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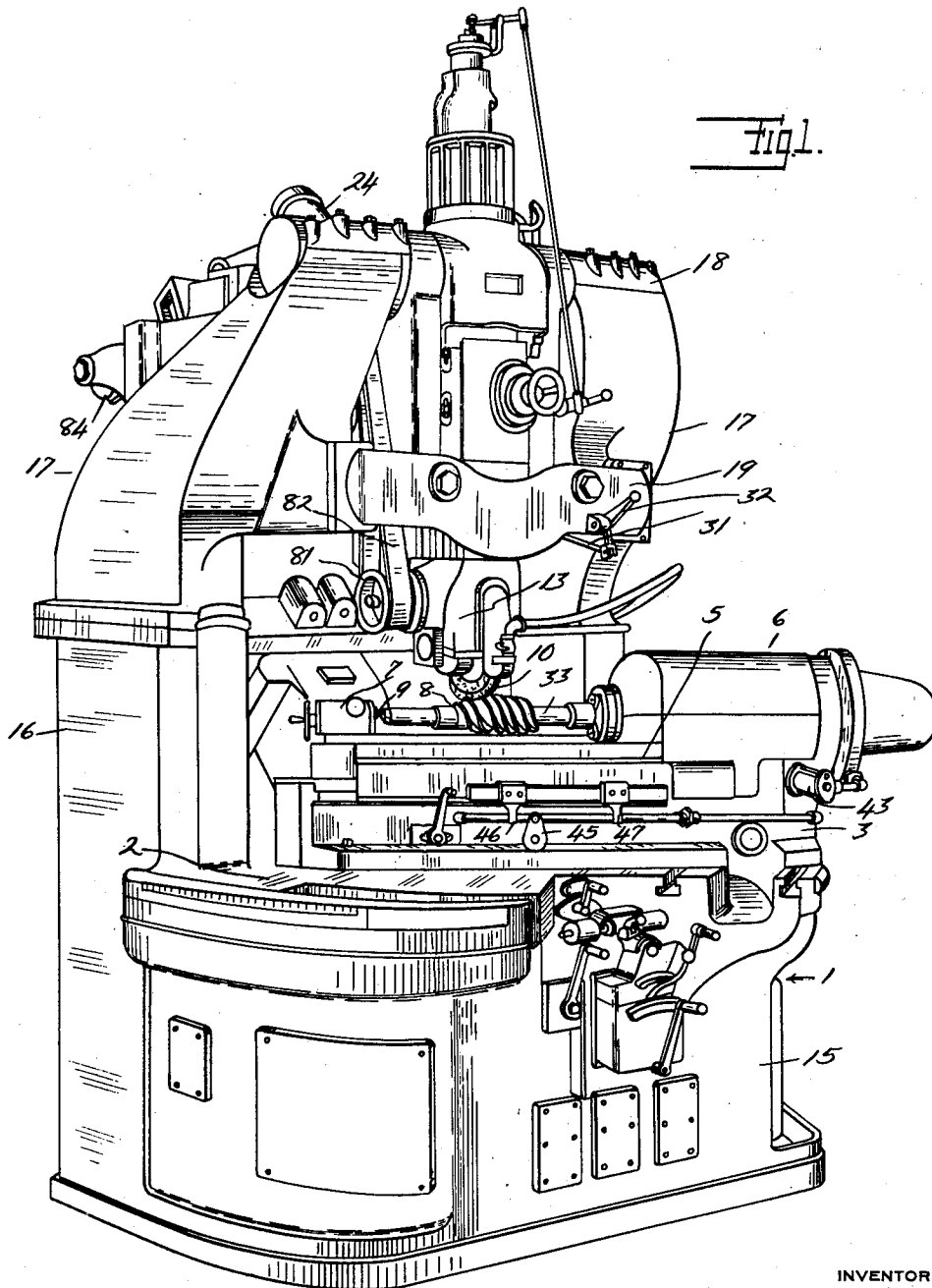
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1,899,654

WORM GRINDING MACHINE

Filed Aug. 31, 1931

7 Sheets-Sheet 1



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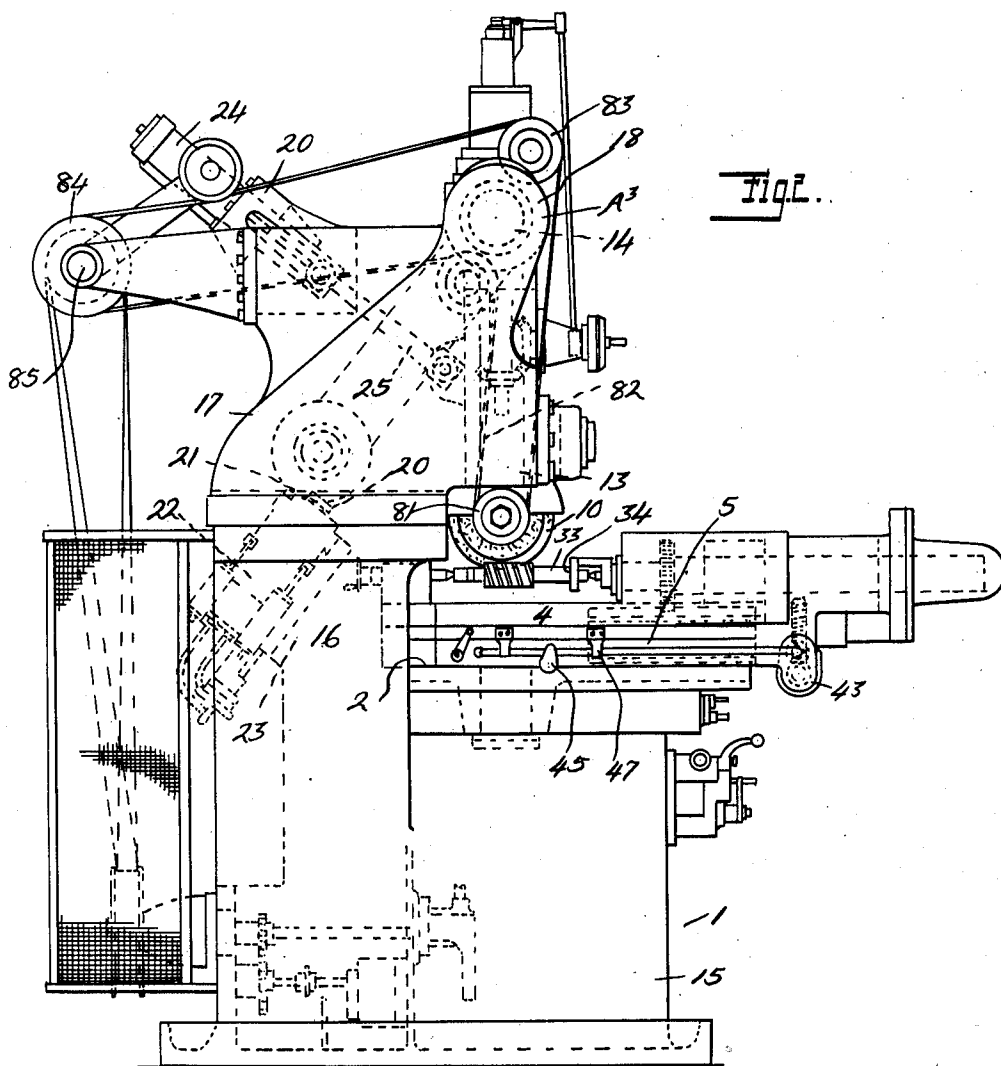


