

April 24, 1945.

W. F. ZIMMERMANN

2,374,254

WORM GEAR HOBGING MACHINE

Filed Sept. 12, 1941

4 Sheets-Sheet 1

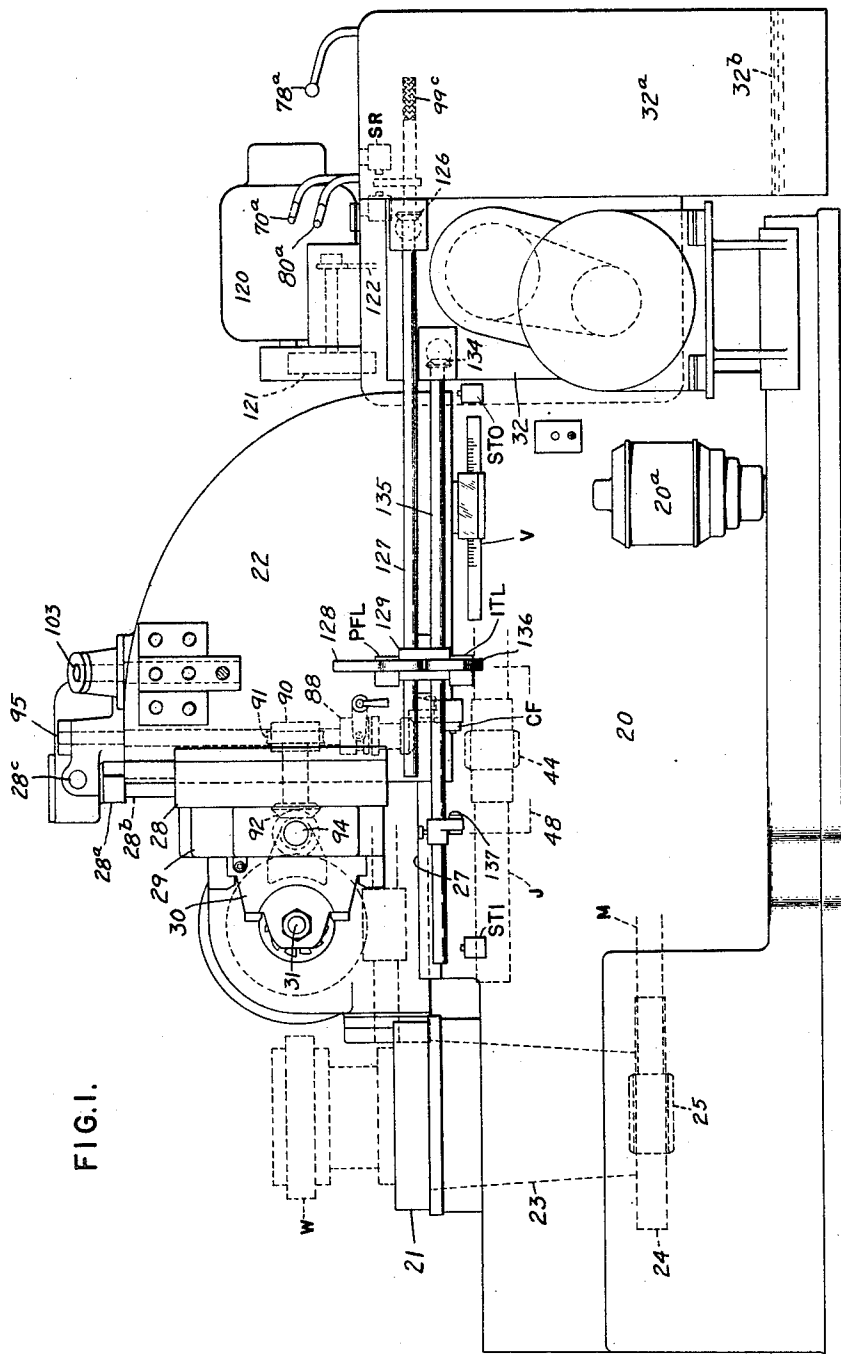


FIG. 1.

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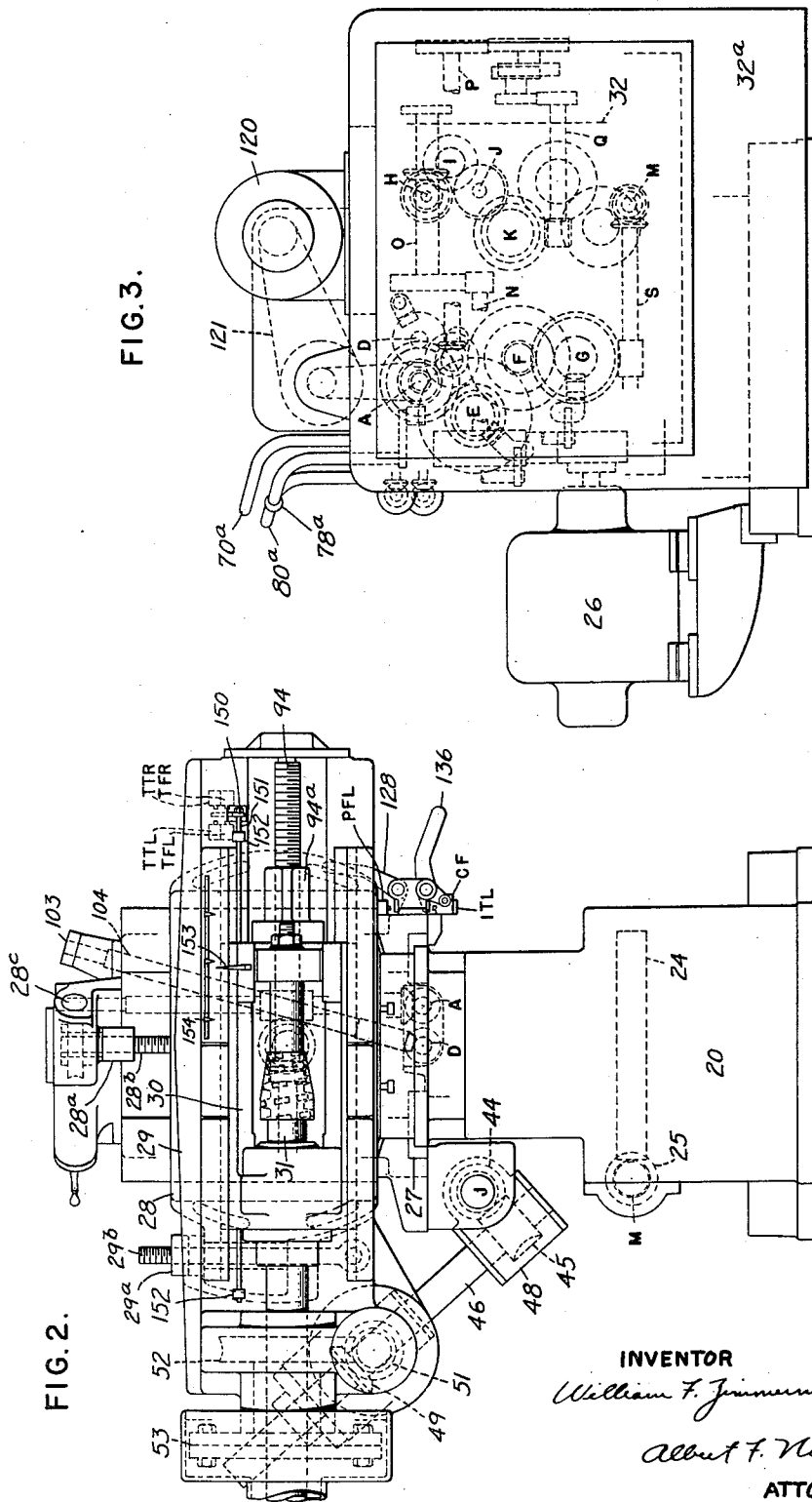
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WORM GEAR HOBBING MACHINE

