Feb. 17, 1953 H. BÜHLER 2,628,458

GEAR GRINDING MACHINE

Filed April 11, 1950 4 Sheets-Sheet 1

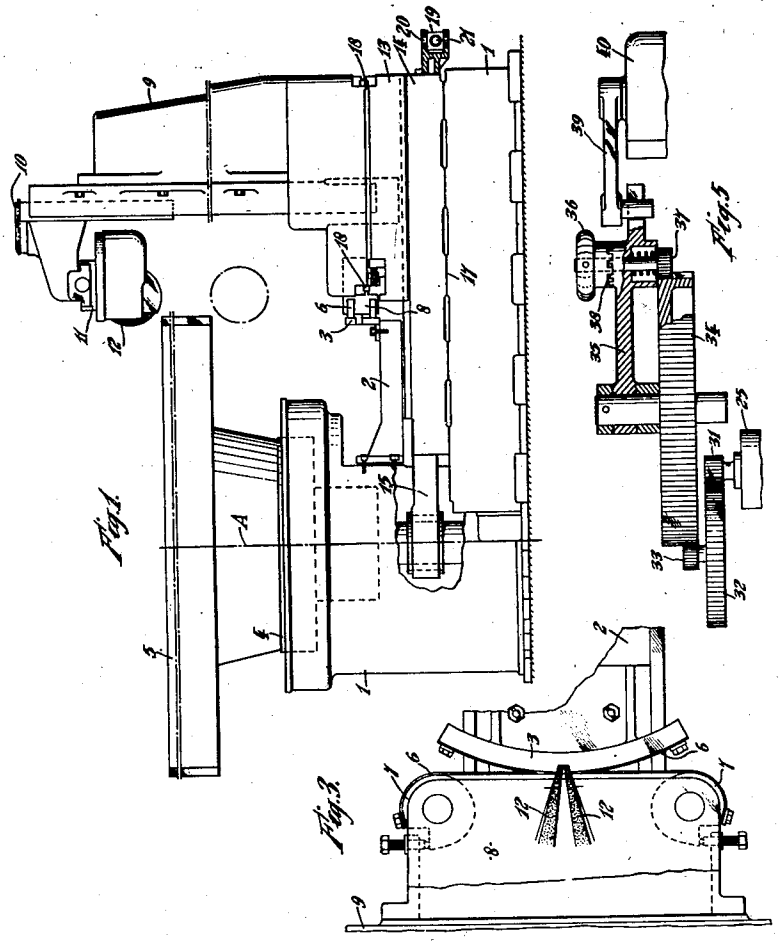

Fig. 1.

Fig. 2.

Fig. 5.

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GEAR GRINDING MACHINE

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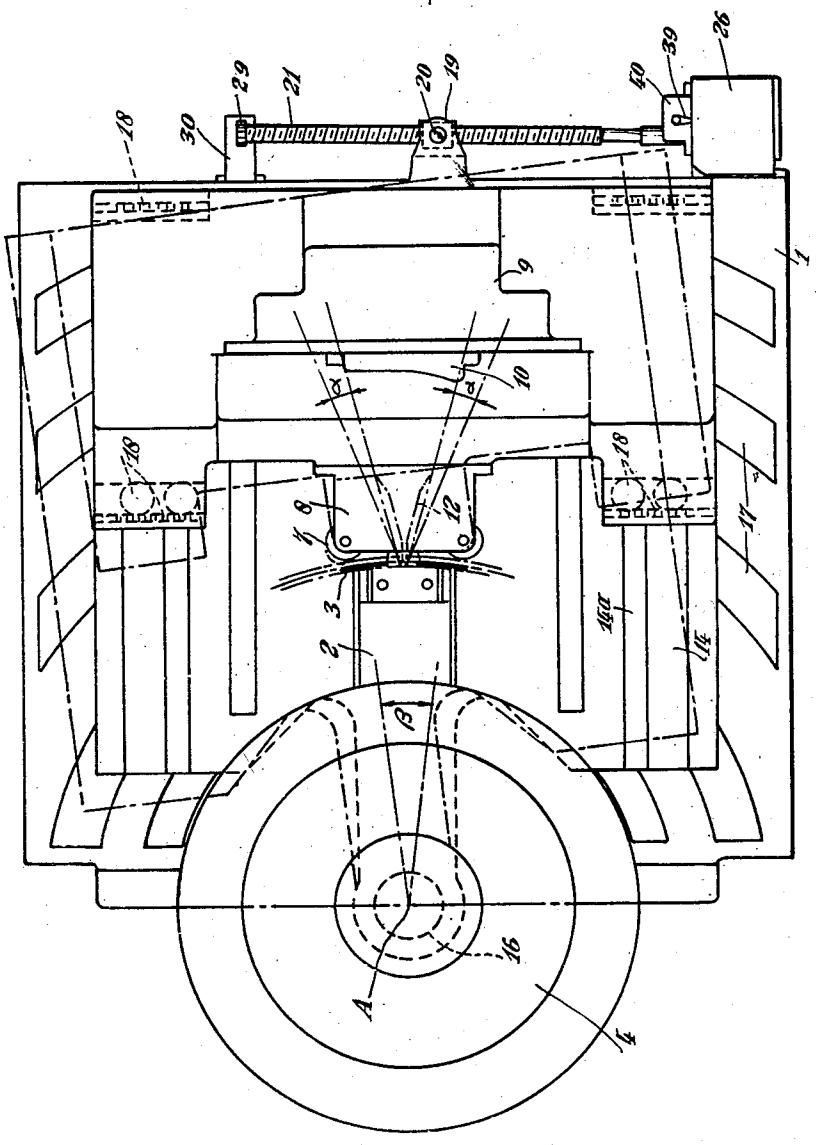
Fig. 2.