Fig. 1.

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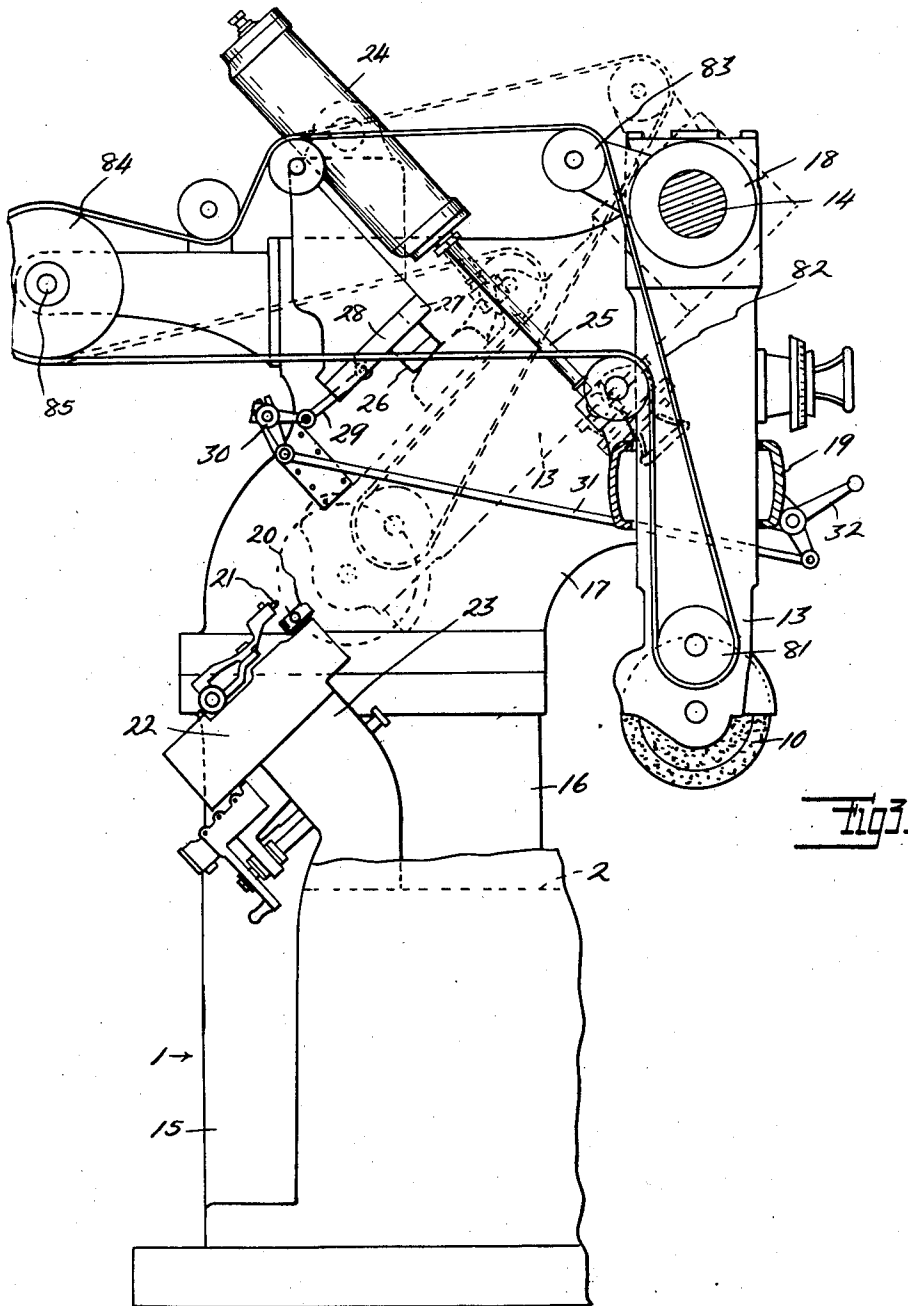
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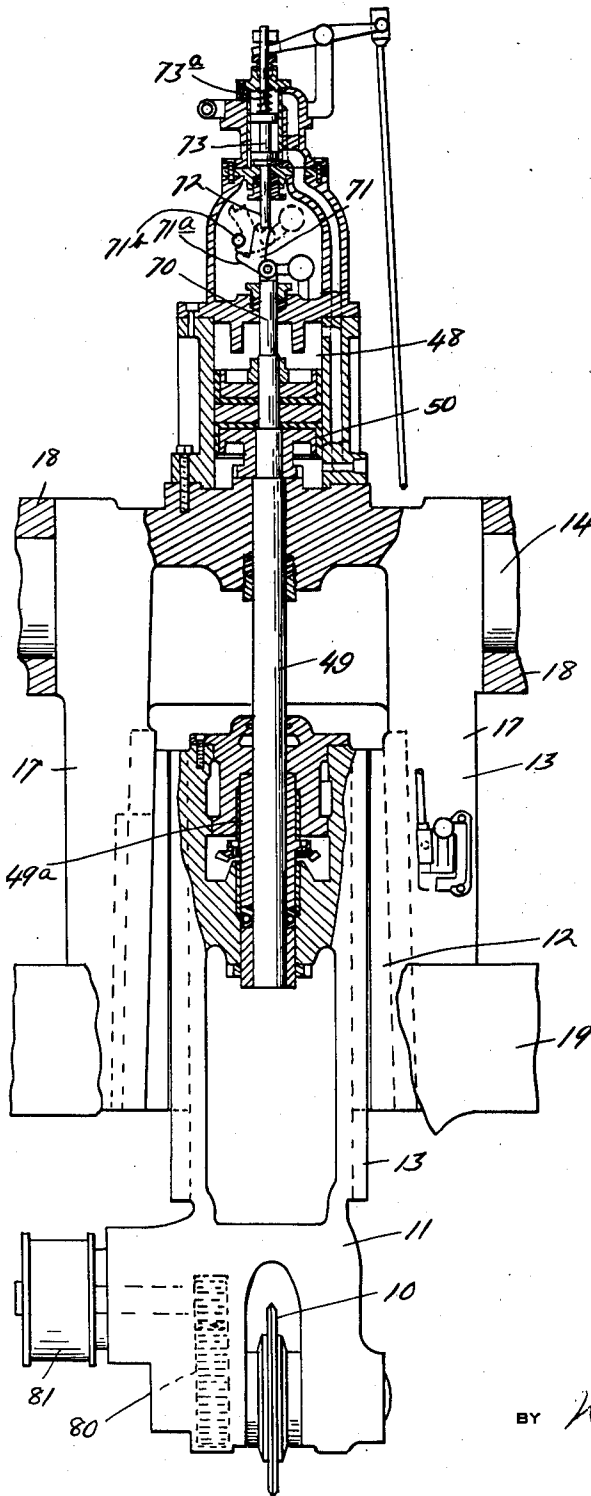
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7 Sheets-Sheet 4