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4 Sheets-Sheet 2



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4 Sheets-Sheet 3

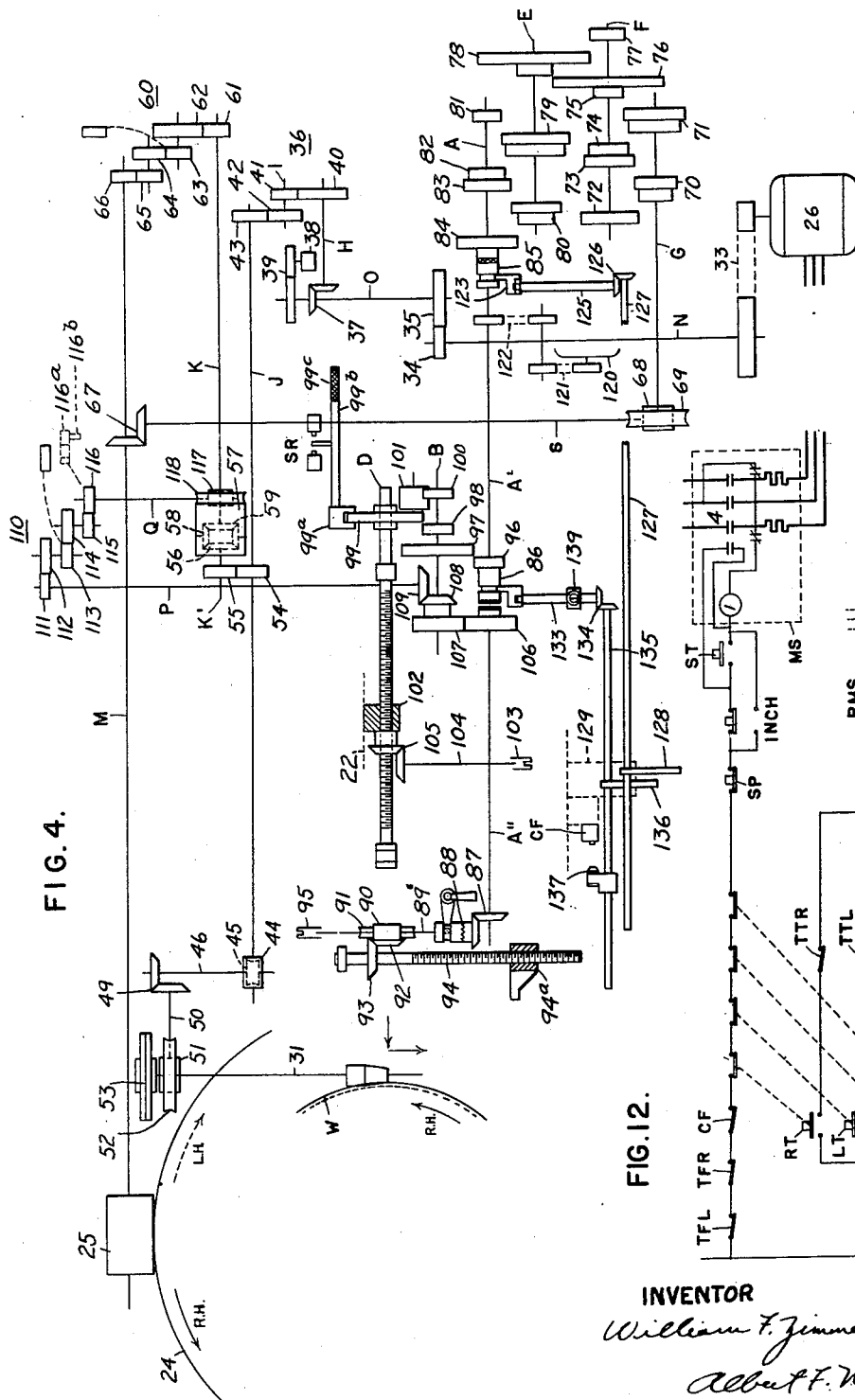
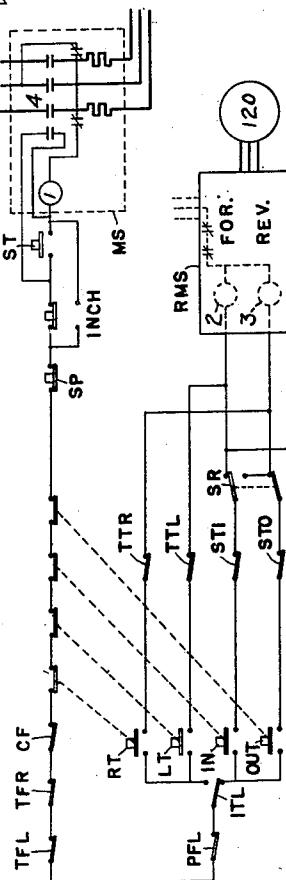


FIG. 12.



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WORM GEAR HOBBING MACHINE

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FIG. 11.

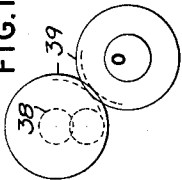


FIG. 5.

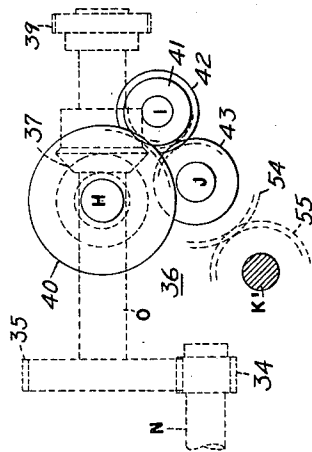


FIG. 8.

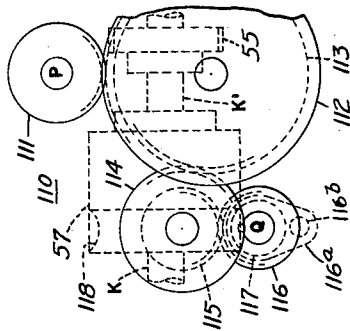


FIG. 6.

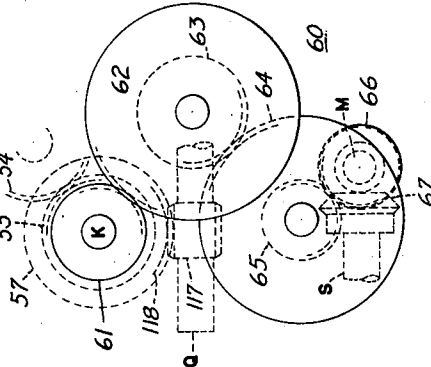
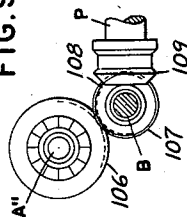


FIG. 9.



UNITED STATES PATENT OFFICE

2,374,254

WORM GEAR HOBGING MACHINE

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Application September 12, 1941, Serial No. 410,512

33 Claims. (Cl. 90-4)

The present invention relates to worm gear hobbing machines and is concerned more particularly with improvements in the transmissions for the work indexing and tool feeding movements and their mode of operation.

A primary aim of the invention is to render available a worm gear cutting machine adapted to cut gears of either hand, and in which it is possible to use a combination roughing and finishing hob, and successively change the cutter feed from a centripetal feed to a tangential feed, with the assurance that the centripetal feed always is in the direction of the blank axis and the tangential feed always is against the direction of blank rotation, regardless of the hand of the gear being cut.

A further aim of the invention is to render available a simplified transmission and control for machines of this class with which it is possible to shift from one directional feed to another directional feed in a single operation during the cutting of gears of either hand thereby to eliminate the confusion and possible damage that otherwise may result when a plurality of operational moves and changes are required in effecting the change-over.

Still another objective of the invention is to eliminate the difficulties heretofore encountered with the prior machines respecting the maintaining of a synchronized relation between the work and cutter movements at all times to the end that the cutter and work may be repeatedly brought into tooling relation by the power feed mechanism provided, by the quick traversing mechanism, or by hand without danger of upsetting the harmonious relation established between the cutter and the work.

The importance of the foregoing aims will become evident when consideration is given to the fact that on a machine constructed in accordance with this invention, left handed worm gears or right handed worm gears may be cut, each of which is given opposite hand work blank rotations. As to each direction of work rotation the centripetal feed of the cutter must remain toward the axes, whereas, the tangential feed must be in a direction in opposition to work rotation and at a compensating rate to preserve the normal effective lead of the hob. These relations are maintained in accordance with this invention, irrespective the "hand" of the gear to be cut or its direction of index motion.

If the hob and the blank are rotating together, as an ordinary worm and worm wheel, no differential action between hob rotation and blank ro-

tation is necessary or required. However, if the hob is shifted tangentially of the blank in the direction of its axis while it is also rotated, the increment of shift is subtractive on the lead when feeding against the work and additive on the lead when feeding with the work. Therefore, to preserve the normal lead of the hob true, relative to the work while tangentially feeding the hob, the work is driven at a slightly reduced rate, which rate is a function of the rate of lateral feed. In the present embodiment of the invention a common source of power drives the cutter, the cutter feed, and the work index trains and the compensating or correlating mechanism takes the form of differential gearing positioned in the work index train; the drive to the work carrier being through the rolling spider gears of the differential. The rate of roll of the spider gears about the driving and driven gears of the differential, determines the output speed and its direction, and this is controlled by changeable lead gearing located in a branch from the feed train. Thus the conjoint action of the two trains (feed and index) is utilized to effect work indexing (rotations) in timed relation with hob rotations and tangential feeding.

When, however, the machine is set up for the cutting of gears solely by the infeed method, no differential action is required and the differential producing mechanism is locked out. The net result is that the work is rotated at one rate when centifeeding the hob and at a different rate when tanfeeding the same hob, but the relative roll between the work and the hob remains the same in both cases.

The problem, therefore, in a machine adapted to cut both left hand and right hand gears, with a hob that has a portion designed for rough cutting using a centifeed motion, and another portion designed for finish cutting using a tanfeed motion, is to be able to shift from centifeed to tanfeed, without losing lead, and in a single operation and in so doing automatically obtain a differential in the work index rates, when tanfeeding, and in a direction compatible with a feed against work rotation, regardless of the hand of the gear being cut. And in the same machine provide means to preserve, or to render it possible to maintain, the centifeed transmission operative in an infeeding direction and the hob downward cutting for each hand of gear to be cut.