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GEAR GRINDING MACHINE

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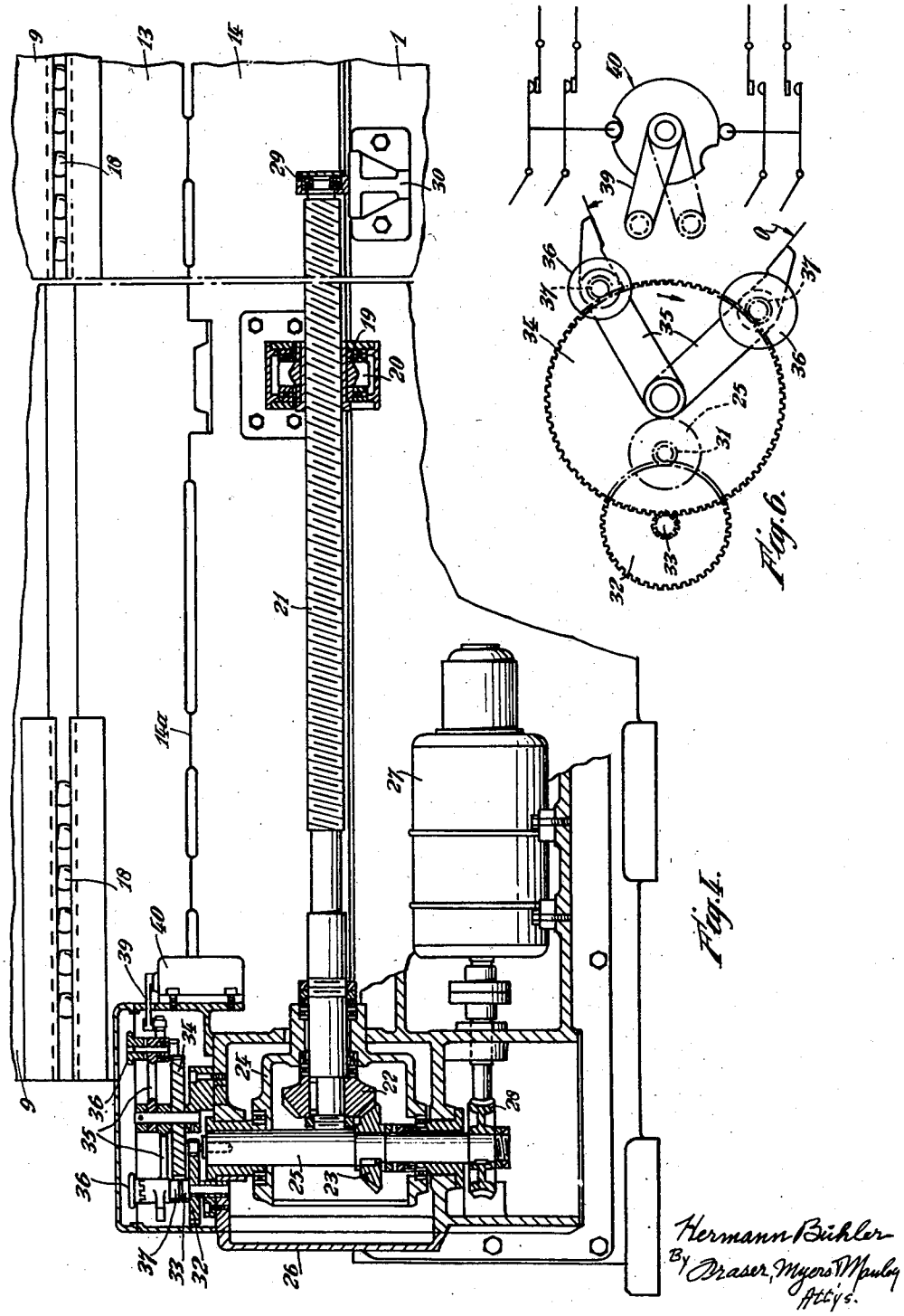

Fig. 1.

Fig. 6.