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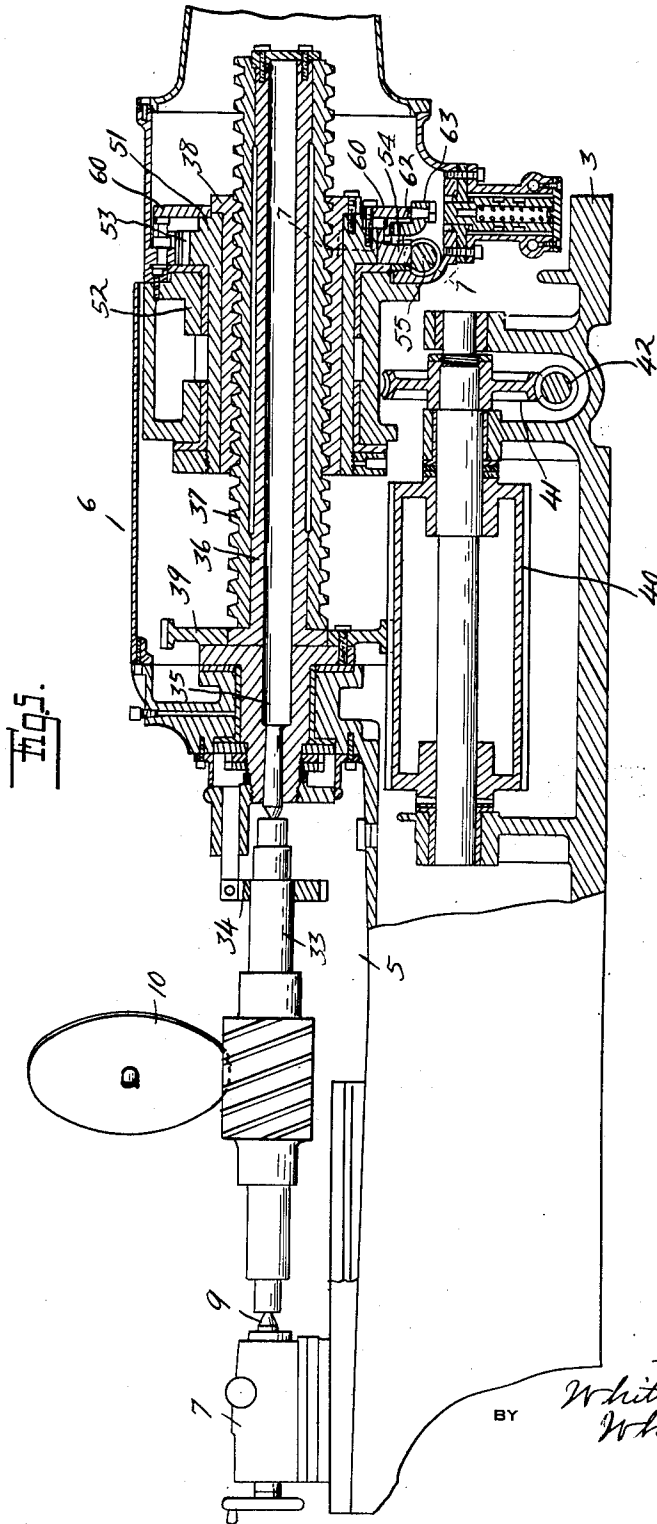
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WORM GRINDING MACHINE