In the case of cutting a right handed worm gear, with a machine constructed in accordance with this invention, the blank will be turning counterclockwise as the hob is slowly fed in, to-

ward the work axis. After the predetermined tooth depth is reached the centifed is disconnected and the hob is then fed tangentially in a clockwise direction. On the other hand, when cutting a left hand worm gear the blank is rotated clockwise as the hob is again fed in (toward the axis) and then tangentially in a counter-clockwise direction.

The present invention further undertakes to render available a worm gear cutting machine involving the foregoing directional features that may be readily converted from left handed worm gear cutting to right handed worm gear cutting, or conversely, in a manner whereby the work index and the main feed trains may have their directions simultaneously changed at the time the machine is set up to accord with the hand of the gear to be cut. During the setting up operation the lead determining train, by which compensation for the lateral feed of the hob is made, is also altered to operate in a direction consistent with the hand of the gear to be cut. All the other directional relations of cutter feeds to work index motions and ratios are brought about automatically by the transmission systems or by sliding gears and clutches built into the machine.

In the present embodiment of the invention a main motor is used to drive the entire machine and is, through suitably arranged speed change gearing connected directly to the cutter spindle. On the tool side of the cutter speed change gearing, power is taken for a branch train leading to the work carrier and which includes the above mentioned differential mechanism. Assuming the casing of the differential to be locked, the power from the motor flows through the differential to change speed index gearing and thence to the work carrier spindle. Reversals in index motions are in the instant embodiment effected by the insertion or removal of an intermediate gear in the index change speed gearing and the drive to the cutter is uneffected.

On the work spindle side of the index change speed gearing, the power for the cutter feeds is taken off. The feed power first enters a feed change mechanism (affording 32 selective feeds) and thence flows to a dual clutch mechanism constructed and arranged to direct the feed power selectively to one or the other of the sub-feed trains, namely, to the centifed or to the tanfeed transmissions. Since the feed power is taken from the index train on the table side of the index change speed and reversing means therein, the rate of feed always bears a fixed relation to work rotation, i. e., the feed is in units per revolution of the work and does not vary merely because the circumferential distance around the blank changes during the cutting or when changing from a large gear to a small gear.

The insertion or removal of an intermediate gear in the index gearing, also changes the direction of motion in the feed transmissions, giving 32 feeds in either direction. With respect to the tanfeed sub-train, the present invention automatically insures a reversal in direction when the work table rotation is reversed, and a feed against the work, for either left or right hand gear cutting, is obtained.

On a machine constructed in accordance with this invention, it is contemplated that the user may desire to cut gears solely by the infeed method, or solely by the tanfeed method, or by a combination of the two methods. The combination method is the more preferable, in that it is more efficiently and expeditiously accomplished.

And as the differential producing mechanism is to be ineffective for part of the tooling operation and to be effective for another part of the tooling operation, the transmissions of the present invention are so arranged that the power for operating the differential is taken off the tanfeed sub-train at the feed screw side of the dual clutch that connects either sub-feed train with the main or common feed gearing. Shifting of the clutch from centifed position to tanfeed position thus automatically renders the differential mechanism effective to correlate the rate of work rotation with the rotation and lateral feed motions of the hob. A system of lead change gearing is incorporated in the drive train to the differential mechanism so that the proper relations between hob and work may be obtained for any given worm gear.

In changing over from R. H. to L. H. gear cutting the work carrier drive train and all trains dependent thereon are reversed. However, and irrespective of the direction of table rotation, means are provided preferably in the lead change gearing, for maintaining the relative roll between the work and the hob constant and operative in the right direction with respect to the direction of lateral or tangential feed. The instrumentalities provided function primarily to maintain (or restore) a previously existing condition or relation in differential action, i. e., to maintain the effective action of the differential mechanism subtractive on the rate of motion of the output shaft (for both R. H. and L. H. gears) notwithstanding a reversal in motion effected in the index train, which reversal also reverses the direction of the main feed works. This alteration in the lead compensating mechanism is made, as with the alteration made in the index gearing, only when changing over the machine from R. H. to L. H. or conversely, and after the machine is set up for cutting gears of either hand, the change from centifed to tanfeed is effected by operating a single lever. Idle or other time consuming operations in correlating directions are thereby avoided.

As herein used the terms centripetal feed and centifed mean a feed movement whereby the hob axis and worm wheel axis are brought closer together, i. e., in a direction radially of the blank. The terms tangential feed and tanfeed, mean a feed movement whereby the hob and work axes remain a definite distance apart and there is relative movement in a lateral direction between the hob and the work blank, for example, a shifting of the work blank axis in a direction parallel to the hob axis, or conversely. In both cases, however, a coplaner relation between hob axis and the medial plane of the blank is maintained, except when it is desirable to make an allowance for an oversized or undersized hob in which case the hob axis may be tilted slightly to correct for the change in hob lead angle.

Tanfeeding against the work index motion, means a relative lateral displacement of cutter and work in opposed directions, that is, in cutting both left and right hand worm gears the tanfeed is in a direction tending to hold back the work rotation and is the converse of a feed in a direction tending to pull the work around.

While the present invention is depicted in a machine wherein the centifed and tanfeed movements are movements imparted to the hob, it is to be understood that one or both feed movements may be imparted to the work blank carrier

or apportioned, as may be desired, between the work and the cutter.

Other objects and advantages will be in part indicated in the following description and in part rendered apparent therefrom in connection with the annexed drawings.

To enable others skilled in the art so fully to apprehend the underlying features hereof that they may embody the same in the various ways contemplated by this invention, drawings depicting a preferred typical construction have been annexed as a part of this disclosure and, in such drawings, like characters of reference denote corresponding parts throughout all the views, of which—

Figure 1 is a side view of a worm gear cutting machine embodying the present invention.

Figs. 2 and 3 are front and rear end views of the machine illustrated in Figure 1.

Fig. 4 is a line diagram of the power transmission mechanisms and their controls.

Fig. 5 is a detail illustration of a portion of the drive to the hobbing cutter, including the speed change gearing.

Fig. 6 is a detail illustration of a portion of the drive to the work spindle index shaft, including the differential mechanism and index change speed gearing.

Fig. 7 is a detail illustration of the feed works drive including the built-in change feed gearing.

Fig. 8 is a detail view of the lead change gearing; and Fig. 9, the power connection from the tangential feed train.

Fig. 10 is a detail figure illustrating the means in the centripetal feed train for maintaining the power feed toward the work axis in both directions of work movement.

Fig. 11 is a detail of a lubricating pump drive.

Fig. 12 is a schematic wiring diagram of the machine and the interlocking thereof with mechanical controls.

Referring more particularly to Figure 1 of the drawings, the machine includes a substantial base member 20, which supports a rotatable work carrier 21 and a relatively translatable tool carrier 22. The work carrier is mounted to rotate on a vertical axis in a tapered bearing 23 and is driven at its lower end by a worm wheel 24, worm 25, and index shaft M.

The tool carrier 22, is mounted on ways 27 for movement toward or away from the work table axis and carries on the table side thereof a vertically movable tool slide 28. On the front face of the slide is an angularly adjustable head 29 in which is mounted, for lateral translation, a cutter spindle supporting carriage 30. With relation to the axis of the work spindle, the tool spindle 31 may be shifted perpendicularly toward or away from the work axis, parallel thereto, and laterally across the axis in a plane normal to the work axis or at an angle thereto. Various combinations of movements between the tool and the work are utilized in the cutting of worm gears and will be described more fully hereinafter.

The tool slide 28 is adjusted vertically on the stanchion 22 by means of a worm and worm wheel driven nut 28^a and elevating screw 28^b. The screw 28^b is secured to the slide 28 and shifts axially through the nut 28^a as the latter is rotated. A hand crank placed on the rear end of the worm shaft 28^c provides the means for actuating the elevating nut. When the cutter slide has been shifted to the proper position relative to the plane of the work W, the guide straps are

tightened and slide is securely clamped in set position.

Normally the pivotal tool head 29 assumes a horizontal position and clamped to the slide 28. Should angular adjustment of the spindle axis be necessary to adapt the machine to using an oversized hob, the head is unclamped from the slide and the adjusting nuts 29^a on a weight carrying bolt 29^b (Fig. 2) are backed off or tightened to thereby tilt the hob axis and so correct for the difference in lead angle due to the increased diameter of the hob.

To the rear of the machine a gear case 32 is attached and which houses and has journaled thereon, all the several trains of mechanisms necessary to propel the hob and work at their proper relative speeds and directions during a normal tooling cycle.

A gear case guard 32^a extends around two sides of the gear case 32 and contains in its lowermost parts an oil reservoir 32^b. Whenever the main drive is operating, the pump 38 takes oil from the reservoir and discharges it over the gears, shafting, and moving parts within the gear case 32, and also to drip tubes (not illustrated) overlying the changeable speed, index, feed and lead gearing.