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GEAR GRINDING MACHINE

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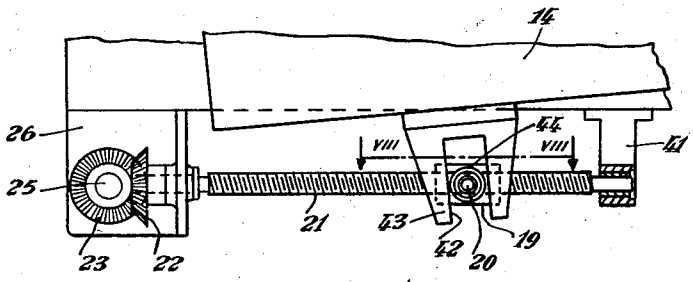

Fig. 7.

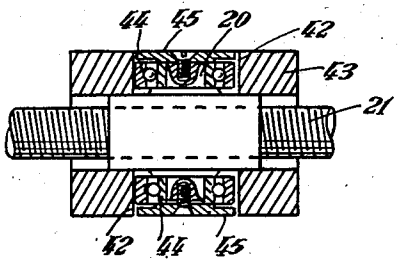

Fig. 8.

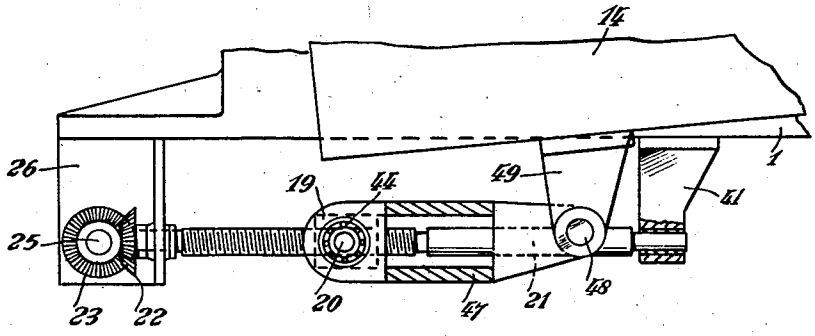

Fig. 9.

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UNITED STATES PATENT OFFICE

2,628,458

GEAR GRINDING MACHINE

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Application April 11, 1950, Serial No. 155,157
In Switzerland February 18, 1950

9 Claims. (Cl. 51—55)

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This invention relates to gear grinding machines operating on the involute-generating principle in which the work and the grinding tool are caused to move relatively to each other with a true rolling motion so that the working surface of the tool describes an involute surface enveloping the flank of the gear tooth to be ground.

It is usual for this rolling motion to be brought about by a member having a cylindrical surface or a surface which is part of a cylinder of diameter corresponding to the base circle diameter of, and mounted coaxially with, the gear wheel to be ground, the cylindrical surface being connected to flexible steel tapes under tension which ensure a relative rolling motion without slipping between themselves and said member (which is hereinafter referred to as the "involute-generating cylinder").

In one known type of such gear grinding machines, the involute-generating cylinder and the work are connected together and mounted for joint rotation and for bodily rectilinear reciprocation perpendicularly to their joint axis, while the other ends of the steel tapes are fastened to a member which in operation remains stationary, the reciprocation of the involute-generating cylinder relatively to the tapes causing the involute-generating cylinder and the work to rotate in an oscillatory manner so that the combined rotary and reciprocating movements thereof, while the tapes are being wound on and unwound from the involute-generating cylinder, represent a true rolling motion of the work with respect to the grinding tool which is also stationary in space during normal operation.

In another known type of such grinding machines, the involute-generating cylinder and the work remain stationary during operation (except for periodical rotation of the work for dividing or indexing purposes, i. e. in order to present different gear teeth successively to the tool) and it is the tool which performs the true rolling motion relatively to the work, which motion is composed of a combined rotary and rectilinear reciprocating movement of the tool and its holder, the latter being mounted for rotation about the joint axis of the involute-generating cylinder and the work and for reciprocation perpendicularly to said axis, the rotary component being in the nature of an oscillation imparted to the tool-holder which is connected by the steel tapes to the involute-generating cylinder so that the tapes, as they are wound on and unwound from the involute-generating cylinder, bring about the reciprocating component of the tool-holder motion.

The present invention relates only to this latter type of gear grinding machine and has for object to provide improvements therein.

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According to the invention the driving means for imparting the rotary component of movement to the tool-holder comprises a power-driven shaft mounted parallel to the axis of the involute-generating cylinder in fixed relation to the machine bed, a screw-threaded spindle driven by said shaft and engaging a nut pivotally connected to the tool-holder, and means between said shaft and the tool-holder adapted to permit said rotary movement of the tool-holder relatively to said shaft notwithstanding the driving connection therebetween by said spindle and said nut.

The said means may take the form of pivotal means enabling said spindle to pivot about an axis provided by said shaft, so that in operation said spindle swings towards and away from the tool-holder. For example, said spindle may be driven through a pair of bevel wheels secured to said spindle and to said shaft respectively, said shaft having mounted for pivotal movement thereon a member which provides the bearing for said spindle and its bevel wheel. The free end of said spindle may be slidably supported.