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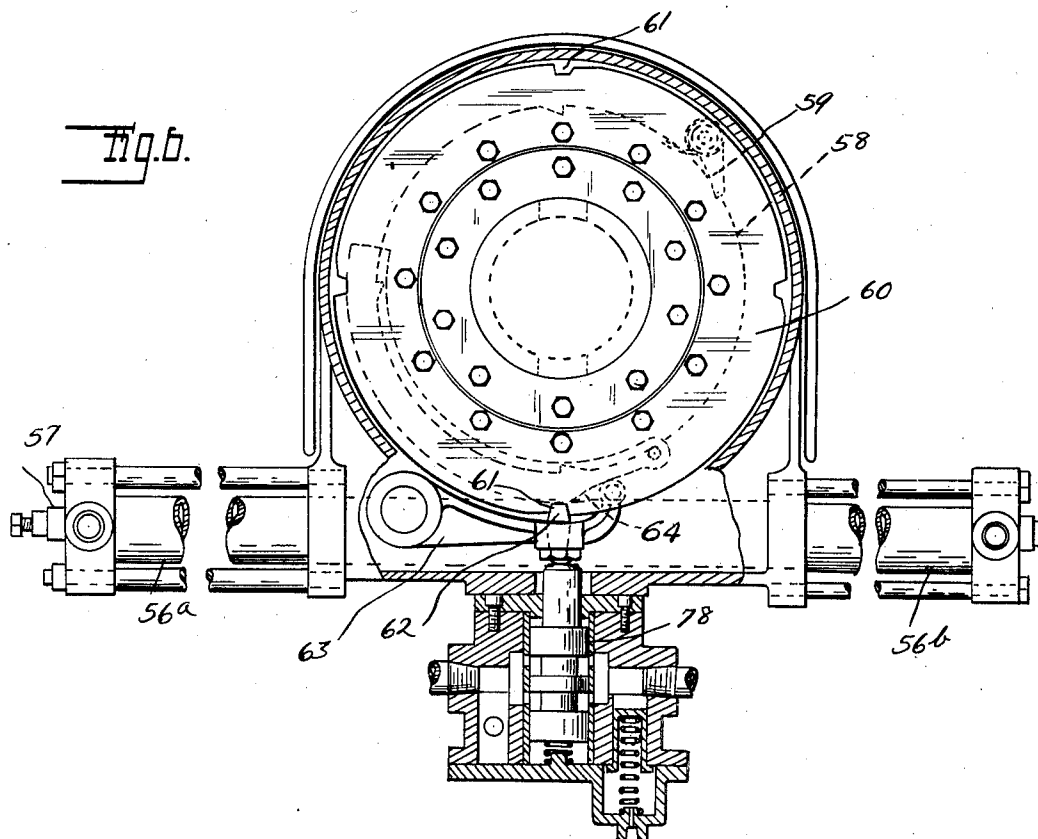
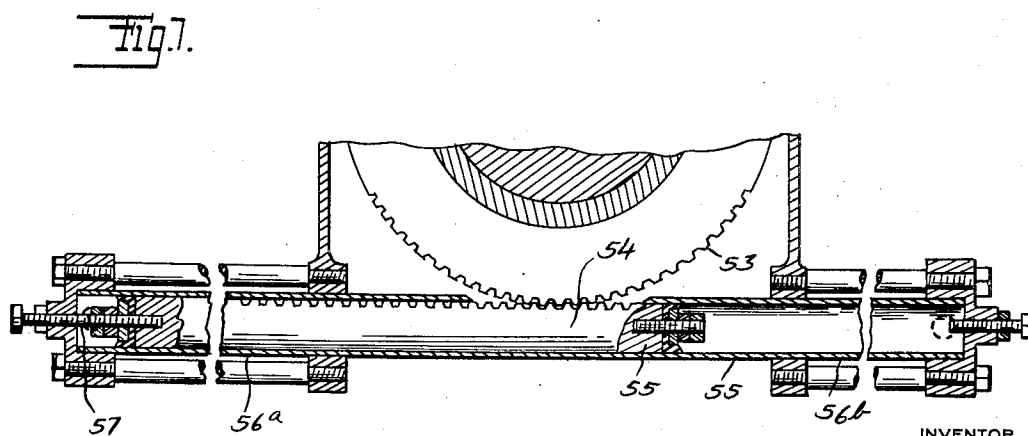
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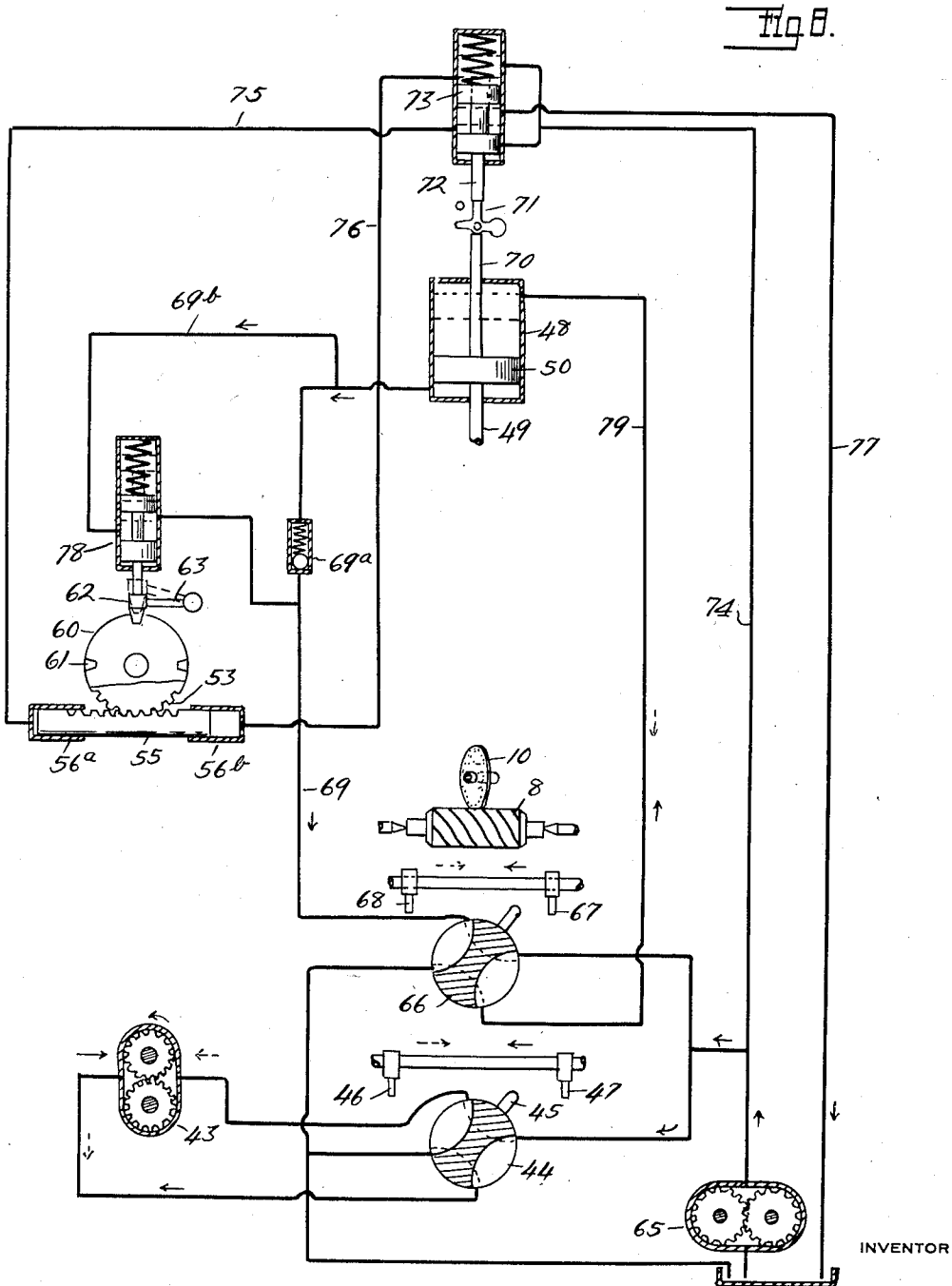
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WORM GRINDING MACHINE