Coolant material is supplied to the work and cutter from a catch basin formed about the main frame 20, by a pump (not illustrated) that is separately driven by motor 20^a.

Referring to the line diagram Fig. 4, and to the detail illustrations Figs. 5 to 11, inclusive, in conjunction with Fig. 3, it will be seen that power from the main drive motor 26 enters the gear case on the operator's side and drives shaft N through the multiple V belt 33. A pair of connecting gears 34, 35, transfers the power to a continuing shaft O which drives the hub speed change gearing 36 through bevel gears 37 and shaft H, and also a lubricating pump 38 through gears 39.

Cutter drive

The speed change gearing 36 is between the shaft H and the cutter main drive shaft J and includes pick-off gears 40, 41, 42, and 43, revolving on axes H, I, and J. The shaft J extends toward the work table and has splined thereto a worm 44 that meshes with a worm gear 45 mounted upon an angularly adjustable shaft 46. The worm and worm gear and shaft just mentioned are journaled in a casing 48 which pivots on shaft J and also slides therealong. The upper splined portion of the shaft 46 drives the bevel gears 49, worm shaft 50, worm 51, and worm wheel 52 mounted on the axis of the hob spindle 31. The hob spindle is releasably connected to the worm wheel 52 through flanged index plates 53 so that when using multiple thread hobs the hob may be precision indexed for each thread without disturbing lead.

Work index

On the tool side of the change speed gearing 36, power is taken to rotate the work spindle 23. Gears 54, 55 transmit the power to a shaft K' which drives a bevel gear 56 that forms part of a differential mechanism 57. Assuming the casing of the differential to be stationary, the gear 56 drives spider gears 58 which in turn reversely drive gear 59 on the output shaft K. Index change gears 60, which includes pick-off gears 61, 62, 63, 64, 65, and 66, and provision for insertion of an intermediate gear for obtaining reversals, conducts the power from the differential mechanism to the main index shaft M that con-

nects with worm gear 24 underlying the work table.

Feeds

On the table side of the index change speed and reverse gearing 36, the tool feeding transmission takes off its power. Starting with bevel gears 67, power is conducted into shaft S which extends across the machine and drives a worm 68 and worm wheel 69 on shaft G. Two double-gear sliding units 70 and 71 are mounted on shaft G and transmit the power at any one of four rates to a parallel shaft F through spaced gears 72, 73, 74, 75 fixed thereon. The four speeds of shaft F are transmitted to a shaft E through either of two back gears 76, 77 and the sliding unit 78 on shaft E. Shaft E transmits the 8 speeds to a main feed shaft A through two more double-gear sliding units 79 and 80 and spaced gears 81, 82, 83, 84 fixed on shaft A; the three serially arranged change speed mechanisms affording 32 selective cutter feed speeds in shaft A.

Tanfeed sub-transmission

Coaxially related with the shaft A, a second feed shaft A' is mounted to receive the feed power through a feed clutch 85 at one end and to deliver the feed power at its other end to either of two sub-feed transmissions through a dual clutch mechanism 86. When the dual clutch is in an intermediate position (illustrated in Fig. 4) no feed power is transmitted to the centripetal feed train or to the tangential feed train. When the dual clutch 86 is shifted from neutral to the left (in Fig. 4) the feed power is transmitted from shaft A' to shaft A'' thence through bevel gears 87, one of which is splined to shaft A'', recutting clutch 88, vertical shaft 89, worm 90, worm wheel 91 (located at the pivotal axis of the head) to bevel gears 92 and 93, to the tangential feeding screw 94 journaled in the head 29. To provide for the vertical adjustment of the tool slide 28, the worm 90 is splined to the shaft 89, and is movable therealong with vertical movements of the tool slide. The upper end of the worm shaft 89 is provided with a crank receiving portion 95 by which the operator may shift the hob laterally, by hand. The feed screw 94 coacts with a traveling nut 94^a secured to the laterally movable cutter spindle carriage 30.

Centifeed sub-transmission

When the dual clutch 86 is shifted to the right (in Fig. 4) a gear 96 thereon transmits power to a gear 97 on shaft B from which it may be directed in reverse directions selectively to shaft D through gears 98, and 99 or gears 100, 101, and 99. The shaft D is the centripetal feed screw shaft which is rotatably but non-translatably journaled to the main frame of the machine, and coacts with a traveling nut 102 secured to the stanchion 22 to feed the cutter or hob radially toward the work axis. When the gear 99, which is splined to the screw shaft D is shifted to an intermediate position (illustrated in Fig. 4) the screw shaft may be rotated manually by applying a crank to the upper end 103 of a shaft 104 which is geared at 105 to the shaft D.

The primary purpose of the motion restoring mechanism comprising gears 98, 100, 101 and sliding gear 99 is to render it possible to power feed the cutter in (toward the work axis) irrespective of the direction of operation of the main feed works whose direction of operation is definitely related to the direction of work table

movement. During the cutting of a right hand worm gear, the work blank W is rotated counter-clockwise (as viewed in Fig. 4), and for a left hand gear it is rotated clockwise. Opposite directions of work rotation are obtained at the index change gear mechanisms 80 by inserting or removing an idler gear (between gears 83—84) and since the tool feed is taken from the index shaft M, a reversal in its motion also reverses the feed motion. Accordingly, the direction restorer 98, 100, 101, and 99 in the centifeed sub-transmission is provided to maintain the driven shaft D unaffected by changes in direction of its driver. In other words, if the main feed gearing has its direction changed, gear arrangement 98—101 may be utilized to restore in the feed shaft D the previously existing condition of motion.

Differential

As previously mentioned, no differential in the relation of work rotation to hob rotation is required when the teeth of the worm gear are cut by the infeed method of hobbing. That is the method employed herein for rough cutting the blank, using the tapered or undersize end portion of the hob. A tapered hob is used in the present method so that its undersize cutting edges will not mutilate or deform the teeth of the gear blank as the hob is progressively fed radially into the work, as would follow if the hob was of full tooth depth.

Correct and full tooth form on the blank is later obtained, however, by feeding the hob laterally, (after infeeding to the correct center distance), for the cutting action then becomes a generating motion instead. The lateral shifting of the hob introduces a further problem of reconciling the phase relation of the work with the hob as the latter is bodily shifted in the direction of its own axis, i. e., tangentially and against the direction of work rotation.

When cutting a right hand gear with a tangential feed of the hob acting against or in opposition to the work rotation, the effect of tanfeeding is to accelerate beyond normal the relative tangential motion between hob and gear and the action could be likened to the action of an ordinary milling cutter on the blank. To prevent such boring action, the relation between feed and index motions must be properly correlated. In the present embodiment, correlation is attained by the differential mechanism, above referred to, which responds to either or both tangential feed and index motions.

As illustrated in Fig. 4, a branch power line is taken off the tanfeed sub-transmission through gears 106, 107, the latter of which is loose on shaft B and includes a bevel gear 108, as a unit therewith. The gear 108 drives a bevel gear 109 on a shaft P that extends across the gear case of the machine to changeable lead gearing 110. The change lead gearing, which includes pick-off gears 111, 112, 113, 114, 115, 116, and provision for insertion of an intermediate gear (between gears 113—114) transmits the power derived from the tanfeed train to a worm shaft Q at a rate selected by the pick-off gears used. And shaft Q, through the worm 117 and worm wheel 118 drives the casing of the differential mechanism 57. If the ratio of the lead gearing 110 is such as to cause the differential casing to revolve slowly in the same direction as driving gear 56 therein, the speed of the output shaft K is slightly reduced. Shaft K is the driver for the work index train and a reduction in the speed

thereof correspondingly reduces the rate of work rotation. Thus by taking power for the differential producing mechanism off the tanfeed train, the harmoniously timed relation between the hob and the blank may be maintained even though the one is simultaneously moving past the axis of the other.

The correlation mechanism is not needed when centifeeding (infeeding the hob) and to insure that it is inactive during centifeeding, the differential drive is taken off only the tanfeed transmission, which is independent of the centifeed transmission. When cutting gears by the infeed method only, it is necessary to lock the differential out of action to prevent creeping, and that is done by removing lead gears 116 and applying in its place a lead locking plate 116^a (Fig. 8). The locking plate comprises a disc that fits the shaft Q and carries a pin 116^b that fits into a socket in the gear case. When the lock is applied to the shaft, the differential casing is securely locked against rotation in either direction.

Tanfeeding against work index

It has been explained above, that the tangential feed of the hob is, in accordance with this invention, always against the work rotation so that the lead of the hob does not pull the work. When setting up the machine for left or right hand gear cutting all that is required to be done to obtain proper work index motion is to add or remove an idler gear in the index change speed train 60, and the consequential reversal in motion at that point also reverses the main feed gearing and the tanfeed sub-transmission. At the same time the correct lead gears 110 are installed with or without an intermediate gear depending upon the hand of the gear to be cut. The intermediate gear in the lead train is used, according to the present system of gearing, when an intermediate gear is used in the index train. Thus the action of the differential mechanism on the relative rates of rotation of the hob and the work is the same when cutting either right handed gears or left handed gears.