Alternatively said means may provide for said nut to have a movement towards and away from the tool-holder, in addition to its pivotal connection thereto, while said spindle has no bodily movement relatively to the machine bed. For example, the pivot of said nut may be slidable in a guide of the tool-holder, or it may be pivoted to the end of a lever adapted to swing towards and away from the tool-holder.

A machine embodying the invention may also have provision for controlling the aforementioned driving means so as to reverse the rotary movement of the tool-holder every time it reaches the end of a predetermined arc of rotation through which it is to oscillate. For this purpose, use is preferably made of the drive of said shaft to operate a trip mechanism which causes the rotation of said spindle to be reversed.

In one embodiment of the invention, the tool-holder comprises an upright standard, upon which one or more grinding wheels are adjustably and reciprocably mounted, and a table mounted for pivotal movement about the axis of the involute-generating cylinder, the standard being mounted on the table so as to be adjustable towards and away from the work, and, in addition, slidable with respect to the table tangentially of the involute-generating cylinder for the purpose of permitting the necessary reciprocating component of the tool-holder motion. In that case the afore-

mentioned driving means drives the tool-holder table, while the flexible tapes are connected to the tool-holder standard.

In order to enable the invention to be readily carried into effect and the foregoing and other features thereof to be explained, a few embodiments will now be described by way of example with reference to the accompanying drawings, wherein:

Fig. 1 is a side elevation of a form of gear grinding machine embodying the invention, certain parts being shown broken away and others in section for greater clarity;

Fig. 2 is a top plan of the machine of Fig. 1, with parts broken away;

Fig. 3 shows a detail of the machine on an enlarged scale, namely the involute-generating cylinder and the steel tapes and associated parts, a view of the grinding wheels being superposed thereon to explain the action;

Fig. 4 is a part-sectional rear elevation of the lower portion of the machine, showing the driving means for imparting the rolling motion to the tool-holder;

Fig. 5 shows a detail of Fig. 4 on an enlarged scale; namely means for automatically obtaining periodic reversal of the rolling motion;

Fig. 6 is a top plan of the detail shown in Fig. 5;

Figs. 7 and 8 show another embodiment, according to the invention, of the driving means for imparting the rolling motion to the tool-holder, both figures being fragmentary views of portions at the rear of the machine, and Fig. 7 being a top plan, while Fig. 8 is a part-sectional elevation of a detail along the section line VIII—VIII of Fig. 7;

Fig. 9 is a part-sectional top plan, similar to Fig. 7 showing yet another embodiment of the driving means as a variant of that shown in Figs. 7 and 8.

In the form shown in Figs. 1–6 of the drawings, the machine comprises a bed 1 to which is secured an arm 2 carrying a stationary member 3 which is a segment of a cylinder and constitutes the involute-generating cylinder of the machine. Concentric with the vertical axis A of the involute-generating cylinder 3 is a circular work table 4 adapted to receive the gear wheel 5 to be ground, the work table 4 being mounted for rotation on the machine bed 1, but only for dividing or indexing purposes, and not for the purpose of the involute-generating rolling motion in which neither it nor the work 5 takes any part. When the grinding of one tooth flank of the gear wheel 5 has been completed, a dividing device of known type (not shown) rotates the work table 4 through an angle corresponding to one tooth pitch of the gear wheel 5 so that the latter presents the next tooth to the tool for grinding.

Fastened to the cylindrical surface of the involute-generating cylinder 3 and passing partly around it in opposite directions are flexible steel tapes 6, best seen in Fig. 3, the other ends of which pass partly around, and are secured to, rollers 7 of a tape-holder 8. The rollers 7 can be adjusted to place the tapes 6 under high tension so that the free portions of the tapes lie in a plane which is tangential to the involute-generating cylinder 3. The tape-holder 8 is rigidly connected to a standard 9 (Fig. 1) forming part of the tool-holder of the machine. The standard 9 has a slide 10 mounted thereon for vertical movement with respect thereto, for which purpose the standard 9 and the slide 10 are provided with suitable cooperating guideways. The slide 10 has mounted thereon two further slides 11, each carrying a grinding wheel 12 and each being adjustable with respect to the slide 10 for the purpose of bringing the grinding wheel into proper operative engagement with the work. As can be seen from Fig. 3, the two grinding wheels are adapted to be set at an angle to each other so that their active surfaces are in operative engagement with opposed flanks of adjacent teeth of the work for grinding these two flanks simultaneously. In the present embodiment, each of the grinding wheels 12 is adapted to be set so that its active surface forms an angle with a line tangential to the involute-generating cylinder 3 equal to 90° minus the pressure angle of the gear being ground. The diameter of the involute-generating cylinder 3 is therefore equal to the pitch circle diameter of the gear being ground. If the grinding wheels were set with their active surfaces at right angles to the tangent of the involute-generating cylinder, the diameter of the latter would of course be made equal to the base circle diameter of the gear being ground. It will be understood of course, that while it is advantageous to provide two grinding wheels a single one would be sufficient.