Filed Aug. 31, 1931

7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE

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WORM GRINDING MACHINE

Application filed August 31, 1931. Serial No. 560,450.

The invention relates to the art of grinding helical teeth by formed grinding wheels. It is the object of the invention

First, to obtain a construction particularly adapted for the grinding of worms for worm gearing;

Second, to perform the work with a high degree of accuracy;

Third, to provide for easily and quickly adjusting the machine for different work;

Fourth, to provide for accurate trimming and re-trimming of the grinder wheel as frequently as necessary to maintain its form;

Fifth, to guard against incomplete operations by making the performance of successive functions dependent upon the completion of prior functions.

With these and various other objects in view the invention consists in the construction as hereinafter set forth.

In the drawings:

Figure 1 is a perspective view of the machine;

Figure 2 is a side elevation with the work carriage arranged (for better illustration of parts) in an abnormal position at right angles to the axis of the grinder;

Figure 3 is a cross section in a plane parallel to Figure 2;

Figure 4 is a sectional elevation of the grinder supporting head and swinging frame;

Figure 5 is a longitudinal section through the work carriage;

Figure 6 is a sectional elevation of the index mechanism;

Figure 7 is a cross section on line 7-7 of Figure 5;

Figure 8 is a diagram illustrating the various hydraulic motors and controls therefor.

In general organization the machine comprises a rigid frame 1 for supporting the various parts of the mechanism. On the lower portion of this frame is a horizontally extending work table 2 having mounted thereon a head member 3 rotatively adjustable about a vertical axis and provided with horizontally extending guideways 4 for a reciprocatory carriage 5. Upon the carriage 5 are head and tail stocks 6 and 7 between which

the work 8 is supported on centers 9. Above the work is the grinder wheel 10 mounted in a head 11 which is vertically adjustable in guides 12 carried by a swinging head 13 mounted on trunnions 14 in the upper portion of the frame. The arrangement is such that the work can be set in proper angular relation to the grinder wheel by adjustment of the head 3 on the table 2 and the grinding is effected by a combined rotary and axial movement of the work in relation to the grinder, as will be hereinafter set forth.

The essential operations performed by the machine are

First, the trimming of the grinder wheel to an exactly predetermined cross sectional contour corresponding to the thread of the worm to be ground;

Second, the rotation and axial advancement of the work while in operative relation to the grinder wheel so that the latter will traverse the entire length of the thread.

This operation is repeated with suitable adjustment of the grinder wheel towards the axis of the worm until the latter is ground to the correct form. If, however, as is generally the case, the work is provided with multiple threads, it is necessary to index from one thread to another during the interval in which the grinder is disengaged from the work. Also to avoid any inaccuracy due to slight lost motion the successive grindings are all performed while the work is traveling axially in one direction which requires the withdrawal of the grinder wheel from engagement with the work during the return movements. Thus my machine comprises in its complete organization means for performing these successive operations in properly timed sequence and with a high degree of accuracy.

Frame

The frame 1 has the hollow base portion 15 the top of which forms the table 2. At opposite ends and to the rear of the table 2 are the upright columns 16 surmounted by the upwardly and forwardly extending arms 17. At the upper ends of these arms are bearings 18 for the trunnions 14 of the swing-

ing frame 13. A cross bar 19 also extends between the front sides of the arms 17 and forms a stop for limiting the forward swinging movement of said frame.

Trimming mechanism

The trimming of the grinder wheel is effected by the swinging of the frame 13 rearward into an inclined position where it comes into operative relation with the trimmers. The detailed construction of this trimming mechanism forms no part of the present invention and therefore will not be described. However, in general construction it comprises a pair of side trimmers 20 and a peripheral trimmer 21. These are mounted upon a head 22 which is adjustable upon an inclined track 23 into proper relation to grinder wheels of different diameters. The head 12 is moved into trimming position by the operation of a hydraulic motor including a cylinder 24 and piston rod 25. The cylinder is pivotally mounted on rearwardly extending portions 26 of the frame and the piston rod 25 is pivotally connected to the swinging frame 13. Thus an upward actuation of the piston within the cylinder will cause the frame 13 to swing from the vertical position shown in full lines in Figure 3 into the positions indicated in dotted lines. It is desirable for proper trimming that the trimmers should move in a radial plane with respect to the grinder wheel and to avoid interference with each other the side trimmers 20 are in a different plane from the peripheral trimmer 21. I have therefore provided stops for arresting the swinging movement of the frame 13 in two different positions, in one of which the plane of movement of the side trimmers 20 is radial with respect to the grinder wheel while in the other position the plane of movement of the trimmer 21 is in a similar position to the periphery of the wheel. These respective stops 26 and 27 are mounted upon a slide 28 on the frame which slide is operated through the medium of the connecting rod 29, bell crank lever 30 and rod 31 from a manually operable bell crank lever 32 at the front of the machine.