Power traverse

In setting up the machine for new work pieces it is convenient to shift the hob laterally or radially by power, and so that power shifting may be effected at a relatively rapid rate a separate reversible motor 120 is provided. The motor 120 has a belt and chain connection 121, 122 with the intermediate feed shaft A', and when the main feed clutch 85 is disengaged, the traverse motor may be operated to propel either of the two sub-feed transmissions and effect the shifting motion at a rapid rate in either direction. When the power traverse is used for traversing the cutter stanchion in or out there is, of course, no change in the phase relation between the cutter and the work, those elements remain stationary. However, in traversing the cutter to the left or to the right, the work and cutter may be in mesh and one or both must rotate as the cutter is axially advanced or withdrawn. In the present system of gearing, the harmonious relation between the hob and the blank is not disturbed during the right or left traversing movement because the drive to the compensating differential mechanism is effective whenever the tanfeeding sub-transmission is in operation, and there is a back drive therethrough which rotates either the cutter or work or both in timed relation as the cutter is shifted laterally to clear the work. During

hand feeding to the left or right the synchronized relation between the hob and the blank is also maintained by virtue of the same gear connections.

Controls

The machine of the present embodiment is controlled by a system of levers and controls interlocked in a manner such as to prevent simultaneous incompatible movements. With reference to the main feed clutch 85 (Fig. 4) the spool thereof has two positions, neutral and engaged with gear 84. A clutch shifter 123 tracks the groove in the spool and is shiftable laterally by a short lever 124 mounted on a shaft 125. The shaft 125 is geared at 126 to a second shaft 127 extending along the side of the machine, and which has splined thereto an actuating lever 128. The lever 128 is mounted between flanges of a bracket 129 mounted to the side of the movable carrier 22. The lever 128 extends generally vertically and when it is rocked outwardly (away from the machine), the clutch 85 engages the power feed.

With reference to the dual clutch 86, a similar shifter 132 tracks a groove in the spool thereof and is shifted laterally by a short lever 132^a on a shaft 133. The shaft 133 is geared at 134 to a shaft 135 which also extends through the traveling bracket 129. A lever 136 is splined to the shaft 135 and travels therealong as the carrier 22 shifts. Lever 136, however, has three positions, tanfeed position, neutral position, and centifeed position. When the lever is lifted to its uppermost position, the clutch 86 is engaged with gear 106 and the tanfeed transmission is operative, and when the lever 136 is rocked to its lowermost position the clutch engages with gear 97 and the centifeed train is operative. Spring actuated detent means, indicated at 139 are provided to hold the clutch in each of its positions.

The shifting of the sliding gear 99 is effected manually by means of a gear straddling shoe 99^a secured to an axially shiftable shaft 99^b, the outer end 99^c of which is knurled to provide a suitable hand grip portion.

Each of the three serially arranged feed change mechanisms has its own gear shift lever. Gears 70—71 of the first series may be brought selectively into mesh by lever 70^a operating through axially shiftable guide rods 70^b and gear straddling shoes 70^c and 70^d spaced thereon. Back gear unit 78, forming part of the second series, is straddled by a shoe 78^b operated from a balled lever 78^a. And gear units 79 and 80 of the third series are arranged for axial shifting selectively to four different positions by means of lever 80^a and gear straddling shoes 80^b and 80^c which are mounted and guided similar to the shifters of the first series.

Interlocks

To the foregoing machine structure there may be added various types of mechanical trip mechanisms and interlocks to facilitate a gear cutting operation and for the purpose of illustration there is herein disclosed a species of trip mechanism that is more fully described in a copending application of Granger Davenport, Serial No. 410,491, filed of even date herewith.

The operation of the main motor 26 is controlled by a magnetic starter MS, whereas, the rapid traverse motor 120 is controlled by a reversing magnetic starter RMS. Each starter is of standard conventional construction and in-

cludes coils 1, and 2 and 3, respectively, for actuating the main switches. Referring to the control circuit for the main drive motor 26 (Fig. 12) the push button starting switch ST is normally open and when pressed will close a circuit across the coil 1 which affects closing of the main switch contacts 4 of the starting panel. Simultaneously a holding circuit is established around the starting switch so that immediate release of the button ST does not stop the motor. The control just explained is effective provided all of the other series connected switches shown in the diagram are in their closed position illustrated. In the circuit ahead of the starting switch there is a double pole double throw switch marked "Inch" that is utilized to inch the tool carriers from position to position. The Inch push button switch has one pair of its contacts connected around the starting switch ST and its other and normally closed pair in series therewith, so that the pressing of the button to inch the tool carrier in or out, left or right, breaks the circuit to the starting switch as well as to the holding circuit. Thus the motor 26 will run so long as the Inch switch is held depressed.

Just ahead of the inching switch the main stop switch SP is serially connected which when depressed will also break the starting switch holding circuit and the motor stops. In series ahead of the stop switch SP there are four serially connected interlocking switches (which will later be explained) and in series ahead of those are three micro switches TLF, TFR, and CF, respectively. The micro switch CF is the switch that is carried by the movable stanchion 22 and arranged to be actuated by the abutment 137 on the rod controlling the dual clutch 86. Assuming all of the series switches in this circuit are closed and the cutter is centifeeding, the power movement continues until the switch CF is engaged by the abutment 137 and opened thereby. Immediately the circuit to the magnetic coil 1 of the starting switch is broken and the power feed immediately stops. The setting of the abutment 137 is, it will be understood, a precision setting so that the cutter will stop infeeding at the precise center distance required.

When the machine is arranged for tanfeeding the cutter, the centifeed switch CF will be closed (by the rocking of abutment 137 off the switch button which movement throws clutch 86 over to its tanfeeding side) and stop switch TFL and TFR control the stopping of the tanfeeding movement left and tanfeeding movement right, respectively. The switches TFL and TFR are mounted in the pivotal head 29 on opposite sides of a short actuating lever 150. A rod 151 which passes through the laterally movable cutter slide 30 connects with the lever 150 and has mounted for adjustment thereon two dogs 152, one at either side of the slide. By appropriately setting the dogs 152, the tangential feeding motion imparted to the slide may be stopped at the completion of the cut in either direction of travel.

Also carried by the traveling slide is a pointer 153 which in cooperation with one or more adjustable points 154 may be used to provide a visual indication of the zone of beginning or of finishing of the actual tooling operation. This indicating means may be used as a guide for example, to aid in hand traversing or power traversing to selected intermediate point where the power feed is to be engaged for the remainder of the lateral movement.

The four serially arranged switches that are in the starting circuit for the main motor (above mentioned) form part of the double pole double throw push button switches in the control circuit of the reversible rapid traverse motor 120. With reference to the lower part of Fig. 12, the reversible motor starting switch is provided with two solenoids 2 and 3 (illustrated in dotted lines), the former for actuating the forward switch and the latter for actuating the reverse switch of the motor. Inasmuch as the traverse motor is used to propel the cutter tangentially to the right or to the left at a rapid rate or in or out at a rapid rate, two sets of controls therefore are provided. For the tangential traverse control there is a push button switch RT connected in a control circuit for the reverse solenoid 3 and a second push button switch LT connected in the circuit to the forward solenoid 2. In each of the solenoid control circuits there is also a limit switch TTR and TTL, respectively, both of which normally are closed. Assuming the circuit is otherwise complete up to the push buttons RT or LT the pressing of one of those buttons will cause motor operation in the forward or reverse direction so long as the button is held depressed and the cutter slide will be propelled to the right or to the left accordingly. If the operator holds the button depressed too long the cutter slide will engage one of the dogs 152 and then shift the rod 151 and lever 150 which lever engages one of the switches TTR or TTL (mounted in the cutter head) depending upon the direction of travel, thus opening the motor control circuit and stopping the power traverse.

In a similar manner push button switches marked "In" and "Out" and serially connected stanchion traverse limit switches STI and STO are in a parallel circuit and also control the forward and reverse solenoids of the reversible magnetic starter RMS. Again assuming all of the switches of the stanchion traversing control circuit up to the In and Out buttons are closed, the pressing of one of the buttons will cause the stanchion to be propelled in or out as the case may be. When the stanchion has reached a predetermined limit of travel in either direction one of the normally closed switches STI or STO is engaged by the stanchion and opened and the circuit to the starting panel RMS is opened and the traverse stops.

All of the push button switches RT, LT, In, and Out are in series with a single switch PFL which is mechanically interlocked or controlled by the power feed lever 123 in such manner that when the lever is rocked to a position engaging the power feed clutch 85 the switch PFL is opened and the rapid traverse motor 120 cannot be started by pressing any of the push buttons RT, LT, etc. When, however, the power feed control lever 123 is rocked to a position disengaging the clutch 85, the switch PFL is closed and the power traverse motor may be operated.