The tool-holder also comprises a slide 13 and a table 14. The standard 9 is mounted upon the slide 13, and the latter in turn upon the table 14 which has an arm 15 pivotally connected to a stationary shaft or pivot 16 coaxial with the joint axis A of the involute-generating cylinder 3 and the work 5. In this way the table 14 can be rotated in an oscillating manner in a horizontal plane about the axis A by means presently to be described. This rotation of the table 14 takes place over part-circular guideways 17 provided on the machine bed 1 upon which the table 14 is thus slidably mounted. The slide 13, together with the standard 9 carried by it, can be adjusted towards and away from the axis A by means of guideways 14a provided on the table 14, for the purpose of bringing the standard 9, and with it the tapes 6, into proper position in relation to the involute-generating cylinder 3. The rectilinear component of the rolling motion of the tool-holder relatively to the work is obtained by movement of the standard 9 along the slide 13 in a direction tangential to the involute-generating cylinder 3, for which purpose the standard 9 is guided by rollers 18 engaging between cooperating portions of the slide 13.

The present invention is more particularly directed to the means for bringing about the rotary movement of the table 14 about the axis A. In the present embodiment this is effected by means of a nut 19 pivotally connected to a bracket on the outer edge of the table 14 at the rear of the machine by a vertical pivot pin 20 (Figs. 1 and 2), the nut 19 being engaged by a motor-driven screw-threaded spindle 21 (Figs. 2 and 4). Referring now particularly to Fig. 4, it will be seen that the spindle 21 is driven by a pair of bevel wheels 22 and 23 housed in a cage 24 in which the spindle 21 is journalled. The bevel wheel 23 is secured on, and driven by, a shaft 25 which extends perpendicularly to the spindle 21 and parallel to the axis A and which has its bearings in a casing 26 secured to the machine bed 1 and is driven by an electric motor 27 via a worm gearing 28. The cage 24, together with the spindle 21 and the bevel wheel 22, is mounted for pivotal movement about the bevel wheel shaft 25. The free end of the spindle 21 is provided with a ring 29 mounted on its tip by means of ball bear-

ings and adapted to roll upon a bearing surface formed on a bracket 30 projecting from the table 14.

As has been hereinbefore indicated, the rotary component of the rolling motion of the tool-holder relatively to the work is in the nature of oscillations, the tool-holder rotating back and forth through a predetermined comparatively small arc, and it follows that the rotation of the table 14 must be a to-and-fro oscillation, means being provided to reverse its rotation when it has reached the end of the predetermined arc. In the present embodiment, this is effected by automatically reversing the motor 27 each time when the table 14 has traversed its arc of rotation about the axis A. For this purpose, the bevel wheel shaft carries at its upper end a pinion 31 (Figs. 5 and 6) driving, by engagement with a gear wheel 32 and associated pinion 33, a larger wheel 34. Mounted coaxially with the latter are two trip arms 35 each of which is provided with a handle 36 by means of which it can be manually adjusted to a desired angular position with respect to the axis of the gear wheel 34. In order to do so, the handle 36 is pulled upwardly against the pressure of a spring, whereupon it can be rotated thereby causing a pinion 37 meshing with the upper part of the gear wheel 34 to run along the teeth of the latter and thus to turn the trip arm 35 about the axis of the gear wheel 34. When the trip arm is in the desired position, the handle 36 is released and is pulled downwardly by the spring, whereby dog-clutch teeth 38 on the handle 36 and the trip arm 35 are engaged with each other, thus locking the handle 36, and with it the pinion 37, against further rotation relatively to the gear wheel 34, so that the trip arm is then constrained to rotate with the gear wheel 34. As will now be appreciated, the initial upward pull on the handle before adjustment of the trip arm 35 is necessary in order to disengage the dog-clutch teeth 38 from each other so as to free the pinion 37 for rotation. These adjusting and locking arrangements are of course provided for each of the two trip arms 35 and adjustment is effected with the shaft 25 and the gear wheel 34 stationary. When the latter are subsequently driven in one direction, one of the arms 35 is adapted to strike a switch arm 39 of a switch 40 which switch arm extends into the path of the two trip arms. The switch 40 has been diagrammatically shown in Fig. 6 and is so arranged that, when actuated by the switch arm 39 being struck by either trip arm 35 and so moved in either direction, it alters the connections of the electric circuit energising the motor 27 in such a manner as to change the direction of rotation of the latter but does not entirely cut it out, the motor being always left running in one direction or the other. Each reversal of the motor 27 of course affects the gear wheel 34 also, causing the trip arms 35 to rotate in the opposite direction. The fact of the pinion 37 engaging only the upper part of the gear wheel 34 enables it, if necessary, to be moved past the driving pinion 33 which only engages the lower part of the gear wheel 34.