Work actuating mechanism

As has been stated, the worm to be ground is mounted between the centers 9 in the head and tail stocks 6 and 7 on the reciprocatory carriage 5. The tail stock is adjustable upon said carriage so as to receive worms of different lengths, these being preferably mounted upon suitable mandrels 33 held by the centers 9. The mandrels 33 are rotatively driven through the medium of a dog 34 connecting the same to a revoluble spindle 35 mounted in bearings in the head stock 6. At the same time axial movement is imparted to the carriage 5 through the medium of a master worm 36 mounted on an extension 37 of the spindle

35 and engaging a nut 38 mounted on the head 3. Thus a predetermined spiral movement will be imparted to the work such as to move the same in proper grinding relation to the stationary grinder wheel.

The spindle 35 is driven rotatively through the medium of a gear wheel 39 mounted thereon which is in sliding mesh with a long driving pinion 40 mounted in bearings on the head 3. The pinion 40 in turn is driven through the medium of a worm gearing 41 from a transversely extending shaft 42 actuated by a reversible hydraulic rotary motor 43. Operation of this motor in reverse directions is controlled by a reversing hydraulic valve 44 having an actuating rock arm 45 alternately engaged by dogs 46 and 47 on the traveling carriage. The arrangement is such that the carriage 5 will travel in one direction until the valve 45 is reversed by engagement of one of the dogs 46 and 47 whereupon the carriage will be driven in the opposite direction until said valve is again reversed by the other dog. These dogs 46 and 47 are adjustably secured upon the carriage 5 and can thus be set to give any desired length of movement of the carriage before reversal.

Grinder wheel raising and lowering mechanism

For greater accuracy in the performance of the grinding operation the work is ground only when moving axially in one direction and the grinder wheel is disengaged therefrom during the return movement. This is accomplished by a hydraulic motor 48 mounted at the upper end of the swinging frame 13 and connected by a rod 49 with the head 11 in which the grinder wheel 10 is journaled. In normal position of the grinder wheel while performing its work the piston 50 of the hydraulic motor 48 is lowered and is supported on a stop at the lower end of the cylinder. After the completion of a grinding cut fluid is admitted to the lower end of the cylinder to raise the piston 50 which will lift the grinder 10 a sufficient distance to clear the work while the carriage is being returned to its initial position. The timing and control of the motor 48 is through mechanism that will be hereinafter described.

Index mechanism

Where the work to be ground is a multiple thread worm it is necessary to index from one thread to another between successive grinding operations. This indexing is accomplished during the return movement of the carriage after the completion of each grinding cut by mechanism of the following construction. The nut 38 is exchangeably mounted a carrier 51 which is rotatively mounted in a bearing 52 upon the head 3. Independently rotatable on the carrier 51 is the ring gear 53 which is in mesh with a rack 54 on a

piston member 55, the opposite ends of which engage hydraulic cylinders 56a and 56b mounted on the head 3. The traveling movement of the piston 55 in the cylinders 56a and 56b is exactly predetermined by a limiting stop 57 and thus a corresponding oscillation of the ring gear 53 will be effected when the piston is reciprocated. The ring gear 53 has connected thereto a ratchet wheel 58 adapted to engage a pawl 59 on the carrier 51. Thus the reciprocation of the rack 54 will oscillate the ring gear 53 and ratchet wheel 58, the pawl 59 sliding over the ratchet wheel when the latter is moved in one direction and being actuated by a movement in the opposite direction to transmit a similar rotation to the carrier 51.

Precision in this rotative adjustment is obtained through an index plate 60 mounted upon the carrier 51, said plate being provided with notches 61 which are engaged by a wedge shaped dog 62 to lock the plate from movement. The dog 62 is upon a rock arm 63 which is actuated to withdraw the dog by a cam 64 moving with the ratchet wheel 58. This disengagement occurs when said ratchet wheel is moving independently of the pawl 59 so that during reverse rotation when the ratchet wheel is engaged with the pawl and is driving the latter the index plate will be unlocked. Near the completion of this driving movement the cam 64 will be withdrawn to permit the dog 62 to enter another locking notch 61 which again locks the index plate from movement. Thus each operation of the indexing mechanism will rotate the carrier 51 a sufficient distance to advance from one thread to another so that successive grinding operations will be performed on successive threads until the cycle is completed.

Control and timing mechanism

The control and timing mechanism for the several hydraulic motors above described is such as to cause the operation thereof in proper sequence together with certain safeguards which prevent a subsequent operation if the prior operation is not fully performed. Thus after each grinding operation effected during movement of the carriage in one direction the hydraulic motor 48 is operated to raise the grinder head and disengage the grinder wheel from the work during the return movement of the carriage. This raising of the grinder head automatically operates the indexing motor which rotatively advances the work during said return movement of the carriage and the completion of the index movement and relocking of the indexing plate controls the hydraulic motor 48 to lower the grinding head prior to another grinding advancement of the carriage. If, however, the indexing movement has not been completed or if the index plate has not been fully locked, then the grinding head will re-

main in its elevated position so that no harm can come to the work during the reciprocation of the carriage.

As illustrated in the diagram, Figure 8, the fluid for operating the several hydraulic motors is placed under pressure by the operation of a pump 65 which delivers fluid to the valve 44 and also to a valve 66. The valve 44 as previously described controls the reverse operation of the rotary motor 43 and in the position shown in full lines in the diagram is driving this motor in a direction to advance the carriage 5 in the direction of the full line arrow. The completion of the movement of the carriage 5 will cause the dog 47 to engage the rock arm 45 and shift the valve 44 into the position indicated in dotted lines which will reverse the rotation of the motor 43 and correspondingly reverse the direction of movement of the carriage. At the completion of this return movement the dog 46 will again reverse the valve 44 into the position shown in full lines and the cycle will be repeated.

