread the finishing action across the face of said work gear, means for regulating the pressure contact between the teeth of said members, and means for actuating said pressure-regulating means in predetermined portions of said feeding movement.

6. A gear finishing machine comprising a frame, a pair of shafts in said frame, means for angularly adjusting one of said shafts on said frame to cause the axes of said shafts to be crossed, one of said shafts being adapted to mount a work gear member to be finished, a rotary finishing tool member mounted on the other of said shafts and having gear teeth adapted to mesh with said work gear when said axes are crossed, means for driving one of said members whereby the other of said members is driven by the intermeshing action of said gears, means for feeding one of said members relative to the other in a direction to spread the finishing action across the face of said work gear, means for resisting the rotation of said driven member, means for regulating the amount of said resistance to rotation, and means automatically responsive to travel of said fed member for actuating said regulating means in predetermined portions of said feeding movement to vary the pressure contact between said members in different portions of the face width of said work gear.

7. A gear finishing machine comprising a frame, a pair of shafts in said frame, means for angularly adjusting one of said shafts on said frame to cause the axes of said shafts to be crossed, one of said shafts being adapted to mount a work gear member to be finished, a rotary finishing tool member mounted on the other of said shafts and having gear teeth adapted to mesh with said work gear when said axes are crossed, means for driving one of said members whereby the other of said members is driven by the intermeshing action of said gears, means for feeding one of said members relative to the other in a direction to spread the finishing action across the face of said work gear, means for resisting the rotation of said driven member, means for regulating the amount of said resistance to rotation, and cam means operably connected to said feeding means to said regulating means to vary the pressure contact between said members in different portions of the face width of said work gear.

8. A gear finishing machine comprising a frame, a pair of shafts in said frame, means for angularly adjusting one of said shafts on said frame to cause the axes of said shafts to be crossed, one of said shafts being adapted to mount a work gear member to be finished, a rotary finishing tool member mounted on the other of said shafts and having gear teeth adapted to mesh with said work gear when said axes are crossed, means for driving one of said members whereby the other of said members is driven by the intermeshing action of said gears, means for feeding one of said members relative to the other in a direction to spread the finishing action across the face of said work gear, means for resisting the rotation of said driven member, means for regulating the amount of said resistance to rotation, and cam means operably connected to said regulating means and operably connected to said feeding means to increase the pressure contact between said members at the ends of said work gear.

ROBERT S. DRUMMOND.