The operation of this form of gear grinding machine is as follows:

Before starting the machine up, the trip arms 35 are first adjusted so as to enclose between them the desired angle O (Fig. 6) which ensures that the switch 40 is actuated to cause the table 14 to oscillate about axis A through an arc subtending an angle β (Fig. 2), the latter being so chosen that each of the two grinding wheels 12 rolls through an angle at least equal to the angle α (Fig. 2) which brings its active surface progressively into engagement with the whole depth of the tooth flank being ground by it from near the base circle level to the tip of the tooth. The motor 27 is then started up and, in conjunction with the reversing switch mechanism described in the foregoing, causes the table 14 to be slowly swung to and fro about the axis A through the angle β, the broken lines in Fig. 2 indicating the table in the position at the end of the arc of traverse in one direction. This movement of the table 14 also causes the nut 19 bodily to make a small movement in an arc of a circle, the nut 19 in turn rocking the spindle 21 about the bevel wheel shaft 25 through a small angle, while the tip of the spindle 21 rolls along the bearing surface 30, the necessary rotation of the nut 19 relatively to the table 14 being allowed for by the pivot 20. As the standard 9 is coupled by the tapes 6 to the stationary involute-generating cylinder 3, it is unable entirely to follow the rotary swinging movement of the table 14, since this would involve both rollers 7 making a circular movement about the axis A which the tapes 6 will clearly not permit. Instead, the standard 9, while being swung round on the table 14, is forced by the tapes 6 to reciprocate laterally across the table 14 by being displaced relatively to the slide 13 along the guides 18. It will be appreciated that this reciprocating movement takes place tangentially of the involute-generating cylinder 3 and that it constitutes the reciprocating component of movement of the tool holder which combines with the rotary component imparted to the standard 9 by the table 14 ot provide the necessary true rolling motion of the tool-holder through an angle equal to $\beta=2\alpha$, so that each grinding wheel 12 rolls through the desired angle α (Fig. 2) with its active surface describing an involute profile.

While the rolling motion of the grinding wheels 12 as described in the foregoing is taking place comparatively slowly, the slide 10 carrying the grinding wheels is moved rapidly up and down along the standard 9 by known power-operated means which have not been shown in the drawings as they are not relevant to the present invention. This results in the grinding wheels moving along the whole length of the teeth, i. e. along the whole width of the gear wheel 5, which of course is stationary at this time, so that during successive strokes of the slide 10 each of the two tooth flanks with which the grinding wheels are simultaneously in engagement will be ground along the whole length thereof and successively over areas thereof contiguous in the direction of the tooth depth, i. e. from root to tip or vice versa. Driving means (not shown) are of course provided for rotating the grinding wheels 12.

After the whole area of each of the two tooth flanks has been ground once or twice, i. e. after the table 14 has swung through the angle β a few times, the vertical reciprocating movement of the slide 10 and the rotary swinging movement of the table 14 are interrupted (by known means which it is not necessary to describe or show herein) for a period just long enough to enable the work table 4 to be rotated by the dividing device already referred to so as to turn the gear wheel 5 by one tooth pitch and present two other tooth flanks to the grinding wheels, whereupon the movement of the slide 10 and the

table 14 are resumed and the operation is repeated.

In the embodiment described in the foregoing, in order to permit the rotary motion of the table 14 notwithstanding its connection to the spindle 21 by means of the pivoted nut 19 and the rectilinear motion of the latter on the former, the spindle 21 is adapted for pivotal movement in a horizontal plane about the axis of the bevel wheel shaft 25, the opposite end of the spindle being free to swing towards and away from the table 14. In the two embodiments according to Figs. 7 to 9, the same result is achieved with the spindle 21 having both its ends supported so that the spindle has no bodily movement relatively to the machine bed 1, while the pivoted nut 19 is so mounted on the table 14 that the latter can move towards and away from the nut 19. Two examples of how this may be carried into practical effect are shown in Figs. 7 and 8 and Fig. 9 respectively. It may be assumed that in both these embodiments, the remainder of the machine is substantially the same as in Figs. 1–6, including the means for automatically obtaining reversal of the swinging motion of the table 14 at either end of its oscillating motion through the arc for which it has been adjusted.

Referring first to Figs. 7 and 8, the spindle 21, again driven through bevel wheels 22, 23 by the shaft 25, is in this case journalled directly in the casing 26 fixed to the machine bed 1, the cage 24 being omitted as unnecessary. The opposite end of the spindle 21 is journalled in a bearing bracket 41 on the bed 1. The nut 19 engaging the spindle is again mounted for pivotal movement with respect to the table 14 about a vertical axis, and in addition it is slidable towards and away from the table 14. For this purpose the nut 19 has two pivot pins 20 projecting respectively from the top and bottom thereof in opposite directions. The pivot pins are rotatably as well as slidably mounted in a guideway 42 provided by slots in a forked bracket 43 on the table 14. The bracket 43 receives the nut 19 movably between its top and bottom prongs. Each of the pivot pins 20 is surrounded by a ball-bearing ring 44, by means of which the pins 20 engage the guideway 42. The distance between the opposed guide faces of the guideway 42 is slightly larger than the outside diameter of the ball-bearing rings 44, so that the latter, in operation, engage the guideway 42 on one side thereof only, for reasons which will be readily apparent. The ball-bearing rings 44 are held in position by members 45 screwed to the top and bottom respectively of the two pivot pins. For greater clarity the members 45 have been omitted in Fig. 7.