The motor 48 is controlled by the valve 66 which valve is reversed by the operation of a pair of dogs 67 and 68 adjustably mounted on the reciprocating carriage 5, preferably on the reverse side thereof from the dogs 46 and 47. The dog 67 is so set that after the completion of the grinding cut through the work but before the reversal of the carriage it will actuate the valve 63 from the position shown in full lines, Figure 8 to the position indicated in dotted lines. In the latter position fluid under pressure delivered by the pump 65 will pass to a conduit 69 leading to the motor 48 below the piston 50 therein. This will raise the piston which through the medium of the rod 49 lifts the head 11 and grinder wheel 10 so as to clear the work during the return movement of the carriage. The piston 50 is provided with an upwardly extending rod 70 carrying a gravity latch lever 71 which normally is in engagement with a stem 72 of a valve 73 arranged in axial alignment with the rod 70. This valve 73 controls the operation of the motor 56 which actuates the index mechanism and is supplied through the conduit 74 with fluid under pressure delivered by the pump 65. Normally the piston 55 is to the left, Figure 7, being at the outer end of the cylinder 56a. When, however, the valve 73 is raised, pressure fluid will be admitted to a conduit 75 leading to the cylinder 56a which moves the piston 55 towards the outer end of the opposite cylinder 56b. This through the mechanism previously described will move the ratchet wheel 58 in the direction where it slides over the pawl 59 and at the same time will unlock the index plate 60 through the operation of the cam 64 and lever 63, withdrawing the locking dog 62. All of these movements occur while the rod 70 is rising and while the latch dog 71 is in engagement with the stem 72 of the valve 73. How-

ever, during this movement a finger 71a on the latch 71 engaging a stop 71b will trip said latch, disengaging it from the stem 72 and permitting the valve 73 under the actuation of a spring 73a to return to its original position. In such position a pressure fluid is cut off from the conduit 75 and is admitted to a conduit 76 leading to the cylinder 56b while at the same time the conduit 75 is connected with an exhaust conduit 77 leading to the sump which holds the oil for the pump 65. In this position of parts the piston 55 is actuated in the reverse direction and through the ratchet wheel 58 and pawl 59 moves the index plate 60 to bring another locking notch 61 into registration with the locking dog 62. At the same time the cam 64 is withdrawn to permit the re-engagement of the locking dog 62 with said notch.

A vital point in the successful operation of the machine is that this indexing mechanism should be complete which requires the full engagement of the wedge shaped dog 62 with the notch 61. If for any reason this full engagement is not effected, then it is essential to prevent a succeeding grinding operation which would be sure to injure the work. I have therefore devised a construction which prevents the lowering of the grinding head 11 and the engagement of the grinder 10 with the work in case the index operation has not been completed, the construction being as follows:

Safety lock

As has been previously described, the raising of the head 11 is effected by the admission of fluid under pressure through the conduit 69 to the motor 48 below the piston 50. In this conduit 69 there is placed a check valve 69a which prevents return of the fluid even when the valve 66 is turned into the full line position which connects said conduit with the sump. The conduit 69 is provided with a branch 69b forming a shunt around the check valve 69a in which branch is located a valve 78. This valve 78 is associated with the rock arm 63 and dog 62 for the index plate, the arrangement being such that when said dog is in full locking engagement with the index plate the valve 78 will be in an open position permitting free passage of fluid through the branch 69b around the valve 69a. Thus under normal conditions the return movement of the carriage 5 will cause the dog 68 to reverse the valve 66 or into the position shown in full lines, Figure 8. This will connect the conduit 69 with the sump and will admit pressure fluid delivered by the pump 65 to a conduit 79 leading to the upper end of the cylinder 48 which will move the piston 50 downward. This downward movement is permitted as the fluid beneath the piston 50 can flow through the conduit 69, branch 69b, past the open valve 78 into the conduit 69 and

through the valve 66 to the sump. If, however, the indexing operation has not been completed so that the dog 62 is held from full engagement with the notch 61, this will hold the valve 78 in a position where it blocks the passage of fluid through the branch conduit 69b and consequently prevents lowering of the piston, thereby holding the head 11 elevated and the grinder wheel 10 out of engagement with the work. As the reciprocation of the carriage 5 is independently controlled, this will take place, but no harm will be done to the work as the grinder wheel is out of contact therewith.

Grinder drive mechanism

The grinder wheel 10 is preferably driven through a step-up gearing 80 from the pulley 81 which is driven by a belt 82 passing around idler pulleys 83 and drive pulleys 84 upon a shaft 85. The arrangement is such as to permit of driving the grinder wheel not only in engagement with the work but also in its two trimming positions.

Complete operation

In the complete operation of the machine, the operator first selects a master worm 37 and corresponding nut 38 which is proper for the grinding of a worm of the pitch desired. After these elements are properly mounted in the machine the worm blank 8 is mounted upon a mandrel 33 and the latter is engaged with the centers 9 coupled with a spindle 35 by the dog 34. The head 3 is then adjusted on the table 2 so as to correspond to the pitch of the worm and after the work is properly registered with the grinder wheel the dog 34 is locked to the mandrel 33. The grinder wheel is then trimmed to proper form by first swinging the frame 13 rearward through the operation of the hydraulic motor 24 into a position for registration with the trimmers 20 in which position it is arrested by the stop 26. After the trimming of the sides of the wheel, which will not be explained in detail, the stop 26 is withdrawn by the operation of the bell crank lever 32 and the frame 13 is adjusted into registration with the trimmer 21 which trims the periphery of the wheel. The swinging frame with the trimmed wheel is then returned to the vertical position where it is locked by the pressure of the hydraulic cylinder 24 against the limiting cross bar 19.

The machine is then set in operation, the motor 43 causing the reciprocation of the carriage and the other operations following in proper sequence as previously described. These in brief are first, a grinding cut through one of the threads of the worm, then the raising of the grinder wheel out of engagement with the work and the indexing of the work which is accomplished during the return movement of the carriage; then the lowering of the grinder wheel to

traverse another thread of the work and so on in successive cycles until the worm is ground to proper form and size. Whenever necessary the grinder wheel may be re-trimmed and fed downward into the work. This downward feeding is accomplished by a threaded engagement between the rod 49 and a rotatively adjustable nut 49a which attaches the same to the head 11 and which is operated by suitable control mechanism not described in detail.

What I claim as my invention is:

1. In a grinding machine, the combination of a rigid frame having a bed or table portion and an upwardly extending bifurcated portion overhanging the same, a rotary and axially movable work holder mounted on said table beneath said overhanging portion to be angularly adjustable about a vertical axis centrally between the furcations, a frame pivotally mounted in and depending from said bifurcated overhanging portion, a grinder wheel mounted at the lower end of said depending frame in operative relation to the work, and a trimmer between the furcations of said bifurcated portion with which said grinder is engaged by the swinging of said depending frame.