Although two sets of control buttons for the power traverse motor are provided, one set for the cutter traverse right and left, and the other set for cutter traverse in or out, the two sets are never available for concurrent operation. To prevent confusion in this respect a selector switch ITL is connected in series with the switch PFL and arranged to connect one or the other of the two sets of traverse motor control buttons with the main power line. The selector switch ITL is also interlocked with the infeeding and tanfeeding control lever 136 in such manner

that when the lever is rocked to a position engaging the dual clutch 86 with the tanfeeding sub-transmission (gear 106, etc.) the switch TTL is moved to a position completing a portion of the control circuit including the right and left push button switch RT and LT. At the same time the circuit to the In and Out switches is opened. When the lever 136 is rocked to its other position, that is, to engage the centifeed transmission (gears 96, 97, etc.) the switch is actuated to a position completing a portion of the circuit to the In and Out buttons, and opening the circuit involving the right and left control buttons. Accordingly, when the dual clutch 86 is set for infeed, the In and Out buttons take the control for forward and reverse movements of the motor exclusively, and when the clutch 86 is set for tangential feeding, the right and left control buttons take control exclusively; but neither set of buttons has any control over the motor if the power feed lever 128 is shifted to a position wherein main feed clutch 85 is engaged.

With reference to Fig. 4, it will be observed that there is a motion direction restoring device, including sliding gear 99, between the dual clutch element 86 and the centifeed screw D. Therefore, irrespective of the direction that the traverse motor 120 may be operated, the motion in the screw shaft D may be reversed by sliding the gear 99. When the machine is set up for cutting a left or right hand gear, using the infeed method of cutting for a portion at least of the tooling, the sliding gear 99 will be shifted by rod 99^c to restore in shaft D proper directional rotation for power infeed, the main feed works. Ordinarily, therefore, the In and Out legends on the stanchion traverse control buttons are in themselves meaningless unless the terms are related to direction of movement of the stanchion and which must be consistent in their operation regardless of the hand of the gears being cut. That is, irrespective of whether the work index is clockwise or counterclockwise it is desirable to have the cutter stanchion move in (toward the work) whenever the In button is pressed, and away from the work whenever the Out button is pressed. Therefore, to avoid the confusion that might otherwise exist by reason of the reversibility of the index and main feed drives and the effect thereof on the elements of the transmissions, another set of switches are incorporated in the In and Out control circuits of the reversing motor 120. The reversing switches SR (Fig. 12) are, in effect, direction restoring or coordinating switches and are arranged to be actuated in unison by the sliding gear shifting rod 99^c (Fig. 1). One of the restoring switches SR is in the In circuit and selectively closes the circuit to the forward solenoid 2 or to the reverse solenoid 3. The other restoring switch SR is in the Out control circuit and selectively closes the circuit to the reverse solenoid 3 or the forward solenoid 2.

As shown in the diagram the restoring switches SR are connected so that the motor 120 runs forward in the one direction when the push button In is pressed, and reversely under another condition when the push button Out is pressed. Forward and reverse rotations of the motor 120 are, however, necessary depending upon the position of sliding gear 99 which has been previously shifted. The gear shifting rod 99^c is connected to operate the restoring switches SR in unison and in a direction compatible with the positioning of the sliding

gear 99. Accordingly, irrespective of the position of gear 99 the control of the power traverse motor is interlocked and related therewith as always to give a traverse "in" when the In button is pressed, and always a traverse "away" from the work whenever the Out button is pressed.

It will be noted that no restoring-a-relation set of control switches is necessary in the control circuit for left and right cutter traverse, for the reason that all rapid traverse directional relations of the elements in the tanfeeding train are controlled by the fixed relations of the gearing that lies between the rapid traverse motor 120 and the ultimate feed screw 94.

To insure against inadvertent simultaneous operation of the main motor 26 and the traverse motor 120, the control circuits therefore are further interlocked by connecting the starting circuit of the main motor 26 in series with each of the push buttons RT, LT, In and Out as shown in the diagram. Each of the push buttons comprises a pair of normally closed contacts and a pair of normally open contacts. The normally closed pair of each button is connected in series with the starting circuit of the main motor 26, as represented by the dotted lines of the diagram (Fig. 12), and the open pair of contacts of each button is part of the control circuit for the reversible motor 120. Therefore, all of the control buttons for the rapid traverse motor must be released before the starting circuit of the main motor may be completed. If the main motor 26 is running, a pressing of any of the buttons for the traverse motor, at once stops the main motor. However, pressing of any one of the traverse motor buttons, under this condition, does not necessarily mean that the traverse motor will operate, for its operation is again dependent upon the positions of the power feed control lever 128 as well as the position of the tanfeed lever 136. Insofar as the main motor 26 is concerned, all of the control buttons for the motor 120 are stop switches.

Operation

To operate the machine for the composite method of gear cutting, infeed followed by a tangential feed, the machine is initially set up for the number of teeth, hand, and lead, and feed and speed of the cutter according to the machine's chart which shows the gears to be used and their location. The dual clutch lever 136 is set for infeed and likewise the sliding gear 99. The work and cutter are mounted on their spindles and the tapered portion of the hob centralized with relation to the work. The vertical slide 28 is clamped, and the cutter slide 30 and the stanchion 22, left unclamped.

The machine is then started and the cutter fed by hand to cutting position. The infeed precision abutment 137 is preset to stop the infeed at the precise center distance and the tangential feed stops 152 also properly set to stop the machine when the cutter has completed the tangential tooling. The power feed is then engaged and the cutter is power fed into the work until the sensitive switch CF is actuated whereupon the infeed stops. Without more ado, the operator shifts the dual clutch lever 136 to its tanfeeding position. That single operational movement disconnects the centifeed and engages the tanfeed transmissions, and simultaneously the abutment 137 rides off the sensitive switch CF and the latter closes, thus restoring that portion of the main motor starting circuit, and the drive is restarted by pressing the start button ST.

The power feed is now tangentially of the work, and always in a direction opposed to the work rotation irrespective of the direction of work rotation, this relation being automatically obtained by the present system of gearing when the machine is initially set up for the work in hand. Hence nothing need be done when shifting from centifed to tanfeed when cutting either right or left hand gears except throw the control lever 136 and start the machine. The tangential feed continues operating until the slide reaches the preset dog 152 and actuates one of the limit switches TFL or TFR. Immediately the machine stops and the finished gear is removed.

Without further analysis, the foregoing will so fully reveal the gist of this invention that others can, by applying current knowledge, readily adapt it for various utilizations by retaining one or more of the features that, from the standpoint of the prior art, fairly constitute essential characteristics of either the generic or specific aspects of this invention and, therefore, such adaptations should be, and are intended to be, comprehended within the meaning and range of equivalency of the following claims:

Having thus revealed this invention, I claim as new and desire to secure the following combinations and elements, or equivalents thereof, by Letters Patent of the United States:

1. A hobbing machine for cutting left or right handed worm gears by the tangential feed method comprising rotatable work and tool carriers, a work rotating transmission and a tool rotating transmission connected to a common source of power, a third transmission for effecting feed movement of one of said carriers relative to the other in a direction tangent to the work axis and opposed to the direction of roll of the blank, said third transmission being connected to and receiving power off said work rotating transmission so that the rate of feed is directly related to work rotations; means for effecting simultaneous reversals in said feed and said work rotating transmissions thereby to maintain the direction of feed opposed to the roll of the work for both right and left hand gear cutting.

2. A machine for generating left or right handed teeth on a worm gear wheel blank combining a rotatable carrier adapted to mount a work blank; a rotatably mounted hob arranged in cooperative relation with the work blank; power means including a reversing mechanism for rotating the blank carrier selectively in opposite directions according to the hand of the gear to be cut; electively available means for effecting relative feed movements between the hob and the work blank selectively radially inwardly of the blank and tangentially of the blank in opposite directions, comprising a centripetal feed train of mechanisms and a tangential feed train of mechanisms, both of said two trains of feed mechanisms being connected to said power means at a point therein beyond the reversing mechanism for the blank carrier; and means in one of said two trains of feed mechanisms for effecting reversals in direction of the feed motion imparted therethrough independently of the direction of rotation of the work blank and of the direction of feed motion that may be imparted to the other of said feed trains consequent upon a change in the direction of rotation of the work carrier.

3. A gear generator combining a work carrier; a hob carrier; power means to rotate the carriers in synchronism; a transmission connected with the power means for shifting the axis

of one of the carriers toward the other at a feed rate; another transmission connected with said power means for shifting one of the carriers relative to the other in a transverse direction; a motion reverser in the work carrier rotating power means for electively reversing rotation of the carrier in accordance with the hand of the worm gear to be cut and simultaneously the direction of feed motion of said two carrier shifting transmissions; and motion direction restoring means in the transmission for shifting the axis of one carrier toward the other operative to maintain the direction of the feed movement in a tooling direction irrespective of a change in the direction of work carrier rotation.