In operation, as the nut 19 courses along the spindle 21, the ball-bearings 44 roll along the guide faces of the guideways 42, the table 14 thus being free to assume different angular positions with respect to the nut 19, because the bracket 43 pivots about the nut 19 and slides along it radially with respect to the axis of oscillation A of the table 14.

Fig. 9 shows a modification of the embodiment according to Figs. 7 and 8, the only change being in regard to the mounting of the nut 19 on the table 14 whilst the drive and mounting of the spindle 21 are the same as in Figs. 7 and 8. The nut 19, its pivot pins 20 and ball-bearings 44 are also constructed as in Figs. 7 and 8, but in the present embodiment the ball-bearings 44 are engaged in the end of a lever 47 pivoted at 48 to a forked bracket 49 on the table 14. As will be readily apparent, the operation of this embodiment is analogous to that of Figs. 7 and 8, in that the lever 47, during the travel of the nut 19 along the spindle 21, makes small pivotal movements about the pivots 20 and 48, thus allowing relative movement of the table 14 and the nut 19 towards and away from each other and permitting the former to take up different angular positions with respect to the latter.

What I claim and desire to secure by Letters Patent is:

1. In a gear grinding machine, the combination of a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder, at least one grinding wheel carried by said tool-holder, said tool-holder being mounted on said bed for rotary movement about the axis of, and for rectilinear sliding movement tangentially of, said cylinder, and flexible tapes coupling said tool-holder to said cylinder for constraining said tool-holder to perform a combination of both said movements and causing an involute-generating motion of said grinding wheel relatively to the work, with driving means for imparting said rotary movement to said tool-holder comprising a power-driven shaft mounted in fixed relation to said bed and extending parallel to said cylinder axis, a screw-threaded spindle coupled to said shaft for being driven thereby, a nut engaging said spindle and having pivotal connection with said tool-holder, means between said shaft and said tool-holder for permitting said rotary movement of said tool-holder relatively to said shaft notwithstanding the driving connection therebetween by said spindle and said nut, a reversible electric motor coupled to said shaft for driving same, switch means electrically connected in the energizing circuit of said motor for reversing the latter, a control device including rotatable means driven by said shaft and operatively associated with said switch means for periodically actuating said switch means to cause reversal of said motor and of said shaft and said spindle, and means for adjusting the operative relation of said rotatable means to said switch means to vary the angle of said rotary movement of said tool-holder.

2. In a gear grinding machine, the combination of a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder including a table mounted on said bed for rotary oscillating movement about the axis of said cylinder and a standard mounted on said tool-holder table for rectilinear reciprocating movement relatively thereto tangentially of said cylinder, at least one grinding wheel carried by said tool-holder standard for reciprocation relatively thereto parallel to said cylinder axis, and flexible tapes coupling said tool-holder standard to said cylinder for constraining said tool-holder standard to make said reciprocating movement when said tool-holder table makes said rotary oscillating movement for resultant involute-generating motion of said grinding wheel, with driving means for imparting said rotary oscillating movement to said tool-holder table, comprising a power-driven screw-threaded spindle, a nut pivotally connected to said tool-holder table and engaging said spindle intermediate its ends, means for supporting said spindle adjacent one end thereof for

rotation and for bodily pivotal movement thereof about an axis parallel to said cylinder axis, a pair of bevel wheels for driving said spindle, and a power-driven shaft extending parallel to the axis of said cylinder and having one of said bevel wheels secured thereon, and said spindle supporting means comprising a bearing member mounted for pivotal movement upon said shaft and having said spindle rotatably journaled therein, said shaft thus providing said axis of said bodily pivotal movement of said spindle.

3. In a gear grinding machine, the combination of a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder including a table mounted on said bed for rotary oscillating movement about the axis of said cylinder and a standard mounted on said tool-holder table for rectilinear reciprocating movement relatively thereto tangentially of said cylinder, at least one grinding wheel carried by said tool-holder standard for reciprocation relatively thereto parallel to said cylinder axis, and flexible tapes coupling said tool-holder standard to said cylinder for constraining said tool-holder standard to make said reciprocating movement when said tool-holder table makes said rotary oscillating movement for resultant involute-generating motion of said grinding wheel, with driving means for imparting said rotary oscillating movement to said tool-holder table comprising a power-driven screw-threaded spindle, a nut pivotally connected to said tool-holder table and engaging said spindle intermediate its ends, means for supporting said spindle adjacent one end thereof for rotation and for bodily pivotal movement thereof about an axis parallel to said cylinder axis, and means for slidably supporting the other end of said spindle.

4. The combination claimed in claim 3, said means for slidably supporting said other spindle end comprising a plane bearing surface provided on said tool-holder table, and a ring member mounted on said other spindle end for rotation relatively thereto and for rolling movement upon said bearing surface.