2. In a grinding machine, the combination of a rigid frame provided with a bed or table portion and a pair of upwardly extending columns in rear thereof having their upper ends overhanging said bed or table, a trimming mechanism mounted between said columns, a swinging frame between said columns pivotally attached thereto at its upper ends, a grinder wheel mounted on said swinging frame at the lower end thereof and carried thereby into operative relation to said trimming mechanism, and a work holder mounted on said table in operative relation to said grinder wheel in one position of adjustment of said swinging frame.

3. In a grinding machine, the combination of a rigid frame having a bed or table portion, a pair of columns in rear thereof extending upward and forwardly to overhang said bed or table, a frame having trunnions engaging the upper ends of said overhanging columns adapted to swing between the same, a grinder wheel carried by the lower end of said last mentioned frame, trimming mechanism located between said columns in operative relation to said grinder wheel upon the rearward swinging of said frame, a hydraulic motor for swinging said frame, a stop for limiting the forward movement of said frame, and a work holder mounted on said table in operative relation to said grinder wheel when said swinging frame is engaged with said stop.

4. In a grinding machine, the combination of a rigid frame having a bed or table portion and a pair of columns extending upward

and overhanging said bed or table portion, a frame arranged between said columns and provided with trunnions for pivotally supporting the same at the upper ends of said columns, a cross bar between said columns forming a limiting stop for the forward movement of said trunnion frame, a head vertically adjustably mounted in said trunnion frame, a grinder wheel carried by said head, a hydraulic motor for swinging said trunnion frame rearward between said columns, trimming mechanism between said columns in operative relation to said grinder wheel when said trunnion frame is swung rearward, a hydraulic motor carried by said trunnion frame for raising and lowering said head, drive mechanism for the grinder operative in the various positions of adjustment thereof, and a work holder mounted on said bed or table in operative relation to said grinder wheel when said trunnion frame is in its forward position in engagement with said stop.

5. In a worm grinding machine, the combination with a bed or table, of a head mounted thereon to be adjustable about a vertical axis, a carriage mounted for reciprocation on said head, a rotary work holder mounted on said carriage and provided with a driving spindle, an exchangeable master screw and stationary nut detachably secured to said spindle and head, a rotary motor mounted on said head, a transmission gearing between said motor and spindle permitting the reciprocatory movement of said carriage on said head, means for reversing said motor, dogs adjustably mounted on said carriage to engage and actuate said reversing means thereby determining the length of reciprocation of said carriage, and a grinder wheel mounted above said carriage in operative relation to the work.

6. In a worm grinding machine, the combination with a bed or table, of a head mounted thereon to be adjustable about a vertical axis, a carriage mounted for reciprocation on said head, a rotary work holder mounted on said carriage and provided with a driving spindle, an exchangeable master screw and stationary nut detachably secured to said spindle and head, a rotary motor mounted on said head, a transmission gearing between said motor and spindle permitting the reciprocatory movement of said carriage on said head, means for reversing said motor, dogs adjustably mounted on said carriage to engage and actuate said reversing means, thereby determining the length of reciprocation of said carriage, a grinder wheel mounted above said carriage in operative relation to the work while said carriage is traveling in one direction, and means for raising said grinder wheel out of engagement with the work while said carriage is traveling in the reverse direction.

7. In a worm grinding machine, the combi-

nation with a bed or table, of a grinder wheel above said bed or table, means for raising and lowering said grinder wheel in a fixed line perpendicular to said table, a work holder, means for imparting to said work holder simultaneous axial and rotary motion, alternately in opposite directions, and means automatically operating at the completion of axial movement in one direction for causing the raising of said grinder wheel out of engagement with the work, and for returning it into engagement with the work at the completion of the return axial movement.

8. In a worm grinding machine, the combination with a bed or table, of a grinder wheel above said bed or table, a work holder for the worm to be ground, angularly adjustable about a vertical axis passing through the center of said grinder wheel, means for imparting to said work holder simultaneous axial and rotary movements alternately in opposite directions to trace by said grinder wheel a predetermined spiral thread, index mechanism for adjusting said work holder to trace by said grinder wheel successive threads of a multiple thread work, means for raising the grinder wheel out of engagement with the work after completion of the axial movement in one direction and returning it into engagement with the work at the completion of the return axial movement, means for operating the indexing mechanism during the interval in which said grinder wheel is out of engagement with the work and means for preventing the re-engagement of the grinder wheel with the work upon an incomplete indexing operation.

9. In a worm grinding machine, the combination with a bed or table, of a grinder wheel above said bed or table, a rotary and axially movable work holder mounted on said bed or table and angularly adjustable about a vertical axis passing through said grinder wheel, a rotary hydraulic motor for imparting rotary movement to said work holder alternately in opposite directions, an exchangeable master screw for effecting the simultaneous axial movement of said work holder during rotation thereof, an index mechanism for rotatively advancing said work holder independent of said master screw, a hydraulic motor for operating said index mechanism, a hydraulic motor for raising and lowering said grinder wheel and controlling means for said hydraulic motor whereby the completion of the axial movement of said work holder in one direction will actuate the motor for raising said grinder wheel out of engagement with the work, the raising of said grinder wheel will actuate the indexing motor, the operation of said indexing mechanism and the return axial movement of the work holder will actuate the motor for returning the grinder wheel into engagement with the work.

10. In a worm grinding machine, the combination with a bed or table, of a rotary and axially movable work holder mounted on said bed or table, a reversible hydraulic motor for actuating said work holder rotatively alternately in opposite directions, a master screw for causing the simultaneous axial movement of said work holder, an index mechanism for rotatively advancing said work holder independent of said master screw, a hydraulic motor for operating said index mechanism, a grinder wheel vertically adjustably mounted above the work, a hydraulic motor for alternately raising and lowering said grinder wheel, a reversing valve controlling said last mentioned hydraulic motor, said valve being operated by the completion of the axial movement of said work holder in one direction to cause the raising of said grinder wheel out of engagement with the work and by the completion of axial movement in the opposite direction to lower said grinder wheel into engagement with the work, a check valve for preventing the latter operation, a valve actuated by the raising of the grinder wheel out of engagement with the work causing the operation of the motor for said indexing mechanism, and a valve actuated by the completion of the indexing movement for by-passing around said check valve to permit the return of the grinder wheel into engagement with the work.

In testimony whereof I affix my signature.
FREDERICK A. WARD.