4. A machine for cutting left or right hand worm gears combining a rotatable carrier adapted to support a work blank; a rotatable hob adapted to perform the tooling operation on the blank; a power transmission mechanism for rotating the hob and the blank synchronously; reversing means for said work rotating transmission; a first feed transmission for effecting relative movement at a feed rate between the hob and blank in a direction radially inwardly of the latter and a second feed transmission for effecting relative movement at a feed rate between the hob and the blank in a direction tangentially of the blank and always against the rotation thereof, said two feed transmissions being connected to receive power from said work rotating transmission at a point beyond the motion reversing means incorporated therein; clutch means common to said two feed transmissions adapted when actuated to direct the power selectively through one or the other of two transmissions, and additional independently operable reversing means in the radial feed transmission at a point in the drive beyond said clutch for maintaining the feed motion always toward the work axis irrespective of the direction of motion imparted through said clutch; and a single manually operable lever for actuating said clutch selectively to a position operative to effect power feed movements of the hob toward the work axis or tangentially thereof in a direction against the roll of the work when cutting gears of either right hand or left hand.

5. A worm gear generating machine combining a rotatable carrier adapted to mount a work blank; a rotatably mounted hob arranged in cooperative relation with the work blank; a main transmission including a reversing mechanism for rotating the carrier selectively in opposite directions; a sub-transmission connected with the main transmission for effecting relative movement at a feed rate between the hob and the work blank radially and tangentially of the blank selectively, comprising a centripetal feed train of mechanism and a tangential feed train of mechanism, a clutch mechanism common to said two feed trains operative to connect the feed power electively with one of said trains and automatically to disconnect the feed power from the other; and means in one of said two feed trains of mechanisms for unidirectionalizing the feed motion imparted therethrough irrespective of the direction of carrier rotation or of the direction of feed that may be imparted through the other of said trains as a result of a change in direction of carrier rotation.

6. A worm gear cutting machine adapted to cut either right or left hand gears combining a rotatable carrier adapted to support a work blank; a rotatable hob adapted to perform the tooling operation on the blank; power transmis-

sion mechanisms for rotating the hob and blank synchronously; reversing means for the said work rotating transmission; a first sub-transmission for effecting relative movement at a feed rate between the hob and blank in a direction radially of the latter and a second sub-transmission for effecting relative movement at a feed rate between the hob and the blank in a direction tangentially of the blank and always opposed to the rotation thereof; said two sub-transmissions being connected to receive power from said work rotating transmission at a point beyond the motion reversing means incorporated therein; separate independently operable means in the radial feed sub-transmission operative to maintain the radial feed motion imparted therethrough in a tooling direction irrespective of the direction of motion imparted to the work carrier; and manually operable clutch means common to said two sub-transmissions for directing the feed power selectively through one sub-transmission or the other.

7. A worm gear wheel generating machine combining a rotatable carrier adapted to mount a work blank, a rotatably mounted hob arranged in cooperative relation with the work blank; electively available reversible means for effecting relative feed movement between the hob and the work blank selectively radially and tangentially of the blank, comprising a centripetal feed train of mechanism and a tangential feed train of mechanism, a source of feed power common to both of said two feed trains, a clutch mechanism at the juncture of said two trains and the said power source operative automatically to disconnect the feed power from the one when connecting the power to the other of said feed trains; and means in one of said two feed trains of mechanisms at a point therein situate beyond said clutch in the direction of the flow of power therethrough, operative to maintain the direction of the feed motion imparted therethrough unidirectional irrespective of the direction of feed motion that may be imparted through said clutch to the other of said trains.

8. A worm gear cutting machine adapted to cut left or right handed gears by the tangential feeding method and in which the blank rotation is opposed to the tangential movement between the hob and the blank when cutting a gear of either hand comprising a rotatable work blank carrier, a rotatable hob carrier, power means for rotating said carriers in harmonious relation including a hob carrier drive train and a branching reversible work carrier drive train, a feeding transmission connected with said branch work carrier drive train for effecting relative movement between said carriers laterally at a feeding rate based upon revolutions of the work carrier, a lead correlating train connected with said feeding train and with said branch work carrier drive train for modifying the rate of effective action of the latter train in proportion to rate of the lateral feed movement between the carriers during the progress of the tooling, and means operative to maintain the relative rates and directional relations of the movements of said carriers the same irrespective of the hand of the gear to be cut.

9. A worm gear cutting machine adapted to cut left or right handed gears by the tangential feeding method and in which the blank rotation is opposed to the tangential movement between the hob and the blank when cutting gears of either hand comprising a rotatable work blank carrier, a rotatable hob carrier, means for shifting the

hob carrier in the direction of its axis of rotation and tangentially relative to the axis of the work carrier; power means for rotating said carriers in harmonious relation including a hob carrier drive train and a reversible work carrier drive train branching therefrom; a hob tangential feeding transmission connected with said branch work carrier drive train constructed and arranged to feed the hob laterally at a rate based upon revolutions of the work carrier and in a direction opposed to the roll of the blank irrespective of the direction of work blank rotation; a lead correlating train connected with said feeding transmission and with said branch work carrier drive train for modifying the rate of rotation of the work carrier to compensate for the tangential feed movement of the hob relative to the blank during the progress of the tooling, and additional means for maintaining the action of said lead correlating train on the rate of rotation of the work carrier compatible with a feed of the hob against the rotation of the work, in each direction of rotation of the work carrier.

10. A hobbing machine for cutting either left or right handed worm gears with a feed against the rotation of the blank comprising a rotatable work carrier and a rotatable tool carrier, a work rotating transmission and a tool rotating transmission connected to a common source of power, a third transmission for effecting feed movement of one of said carriers relative to the other in a direction tangent to the work axis and opposed to the direction of roll of the blank, said third transmission being connected to and receiving power off said work rotating transmission so that the rate of feed is directly related to work rotations; a lead compensating transmission connected between said work rotating transmission and said feed transmission for modifying the rate of action of the work rotating transmission to compensate for the tangential movement between the tool and the work; means for effecting reversals in said feed transmission, in said work rotating transmission and in said lead compensating transmission for maintaining said relative rates and the said directional relations between the work and the tool the same for both left and right hand gear cutting.

11. A worm gear cutting machine adapted selectively to finish cut left or right handed gears by the tangential feeding method combining a rotatable work blank carrier, a rotatable and laterally shiftable hob carrier, power means for rotating said carriers in harmonious relation including a hob drive train and a work index drive train, a hob feeding transmission connected with said index train for imparting an axial feed movement to the hob at a rate based upon revolutions of the work carrier, said feed transmission including a clutch, a lead correlating train connected on the tool side of said clutch with said hob feeding transmission and with said index train for differentially modifying the rate of action of the index train to compensate for the lateral feed of the hob relative to the work during the progress of the tooling, means operable to reverse said feed transmission and said index train collectively, means for maintaining the rate modifying action of said lead correlating train compatible with a feed against the work rotation irrespective of the direction of work rotation, and manually operable means for feeding the hob tangentially and concurrently preserving the harmonious relation between the thread of the hob and the work.

12. A worm gear cutting machine for cutting

either left or right handed worm gears by tangentially feeding the cutter against the work rotation for each hand of gear to be cut comprising a rotatable work carrier and a rotatable cutter carrier, a work rotating transmission and a cutter rotating transmission connected to a source of power, a third transmission also connected to said source of power for effecting feed movement of said cutter carrier relative to the work carrier in a direction tangent to the work axis and opposite to the direction of rotation of the blank, a lead determining transmission including a differential mechanism operatively connected across said work rotating transmission and said feed transmission for making a correction in the rate of work rotation to compensate for the lateral feed of the cutter, means for effecting reversals in said feed and in said work rotating transmissions thereby maintaining said directional relations the same for both right and left hand gear cutting; a clutch mechanism interposed in said feed transmission ahead of said lead determining transmission for disconnecting the feed transmission from said power source; and manually operable means connected to the feed transmission on the tool side of said clutch for operating said feed and lead determining transmissions simultaneously by hand thereby preserving the harmonious relation between the cutter and the work during hand feeding operations.

13. A worm gear cutting machine combining a rotatable carrier adapted to support a work blank; a rotatable hob adapted to perform the tooling operation on the blank; a power transmission for rotating the hob and blank synchronously including a speed change mechanism common to both of said rotating transmissions and a combined change of speed and reversing means for but one of said rotating transmissions; a first sub-transmission for effecting relative movement at a feed rate between the hob and blank in a direction radially of the latter and a second sub-transmission for effecting relative movement at a feed rate between the hob and the blank in a direction tangentially of the blank, said two sub-transmissions being connected to receive power from said power transmission at a point thereof beyond the motion reversing means incorporated therein; and separate independently operable reversing means in the radial feed sub-transmission operative to maintain the feed motion therein unidirectional irrespective of a change in the direction of motion effected at said first mentioned change speed and reversing means.

14. In a worm gear hobbing machine the combination of a work blank rotating train of mechanisms, a hob rotating train of mechanisms, and main power means common to both trains for rotating the work and hob in timed relation, a hob feeding train of mechanisms arranged to feed the hob tangentially of the work and adapted to receive feed power off said work rotating train of mechanisms, lead compensating means connected across said work rotating and said hob feeding trains of mechanisms for synchronizing the hob and work rotations with the tangential feed motion imparted to the hob, a feed clutch in said feed train of mechanisms ahead of said lead compensating means connection for disconnecting the feed train from the power while preserving the phase relation between the hob and the work, and auxiliary power means operative subsequent to the opening of said feed clutch for traversing the hob tangentially of the work, said last men-

tioned power means also operating through said lead compensating means to preserve the phase relation between the hob and the work during the period the hob is being tangentially traversed.