5. In a gear grinding machine, the combination of a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder including a table mounted on said bed for rotary oscillating movement about the axis of said cylinder and a standard mounted on said tool-holder table for rectilinear reciprocating movement relatively thereto tangentially of said cylinder, at least one grinding wheel carried by said tool-holder standard for reciprocation relatively thereto parallel to said cylinder axis, and flexible tapes coupling said tool-holder standard to said cylinder for constraining said tool-holder standard to make said reciprocating movement when said tool-holder table makes said rotary oscillating movement for resultant involute-generating motion of said grinding wheel, with driving means for imparting said rotary oscillating movement to said tool-holder table, said driving means comprising a power-driven screw-threaded spindle mounted on said bed for rotation but not for bodily movement relative thereto, a nut engaging said spindle, means pivotally connecting said nut to said tool-holder table, cooperating guide means on said pivot means and said tool-holder table respectively for permitting relative bodily movement between said nut and said tool-holder table in a direction towards and away from said cylinder axis, said pivotal connecting means consisting of pivot means projecting from said nut and said cooperating guide means being annular and rotatably mounted on said pivot means and a forked bracket projecting from said tool-holder table and having guide surfaces for rolling engagement by said annular guide means and for sliding engagement by said nut to prevent rotation of the nut with said spindle.

6. In a gear grinding machine, the combination of a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder including a table mounted on said bed for rotary oscillating movement about the axis of said cylinder and a standard mounted on said tool-holder table for rectilinear reciprocating movement relatively thereto tangentially of said cylinder, at least one grinding wheel carried by said tool-holder standard for reciprocation relatively thereto parallel to said cylinder axis, and flexible tapes coupling said tool-holder standard to said cylinder for constraining said tool-holder standard to make said reciprocating movement when said tool-holder table makes said rotary oscillating movement for resultant involute-generating motion of said grinding wheel, with driving means for imparting said rotary oscillating movement to said tool-holder table, said driving means comprising a power-driven screw-threaded spindle mounted on said bed for rotation but not for bodily movement relatively thereto, a nut engaging said spindle, and a lever having said nut pivotally mounted thereon and being pivotally connected to said tool-holder table for permitting relative bodily movement between said nut and said tool-holder table in a direction towards and away from said cylinder axis.

7. In a gear grinding machine, in combination, a machine bed, a normally stationary work table mounted on said bed, a stationary involute-generating cylinder coaxial with said work table, a tool-holder including a table mounted on said bed for rotary oscillating movement about the axis of said cylinder and a standard mounted on said tool-holder table for rectilinear reciprocating movement relatively thereto tangentially of said cylinder, at least one grinding wheel carried by said tool-holder standard for reciprocation relatively thereto parallel to said cylinder axis, and flexible tapes coupling said tool-holder standard to said cylinder for constraining said tool-holder standard to make said reciprocating movement when said tool-holder table makes said rotary oscillating movement for resultant involute-generating motion of said grinding wheel, driving means for imparting said rotary oscillating movement to said tool-holder table, said driving means including a power-driven shaft mounted on said bed for rotation but not for bodily movement relatively thereto and extending parallel to said cylinder axis, a rotatable screw-threaded spindle coupled to said shaft for being driven thereby, a nut engaging said spindle and having pivotal connection with said tool-holder table, and means between said shaft and said tool-holder table for permitting said rotary oscillating movement of said tool-holder table relatively to said shaft notwithstanding the driving connection therebetween by said spindle and said nut, a control device operated by said driv-

ing means for periodically causing reversal of the rotation of said shaft and said spindle, and means for adjusting said control device to cause said reversal after said tool-holder table has been moved through a predetermined angle of said rotary oscillating movement thereof.

8. The combination claimed in claim 7, said driving means further including a reversible electric motor coupled to said shaft for driving the same, and said control device comprising a switch electrically connected in the energising circuit of said motor for reversing the latter, a switch arm for actuating said switch, a pair of trip arms coaxially mounted for joint rotation and coupled to said shaft to be rotated thereby, said trip arms projecting into the path of said switch arm for striking the latter and thereby actuating said switch to cause reversal of said motor and, hence, of the rotation of said shaft and said spindle, and means for adjusting the angle enclosed between said trip arms and the positions thereof relative to said switch arm for determining the angle of said oscillating rotary movement of said tool-holder table.

9. The combination claimed in claim 8, said adjusting means comprising a gear wheel for driving said trip arms and having said trip arms mounted thereon coaxially therewith, a manually operable member rotatably mounted on each of said trip arms for axial reciprocation relatively thereto between two positions, a pinion secured to each of said manually operable members and extending therefrom into gearing engagement with said gear wheel, spring means associated with each of said manually operable members for biasing it to one of said positions, clutch means associated with each of said manually operable members and effective, in said biased position of said manually operable member, for locking it and said pinion against rotation on said trip arm to couple said trip arm to said gear wheel for joint rotation therewith, said clutch means being rendered ineffective upon manual reciprocation of said manually operable member to the other of said positions to permit said rotation of said manually operable member and said pinion for angular adjustment of said trip arm relatively to said gear wheel.

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