15. The combination set forth in claim 14 characterized by the provision of means for rendering one of said power means ineffective when the other of said power means is operative.

16. A worm gear hobbing machine for cutting right or left hand gears combining a rotatable work carrier and a rotatable hob carrier, main power means for rotating said carriers in synchronism, feed means connected to said main power means for shifting the hob carrier electively radially of the work and tangentially thereto in accordance with the hand of the gear to be cut, control means for said elective feed means, a main feed clutch common to said elective feed means operative to disconnect the same from said main power means; an auxiliary source of power connected to operate said elective feed means for traversing said hob carrier electively radially and tangentially and in reverse directions, control means for said main clutch and for said auxiliary source of power, and means interlocking said control means to render one power means ineffective to propel the hob carrier when the other power means is operative.

17. The combination set forth in claim 16 including means for relating the direction of motion delivered by said auxiliary source to said feed means in harmony with the direction of the power feed when cutting either right hand or left hand gears.

18. The combination of claim 16 including independently operable means in one of said elective feed means for unidirectionalizing the power feed for both right and left hand gear cutting setups; and an interlock between said independently operable means and the control means for said auxiliary power source for harmonizing the direction of traverse motion imparted thereby with the direction of the power feed for each hand of gear to be cut.

19. A machine tool embodying a reversible work carrier and a tool carrier, power means for actuating one of the carriers to effect the tooling operation; means for effecting a feed movement of one of said carriers relative to the other electively in transverse planes and in opposite directions in each plane; a second and separate means for traversing said one carrier relative to the other electively in transverse planes and also selectively in opposite directions in each of said transverse planes; control means for the carrier feed means; control means for the carrier traversing means; and means for effecting carrier movement by but one of said carrier moving means at any one time.

20. The combination set forth in claim 19 including means for correlating directions of motion imparted to the carrier by the traversing means with the direction of motion imparted to the carrier by said feed means for any selected cycle of machine operation.

21. A machine tool combining a member to be driven in transverse directions, a transmission including a mechanical reversing means for driving the member electively operable in opposite directions in one of said transverse directions, another transmission electively operable to receive power through said mechanical reversing means for driving said member electively in opposite directions in another of said transverse directions including therein a direction restoring

device for reversing the effective action of said mechanical reversing means on the directions of movement of the member when driven by the second named transmission, said second transmission being adapted to drive said member in a given direction irrespective of the direction of power flow previously determined by the setting of said reversing means, and means for rendering but one of said transmissions effective to propel said member at any one time.

22. A machine tool combining a member to be driven in transverse directions, a transmission including a mechanical reversing means for driving the member electively operable in opposite directions in one of said transverse directions, another transmission electively operable to receive power through said mechanical reversing means for driving said member electively in opposite directions in another of said transverse directions including therein a direction restoring device for reversing the effective action of said mechanical reversing means on the directions of movement of the member when driven by the second named transmission, said second transmission being constructed and arranged to receive power through said mechanical reverser and adapted to drive said member in a given direction irrespective of the direction of power flow previously determined by the setting of said reversing means.

23. Power transmission means for propelling an element combining a main power source; power transmitting connections between said source and the element to be propelled for propelling same including two reversing mechanisms connected in series, a selectively operable second power source connected into said power transmitting connections at a point between said two reversing mechanisms whereby said element to be propelled is propelled in a direction determined by the position of one of said reversing mechanisms when activated by said second power source, and in a direction determined by the position of both of said reversing mechanisms when activated by said main power source.

24. A power transmission for propelling elements of a machine tool combining a main source of power and a first train of connections therefrom to one element of the machine; a second train of connections branching from said first train and leading to another element of the machine; motion reversing means in said second train; and a third train of connections branching from said second train at a point beyond said reversing means and leading to another element of the machine; motion reversing means also in said third train, said first mentioned reversing means being operative to change the direction of motion in the trains leading to said second and third elements, and said second mentioned reversing means being operative to control the direction of motion in the train to said third element irrespective of the prepositioning of said first mentioned reversing means.

25. The combination of claim 24, characterized by the provision of a fourth train of mechanisms branching from said third train at a point between said two reversing means so that the direction of motion in the last mentioned train corresponds at all times with the direction of motion resulting in said second mentioned train.

26. A power transmission for a machine tool combining a source of power and a train of power transmitting connections between said

source and an element of the machine to be propelled thereby; a differential mechanism in said connections including a rotatable but normally stationary differential housing, a second train of power transmitting connections branching from said first train at a point beyond said differential mechanism and including a selector clutch; two subtrains of connections each adapted to receive power selectively through said selector clutch and each being connected to propel an element of the machine tool; and power transmitting connections between one of said subtrains and said differential casing for actuating the latter whenever said selector clutch is positioned to render the respective subtrain effective, thereby automatically to effect a modification in the drive to said first mentioned element whenever one of said subtrains is rendered effective and a zero modification in the drive to said first mentioned element whenever the other of said subtrains is rendered effective.

27. The combination set forth in claim 26 characterized by the inclusion of motion reversing means in the connections between the said subtrain and said differential housing operable to effect said modification selectively additively or subtractively at will.

28. A power transmission for a machine tool combining a source of power and a train of power transmitting connections between said source and an element of the machine to be propelled thereby; a differential mechanism in said connections including a rotatable but normally stationary differential housing; a second train of power transmitting connections branching from said first train and including a selector clutch; two subtrains of connections each adapted to receive power selectively through said selector clutch and each being connected to propel an element of the machine tool; and power transmitting connections between one of said subtrains and said differential casing including a non-reversible worm and worm wheel drive for actuating the latter whenever said selector clutch is positioned to render the respective subtrain effective, thereby automatically to effect a modification in the drive to said first mentioned element whenever one of said subtrains is rendered effective, and locking of the casing of the differential and a zero modification in the drive to said first mentioned element whenever the other of said subtrains is rendered effective.

29. A machine tool transmission combining a tool drive train, a work drive train, and a feed drive train connected in parallel to a common source of power, a first speed change mechanism between said source and said three drive trains, a second speed change mechanism between the tool drive train and the work and the feed drive trains, a third speed change mechanism between said work drive train and the said feed train, each of the respective drive trains thereby being subjected to the effects of the speed change mechanisms ahead of and in series therewith, and motion reversing means in the said work drive train between the tool drive train and the feed train take off for effecting simultaneous reversals of motion in said work and said feed trains independently of the direction of motion in said tool drive train.

30. A machine tool transmission combining a first drive train, a second drive train, and a third drive train connected in parallel to a unidirectional common source of power, a first speed change mechanism between said source of power

and the three drive trains connected therewith, a second series connected speed change mechanisms between said first drive train and the remaining two, and a third series connected speed change mechanism between the first two drive trains and the remaining third drive train, each of said three drive trains thereby being driven at a rate determined by the speed change mechanisms ahead of and in series therewith, motion reversing means operative to reverse the direction of motion in two of said drive trains concurrently, and additional motion reversing means in one of the latter two trains operative to reverse the effective action of said first mentioned reversing means on the said one of the latter two trains.

31. A drive transmission for a machine tool combining a source of power, a transmission driven thereby connected to propel a member, another parallel connected transmission for propelling another member at a rate related to the rate of movement of the first member, a differential mechanism and a motion reversing means in said parallel connected transmission, the latter for effecting a reversal in the motion imparted to the driven member relative to the direction of motion imparted to the first mentioned member, a third transmission connected to receive power from the outgoing side of said motion reversing means and connected to actuate one of said propelled members relative to the other, said third transmission also having a branch connection with said differential mechanism operative to modify the rate of propulsion of said second transmission in accordance with the rate of relative actuation effected by said third transmission, and motion reversing means in said branch connection operative to maintain the rate modi-

fyng action of said differential mechanism consistent when the direction of motion imparted to said second mentioned member is reversed.

32. A machine tool combining a member to be rotated and shifted relative to another member, a main transmission for rotating the member, a feed transmission branching from the main transmission for shifting the member relative to another, a differential mechanism serially arranged in said main transmission but having a back driving power transmitting connection with said feed transmission for correlating the rates of member rotation and relative feed movement, clutch means between said main and branch transmissions for disconnecting the latter from the former, and a reversible auxiliary power transmission connected to said branch feed transmission at the member side of said clutch for effecting said relative shifting of the member at a relatively rapid rate, said back driving connection of the branch transmission with the said differential mechanism remaining effective to maintain the said correlated relation between the rotary and shifting movements when such movements are effected by either the main or the auxiliary power transmission.

33. The combination set forth in claim 32 including motion reversing means in said main transmission beyond said differential mechanism and ahead of said feed branch transmission for effecting reverse rotation of said member, and reversing means in said back driving connections to the differential to maintain the direction of motion therein and its action on the differential mechanism unaffected by a reversal in the rotary and feed motion imparted to said member.

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